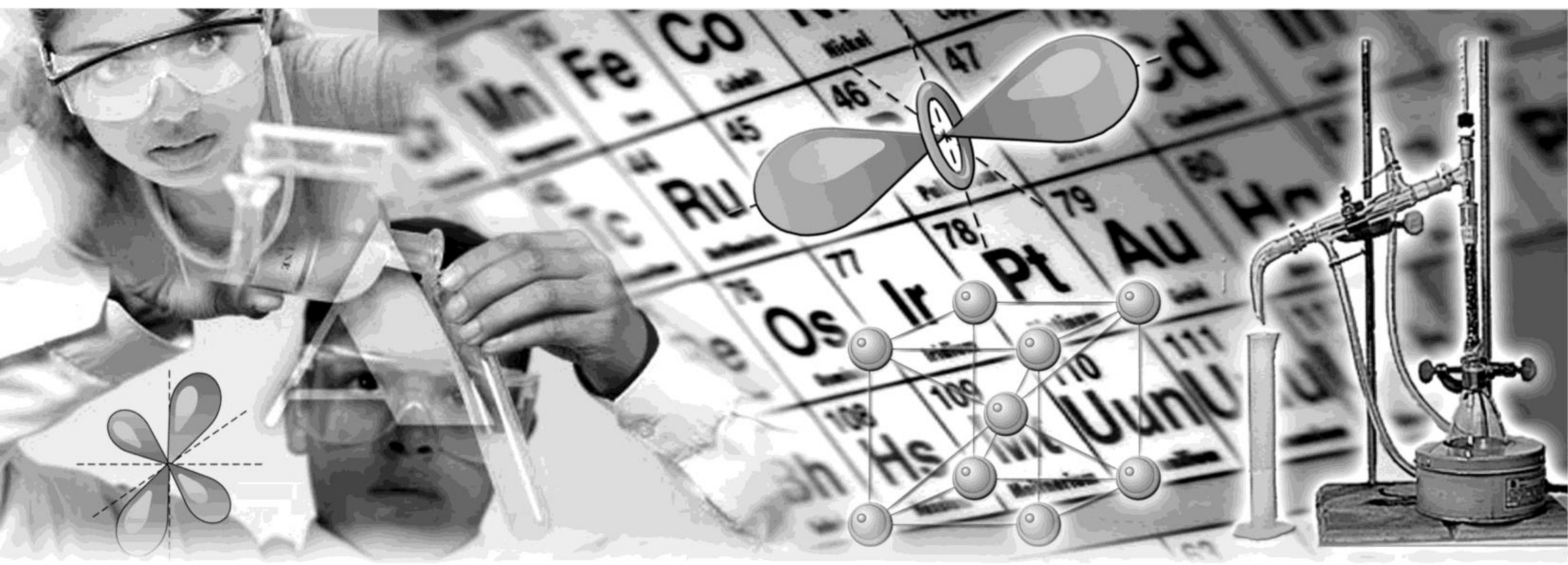


Chapter
18

s and p-Block Elements

Alkali Metals and Their Compounds

The group 1 of the periodic table contains six elements, namely lithium (*Li*), sodium (*Na*), potassium (*K*), rubidium (*Rb*), caesium (*Cs*) and francium (*Fr*). All these elements are ***typical metals***. Francium is radioactive with longest lived isotope ^{223}Fr with half life period of only 21 minute. These are usually referred to as alkali metals since their hydroxides form strong bases or alkalies.

(1) **Electronic configuration**

Elements	**Discovery**	**Electronic configuration** (ns^1)
$_{3}\text{Li}$	Arfwedson (1817)	$[\text{He}]^2\, 2s^1$
$_{11}\text{Na}$	Davy (1807)	$[\text{Ne}]^{10}\, 3s^1$
$_{19}\text{K}$	Davy (1807)	$[\text{Ar}]^{18}\, 4s^1$
$_{37}\text{Rb}$	Bunsen (1861)	$[\text{Kr}]^{36}\, 5s^1$
$_{55}\text{Cs}$	Bunsen (1860)	$[\text{Xe}]^{54}\, 6s^1$
$_{87}\text{Fr}$	Percy (1939)	$[\text{Rn}]^{86}\, 7s^1$

(2) **Occurrence :** Alkali metals are very reactive and thus found in combined state some important ores of alkali metals are given ahead.

(i) ***Lithium*** : Triphylite, Petalite, lepidolite, Spodumene [$LiAl(SiO_3)_3$], Amblygonite [$Li(Al\,F)PO_4$]

(ii) ***Sodium*** : Chile salt petre ($NaNO_3$), Sodium chloride ($NaCl$), Sodium sulphate (Na_2SO_4), Borax ($Na_2B_4O_7 10H_2O$), Glauber salt ($Na_2\,SO_4.10H_2O$)

(iii) ***Potassium*** : Sylime (KCl), carnallite ($KCl.MgCl_2.6H_2O$) and Felspar ($K_2O.Al_2O_3.6SiO_2$)

(iv) ***Rubidium*** : Lithium ores Lepidolite, triphylite contains 0.7 to 3% Rb_2O

(v) ***Caesium*** : Lepidolite, Pollucite contains 0.2 to 7% Cs_2O

(3) **Extraction of alkali metals :** Alkali metals cannot be extracted by the usual methods for the extraction of metals due to following reasons.

(i) Alkali metals are strong reducing agents, hence cannot be extracted by reduction of their oxides or other compounds.

(ii) Being highly electropositive in nature, it is not possible to apply the method of displacing them from their salt solutions by any other element.

(iii) The aqueous solutions of their salts cannot be used for extraction by electrolytic method because hydrogen ion is discharged at cathode instead of an alkali metal ions as the discharge potentials of alkali metals are high. However, by using *Hg* as cathode, alkali metal can be deposited. The alkali metal readily combines with *Hg* to form an amalgam from which its recovery difficult. The only successful method, therefore, is the electrolysis of their fused salts, usually chlorides. Generally, another metal chloride is added to lower their fusion temperature.

Fused *NaCl* : $NaCl \xrightarrow{fusion} Na^+ + Cl^-$

Electrolysis : Anode : $2Cl^- \rightarrow Cl_2 + 2e^-$

of fused salt : Cathode : $2Na^+ + 2e^- \rightarrow 2Na$

(4) **Alloys Formation**

(i) The alkali metals form alloys among themselves as well as with other metals.

(ii) Alkali metals also get dissolved in mercury to form amalgam with evolution of heat and the amalgamation is highly exothermic .

Physical properties

(1) **Physical state**

(i) All are silvery white, soft and light solids. These can be cut with the help of knife. When freshly cut, they have bright lustre which quickly tarnishes due to surface oxidation.

(ii) These form diamagnetic colourless ions since these ions do not have unpaired electrons, (*i.e.* M^+ has ns^0configuration). That is why alkali metal salts are colourless and diamagnetic.

(2) **Atomic and ionic radii**

(i) The alkali metals have largest atomic and ionic radii than their successive elements of other groups belonging to same period.

(ii) The atomic and ionic radii of alkali metals, however, increases down the group due to progressive addition of new energy shells.

No doubt the nuclear charge also increases on moving down the group but the influence of addition of energy shell predominates

	Li	*Na*	*K*	*Rb*	*Cs*	*Fr*
Atomic radius (pm)	152	186	227	248	265	375
Ionic radius of M^+ ions (pm)	60	95	133	148	169	–

(3) **Density**

(i) All are light metals, *Li*, *Na* and *K* have density less than water. Low values of density are because these metals have high atomic volume due to larger atomic size. On moving down the group the atomic size as well as atomic mass both increase but increase in atomic mass predominates over increase in atomic size or atomic volume and therefore the ratio mass/volume *i.e.* density gradually increases down the groups

(ii) The density increases gradually from *Li* to *Cs*, *Li* is lightest known metal among all.

Li = 0.534, *Na* = 0.972, *K* = 0.86, *Rb* = 1.53 and *Cs* = 1.87 g/ml at 20$^{\circ}C$.

(iii) *K* is lighter than *Na* because of its unusually large atomic size.

(iv) In solid state, they have body centred cubic lattice.

(4) **Melting point and Boiling point**

(i) All these elements possess low melting point and boiling point in comparison to other group members.

	Li	*Na*	*K*	*Rb*	*Cs*	*Fr*
melting point (K)	453.5	370.8	336.2	312.0	301.5	–
boiling point (K)	1620	1154.4	1038.5	961.0	978.0	–

(ii) The lattice energy of these atoms in metallic crystal lattice relatively low due to larger atomic size and thus possess low melting point and boiling point on moving down the group, the atomic size increases and binding energy of their atoms in crystal lattice decreases which results lowering of melting point.

(iii) Lattice energy decreases from *Li* to *Cs* and thus melting point and boiling also decreases from *Li* to Cs.

(5) **Ionisation energy and electropositive or metallic character**

(i) Due to unpaired lone electron in ns sub-shell as well as due to their larger size, the outermost electron is far from the nucleus, the removal of electron is easier and these low values of ionisation energy. (*I.E.*)

(ii) Ionisation energy of these metal decreases from *Li* to *Cs*.

Ionisation energy	*Li*	*Na*	*K*	*Rb*	*Cs*	*Fr*
IE_1	520	495	418	403	376	–
IE_2	7296	4563	3069	2650	2420	–

A jump in 2nd ionisation energy (huge difference) can be explained as,

$$Li{:}1s^2\,2s^1 \xrightarrow[2s\,electron]{\text{Re}\,moval of} Li^+{:}1s^2 \xrightarrow[1s\,electron]{\text{Re}\,moval\ of} Li^{2+}{:}1s^1$$

Removal of 1s electrons from Li^+ and that too from completely filled configuration requires much more energy and a jump in 2nd ionisation is noticed.

(iii) Lower are ionisation energy values, greater is the tendency to lose ns^1 electron to change in M^+ ion (*i.e.* $M \rightarrow M^+ + e^-$) and therefore stronger is electropositive character.

(iv) Electropositive character increases from *Li* to *Cs*.

Due to their strong electropositive character, they emit electrons even when exposed to light showing ***photoelectric effect***. This property is responsible for the use of *Cs* and *K* in photoelectric cell.

(6) **Oxidation number and valency**

(i) Alkali metals are univalent in nature due to low ionisation energy values and form ionic compounds. Lithium salts are, however, covalent.

(ii) Further, the M^+ ion acquires the stable noble gas configuration. It requires very high values of energy to pull out another electron from next to outer shell of M^+ ion and that is why their second ionisation energy is very high. Consequently, under ordinary conditions, it is not possible for these metals to form M^{2+} ion and thus they show +1 oxidation state.

(iii) Since the electronic configuration of M^+ ions do not have unpaired electron and thus alkali metal salts are diamagnetic and colourless. Only those alkali metal salts are coloured which have coloured anions e.g. $K_2Cr_2O_7$ is orange because of orange coloured $Cr_2O_7^{2-}$ ion, $KMnO_4$ is violet because of violet coloured MnO_4^{1-} ion.

(7) **Hydration of Ions**

(i) Hydration represents for the dissolution of a substance in water to get adsorb water molecule by weak valency force. Hydration of ions is the exothermic process (*i.e* energy is released during hydration) when ions on dissolution water get hydration.

(ii) The energy released when 1 mole of an ion in the gaseous state is dissolved in water to get it hydrated is called hydration energy $M_{(g)}{}^{+} + Aq \rightarrow M^{+}{}_{(aq)}\,; \Delta H = -ve.$

(iii) Smaller the cation, greater is the degree of hydration. Hydration energy is in the order of, $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$

(iv) Li^+ being smallest in size has maximum degree of hydration and that is why lithium salts are mostly hydrated, $LiCl.\ 2H_2O$ also lithium ion being heavily hydrated, moves very slowly under the influence of electric field and, therefore, is the poorest conductor current among alkali metals ions It may, therefore, be concluded that it is the degree of hydration as well as the size of ion is responsible for the current carried by an ion.

Relative ionic radii	$Cs^+ > Rb^+ > K^+ > Na^+ > Li^+$
Relative hydrated ionic radii	$Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$
Relative conducting power	$Cs^+ > Rb^+ > K^+ > Na^+ > Li^+$

(8) **Electronegativity, Electro positivity and metallic character.**

(i) These metals are highly electropositive and thereby possess low values of electronegativities. Metallic character and electro positivity increase from *Li* to *Cs* (*Li* < *Na* < *K* < *Rb* < *Cs*)

(ii) Electronegativity of alkali metals decreases down the group as the trend of numerical values of electronegativity given below on Pauling scale suggests.

	Li	*Na*	*K*	*Rb*	*Cs*	*Fr*
Electronegativity	0.98	0.93	0.82	0.82	0.79	–

Fr being radioactive elements and thus studies on physical properties of this element are limited.

(9) **Specific heat :** It decreases from *Li* to *Cs*.

	Li	*Na*	*K*	*Rb*	*Cs*	*Fr*
Specific heat (Cal/g)	0.941	0.293	0.17	0.08	0.049	–

(10) **Conduction power :** All are good conductors of heat and electricity, because of loosely held valence electrons.

(11) **Standard oxidation potential and reduction properties**

(i) Since alkali metals easily lose ns^1 electron and thus they have high values of oxidation potential *i.e.*,

$$M + aq \rightarrow M^{+}{}_{(aq)} + e$$

(ii) The standard oxidation potentials of a alkali metals (in volts) are listed below,

Li	*Na*	*K*	*Rb*	*Cs*
+3.05	+2.71	+2.93	+2.99	+2.99

(iii) More is oxidation potential, more is the tendency to get oxidized and thus more powerful is reducing nature in aqueous medium that is why alkali metals liberate H_2 from H_2O and HCl.

$$2H_2O + 2M \rightarrow 2MOH + H_2\ ;\ 2HCl + 2M \rightarrow 2MCl + H_2$$

(iv) However, an examination of ionisation energy for alkali metals reveals that *Li* should have the minimum tendency to lose electron and thus its reducing nature should be minimum. The greatest reducing nature of *Li* in aq. medium is accounted due to the maximum hydration energy of Li^+ ion. For Lithium

$Li_{(s)} \rightarrow Li_{(g)};$ ΔH_1 = Heat of sublimation, ΔH_s

$Li_{(g)} \rightarrow Li^{+}{}_{(g)} + e;$ $\Delta H_2 = IE_1$

$Li^{+}{}_{(g)} \rightarrow Li^{+}{}_{(aq);}$ ΔH_3 = – Heat of hydration, ΔH_h

$$Li_{(s)} + H_2O \rightarrow Li^{+}{}_{(aq)} + e; \Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 = \Delta H_s + IE_1 - \Delta H_h$$

Similarly, for sodium,

$$Na_{(s)} + H_2O \rightarrow Na^{+}{}_{(aq)} + e; \Delta H = \Delta H_{(s)} + IE_1 - \Delta H_h$$

ΔH_h for *Li* > ΔH_h for *Na*. Therefore, large negative ΔH values are observed in case of *Li* and this explains for more possibility of *Li* to get itself oxidized or have reducing nature.

(12) **Characteristic flame colours :** The alkali metals and their salts give characteristic colour to Bunsen flame. The flame energy causes and excitation of the outermost electron which on reverting back to its initial position gives out the absorbed energy as visible light. These colour differ from each other *Li* –crimson, *Na*–Golden yellow, *K* – Pale violet , *Rb*-Red violet and *Cs* –Blue violet. These different colours are due to different ionisation energy of alkali metals. The energy released is minimum in the case of Li^+ and increases in the order.

Energy released : $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$

λ released : $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$

Frequency released : $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$

Chemical properties

(1) **Formation of oxides and hydroxides**

(i) These are most reactive metals and have strong affinity for O_2 quickly tranish in air due to the formation of a film of their oxides on the surface. These are, therefore, kept under kerosene or paraffin oil to protect them from air,

$$M + O_2 \rightarrow \underset{\text{Oxide}}{M_2O} \longrightarrow \underset{\text{Peroxide}}{M_2O_2}$$

(ii) When burnt air (O_2), lithium forms lithium oxide (Li_2O) sodium forms sodium peroxide (Na_2O_2) and other alkali metals form super oxide (Mo_2 *i.e.* KO_2,RbO_2 or CsO_2)

$$2Li + \frac{1}{2}O_2 \rightarrow \underset{\text{Lithuim oxide}}{Li_2O} \;\; ; \; 2Na + O_2 \rightarrow Na_2\,O_2$$

$$K + O_2 \rightarrow \underset{\text{Potassium super oxide}}{KO_2}$$

The reactivity of alkali metals towards oxygen to form different oxides is due to strong positive field around each alkali metal cation. Li^+ being smallest, possesses strong positive field and thus combines with small anion O^{2-} to form stable Li_2O compound. The Na^+ and K^+ being relatively larger thus exert less strong positive field around them and thus reacts with larger oxygen anion i.e, $O_2^{2-}$and O_2^{1-} to form stable oxides.

The monoxide, peroxides and superoxides have O_2 and O_2^{2-}, O_2^{1-} ions respectively. The structures of each are,

Monoxide (O_2) Peroxide ($O_2{}^{2-}$) Superoxide

The $O_2{}^{-1}$ ion has a three electron covalent bond and has one electron unpaired. It is therefore superoxides are paramagnetic and coloured KO_2 is light yellow and paramagnetic substance.

(iii) The oxides of alkali metals and metal itself give strongly alkaline solution in water with evolution of heat

$$M + H_2O \rightarrow MOH + \frac{1}{2}H_2; \qquad \Delta H = -ve$$

$$Li_2O + H_2O \rightarrow 2LiOH; \qquad \Delta H = -ve$$

$$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_{2(l)}\,; \qquad \Delta H = -ve$$

$$2KO_2 + 2H_2O \rightarrow 2KOH + H_2O_{2(l)} + O_{2(g)}\,; \qquad \Delta H = -ve$$

The peroxides and superoxides act as strong oxidising agents due to formation of H_2O_2

(iv) The reactivity of alkali metals towards air and water increases from *Li* to *Cs* that is why lithium decomposes H_2O very slowly at 25^oC whereas *Na* does so vigorously, *K* reacts producing a flame and *Rb, Cs* do so explosively.

$$M + H_2O \rightarrow MOH + \frac{1}{2}H_2$$

(v) The basic character of oxides and hydroxides of alkali metals increases from *Li* to *Cs*. This is due to the increase in ionic character of alkali metal hydroxides down the group which leads to complete dissociation and leads to increase in concentration of OH^- ions.

(2) **Hydrides**

(i) These metals combine with *H* to give white crystalline ionic hydrides of the general of the formula *MH*.

(ii) The tendency to form their hydrides, basic character and stability decreases from *Li* to *Cs* since the electropositive character decreases from *Cs* to *Li*.

$2M + H_2 \rightarrow 2MH$; Reactivity towards H_2 is $Cs < Rb < K < Na < Li$.

(iii) The metal hydrides react with water to give *MOH* and H_2 ; $MH + H_2O \rightarrow MOH + H_2$

(iv) The ionic nature of hydrides increases from *Li* to *Cs* because of the fact that hydrogen is present in the these hydrides as H^- and the smaller cation will produce more polarisation of anion (according to Fajans rule) and will develop more covalent character.

(v) The electrolysis of fused hydrides give H_2 at anode. NaH_{fused} Contains Na^+ and H^- *i.e.*,

At cathode: $Na^+ + e^- \rightarrow Na$; At anode: $H^- \rightarrow \frac{1}{2}H_2 + e^-$

(vi) Alkali metals also form hydrides like $NaBH_4$, $LiAlH_4$ which are good reducing agent.

(3) **Carbonates and Bicarbonates**

(i) The carbonates (M_2CO_3) & bicarbonates ($MHCO_3$) are highly stable to heat, where M stands for alkali metals.

(ii) The stability of these salts increases with the increasing electropositive character from *Li* to *Cs*. It is therefore Li_2CO_3 decompose on heating, $Li_2CO_3 \rightarrow Li_2O + CO_2$

(iii) Bicarbonates are decomposed at relatively low temperature, $2MHCO_3 \xrightarrow{300^0C} M_2CO_3 + H_2O + CO_2$

(iv) Both carbonates and bicarbonates are soluble in water to give alkaline solution due to hydrolysis of carbonate ions or bicarbonate ions.

(4) **Halides**

(i) Alkali metals combine directly with halogens to form ionic halide M^+X^-.

(ii) The ease with which the alkali metals form halides increases from *Li* to *Cs* due to increasing electropositive character from *Li* to *Cs*.

(iii) Lithium halides however have more covalent nature. Smaller is the cation, more is deformation of anion and thus more is covalent nature in compound. Also among lithium halides, lithium iodide has maximum covalent nature because of larger anion which is easily deformed by a cation. Thus covalent character in lithium halides is, $LiI > LiBr > LiCl > LiF$

(iv) These are readily soluble in water. However, lithium fluoride is sparingly soluble. The low solubility of LiF is due to higher forces of attractions among smaller Li^+ and smaller F^- ions (high lattice energy).

(v) Halides having ionic nature have high m.pt. and good conductor of current. The melting points of halides shows the order, $NaF > NaCl > NaBr > NaI$

(vi) Halides of potassium, rubidium and caesium have a property of combining with extra halogen atoms forming polyhalides.

$KI + I_2 \rightarrow KI_3$; In $KI_{3(aq)}$ the ions K^+ and I^-_3 are present

(5) **Solubility in liquid NH_3**

(i) These metals dissolve in liquid NH_3 to produce blue coloured solution, which conducts electricity to an appreciable degree.

(ii) With increasing concentration of ammonia, blue colour starts changing to that of metallic copper after which dissolution of alkali metals in NH_3 ceases.

(iii) The metal atom is converted into ammoniated metal in i.e. M^+ (NH_3) and the electron set free combines with NH_3 molecule to produce ammonia solvated electron.

$$Na + (x+y)NH_3 \rightarrow \underset{\text{Ammoniated cation}}{[Na(NH_3)_x]^+} + \underset{\text{Ammoniated electron}}{[e(NH_3)_y]^-}$$

(iv) It is the ammoniated electron which is responsible for blue colour, paramagnetic nature and reducing power of alkali metals in ammonia solution. However, the increased conductance nature of these metals in ammonia is due to presence of ammoniated cation and ammonia solvated electron.

(v) The stability of metal-ammonia solution decreases from Li to Cs.

(vi) The blue solution on standing or on heating slowly liberates hydrogen, $2M + 2NH_3 \rightarrow 2MNH_2 + H_2$. Sodamide $(NaNH_2)$ is a waxy solid, used in preparation of number of sodium compounds.

(6) **Nitrates :** Nitrates of alkali metals (MNO_3) are soluble in water and decompose on heating. $LiNO_3$ decomposes to give NO_2 and O_2 and rest all give nitrites and oxygen.

$2MNO_3 \rightarrow 2MNO_2 + O_2$ (except Li)

$4\,LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$

(7) **Sulphates**

(i) Alkali metals' sulphate have the formula M_2SO_4 .

(ii) Except Li_2SO_4, rest all are soluble in water.

(iii) These sulphates on fusing with carbon form sulphides, $M_2SO_4 + 4C \rightarrow M_2S + 4CO$

(iv) The sulphates of alkali metals (except Li) form double salts with the sulphate of the trivalent metals like Fe, Al, Cr etc. The double sulphates crystallize with large number of water molecules as alum. e.g. K_2SO_4 . $Al_2\,(SO_4)_3$. 24 H_2O.

(8) **Reaction with non-metals**

(i) These have high affinity for non-metals. Except carbon and nitrogen, they directly react with hydrogen, halogens, sulphur, phosphorus etc. to form corresponding compounds on heating.

$2Na + H_2 \xrightarrow{300^0 C} 2NaH$; $2K + H_2 \rightarrow 2KH$

$2Na + Cl_2 \rightarrow 2NaCl$; $2K + Cl_2 \rightarrow 2KCl$

$2Na + S \rightarrow Na_2S$; $2K + S \rightarrow K_2S$

$3Na + P \rightarrow Na_3P$; $3K + P \rightarrow K_3P$

(ii) Li reacts, however directly with carbon and nitrogen to form carbides and nitrides.

$2Li + 2C \rightarrow LiC_2$; $6Li + 2N_2 \rightarrow 2\,Li_3N$

(iii) The nitrides of these metals on reaction with water give NH_3.

$M_3N + 3H_2O \rightarrow 3MOH + NH_3$

(9) **Reaction with acidic hydrogen :** Alkali metals react with acids and other compounds containing acidic hydrogen (*i.e,* H atom attached on F, O, N and triply bonded carbon atom, for example, HF, H_2O, ROH, RNH_2, $CH \equiv CH$) to liberate H_2 .

$$M + H_2O \rightarrow MOH + \frac{1}{2}H_2 \quad ; \quad M + HX \rightarrow MX + \frac{1}{2}H_2$$

$$M + ROH \rightarrow ROH + \frac{1}{2}H_2\ ; \ M + RNH_2 \rightarrow RNHNa + \frac{1}{2}H_2$$

(10) **Complex ion formation :** A metal shows complex formation only when it possesses the following characteristics, (i) Small size (ii) High nuclear charge (iii) Presence of empty orbitals in order to accept electron pair ligand. Only Lithium in alkali metals due to small size forms a few complex ions Rest all alkali metals do not possess the tendency to form complex ion.

Anomalous behaviour of Lithium

Anomalous behaviour of lithium is due to extremely small size of lithium its cation on account of small size and high nuclear charge, lithium exerts the greatest polarizing effect out of all alkali metals on negative ion. Consequently lithium ion possesses remarkable tendency towards solvation and develops covalent character in its compounds. Li differs from other alkali metals in the following respects,

(1) It is comparatively harder than other alkali metals. Li can'nt be stored in kerosene as it floats to the surface, due to its very low density. Li is generally kept wrapped in parrafin wax.

(2) It can be melted in dry air without losing its brilliance.

(3) Unlike other alkali metals, lithium is least reactive among all. It can be noticed by the following properties,

(i) It is not affected by air. (ii) It decomposes water very slowly to liberate H_2. (iii) It hardly reacts with bromine while other alkali metals react violently.

(4) Lithium is the only alkali metal which directly reacts with N_2 to form Lithium nitride (Li_3N)

(5) Lithium when heated in NH_3 forms amide, Li_2NH while other metals form amides, MNH_2.

(6) When burnt in air, lithium form Li_2O sodium form Na_2O and Na_2O_2 other alkali metals form monoxide, peroxide and superoxide.

(7) Li_2O is less basic and less soluble in water than other alkali metals.

(8) $LiOH$ is weaker base than $NaOH$ or KOH and decomposes on heating.

$$2LiOH \xrightarrow{\Delta} Li_2O + H_2O$$

(9) $LiHCO_3$ is liquid while other metal bicarbonates are solid.

(10) Only Li_2CO_3 decomposes on heating

$$Li_2CO_3 \xrightarrow{heat} Li_2O + CO_2 .$$

Na_2CO_3, K_2CO_3 etc. do not decompose on heating.

(11) $LiNO_3$ and other alkali metal nitrates give different products on heating

$4LiNO_3 = 2Li_2O + 4NO_2 + O_2$; $2NaNO_3 = 2NaNO_2 + O_2$

(12) $LiCl$ and $LiNO_3$ are soluble in alcohol and other organic solvents. These salts of other alkali metals are, however, insoluble in organic solvents.

(13) $LiCl$ is deliquescent while $NaCl$, KBr etc. are not. Lithium chloride crystals contain two molecules of water of crystallisation ($LiCl.\ 2H_2O$). Crystals of $NaCl$ KBr, KI etc do not conation water of crystallisation.

(14) Li_2SO_4 does not form alums like other alkali metals.

(15) Li reacts with water slowly at room temperature Na reacts vigorously Reaction with K. Rb and Cs is violent.

(16) Li reacts with Br_2 slowly. Reaction of other alkali metals with Br_2 is fast.

(17) $Li_2\ CO_3$ $Li_2C_2O_4$, LiF , Li_3PO_4 are the only alkali metal salts which are insoluble or sparingly soluble in water.

Diagonal Relationship of *Li* with *Mg*

Due to its small size lithium differs from other alkali metals but resembles with Mg as its size is closer to Mg Its resemblance with Mg is known as diagonal relationship. Generally the periodic properties show either increasing or decreasing trend along the group and vice versa along the period which brought the diagonally situated elements to closer values. Following are the characteristic to be noted.

Period	Group I	Group II
2	*Li*	*Be*
3	*Na*	*Mg*

(1) Both Li and Mg are harder and higher m.pt than the other metals of their groups.

(2) Due to covalent nature, chlorides of both Li and Mg are deliquescent and soluble in alcohol and pyridine while chlorides of other alkali metals are not so.

(3) Fluorides, phosphates of Li and Mg are sparingly soluble in water whereas those of other alkali metals are soluble in water.

(4) Carbonates of Li and Mg decompose on heating and liberate CO_2 Carbonates of other alkali metals are stable towards heat and decomposed only on fusion.

$$Li_2CO_3 \rightarrow Li_2O + CO_2 \ ; \ Mg\ CO_3 \rightarrow MgO + CO_2$$

(5) Hydroxides and nitrates of both Li and Mg decompose on heating to give oxide. Hydroxides of both Li and Mg are weak alkali.

$$4\ LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$$

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

$$2LiOH \rightarrow Li_2O + H_2O \ ; \ Mg(OH)_2 \rightarrow MgO + H_2O$$

Hydroxides of other alkali metals are stable towards heat while their nitrates give O_2 and nitrite.

$$2KNO_3 \rightarrow 2KNO_2 + O_2$$

(6) Both Li and Mg combine directly with N_2 to give nitrides Li_3N and Mg_3N_2. Other alkali metals combine at high temperature, $6Li + N_2 \rightarrow 2Li_3N$; $3Mg + N_2 \rightarrow Mg_3N_2$. Both the nitrides are decomposed by water to give NH_3

$$Li_3N + 3H_2O \rightarrow 3LiOH + NH_3 \ ;$$

$$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$$

(7) Bicarbonates of Li and Mg are more soluble in water than carbonates whereas carbonates of alkali metals are more soluble.

(8) Both Li and Mg combine with carbon on heating.

$$2Li + 2C \rightarrow Li_2C_2 \ ; \ Mg + 2C \rightarrow Mg\ C_2$$

(9) The periodic properties of Li and Mg are quite comparable

	Li	*Mg*
Electronegativity	1.0	1.2

Atomic radii 1.23 1.36

Ionic radii 0.60(Li^+) 0.65(Mg^{+2})

Atomic volume 12.97 c.c 13.97 c.c

(10) Both have high polarizing power.

Polarizing Power = Ionic charge / (ionic radius)^2.

(11) Li and Mg Form only monooxide on heating in oxygen.

$$4Li + O_2 \rightarrow 2\ Li_2O\ ;\ 2Mg + O_2 \rightarrow 2\ MgO$$

(12) Li_2SO_4 like $MgSO_4$ does not form alums.

(13) The bicarbonates of Li and Mg do not exist in solid state, they exist in solution only.

(14) Alkyls of Li and Mg (R. Li and R.MgX) are soluble in organic solvent.

(15) Lithium chloride and $MgCl_2$ both are deliquescent and separate out from their aqueous solutions as hydrated crystals, $LiCl.\ 2H_2O$ and $MgCl_2\ .\ 2H_2O$.

Uses of Lithium

(1) It is used as a deoxidiser in metallurgy of Cu and Ni.

(2) It is used as an alloying metal with

(i) Pb to give toughened bearings.

(ii) Al to give high strength Al-alloy for aircraft industry.

(iii) Mg (14% Li) to give extremely tough and corrosion resistant alloy which is used for armour plate in aerospace components.

Sodium and its compounds

(1) **Ores of sodium :** $NaCl$ (common salt), $NaNO_3$ (chile salt petre), $Na_2SO_4.10H_2O$ (Glauber's salt), borax (sodium tetraborate or sodium borate, $(Na_2B_4O_7.10H_2O)$.

(2) **Extraction of sodium :** It is manufactured by the electrolysis of fused sodium chloride in the presence of $CaCl_2$ and KF using graphite anode and iron cathode. This process is called ***Down process***.

$$NaCl \rightleftharpoons Na^+ + Cl^-\ .$$

At cathode : $Na^+ + e^- \rightarrow Na$;

At anode : $Cl^- \rightarrow Cl + e^-$; $Cl + Cl \rightarrow Cl_2 \uparrow$

Sodium cannot be extracted from aqueous $NaCl$ because $E^0_{H_2O/H_2}$ (–0.83V) is more than $E^0 Na^+/Na$ (–2.71V).

Anode and cathode are separated by means of a wire gauze to prevent the reaction between Na and Cl_2.

(3) **Compound of sodium**

(i) ***Sodium chloride*** : It is generally obtained by evaporation of sea water by sun light. However $NaCl$ so obtained contains impurities like $CaSO_4, CaCl_2$ and $MgCl_2$ which makes the salt deliquescent. It is then purified by allowing HCl gas to pass through the impure saturated solution of $NaCl$. The concentration of Cl^- ions increases and as a result pure $NaCl$ gets precipitated due to common ion effect.

(ii) ***Sodium hydroxide NaOH*** *(Caustic soda)*

Preparation

(a) *Gossage process* :

$$\underset{\text{(10\% solution)}}{Na_2CO_3} + Ca(OH)_2 \rightarrow 2NaOH \downarrow + CaCO_3$$

(b) *Electrolytic method* : Caustic soda is manufactured by the electrolysis of a concentrated solution of $NaCl$.

At anode: Cl^- discharged; At cathode: Na^+ discharged

(c) *Castner - Kellener cell* (Mercury cathode process) : $NaOH$ obtained by electrolysis of *aq.* solution of brine. The cell comprises of rectangular iron tank divided into three compartments.

Outer compartment – Brine solution is electrolysed ; Central compartment – 2% $NaOH$ solution and H_2

Properties : White crystalline solid, highly soluble in water, It is only sparingly soluble in alcohol.

(a) *Reaction with salt* :

$$FeCl_3 + 3NaOH \rightarrow \underset{\text{(Insoluble hydroxide)}}{Fe(OH)_3} \downarrow + 3NaCl$$

$$HgCl_2 + 2NaOH \rightarrow 2NaCl + \underset{\text{unstable}}{Hg(OH)_2} \rightarrow \mathrm{H}_2O + \underset{\text{yellow}}{HgO \downarrow}$$

$$AgNO_3 + 2NaOH \rightarrow 2NaNO_3 + 2AgOH \rightarrow \underset{\text{Brown}}{Ag_2O} \downarrow + H_2O$$

Zn, Al, Sb, Pb, Sn and As forms insoluble hydroxide which dissolve in excess of $NaOH$ (amphoteric hydroxide).

$$NH_4Cl + NaOH \xrightarrow{\text{heat}} NaCl + NH_3 \uparrow + H_2O$$

(b) *Reaction with halogens* :

$$X_2 + 2NaOH\ \text{(cold)} \rightarrow NaX + \underset{\text{sod. hypohalite}}{NaXO} + H_2O$$

$$3X_2 + 6NaOH\ \text{(hot)} \rightarrow 5NaX + \underset{\text{(Sod. halate)}}{NaXO_3} + 3H_2O\ ;$$

$(X = Cl, Br, I)$

(c) *Reaction with metals* : Weakly electropositive metals like Zn, Al and Sn etc.

$$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2 \uparrow$$

(d) *Reaction with sand, SiO_2* :

$$2NaOH + SiO_2 \rightarrow \underset{\text{Sod. silicate (glass)}}{Na_2SiO_3} + H_2O$$

(e) *Reaction with CO*:

$$NaOH + CO \xrightarrow[5-10\ atm]{150-200^o C} \underset{\text{Sod. formate}}{HCOONa}$$

$NaOH$ breaks down the proteins of the skin flesh to a pasty mass, therefore it is commonly known as caustic soda.

Caustic property : sodium hydroxide breaks down the proteins of the skin flesh to a pasty mass, therefore, it is commonly known as caustic soda.

Uses : Sodium hydroxide is used :

(a) in the manufacture of soidum metal, soap (from oils and fats), rayon, paper, dyes and drugs,

(b) for mercurinzing cotton to make cloth unshrinkable and

(c) as a reagent in the laboratory.

(iii) ***Sodium carbonate or washing soda,*** $\mathbf{Na_2CO_3}$

It exists in various forms, namely anhydrous sodium carbonate Na_2CO_2 (soda-ash); monohydrate $Na_2CO_3.H_2O$ (crystal carbonate); hyptahydrate $Na_2CO_3.7H_2O$ and decahydrate $Na_2CO_3.10H_2O$ (washing soda or sal soda).

Preparation **:** (a) *Solvay process* : In this process, brine $(NaCl)$, NH_3 and CO_2 are the raw materials.

$$NH_3 + CO_2 + H_2O \rightarrow NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \xrightarrow{30^o C} NaHCO_3 \downarrow + NH_4Cl$$

$$2NaHCO_3 \xrightarrow{250^o C} Na_2CO_3 + H_2O + CO_2$$

$$2NH_4Cl + \underset{\substack{\text{slaked}\\ \text{lime}}}{Ca(OH)_2} \rightarrow CaCl_2 + 2H_2O + 2NH_3$$

$CaCl_2$ so formed in the above reaction is a by product of solvay process.

Properties

(a) $\underset{\text{(decahydra te)}}{Na_2CO_3.10H_2O} \xrightarrow{\text{dry air}} \underset{\text{(Monohydrate)}}{Na_2CO_3.H_2O} + 9H_2O$

$$Na_2CO_3.H_2O \xrightarrow{\Delta} Na_2CO_3$$

It does not decompose on funrther heating even to redness (m.pt. 853°C)

(b) It is soluble in water with considerable evolution of heat.

$$Na_2CO_3 + H_2O \rightarrow \underset{\text{Weakacid}}{H_2CO_3} + 2Na^+ + 2OH^-$$

(c) It is readily decomposed by acids with the evolution of CO_2 gas.

(d) $Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$

Uses **:** In textile and petroleum refining, Manufacturing of glass, $NaOH$ soap powders etc.

(iv) ***Sodium peroxide*** $\mathbf{(Na_2O_2)}$

Preparation **:** It is manufactured by heating sodium metal on aluminium trays in air (free from CO_2)

$$2Na + O_2\,\text{(air)} \xrightarrow{\Delta} Na_2O_2$$

Properties **:** (a) When pure it is colourless. The faint yellow colour of commercial product is due to presence of small amount of superoxide (NaO_2).

(b) On coming with moist air it become white due to formation of $NaOH$ and Na_2CO_3.

$$2Na_2O_2 + 2H_2O \rightarrow 4NaOH + O_2 \;;$$

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

(c) It is powerful oxidising agent. It oxidises Cr (III) hydroxide to sodium chromate, Mn (II) to sodium manganate and sulphides to sulphates.

Uses : As a bleaching agent and it is used for the purification of air in confined spaces such as submarines because it can combine with CO_2 to give Na_2CO_3 and oxygen, $2CO_2 + 2Na_2O_2 \rightarrow 2Na_2CO_3 + O_2$.

(v) ***Micro cosmic salt*** $\mathbf{[Na\,(NH_4)\,HPO_4.\,4H_2O]}$

Prepared by dissolving equimolar amounts of Na_2HPO_4 and NH_4Cl in water in 1 : 1 ratio followed by crystallization

$$NH_4Cl + Na_2HPO_4 \longrightarrow \underset{\downarrow \textit{Crystallization}}{Na(NH_4)HPO_4} + NaCl$$

$$\underset{\text{(Colourless crystal)}}{Na(NH_4)HPO_4.4H_2O}$$

Chemical properties :

On heating M.C.S, $NaPO_3$ is formed. $NaPO_3$ forms coloured beads with oxides of transition metal cloudy SiO_2

$$Na(NH_4)HPO_4 \xrightarrow{\Delta} \underset{\substack{\text{(Sodium meta}\\ \text{phosphate)}}}{NaPO_3} + H_2O + NH_3$$

$$\underset{\substack{\text{(Transparent}\\ \text{glassy bead)}}}{NaPO_3} + CuO \xrightarrow{\Delta} \underset{\text{(blue bead)}}{CuNaPO_4}$$

$NaPO_3 + CoO \longrightarrow CoNaPO_4$ (blue bend)

$NaPO_3 + MnO \longrightarrow NaMnO_4$ (blue bead)

Uses : (a) For the formation of sodium meta phosphate and copper sodium phosphate

(b) It is used for the detection of colured ion

(c) It is espacially used for testing silica with which a cloudy bead containing floating properties of silica is obtained.

(vi) ***Sodium bi Carbonate ($NaHCO_3$, Baking soda)***

Preparation : It is an inter mediate compound in manufacture of sodium carbonate by the solvay's process

$$NaCl + NH_3 + CO_2 + H_2 \longrightarrow NaHCO_3 + NH_4Cl$$

Properties:

$$2NaHCO_3 \xrightarrow{50-100^o C} Na_2CO_3 + H_2O + CO_2$$

It is amphiprotic $HCO_3^- + H^+ \rightleftharpoons H_2CO_3$

$$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$$

Uses : (a) Baking powder contains $NaHCO_3$, $Ca(H_2PO_4)_2$ and starch.

Improved Baking powder contains 40% starch 30% $NaHCO_3$, 20% $NaAl(SO_4)_2$ and 10% $CaH_2(PO_4)$

(b) In pharmacentical industry (Antacids etc.)

(c) Fire extingerishers.

(vii) ***Sodium Sulphate Na_2SO_4* or *salt cake***

Preparation : It is the by-product of HCl industry

$$2NaCl + H_2SO_4 \longrightarrow Na_2SO_4 + HCl$$

Properties : When aqueous solution of Na_2SO_4 is cooled below $32^o C$ Glauber's salt $(Na_2SO_4.10H_2O)$ gets crystallised and if cooled to $12^o C$, $Na_2SO_4 7H_2O$ crystals are formed.

$$Na_2SO_4.10H_2O \xrightarrow{\text{(indry air)}} Na_2SO_4 + 10H_2O$$

Uses : Na_2SO_4 finds use in paper industry detergent and glass manufacturing.

Alkaline Earth Metals and Their Compounds

The group 2 of the periodic table consists of six metallic elements. These are beryllium (*Be*), magnesium (*Mg*), calcium (*Ca*), strontium (*Sr*), barium (*Ba*) and radium (*Ra*). These (except *Be*) are known as alkaline earth metals as their oxides are alkaline and occur in earth crust.

(1) **Electronic configuration**

Element	Electronic configurations (ns^2)
$_4 Be$	$[He]2s^2$
$_{12} Mg$	$[Ne]3s^2$
$_{20} Ca$	$[Ar]4s^2$
$_{38} Sr$	$[Kr]5s^2$
$_{56} Ba$	$[Xe]6s^2$
$_{88} Ra$	$[Rn]7s^2$

Radium was discovered in the ore pitch blende by madam Curie. It is radioactive in nature.

(2) **Occurrence :** These are found mainly in combined state such as oxides, carbonates and sulphates *Mg* and *Ca* are found in abundance in nature. *Be* is not very abundant, *Sr* and *Ba* are less abundant. *Ra* is rare element. Some important ores of alkaline earth metals are given below,

(i) ***Baryllium*** : Beryl ($3BeO.Al_2O_3.6SiO_2$); Phenacite (Be_2SiO_4)

(ii) ***Magnesium*** : Magnesite ($MgCO_3$); Dolomite ($CaCO_3$. $MgCO_3$); Epsomite($MgSO_4$. $7H_2O$); Carnallite ($MgCl_2.KCl$. $6H_2O$); Asbestos [$CaMg_3(SiO_3)_4$]

(iii) ***Calcium*** : Limestone ($CaCO_3$); Gypsum : ($CaSO_4.2H_2O$), Anhydrite ($CaSO_4$); Fluorapatite [($3Ca_3(PO_4)_2.CaF_2$)] Phosphorite rock [$Ca_3(PO_4)_2$]

(iv) ***Barium*** : Barytes ($BaSO_4$) ; witherite ($BaCO_3$)

(v) ***Radium*** : Pitch blende (U_3O_8); (*Ra* in traces); other radium rich minerals are carnotite [K_2UO_2)] (VO_4)₂ $8H_2O$ and antamite [$Ca(UO_2)_2$]

(3) **Extraction of alkaline earth metals**

(i) *Be* and *Mg* are obtained by reducing their oxides carbon,

$$BeO + C \to Be + CO \;\; ; \;\; MgO + C \to Mg + CO$$

(ii) The extraction of alkaline earth metals can also be made by the reduction of their oxides by alkali metals or by electrolysing their fused salts.

(4) **Alloy formation** : These dissolve in mercury and form amalgams.

Physical properties

(1) **Physical state :** All are greyish-white, light, malleable and ductile metals with metallic lustre. Their hardness progressively decrease with increase in atomic number. Although these are fairly soft but relatively harder than alkali metals.

(2) **Atomic and ionic radii**

(i) The atomic and ionic radii of alkaline earth metals also increase down the group due to progressive addition of new energy shells like alkali metals.

	Be	*Mg*	*Ca*	*Sr*	*Ba*	*Ra*
Atomic radius (pm)	112	160	197	215	222	–
Ionic radius of M²⁺ ion (pm)	31	65	99	113	135	140

(ii) The atomic radii of alkaline earth metals are however smaller than their corresponding alkali metal of the same period. This is due to the fact that alkaline earth metals possess a higher nuclear charge than alkali metals which more effectively pulls the orbit electrons towards the nucleus causing a decrease in size.

(3) **Density**

(i) Density decreases slightly upto *Ca* after which it increases. The decrease in density from *Be* to *Ca* might be due to less packing of atoms in solid lattice of *Mg* and *Ca*.

Be	*Mg*	*Ca*	*Sr*	*Ba*	*Ra*
1.84	1.74	1.55	2.54	3.75	6.00

(ii) The alkaline earth metals are more denser, heavier and harder than alkali metal. The higher density of alkaline earth metals is due to their smaller atomic size and strong intermetallic bonds which provide a more close packing in crystal lattice as compared to alkali metals.

(4) **Melting point and Boiling point**

(i) Melting points and boiling points of alkaline earth metals do not show any regular trend.

	Be	*Mg*	*Ca*	*Sr*	*Ba*	*Ra*
melting points (K)	1560	920	1112	1041	1000	973
boiling point (K)	2770	1378	1767	1654	1413	–

(ii) The values are, however, more than alkali metals. This might due to close packing of atoms in crystal lattice in alkaline earth metals.

(5) **Ionisation energy and electropositive or metallic character**

(i) Since the atomic size decreases along the period and the nuclear charge increases and thus the electrons are more tightly held towards nucleus. It is therefore alkaline earth metals have higher ionisation energy in comparison to alkali metals but lower ionisation energies in comparison to p-block elements.

(ii) The ionisation energy of alkaline earth metals decreases from *Be* to *Ba*.

	Be	*Mg*	*Ca*	*Sr*	*Ba*	*Ra*
First ionisation energy ($k\,J\,mol^{-1}$)	899	737	590	549	503	509
Second ionisation energy ($kJ\,mol^{-1}$)	1757	1450	1146	1064	965	979

(iii) The higher values of second ionisation energy is due to the fact that removal of one electron from the valence shell, the remaining electrons are more tightly held in which nucleus of cation and thus more energy is required to pull one more electron from monovalent cation.

(iv) No doubt first ionisation energy of alkaline earth metals are higher than alkali metals but a closer look on 2nd ionisation energy of alkali metals and alkaline earth metals reveals that 2nd ionisation energy of alkali metals are more

	Li	*Be*
1st ionisation energy ($kJ\,mol^{-1}$)	520	899
2nd ionisation energy ($kJ\,mol^{-1}$)	7296	1757

This may be explained as,

$$Li : 1s^2, 2s^1 \xrightarrow[\text{electron}]{\text{removal of 2s}} Li^+ : 1s^2 \xrightarrow[\text{electron}]{\text{removal of 1s}} Li^{2+} : 1s^1$$

$$Be : 1s^2, 2s^2 \xrightarrow[\text{electron}]{\text{removal of 2s}} Be^+ : 1s^2, 2s^1 \xrightarrow[\text{electron}]{\text{removal of 2s}} Be^{2+} : 1s^2$$

The removal of 2nd electron from alkali metals takes place from 1s sub shell which are more closer to nucleus and exert more nuclear charge to hold up 1s electron core, whereas removal of 2nd electron from alkaline earth metals takes from 2s sub shell. More closer are shells to the nucleus, more tightly are held electrons with nucleus and thus more energy is required to remove the electron.

(v) All these possess strong electropositive character which increases from *Be* to *Ba*.

(vi) These have less electropositive character than alkali metals as the later have low values of ionisation energy.

(6) **Oxidation number and valency**

(i) The IE_1 of the these metals are much lower than IE_1 and thus it appears that these metals should form univalent ion rather than divalent ions but in actual practice, all these give bivalent ions. This is due to the fact that M^{2+} ion possesses a higher degree of hydration or M^{2+} ions are extensively hydrated to form $[M(H_2O)_x]^{2+}$, a hydrated ion. This involves a large amount of energy evolution which counter balances the higher value of second ionisation energy.

$$M \rightarrow M^{2+}, \qquad \Delta H = IE_1 + E_2$$

$$M^{2+} + {}_xH_2O \rightarrow [M(H_2O)_x]^{2+}; \; \Delta H = - \text{hydration energy.}$$

(ii) The tendency of these metals to exist as divalent cation can thus be accounted as,

(a) Divalent cation of these metals possess noble gas or stable configuration.

(b) The formation of divalent cation lattice leads to evolution of energy due to strong lattice structure of divalent cation which easily compensates for the higher values of second ionisation energy of these metals.

(c) The higher heats of hydration of divalent cation which accounts for the existence of the divalent ions of these metals in solution state.

(7) **Hydration of ions**

(i) The hydration energies of alkaline earth metals divalent cation are much more than the hydration energy of monovalent cation.

	Mg^+	Mg^{2+}
Hydration energy or Heat of hydration ($kJ\ mol^{-1}$)	353	1906

The abnormally higher values of heat of hydration for divalent cations of alkaline earth metals are responsible for their divalent nature. $MgCl_2$ formation occurs with more amount of heat evolution and thus $MgCl_2$ is more stable.

(ii) The hydration energies of M^{2+} ion decreases with increase in ionic radii.

	Be^{2+}	Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}
Heat of hydration $kJ\ mol^{-1}$	2382	1906	1651	1484	1275

(iii) Heat of hydration are larger than alkali metals ions and thus alkaline earth metals compounds are more extensively hydrated than those of alkali metals e.g $MgCl_2$ and $CaCl_2$ exists as $Mg\ Cl_2 .6H_2O$ and $CaCl_2.\ 6H_2O$ which $NaCl$ and KCl do not form such hydrates.

(iv) The ionic mobility, therefore, increases from Be^{2+} to Ba^{2+}, as the size of hydrated ion decreases.

(8) **Electronegativities**

(i) The electronegativities of alkaline earth metals are also small but are higher than alkali metals.

(ii) Electronegativity decreases from *Be* to *Ba* as shown below,

	Be	*Mg*	*Ca*	*Sr*	*Ba*
Electronegativity	1.57	1.31	1.00	0.95	0.89

(9) **Conduction power :** Good conductor of heat and electricity.

(10) **Standard oxidation potential and reducing properties**

(i) The standard oxidation potential (in volts) are,

Be	*Mg*	*Ca*	*Sr*	*Ba*
1.69	2.35	2.87	2.89	2.90

(ii) All these metals possess tendency to lose two electrons to give M^{2+} ion and are used as reducing agent.

(iii) The reducing character increases from *Be* to *Ba*, however, these are less powerful reducing agent than alkali metals.

(iv) Beryllium having relatively lower oxidation potential and thus does not liberate H_2 from acids.

(11) **Characteristic flame colours**

The characteristic flame colour shown are : *Ca* - brick red; *Sr* –crimson ; *Ba*-apple green and *Ra*-crimson.

Chemical Properties

(1) **Formation of oxides and hydroxides**

(i) The elements (except *Ba* and *Ra*) when burnt in air give oxides of ionic nature $M^{2+}O^{2-}$ which are crystalline in nature. *Ba* and *Ra* however give peroxide. The tendency to form higher oxides increases from *Be* to *Ra*.

$2M + O_2 \rightarrow 2MO$ (M is Be, Mg or Ca)

$2M + O_2 \rightarrow MO_2$ (M is Ba or Sr)

(ii) Their less reactivity than the alkali metals is evident by the fact that they are slowly oxidized on exposure to air, However the reactivity of these metals towards oxygen increases on moving down the group.

(iii) The oxides of these metals are very stable due to high lattice energy.

(iv) The oxides of the metal (except *BeO* and *MgO*) dissolve in water to form basic hydroxides and evolve a large amount of heat. *BeO* and *MgO* possess high lattice energy and thus insoluble in water.

(v) *BeO* dissolves both in acid and alkalies to give salts *i.e. BeO* possesses amphoteric nature.

$BeO+2NaOH \rightarrow Na_2BeO_2+H_2O$; $BeO+2HCl \rightarrow BeCl_2+H_2O$

Sod. beryllate

Beryllium chloride

(vi)The basic nature of oxides of alkaline earth metals increases from *Be* to *Ra* as the electropositive Character increases from *Be* to *Ra*.

(vii)The tendency of these metal to react with water increases with increase in electropositive character *i.e. Be* to *Ra*.

(viii) Reaction of *Be* with water is not certain, magnesium reacts only with hot water, while other metals react with cold water but slowly and less energetically than alkali metals.

(ix) The inertness of *Be* and *Mg* towards water is due to the formation of protective, thin layer of hydroxide on the surface of the metals.

(x) The basic nature of hydroxides increase from *Be* to *Ra*. It is because of increase in ionic radius down the group which results in a decrease in strength of $M - O$ bond in $M -(OH)_2$ to show more dissociation of hydroxides and greater basic character.

(xi) The solubility of hydroxides of alkaline earth metals is relatively less than their corresponding alkali metal hydroxides Furthermore, the solubility of hydroxides of alkaline earth metals increases from *Be* to *Ba*. $Be\ (OH)_2$ and $Mg\ (OH)_2$ are almost insoluble, $Ca\ (OH)_2$ (often called lime water) is sparingly soluble whereas $Sr(OH)_2$ and $Ba\ (OH)_2$ (often called baryta water) are more soluble.

The trend of the solubility of these hydroxides depends on the values of lattice energy and hydration energy of these hydroxides. The magnitude of hydration energy remains almost same whereas lattice energy decreases appreciably down the group leading to more –Ve values for $\Delta H_{\text{solution}}$ down the group.

$$\Delta H_{\text{solution}} = \Delta H_{\text{lattice energy}} + \Delta H_{\text{hydration energy}}$$

More negative is $\Delta H_{\text{solution}}$ more is solubility of compounds.

(xii) The basic character of oxides and hydroxides of alkaline earth metals is lesser than their corresponding alkali metal oxides and hydroxides.

(xiii) Aqueous solution of lime water $[Ca(OH)_2]$ or baryta water $[Ba(OH)]_2$ are used to qualitative identification and quantative estimation of carbon dioxide, as both of them gives white precipitate with CO_2 due to formation of insoluble $CaCO_3$ or $BaCO_3$

$$\underset{\text{(white ppt)}}{Ca(OH)_2 + CO_2 \rightarrow CaCO_3} + H_2O\ ;\ \underset{\text{(white ppt)}}{Ba(OH)_2 + CO_2 \rightarrow BaCO_3} + H_2O$$

SO_2 also give white ppt of $CaSO_3$ and $BaSO_3$ on passing through lime water or baryta water. However on passing CO_2 in excess, the white turbidity of insoluble carbonates dissolve to give a clear solution again due to the formation of soluble bicarbonates,

$$CaCO_3 \rightarrow H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

(2) **Hydrides**

(i) Except Be, all alkaline earth metals form hydrides (MH_2) on heating directly with H_2 . $M + H_2 \rightarrow MH_2$.

(ii) BeH_2 is prepared by the action of $LiAlH_4$ On $BeCl_2$

$$2BeCl_2 + LiAlH_4 \rightarrow 2BeH_2 + LiCl + AlCl_3.$$

(iii) BeH_2 and MgH_2 are covalent while other hydrides are ionic.

(iv) The ionic hydrides of Ca, Sr, Ba liberate H_2 at anode and metal at cathode.

$$CaH_2 \xrightleftharpoons{\text{fusion}} Ca^{2+} + 2H^-$$

Anode : $2H^- \rightarrow H_2 + 2e^-$ Cathode : $Ca^{2+} + 2e^- \rightarrow Ca$

(v) The stability of hydrides decreases from Be to Ba.

(vi) The hydrides having higher reactivity for water, dissolves readily and produce hydrogen gas.

$$CaH_{2(s)} + 2H_2O \rightarrow Ca(OH)_2 + 2H_2\uparrow$$

(3) **Carbonates and Bicarbonates**

(i) All these metal carbonates (MCO_3) are insoluble in neutral medium but soluble in acid medium. These are precipitated by the addition of alkali metal or ammonium carbonate solution to the solution of these metals.

$$(NH_4)_2\,CO_3 + CaCl_2 \rightarrow 2NH_4Cl + CaCO_3$$

$$Na_2CO_3 + BaCl_2 \rightarrow 2NaCl + BaCO_3$$

(ii) Alkaline earth metal carbonates are obtained as white precipitates when calculated amount of carbon dioxide is passed through the solution of the alkaline metal hydroxides.

$$M(OH)_{2\,(aq)} + CO_{2\,(g)} \rightarrow MCO_{3(s)} + H_2O_{(l)}$$

and sodium or ammonium carbonate is added to the solution of the alkaline earth metal salt such as $CaCl_2$.

$$CaCl_{2\,(aq)} + Na_2CO_{3\,(aq)} \rightarrow CaCO_{3(s)} + 2\,NaCl_{(aq)}$$

(iii) Solubility of carbonates of these metals also decreases downward in the group due to the decrease of hydration energy as the lattice energy remains almost unchanged as in case of sulphates.

(vi) The carbonates of these metals decompose on heating to give the oxides, the temperature of decomposition increasing from Be to Ba. Beryllium carbonate is unstable.

$$MCO_3 \xrightarrow{Heat} MO + CO_2$$

(4) **Halides**

(i) The alkaline earth metals combine directly with halogens at appropriate temperatures forming halides, MX_2. These halides can also be prepared by the action of halogen acids (HX) on metals, metal oxides, hydroxides and carbonates.

$$M + 2HX \rightarrow MX_2 + H_2\ ;\ MO + 2HX \rightarrow MX_2 + H_2O$$

$$M(OH)_2 + 2HX \rightarrow MX_2 + 2H_2O$$

$$MCO_3 + 2HX \rightarrow MX_2 + CO_2 + H_2O$$

Beryllium chloride is however, conveniently obtained from oxide

$$BeO + C + Cl_2 \xrightarrow{870-1070\,K} BeCl_2 + CO$$

(ii) $BeCl_2$ is essentially covalent, the chlorides $MgCl_2$, $CaCl_2$, $SrCl_2$ and $BaCl_2$ are ionic; the ionic character increases as the size of the metal ion increases. The evidence is provided by the following facts,

(a) Beryllium chloride is relatively low melting and volatile whereas $BaCl_2$ has high melting and stable.

(b) Beryllium chloride is soluble in organic solvents.

(iii) The halides of the members of this group are soluble in water and produce neutral solutions from which the hydrates such : $MgCl_2\ 6H_2O$, $CaCl_2.6H_2O$. $BaCl_2\ 2H_2O$ can be crystallised. The tendency to form hydrated halides decreases with increasing size of the metal ions.

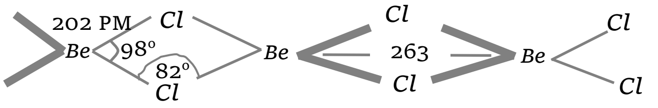
(iv) $BeCl_2$ is readily hydrolysed with water to form acid solution, $BeCl_2 + 2H_2O \rightarrow Be\ (OH)_2 + 2HCl$.

(v) The fluorides are relatively less soluble than the chlorides due to high lattice energies. Except $BeCl_2$

and $MgCl_2$ the chlorides of alkaline earth metals impart characteristic colours to flame.

$CaCl_2$	$SrCl_2$	$BaCl_2$
Brick red colour	Crimson colour	Grassy green colour

Structure of $BeCl_2$: In the solid phase polymeric chain structure with three centre two electron bonding with *Be*-Cl-*Be* bridged structure is shown below,



In the vapour phase it tends to form a chloro-bridged dimer which dissociates into the linear triatomic monomer at high temperature at nearly 1200 *K*.

(5) **Solubility in liquid ammonia :** Like alkali metals, alkaline earth metals also dissolve in liquid ammonia to form coloured solutions When such a solution is evaporated, hexammoniate, $M(NH_3)_6$ is formed.

(6) **Nitrides**

(i) All the alkaline earth metals direct combine with N_2 give nitrides, M_3N_2.

(ii) The ease of formation of nitrides however decreases from *Be* to *Ba*.

(iii) These nitrides are hydrolysed water to liberate

NH_3, $M_3N_2 + 6H_2O \rightarrow 3M(OH)_2 + 2NH_3$

(7) **Sulphates**

(i) All these form sulphate of the type $M\ SO_4$ by the action of $H_2\ SO_4$ on metals, their oxides, carbonates or hydroxides.

$M + H_2SO_4 \rightarrow MSO_4 + H_2$; $MO + H_2SO_4 \rightarrow MSO_4 + H_2O$

$MCO_3 + H_2SO_4 \rightarrow MSO_4 + H_2O + CO_2$

$M(OH)_2 + H_2SO_4 \rightarrow MSO_4 + 2H_2O$

(ii) The solubility of sulphates in water decreases on moving down the group $BeSO_4$ and $MgSO_4$ are fairly soluble in water while $BaSO_4$ is completely insoluble. This is due to increases in lattice energy of sulphates down the group which predominates over hydration energy.

(iii) Sulphate are quite stable to heat however reduced to sulphide on heating with carbon.

$MSO_4 + 2C \rightarrow MS + 2CO_2$

(8) **Action with carbon** : Alkaline metals (except *Be*, *Mg*) when heated with carbon form carbides of the type MC_2 These carbides are also called acetylides as on hydrolysis they evolve acetylene.

$MC_2 + 2H_2O \rightarrow M(OH)_2 + C_2H_2$

(9) **Action with sulphur and phosphorus :** Alkaline earth metals directly combine with sulphur and phosphorus when heated to form sulphides of the type *MS* and phosphides of the type M_3P_2 respectively.

$M + S \rightarrow MS$; $3M + 2P \rightarrow M_3P_2$

Sulphides on hydrolysis liberate H_2S while phosphides on hydrolysis evolve phosphine.

MS + dil. acid $\rightarrow H_2S$; M_3P_2 + dil. acid $\rightarrow PH_3$

Sulphides are phosphorescent and are decomposed by water

$2MS + 2H_2O \rightarrow M(OH)_2 + M(HS)_2$

(10) **Nitrates :** Nitrates of these metals are soluble in water On heating they decompose into their corresponding oxides with evolution of a mixture of nitrogen dioxide and oxygen.

$$M(NO_3)_2 \rightarrow MO + 2NO_2 + \left(\frac{1}{2}\right)O_2$$

(11) **Formation of complexes**

(i) Tendency to show complex ion formation depends upon smaller size, high nuclear charge and vacant orbitals to accept electron. Since alkaline metals too do not possess these characteristics and thus are unable to form complex ion.

(ii) However, Be^{2+} on account of smaller size forms many complex such as $(BeF_3)^{1-}$, $(BeF_4)^{2-}$.

Anomalous behaviour of Beryllium

Beryllium differs from rest of the alkaline earth metals on account of its small atomic size, high electronegativity Be^{2+} exerts high polarizing effect on anions and thus produces covalent nature in its compounds. Following are some noteworthy difference of *Be* from other alkaline earth metals,

(1) *Be* is lightest alkaline earth metal.

(2) *Be* possesses higher m.pt. and b.pt than other group members.

(3) *BeO* is amphoteric in nature whereas oxides of other group members are strong base.

(4) It is not easily effected by dry air and does not decompose water at ordinary temperature.

(5) $BeSO_4$ is soluble in water.

(6) *Be* and *Mg* carbonates are not precipitated by $(NH_4)_2CO_3$ in presence of NH_4Cl.

(7) *Be* and *Mg* salts do not impart colour to flame.

(8) *Be* does not form peroxide like other alkaline earth metals.

(9) It does not evolve hydrogen so readily from acids as other alkaline earth metals do so.

(10) It has strong tendency to form complex compounds.

(11) Be_3N_2 is volatile whereas nitrides of other alkaline earth metals are non-volatile.

(12) It's salts can never have more than four molecules of water of crystallization as it has only four available orbitals in its valence shell.

(13) Berylium carbide reacts water to give methane whereas magnesium carbide and calcium carbide give propyne and acetylene respectively.

$Be_2C + 4H_2O \rightarrow 2Be(OH)_2 + CH_4$

$Mg_2C_3 + 4H_2O \rightarrow 2Mg(OH)_2 + C_3H_6$

$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_4$

Diagonal relationship of *Be* with *Al*

Due to its small size *Be* differs from other earth alkaline earth metals but resembles in many of its properties with *Al* on account of diagonal relationship.

(1) Be^{2+} and Al^{3+} have almost same and smaller size and thus favour for covalent bonding.

(2) Both these form covalent compounds having low m. pt and soluble in organic solvent.

(3) Both have same value of electronegativity (*i.e.* 1.5).

(4) The standard O.P of these elements are quite close to each other ; Be^{2+}=1.69 volts and Al^{3+}= 1.70 volts.

(5) Both become passive on treating with conc. HNO_3 in cold.

(6) Both form many stable complexes e.g. $(BeF_3)^-$, $(AlH_4)^-$.

(7) Like *BeO*, Al_2O_3 is amphoteric in nature. Also both are high melting point solids.

$Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$

$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

(8) Be and Al both react with *NaOH* to liberate H_2 forming beryllates and alluminates.

$Be + 2NaOH \rightarrow Na_2BeO_2 + H_2$

$2Al + 6NaOH \rightarrow 2Na_3AlO_3 + 3H_2$

(9) $Be_2\ C$ and Al_4C_3 both give CH_4 on treating with water.

$Be_2C + 2H_2O \rightarrow CH_4 + 2BeO$

$Al_4C_3 + 6H_2O \rightarrow 3CH_4 + 2Al_2O_3$

(10) Both occur together in nature in beryl ore, $3BeO.\ Al_2O_3.\ 6SiO_2$.

(11) Unlike other alkaline earths but like aluminium, beryllium is not easily attacked by air (Also *Mg* is not attacked by air)

(12) Both *Be* and *Al* react very slowly with dil. *HCl* to liberate H_2.

(13) Both *Be* and *Al* form polymeric covalent hydrides while hydrides of other alkaline earth are ionic.

(14) Both $BeCl_2$ and $AlCl_3$ are prepared is similar way.

$BeO + C + Cl_2 \rightarrow BeCl_2 + CO$

$Al_2O_3 + 3C + 3Cl_2 \rightarrow 2AlCl_3 + 3CO$

(15) Both $BeCl_2$ and $AlCl_3$ are soluble in organic solvents and act as catalyst in Friedel –Crafts reaction.

(16) Both *Be* $(OH)_2$ and *Al* $(OH)_3$ are amphoteric whereas hydroxides of other alkaline earths are strong alkali.

(17) The salts of *Be* and *Al* are extensively hydrated.

(18) $BeCl_2$ and $AlCl_3$ both have a bridged polymeric structure.

(19) *Be* and *Al* both form fluoro complex ions $[BeF_4]^{2-}$ and $[AlF_6]^{3-}$ in solution state whereas other members of 2nd group do not form such complexes.

Magnesium and its compounds

(1) **Ores of magnesium :** Magnesite $(MgCO_3)$, Dolomite $(MgCO_3.CaCO_3)$, Epsomite (epsom salt) $(MgSO_4.7H_2O)$ Carnallite $(MgCl_2.KCl.6H_2O)$ Asbestos $(CaMg_3(SiO_3)_4)$, Talc $(Mg_2\ (Si_2O_5)_2.Mg(OH)_2)$.

(2) **Extraction of magnesium :** It is prepared by the electrolysis of fused magnesium chloride which in turn is obtained from carnallite and magnesite.

Carnallite $(MgCl_2.KCl.6H_2O)$ can't be directly converted into anhydrous $MgCl_2$ by heating because all the water of crystallisation cannot be removed by heating. Moreover, strong heating may change it to MgO.

$$MgCl_2 + 2H_2O \xrightarrow{\Delta} MgO + 2HCl + H_2O$$

In Dow's process, magnesium chloride is obtained from sea water as $MgCl_2.6H_2O$. It is rendered anhydrous by heating it in a current of dry HCl gas. The anhydrous magnesium chloride is fused with $NaCl$ (to provide conductivity to the electrolyte and to lower the fusing temperature of anhydrous $MgCl_2$) and then electrolysed at 700^oC.

(3) **Compounds of magnesium**

(i) ***Magnesia (MgO) :*** It is used as magnesia cement. It is a mixture of MgO and $MgCl_2$. It is also called Sorel's cement.

(ii) ***Magnesium hydroxide :*** It aqueous suspension is used in Medicine as an antacid. Its medicinal name is milk of magnesia.

(iii) ***Magnesium sulphate or Epsom salt*** $(MgSO_4.7H_2O)$: It is isomorphous with $ZnSO_4.7H_2O$. It is used as a purgative in medicine, as a mordant in dyeing and as a stimulant to increase the secretion of bile.

(iv) ***Magnesium chloride*** $(MgCl_2.6H_2O)$: It is a deliquescent solid. Hydrated salt on heating in air undergoes partial hydrolysis.

$$MgCl_2.6H_2O \xrightarrow{\text{Heat}} Mg(OH)Cl + HCl + 5H_2O\ .$$

Calcium and its compounds

(1) **Ores of calcium :** Lime stone or marble or chalk $(CaCO_3)$, Gypsum $(CaSO_4.2H_2O)$, Dolomite $(CaCO_3.MgCO_3)$, Fluorspar (CaF_2), phosphorite $Ca_3(PO_4)_2$. Calcium phosphate is a constituent of bones and teeth.

(2) **Manufacture :** It is manufactured by the electrolysis of a molten mixture of calcium chloride containing some calcium fluoride. Calcium chloride is obtained as a by product of the solvay process.

(3) **Compounds of calcium**

(i) ***Calcium oxide or Quick lime or Burnt lime (CaO)*** : It's aqueous suspension is known as slaked lime.

$$CaO + H_2O \xrightarrow{\text{hissing sound}} \underset{\substack{\text{slaked}\\\text{lime}}}{Ca(OH)_2} + \text{Heat},$$

When exposed to oxy-hydrogen flame, it starts emitting light called lime light.

CaO is used as basic flux, for removing hardness of water, as a drying agent (for NH_3 gas) for preparing mortar (CaO+ sand +water).

Mortar : Mortar used in making buildings is a mixture of lime (CaO) and sand in the ratio 1 : 3 with enough water to make a thick paste. When the mortar is placed between bricks, it slowly absorbs CO_2 from the air and the slaked lime revers to $CaCO_3$.

$$Ca(OH)_2(s) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

Although the sand in the mortar is chemically inert, the grains are bound together by the particles of calcium carbonate and a hard material results.

(ii) ***Calcium chloride*** $(CaCl_2.6H_2O)$: Fused $CaCl_2$ is a good dessicant (drying agent). It can't be used to dry alcohol or ammonia as it forms additional products with them.

(iii) ***Calcium carbonate ($CaCO_3$) :***

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O\ .$$

It is insoluble in water but dissolves in the presence of CO_2 due to the formation of calcium bicarbonate.

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

It is a constituent of protective shells of marine animals.

(iv) ***Gypsum*** $(CaSO_4.2H_2O)$: On partially dehydrates to produce plaster of paris.

$$\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow{120\,^oC} \underset{\substack{\text{Plaster of}\\\text{paris}}}{CaSO_4}.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O$$

Plaster of paris :

$$\underset{\text{Plaster of paris}}{CaSO_4.\frac{1}{2}H_2O} \xrightarrow[\text{Setting}]{H_2O} \underset{\text{orthorhomb ic}}{CaSO_4.2H_2O} \xrightarrow{\text{Hardening}} \underset{\text{Monoclinic (gypsum)}}{CaSO_4.2H_2O}$$

$$\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow{200\,^oC} \underset{\text{dead burnt plaster}}{CaSO_4(\text{anhydrous})}$$

Gypsum when heated to about $200\,^oC$ is converted into anhydrous calcium sulphate. The anhydrous form (anhydrite) is known as dead burnt plaster because it does not set like plaster of paris when moistened with water.

(v) ***Calcium Hydroxide*** $Ca(OH)_2$ (slaked lime)

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + Ca(HCO_3)_2$$

Suspension of $Ca(OH)_2$ in water is called milk of lime.

$$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$$

(vi) **Cement :** (a) It is essentially a mixture of lime stone and clay. It is also called Portland cement because in presence of water it sets to a hard stone-like mass resembling with the famous Portland rock, a famous building stone of England. The approximate composition of cement is

Calcium oxide (CaO)	50 – 60 %
Silica (SiO_2)	20 – 25%
Alumina (Al_2O_3)	5 – 10%
Magnesia (MgO)	1 – 3%
Ferric oxide (Fe_2O_3)	1 – 3%

The above compounds are provided by the two raw materials, namely lime stone (which provides CaO) and clay which provides SiO_2, Al_2O_3 and Fe_2O_3. In cement, almost entire amount of lime is present in the combined state as calcium silicates ($2CaO.SiO_2$ and $3CaO.SiO_2$) and calcium aluminates ($3CaO.Al_2O_3$ and $4CaO.Al_2O_3$).

(b) Cement containing excess amount of lime cracks during setting; while cement containing less amount of lime is weak in strength.

(c) Cement with excess of silica is slow-setting and that having an excess of alumina is quick-setting.

(d) Cement containing no iron oxide is white but hard to burn.

Cement is manufactured by two processes, viz, wet and dry. A small amount (2–3%) of gypsum is added to slow down the setting of the cement so that it gets sufficiently hardened. Setting of cement is an exothermic process and involves hydration of calcium aluminates and calcium silicates.

Boron Family

Group 13 of long form of periodic table (previously reported as group III A according to

Mendeleefs periodic table) includes boron (B) ; aluminium (Al) , gallium (Ga), indium (In) and thallium (Tl) Boron is the first member of group 13 of the periodic table and is the only non-metal of this group. The all other members are metals. The non-metallic nature of boron is due its small size and high ionisation energy. The members of this family are collectively known as boron family and sometimes as aluminium family.

(1) **Electronic configuration**

Element	**Electronic configuration** ($ns^2\ np^1$)
$_5B$	$[He]2s^2 2p^1$
$_{13}Al$	$[Ne]3s^2 3p^1$
$_{31}Ga$	$[Ar]3d^{10} 4s^2 4p^1$
$_{49}In$	$[Kr]4d^{10} 5s^2 5p^1$
$_{81}Tl$	$[Xe]4f^{14} 5d^{10} 6s^2 6p^1$

(2) **Occurrence :** The important of this group elements are given below,

Boron : Borax (Tincal) ($Na_2B_4O_7.10H_2O$), Colemanite ($Ca_2B_6O_{11}5H_2O$)

Boracite ($2Mg_3B_8O_{15}.MgCl_2$), Boronatro calcite ($CaB_4O_7.NaBO_2.8H_2O$),

Kernite ($Na_2B_4O_7.4H_2O$), Boric acid (H_3BO_3)

Aluminium **:** Corundum (Al_2O_3), Diaspore ($Al_2O_3.H_2O$), Bauxite ($Al_2O_3.\ 2H_2O$), and Cryolite (Na_3AlF_6).

Physical properties

(1) A regular increasing trend in density down the group is due to increase in size.

(2) Melting points do not vary regularly and decrease from B to Ga and then increase.

(3) Boron has very high melting point because it exist as giant covalent polymer in both solid and liquid state.

(4) Low melting point of Ga ($29.8^{\circ}C$) is due to the fact that consists of only Ga_2 molecule; it exist as liquid upto $2000^{\circ}C$ and hence used in high temperature thermometry.

(5) Boiling point of these elements however show a regular decrease down the group.

(6) The abrupt increase in the atomic radius of Al is due to greater screening effect in Al (it has 8 electrons in its penultimate shell) than in B (it has 2 electrons in its penultimate shell)

(7) The atomic radii of group 13 elements are smaller than the corresponding s-block elements. This is due to the fact that when we move along the period, the new incoming electron occupy the same shell whereas the nuclear charge increases regularly showing more effective pull of nucleus towards shell electrons. This ultimately reduces the atomic size.

(8) The atomic radius of Ga is slightly lesser than of Al because in going from Al to Ga, the electrons have already occupied $3d$ sub shell in Ga. The screening effect of these intervening electrons being poor and has less influence to decrease the effective nuclear charge, therefore the electrons in Ga experience more forces of attractions towards nucleus to result in lower size of Ga than Al

(9) **Oxidation state**

(i) All exhibit +3 oxidation state and thus complete their octet either by covalent or ionic union.

(ii) Boron being smaller in size cannot lose its valence electrons to form B^{3+} ion and it usually show +3 covalence. The tendency to show +3 covalence however decreases down the group even Al shows +3 covalence in most of its compounds.

(iii) Lower elements also show +1 ionic state e.g Tl^+, Ga^+. This is due to inert pair effect. The phenomenon in which outer shell 's' electrons (ns^2) penetrate to (n-1) d-electrons and thus become closer to nucleus and are more effectively pulled the nucleus. This results in less availability of ns^2 electrons pair for bonding or ns^2 electron pair becomes inert. The inert pair effect begins after $n \geq 4$ and increases with increasing value of n.

(iv) The tendency to form M^+ ion increases down the gp. $Ga^{+1} < Tl^{+1}$

(10) **Hydrated ions :** All metal ions exist in hydrated state.

(11) **Ionisation energy**

(i) Inspite of the more charge in nucleus and small size, the first ionisation energies of this group elements are lesser than the corresponding elements of s block. This is due to the fact that removal of electron from a p-orbitals (being far away from nucleus and thus less effectively held than s-orbitals) is relatively easier than s-orbitals.

(ii) The ionisation energy of this group element decrease down the group due to increases in size like other group elements.

(iii) However, ionisation energy of Ga are higher than that of Al because of smaller atomic size of Ga due to less effective shielding of $3d$ electrons in Ga. Thus valence shell exert more effective nuclear charge in Ga to show higher ionisation energies.

(12) **Electropositive character**

(i) Electropositive character increases from B to Tl.

(ii) Boron is semi metal, more closer to non-metallic nature whereas rest all members are pure metals.

(iii) Furthermore, these elements are less electropositive than s-block elements because of smaller size and higher ionisation energies.

(13) **Oxidation potential**

(i) The standard oxidation potentials of these element are quite high and are given below,

	B	Al	Ga	In	Tl
E^oop for $M \rightarrow M^{3+} + 3e$	–	+1.66	+0.56	+0.34	+1.26
E^oop for $M \rightarrow M^{+} + e$	–	+0.55	–	+0.18	+0.34

(ii) However Boron does not form positive ions in aqueous solution and has very low oxidation potential.

(iii) The higher values of standard oxidation potentials are due to higher heats of hydration on account of smaller size of trivalent cations.

(iv) Aluminium is a strong reducing agent and can reduce oxides which are not reduced even by carbon. This is due to lower ionisation energy of aluminium than carbon. The reducing character of these elements is $Al > Ga > In > Tl$.

(14) **Complex formation :** On account of their smaller size and more effective nuclear charge as well as vacant orbitals to accept elements, these elements have more tendency to form complexes than-s block elements.

Chemical properties

(1) **Hydrides**

(i) Elements of group 13 do not react directly with hydrogen but a number of polymeric hydrides are known to exist.

(ii) Boron forms a large no. of volatile covalent hydrides, known as boranes *e.g.* $B_2H_6, B_4H_{10}, B_5H_{11}, B_6H_{10}$ Two series of borones with general formula B_nH_{n+4} and B_nH_{n+6} are more important.

(iii) Boranes are electron deficient compounds. It is important to note that although BX_3 are well known, BH_3 is not known. This is due of the fact that hydrogen atoms in BH_3 have no free electrons to form $p\pi-p\pi$ back bonding and thus boron has incomplete octet and hence BH_3 molecules dimerise to form B_6H_6 having covalent and three centre bonds.

(iv) Al forms only one polymeric hydride $(AlH_3)_n$ commonly known as alane It contains $Al.....H......Al$ bridges.

(v) Al and Ga forms anionic hydrides e.g. $LiAlH_4$ and $LiGa\ H_4$,

$$4LiH + AlCl_3 \xrightarrow{ether} Li[AlH_4] + 3LiCl$$

(2) **Reactivity towards air**

(i) Pure boron is almost unreactive at ordinary temperature. It reacts with air to form B_2O_3 when heated It does react with water. Al burns in air with evolution of heat give Al_2O_3.

(ii) Ga and In are not effected by air even when heated whereas Tl is little more reactive and also form an oxide film at surface. In moist air, a layer of $Tl\ (OH)$ is formed.

(iii) Al decomposes H_2O and reacts readily in air at ordinary temperature to form a protective film of its oxides which protects it from further action.

(3) **Oxides and hydroxides**

(i) The members of boron family form oxide and hydroxides of the general formula M_2O_3 and $M\ (OH)_3$ respectively.

(ii) The acidic nature of oxides and hydroxides changes from acidic to basic through amphoteric from B to Tl.

B_2O_3 and $B(OH)_3 >$ Al_2O_3 and $Al(OH)_3 >$
(acidic) (amphoteric)
Ga_2O_3 and $Ga(OH)_3 >$ In_2O_3 $In\ (OH)_3 >$ Tl_2O_3 $Tl(OH)_3$
(amphoteric) (basic) (strong basic)

$B(OH)_3$ or H_3BO_3 is weak monobasic Lewis acid.

(iii) Boric acid, $B(OH)_3$ is soluble in water as it accepts lone pair of electron to act as Lewis acid. Rest all hydroxides of group 13 are insoluble in water and form a gelatinous precipitate.

$$B(OH)_3 + H_2O \rightarrow B(OH)_4^{1-} + H^+$$

(iv) Al_2O_3 being amphoteric dissolves in acid and alkalies both.

$$Al_2O_3 + 3H_2SO_4 \rightarrow Al_2\ (SO_4)_3 + 3H_2O$$

$$Al_2O_3 + 2NaOH \xrightarrow{fuse} \underset{\text{Sodium meta aluminate}}{2NaAlO_3} + H_2O$$

(v) One of the crystalline form of alumina (Al_2O_3) is called corrundum. It is very hard and used as abrasive. It is prepared by heating amorphous form of Al_2O_3 to 2000 K.

(4) **Action of Acids**

(i) Boron does not react with non oxidizing acids, however, it dissolves in nitric acid to form boric acids.

(ii) Al, Ga and In dissolve in acids forming their trivalent cations; however, Al and Ga become passive due to the formation of protective film of oxides.

(iii) Thallium dissolves in acids forming univalent cation and becomes passive in HCl due to the formation of water insoluble $TICl$.

(5) **Action of Alkalies**

(i) Boron dissolves only in fused alkalies,

$2B + 6NaOH$ (fused)$\rightarrow 2Na_3BO_3 + 3H_2$

(ii) Al and Ga dissolves in fused as well as in aqueous alkalies, $2Al + 2\ NaOH + 2H_2O \rightarrow 2NaAl\ O_2 + 3H_2$

(iii) Indium remains unaffected in alkalies even on heating.

(6) **Halides**

(i) All the group 13 elements from the trihalides, MX_3 on directly combining with halogens.

$M + X_2 \rightarrow MX_3$

(ii) All the trihalides of group 13 elements are known except Tl (III) iodide.

(iii) Due to small size and high electronegativity of boron, all boron halides are covalent and Lewis acids. These exist as monomeric molecules having plane triangular geometry (sp^2 hybridization).

(iv) All Boron trihalides except BF_3 are hydrolysed to boric acid.

$BX_3 + 3H_2O \rightarrow B(OH)_3 + 3HX$; [$X = Cl, Br, I$]

However, BF_3 forms as addition product with water,

$$BF_3 + H_2O \rightarrow H^+ [BF_3OH]^- \xrightleftharpoons{H_2O} H_3O^+ [BF_3OH]^-$$

.

BF_3 having less tendency for hydrolysis as well as Lewis acid nature, is extensively used as a catalyst in organic reactions e.g. Friedel- Crafts reaction.

(v) Boron atom, in BX_3, has six electrons in the outermost orbit and thus it can accept a pair of electrons form a donor molecule like NH_3 to complete its octet. Hence boron halides act as very efficient Lewis acids. The relative Lewis acid character of boron trihalides is found to obey the order ; $BI_3 > BBr_3 > BCl_3 > BF_3$.

However, the above order is just the reverse of normally expected order on the basis relative electronegativities of the halogens. Fluorine, being the most electronegative, should create the greatest electron deficiency on boron and thus B in BF_3 should accept electron pair from a donor very rapidly than in other boron trihalides. But this is not true.

This anomalous behaviour has been explained on the basis of the relative tendency of the halogen atom to back-donate its unutilised electrons to the vacant p orbitals of boron atom. In boron trifluoride, each fluorine has completely filled unutilised $2p$ orbitals while boron has a vacant $2p$ orbital. Now since both of these orbitals belong to same energy level ($2p$) they can overlap effectively as a result of which fluorine electrons are transferred into the vacant $2p$ orbital of boron resulting in the formation of an additional $p\pi$–$p\pi$ bond. This type of bond formation is known as ***back bonding*** or ***back donation***. Thus the B- F bond has some double bond character. Back bonding may take place between boron and of the three fluorine atoms and thus boron trifluoride is regarded as a resonance hybrid of some structures.

Resonance in boron trifluoride is also evidenced by the fact that the three boron-fluorine bonds are *indentical* and are shorter than the usual single boron-fluorine bond As a result of back bonding, the electron deficiency of boron is reduced and hence Lewis acid nature is decreased. The tendency for the formation of back bonding ($p\pi$- $p\pi$ bond) is maximum in BF_3 and decreases very rapidly from BF_3 to BI_3 This is probably due to the fact that overlapping of the vacant $2p$ orbitals of boron cannot take place easily with the p-orbitals of high energy levels ($3p$ in Cl, $4p$ in Br and $5p$ in iodine). Thus BI_3Br_3 and BCl_3 are stronger Lewis acids than the BF_3.

(vi) Lewis acid character of halides of the group 13 elements decreases in the order, $B > Al > Ga > In$.

(vii) Boron halides form complex halides of the type, [BF_4^-], in which boron atom extends its coordination number to four by utilising empty p-orbital. It cannot extend its coordination number beyond four due to non availability of d-orbitals. However, the other trihalides of this group form complex halides of the type $(AlF_6)^{3-}$, $(GaCl_6)^{3-}$ and $(InCl_6)^{3-}$, etc where the central atom extends its coordination number to 6 by the use of d-orbitals.

(viii) The fluorides of Al, Ga In and Tl are ionic and have high melting points. The high melting points of metal fluorides can be explained on the basis that their cations are sufficiently large and have vacant d-orbitals for attaining a coordination number of six towards the relatively small fluorine atom.

(ix) Other halides of Al, Ga, In and Tl are largely covalent in anhydrous state and possess low melting point. These halides do not show backbonding because of increases in the size of the element. However, the make use of vacant p-orbitals by co-ordinate bond *i.e.* metal atoms complete their octet by forming dimers. Thus aluminium chloride, aluminium bromide and indium iodide exist as dimers, both in the vapour state and in non-polar solvents.

The dimer structure for Al_2Cl_6 is evidenced by the following facts,

(a) Vapour density of aluminium chloride measured at 400^oC corresponds to the formula Al_2Cl_6.

(b) Bond distance between aluminium chlorine bond forming bridge is greater (2.21Å) than the distance between aluminum-chlorine bond present in the end (2.06 Å). The dimeric structure disappears when the halides are dissolved in water This is due to high heat of hydration which split the dimeric structure into $[M(H_2O)_6]^{3+}$ and $3X^-$ ions and the solution becomes good conductor of electricity.

$Al_2Cl_6 + 2H_2O \rightarrow 2[Al(H_2O)_6]^{3+} + 6Cl^-$; Therefore Al_2Cl_6 is ionic in water.

The dimeric structure may also split by reaction with donor molecules e.g. R_3N. This is due to the formation of complexes of the type R_3NAlCl_3 The dimeric structure of Al_2Cl_6 exist in vapour state below 473K and at higher temperature it dissociates to trigonal planar $AlCl_3$ molecule.

Boron halides do not exist as dimer due to small size of boron atom which makes it unable to co-ordinate four large-sized halide ions.

(x) BF_3 and $AlCl_3$ acts as catalyst and Lewis acid in many of the industrial process.

Anomalous Behaviour of Boron

Like *Li* and *Be*, Boron – the first member of group 13 also shows anomalous behaviour due to extremely low size and high nuclear charge/size ratio, high electronegativity and non-availability of d electrons. The main point of differences are,

(1) Boron is a typical non- metal whereas other members are metals.

(2) Boron is a bad conductor of electricity whereas other metals are good conductors.

(3) Boron shows allotropy and exists in two forms – crystalline and amorphous. Aluminium is a soft metal and does not exist in different forms.

(4) Like other non-metals, the melting point and boiling point of boron are much higher than those of other elements of group 13.

(5) Boron forms only covalent compounds whereas aluminium and other elements of group 13 form even some ionic compounds.

(6) The hydroxides and oxides of boron are acidic in nature whereas those of others are amphoteric and basic.

(7) The trihalides of boron (BX_3) exist as monomers On the other hand, aluminium halides exist as dimers (Al_2X_6).

(8) The hydrides of boron *i.e.* boranes are quite stable while those of aluminium are unstable.

(9) Dilute acids have no action on boron Others liberate H_2 from them.

(10) Borates are more stable than aluminates.

(11) Boron exhibit maximum covalency of four e.g., BH^-_4 ion while other members exhibit a maximum covalency of six e.g., $[Al(OH)_6]^{3-}$.

(12) Boron does not decompose steam while other members do so.

(13) Boron combines with metals to give borides e.g. Mg_3B_2. Other members form simply alloys.

(14) Concentrated nitric acid oxidises boron to boric acid but no such action is noticed other group members.

$B + 3HNO_3 \rightarrow H_3BO_3 + 3NO_2$

Diagonal relationship between Boron and Silicon

Due to its small size and similar charge/mass ratio, boron differs from other group 13 members, but it resembles closely with silicon, the second element of group 14 to exhibit diagonal relationship. Some important similarities between boron and silicon are given below,

(1) Both boron and silicon are typical non-metals, having high m.pt. b.pt nearly same densities (B=2.35gml^{-1} S=2.34 $g//ml$). low atomic volumes and bad conductor of current. However both are used as semiconductors.

(2) Both of them do not form cation and form only covalent compounds.

(3) Both exists in amorphous and crystalline state and exhibit allotropy.

(4) Both possess closer electronegativity values (B=2.0; Si=1.8).

(5) Both form numerous volatile hydrides which spontaneously catch fire on exposure to air and are easily hydrolysed.

(6) The chlorides of both are liquid, fume in most air and readily hydrolysed by water.

$BCl_3 + 3H_2O \rightarrow B(OH)_3 + 3HCl$

$SiCl_4 + H_2O \rightarrow Si(OH)_4 + 4HCl$

(7) Both form weak acids like H_3BO_3 and H_2SiO_3.

(8) Both form binary compounds with several metals to give borides and silicide. These borides and silicide react with H_3PO_4 to give mixture of boranes and silanes.

$3Mg+2B \rightarrow Mg_3B_2$; $Mg_3B_2+H_3PO_4 \rightarrow$ Mixture of boranes

(Magnesium boride)

$2Mg$ + Si $\rightarrow Mg_2Si$; $Mg_2Si + H_3PO_4 \rightarrow$Mixture of silanes

(magnesium silicide)

(9) The carbides of both Boron and silicon (B_4C and SiC) are very hard and used as abrasive.

(10) Oxides of both are acidic and can be reduced by limited amount of *Mg* In excess of *Mg* boride and silicide are formed.

$B_2O_3+3Mg \rightarrow 3MgO+2B$; $SiO_2+2Mg \rightarrow 2MgO+Si$

(11) Both the metals and their oxides are readily soluble in alkalies.

$2B + 6NaOH \rightarrow \underset{\text{(borate)}}{2Na_3BO_3} + 3H_2 \uparrow$

$Si + 2NaOH + H_2O \rightarrow \underset{\text{(silicate)}}{Na_2SiO_3} + 2H_2 \uparrow$

$B_2O_3 + 6NaOH \rightarrow 2Na_3BO_3 + 3H_2O$

$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$

Both borates and silicates have tetrahedral structural units BO_4^{n-} and SiO_4^{n-} respectively. Boro silicates are known in which boron replaces silicon in the three dimensional lattice. Boron can however form planar BO_3 units.

(12) Acids of both these elements form volatile esters on heating with alcohol in presence of conc. H_2SO_4.

$B(OH)_3 + 3ROH \rightarrow B(OR)_3 + 3H_2O$

$Si(OH)_4 + 4ROH \rightarrow Si(OR)_4 + 4H_2O$

Boron and its compounds

Boron is the first member of group –13 (IIIA) of the periodic table. Boron is a non- metal . It has a small size and high ionization energy due to which it can not lose its valence electrons to form B^{+3} ion. Its compounds especially the hydrides and halides are electron deficient and behave as Lewis acid.

(1) **Ores of boron**

(i) *Borax or tincal* : $Na_2B_4O_7 . 10H_2O$

(ii) *Kernite or Rasorite* : $Na_2B_4O_7 . 4H_2O$

(iii) *Colemanite* : $Ca_2B_6O_{11} . 5H_2O$

(iv) *Orthoboric acid* : H_3BO_3 (It occurs in the jets of steam called soffioni escaping from ground in the volcanic region of the *Tuscany*). Boron is present to a very small extent (0.001%) in earth's crust.

(2) **Isolation :** Elemental boron in the form of dark brown powder is obtained either by reduction of boric oxide with highly electropositive metals like *K*, *Mg*, *Al*, *Na*, etc. in the absence of air and boron halides with hydrogen at high temperature eg.

$B_2O_3 + 6K \xrightarrow{Heat} 2B + 3K_2O$

$2BCl_3 + 3H_2 \xrightarrow{1270\,K} 2B + 6HCl.$

By thermal decomposition of boron triiodide over red hot tungsten filament and boron hydrides for example,

$2BI_3 \xrightarrow{W,heat} 2B + 3I_2$; $B_2H_6 \xrightarrow{Heat} 2B + 3H_2$

(3) **Properties :** It exists in mainly two allotropic forms *i.e.* amorphous dark brown powder and crystalline black very hard solid. It occurs in two isotopic forms, *i.e.*, ${}_5B^{10}$ (20% abundance) and ${}_5B^{11}$ (80% abundance). With air, boron forms B_2O_3 and BN at 973*K*, with halogens, trihalides (BX_3) are formed, with metals borides are formed. eg.

$4B + 3O_2 \xrightarrow{Heat} \underset{\text{Boron trioxide}}{2B_2O_3}$

$2B + N_2 \xrightarrow{Heat} \underset{\text{Boron nitride}}{2BN}$

$2B + 3X_2 \longrightarrow \underset{\text{Boron trihalide}}{2BX_3}$

$3Mg + 2B \xrightarrow{Heat} \underset{\text{Magnesium boride}}{Mg_3B_2}$

Water, steam and *HCl* have no action on *B*. oxidising acids (HNO_3, H_2SO_4) convert boron to H_3BO_3.

$B + 3HNO_3 \longrightarrow H_3BO_3 + 3NO_2$

$2B + 3H_2SO_4 \longrightarrow 2H_3BO_3 + 3SO_2$

Fused alkalies (*NaOH*, *KOH*) dissolve boron forming borates, liberating hydrogen.

$2B + 6KOH \xrightarrow{Fused} 2K_3BO_3 + 3H_2$

(4) **Uses of Boron :** Boron is used in atomic reactors as protective shields and control rods, as a semiconductors for making electronic devices in steel industry for increasing the hardness of steel and in making light composite materials for air crafts.

(5) **Compounds of Boron**

(i) ***Boron Hydrides***

Boron forms hydrides of the types B_nH_{n+4} and B_nH_{n+6} called boranes. Diborane is the simplest boron hydride which is a dimer of BH_3.

Preparation

(a) $8BF_3 + 6LiH \xrightarrow{450\,K} B_2H_6 + 6LiBF_4$

(b) $4BCl_3 + LiAlH_4 \longrightarrow 2B_2H_6 + 3AlCl_3 + 3LiCl$

(c) In the laboratory, it is prepared by the oxidation of sod. Borohydride with I_2.

$2NaBH_4 + I_2 \xrightarrow{\text{Polyether}} B_2H_6 + 2NaI + H_2$

Properties : (a) Since Boron in boranes never complete its octet of electrons hence all boranes are called as electron-deficient compounds or Lewis acids.

(b) All boranes catch fire in the presence of oxygen to liberated a lot of heat energy. Thus, they can also be used as high energy fuels.

$B_2H_6 + 3O_2 \longrightarrow 2B_2O_3 + 3H_2O; \Delta H = -1976\,KJ/mole$

(c) Boranes are readily hydrolysed by water.

$B_2H_6 + 6H_2O \longrightarrow 2H_3BO_3 + 6H_2$

(d) With carbon monoxide

$B_2H_6 + 2CO \longrightarrow (BH_3 \leftarrow CO)_2$

(e) Boranes are used for formation of hydroborates or borohydrides such as $LiBH_4$ or $NaBH_4$, which are extensively used as reducing agents in organic synthesis.

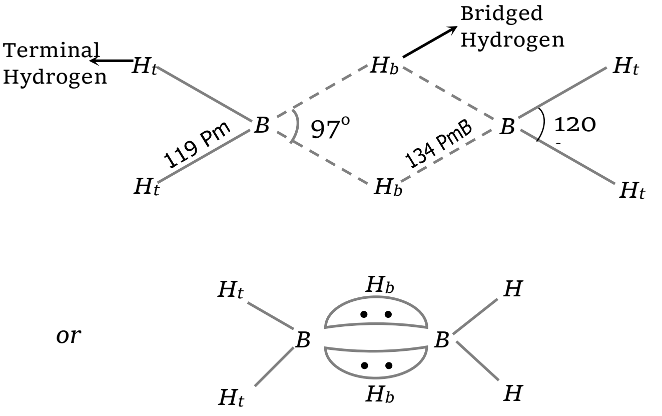
$2LiH + B_2H_6 \xrightarrow{\text{Diethyl ether}} 2Li^+[BH_4]^-$

$2NaH + B_2H_6 \xrightarrow{\text{Diethyl ether}} 2Na^+[BH_4]^-$

Structure of diborane : B_2H_6 has a three centre electon pair bond also called a banana shape bond.

(a) $B - H_t$: It is a normal covalent bond (two centre electron pair bond *i.e.*, $2c - 2e$).

(b) $B-H_b$: This is a bond between three atoms, $B-H_b-B$, (three centre electron pair bond *i.e.,* $3c-2e$).



Structure of diborane (B_2H_6)

The other boron hydrides are $B_5H_9, B_4H_{10}, B_5H_{11}$ etc.

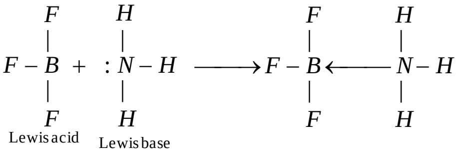
(ii) ***Boron Halides***

Boron reacts with halogens on strong heating to form boron halides .

$$2B + 3X_2 \xrightarrow{Heat} 2BX_3 (X = F, Cl, Br, I)$$

BF_3 and BCl_3 are gases, BBr_3 is a volatile liquid while BI_3 is a solid.

In these halides, the central boron atom has three shared pairs of electrons with the halogen atoms. Therefore, these have two electrons less than the octet and are electron deficient compounds. They acts as Lewis acids.



$$\underset{\text{Lewis acid}}{F-\overset{\overset{F}{|}}{\underset{\underset{F}{|}}{B}}} + \underset{\text{Lewis base}}{:\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{N}}-H} \longrightarrow F-\overset{\overset{F}{|}}{\underset{\underset{F}{|}}{B}} \longleftarrow \overset{\overset{H}{|}}{\underset{\underset{H}{|}}{N}}-H$$

The relative acidic strength of boron trihalides decreases as : $BI_3 > BBr_3 > BCl_3 > BF_3$.

(iii) ***Borax*** ($Na_2B_4O_7 . 10H_2O$)

It occurs naturally as **tincal** (Suhaga) which contains about 50% borax in certain land, lakes. It is also obtained from the mineral colemanite by boiling it with a solution of Na_2CO_3 .

$$\underset{\text{Colemanite}}{Ca_2B_6O_{11}} + 2Na_2CO_3 \longrightarrow \underset{\text{Borax}}{Na_2B_4O_7} + 2CaCO_3 + 2NaBO_2$$

Properties : (a) Its aqueous solution is alkaline due to hydrolysis,

$$Na_2 B_4O_7 + 7H_2O \longrightarrow 2NaOH + 4H_3BO_3 .$$

(b) On heating borax loses its water of crystallization and swells up to form a fluffy mass. On further heating, it melts to give a clear liquid which solidifies to a transparent glassy bead consisting of sodium metaborate ($NaBO_2$) and boric anhydride (B_2O_3),

$$Na_2B_4O_7.10H_2O \xrightarrow[-10H_2O]{\Delta} Na_2B_4O_7 \xrightarrow{\Delta} \underset{\text{Borax bead}}{2NaBO_2 + B_2O_3}$$

Borax bead is used for the detection of coloured basic radicals under the name borax bead test.

Borax bead test **:** Borax bead is a mixture of $NaBO_2$ and B_2O_3. B_2O_3 on heating combines readily with a number of coloured transition metal oxides such as *Co*, *Ni*, *Cr*, *Cu*, *Mn*, etc. to form the corresponding metaborates which possess characteristic colours,

$$CoSO_4 \xrightarrow{\Delta} CoO + SO_3 \; ; \; CoO + B_2O_3 \longrightarrow \underset{\substack{\text{Cobalt meta borate} \\ \text{(Blue)}}}{Co(BO_2)_2}$$

Colours of some important metaborates are : Cupric metaborate, $Cu(BO_2)_2$ is dark blue, chromium metaborate, $Cr(BO_2)_2$ is green, nickel metaborate, $Ni(BO_2)_2$ is brown and manganese metaborate, $Mn(BO_2)_2$ is pink violet.

(c) When heated with C_2H_5OH and conc. H_2SO_4 it gives volatile vapours of triethyl borate which burns with a green edged flame.

$$Na_2B_4O_7 + H_2SO_4 + 5H_2O \longrightarrow Na_2SO_4 + 4H_3BO_3$$

$$H_3BO_3 + 3C_2H_5OH \longrightarrow \underset{\text{Triethyl borate}}{B(OC_2H_5)_3} + 3H_2O$$

This reaction is used as a test for borate radical in qualitative analysis.

Uses : (a) In making optical and hard glasses. (b) In the laboratory for borax bead test. (c) In softening of water. (d) In the preparation of medicinal soaps due to its antiseptic character.

(iv) **Boric acid or orthoboric acid (** H_3BO_3)

It is obtained from borax by treating with dil. *HCl* or dil. H_2SO_4,

$$Na_2B_4O_7 + 2HCl + 5H_2O \longrightarrow 2NaCl + 4H_3BO_3$$

It can also be obtained from the mineral colemanite by passing SO_2 through a mixture of powdered mineral in boiling water,

$$Ca_2B_6 O_{11} + 4SO_2 + 11H_2O \longrightarrow 2Ca(HSO_3)_2 + 6H_3BO_3$$

Properties : (a) It is a very weak monobasic acid, does not act as a proton doner but behaves as a Lewis acid *i.e.* it accepts a pair of electrons from OH^- ion of H_2O ,

$$H_3BO_3 + H_2O \longrightarrow [B(OH)_4]^- + H^+$$

It acts as a strong acid in presence of polyhydroxy compounds such as glycerol, mannitol etc. and can be titrated against strong alkali .

(b) With *NaOH* it forms, sodium metaborate,

$$H_3BO_3 + NaOH \longrightarrow NaBO_2 + 2H_2O$$

(c) With C_2H_5OH and conc. H_2SO_4, it gives triethyl borate

$$H_3BO_3 + 3C_2H_5OH \xrightarrow{Conc.H_2SO_4} B(OC_2H_5)_3 + 3H_2O$$

(d) ***Action of heat*** **:** The complete action of heat on boric acid may be written as,

$$\underset{\text{Boric acid}}{H_3BO_3} \xrightarrow{373\,K} \underset{\text{Metaboric acid}}{HBO_2} \xrightarrow{433\,K} \underset{\text{Tetra boric acid}}{H_2B_4O_7} \xrightarrow{\text{Red hot}} \underset{\text{Boron oxide}}{B_2O_3}$$

Structure : In boric acid, planar BO_3^{-3} units are joined by hydrogen bonds to give a layer structure.

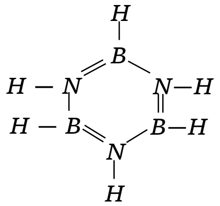
Uses : (a) As a food preservative. (b) As a mild antiseptic for eye wash under the name boric lotion. (c) For the preparation of glazes and enamels in pottery.

(v) **Borazine or Borasole or Triborine triamine (** $B_3N_3H_6$)

It is a compound of *B*, *N* and *H*. It is a colourless liquid and is also called inorganic benzene.

$$2\,B_2H_6 + 6NH_3 \xrightarrow{180^oC} 2B_3N_3H_6 + 12H_2\,.$$

It has a six membered ring of alternating *B* and *N* atoms, each is further linked to a *H*- atom.



Borazine

(vi) **Boron nitride (*BN*)**

It is prepared by treating BCl_3 with an excess of NH_3 and pyrolysing the resulting mixture in an atmosphere of NH_3 at 750°C,

$$BCl_3 + NH_3 \longrightarrow [\,H_3N \longrightarrow BCl_3\,] \xrightarrow[\text{Excess}\,NH_3]{750^oC} BN + 3HCl\,.$$

It is a colourless, good insulator, diamagnetic and almost unreactive solid

Aluminium and its compounds

(1) **Ores of Aluminium :** Bauxite ($Al_2O_3.2H_2O$), Cryolite (Na_3AlF_6, Felspar ($KAlSi_3O_8$), Kaolinite ($Al_2O_3.2SiO_2.2H_2O$), Mica ($K_2O.3Al_2O_3.6SiO_2.2H_2O$), Corundum ($Al_2O_3$), Diaspore ($Al_2O_3.H_2O$), Alunite or alum stone [$K_2SO_4.Al_2(SO_4)_3$. $4Al(OH)_3$].

(2) **Extraction :** Aluminium is obtained by the electrolysis of the oxide (alumina) dissolved in fused cryolite. This involves following steps,

Purification of ore

(i) ***Baeyer's process***

$$\underset{\substack{\text{Finely powdered}\\ \text{(red)}}}{\text{Bauxite}} \xrightarrow[FeO \to Fe_2O_3]{\text{Roasted}} \text{Roasted ore} \xrightarrow[\substack{\text{High pressure } (150^oC,\ 80\ \text{atm})\\ \text{filtered, } Fe_2O_3 \text{ as residue}}]{+\text{Caustic soda solution}}$$

$$\underset{\text{(Sod. Aluminate)}}{Filtrate} \xrightarrow[CO_2]{Filtered} Pure\ Al_2O_3 \xrightarrow{Heat} Al(OH)_3$$

(ii) ***Hall's process***

$$\underset{\substack{\text{(Finely powdered)}\\ \text{(red)}}}{\text{Bauxite}} \xrightarrow[\substack{\text{Fused, extracted with}\\ \text{water. Residue } Fe_2O_3}]{+Na_2CO_3} \text{Solution} \xrightarrow[\substack{50\text{-}60^oC \text{ and filtered.}\\ \text{Filtrate } (Na_2CO_3)}]{CO_2}$$

$$\text{Precipitate } Al(OH)_3 \xrightarrow{Heat} Pure\ Al_2O_3$$

(iii) ***Serpek's process***

$$\underset{\substack{\text{(Finely powdered)}\\ \text{(white)}}}{\text{Bauxite}} \xrightarrow[\substack{\text{Heated to}\\ 1800^oC}]{+Coke+N_2} \underset{\text{Si which volatalises}}{\text{Silica reduced to}} + \underset{\text{aluminium nitride}}{\text{Alumina form}}\ AlN$$

$$\xrightarrow{Hydrolysis} Pure\ Al_2O_3 \xrightarrow{Heated} Al(OH)_3$$

(iv) ***Hall and Heroult process*** : It is used for extraction of aluminium. In this process a fused mixture of alumina (20%), cryolite (60%) and fluorspar (20%) is electrolysed using carbon electrodes. Whereas cryolite makes Al_2O_3 conducting fluorspar decreases the melting point of alumina.

Aluminium is refined by Hoope's electrolytic process.

(3) **Compounds of Aluminium**

(i) ***Aluminium oxide or Alumina*** (Al_2O_3) **:** It occurs in nature as colourless corundum and several coloured minerals like ruby (red), topaz (yellow), Sapphire (blue), amethyst (violet) and emerald (green). These minerals are used as ***precious stones*** (gems).

(ii) ***Aluminium chloride*** (Al_2Cl_6) **:** It is prepared by passing dry chlorine over aluminium powder.

$$Al_2O_3 + 3C + 3Cl_2 \to \underset{\text{(anhydrous)}}{2AlCl_3} + 3CO(g)$$

It exists as dimer Al_2Cl_6, in inert organic solvents and in vapour state. It sublimes at $100\,^oC$ under vacuum. Dimeric structure disappears when $AlCl_3$ is dissolved in water. It is hygroscopic in nature and absorbs moisture when exposed to air.

(iii) ***Thermite* :** A mixture of aluminium powder and Fe_2O_3 in the ratio 1:3. It is used for welding of iron. The reaction between *Al* and Fe_2O_3 is highly exothermic,

$$Al + Fe_2O_3 \to Al_2O_3 + Fe + \text{Heat}$$

(iv) ***Aluminium sulphate* [*Al*₂(*SO*₄)₃] :** It is used for the preparation of alums e.g., potash alum $Al_2(SO_4)_3.K_2SO_4\ .24H_2O$. It is also used for making fire proof clothes.

(iv) **Alums :** In general, the term alum is given to double sulphates of the type $M_2SO_4.M_2'(SO_4)_3.24H_2O$ where *M* is a univalent cation like Na^+, K^+ and NH_4^+, M' is a trivalent cation like Al^{3+}, Fe^{3+} and Cr^{3+}.

Some important points to be noted about the alums are

(a) General formula is $M_2SO_4.M_2'(SO_4)_3.24H_2O$

M = Monovalent metal; M' = Trivalent metal

In alum crystals, 6 water molecules are held by monovalent ion, 6 water molecules are held by trivalent ion, 12 water molecules are held in the crystal structure.

(b) All alums are isomorphous. Aqueous solutions of alums are acidic due to cationic hydrolysis of trivalent cation.

(c) Double sulphates of divalent ions and trivalent ions with 24 water molecules in their crystals are known as Pseudoalums. General formula is $MSO_4.M'_2(SO_4)_3.24H_2O$

$M =$ Bivalent metal; $M' =$ Trivalent metal

(d) Pseudoalums are not isomorphous with alums.

(e) Feather alum or 'Hair-salt' $Al_2SO_4.18H_2O$ is a native form of aluminium sulphate.

(f) Potash alum is used for tanning of leather, as mordant in dyeing and calico printing, for sizing paper, as a syptic to stop bleeding and purification of water.

Some important alums are

Potash alum $K_2SO_4.Al_2(SO_4)_3.24H_2O$

Sodium alum $Na_2SO_4.Al_2(SO_4)_3.24H_2O$

Ammonium alum $(NH_4)_2SO_4.Al_2(SO_4)_3.24H_2O$

Chrome alum $K_2SO_4.Cr_2(SO_4)_3.24H_2O$

Carbon Family

Carbon is the first member of group 14 or IVA of the periodic table. It consists of five elements carbon (*C*), silicon (*Si*), germanium (*Ge*), tin (*Sn*) and lead (*Pb*). Carbon and silicon are nonmetals, germanium is metalloid and tin and lead are metals.

(1) **Electronic configuration**

Elements	**Electronic configuration (** $ns^2\ np^2$ **)**
$_6C$	$[He]2s^2 2p^2$
$_{14}Si$	$[Ne]3s^2 3p^2$
$_{32}Ge$	$[Ar]3d^{10} 4s^2 4p^2$
$_{50}Sn$	$[Kr]4d^{10} 5s^2 5p^2$
$_{82}Pb$	$[Xe]4f^{14} 5d^{10} 6s^2 6p^2$

Physical properties

(1) **Non-metallic nature :** The non-metallic nature decreases along the group.

C Si	*Ge*	*Sn*	*Pb*
Non-metals	metalloid	metal	metal

(2) **Abundance :** Carbon and silicon are most abundant elements in earth's crust whereas germanium occurs only as traces. Tin and lead also occur in small amounts. Only carbon occurs in free state as coal, diamond and graphite and in combined state as carbonates, CO_2 petroleum and natural gas Silicon is the second most abundant element after oxygen in earth's crust in form of silicates and silica. Germanium found in traces in coal and in certain deposits. It important constituent for making conductors and transistors The important ore of tin is tin stone (SnO_2) or cassiterite. Lead is found is form of galena (PbS) anglesite ($PbSO_4$) and cerussite ($PbCO_3$) The abundance ratio in earth's crust is given below,

(3) **Density :** The density of these elements increases down the group as reported below

Element	*C*	*Si*	*Ge*	*Sn*	*Pb*
Density (g/ml)	3.51 (for diamond) 2.22 (for graphite)	2.34	5.32	7.26	11.34

(4) **Melting point and boiling points**

(i) The melting point and boiling point of this group members decrease down the group.

Element	*C*	*Si*	*Ge*	*Sn*	*Pb*
m.pt.(*K*)	4373	1693	1218	505	600
b.pt.(*K*)	–	3550	3123	2896	2024

(ii) The melting point and boiling point of group 14 elements are however, higher than their corresponding group 13 elements. This is due to the formation of four covalent bonds on account of four electrons in their valence shells which results in strong binding forces in between their atoms in solid as well as in liquid state.

(5) **Atomic radii and atomic volume**

(i) Both atomic radii and atomic volume increases gradually on moving down the group due to the effect of extra shell being added from member to member.

	C	*Si*	*Ge*	*Sn*	*Pb*
Atomic radius (pm)	0.77	111	122	141	144
Atomic volume (*ml*)	3.4	11.4	13.6	16.3	18.27

(ii) The atomic radii of group 14 elements are than their corresponding group 13 elements due to increase in nuclear charge in the same period.

(iii) Some of the ionic radii involving six co-ordination of these group elements are given below,

	C	*Si*	*Ge*	*Sn*	*Pb*
Ionic radius (M^{2+}) in pm	–	–	73	118	119
Ionic radius (M^{++}) in pm	–	40	53	69	78

(6) **Electronegativity :** The electronegativity decreases from *C* to *Si* and then becomes constant.

	C	*Si*	*Ge*	*Sn*	*Pb*
Electronegativity on pauling scale	2.5	1.8	1.8	1.7	1.6

The electronegativity from silicon onwards is almost is almost constant or shows a comparatively smaller decreases due to screening effects of d^{10} electrons in elements from *Ge* onwards.

(7) **Ionisation energy**

(i) The ionisation energy decreases regularly down the group; Pb however shows a higher value than *Sn* due to poor shielding of inner *f*-orbitals as a result of which effective nuclear charge experienced by outer shell electrons becomes more in Pb.

Ionisation energy ($kJ\ mol^{-1}$)	*C*	*Si*	*Ge*	*Sn*	*Pb*
IE_1	1086	786	761	708	715
IE_2	2352	1577	1537	1411	1450

(ii) The first ionisation energies of group 14 elements are higher than their corresponding group 13 elements because of smaller size.

(iii) The electropositive character of these elements increases down the group because of decreases in ionisation energy.

(8) **Oxidation state**

(i) Presence of four electrons in outermost shell of these elements reveals that the members of this family can gain four electrons forming M^{4+} or M^{4-} ions to show ionic nature or exhibit tetravalent covalent nature by sharing of four electron pairs in order to attain stable configuration.

(ii) The formation of M^{4+} or M^{4-} ions require huge amount of energy which is normally not available during normal course of reactions, therefore, these elements usually do not form M^{4+} or M^{4-} ions, but they usually form compounds with covalence of four.

(iii) *Ge, Sn* and *Pb* also exhibit +2 oxidation state due to inert pair effect.

(iv) Sn^{2+} and Pb^{2+} show ionic nature.

(v) The tendency to form +2 ionic state increases on moving down the group due to inert pair effect.

(9) **Catenation**

(i) The tendency of formation of long open or closed atom chains by the combination of same atoms in themselves is known as catenation.

(ii) The catenation is maximum in carbon and decreases down the group.

(iii) This is due to high bond energy of catenation.

(iv) Only carbon atoms also form double or triple bonds involving pπ-pπ multiple bond within itself.

$> C = C<; \; - C \equiv C -$

(v) Carbon also possesses the tendency to form closed chain compounds with *O, S* and *N* atoms as well as forming *pπ-pπ* multiple bonds with other elements particularly nitrogen and oxygen e.g. $C = O$; $C = N$; $C \equiv N$; $C = S$ are the functional groups present in numerous molecules due to this reason.

(vi) Carbon can form chain containing any number of carbon atoms *Si* and *Ge* cannot extend the chain beyond 6 atoms, while *Sn* and *Pb* do not form chains containing more than one or two atoms.

(vii) The reason for greater tendency of carbon for catenation than other elements in the group may further be explained by the fact that the $C - C$ bond energy is approximately of the same magnitude as the energies of the bond between *C* and other elements. On the other hand, the $Si - Si$ bond is weaker than the bond between silicon and other elements.

Bond	Bond energy (k J/mol)	Bond	Bond energy (kJ/mol)
$C–C$	348	$Si–Si$	180
$C–O$	315	$Si–O$	372
$C–H$	414	$Si–H$	339
$C–Cl$	326	$Si–Cl$	360
$C–F$	439	$Si–F$	536

(10) **Allotropy**

The phenomenon of existence of a chemical element in two or more forms differing in physical properties but having almost same chemical nature is known as allotropy. If an element or compound exists in two or more forms, it is also known as polymorphism e.g. zinc blende and wurtzite are polymorphs of *ZnS*.

Kinds of allotropy. Allotropy is of three types :

(i) ***Enantiotropy*** : When two forms of a solid substance exist together in equilibrium with each other at a particular temperature under normal pressure it is called enantiotropy.

For example, at normal pressure and temperature between $368.6\,K$ and $285\,K$, sulphur (solid) exist in two forms (rhombic sulphur), S_R and (monoclinic sulphur), S_M in equilibrium with each other. $S_R \rightleftharpoons S_M$

(ii) ***Monotropy*** : It is the type of allotropy in which only one allotrope is stable, under normal conditions the other being unstable e.g., diamond and graphite, oxygen and ozone etc.

(iii) ***Dynamictropy*** : It is the type of allotropy in which there is a true equilibrium between the two allotropes, one changing into the other at exactly the same rate as the reverse occurs. Both allotropes are stable over a wide range of temperature.

For example, liquid sulphur exist in two forms, the pale yellow mobile form called S_λ and dark viscous form called S_μ in equilibrium with each other. $S_\lambda \rightleftharpoons S_\mu$

With increase in temperature, the later form is formed at the expense of the former but when the liquid is cooled, the reverse change occur. Thus sulphur shows both enantiotropy and dynamictropy.

Cause of allotropy : (i) In general the allotropy among solid substances is due to the difference in crystalline structure. (ii) It may also be due to the presence of different number of atoms e.g., O_2 and O_3, S_8, S_2 etc. (iii) It may be due to the difference in nuclear spins e.g., ortho and para hydrogen.

Different allotropic forms Except lead, all elements show allotropy.

(i) Carbon has two crystalline allotropic forms i.e., diamond and graphite. In diamond C atom is sp^3 hybridised and it has a three dimensional network structure. Since no valence electron is available, hence diamond is a bad conductor of electricity. However in graphite C atom is sp^2 hybridised and has a delocalised π-electron cloud responsible for its high electrical conductivity. It may be noted that diamond is thermodynamically less stable than graphite at ordinary temperatures.

(ii) Silicon has both crystalline and amorphous forms.

(iii) Tin has three crystalline modifications with the following equilibrium temperature

$$\underset{\text{(Grey)}}{\alpha - tin} \overset{15.2^oC}{\rightleftharpoons} \underset{\text{(White)}}{\beta - Sn} \overset{161^oC}{\rightleftharpoons} \underset{\text{(Rhombic)}}{\gamma - Sn} \overset{232^oC}{\rightleftharpoons} \text{Liquid tin}$$

The conversion of white tin to grey tin is accompanied by an increase in volume and the latter, being very brittle, easily crumbles down to powder. This phenomenon is called tin disease tin pest or tin plague.

Chemical properties

(1) **Hydrides :** All the elements of group 14 combine with hydrogen directly or indirectly to form the covalent hydrides, MH_4 (*M* = *C, Si, Ge, Sn* or *Pb*). The number of hydrides and the ease of preparation decrease on going from carbon to lead.

The hydrides of silicon are called *silanes* having the general formula Si_nH_{2n+2}. The hydrides of germanium are called *germanes* while those of tin are called the *stannanes*. Only lead forms an unstable hydride of the formula, PbH_4 called the *plumbane*.

Three hydrides of germanium, *i.e.,* GeH_4, Ge_2H_6 and Ge_3H_8 and only two hydrides of tin *i.e.,* SnH_4 and Sn_2H_6 are well known.

(2) **Oxides :** *Carbon forms five oxides* CO, CO_2, C_3O_2 (carbon suboxide), C_5O_2 and $C_{12}O_9, C_3O_2$ is the anhydride of malonic acid and CO_2 is the anhydride of H_2CO_3 (carbonic acid) CO_2 *is a non-polar linear molecule due to maximum tendency of C to form* $p\pi$*–*$p\pi$ *multiple bond with oxygen. Si* forms SiO_2. *Pb* forms a number of oxides. *PbO* can be obtained by heating $Pb(NO_3)_2$, $2Pb(NO_3)_2 \xrightarrow{\text{Heat}} 2PbO + 4NO_2 + O_2$.

The red form of *PbO* is called ***litharge*** and the yellow form is ***massicot***. Pb_3O_4 (Red lead, or Sindur) is prepared by heating litharge in air at 470°*C*, $6PbO + O_2 \xrightarrow{470^oC} 2Pb_3O_4$, Pb_3O_4 is a mixed oxide of $PbO_2.2PbO.Pb_2O_3$ is called lead sesquioxide. GeO_2, SnO_2 etc. are also network solids.

CO_2 and SiO_2 is acidic, GeO_2 is weakly acidic while SnO_2 and PbO_2 are amphoteric in nature.

All the elements of group 14 except silicon from monoxides *e.g.,* CO, GeO, SnO and *PbO*. Out of these monoxides only *CO* is neutral, while all other monoxides are basic.

(3) **Halides :** Elements of group 14 react with halogens directly to form tetrahedral and covalent halides except *C* where its halide is produced by the action of halogens on hydrocarbons. $PbBr_4$ and PbI_4 do not exist because Pb^{4+} is a strong oxidant and Br^- and I^- are strong reductants. Hence Pb^{4+} ion is difficult to survive in presence of strong reductants Br^- and I^- and is immediately reduced to Pb^{2+}.

(4) **Carbides :** Carbides are binary compounds of carbon with elements of lower or about equal electronegativity.

Preparation : Carbides are generally prepared by heating the elements orits oxide with carbon or hydrocarbon at very high temperatures.

$$Ca + 2C \longrightarrow BaC_2\ ;\quad 2Li + 2C \longrightarrow Li_2C_2$$

$$CaO + 3C \longrightarrow CaC_2 + CO$$

$$4Li + C_2H_2 \longrightarrow Li_2C_2 + LiH$$

Carbides are classified into three types on the basis of chemical bonding.

(1) **Salt like carbides :** These carbides are formed by the metals of groups IA, IIA, IIIA (except boron), coinage metals, Zinc, cadmium & some lanthanides.

(i) ***Acetylides*** *:* These are ionic carbides which yield acetylene on hydrolysis. The alkali metals and copper, silver and gold form M_2C_2 type compounds. These contain C_2^{2-} ions.

(ii) ***Methanides*** : These carbides evolve methane on hydrolysis. Al_4C_3, Be_2C, Mn_3C etc are some are of methanides. These contains C^{4-} groups.

(iii) ***Allylides*** : These carbides evolve allylene (methyl acetylene) on hydrolysis. This type of the carbides is only Mg_2C_3 it contains C_3^{4-} discrete groups.

(2) **Mixed carbides :** These carbides yield a mixture of hydrocarbons on hydrolysis, carbides of iron group, UC_2 and ThC_2 belong to this group.

(3) **Covalent carbides :** The only true covalent carbides are those of *SiC* (carborundum) and $B_4C, B_{13}C_2$ etc. These are chemicallyinert so become hard.

On account of hardness, these are used as abrasives.

(4) **Metallic or interstitial carbides :** If these carbides possess metallic lustre high electrical conductivity and chemically inert. These are extremely hard like diamond and possess very high melting points.

Ability to form complexes : The ability of group 14 elements to form complexes is highly favoured by a high charge, small size and availability of empty orbitals of the right energy. The compounds in which carbon shows a covalency of four possess a closed shell electronic configuration of a noble gas and therefore carbon does not form complexes. Silicon and other heavier elements, however, can form complexes due to the availability of energetically suitable empty d-orbitals and a coordination number of six is found in these complexes. For example, in the formation of $[SiF_6]^{2-}$, four covalent and two co-ordinate bonds are formed as a result of sp^3d^2 hybridisation. As such the resulting ion has an octahedral geometry. Thus elements like Si, Ge, Sn and Pb have an ability to increase their co-ordination number from four to six. Other examples of hexa co-ordianted species are : $[GeF_6]^{2-}, [SnCl_6]^{2-}, [PbCl_6]^{2-}$ etc.

Anomalous behaviour of Carbon

Carbon is found differ in many properties from the rest of the members of group 14. This is because of the following : (i) Its smallest size (ii) Its high electronegativity (iii) Its property to catenate (iv) Absence of *d*-orbitals in it.

Some of the properties in which it differs from other members are,

(1) The melting and boiling points of carbon are very high as compared to the rest to the members of the family.

(2) Carbon in its diamond form is one of the hardest substance known.

(3) It has maximum tendency to show catenation.

(4) Carbon has high tendency to form $P\pi - P\pi$ multiple bonds with other elements like nitrogen, oxygen, sulphur etc. Other members of the family form $P\pi - d\pi$ bonds and that also to a lesser extent.

(5) CO_2 is a gas while the dioxides of all other members are solids.

(6) Carbon is not affected by alkalies whereas other members react on fusion. For example, silicon form silicates, $Si + 2NaOH + 1/2\,O_2 \rightarrow \underset{\text{Sodium silicate}}{Na_2SiO_3} + H_2$.

Silicon and its compounds

Silicon, being a second member of group – 14, has a much larger size and lower electronegativity than that of carbon. As a result silicon does not form double bond with itself or with oxygen. Thus *SiO* bonds are much stronger than *Si* – *Si* and *Si* –*H* bonds. Silicon has vacant 3*d*-orbitals in its valence shell due to which it can extend its covalency from four to five and six.

(1) **Occurrence :** Silicon is the second most abundant element (27.7%) in earth's crust next to oxygen .It does not occur in free state. It occurs mainly in the form of Silica and silicates. Silicates are formed in rocks and clay as silicates of *Mg*, *Al*, *K* or *Fe*. e.g. Feldspar ; $K_2Al_2O_3.6SiO_2$, Kaolinite; $Al_2O_3.2SiO_2.2H_2O$.

(2) **Preparation :** Elemental silicon is obtained by reduction of silica with high purity coke in an electric furnace using excess of silica e.g. $SiO_2 + 2C \longrightarrow Si + 2CO$

Very high purity silicon required for making semiconductors is obtained by reduction of highly purified $SiCl_4$ form ($SiHCl_3$) with hydrogen followed by purification by zone refining eg.

$$SiCl_4 + 2H_2 \longrightarrow Si + 4HCl \;;\; SiHCl_3 + H_2 \longrightarrow Si + 3HCl$$

(3) **Properties :** (i) Silicon exists in three isotopes ${}_{14}Si^{29}$ (most common), ${}_{14}Si^{30}$ with air at high temperature SiO_2 form,

$$Si + O_2 \longrightarrow SiO_2.$$

(ii) With steam, *Si* reacts when heated to redness to liberate hydrogen, $Si + 2H_2O \xrightarrow{\text{Redness}} SiO_2 + 2H_2$.

(iii) With halogens, *Si* reacts at elevated temperature forming SiX_4 except fluorine which reacts at room temperature.

(iv) Silicon combines with *C* at 2500*K* forming Silicon Carbide (*SiC*) known as carborundum (an extremely hard substance),

$$Si + C \xrightarrow{2500\,K} SiC.$$

(v) It reacts with metals like *Ca, Mg* etc in an electric arc furnace to form Silicides (Ca_2Si, Mg_2Si etc.)

(vi) Silicon dissolves in hot aqueous alkalies liberating hydrogen, $Si + 4NaOH \xrightarrow{Heat} Na_4SiO_4 + 2H_2 \uparrow$

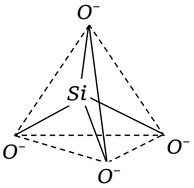
(vii) It also dissolves in fused Na_2CO_3 displacing carbon $Na_2SiO_3 + C$.

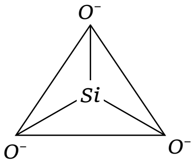
(4) **Uses of silicon :** (i) It is added to steel as ferrosilicon (an alloy of *Fe* and *Si*) to make it acid resistant.

(ii) It is used in the pure form as a starting material for production of silicon polymers (Silicones).

(5) **Compounds of silicon**

(i) ***Silicates*** : Silicates are the metal derivatives of silicic acid (H_4SiO_4). The basic of all silicates is the SiO_4^{4-} anion. In SiO_4^{4-} anion, *Si* is sp^3 hybridised, and it forms four covalent bonds with four negatively charged oxygen atoms. SiO_4^{4-} anion has a tetrahedral shape.

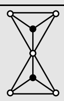
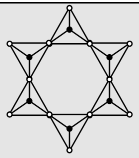
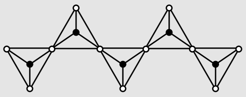
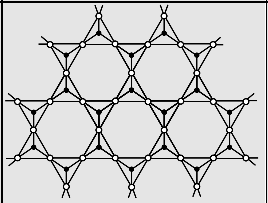




Alkali metal silicates are commonly prepared by fusing metal oxides or metal carbonates with sand (SiO_2) at high temperatures. For examples, sodium silicate can be prepared by fusing sand with sodium carbonate.

$$\underset{\text{sand}}{Na_2CO_3 + SiO_2} \xrightarrow{\text{Fusion}} \underset{\text{sodium silicate}}{Na_2SiO_3} + CO_2(g)$$

Table 18.1 Classification of silicates

No. of carners of SiO_4 tetrahe-dra shared	No. of com-mon oxygen atoms	Structure ● ***Silicon*** ○ **Oxygen** Diagram and Description	Net cha-rge and Anion in the silicate structure	Example
Zero	Zero	 Discrete SiO_4^{4-}anion	Si = +4 O = − 8 Net = − 4 SiO_4^{4-}	ortho-silicates Mg_2SiO_4
1	1	 Island structure	Si = + 8 O = − 14 Net = − 6 $(Si_2O_7)^{6-}$	Pyro-silicates
2	2	Ring anion	Si= +12 O = −18 Net = − 6 $(Si_3O_9)^{6-}$	Wollas-tonite $Ca_3Si_3O_9$
2	2	 Ring anion	Si =+24 O = −36 Net=− 12 $(Si_6O_{18})^{12-}$	Beryl, $Be_3Al_2Si_6O_{18}$
2	2	 Chain anion	Si = +4 O = −6 Net = − 2 $(SiO_3^{2-})_n$	Pyroxenes, e.g., $MgCaSi_2O_6$ Asbestos
3	3	 Two dimensional sheet structure	Si = +8 O = −10 Net = − 2 $(Si_2O_5^{2-})_n$	Clays, talc kaolinite
4	4	– Three dimensional network	Si = +4 O = −4 $(SiO_3)_n$	Quartz, Tridymite and Cristo-balite

(ii) ***Silica or silicon dioxide*** **(** SiO_2 **)**

It occurs in nature in various forms such as sand, quartz and flint .It is also a constituent of various rocks. It is solid at room temperature. It is insoluble in water.

Silica has a three dimensional network structure in which each *Si* is bonded to four oxygen atoms which are tetrahedrally disposed around silicon atom. Each *O* atom is shared by two *Si* atoms. It may be noted that CO_2 is a gas, while SiO_2 is hard solid with very high melting point.

$$SiO_2 + 4HF \longrightarrow SiF_4 + 2H_2O$$

$$SiF_4 + 2HF \longrightarrow \underset{\text{(Hydroflouro silicic acid)}}{H_2SiF_6}$$

HF readily dissolves Silica, therefore *HF* can not be store in glass bottles which contain Silica.

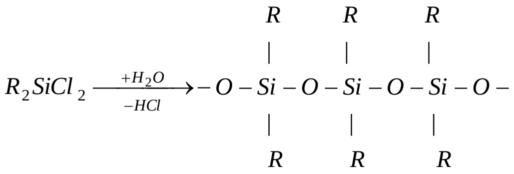
It is used in large amount to form mortar which is a building material. It is also used in the manufacture of glass and lenses.

(iii) ***Silicones***

Polymeric organo-silicon compounds containing $Si-O-Si$ bonds are called silicones. These have the general formula $(R_2SiO)_n$. Where R is CH_3-group (majority cases) or C_6H_5-group.

Preparation : The preparation of silicones is generally carried out by the hydrolysis of dialkyldichlorosilanes (R_2SiCl_2) or diaryldichlorosilanes (Ar_2SiCl_2), which are prepared by passing vapours of RCl or $ArCl$ over silicon at $570\,K$ with copper as a catalyst.

$$2RCl + Si \xrightarrow{Cu,\,570\,K} R_2SiCl_2$$



$$R_2SiCl_2 \xrightarrow[-HCl]{+H_2O} -O-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{Si}}-O-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{Si}}-O-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{Si}}-O-$$

Silicones may be obtained in the form of oils, rubber on resins depending upon the extent of polymerisation which depends upon reaction conditions and nature of alkyl groups.

Properties and Uses : Silicones are water repellent and quite inert chemically. These resist oxidation, thermal decomposition and attack by organic reagents. These are also good electrical insulators and antifoaming agents. These have found the following uses :

(a) Silicones have been used for making water-proof papers, wools, textiles, wood etc., after coating these articles with silicones.

(b) The viscosities of silicones do not change with changes in temperature, therefore, these are used as all weather lubricants.

(c) As antifoaming agent in industrial processes.

(d) As a mould releasing agent in rubber industry and foundry. It avoids the sticking of the castings to the mould.

(e) For making body implants in cosmetic surgery due to its inert nature.

(f) Silicones are now incorporated in paints for resisting dampness and for water proofing.

(g) Due to their water repellent nature and high dielectric constant, silicones are used in electrical condensers.

(iv) ***Silica gel* :** When a mineral acid (Such as HCl) is added to a concentrated solution of a silicate, gelatinous white ppt. of hydrated silica (silicic acid) separate out.

$$Na_2SiO_3 + 2HCl \longrightarrow 2NaCl + SiO_2.xH_2O$$

The white ppt. thus obtained is heated to lose water. When the water content is very low, the solid product is called silica gel. It possesses excellent absorptive properties due to its porous nature and is used for absorbing moisture and an adsorbent in chromatography.

(v) ***Silanes* :** The hydrides of silicon are called silanes. For example; SiH_4 Silane, Si_2H_6 disilane, Si_3H_8 Trisilane Si_4H_{10} Tetrasilane.

Silanes are poisonous. These are much less stable than the corresponding alkanes and are decomposed into elements on heating above $450\,^oC$. Their thermal stability decreases with increase in molecular mass. Unlike alkanes, silanes are reducing agents.

(vi) ***Glass***

Glass is an amorphous and transparent solid which is obtained by solidification of various silicates and borates of potassium and calcium.

Preparation : Ordinary glass is a mixture of sodium and calcium silicates and is produced by fusing together a mixture of sodium carbonate, calcium oxide and silicon dioxide (Silica) in a furnace at about 1700K

$$Na_2CO_3 + SiO_2 \longrightarrow Na_2SiO_3 + CO_2 \uparrow$$

$$CaO + SiO_2 \longrightarrow CaSiO_3$$

On continuously heating the entire amount of CO_2 is driven out and clear viscous fused mass is obtained. It is poured into moulds to get different types of articles, which are allowed to cool gradually.

This typed of glass is called soda glass or soft glass which has the approximate composition, $Na_2SiO_3, CaSiO_3, 4SiO_2$.

Various varieties of glass : The different varieties of glasses and their special constituents are given below,

Table 18.2

Type of glass	Constituents	Special use
Soft glass	$Na_2CO_3, CaCO_3, SiO_2$	Ordinary glass for window panes, test tubes, bottles, etc.
Hard glass	$K_2CO_3, CaCO_3, SiO_2$	For combustion tubes and chemical glassware
High refractive index glass (Flint glass)	Lead oxide, K_2CO_3	For making lenses cut glasses
Pyrex glass	$Na_2CO_3, Al_2O_3, B_2O_3$ or borax, sand	For high quality glass apparatus cooking utensils
Crook's glass	$K_2CO_2, PbCO_3, CeO_2$, sand	Absorbs ultra violet rays, for making lenses
Jena glass	Zinc and Barium Boro silicates	It is resistant to heat shock and common reagent. It is used for making good quality of glass wares.

Coloured glass : Addition of transition metal compounds to glass give coloured glasses . Small amounts of *Cr*(III), *Mn*(IV), *Co*(II) and *Fe*(III) compounds impart green, violet blue or brown colour respectively

Table 18.3

Compound added – Colour imparted	Compound added – Colour imparted
Cobalt axide (CoO) – Blue	Chromium oxide (Cr_2O_3) – Green
Cuprous oxide (Cu_2O) – Red	Auric chloride ($AuCl_3$) – Ruby
Cadmium sulphide (CdS) – Lemon yellow	Manganese dioxide (MnO_2) – Purple

Etching of glass : Glass is attacked by hydrofluoric acid. This property is used in the etching of glass. The glass to be etched is coated with a thin layer of wax and the design to be produced is scratched with a needle. An aqueous solution of HF is applied to the exposed part. After some time it is placed in hot water and wax is removed from the surface. The marks are engraved on the exposed parts.

Tin and its Compounds

(1) **Important ore :** Cassiterite (tin stone) SnO_2

(2) **Extraction of tin from tin stone.**

(i) ***Concentration*** : The powdered tin stone is concentrated by gravity separation and the magnetic impurities like wolframite etc., are separated from tin stone by magnetic separators.

(ii) ***Roasting*** : The concentrated ore is heated in a current of air when impurities like S and As are oxidised to volatile SO_2 and As_2O_3. Iron pyrites change to their oxides and sulphates.

(iii) ***Leaching and washing*** : The roasted ore is treated with water when $CuSO_4$ and $FeSO_4$ are washed away from the main ore. Further lighter ferric oxide is washed away leaving behind heavier ore particles known as black tin containing 60 to 70% SnO_2.

$$SnO_2 + 2C \longrightarrow Sn + 2CO$$

$$\underset{\text{Flux}}{CaCO_3} \longrightarrow CaO + CO_2 \,;\; CaO + SiO_2 \longrightarrow \underset{\text{Slag}}{CaSiO_3}$$

Molten tin is drawn into blocks. It contains 99.5 percent of tin metal and is called block tin.

Refining of tin : It is purified by liquation, poling and electrolytic refining.

For very high purity, it is purified by electrolytic method. The electrolyte consists of tin sulphate containing a small amount of hydrofluorosilicic acid (H_2SiF_6) and sulphuric acid. Impure tin makes anode while pure tin sheet serves as cathode.

(3) **Comounds of Tin**

(i) ***Stannic oxide, SnO₂*** **:** It is prepared by heating tin strongly in air. $Sn + O_2 \longrightarrow SnO_2$

It can also be prepared by heating metastannic acid obtained by the action of conc. HNO_3 on tin.

$$Sn + 4HNO_3(conc.) \longrightarrow H_2SnO_3 + 4NO_2 + H_2O$$

$$H_2SnO_3 \xrightarrow{\Delta} SnO_2 + H_2O$$

It occurs in nature as tin stone. It is a white solid insoluble in water and is amphoteric in nature. With $NaOH$ it forms Na_2SnO_3. It is used for making enamels and glazes for tiles, pottery etc. it is also used as a polishing powder.

(ii) ***Stannous oxide, SnO* :** It is prepared by heating stannous oxalate $SnC_2O_4 \xrightarrow{\Delta} SnO + CO + CO_2$

Oxidation of SnO to SnO_2 is checked by CO. It is a grey solid which oxidises readily to SnO_2 when heated in air.

$$2SnO + O_2 \longrightarrow 2SnO_2$$

It is amphoteric in nature and reacts both with acids and alkalies. With $NaOH$ it forms Na_2SnO_2.

(iii) ***Stannous sulphide, SnS* :** It is insoluble in water but soluble in hot conc. HCl. In yellow ammonium polysulphide it gets converted to ammonium thiostannate $(NH_4)_2SnS_3$.

(iv) ***Stannous chloride, SnCl₂* :** When Sn is heated with HCl (conc.) $SnCl_2$ is formed.

$$Sn(s) + HCl(Conc.) \longrightarrow SnCl_2(aq) + H_2(g)$$

On concentrating the resulting solution, crystals of $SnCl_2.2H_2O$ are obtained. When it is heated, basic tin chloride is obtained.

$$SnCl_2.2H_2O(s) \xrightarrow{\Delta} Sn(OH)Cl + HCl + H_2O$$

To obtain anhydrous $SnCl_2$, heat Sn in dry HCl gas.

$$Sn + 2HCl \xrightarrow{\Delta} SnCl_2 + H_2$$

(a) It exists as a anhydrous (white powder, m.p. = $520K$, rhombic solid) as well as dihydrate $SnCl_2.2H_2O$ (white, m.p. $=480K$, monoclinic) and is used as a strong reducing agent in conc. HCl in laboratory.

$SnCl_2$ also reduces $HgCl_2$

$$2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$$

$$Hg_2Cl_2 + SnCl_2 \longrightarrow 2Hg + SnCl_4$$

(b) It is precipitated as hydroxide by an alkali.

(c) If forms addition compounds with NH_3 such as $SnCl_2.NH_3$ and $SnCl_2.2NH_3$.

(v) ***Stannic chloride, SnCl₄* :** It is obtained by the action of Cl_2 on molten Sn

$$Sn + 2Cl_2 \longrightarrow SnCl_4$$

It can also be obained by distilling tin with mercuric chloride.

$$Sn + 2HgCl_2 \longrightarrow SnCl_4 + 2Hg$$

(a) It is a colourless fuming liquid (b.p $388K$) soluble in water.

It is used as a strong reducing agent in laboratory. It is also used as a mordant in dyeing.

(b) It can exist as $SnCl_4.5H_2O$ and with excess water it is hydrolysed to form basic chloride and ultimately stannic acid (H_2SnO_4).

$$SnCl_4 + H_2O \longrightarrow Sn(OH)Cl + HCl$$

$$Sn(OH)Cl + 3H_2O \longrightarrow Sn(OH)_4 \text{ or } H_2SnO_4 + 3HCl$$

Its hydrolysis is prevented by HCl which forms complex anion $[SnCl_6]^{2-}$

(c) It forms double salts with NH_3, N_2O, PCl_5 e.g., $SnCl_4.4NH_3$.

It is used as a mordant and tinning agent.

(vi) ***Stannous fluoride, SnF₂* :** It is obtained by dissolving SnO in HF

$$SnO + 2HF \longrightarrow SnF_2 + H_2O$$

It is a white crystalline solid insoluble in water. It is used in tooth pastes to help in controlling dental decay.

Tinning : During cooking, organic acids present in food stuff attack the household utensils made of copper, brass etc. in the presence of air. since tin is not attacked by organic acids, the utensils are protected by tinning.

Lead

(1) **Some important ores**

Galena; $-PbS$ (Main); Cerussite $-PbCO_3$

Anglesite $-PbSO_4$, lararkite $PbO.PbSO_4$

(2) **Extraction from galena**

(i) ***Concentration* :** The finely powdered ore is concentrated by froth floatation process.

(ii) ***Reduction process***

(a) *Self reduction process*

• **Roasting** : The concentrated ore is heated in air. lead sulphide is partially converted into lead oxide and lead sulphate.

$$2PbS + 3O_2 \xrightarrow{\Delta} 2PbO + 2SO_2$$

$$PbS + 2O_2 \xrightarrow{\Delta} PbSO_4$$

• **Self reduction :** The supply of air is cut off and the temperature is raised to melt the charge. The galena reduces both PbO and $PbSO_4$ to metallic lead.

$$PbS + 2PbO \xrightarrow{\Delta} 3Pb + SO_2$$

$$PbS + PbSO_4 \xrightarrow{\Delta} 2Pb + 2SO_2$$

(b) *Carbon reduction process*

• **Roasting :** The powdered ore is mixed with lime and roasted in excess of air. the impurities like S and As are oxidised to their volatile oxides while PbS is converted to PbO.

$$S+O_2\xrightarrow{\Delta}SO_2\,;\quad 4As+3O_2\xrightarrow{\Delta}2As_2O_3$$

$$2PbS+3O_2\xrightarrow{\Delta}2PbO+2SO_2$$

• **Smelting :** Roasted ore is mixed with coke and lime (flux) and smelted in a blast furnance. PbO is reduced to Pb.

$$PbO+C\xrightarrow{\Delta}Pb+CO\,;\quad PbO+CO\xrightarrow{\Delta}Pb+CO_2$$

$$\underset{\text{Lime}}{CaCO_3}\xrightarrow{\Delta}CaO+CO_2\,;\quad CaO+SiO_2\xrightarrow{\Delta}\underset{\text{Slag}}{CaSiO_3}$$

(iii) ***Purification*** **:** It is purified electrolytically. The electrolyte consists of lead silicofluoride $(PbSiF_6)$ and hydrofluosilicic acid. Impure lead is made anode and sheet of pure lead serves as cathode.

Properties of Lead

With oxygen lead form oxides, with chlorine it forms chloride $PbCl_2$, with sulphur it gives sulphide PbS and with H_2SO_4 the corresponding sulphate $PbSO_4$. With $NaOH$ it forms plumbate.

$$Pb+2NaOH\longrightarrow Na_2PbO_2+H_2$$

(3) Compounds of Lead

(i) ***Lead oxide (Litharge), PbO*** **:** It is prepared by heating the nitrate.

$$2Pb(NO_3)_2\xrightarrow{\Delta}2PbO+4NO_2+O_2$$

It exist in two varieties yellow form (messicol) and red form (litherage). Yellow form is prepared by gently heating lead in air while fusion yield red form. It is insoluble in water and amphoteric in nature.

It dissolves in $NaOH$ to form sod. Plumbite.

$$PbO+2NaOH\longrightarrow Na_2PbO_2+H_2O$$

It can be reduced with various reducing agents (C, H_2, CO etc.) to lead.

It is used in paints and varnishes, for making flint glass, for making lead (II) salts and for glazing pottery.

(ii) ***Lead dioxide, PbO₂*** **:** It is prepared by heating $Pb_3O_4(2PbO+PbO_2)$ with dilute HNO_3

$$Pb_3O_4+4HNO_3\xrightarrow{\Delta}2Pb(NO_3)_2+2H_2O+PbO_2$$

It is amphoteric in nature and dissolve in $NaOH$ to form sodium plumbate.

$$2NaOH+PbO_2\longrightarrow Na_2PbO_3+H_2O$$

It is a powerful oxidising agent. It reacts with conc. HCl on warming to give $PbCl_4$

$$PbO_2+4HCl\xrightarrow{Warm}PbCl_4+H_2O$$

It is a chocolate brown solid insoluble in water and nitric acid. It is a powerful oxidizing agent. It is amphoteric in nature and is used in lead storage batteries and in safety matches.

(iii) ***Minium or sindhur or Red lead, Pb₃O₄*** **:** It is prepared by heating PbO in air to above $673K$.

$$6PbO+O_2\xrightarrow{673K}2Pb_3O_4$$

It is a red crystalline solid insoluble in water.

It is a mixed oxide PbO_2+2PbO and reacts with HNO_3 to form $Pb(NO_3)_2$ and PbO_2

$$2PbO.PbO_2+4HNO_3\to Pb(NO_3)_2+2H_2O+PbO_2$$

It is a strong oxidising agent. It liberates chlorine with conc. HCl and O_2 with conc. H_2SO_4

$$Pb_3O_4+8HCl\longrightarrow 3PbCl_2+4H_2O+Cl_2$$

$$2Pb_3O_4+6H_2SO_4\longrightarrow 6PbSO_4+6H_2O+O_2$$

It is used as a protective paint in iron, steel and silver mirrors and in glass industry.

(iv) ***Lead chloride, PbCl₂*** **:** It can be prepared by treating a salt of lead with dil. HCl

$$Pb(NO_3)_2+2HCl\longrightarrow PbCl_2+2HNO_3$$

It can also be obtained by dissolving lead (II) oxide to lead (II) carbonate in HCl. It is soluble in hot water but precipitate out in cold water. it is soluble in conc. HCl due to the formation of a complex, tetrachloroplumbate (II) ion.

$$PbCl_2+2HCl\longrightarrow H_2[PbCl_4]$$

It also reacts with hot lime water to give $Pb(OH)Cl$ which is used as white pigment.

$$PbCl_2+Ca(OH)_2\longrightarrow Pb(OH)Cl+CaO+HCl$$

(v) ***Lead tetrachloride, PbCl₄*** **:** It is obtained by heating of PbO_2 with conc. HCl.

It is a yellow oily fuming liquid which decomposes into $PbCl_2$ at $373K$.

$$PbCl_4\xrightarrow{373K}PbCl_2+Cl_2$$

It also combines with HCl to form complex hexachloroplumbate (IV) ion.

$$PbCl_4+2HCl\longrightarrow H_2[PbCl_6]$$

Nitrogen Family

Nitrogen is the first member of group 15 or VA of the periodic table. It consists of five elements nitrogen (N), phosphorus (P), arsenic (As), antimony (Sb) and bismuth (Bi). The elements of this group are collectively called ***pnicogens*** and their compounds as pniconides. The name is derived from Greek word "Pniomigs" meaning suffocation. Pniconide contain M^{3-} species.

(1) **Electronic configuration**

Elements	Electronic configuration ($ns^2\ np^3$)
$_7N$	$[He]2s^2 2p^3$
$_{15}P$	$[Ne]3s^2 3p^3$
$_{33}As$	$[Ar]3d^{10} 4s^2 4p^3$
$_{51}Sb$	$[Kr]4d^{10} 5s^2 5p^3$
$_{83}Bi$	$[Xe]4f^{14} 5d^{10} 6s^2 6p^3$

Physical properties

(1) **Physical state :** Nitrogen– (gas), phosphorus – (solid) (vaporises easily), *As*, *Sb*, *Bi*–solids.

Nitrogen is the most abundant gas in the atmosphere. It constitutes about 78% by volume of the atmosphere. Phosphorus is the most reactive element in this group and its yellow form is always kept under water.

(2) **Atomic radii :** Atomic radii increases with atomic number down the group i.e., from *N* to *Bi* due to addition of extra principal shell in each succeding elements.

(3) **Ionisation energy :** The ionisation values of the elements of this group decreases down the group due to gradual increases in atomic size.

(4) **Electronegativity :** Generally the elements of nitrogen family have high value of electronegativity. This value shows a decreasing trend in moving down the group from nitrogen to bismuth.

(5) **Non-metallic and metallic character :** Nitrogen and phosphorus are non-metals, arsenic and antimony are metalloids (semi-metal) and bismuth a typical metal.

(6) **Molecular state :** Nitrogen readily forms triple bond (two $p\pi - p\pi$ bonds) and exists as discrete diatomic gaseous molecule $(N \equiv N)$ at room temperature. Phosphorus, arsenic and antimony exist in the form of discrete tetra atomic molecules such as P_4, As_4, Sb_4 in which the atoms are linked to each other by single bonds.

(7) **Melting and boiling points :** The melting points and boiling points of group 15 elements do not show a regular trend. M.pt. first increases from *N* to As and then decreases from *As* to *Bi*. Boiling point increases from *N* to *Sb*. Boiling point of *Bi* is less than *Sb*.

(8) **Allotropy :** All the members of group 15 except *Bi* exhibit the phenomenon of allotropy.

(i) Nitrogen exists in two solid and one gaseous allotropic forms.

(ii) Phosphorus exists in several allotropic forms such as white, red, scarlet, violet and black form.

(a) *White or yellow phosphorus* : White phosphorus is prepared from rock phosphate $Ca_3(PO_4)_2, SiO_2$ and coke which are electrically heated in a furnace.

$$2Ca_3(PO_4)_2 + 6SiO_2 \xrightarrow{\Delta} 6CaSiO_3 + P_4O_{10};$$

$$P_4O_{10} + 10C \xrightarrow{\Delta} P_4 + 10CO$$

When exposed to light, it acquires a yellow colour.

(b) *Red phosphorus* : It is obtained by heating yellow phosphorus, between 240 –250°*C* in the presence of an inert gas. Yellow phosphorus can be separated from red phosphorus by reaction with *NaOH* (*aq*) or *KOH* (*aq*) when the former reacts and the latter remains unreacted.

(iii) Arsenic exists in three allotropic forms namely grey, yellow and black. Antimony also exists in three forms, viz., metallic, yellow and explosive.

(9) **Oxidation state :** The members of the group 15 exhibit a number of positive and negative oxidation states.

(i) ***Positive oxidation states*** **:** The electronic configuration (ns^2np^3) for the valence shell of these elements shows that these elements can have +3 and +5 oxidation states. In moving down this group, the stability of +3 oxidation state increases. It may be pointed out here that nitrogen does not exhibit an oxidation state of +5, because it fails to expand its octet due to nonavailability of vacant *d*-orbitals.

(ii) ***Negative oxidation states*** **:** For example oxidation state of nitrogen is –3. The tendency of the elements to show –3 oxidation state decreases on moving down the group from *N* to *Bi*.

(10) **Catenation** (self linkage) **:** Elements of group 15 also show some tendency to exhibit catenation. This tendency goes on decreasing in moving down the group due to gradual decrease in their bond (*M*–*M*) energies.

Chemical properties

(1) **Hydrides :** All the members form volatile hydrides of the type AH_3. All hydrides are pyramidal in shape. The bond angle decreases on moving down the

group due to decrease in bond pair–bond pair repulsion.

$$\underset{107^o}{NH_3} \quad \underset{94^o}{PH_3} \quad \underset{92^o}{AsH_3} \quad \underset{91^o}{SbH_3} \quad \underset{90^o}{BiH_3}$$

The decreasing order of basic strength of hydrides is as follows : $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$.

The increasing order of boiling points is as follows :

$$PH_3 < AsH_3 < NH_3 < SbH_3.$$

NH_3 is thermally most stable and BiH_3 is least stable. This is because in NH_3, $N - H$ covalent bond is the strongest due to small size of N atom. Hence, the *decomposition temperature of NH_3 will be the highest*. The increasing order of reducing character is as follows, $NH_3 < PH_3 < AsH_3 < SbH_3 < BiH_3$.

(2) **Halides :** The members of the family form trihalides (MX_3) and pentahalides (MX_5). The trihalides are sp^3-hybridized with distorted tetrahedral geometry and pyramidal shape while pentahalides are sp^3d-hybridized and are trigonal *bi*pyramidal in shape. The trihalides are hydrolysed by water and ease of hydrolysis decreases when we move down the group. Hence, NCl_3 is easily hydrolysed but $SbCl_3$ and $BiCl_3$ are partly and reversibly hydrolysed. NF_3 is not hydrolysed due to lack of vacant *d*-orbital with nitrogen. PF_3 and PF_5 are also not hydrolysed because the $P - F$ bond is stronger than $P - O$ covalent bond. The hydrolysis products of the halides are as follows :

$$NCl_3 + 3H_2O \rightarrow NH_3 + 3HOCl$$

$$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$$

$$2AsCl_3 + 3H_2O \rightarrow As_2O_3 + 6HCl$$

$$SbCl_3 + H_2O \rightarrow SbOCl + 2HCl$$

$$BiCl_3 + H_2O \rightarrow BiOCl + 2HCl$$

Their basic character follows this decreasing order as $NI_3 > NBr_3 > NCl_3 > NF_3$. Except NF_3, the trihalides of nitrogen are unstable and decompose with explosive violence. NF_3 is stable and inert. NCl_3 is highly explosive. Trifluorides and trichlorides of phosphorus and antimony act as Lewis acid. The acid strength decreases down the group. For example, acid strength of tri-chlorides is in the order ; $PCl_3 > AsCl_3 > SbCl_3$.

Nitrogen does not form pentahalides due to non-availability of vacant *d*-orbitals. The pentachloride of phosphorus is not very stable because axial bonds are longer (and hence weaker) than equitorial bond. Hence, PCl_5 decomposes to give PCl_3 and Cl_2 ;

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2.$$

The unstability of PCl_5 makes it a very good chlorinating agent. All pentahalides act as lewis acids since they can accept a lone pair of electron from halide ion.

Solid PCl_5 is an ionic compound consisting of $[PCl_4]^+$ $[PCl_6]^-$, $[PCl_4]^+$ has a tetrahedral structure, while $[PCl_6]^-$ has an octahedral structure.

Since, PCl_5 reacts readily with moisture it is kept in well stoppered bottles.

PI_5 does not exist due to large size of I atoms and lesser electronegativity difference between phosphorus and iodine.

Down the group, the tendency to form pentahalides decreases due to inert pair effect. *e.g., BiF_5 does not exist.*

(3) **Oxides :** These elements form oxides of the type X_2O_3, X_2O_4 and X_2O_5.

The acidic strength of oxides :

$$N_2O < NO < N_2O_3 < N_2O_4 < N_2O_5.$$

The decreasing order of stability of oxides of group 15 follows as,

$$P_2O_5 > As_2O_5 > Sb_2O_5 > Bi_2O_5$$

The nature of oxides of group 15 elements is as follows,

N_2O_3 and P_2O_3 (acidic) ; As_2O_3 and Sb_2O_3 (amphoteric);

Bi_2O_3 (basic)

(4) **Oxyacids :** N_2 and P_4 of this group forms oxyacids which are discussed further. In this chapter.

Anamalous behaviour of Nitrogen

Nitrogen is known to differ form other members of the family because of the following facts,

(1) Its small size (2) Its high electronegativity (3) Its high ionisation energy (4) non-availability of *d*-orbital in the valence shell. (5) Its capacity to form $p\pi$-$p\pi$ multiple bonds.

The main points of difference are,

(i) Nitrogen is a gas while other members are solids.

(ii) Nitrogen is diatomic while other elements like phosphorus and arsenic form tetra-atomic molecules (P_4, As_4).

(iii) Nitrogen form five oxides $(N_2O, NO, N_2O_3, N_2O_4$ and $N_2O_5)$ while other members of the family form two oxides (tri and pentaoxides).

(iv) Hydrides of nitrogen show H-bonding while those of other elements do not.

(v) Nitrogen does not show pentacovalency because of absence of *d*-orbitals while all other elements show pentacovalency.

(vi) Nitrogen dos not form complexes because of absence of d-orbitals while other elements show complex formation e.g., $[PCl_6]^-, [AsCl_6]^-$ etc.

(vii) The hydride of nitrogen (NH_3) is highly basic in nature while the hydrides of other elements are slightly basic.

(viii) Except for NF_3, other halides of nitrogen e.g., NCl_3, NBr_3 and NI_3 are unstable.

Nitrogen and its compounds

N_2 was discovered by ***Daniel Rutherford***. It is the first member of group 15 in the periodic table.

Occurrence : N_2, occurs both in the free state as well as in the combined state. N_2 occurs in atmosphere to the extent of 78% by volume in free state. N_2 is present in many compounds such as potassium nitrate (nitre). Sodium nitrate (Chile salt peter) and many ammonium compounds. N_2 is an important constituent of proteins in plants and animals in combined state.

Preparation : It is prepared by the following methods,

(1) **Laboratory method** : In the laboratory N_2 is prepared by heating an aqueous solution containing an equivalent amounts of NH_4Cl and $NaNO_2$.

$$NH_4Cl\,(aq.) + NaNO_2(aq.) \xrightarrow{\text{Heat}} N_2(g) + 2H_2O(l) + NaCl$$

(2) **Commercial preparation :** Commercially N_2 is prepared by the fractional distillation of liquid air.

Physical properties : N_2 is a colourless, odourless and tasteless gas. It is a non-toxic gas. It's vapour denstiy is 14. It has very low solubility in water.

Chemical properties

(1) N_2 is neutral towards litmus. It is chemically unreactive at ordinary temp. It is neither combustible nor it supports combustion.

(2) The $N - N$ bond in N_2 molecule is a triple bond $(N \equiv N)$ with a bond distance of 109.8 *pm* and bond dissociation energy of 946 *kJ mol*$^{-1}$

(3) **Combination with compounds :** N_2 combines with certain compounds on strong heating . eg

$$\underset{\text{Calsium carbide}}{CaC_2} + N_2 \xrightarrow{1300\,K} \underset{\text{Calsium cyanamide}}{CaCN_2 + C}$$

$$\underset{\substack{\text{Aluminium}\\ \text{oxide}}}{Al_2O_3} + N_2 + 3C \xrightarrow{2100\,K} \underset{\text{Al.nitride}}{2AlN} + 3CO$$

Both these compounds are hydrolysed on boiling with water to give ammonia.

$$CaCN_2 + 3H_2O \longrightarrow CaCO_3 + 2NH_3$$

$$AlN + 3H_2O \longrightarrow Al\,(OH)_3 + NH_3$$

Therefore, calcium cyanamide is used as a fertilizer under the name nitrolim $(CaCN_2 + C)$

Uses of nitrogen : N_2 is mainly used in the manufacture of compounds like $NH_3, HNO_3, CaCN_2$ etc.

Compounds of nitrogen

(1) **Hydrides of nitrogen – Ammonia**

Preparation of ammonia : Ammonia is prepared in the laboratory by heating a mixture of NH_4Cl and slaked lime, $Ca(OH)_2$

$$2NH_4Cl + Ca(OH)_2 \xrightarrow{\Delta} CaCl_2 + 2NH_3 + 2H_2O$$

Moist NH_3 gas is dried over quick lime, CaO. However, it cannot be dried over conc. H_2SO_4, P_2O_5 because being basic it forms salts with them. Anhydrous $CaCl_2$ also cannot be used because it forms a complex $CaCl_2.8NH_3$ with it.

Manufacture : (i) Ammonia is manufacture by Haber's process. A mixture of pure N_2 and H_2 (in the ratio 1 : 3 by volume) is compressed to 200 – 1000 atmospheres and passed over finely divided Fe (as catalyst) and Mo (as promoter) at $750\,K$

$$N_2 + 3H_2 \xrightleftharpoons{Fe + Mo,\ 750\text{K},\ 200\text{–}1000} 2NH_3 + 93.6\,KJ\,mol^{-1}$$

Favourable conditions for maximum yield of NH_3 are :

(a) excess of reactants (N_2 and H_2) (b) high pressure (c) low temperature and (d) use of catalyst and a promoter.

(ii) By the hydrolysis of calcium cyanamide $(CaCN_2)$ with super-heated steam at $450\,K$. $CaCN_2$ itself is obtained by heating CaC_2 and N_2 at $1270\,K$.

$$CaC_2 + N_2 \xrightarrow{\Delta} CaCN_2 + C$$

$$CaCN_2 + 3H_2O \xrightarrow{450\,K} CaCO_3 + 2NH_3$$

Properties of NH_3 : It is a colourless gas with pungent smell, highly soluble in H_2O and basic in nature. It liquefies on cooling under pressure to give liquid ammonia (bp. 240*K*). On heating, it causes intense cooling and hence is used as a refrigerant in ice, factories and cold storages.

It burns in excess of air to give N_2 and H_2O and is oxidised to NO when passed over heate Pt at $1075\,K$.

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O$$

$4NH_3 + 5O_2 \xrightarrow{Pt.1075\,K} 4NO + 6H_2O$ (ostwald process)

It reduces heated CuO to Cu and Cl_2 to HCl (which combines with NH_3 to give NH_4Cl).

$$2NH_3 + 3CuO \xrightarrow{Heat} 3Cu + 3H_2O + N_2$$

$$\underset{\text{Excess}}{8NH_3} + 3Cl_2 \longrightarrow 6NH_4Cl + N_2$$

With excess of Cl_2, it gives NCl_3. With Br_2 it gives NH_4Br and N_2 is set free.

$$NH_3 + \underset{\text{Excess}}{3Cl_2} \longrightarrow NCl_3 + 3HCl$$

$$8NH_3 + 3Br_2 \longrightarrow 6NH_4Br + N_2$$

With I_2, it gives nitrogen triiodide ammonia (brown ppt) which is explosive in dry state and decomposes when struck

$$2NH_3 + 3I_2 \longrightarrow NH_3.NI_3 + 3HI$$

$$8NH_3.NI_3 \longrightarrow 5N_2 + 9I_2 + 6NH_4I$$

It forms amides with active metals like Na, K etc.

$$2Na + 2NH_3 \xrightarrow{575\,K} 2NaNH_2 + H_2$$

It forms complexes with many substances, *e.g.,*

$[Ca(NH_3)_6]\ Cl_2$, $[Co(NH_3)_6]Cl_2, [Cu(NH_3)_4]SO_4$,

$[Ag(NH_3)_2]Cl$, $[Cd(NH_3)_4Cl_2$ etc.

Its aqueous solution is weakly basic due to the formation of OH^- ions, $NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

With sodium hypochlorite in presence of glue or gelatine, excess of ammonia gives hydrazine

$$2NH_3 + NaOCl \longrightarrow NH_2.NH_2 + NaCl + H_2O$$

It undergoes self ionization in liquid state and acts as a solvent. $2NH_3 \longrightarrow NH_4^+ + NH_2^-$

Many polar compounds are soluble in liquid ammonia.

With Nessler’s reagent (an alkaline solution of K_2HgI_4), ammonia and ammonium salts give a brown precipitate due to the formation of Millon’s base.

$$K_2HgI_4 \rightleftharpoons 2KI + HgI_2$$

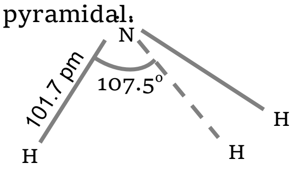
$$HgI_2 + 2NH_3 \longrightarrow I - Hg - NH_2 + NH_4I$$

$$2NH_2 - Hg - I + H_2O \longrightarrow NH_2 - Hg - O - Hg - I + NH_4I$$

or $2K_2HgI_4 + NH_3 + 3KOH \longrightarrow H_2N - Hg - O - Hg - I + 7KI + 2H_2O$

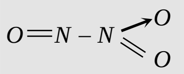
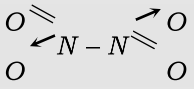
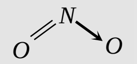
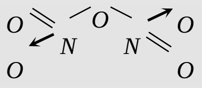
It is used as a refrigerant and in the manufacture of fertilizers.

Strcture of NH_3 : The N atom in NH_3 is sp^3-hybridized containing a lone pair of electrons due to which the $H-N-H$ bond angle is 107.5^o. As a result NH_3 molecule is pyramidal.



(2) **Oxides of nitrogen :** Nitrogen combines with O_2 under different conditions to form a number of binary oxides which differ with respect to the oxidation state of the nitrogen atom. The important oxides are $N_2O, NO, N_2O_3, NO_2, N_2O_4$ and N_2O_5. N_2O and NO both are neutral. Nitrous oxide (N_2O) has a sweet taste and its main use is as anaesthetic. When inhaled in mild quantities it causes hysterical laughter so it is also called Laughing gas. Nitric oxide (NO) can be obtained by treating a mixture of sodium nitrite and ferrous sulphate with dil. H_2SO_4. N_2O_5 is the strongest oxidising agent.

Table : 18.4 *Oxides of Nitrogen*

Oxide	Structure	Physical appearance	Preparation
Nitrous oxide (N_2O) +1	$N \equiv N \rightarrow O$	Colourless gas	By heating ammonium nitrate upto 240°C $NH_4NO_3 \xrightarrow{\Delta} N_2O + 2H_2O$, It is Collected over hot water
Nitric oxide (NO) +2	$N = O$	Colourless	(a) By the action of cold dil. HNO_3 on copper turnings (Laboratory method) $3Cu + 8\text{ dil. } HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$ (b) By the action of H_2SO_4 on a mixture of $FeSO_4$ and KNO_3 (4:1) $2KNO_3 + 5H_2SO_4 + 6FeSO_4 \rightarrow 2KHSO_4 + 3Fe_2(SO_4)_3 + 4H_2O + 2NO$ (c) By catalytic oxidation of ammonia. $4NH_3 + 5O_2 \xrightarrow[850^0C]{Pt} 4NO + 6H_2O$
Dinitrogen trioxide (N_2O_3) +3		Blue solid	(a) By the action of 50% HNO_3 on arsenious oxide. $2HNO_3 + As_2O_3 + 2H_2O \rightarrow NO + NO_2 + 2H_3AsO_4$ $\downarrow$ 250 K N_2O_3
Dinitrogen tetraoxide (N_2O_4) +4		Colourless liquid	(a) By heating nitrates of heavy metals, e.g., lead nitrate. $2Pb(NO_3)_2 \xrightarrow{673\ K} 4NO_2 + 2PbO + 2O$ (b) By heating copper turnings with conc. HNO_3. $Cu + 4\ HNO_3\text{ (conc.)} \rightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2$
Nitrogen dioxide (NO_2) +4		Brown gas	
Dinitrogen pentoxide (N_2O_5) +5		Colourless gas	(a) By dehydrating HNO$_3$ with phosphorus pentoxide $4HNO_3 + P_4O_{10} \rightarrow 2N_2O_5 + 4HPO_3$

(3) **Oxyacids of nitrogen :** Oxyacids of nitrogen are HNO_2, HNO_3, $\underset{\text{(Nitroxylic acid)}}{H_4N_2O_4}$ and $\underset{\text{(Pernitric acid)}}{HNO_4}$, which are explosive.

(i) ***Nitrous acid (HNO₂)*** **:** It is prepared by adding ice cold dil, HCl or dil, H_2SO_4 to a well cooled solution of any nitrite $(NaNO_2, Ba(NO_2)_2$ etc.).

$$NaNO_2 + HCl \longrightarrow NaCl + HNO_2$$

$$2KNO_2 + H_2SO_4 \longrightarrow K_2SO_4 + 2HNO_2$$

It oxidises H_2S to S, KI to I_2 and acts as a reducing agent in presence of strong oxidising agent, i.e., it reduces acidified $KMnO_4, K_2Cr_2O_7, H_2O_2$ etc. to Mn^{2+}, Cr^{3+} and H_2O respectively.

(ii) ***Nitric acid (HNO₃)*** : HNO_3 is called aqua fortis. It is prepared in the laboratory by distillation of nitre with conc. H_2SO_4.

$$2NaNO_3 + H_2SO_4 \longrightarrow 2HNO_3 + Na_2SO_4 .$$

Commercially, it is obtained by Ostwald's process. In this process, NH_3 is first catalytically oxidised to NO which is cooled to about $300\,K$ and then oxidised by air to NO_2. Absorption of NO_2 in water in presence of oxygen gives HNO_3

$$4NH_3 + 5O_2 \xrightarrow{Pt. 1975\ K} 4NO + 6H_2O$$

$$2NO + O_2 \rightleftharpoons 2NO_2\ ;\ 4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$$

From air (Birkeland Eyde electric arc process)

$$N_2 + O_2 \rightleftharpoons 2NO\ ;\ \Delta H_f^o = +135\ kJ\ mol^{-1}$$

$$2NO + O_2 \xrightarrow{50^o C} 2NO_2$$

$$2NO_2 + H_2O \longrightarrow HNO_2 + HNO_3$$

$$3HNO_2 \longrightarrow HNO_3 + H_2O + 2NO$$

Properties : It is a very strong acid and decomposes on boiling or in presence of sunlight. It acts as a strong oxidising agent. It oxidises nonmetals and metalloids to their respective oxy-acids, *i.e.*, C to H_2CO_3, S to H_2SO_4, P to H_3PO_4, I_2 to HIO_3, As to H_3AsO_4 (arsenic acid) and Sb to H_3SbO_4 (antimonic acid), while nitric acid itself is reduced to NO_2.

$$I_2 + 10HNO_3 \longrightarrow 2HIO_3 + 10NO_2 + 4H_2O$$

Nitric acid reacts with metals to form nitrates and is itself reduced to NO, N_2O, NO_2 or NH_3 (which further reacts with HNO_3 to give NH_4NO_3) depending upon the concentration of the acid, activity of the metal and the temperature of the reaction.

(i) Very active metals such as Mn, Mg, Ca, etc. give H_2 on treatment with very dilute HNO_3 (2%).

(ii) Less active metals like Cu, Hg, Ag, Pb etc. give NO with dil. HNO_3. Zinc, however, gives N_2O with dil HNO_3 and NH_4NO_3 with very dilute HNO_3.

$$Zn + 10HNO_3(\text{dilute}) \longrightarrow 4Zn(NO_3)_2 + N_2O + 5H_2O$$

$$Zn + 10HNO_3(\text{very dilute}) \longrightarrow 4Zn(NO_3)_2 + NH_4NO_3 + 3H_2O$$

Similarly, Fe and Sn react with dilute nitric acid to give NH_4NO_3.

(iii) Conc. HNO_3 gives NO_2 both with active metals (Zn, Pb etc.) and less active metals (Cu, Hg, Ag etc.)

$$Cu + 4HNO_3(\text{Conc.}) \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$$

Tin is, however, oxidized by conc. HNO_3 to metastannic acid (H_2SnO_3).

$$Sn + 4HNO_3 \longrightarrow H_2SnO_3 + 4NO_2 + H_2O$$

Passivity : Fe, Cr, Ni and Al become passive in conc. HNO_3 (i.e., lose their normal reactivity) due to the formation of a thin protective layer of the oxide on the surface of the metal which prevents further action. Nitric acid has no action on noble metals (Au, Pt) but these metals dissolve in aqua regia (3 vol. HCl + 1 vol. HNO_3) forming their respective chlorides.

$$HNO_3 + 3HCl \longrightarrow 2H_2O + NOCl + 2[Cl]$$

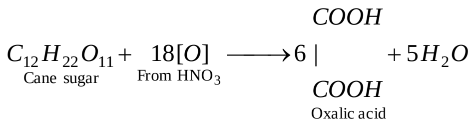
$$Au + 3[Cl] \longrightarrow AuCl_3;\ Pt + 4[Cl] \longrightarrow PtCl_4$$

These chlorides subsequently dissolve in excess of HCl forming their corresponding soluble complexes. Thus,

$$\underset{\text{Auric chloride}}{AuCl_3} + HCl \longrightarrow \underset{\text{Aurochloric acid}}{HAuCl_4}$$

$$\underset{\text{Platinic chloride}}{PtCl_4} + 2HCl \longrightarrow \underset{\text{Chloro platinic acid}}{H_2PtCl_6}$$

Sugar on oxidation with nitric acid gives oxalic acid. Nitric acid reacts with glycerine to give glycerol trinitrate or nitro glycerine, with toluene it gives 2, 4, 6-trinitrotoluene (T.N.T.) and with cellulose (cotton) it gives cellulose trinitrate (gun cotton). All these are used as explosives.



$$\underset{\text{Cane sugar}}{C_{12}H_{22}O_{11}} + \underset{\text{From HNO}_3}{18[O]} \longrightarrow 6\ \underset{\substack{COOH \\ \text{Oxalic acid}}}{\overset{COOH}{|}} + 5H_2O$$

Table : 18.5 ***Oxyacids of nitrogen***

Name of oxoacid	la M.	Structure	Oxidation State of N	Basicity	pK$_a$	Nature

Hyponitrous acid	$H_2N_2O_2$	$\begin{array}{c} \ddot{N}-OH \\ \| \\ HO-\underset{..}{N} \end{array}$	+1	2(dibasic)	Very weak	Highly explosive
Nitrous acid	HNO_2	$H-\underset{\underset{O}{\downarrow}}{N}=O$	+3	1 (monobasic)	3.3	Unstable, Weak acid
Nitric acid	HNO_3	$H-O-\underset{\underset{O}{\downarrow}}{N}=O$	+5	1 (monobasic)	-3.0	Stable, Strong acid
Pernitric acid	HNO_4	$O=\underset{\underset{O}{\downarrow}}{N}-O-O-H$	+5	1 (monobasic)		Unstable and explosive

Phosphorus and its compounds

It is the second member of group 15 (VA) of the Periodic table. Due to larger size of *P*, it can not form stable $P\pi$ - $P\pi$ bonds with other phosphorous atoms where as nitrogen can form $P\pi$ – $P\pi$ bonds .

(1) **Occurrence :** Phosphorous occurs mainly in the form of phosphate minerals in the crust of earth. Some of these are :

(i) Phosphorite $Ca_3(PO_4)_2$, (ii) Fluorapatite $Ca_5(PO_4)_3F$, (iii) Chlorapatite $3Ca_3(PO_4)_2.CaCl_2$, (iv) Hydroxyapatite; $Ca_5(PO_4)_3OH$. Phosphates are essential constituents of plants and animals. It is mainly present in bones, which contains about 58% calcium phosphate.

(2) **Isolation :** Elemental phosphorus is isolated by heating the phosphorite rock with coke and sand in an electric furnace at about 1770*K*,

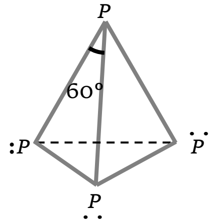
$$2Ca_3(PO_4)_2 + 6SiO_2 \longrightarrow \underset{\text{Calicum silicate}}{6CaSiO_3} + P_4O_{10} \;;$$

$$P_4O_{10} + 10C \longrightarrow P_4 + 10CO$$

(3) **Allotropic forms of phosphorus** : Phosphorus exists in three main allotropic forms,

(i) White phosphorus, (ii) Red phosphorus, (iii) Black phosphorus

(i) ***White or yellow phosphorus*** **:** It is obtained from phosphate rock or phosphorite as explained above. It exists as P_4 units where four P atoms lie at the corners of a regular tetrahedron with $\angle PPP = 60^o$. Each P atom is linked to three other P atoms by covalent bonds. there are total six bonds and four lone pairs of electrons present in a P_4 molecule of white phosphorus.



Properties : White phosphorus is extremely reactive due to strain in the P_4 molecule, poisonous, soft, low melting $(317K)$ solid, soluble in CS_2, alcohols and ether. It has a garlic odour. Persons working with white P develop a disease known as Phossy jaw in which jaw bones decay. It turns yellow on exposure to light. Hence, it is also called yellow phosphorus.

It spontaneously catches fire in air with a greenish glow which is visible in the dark $(P_4 + 3O_2 \rightarrow P_4O_6)$. This phenomenon is called phosphorescence. Because of its very low ignition temperature $(303K)$, it is always kept under water.

With sulphur it gives tetraphoshorus trisulphide with explosive violence which is used in “strike anywhere matches”.

$$8P_4 + 3S_8 \longrightarrow 8P_4S_3$$

With metals phosphorus forms phosphides. For example,

$$P_4 + 6Mg \longrightarrow 2Mg_3P_2$$

With aqueous alkalies, on heating, white phosphorus gives phosphine

$$\overset{0}{P_4} + 3NaOH + 3H_2O \longrightarrow \underset{\text{(Phosphine)}}{\overset{-3}{PH_3}} + \underset{\text{Sod. hypophosphite}}{3NaH_2\overset{+1}{P}O_2}$$

It is an example of a disproportionation reaction where the oxidation state of P decreases from 0 to –3 (in PH_3) and increases to +1 (in NaH_2PO_2)

White phosphorus acts as a strong reducing agent. It reduces HNO_3 to NO_2 and H_2SO_4 to SO_2. It also reduces solutions of Cu, Ag and Au salts to their corresponding metals. For examples,

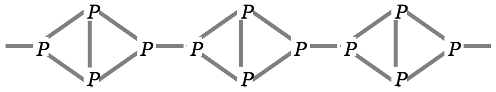
$$P_4 + 8CuSO_4 + 14H_2O \longrightarrow 8Cu + 8H_2SO_4 + 4H_3PO_4$$

$$P_4 + 20AgNO_3 + 16H_2O \longrightarrow 20Ag + 4H_3PO_4 + 20HNO_3$$

(ii) ***Red phosphorus*** : It is obtained by heating white phosphorus at $540-570K$ out of contact with air in an inert atmosphere (CO_2 or coal gas) for several hours.

White phosphorus $\xrightarrow[CO_2 \text{ or coal gas}]{540-570K}$ Red phosphorus

Red phosphorus exists as chains of P_4 tetrahedra linked together through covalent bonds to give a polymeric structure as shown.



Due to its polymeric structure, red phosphorus is much less reactive and has m.p. much higher than that of white phosphorus.

Properties : Red phosphorus is a hard, odourless, non poisonous solid, insoluble in organic solvents such as CS_2, alcohol and ether. Its ignition temperature is much higher than that of white phosphorus and thus does not catch fire easily. It does not show phosphorescence.

It sublimes on heating giving vapours which condense to give white phosphorus. It is denser than white phosphorus and is a bad conductor of electricity.

It burns in oxygen at $565K$ to give phosphorus pentoxide, reacts with halogens, sulphur and alkali metals only when heated forming their corresponding salts.

It does not react with caustic alkalies and this property is made use in separating red phosphorus from white phosphorus.

(iii) ***Black phosphorus*** : It is obtained by heating white phosphorus at $470K$ under high pressure (4000–12000atm) in an inert atmosphere.

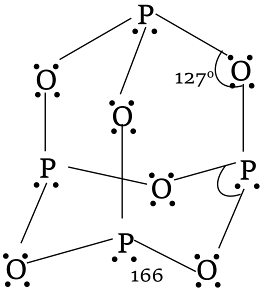
White phosphorus $\xrightarrow[4000-12000 \text{ atm. pressure}]{470K}$ Black phosphorus

It has a double layered structure. Each layer is made up of zig-zag chains with $P-P-P$ bond angle of 99^o. Since it is highly polymeric, it has high density. It is the most stable (inactive) form of phosphorus and has a black metallic luster. It is a good conductor of heat and electricity.

(4) **Compounds of phosphorus**

(i) ***Oxides and oxyacids of phosphorus*** : Phosphorus is quite reactive and forms number of compounds in oxidation states of –3 , +3 and +5. Phosphorus forms two common oxides namely, (a) phosphorus trioxide (P_4O_6) and (b) phosphorus penta oxide (P_4O_{10}).

(a) *Phosphorus (III) oxide (P_4O_6)* :



Phosphorus trioxide

It is formed when P is burnt in a limited supply of air, $P_4 + \underset{\text{(limited)}}{3O_2} \rightarrow P_4O_6$.

It is a crystalline solid with garlic odour. It dissolves in cold water to give phosphorous acid,

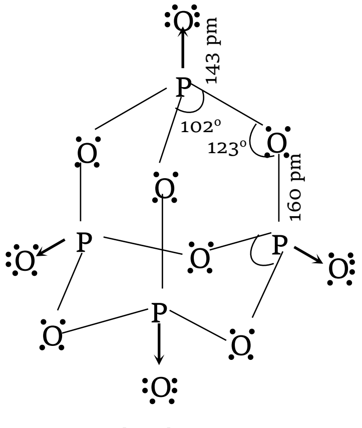
$P_4O_6 + \underset{\text{cold}}{6H_2O} \rightarrow \underset{\text{Phosphorous acid}}{4H_3PO_3}$, It is therefore, considered as anhydride of phosphorus acid.

With hot water, it gives phosphoric acid and inflammable phosphine, $P_4O_6 + 6H_2O$ (hot) $\rightarrow \underset{\text{Phosphoric acid}}{3H_3PO_4} + PH_3$

It reacts vigorously with Cl_2 to form a mixture of phosphoryl chloride and meta phosphoryl chloride.

$$P_4O_6 + 4Cl_2 \rightarrow \underset{\text{Phosphoryl chloride}}{2POCl_3} + \underset{\text{Metaphosphoryl chloride}}{2PO_2Cl}$$

(b) *Phosphorus (V) oxide* (P_4O_{10}):



Phosphorus

It is prepared by heating white phosphorus in excess of air, $P_4 + 5O_2(excess) \rightarrow P_4O_{10}$. It is snowy white solid. It readily dissolves in cold water forming metaphosphoric acid.

$P_4O_{10}+\underset{\text{(Cold)}}{2H_2O} \rightarrow \underset{\text{Metaphosphoric acid}}{4HPO_3}$. With hot water, it gives phosphoric acid, $P_4O_{10}+\underset{\text{Hot}}{6H_2O} \rightarrow \underset{\text{Phosphoric acid}}{4H_3PO_4}$.

P_4O_{10} is a very strong dehydrating agent. It extracts water from many compounds including H_2SO_4 and HNO_3,

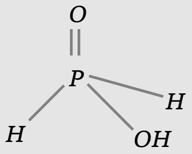
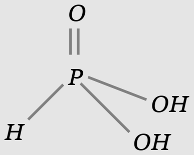
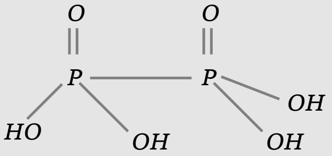
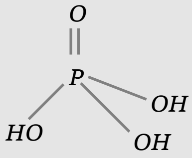
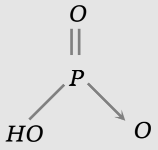
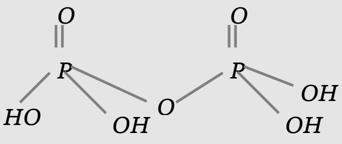
$$H_2SO_4 \xrightarrow[-H_2O]{P_4O_{10}} SO_3\;;\; 2HNO_3 \xrightarrow[-H_2O]{P_4O_{10}} N_2O_5$$

$$\underset{\text{Acetamide}}{CH_3CONH_2} \xrightarrow[-H_2O]{P_4O_{10}} \underset{\text{Methylcyanide}}{CH_3CN}$$

(ii) ***Oxyacids of phosphorus*** **:** Phosphorus forms a number of oxyacids which differs in their structure and oxidation state of phosphorus. These are $H_3PO_2, H_3PO_3, H_4P_2O_6, H_3PO_4$, $(HPO_3)_n, H_4P_2O_5, H_4P_2O_7$. From these H_3PO_2, H_3PO_3 are reducing agents. $H_4P_2O_5$ (pyrophosphoric acid) is dibasic acid.

$(HPO_3)_n$ is formed by dehydration of H_3PO_4 at 316^oC.

Table : 18.6 *Oxyacids of phosphorus*

Name	Oxidation state of P and Basicity	Structure
Hypophosphorous acid H_3PO_2	+1 Monobasic	
Phosphorous acid H_3PO_3	+3 Dibasic	
Hypophosphoric acid $H_4P_2O_6$	+4 Tetrabasic	
Orthophosphoric acid H_3PO_4	+5 Tribasic	
Metaphosphoric acid $(HPO_3)_n$	+5 Monobasic	
Pyrophospric acid (Diphosphoric acid). $H_4P_2O_7$	+5 Tetrabasic	

(5) **Chemical Fertilizers :** The chemical substances which are added to the soil to keep up the fertility of soil are called fertilizers.

Types of fertilizers : Chemical fertilizers are mainly of four types,

(i) ***Nitrogenous fertilizers*** : e.g. Ammonium sulphate $(NH_4)_2SO_4$, Calcium cyanamide $CaCN_2$, Urea NH_2CONH_2 etc.

(ii) ***Phosphatic fertilizers*** **:** e.g. $Ca(H_2PO_4)_2.H_2O$ (Triple super phosphate), Phosphatic slag etc.

(iii) ***Potash fertilizers*** **:** e.g. Potassium nitrate (KNO_3), Potassium sulphate (K_2SO_4) etc.

(iv) ***Mixed fertilizers*** **:** These are made by mixing two or more fertilizers in suitable proportion. e.g. NPK (contains nitrogen, phosphorus and potassium).

NPK is formed by mixing ammonium phosphate, super phosphate and some potassium salts.

Oxygen Family

Oxygen is the first member of group 16 or VIA of the periodic table. It consists of five elements Oxygen (O), sulphur (S), selenium (Se), tellurium (Te) and polonium (Po). These (except polonium) are the ore forming elements and thus called ***chalcogens***.

(1) **Electronic configuration**

Elements	Electronic configuration ($ns^2\ np^4$)
$_8O$	$[He]2s^2 2p^4$
$_{16}S$	$[Ne]3s^2 3p^4$
$_{34}Se$	$[Ar]3d^{10} 4s^2 4p^4$
$_{52}Te$	$[Kr]4d^{10} 5s^2 5p^4$
$_{84}Po$	$[Xe]4f^{14} 5d^{10} 6s^2 6p^4$

Physical properties

(1) **Physical state :** Oxygen is gas while all other are solids.

(2) **Atomic radii :** Down the group atomic radii increases because the increases in the number of inner shells overweighs the increase in nuclear charge.

(3) **Ionisaion energy :** Down the group the ionisation energy decrease due to increase in their atomic radii and shielding effect.

(4) **Electronegativity :** Down the group electronegativity decreases due to increase in atomic size.

(5) **Electron affinity :** Element of this group have high electron affinity, electron affinity decreases down the group.

(6) **Non – metallic and metallic character :** These have very little metallic character because of their higher ionisation energies.

(7) **Nature of bonding :** Compound of oxygen with non metals are predominantly covalent. *S, Se*, and *Te* because of low electronegativities show more covalent character.

(8) **Melting and boiling points :** The melting point and boiling points increases on moving down the group.

(9) **Catenation :** Oxygen has some but sulphur has greater tendency for catenation.

$$\underset{(H_2O_2)}{H-O-O-H,} \quad \underset{(H_2S_2)}{H-S-S-H,}$$

$$\underset{(H_2S_3)}{H-S-S-S-H,} \quad \underset{(H_2S_4)}{H-S-S-S-S-H}$$

(10) **Allotropy**

Oxygen –	O_2 and O_3
Sulphur –	Rhombic , monoclinic, plastic sulphur
Selenium –	Red (non-metallic) grey (metallic)
Tellurium –	Non-metallic and metallic (more stable)
Polonium –	α and β (both metallic)

(11) **Oxidation states :** Oxygen shows – 2, + 2 and –1 oxidation states. Other elements show +2 ,+4 and +6 oxidation states.

Chemical properties

(1) **Hydrides :** The elements of this group form hydrides such as H_2O, H_2S, H_2Se, H_2Te an H_2Po. Following are their characteristics.

(i) ***Physical states*** **:** Water is colourless and odourless while hydrides of the rest of the elements of this group are colourless, unpleasant smelling poisonous gases.

(ii) ***Volatile nature*** **:** Volatility increases from H_2O to H_2S and then decreases. The low volatility and abnormally high boiling point of water is due to the association of water molecules on account of hydrogen bonding because of strongly electronegative oxygen atom linked to hydrogen atom. thus, water is liquid while H_2S and other hydrides are gases under normal condition of temperature and pressure.

(iii) ***Acidic character*** **:** The hydrides of this group behave as weak diprotic acids in aqueous solution, the acidic character increasing from H_2S to H_2Te when H_2O is neutral.

(iv) ***Thermal stability*** **:** The thermal stability decreases from H_2O to H_2Po because the size of the central atom (from O to Po) increases resulting in longer and weaker $M-H$ bond consequently the bond strength decreases. This results in the decrease of the thermal stability.

(v) ***Reducing character*** **:** The reducing power of the hydrides increases from H_2O to H_2Po due to the decreasing bond strength from H_2O to H_2Po.

(vi) ***Bond angle*** **:** All these hydrides are angular molecules and the bond angle $H-X-H$ (X is O, S, Se, Te) decreases from H_2O to H_2Te.

Increasing order of reducing power of hydrides :

$H_2O < H_2S < H_2Se < H_2Te$

Increasing order of bond angles in hydrides :

$H_2Te < H_2Se < H_2S < H_2O$

The order of stability of hydrides :

$H_2O > H_2S > H_2Se > H_2Te$

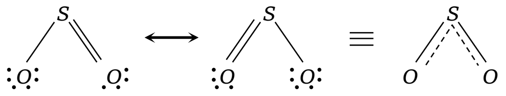
The order of increasing acidic nature of hydrides :

$H_2O < H_2S < H_2Se < H_2Te$

(2) **Oxides :** These elements form monoxides (MO), dioxides (MO_2) and trioxides (MO_3).

(i) ***Dioxides*** : Sulphur, selenium and tellurium burn in air to form SO_2, SeO_2 and TeO_2. The dioxide molecules contain $p\pi - p\pi$ bonds which become weaker with increase in atomic number because of the increase in the bond length.

(a) Sulphur dioxide, SO_2 is a gas at room temperature and exists as individual molecules even in the solid state. Its molecule has bent structure and is a resonance hybrid of the following canonical structures.



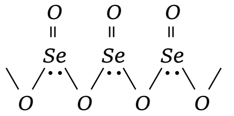
SO_2 is acidic in nature and also called the anhydride of sulphurous acid. It can act as reducing and oxidising agent. SO_2 also acts as a beleaching agent in the presence of moisture, but in contrast to Cl_2, its bleaching action is temporary.

$$SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2[H]$$

Colouring matter $+2[H] \rightleftharpoons$ Colourless compound

Hence, SO_2 bleaches due to reduction and the bleaching action is temporary.

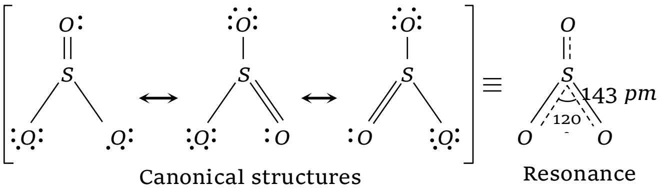
(b) Selenium dioxide, SeO_2 is a solid with polymeric zig-zag structure at room temperature however it exist as discrete molecules in the gaseous phase.



(c) Tellurium dioxide, TeO_2 is also a solid with polymeric zig-zag structure at room temperature very similar to that of selenium dioxide.

(ii) ***Trioxides*** : Sulphur, selenium and tellurium can form trioxides also.

(a) *Sulphur trioxide,* SO_3 : In the gaseous state monomeric SO_3 has a planar structure with $S-O$ bond distance of 143 pm and $O-S-O$ bond angle of $120^o . SO_3$ molecule is a resonance hybrid of following structures.



Canonical structures Resonance

In the solid phase sulphur trioxide polymerises to cyclic trimer or to a stable linear chain structure. SO_3 is the anhydride of H_2SO_4. It is acidic in nature and acts as oxidising agent.

(b) *Selenium trioxide,* SeO_3 : it is a solid substance which exists as a cyclic tetramer, however in the vapour phase it exists as a monomer

(c) *Tellurium trioxide,* TeO_3 : It is a solid at room temperature existing as a polymer.

The increasing order of acidic nature of oxides is $TeO_3 < SeO_3 < SO_3$.

(3) **Oxyacids :**

$$H_2SO_3, H_2SO_4, H_2S_2O_3, H_2SO_5, H_2S_2O_8, H_2S_2O_7, H_2S_2O_6$$

(4) **Halides :** Oxygen : OF_2, Cl_2O, Br_2O

Sulphur : $S_2F_2, S_2Cl_2, SF_2, SCl_2, SBr_2, SF_4, SCl_4$ and SF_6

Selenium and tellurium : SeF_6 and TeF_6

Anamolous Behaviour of Oxygen

Oxygen is the first member of the group 16 family and differs from the other members of the family because of

(1) Its small size

(2) Its high electronegativity

(3) Its high ionisation energy

(4) Absence of d -orbitals in the valence shell

It differs from the other members of the family as follows

(1) **Elemental state :** Oxygen is a diatomic gas while others are octa-atomic solids with eight membered puckered ring structure.

(2) **Oxidation states :** Oxygen shows O.S. of –2 in most of its compounds. It also shows an O. S. of +2 in F_2O and –1 in H_2O_2 or other peroxides. It cannot show O.S. beyond 2. Other elements show oxidation states of +2, +4 and +6 because these elements have vacant d -orbitals so that their valence shell can expand.

(3) **Hydrogen-bonding :** Oxygen atom is very small and has quite high nuclear charge. therefore, it has high value of electronegativity and is able to form H -bonds. the other elements, because of their large size, cannot form H -bonds. As a result, H_2O is liquid while H_2S is a gas and H_2Se etc., are solids.

(4) **Maximum covalency :** Oxygen has a maxium covalency of two while other elements can show a maximum covalency of six. This is because these elements have vacant d -orbitals while oxygen has not.

(5) **Types of compounds :** The compounds of oxygen are mainly ionic and polar covalent due to high electronegativity of oxygen while those of others are not.

(6) **Magnetic character :** Oxygen is paramagnetic while others are not.

Oxygen and its compounds

Oxygen is the most abundant element in the earth crust (46.5%). It was discovered by ***Karl Scheele*** and ***Joseph Priestley***. It occurs in three isotopic forms :

$$\underset{(Abundance : 99.76\%)}{_8O^{16}} \qquad \underset{(Abundance : 0.037\%)}{_8O^{17}} \qquad \underset{(Abundance : 0.204\%)}{_8O^{18}}$$

Out of the three isotopes, $_8O^{18}$ is radioactive.

Occurrence : In free state, it occurs in air and constitutes 21% by volume of air.

Preparation of Dioxygen : Oxygen is prepared by the following methods.

(1) **By the decomposition of oxygen rich compounds** : e.g.

$$\underset{Pot. Nitrate}{2KNO_3} \xrightarrow{Heat} 2KNO_2 + O_2 \; ; \; \underset{Pot. Chlorate}{2KClO_3} \xrightarrow[MnO_2]{Heat} 2KCl + 3O_2$$

(2) **By heating dioxides, Peroxides and higher oxides** : e.g.

$$\underset{\text{Silver oxide}}{2Ag_2O} \xrightarrow{Heat} 4Ag + O_2 \; ; \quad \underset{\text{Manganese dioxide}}{3MnO_2} \xrightarrow{Heat} Mn_3O_4 + O_2$$

$$\underset{\text{Barium peroxide}}{2BaO_2} \xrightarrow{Heat} \underset{\text{Barium oxide}}{2BaO} + O_2$$

(3) **Laboratory Method** : In the laboratory, O_2 is prepared by thermal decomposition of potassium chlorate.

$$2KClO_3 \xrightarrow[MnO_2]{420\,K} 2KCl + 3O_2$$

In the absence of MnO_2 catalyst, the decomposition takes place at 670-720 *K*. Therefore, MnO_2 acts as a catalyst and also lowers the temperature for the decomposition of $KClO_3$.

(4) O_2 can also be prepared by the action of water on sodium peroxide as, $2Na_2O_2 + 2H_2O \rightarrow 4NaOH + O_2$.

(5) **Industrial preparation :** The main sources for the industrial preparation of dioxygen are air and water.

(i) ***From air :*** O_2 is prepared by fractional distillation of air. During this process, N_2 with less boiling point (78 *K*) distills as vapour while O_2 with higher boiling point (90 *K*) remains in the liquid state and can be separated.

(ii) ***From water :*** O_2 can also be obtained by the electrolysis of water containing a small amount of acid or alkali, $2H_2O \xrightarrow{Electrolysis} 2H_2(g) + O_2(g)$.

Physical properties of O_2 : It is a colourless, tasteless and odourless gas. It is slightly soluble in water and its solubility is about $30\,cm^3$ per litre of water at 298 *K*.

Table : 18.7 ***Physical properties of atomic and molecular oxygen***

Atomic properties	Molecular properties
Atomic radius (pm) – 73	Bond length (pm) – 120.7
Ionic radius O^{2-} (pm) – 140	Bond energy ($kJ\ mol^{-1}$) – 493
Electronegativity – 3.5	Density at S.T.P. (gcm^{-3})– 1.429
Ionisation energy ($kJ\ mol^{-1}$) – 1310	Melting point (*K*) – 54.4
Electron affinity ($kJ\ mol^{-1}$) – 140	Boiling point (*K*) – 90.2

Chemical properties of O_2 : It does not burn itself but helps in burning. It is quite stable in nature and its bond dissociation energy is very high. Therefore, it is not very reactive as such, $O_2 \rightarrow O + O$.

Therefore, dioxygen reacts at higher temperatures. However, once the reaction starts, it proceeds of its own. This is because the chemical reactions of dioxygen are exothermic and the heat produced during the reaction is sufficient to sustain the reactions.

(1) **Action with litmus** : Like dihydrogen, it is also neutral and has no action on blue or red litmus.

(2) **Reaction with metals** : Active metals like *Na, Ca* react at room temp. to form their respective oxides.

$$4Na + O_2 \rightarrow 2Na_2O \; ; \quad 2Ca + O_2 \rightarrow 2CaO$$

It reacts with *Fe, Al, Cu* etc. metals at high temperature

$$4Al + 3O_2 \rightarrow 2Al_2O_3 \; ; \quad 4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

(3) **Action with Non-metals** : It form oxides.

$$2H_2 + O_2 \xrightarrow[\text{Electric discharge}]{1073\,K} 2H_2O \; ;$$

$$N_2 + O_2 \xrightarrow{3273\,K} \underset{\text{Nitric oxide}}{2NO}$$

$$S + O_2 \xrightarrow{Heat} SO_2 \; ; \quad C + O_2 \xrightarrow{Heat} CO_2$$

(4) **Reaction with compounds** : Dioxygen is an oxidising agent and it oxidises many compounds under specific conditions. e.g. $4HCl + O_2 \xrightarrow[CuCl_2]{700\,K} 2H_2O + 2Cl_2$;

$$4NH_3 + 5O_2 \xrightarrow[Pt]{1073\,K} 4NO + 6H_2O$$

$$CS_2 + 3O_2 \xrightarrow{Heat} CO_2 + 2SO_2 \; ;$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Uses of dioxygen

(1) It is used in the oxy-hydrogen or oxy-acetylene torches which are used for welding and cutting of metals.

(2) It is used as an oxidising and bleaching agent,

(3) Liquid O_2 is used as rocket fuel.

(4) It is used in metallurgical processes to remove the impurities of metals by oxidation.

Compounds of Oxygen

(1) **Oxides :** A binary compound of oxygen with another element is called oxide. On the basis of acid-base characteristics, the oxides may be classified into the following four types,

(i) ***Basic oxides*** : Alkali, alkaline earth and transition metals form basic oxides - Na_2O, MgO, Fe_2O_3 etc. their relative basic character decreases in the order : alkali metal oxides>alkaline earth metal oxides>transition metal oxides.

(ii) ***Acidic oxides*** : Non-metal oxides are generally acidic - $CO_2, SO_2, SO_3, NO_2, N_2O_5, P_4O_{10}, Cl_2O_7$ etc.

(iii) ***Amphoteric oxides*** : Al_2O_3, SnO_2 etc.

(iv) ***Neutral oxides*** : H_2O, CO, N_2O, NO etc.

Trends of oxides in the periodic Table : On moving from left to the right in periodic table, the nature of the oxides change from basic to amphoteric and then to acidic. For example, the oxides of third period has the following behaviour,

Na_2O strongly basic	MgO basic	Al_2O_3 amphoteric	SiO_2 weakly acidic	P_4O_{10} acidic	SO_2 strongly acidic	Cl_2O_7 very strongly acidic

Basic to acidic character increases

However, on moving down a group, acidic character of the oxides decreases. For example in the third group, the acidic character of oxides decreases as:

B_2O_3 acidic	Al_2O_3 amphoteric	Ga_2O_3 (weakly basic)	In_2O_3, Tl_2O_3 basic

Acidic to basic character increases

On the basis of oxygen content the oxides may be classified into the following types,

Normal oxides : These contain oxygen atoms according to the normal oxidation number *i.e.* – 2. For example, MgO, H_2O, CaO, Li_2O, Al_2O_3 etc.

Polyoxides : These contain oxygens atoms more than permitted by the normal valency. Therefore, these contain oxygen atoms in oxidation state different than –2.

Peroxides : These contains O_2^{2-} ion having oxidation number of oxygen as –1. For example, $H_2O_2, Na_2O_2, BaO_2, PbO_2$ etc.

Superoxides : These contains O_2^- ion having oxidation number of oxygen as –1/2. For example, KO_2, PbO_2, etc.

Suboxides : These oxides contain less oxygen than expected from the normal valency. For example, N_2O.

Mixed oxides : These oxides are made up of two simple oxides. For example, red lead $Pb_3O_4 (2PbO_2 + PbO_2)$, magnetic oxide of iron, $Fe_3O_4 (FeO + Fe_2O_3)$ and mixed oxide of manganese, $Mn_3O_4 (MnO_2 + 2MnO)$.

Ozone or trioxygen

Ozone is an allotrope of oxygen. It is present in the upper atmosphere, where it is formed by the action of U. V. radiations on O_2, $3O_2 \xrightarrow{U.V. \text{ radiation}} \underset{Ozone}{2O_3}$.

O_3 protects us from the harmful U. V. radiations which causes skin cancer. Now a days, ozone layer in the atmosphere is depleting due to NO released by supersonic aircrafts and chlorofluoro carbons (CFC'S) *i.e.* freon which is increasingly being used in aerosols and as a refrigerant.

Preparation : Ozone is prepared by passing silent electric discharge through pure, cold and dry oxygen in a specially designed apparatus called ozoniser. The formation of ozone from oxygen is an endothermic reaction.

$$3O_2 \xrightleftharpoons[\text{discharge}]{\text{Silent electric}} 2O_3 \quad \Delta H = +285.4\,kJ$$

Ozone is prepared in the laboratory by the following two types of ozonisers,

(a) Siemen's ozoniser, (b) Brodie's ozoniser

For the better yield of ozone : (a) Only pure and dry oxygen should be used. (b) The ozoniser must be perfectly dry. (c) A fairly low temperature $(\approx 273\,K)$ must be maintained. (d) The electric discharge must be sparkless.

Physical properties : Ozone is a light blue coloured gas, having pungent odour. It is heavier than air. Its vapour density is 24. It is slightly soluble in water.

Chemical properties : The important chemical properties of ozone are discussed below,

(1) **Decomposition** : Pure ozone decomposes on heating above 475 K to form O_2 gas.

$$2O_3 \xrightarrow{475\,K} 3O_2 \quad \Delta H = -285.4\,kJ$$

(2) **Oxidising agent** : Ozone is one of the most powerful oxidising agent with the liberation of dioxygen. In fact, ozone is a stronger oxidising agent than molecular oxygen because ozone has higher energy content and decomposes to give atomic oxygen as:

$$O_3 \rightarrow O_2 + \underset{\text{Atomic oxygen}}{O}$$

Therefore, ozone oxidises a number of non-metals and other reducing agents. e.g.

$$\underset{Metal}{2Ag} + O_3 \rightarrow \underset{Silver\ oxide}{Ag_2O} + O_2\ ; \quad \underset{Non-metal}{S} + 3O_3 \rightarrow SO_3 + 3O_2$$

$$\underset{Compound}{PbS} + 4O_3 \rightarrow PbSO_4 + 4O_2$$

Mercury is oxidised to mercurous oxide,

$$2Hg + O_3 \rightarrow \underset{Mercurous\ oxide}{Hg_2O} + O_2$$

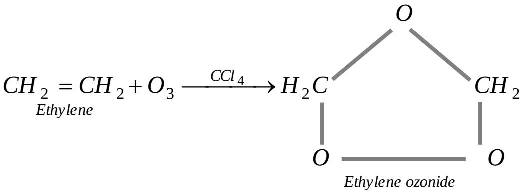
During this reaction mercury loses its meniscus and starts sticking to the sides of the glass. This is known as tailing of mercury. Mercurous oxide formed in this reaction dissolves in mercury and starts sticking to the glass surface.

(3) **Bleaching agent :** Due to the oxidising action of ozone, it acts as a mild bleaching agent as well as a sterilizing agent. It acts as a bleaching agent for vegetable colouring matter.

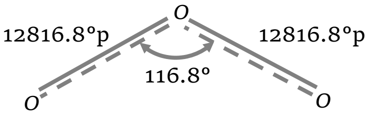
$$Vegetable\ \ colouring\ \ matter + O_3 \rightarrow \underset{(Colourless)}{Oxidised\ coloured\ \ matter} + O_2$$

For example, ozone bleaches indigo, ivory, litmus, delicate fabrics etc.

(4) **Formation of ozonides :** Ozone reacts with alkenes in the presence of CCl_4 to form an ozonide. e.g.



Structure of O_3 : The structure of O_3 molecule is angular as shown in fig. The $O-O-O$ bond angle is 116.8° and $O-O$ bond length is 128 pm.



Uses of ozone

(1) O_3 is used for disinfecting water for drinking purposes because ozone has germicidal properties.

(2) It is used for purifying air of crowded places such as cinemas, under ground railway, auditoriums, tunnels, mines etc.

(3) It is used in industry for the manufacture of $KMnO_4$, artificial silk, synthetic camphor etc.

Sulphur and its compounds

Sulphur is the second member of oxygen family and belongs to group-16 (VI A) of the periodic table.

Occurrence : Sulphur occurs in the earth's crust to the extent of 0.05%. It occurs in the free state as well as in combined state. Sulphur occurs mainly as sulphides and sulphates. eg.

Table 18.8

Sulphide Ores	Sulphate Ores
Iron pyrites (fool's gold) – FeS_2	Gypsum – $CaSO_4.2H_2O$
Galena – PbS	Epsom salt – $MgSO_4.7H_2O$
Copper pyrites – $CuFeS_2$	Barytes – $BaSO_4$
Cinnabar – HgS	Zinc blende – ZnS

Extraction of sulphur (Frasch process) **:** Sulphur is generally extracted from underground deposits by drilling three concentric pipes upto the beds of sulphur (700 – 1200 feet deep).

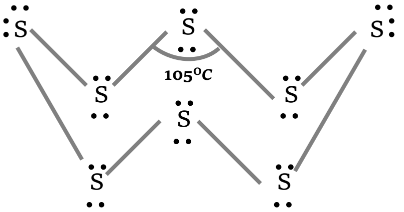
Allotropy in sulphur : Sulphur exists in four allotropic forms,

(1) **Rhombic or octahedral or α-sulphur** : It is a bright yellow solid, soluble in CS_2 and stable at room temp. All other varieties of sulphur gradually change into this form on standing.

(2) **Monoclinic sulphur or prismatic or β-sulphur**: It is prepared by melting the sulphur and then cooling it till a crust is formed. On removing the crust, needle shaped crystals of monoclinic sulphur separate out. It is dull yellow in colour, soluble in CS_2 and stable only above 369K. Below this temperature it changes into rhombic form.

Thus, at 369K both these varities co-exist. This temperature is called transition temperature and the two sulphurs are called enantiotropic substances. It also exist as molecules similar to that of rhombic sulphur but the symmetry of the crystals is different.

(3) **Plastic or amorphous or γ -sulphur** : It is a super cooled liquid insoluble in CS_2, soft and amorphous. It consists of long zig-zag chains of S-atoms.



(4) **Colloidal or δ -sulphur** : It is prepared by passing H_2S through a solution of an oxidizing agent or water or by treating sodium thiosulphate with dil. HCl.

Properties of sulphur : It burns in air with, a blue flame forming SO_2, gives sulphur hexafluoride with F_2 and sulphur mono chloride with Cl_2, sulphides with metals like Na, Ca, Zn, Hg, Fe, Cu etc., reduces HNO_3 to NO_2 and H_2SO_4 to SO_2. With $NaOH$ solution on heating,

$$S_8+12NaOH \longrightarrow 4Na_2S+2Na_2S_2O_3+6H_2O\ .$$

It gives sodium sulphide and sodium thiosulphate, with excess of sulphur, $2Na_2S+S_8 \longrightarrow 2Na_2S_5$.

Uses of sulphur : It is used in the manufacture of matches, gun powder (mixture of charcoal, sulphur and potassium nitrate), explosives and fire works SO_2, H_2SO_4, CS_2 and dyes, sulpha drugs and ointment for curing skin diseases and in the vulcanization of rubber.

Compounds of Sulphur

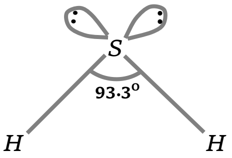
(1) **Hydrogen Sulphide :** It is prepared in the laboratory by the action of dil. H_2SO_4 on ferrous sulphide in kipp's apparatus, $FeS+H_2SO_4 \rightarrow FeSO_4+H_2S$. It is colourless gas having foul smell resembling that of rotten eggs. It reacts

with many cations (of group II and IV) to give coloured sulphides,

$$Cu^{+2} + S^{-2} \rightarrow \underset{\text{Black}}{CuS} \; ; \; Cd^{+2} + S^{-2} \rightarrow \underset{\text{(Yellow)}}{CdS} \; ;$$

$$Ni^{+2} + S^{-2} \rightarrow \underset{\text{(Black)}}{NiS} \; ; \; Co^{+2} + S^{-2} \rightarrow \underset{\text{(Black)}}{CoS}$$

The solubility of sulphides can be controlled by the H^+ ions concentration and therefore, H_2S finds extensive use in qualitative analysis of cation radicals.



(2) **Halides of sulphur :** Two important halides of sulphur are SF_4 and SF_6.

(i) ***Sulphur tetrafluoride*** : SF_4 is formed by the reaction of sulphur with CoF_3.

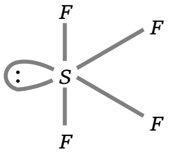
$$S + 4CoF_3 \longrightarrow SF_4 + 4CoF_2$$

It is a colour gas which is quite reactive. It is hydrolysed with water.

$$SF_4 + 2H_2O \longrightarrow SO_2 + 4HF$$

It is used for fluorinating inorganic and organic compounds.

Structure : It has see-saw structure with sp^3d -hybrdization and is derived from triogonal bipyramid geometry in which an equatorial position is occupied by a lone pair of electrons.

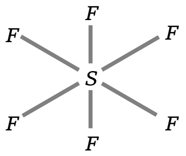


(ii) ***Sulphur hexafluoride*** : SF_6 is prepared by burning sulphur in a stream of fluorine. OF_6 is not known though sulphur forms SF_6. This is because oxygen has no d -orbitals in its valence shell.

SF_6 is a colourless gas. It is extremely inert substance even at red heat. It does not react with water. on account of its chemical inertness and dielectric strength, it is used as an insulator in high voltage generators and switch-gears.

Structure : It has an octahedral structure with sp^3d^2 -hybridisation around the central sulphur atom.

Therefore, all $S-F$ bond distances are equal in its structure.



(3) **Oxides of sulphur :** Sulphur forms several oxides of which sulphur dioxide (SO_2) and sulphur trioxide (SO_3) are most important.

(i) ***Sulphur dioxide*** **(SO_2)** : It is prepared by burning sulphur or iron pyrites in air.

$$S_8 + 8O_2 \rightarrow 8SO_2 \; ;$$

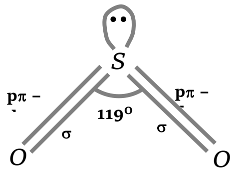
$$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$$

In laboratory, it is prepared by heating copper turnings with conc. H_2SO_4

$$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$$

It is a colourless gas with irritating and suffocating smell.

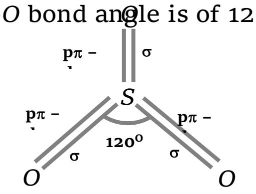
SO_2 molecule has a bent structure with a O – S – O bond angle of 119°. Sulphur is sp^2 hybridized.



(ii) ***Sulphur trioxide*** **(SO_3)**: It is formed by the oxidation of SO_2.

$$2SO_2 + O_2 \xrightarrow[V_2O_5]{700\,K,\,2atm.} 2SO_3$$

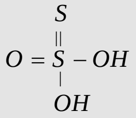
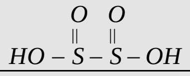
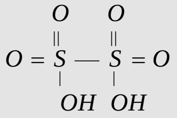
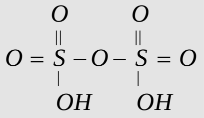
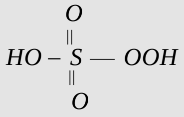
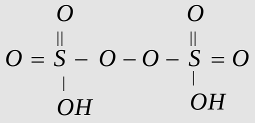
In the gaseous phase, it exists as planar triangular molecular species involving hybridization of the S-atom. It has three S–O σ bonds and three S–O π bonds. The O–S–O bond angle is of 120°.



(4) **Oxyacids of sulphur :** Sulphur forms many oxyacids. Some of these are,

Table : 18.9 Oxyacids of sulphur

Formula	*Name*	Important properties	Structural formula
H_2SO_3 (+4)	Sulphurous acid	Free acid does not exist diprotic, strong reducing agent	$O = \overset{\cdot\cdot}{S} - OH$ $\;\;\;\; \vert$ $\;\;\; OH$
H_2SO_4 (+6) (Oil of vitriol)	Sulphuric acid	Stable diprotic, dehydrating agent	$\;\;\; O$ $\;\;\; \Vert$ $O = S - OH$ $\;\;\;\; \vert$ $\;\;\; OH$

$H_2S_2O_3$ (–2 and +6)	Thiosulphuric acid	Free acid does not exist but its salts e.g. $Na_2S_2O_3$ All quite stable reducing agent	 $O = \overset{S}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} - OH$
$H_2S_2O_4$ (+3)	Dithionous acid		 $HO - \overset{O}{\overset{\Vert}{S}} - \overset{O}{\overset{\Vert}{S}} - OH$
$H_2S_2O_6$ (+5)	Dithionic acid	Free acid is moderately stable but its salts are quite stable.	 $O = \overset{O}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} - \overset{O}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} = O$
$H_2S_2O_7$ (+6) (Oleum)	Disulphuric acid (Pyrosulphuric acid)	Strong oxidising agent	 $O = \overset{O}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} - O - \overset{O}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} = O$
H_2SO_5 (+6) (Caro's acid)	Peroxomonosulphuric acid (Its salts known as persulphates)	Stable crystalline solid, powerfull oxidising agent	 $HO - \overset{O}{\overset{\Vert}{\underset{\underset{O}{\Vert}}{S}}} - OOH$
$H_2S_2O_8$ (+6) (Marshals acid)	Peroxodisulphuric acid (its salts are known as disulphates)	Strong oxidising agent.	 $O = \overset{O}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} - O - O - \overset{O}{\overset{\Vert}{\underset{\underset{OH}{\vert}}{S}}} = O$

Sulphuric acid (H_2SO_4) **:** H_2SO_4 is a very stable oxyacid of sulphur. It is often called king of chemicals, since it is one of the most useful chemicals in industry.

Manufacture of sulphuric acid : H_2SO_4 can be manufactured by following process,

Lead chamber process : In this process, SO_2 is oxidized to SO_3 by the oxides of nitrogen and the SO_3 thus formed is dissolved in steam to form H_2SO_4.

$$SO_2 + NO_2 \rightarrow SO_3 + NO \;;\; 2NO + O_2 \rightarrow 2NO_2$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Contact process : In the contact process, SO_2 obtained by burning of S or iron pyrities is catalytically oxidized to SO_3 in presence of finely divided Pt or V_2O_5 as catalyst.

$$S + O_2 \rightarrow SO_2 \text{ or } 4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$$

$$2SO_2 + O_2 \xrightleftharpoons{V_2O_5 \text{ or Pt, 673-732 K}} 2SO_3 .$$

V_2O_5 is, however, preferred since is much cheaper than Pt and is also not poisoned by arsenic impurities.

The favorable conditions for maximum yield of SO_3 are,

(a) High concentration of SO_2 and O_2. (b) Low temperature of 673 to 723 K, (c) High pressure about 2 atmospheres.

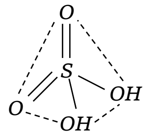
SO_3 thus obtained is absorbed in 98% H_2SO_4 to form oleum which on dilution with water gives H_2SO_4 of desired concentration.

$$SO_3 + H_2SO_4 \rightarrow \underset{\text{oleum}}{H_2S_2O_7} \;;\; H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$$

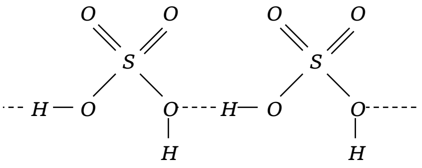
Contact process is preferred over lead chamber process (gives 98% pure H_2SO_4) since it gives H_2SO_4 of greater purity (100%).

Structure : H_2SO_4 is a covalent molecule with sulphur in a +6 oxidation state. The two oxygen atoms are linked to sulphur by double bonds while the other two oxygen atoms.

Are linked by single covalent bonds. Thus it has tetrahedral structure. Infact, sulphuric acid has an associated structure due to the presence of hydrogen bonds. As a result, it is a dense and viscous liquid and has a high boiling point of $590\,K$



Structure of



H-bonding in conc. H_2SO_4

Properties : H_2SO_4 has high b.p. ($611K$) and is also highly viscous due to H-bonding. It has strong affinity for H_2O and a large amount of heat is evolved when it is mixed with water.

(i) H_2SO_4 is a strong dibasic acid. It neutralizes alkalies, liberates CO_2 from carbonates and bicarbonates.

(ii) It reacts with more electropositive (than hydrogen) metals to evolve H_2 and produces SO_2 on heating with less electropositive metals than hydrogen .eg.,

$$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O \;;$$

$$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$$

(iii) It is a strong oxidizing agent and oxidises as follows,

$$H_2SO_4 \rightarrow H_2O + SO_2 + O$$

$$C + 2H_2SO_4 \rightarrow 2SO + CO + 2H_2O$$

$$S + 2H_2SO_4 \rightarrow 3SO_2 + 2H_2O$$

$$P_4 + 10H_2SO_4 \rightarrow 4H_2PO_4 + 10SO_2 + 4H_2O$$

$$2HBr + H_2SO_4 \rightarrow Br_2 + 2H_2O + SO_2$$

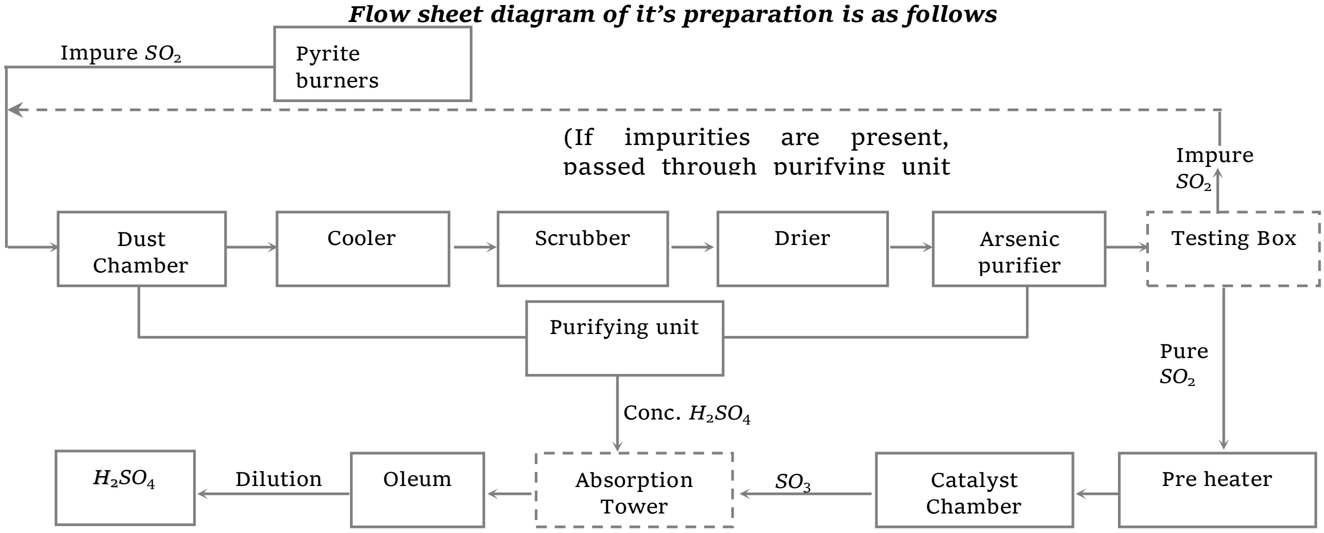
$$2HI + H_2SO_4 \rightarrow 2H_2O + I_2 + 2SO_2$$

(iv) It reacts with number of salts. It liberates HCl from chlorides, H_2S from sulphides, HNO_3 from nitrates.

(v) It acts as a strong dehydrating agent, as it dehydrates, sugar to sugar charcoal (carbon), formic acid to CO, oxalic acid to $CO + CO_2$ and ethyl alcohol to ethylene.

(vi) It is also a good sulphonating agent and used for sulphonation of aromatic compounds. eg.,

Flow sheet diagram of it's preparation is as follows



$$BaCl_2 + H_2SO_4 \rightarrow \underset{\text{(white ppt)}}{BaSO_4} + 2HCl$$

$$Pb(NO_3)_2 + H_2SO_4 \rightarrow \underset{\text{(white ppt.)}}{PbSO_4} + 2HNO_3$$

$$\underset{\text{Sugar}}{C_{12}H_{22}O_{11}} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Carbon}}{12C} + 11H_2O$$

$$HCOOH \xrightarrow{Conc.H_2SO_4} CO + H_2O$$

Uses : H_2SO_4 is used (i) in the preparation of fertilizers like $(NH_4)_2SO_4$ and super phosphate of lime, (ii) in lead storage batteries (iii) in preparation of dyes, paints and explosives (iv) in textile and paper industry (v) for training of tanning (vi) as a dehydrating agent.

(5) **Sodium thiosulphate** $Na_2S_2O_3.5H_2O$ **:** It is manufactured by saturating a solution of sodium carbonate with SO_2 which gives a solution of sodium sulphite,

$$Na_2CO_3 + SO_2 + H_2O \rightarrow Na_2SO_3 + CO_2 + H_2O$$

The resulting solution is boiled with powdered sulphur as, $Na_2SO_3 + S \xrightarrow{373K} Na_2S_2O_3$

The solution is then cooled to get crystals of sodium thiosulphate.

Physical properties : (i) Sodium thiosulphate is a colourless crystalline solid. In the hydrated form, it is called hypo. (ii) It melts at 320 K and loses its water molecules of crystallization on heating to 490K.

Chemical properties

(i) ***Action with halogens*** : It reacts with halogens as,

(a) Chlorine water oxidizes sodium thiosulphate to sodium sulphate and sulphur is precipitated,

$$Na_2S_2O_3 + Cl_2 + H_2O \rightarrow 2HCl + Na_2SO_4 + S$$

This property enables it to act as an antichlor in bleaching *i.e.* it destroys the unreacted chlorine in the process of bleaching.

(b) Bromine water also oxidizes sodium thiosulphate to sodium sulphate and sulphur,

$$Na_2S_2O_3 + Br_2 + H_2O \rightarrow Na_2SO_4 + 2HBr + S$$

(c) With iodine it forms a soluble compound called sodium tetrathionate,

$$2Na_2S_2O_3 + I_2 \rightarrow \underset{\text{Sod. tetrathionate}}{Na_2S_4O_6} + 2NaI$$

Therefore, hypo is commonly used to remove iodine stains from the clothes.

(ii) ***Action of heat*** : Upon heating, sodium thiosulphate decomposes to form sodium sulphate and sodium pentasulphide,

$$4Na_2S_2O_3 \xrightarrow{\text{Heat}} 3Na_2SO_4 + \underset{\text{Sodium pentasulphide}}{Na_2S_5}$$

(iii) ***Action with acids*** : Sodium thiosulphate reacts with dilute hydrochloric acid or Sulphuric acid forming sulphur dioxide and sulphur. The solution turns milky yellow due to sulphur.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + H_2O + S$$

(iv) ***Action with silver halides*** **:** Sodium thiosulphate forms soluble complex when treated with silver chloride or silver bromide,

$$2Na_2S_2O_3 + 2AgBr \rightarrow \underset{\substack{\text{Sodium dithiosulphate} \\ \text{argentate (I)compex}}}{Na_3Ag(S_2O_3)_2} + NaBr\ .$$

This property of hypo is made use in photography.

Uses of sodium thiosulphate

(i) It is largely used in photography as a fixing agent.

(ii) It is used as a preservative for fruit products such as jams and squashes.

(iii) It is used as an antichlor in bleaching.

(iv) It is used as a volumetric agent for the estimation of iodine.

(v) It is used in medicine.

Halogen Family

Fluorine is the first member of group 17 or VIIA of the periodic table. It consists of five elements Fluorine (F), Chlorine (Cl), bromine (Br), iodine (I) and astatine (At). These are known as halogen because their salts are found in sea water. Halogen is a greek word meaning a sea salt.

(1) **Electronic configuration**

Elements	**Electronic configuration** ($ns^2\ np^5$)
$_9F$	$[He]2s^2 2p^5$
$_{17}Cl$	$[Ne]3s^2 3p^5$
$_{35}Br$	$[Ar]3d^{10} 4s^2 4p^5$
$_{53}I$	$[Kr]4d^{10} 5s^2 5p^5$
$_{85}At$	$[Xe]4f^{14} 5d^{10} 6s^2 6p^5$

Physical properties

(1) **Atomic and ionic radii :** A halogen atom has the smallest radius as compared to any other element in its period. This is due to the increased effective nuclear charge which results in greater attraction of the electrons by the nucleus. The atomic radii. Increase from fluorine to iodine down the group due to increase in number of shells.

Element	F	Cl	Br	I
Covalent radius (pm)	72	99	114	133
Ionic radius (pm)	133	184	196	220

(2) **Ionization energy :** Ionization energy of these elements are higher than those of the corresponding elements of group 16 due to increased nuclear charge. these values decrease systematically as we move down the group from F to 1

Element	F	Cl	Br	I
I.E.₁ ($kJ\ mol^{-1}$)	1680	1256	1142	1008

Thus iodine which has a comparatively low value of I.E., has a tendency to lose an electon to form positive iodinium ion, I^+ and thus shown electropositive or metallic character.

(3) **Electronegativity :** Fluorine is the most electronegative element in the periodic table. With increase in atomic number down the group, the electronegativity decreases.

Element	F	Cl	Br	I	At
Electronegativity	4.0	3.2	3.0	2.7	2.2

The decreasing order of electronegativity is $F > Cl > Br > I$

(4) **Electron affinity :** Electron affinity of chlorine, bromine and iodine decrease as the size of the atom increases. The electron affinity of fluorine is, however, lower than that of Cl and Br, because of its small size as a result of which inter-electronic repulsions present in its $2p$ subshell are comparatively large. Thus chlorine has the highest electron affinity.

Element	F	Cl	Br	I
Electron affinity ($kJ\ mol^{-1}$)	333	348	325	296

The decreasing order of electron affinity is $Cl > F > Br > I$

(5) **Oxidation states :** All the halogens show an oxidation state of –1. Fluorine being the most electronegative element always shows an oxidation state of –1 while other halogens also show positive oxidation states up to a maximum of +7 (*i.e.* +1, +3, +5 and +7) due to the availability of vacant d-orbitals in the valence shell of these atoms. Some halogens also show +4 and +6 oxidation states in oxides and oxy acids.

(6) **Nature of bonds :** All the halogens have seven electrons in the valence shell and hence require one more electron to acquire the nearest inert gas configuration either by gaining an electron from the metallic atom to form halide, X^- ion, or by sharing an electron with an electronegative element. Thus, halogens form both ionic and covalent compounds. The halides of highly electropositive metals are ionic while those of weakly electropositive metals and non-metals are covalent. The tendency to form ionic compounds decreases from F to I. Thus, F because of its high electronegativity forms ionic compounds even with less electropositive metals like Hg, Bi, Sn etc. while other halogens form only covalent compounds.

(7) **Non-metallic character :** All the halogens are non-metallic in nature due to their high ionization energies. The non-metallic character gradually decreases down the group. However, iodine is, solid and has metallic lustre.

(8) **Atomicity and physical state :** All the halogens exist as diatomic covalent molecules (F_2, Cl_2, Br_2 and I_2). F_2 and Cl_2 are gases at room temperature, Br_2 is corrosive liquid and I_2 is volatile solid.

(9) **Colour :** All the halogens have characteristic colours. F_2 is light yellow, Cl_2 is greenish yellow, Br_2 is reddish brown and I_2 is deep violet. The colour of halogens is due to the reason that their molecules absorb light in the visible region as a result of which electron are excited to higher energy levels. The amount of energy needed for excitation decreases

progressively from F_2 to I_2 and consequently there is a progressive deepening of colour of the halogens from F_2 to I_2. Since, fluorine atom requires large amount of energy for excitation of electrons and therefore absorbs violet light and apears yellow. On the other hand, iodine requires low energy for excitation of electrons (absorbs yellow light) and appears deep violet.

(10) **Bond dissociation energy :** Bond dissociation energies of chlorine, bromine and iodine decrease down the group as the size of the atom increases. The bond dissociation energy of fluorine, is however, lower than those of chlorine and bromine because of inter electronic repulsions present in the small atom of fluorine

X_2	F_2	Cl_2	Br_2	I_2
Bond dissociation energy ($kJ\ mol^{-1}$)	158	243	192	151

Hence bond energy decreases in the order $Cl_2 > Br_2 > F_2 > I_2$

(11) **Bond length in X_2 molecule :** As the size of the halogen atom increase, the bond length of $X-X$ bond in X_2 molecule increases from F_2 to I_2

X–X bond	F–F	Cl–Cl	Br–Br	I–I
Bond length (pm)	143	199	228	266

Thus, the bond length increases in the order $F_2 < Cl_2 < Br_2 < I_2$.

(12) **Melting points and boiling points :** Melting points and boiling points of these elements increase as we move down the group from F to I due to an increase in the vander Waals forces of attraction which increase down the group as the size of the atom increases.

Element	F	Cl	Br	I
Melting point (K)	54	172	266	386
Boiling point (K)	85	239	332	458

Hence, the melting points and boiling points show the order as $F < Cl < Br < I$.

(13) **Solubility :** Halogens, being non polar in nature do not readily dissolve in a polar solvent like water. however, fluorine reacts with water vigorously even at low temperature (exothermally) forming a mixture of ozone and oxygen

$$2F_2 + 2H_2O \longrightarrow 4HF + O_2$$

$$3F_2 + 3H_2O \longrightarrow 6HF + O_3$$

Chlorine and bromine are fairly soluble but iodine is very little soluble in water. chlorine, bromine and iodine are more soluble in organic solvents like CCl_4, CS_2 or $CHCl_3$ and produce coloured solutions. Thus Cl_2, Br_2 and I_2 give yellow, brown and violet colour respectively. It is believed that in non-polar solvents, halogens exist as free molecules just as in the gas phase.

In nucleophilic (electron donating) polar solvents like alcohols, ketones or liquid SO_2, halogens produce brown solution. This colour is due to the complex formation (solvent → halogen) which are charge transfer compounds.

The solubility of iodine (I_2) in water increases with addition of KI or NaI due to the formation of polyhalide (triiodide, I_3^-) ion, $KI + I_2 \rightleftharpoons KI_3$

However, this solution behaves as a simple mixture of KI and free I_2 and contains K^+ and I^- ions and free I_2 molecules. It has a brown colour. The solution of iodine in water (due to its very little solubility) is also brown.

(14) **Oxidising power :** All the halogens acts as strong oxidising agents since they have a strong tendency to attract electrons and have positive values of electrode potentials (E^o). The oxidising power, however, decreases as we move down the group from F to I. *i.e.*, $F_2 > Cl_2 > Br_2 > I_2$

Since F_2 is the strongest oxidising agent, it will oxidise all other halide ions to halogens.

$$F_2 + 2X^- \longrightarrow 2F^- + X_2 (X = Cl, Br, I)$$

Similarly, Cl_2 will displace Br^- and I^- ions from their solutions while Br_2 will displace I^- ions only.

$$Cl_2 + 2X^- \longrightarrow 2Cl^- + X_2 (X = Br, I)$$

$$Br_2 + 2I^- \longrightarrow 2Br^- + I_2$$

Hence F_2 is the strongest and I_2 is the weakest oxidising agent. This is also indicated by the decrease in the electrode potential (E^o) for the reaction $X_2(aq) + 2e^- \longrightarrow 2X^-(aq)$ on moving down the group.

X_2	F_2	Cl_2	Br_2	I_2	At_2
E^o (volts)	2.87	1.36	1.09	0.53	0.3

The electron affinity of fluorine is less than that of chlorine but still it is the strongest oxidising agent. This is because of its low bond dissociation energy $(158\ kJ\,mol^{-1})$ and high heat hydration $(510\ kJ\,mol^{-1})$ as compared to chlorine (for which the values are 243 and $372\ kJ\,mol^{-1}$, respectively).

(15) **Heat of hydration :** The heat of hydration of the halide ion (X^-) decreases as the size of the halogen decreases down the group from F to I.

X^- ion	F^-	Cl^-	Br^-	I^-
Heat of hydration (kJ mol^{-1})	510	372	339	301

Thus, the decreasing order of heat of hydration of halides is as follows :

$$F^- > Cl^- > Br^- > I^-$$

Chemical properties

(1) **Reactivity :** The halogen are most reactive elements due to their low bond dissociation energy, high electron affinity and high enthalpy of hydration of halide ion. $F > Cl > Br > I$

(2) **Reaction with H_2O :** Halogens readily decomposes water. This tendency decreases on moving down the group. Fluorine decomposes water very energetically to give oxygen and ozone,

$$2H_2O + 2F_2 \rightarrow 4HF + \underset{\text{Oxygen}}{O_2}\ ;\quad 3H_2O + 3F_2 \rightarrow 6HF + \underset{\text{Ozone}}{O_3}$$

Fluorine gives fumes in moist air. This is due to the formation of HF, which is a liquid and can absorb moisture to form liquid droplets and therefore, gives fumes with moist air. Chlorine and bromine react less vigorously,

$$Cl_2 + H_2O \rightarrow HCl + \underset{\text{Hypochlorous acid}}{HClO}$$

$$Br_2 + H_2O \rightarrow HBr + \underset{\text{Hypobromous acid}}{HBrO}$$

In the presence of sunlight, $HClO$ (hypochlorous acid) $HBrO$ (hypobromous acid) liberate oxygen.

$$2HClO \rightarrow 2HCl + O_2\ ;\quad 2HBrO \rightarrow 2HBr + O_2$$

Iodine is only slightly soluble in water. However, it dissolves in 10% aqueous solution of Kl due to the formation of I_3^- ions. $I_2 + KI \rightleftharpoons$

$$KI_2 + I^- \rightleftharpoons \underset{\text{Complex ion}}{I_3^-}$$

(3) **Reaction with hydrogen** : Form covalent halides.

$$H_2 + F_2 \xrightarrow{-200^o C} 2HF \text{ (very violent)}$$

$$H_2 + Cl_2 \xrightarrow{\text{Sunlight}} 2HCl$$

$$H_2 + Br_2 \xrightarrow[\text{pt. catalyst}]{\text{Heat}} 2HBr$$

$$H_2 + I_2 \overset{\text{Heat}}{\rightleftharpoons} 2HI \text{ (poor yield)}$$

- Acidic strength in aqueous solution is in the order,

$HI > HBr > HCl < HF.$

- Reducing character of hydrides follow the order,

$HI > HBr > HCl > HF.$

- Boiling point $HF > HI > HBr > HCl$. Thermal stability,

$H - F > H - Cl > H - Br > H - I.$

HCl is also called Muriatic acid.

(4) **Hydrides :** All the halogens combine directly with hydrogen to form halogen acids but their reactivity progressively decreases from fluorine to iodine, $H_2 + X_2 \rightarrow 2HX$ ($X = F, Cl, Br$ or I).

(i) ***Boiling points or volatility*** **:** In other words volatility decreases in the order : $HCl > HBr > HI > HF$ as the boiling points increase in the order : HCl (189K) $<$ HBr (206K) $<$ HI (238K) $<$ HF (292.5K).

(ii) ***Thermal stability*** **:** Thermal stability of the hydrides decrease from HF to HI *i.e.,* $HF > HCl > HBr > HI$.

(iii) ***Acidic strength*** **:** The acidic strength of halogen acids decreases from HI to HF *i.e,* $HI > HBr > HCl > HF$.

(iv) ***Reducing properties*** **:** Since the stability of hydrides decreases from HF to Hl, their reducing properties increase in the order $HF < HCl < HBr < HI$.

(v) ***Dipole moments*** **:** The dipole moments of hydrogen halides decrease in the order : $HF > HCI > HBr > HI$ as the electro negativity of the halogen atom decreases form F to I.

HX	HF	HCl	HBr	Hl

Dipole moment (D) 1.74 1.07 0.78 0.38

(5) **Oxides :** Halogens (except F_2) do not combine readily with oxygen. However, a number of compounds of halogens with oxygen have been prepared by indirect methods. Only two compounds of fluorine with oxygen, *i.e.* oxygen difluorine (OF_2) and oxygen fluoride (O_2F_2) are known. Chlorine forms largest number of oxides *i.e.* Cl_2O, ClO_2, Cl_2O_6 and Cl_2O_7 while iodine forms the least, *i.e.* I_2O_5. Bromine, however, forms three oxides (Br_2O, BrO_2C BrO_3). In all these compounds, bonds are largely covalent. All the oxides of halogens are powerful oxidizing agents. These compounds are very reactive and are unstable towards heat. The stability of oxides is greatest for iodine while bromine oxides are the least stable. For a particular halogen, higher oxides are more stable than the lower ones.

Iodine-oxygen bond is stable due to greater polarity of the bond (due to larger electro negativity difference between I and O) while in chlorine-oxygen bond, the stability is gained through multiple bond formation involving the *d*-orbital of chlorine atom. Bromine lacks both these characteristics and hence forms least stable oxides.

Oxides of chlorine, bromine and iodine are acidic and the acidic character increases as the percentage of oxygen increases in them.

Iodine also forms I_2O_4 and I_4O_9 compounds which are believed not to be true oxides but are basic iodyliodate, $IO(IO_3)$ and normal iodine triodate, $I(IO_3)_3$ having tripositive iodine as the cation.

OF_2 is V-shaped having bond angle 103^o, Cl_2O is also V-shaped with bond angle 111^o while ClO_2 is angular with-bond angle 118^o. It is paramagnetic due to odd number of electrons having three-electron bond. It is regarded as a mixed anhydride of chloric and chlorous acids. $2ClO_2 + H_2O \rightarrow HClO_2 + HClO_3$

(6) **Oxoacids of halogens :** Fluorine does not form any oxoacid since it is the strongest oxidizing agent. Chlorine, bromine and iodine mainly form four series of oxoacids namely hypohalous acid (HXO), halous acid (HXO_2) halic acid (HXO_3) and perhalic acid (HXO_4) as given below :

Table 18.10

Oxidation state	Chlorine	Bromine	Iodine	Thermal stability and acid strength	Oxidising power
+1	$HClO$	$HBrO$	HIO	Increases ↓	Decreases ↓
+3	$HClO_2$	–	–		
+5	$HClO_3$	$HBrO_3$	HIO_3		
+7	$HClO_4$	$HBrO_4$	HIO_4		
	Acidity decreases →				

(i) ***Hybridized ion*** **:** In all these oxoacids, the halogen atom is sp^3 -hybridized.

(ii) ***Acidic character*** **:** All these acids are monobasic containing an$-OH$ group. The acidic character of the oxoacids increases with increase in oxidation number, *i.e.*, $HClO < HClO_2 < HClO_3 < HClO_4$ and the strength of the conjugate bases of these acids follows the order,

$$ClO^- > ClO_2^- > ClO_3^- > ClO_4^-$$

(iii) ***Oxidising power and thermal stability*** **:** The oxidizing power of these acids decreases as the oxidation number increases, *i.e.*, $HClO < HClO_2 < HClO_3 < HClO_4$. Stability of oxoacids of chlorine in the increasing order is, $HClO < HClO_2 < HClO_3 < HClO_4$ and the increasing stability order of anions of oxoacids of chlorine is, $ClO^- < ClO_2^- < ClO_3^- < ClO_4^-$.

As the number of oxygen atoms in an ion increases there will be a greater dispersal of negative charge and thus greater will be the stability of ion formed. For different halogen having the name oxidation number, the thermal stability decreases with increase in atomic number *i.e.*, it is in the order $HClO > HBrO > HIO$ and $ClO^- > BrO^- > IO^-$ However, in HXO_3 is most stable. The stability order being $HClO_3 < HBrO_3 < HIO_3$.

(iv) Perhalates are strong oxidizing agents, the oxidizing power is in the order, $BrO_4^- > IO_4^- > ClO_4^-$.

Thus BrO_4 is the strongest oxidizing agent (though its reaction is quite slow) and ClO_4^- is the weakest.

(v) The acidity of oxoacids of different halogens having the same oxidation number decreases with increase in the atomic size of the halogen i.e. $HClO_4 > HBrO_4 > HIO_4$.

(7) **Reaction with alkalies :**

$$2F_2 + \underset{\text{(cold dilute)}}{2NaOH} \rightarrow 2NaF + OF_2 + H_2O$$

$$2F + \underset{\text{(hot conc.)}}{4NaOH} \rightarrow 4NaF + O_2 + 2H_2O$$

Halogen other than fluorine (Cl_2, Br_2, I_2) react with $NaOH$ as follows,

$$\underset{}{X_2(g)} + \underset{\text{(cold dilute)}}{2OH^-} \xrightarrow{15^o C} X^- + \underset{\text{(hypohalite ion)}}{OX^-} + H_2O$$

$$X_2(g) + \underset{\text{(hot conc)}}{6OH^-} \xrightarrow{70^o C} 5X^- + \underset{\text{(halate ion)}}{XO_3^-} + 3H_2O$$

(8) **Bleaching action of halogen :** Cl_2 acts as bleaching agent, its bleaching action is permanent. Cl_2 water can also act as ink remover.

(9) **Reaction with other halides**

$$2KBr(aq.) + Cl_2(g) \rightarrow 2KCl(aq.) + Br_2(aq.)$$

$$2KI(aq.) + Cl_2(g) \rightarrow 2KCl(aq.) + I_2(aq.)$$

(10) **Inter halogen compounds :** The compounds of one halogen with the other are called inter halogens or inter halogen compounds. The main reason for their formation is the large electronegativity and the size differences between the different halogens. Taking *A* as the less electronegative and *B* as the more electronegative halogen, they are divided into the following four types the less electronegative halogen (A) is always written first.

AB	AB_3	AB_5	AB_7
ClF $BrF, BrCl, ICl$ IBr, IF	ClF_3, BrF_3 IF_3, ICl_3	$BrF_5\, IF_5$	IF_7

These interhalogen compounds are unstable and more reactive

(i) ***General properties***

(a) Largest halogen always serves the central atom.

(b) The highest interhalogen compound i.e. IF_7 is obtained with iodine, the largest halogen attached to the smallest one

(c) The bonds in interhalogen compounds are essentially covalent.

(d) Thermal stability decreases as the size difference decreases and increases as the polarity of the bond increases. Thus *ClF* is thermally more stable as compared to *IBr*.

(e) They ionize in solution or in the liquid state,

$$2ICl \rightleftharpoons I^+ + ICl_2^- ; \quad 2ICl_3 \rightleftharpoons ICl_2^+ + ICl_4^-$$

(f) Hydrolysis of interhalogen compounds always produces a halide ion derived from smaller halogen and oxyhalide derived from larger halogen, $ICl + H_2O \rightarrow Cl^- + OI^- + 2H^+$;

$$BrF_5\, 3H_2O \rightarrow 5F^- + BrO_3^- + 6H^+$$

(g) They are strong oxidizing agents.

(h) Largest number of interhalogens are formed by fluorine due to its smaller size and higher electronegativity or oxidizing power.

(ii) ***Structure*** : Interhalogen compounds are,

(a) *AB* type *i.e. ICl, IBr, IF* etc, are linear

(b) AB_3 type *i.e.* IF_3, ClF_3, BrF_3 have distorted trigonal bipyramidal (dsp^3-hybridization) structures of T-shape due to two lone pairs in equatorial positions ICl_3 is dimeric, I_2Cl_6 and has a planar structure.

(c) AB_5 types *i.e.* BrF_5, IF_5 have distorted octahedral (d^2sp^3-hybridization) shapes or square pyramidal due to a lone pair one of the axial positions.

(d) AB_7 type *i.e.* IF_7, have pentagonal bipyramidal (d^3sp^3-hybridization) structures.

(11) **Polyhalide ions :** Halogens or interhalogens combine with halide ions to form polyhalide ions. The most common example of polyhalide ion formation is furnished by the increase in solubility of iodine in water in the presence of *KI* which is due to the formation of tri iodide ion, I_3^-

$$I^- + I_2 \longrightarrow I_3^-$$

Many other examples of polyhalides ions are

(i) $Cl_3^-, Br_3^-, ICl_2^-, IBr_2^-$ including I_3^-. In these ions, one of the halogen atoms (in case of similar atoms) or halogen atom larger in size undergoes sp^3d-hybridization giving a linear shape with three lone pairs at equatorial positions.

(ii) $Cl_3^+, Br_3^+, I_3^+, ICl_2^+, IBr_2^+$. Here we find central atom sp^3 hybridized giving a bent shape with two lone pairs of electrons on the central atom.

(iii) ICl_4^-, BrF_4^-, I_5^-. Here central atom involves sp^3d^2 hybridization giving square planar shape with two lone pairs of electrons on axial positions.

(iv) ICl_4^+, BrF_4^+, I_5^+. In these ions central atom involves sp^3d hybridization giving a distorted tetrahedral structure with one lone pair of electrons on equatorial position.

(v) I_7^-, IF_6^-. The central atom I undergoes sp^3d^3 hybridization giving a distorted octahedral structure with one lone pair of electrons.

(vi) I_7^+. Here central I atom involves sp^3d^2 hybridization giving an octahedral structure.

Fluorine due to its highest electronegativity (and only –1 oxidation state) does not form polyhalide ions where it acts as a central atom.

(12) **Pseudohalogen and pseudohalides**

Pseudohalogen	Pseudohalide

Cyanogen – $(CN)_2$	Cyanide – CN^-
Oxocyanogen – $(OCN)_2$	Cyanate – OCN^-
Thiocyanogen – $(SCN)_2$	Thiocyanate – SCN^-
Selenocyanogen – $(SeCN)_2$	Selenocyanate – $SeCN^-$

(13) **Anomalous behaviour of fluorine :** Fluorine differs from rest of the elements of its family due to (i) its small size (ii) highest electronegativity, (iii) low bond dissociation energy and (iv) absence of *d*-orbitals in the valence shell. The main points of difference are :

(1) Fluorine is most reactive of all the halogens due to lower value of $F-F$ bond dissociation energy ($F_2 = 158, Cl_2 = 243$, bromine = 192 and iodine = 151 *kJ mol*$^{-1}$) .

(2) Being the most electronegative element, it shows only an oxidation state of –1 and does not show positive oxidation states due to absence of d-orbitals in its valence shell. Other halogens show positive oxidation states of +1, +3, +5 and +7.

(3) Due to small atomic size and high electronegativity of F, HF undergoes strong H-bonding while other halogen acids do not. As a result,

(i) HF is a liquid (boiling point 292.5*K*), while other halogen acids are gases at room temperature (boiling point of $HCl = 189\,K$, $HBr = 206\,K$, $HI = 238\,K$).

(ii) HF is weakest of all the halogen acids due to high strength of $H-F$ bond.

(iii) Due to H-bonding, HF can form acid salts of the type KHF_2, *i.e.,* $K^+[H-F.......F^-]$ while HCl, HBr and HI do not form such salts (*i.e.*, no $KHCl_2, KHBr_2$ and KHI_2 are known).

(4) Fluorides have the maximum ionic character. For example AlF_3 is ionic while other halides of Al are covalent.

(5) Of all the halogens, fluorine has the highest positive electrode potential ($F_2 = 2.87, Cl_2 = 1.36, Br_2 = 1.09$ and $I_2 = 0.53$ volt) *i.e.*, it is most easily reduced and hence acts as the strongest oxidising agent. It brings about the highest oxidation of other elements with which it combines. For example with S, it gives SF_6, with I_2 it gives IF_7. Other halogens do not always bring about the highest oxidation state. For example, with sulphur Cl_2 gives SCl_4, Br_2 gives SBr_2 while I_2 does not react at all. F_2 is so powerful oxidising agent that it can even oxidise inert-gases.

(6) HF cannot be stored in glass bottles sicne it reacts with silicates to form fluorosilicates.

$$Na_2SiO_3 + 6HF \longrightarrow Na_2SiF_6 + 3H_2O$$

While other halogen acids (HCl, HBr and HI) do not react with silicates and hence can be stored in glass bottles.

(7) AgF is soluble in H_2O while all other silver halides *i.e.*, $AgCl, AgBr$ and AgI are insoluble in water. In constant, CaF_2 is insoluble while other calcium halides *i.e.*, $CaCl_2, CaBr_2, CaI_2$ are soluble in H_2O.

(8) Due to absence of d-orbitals, fluorine, does not form polyhalide ions while other halogens form polyhalides of the type I_3^-, Br_3^-, I_5^- etc.

Preparation of halogens and its uses

(1) **Fluorine**

(i) ***Occurrence of fluorine*** : Fluorine does not occur free in nature but occurs mostly as fluorspar CaF_2, cryolite, Na_3AlF_6 and fluorapatite, $CaF_2.3Ca_3(PO_4)_2$. Traces of fluoride occur in sea water, bones, teeth, blood, milk etc.

(ii) ***Difficulties encountered during its isolation*** : (a) F_2 attacks all the materials of the apparatus such as glass, platinum, carbon and other metals, (b) F_2 is the strongest oxidising agent and hence no oxidising agent can oxidise F^- ions to F_2. (c) F_2 cannot be prepared even by electrolysis of an aqueous solution of HF because F_2 formed reacts violently with water. If also cannot be prepared by electrolysis of anhydrous HF because it is not only poisonous, corrosive and volatile but also is a bad conductor of electricity.

(iii) ***Preparation*** : F_2 is now prepared by electrolysis of a solution of KHF_2 (1 part) in anyhydrous HF (5 parts) in a vessel (modern method) made of $Ni-Cu$ alloy or $Ni-Cu-Fe$ alloy called the monel metal using carbon electrodes. During the electrolysis following reactions occur.

$$KHF_2 \longrightarrow KF + HF\ ;\ KF \longrightarrow K^+ + F^-$$

At cathode : $K^+ + e^- \longrightarrow K$; $2K + 2HF \longrightarrow 2KF + H_2 \uparrow$

At anode : $F^- \longrightarrow F + e^-$; $F + F \longrightarrow F_2$

(iv) ***Properties*** : It is the most reactive of all the halogens. It Combines with metals as well as non-metals to form fluorides. It decomposes water forming O_2 and O_3 and reacts vigorously with hydrogen of hydrocarbons leaving behind fluorinated hydrocarbons.

$$2H_2O + 2F_2 \xrightarrow[\text{Oxidation}]{\text{Cold}} 4HF + O_2$$

$$3H_2O + 3F_2 \xrightarrow[\text{Oxidation}]{\text{Hot}} 6HF + O_3$$

(HF being a volatile liquid fumes in air)

$$CH_4 \xrightarrow{F_2} CH_3F \xrightarrow{F_2} CH_2F_2 \xrightarrow{F_2} CHF_3 \xrightarrow{F_2} CF_4$$

It is a strong oxidising agent and oxidises $KClO_3$ to $KClO_4, KIO_3$ to KIO_4 and bisulphates to peroxy sulphates.

$$KClO_3 + F_2 + H_2O \longrightarrow KClO_4 + H_2F_2$$

$$2NaHSO_4 + F_2 \longrightarrow Na_2S_2O_8 + 2HF$$

It reacts with NH_3 to form nitrogen and with H_2S forming SF_6.

$2NH_3 + 3F_2 \longrightarrow N_2 + 6HF$ (oxidation reaction)

$$H_2S + 4F_2 \longrightarrow SF_6 + 2HF$$

Fluorine reacts with cold and dilute sodium hydroxide solution to give oxygen difluoride (OF_2)

$$2F_2 + 2NaOH \text{ (cold, dil)} \longrightarrow 2NaF + H_2O + OF_2$$

However, with hot and concentrated sodium hydroxide solution it gives oxygen

$$2F_2 + 4NaOH \text{(Hot, conc.)} \longrightarrow 4NaF + 2H_2O + O_2$$

Since F_2 is the strongest oxidising agent, it is always reduced and hence does not show disproportionation reactions while others halogens do.

F_2 oxidises all other halide ions to the corresponding halogens $(F_2 + 2X^- \longrightarrow 2F^- + X_2)$; $(X = Cl, Br$ or $I)$

(v) ***Uses of fluorine*** : Fluorine is used in the manufacture of UF_6 (which is used for nuclear power generation), SF_6 (which is used as an electrical insulator), chlorofluorocarbons, teflon, cryolite and HF.

(vi) *Fluorocarbons* are the derivatives of hydrocarbons in which H-atoms are replaced by F-atoms. these are obtained by fluorination of hydrocarbons with F_2 diluted with an inert gas such as N_2 in presence of CuF_2 as catalyst. Fluorocarbons are widely used in industry because of their extreme inertness (non-in-flammability and extreme stability). Freon (CF_2Cl_2) is used as a refrigerant, tetrafluoroethylene $(F_2C = CF_2)$ is used for the manufacture of teflon which is highly non-inflammable, has high thermal stability and is chemically inert *i.e.*, is not attacked by acids and corrosive chemicals. It is used for making pipes, surgical tubes, non-stick utensils and as an electrical insulator.

(2) **Chlorine**

(i) ***Occurrence*** : Chlorine mainly occurs as rock salt $(NaCl)$ Carnallite, $(KCl, MgCl_2.6H_2O)$ and Calcium chloride. $(CaCl_2)$.

(ii) ***Preparation*** : On a commercial scale chlorine is prepared by electrolysis of an aqueous solution of sodium chloride (brine solution) (Nelson cell, Castner and Kellner's cell for the manufacture of $NaOH$) when Cl_2 is evolved at the anode and H_2 is evolved at the cathode.

$$2NaCl + 2H_2O \xrightarrow{\text{Electrolysis}} 2NaOH + Cl_2 \uparrow + H_2 \uparrow$$

It can also be prepared by electrolysis of molten $NaCl$ (Down's cell for the manufacture of metallic sodium). When Cl_2 is evolved at the anode and sodium metal at the cathode.

$$2NaCl \xrightarrow{\text{Electrolysis}} 2Na + Cl_2 \uparrow$$

In the laboratory, Cl_2 is prepared by the action of MnO_2 or $KMnO_4$ or $K_2Cr_2O_7$ on conc. HCl or a mixture of $NaCl$ and Conc. H_2SO_4

$$MnO_2 + 4HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$$

$$2KMnO_4 + 16HCl \longrightarrow 2KCl + 2MnCl_2 + 5Cl_2 + 8H_2O$$

$$K_2Cr_2O_7 + 14HCl \longrightarrow 2KCl + 2CrCl_3 + 7H_2O + 3Cl_2$$

$$MnO_2 + 2NaCl + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + 2H_2O + Cl_2$$

$$2KMnO_4 + 10NaCl + 13H_2SO_4 \longrightarrow$$
$$10NaHSO_4 + K_2SO_4 + 2MnSO_4 + 8H_2O + 5Cl_2$$

Other oxidising agents such as $PbO_2, Pb_3O_4, CaOCl_2, O_3$ etc. also react with HCl to liberate Cl_2.

(iii) ***Properties*** : It combines with metals and non metals to form chlorides. it decomposes water forming HCl and $HClO$ (hypochlorous acid) which is unstable and decomposes giving nascent oxygen which is responsible for oxidising and bleaching action of chlorine.

$$Cl_2 + H_2O \longrightarrow HCl + HClO \ ; \ HClO \xrightarrow{hv} HCl + [O]$$

Coloured matter $+ O \longrightarrow$ Colourless matter.

The bleaching action is permanent and colour is not restored on standing. However, it cannot be used for bleaching delicate articles such as straw, silk, wool etc. which are damaged by it.

Cl_2 oxidises Br^- and I^- ions to Br_2 and I_2 respectively.

$Cl_2 + 2X^- \longrightarrow 2Cl^- + X_2 (X = Br$ or $I)$.

It combines with alkalies forming hypochlorite and chlorate salts in cold and hot conditions respectively.

$$2NaOH \text{(dil.)} + Cl_2 \xrightarrow{\text{Cold}} NaCl + NaClO + H_2O$$

$$6NaOH \text{(Conc.)} + 3Cl_2 \xrightarrow{\text{Heat}} 5NaCl + NaClO_3 + 3H_2O$$

During these reactions, halogen is simultaneously reduced to X^- ion and is oxidised to either hypohalite (XO^-) or halate (XO_3^-) ion. Such reactions are called disproportionation reactions.

With slaked lime, Cl_2 gives bleaching powder $(CaOCl_2)$

$$Ca(OH)_2 + Cl_2 \longrightarrow CaOCl_2 + H_2O$$

With ammonia, Cl_2 reacts as follows :

$$8NH_3(excess) + 3Cl_2 \longrightarrow 6NH_4Cl + N_2\uparrow$$

$$NH_3 + 3Cl_2(excess) \longrightarrow NCl_3 + 3HCl$$

With SO_2 and CO, addition compounds are formed

$SO_2(dry) + Cl_2 \longrightarrow SO_2Cl_2$ (Sulphuryl chloride)

$CO + Cl_2 \longrightarrow COCl_2$ (Carbonyl chloride or phosgene)

Cl_2 is strong oxidising agent. It oxidises $FeCl_2$ to $FeCl_3$, moist SO_2 to H_2SO_4, SO_3^{2-} to SO_4^{2-}, thiosulphate to sulphate and sulphur.

(iv) ***Uses of chlorine*** : It is used in the manufacture of $HCl, NaOCl$, bleaching powder, chlorates, vinyl chloride, insecticides such as DDT, chlorinated organic solvents like $CHCl_3, CCl_4$. It is also used in sterilisation of drinking water, in the extraction of Au and Pt and as a bleaching agent for paper, pulp and textiles.

(3) **Bromine**

(i) ***Occurrence*** : It mainly occurs in sea water and salt lakes as $NaBr, KBr$ and $MgBr_2$.

(ii) ***Preparation*** : On a commercial scale, bromine is prepared either from sea water (containing $NaBr, KBr$ and $MgBr_2$) or the mother liquor (containing $MgBr_2$) left after crystallisation of chlorides from carnallite. On passing Cl_2 gas through these solutions, bromides get oxidised to bromine which is cooled and condensed to Br_2 liquid.

$$2Br^- + Cl_2 \longrightarrow 2Cl^- + Br_2$$

In the laboratory, bromine can be prepared by heating $NaBr$ with MnO_2 and conc. H_2SO_4.

$$2NaBr + MnO_2 + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + 2H_2O + Br_2$$

It is also obtained by adding HCl to a mixture containing potassium bromide and potassium bromate.

$$5KBr + KBrO_3 + 6HCl \longrightarrow 6KCl + 3Br_2 + 3H_2O$$

(iii) ***Properties*** : Bromine is a reddish brown heavy liquid.

Its reaction with water, oxidising and bleaching action, reaction with alkalies, NH_3, metals and non metals are similar to that of chlorine. Br_2 oxidises only iodide ions to I_2. Bromine water reacts with mercuric oxide to form mercury oxy bromide

$$2HgO + \underset{\text{Bromine water}}{2Br_2 + H_2O} \longrightarrow \underset{\text{Mercuryoxy bromide}}{HgBr_2.HgO} + 2HBrO$$

(iv) ***Uses of bromine*** : The main use of bromine is in the manufacture of ethylene bromide which is used as an additive to leaded petrol. It is also used to prepare $AgBr$, bromine water, dyes, drugs and benzyl bromide (an effective tear gas).

(4) **Iodine**

(i) ***Occurrence*** : It mainly occurs in sea weeds or alkali metal iodides. Caliche (crude chile salt petre) which is mainly sodium nitrate contains iodine as sodium iodate $(NaIO_3)$.

(ii) ***Preparation of iodine*** : On a commercial scale iodine is prepared from sea weeds and caliche.

(a) *From sea weeds* : Sea weeds (Laminaria variety) are dried, burnt and ash (called kelp constains about 1% I_2 as iodides of alkali metals besides chlorides and sulphates) is extracted with hot water. sulphates and chlorides are separated by fractional crystallisation, the mother liquor is treated with Cl_2 gas or heated with MnO_2 and conc. H_2SO_4 to liberate I_2 which is cooled and condensed to give violet crystals.

$$2NaI + Cl_2 \longrightarrow 2NaCl + I_2$$

$$2NaI + MnO_2 + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + 2H_2O + I_2$$

(b) *From Caliche* : The mother liquor left after crystallisation of $NaNO_3$ is treated with $NaHSO_3$ to liberate I_2 from $NaIO_3$.

$$2NaIO_3 + 5NaHSO_3 \longrightarrow 3NaHSO_4 + 2Na_2SO_4 + H_2O + I_2$$

In the laboratory, I_2 is prepared by heating a mixture of potassium iodide and MnO_2 with conc. H_2SO_4.

$$2KI + MnO_2 + 3H_2SO_4 \longrightarrow 2KHSO_4 + MnSO_4 + H_2O + I_2$$

(iii) ***Properties*** : It is a dark violet shining solid which sublimes on heating. It is least soluble in water. However, its solubility can be increased by adding $10\% KI$ solution due to the formation of I_3^- complex ion in which I^- ion acts as a lewis base (ligand) and I_2 molecule behaves as a lewise acid (central atom) which accommodates lone pair of electrons donated by I^- ion in the antibonding sigma p_z molecular orbital.

$$I_2 + I^- \longrightarrow I_3^-$$ (complex ion)

The aqueous solution containing I_3^- complex ion has a brown colour. It is soluble in many organic solvents. Its solution in $CS_2, CHCl_3$ and CCl_4 is violet while in strong donor solvents like alcohols, ethers and amines is brown.

With cold, dilute $NaOH$, iodine gives hypoiodous acid

$$NaOH + I_2 \xrightarrow{\text{Cold}} NaI + HIO$$

However, with hot, conc. solution of $NaOH$, the reaction is similar to that of Cl_2 or Br_2.

Iodine does not displace chlorine and bromine from chlorides and bromides respectively, but it displaces them from their oxy salts

$$2KClO_3 + I_2 \longrightarrow 2KIO_3 + Cl_2$$

$$2KBrO_3 + I_2 \longrightarrow 2KIO_3 + Br_2$$

With $Na_2S_2O_3$, iodine solution is decolourised due to the formation of colourless iodide and tetrathionate ions.

$$2Na_2S_2O_3 + I_2 \longrightarrow 2NaI + Na_2S_4O_6$$

With ammonia it reacts as follows

$$2NH_3 + 3I_2 \longrightarrow \underset{\text{(explosive)}}{NI_3.NH_3} + 3HI$$

$$8NI_3.NH_3 \longrightarrow 5N_2 + 9I_2 + 6NH_4I$$

With strong oxidising agents such as HNO_3, O_3 and Cl_2, iodine gives iodic acid (HIO_3)

$$I_2 + 10HNO_3 \longrightarrow 2HIO_3 + 10NO_2 + 4H_2O$$

$$I_2 + H_2O + O_3 \longrightarrow 2HIO_3 + 5O_2$$

$$I_2 + 5Cl_2 + 6H_2O \longrightarrow 2HIO_3 + 10HCl$$

(iv) ***Uses of iodine*** : It is used to prepare tincture of iodine (2% solution of I_2 in alcohol), iodex, iodoform, KI, iodised salt (which contains KI or NaI, 0.5 *g* per kg of $NaCl$) and as a laboratory reagent.

(5) **Hydrogen halides :** All the halogens combine with hydrogen to form hydrogen halides (HX).

(i) ***Preparation of HF and HCl*** : These are prepared by heating fluorides and chlorides respectively with conc. H_2SO_4.

$$CaF_2 + H_2SO_4 \xrightarrow{\text{Heat}} CaSO_4 + 2HF$$

$$2NaCl + H_2SO_4 \xrightarrow{\text{Heat}} Na_2SO_4 + 2HCl$$

(ii) ***Preparation of HBr and HI*** :These are prepared by heating bromides and iodides respectively with phosphoric acid

$$3NaBr + H_3PO_4 \xrightarrow{\text{Heat}} Na_3PO_4 + 3HBr$$

$$3NaI + H_3PO_4 \xrightarrow{\text{Heat}} Na_3PO_4 + 3HI$$

Conc. H_2SO_4 cannot be used for the preparation of HBr and HI because these being strong reducing agents reduced H_2SO_4 to SO_2 and are themselves oxidised to Br_2 and I_2 respectively.

$$2HBr + H_2SO_4 \longrightarrow SO_2 + Br_2 + 2H_2O$$

(6) **Bleaching powder** is obtained by the action of chlorine on dry slaked lime (Hasenclever method).

$$Ca(OH)_2 + Cl_2 \xrightarrow{313\,K} CaOCl_2 + H_2O$$

An aqueous solution of bleaching powder gives tests for Cl^- and ClO^- ions. On long standing, it undergoes auto-oxidation to form calcium chlorate. However, when heated, in presence of $CoCl_2$, it gives O_2

$$6CaOCl_2 \longrightarrow 5CaCl_2 + Ca(ClO_3)_2$$

$$2CaOCl_2 \xrightarrow{CoCl_2} 2CaCl_2 + O_2$$

It is used for bleaching cotton, wood pulp etc., as a disinfectant, as a germicide for sterilization of drinking water, in the manufacture of chloroform and for making wood unshrinkable.

Noble Gases

Helium is the first member of group 18 or zero of the periodic table. It consists of six elements helium (*He*), Neon (*Ne*), argon (*Ar*), krypton (*Kr*), xenon (*Xe*) and radon (*Rn*). Zero group occupies the intermediate position between the elements of VIIA (17th) and IA (1st) groups. These are collectively called as inactive gases or inert gases. However, these are now called noble gases as some compounds of these gases have been obtained under certain specific conditions.

(1) **Electronic configuration**

Elements	**Discovery**	**Electronic configuration** ($ns^2\ np^6$)
$_2He$	Lockyer and Janssen (1868)	$1s^2$
$_{10}Ne$	Ramsay	$1s^2, 2s^2 2p^6$
$_{18}Ar$	Rayleigh and Ramsay (1894)	$1s^2, 2s^2 2p^6, 3s^2 3p^6$
$_{36}Kr$	Ramsay and Travers (1898)	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}$, $4s^2 4p^6$

$_{54}Xe$	Ramsay and Travers (1898)	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}$, $4s^2 4p^6 4d^{10} 4f^{14}$, $5s^2 5p^6$
$_{86}Rn$	Dorn (1900)	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}$, $4s^2 4p^6 4d^{10} 4f^{14}$, $5s^2 5p^6 5d^{10}, 6s^2 6p^6$

(2) **Occurrence :** Due to the inert nature of noble gases, they always occur in the free state. Except radon, all these gases are present in atmosphere in the atomic state.

Element	He	Ne	Ar	Kr	Xe
Abundance (Volume **%)**	5.2×10^{-4}	1.8×10^{-3}	9.3×10^{-1}	1.4×10^{-3}	8.7×10^{-6}

He is also present in natural gas to the extent of 2 to 7%.

(3) **Isolation**

(i) ***Helium*** : It is commercially obtained from natural gas. The natural gas contains hydrocarbons (methane etc.), CO_2, H_2S and *He* as the main constituents.

The natural gas is compressed to about 100 *atm* and cooled to 73*K*. *He* remains unliquefied while other gases get liquefied. About 99% pure *He* is prepared by this method.

(ii) ***Argon, Neon, Krypton and Xenon*** **:** These gases are prepared by the fractionation distillation of liquid air. Fractional distillation of air gives O_2, N_2 and mixture of noble gases. The individual gases may be obtained by adsorption of air on coconut charcoal. The charcoal adsorbs different gases at different temperatures and can be collected.

(iii) ***Radon*** **:** It can be obtained by radio active disintegration of radium (226), $_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + {}_2\alpha^4$.

Properties :

(1) **Atomic radii :** The atomic radii of noble gases increases on moving down the group and their atomic radii correspond to the vander Waal's radii.

(2) **Boiling points :** The m.pt. and b.pt. increases from *He* to *Rn*, because of increase in magnitude of vander Waal's forces.

(3) **Polarizabiltiy :** The polarizability increases down the group, $He < Ne < Ar < Kr < Xe$

(4) **Ionisation energy and electron affinity :** Noble gases have stable $ns^2 np^6$ fully filled electronic configuration, so these have no tendency to add or lose electron. Therefore, ionisation energy of noble gases is very high. On the other hand their electron affinity is zero.

(5) **Heat of vaporisation :** They posses very low values of heat of vapourisation, because of presence of very weak vander Waal's forces of attraction between their monoatomic molecules. However the value of heat of vaporisation increases with atomic number down the group and this shows that there is an increasing polarizability of the larger electronic clouds of the elements with higher atomic number.

(6) **Solubility in water :** They are slightly soluble in water. Their solubility generally increases with the increase in atomic number down the group.

(7) **Adsorption by charcoal :** All of them except helium are adsorbed by cocount charcoal at low temperature. The extent of adsorption increases down the group.

(8) **Characteristic spectra :** All of them give characteristic spectra, by which they can be identified.

(9) **Liquification of gases :** It is difficult to liquify noble gases as their atoms are held by weak vander Waal's forces. Ease of liquification increases down the group from *He* to *Rn*. Helium has the lowest boiling point (4.18 *K*) of any known substance. The ease of liquification increases down the group due to increase in intermolecular forces.

The elements helium (*He*), neon (*Ne*), argon (*Ar*), krypton (*Kr*), xenon (*Xe*) and radon (*Rn*), constitute zero group of the periodic table. These are gases at ordinary temperature and do not have chemical reactivity and therefore, these are called inert gases.

Compounds of Xenon

In 1962, *N*. Bartlett noticed that PtF_6 is a powerful oxidizing agent which combines with molecular oxygen to form ionic compound, dioxygenyl hexafluoro platinate (v) $O_2^+[PtF_6]^-$, $O_{2(g)} + PtF_{6(g)} \rightarrow O_2^+[PtF_6]^-$,This indicates that PtF_6 has oxidized O_2 to O_2^+ . Now, oxygen and xenon have some similarities,

(i) The first ionization energy of *Xe* gas $(1170\, kJ\, \text{mol}^{-1})$ is fairly close to that of oxygen $(1166\, kJ\, mol^{-1})$.

(ii) The molecular diameter of oxygen and atomic radius of *Xe* are similar (4Å)

On this assumption, Bartlett reacted Xenon and PtF_6 in gas phase and a orange yellow solid of the composition *XePtF*6 was obtained, $Xe_{(g)} + PtF_{6(g)} \rightarrow \underset{\text{Orange yellow}}{Xe^+[PtF_6]^-_{(s)}}$.

Some important stable compounds of *Xe* are,

+2	+4	+6
XeF_2	XeF_4, $XeOF_2$	XeF_6, $XeOF_4$, XeO_3

Fluorides : Xenon forms three compounds with fluorine. These are : Xenon difluoride (XeF_2), Xenon tetrafluoride (XeF_4) and Xenon hexafluoride (XeF_6).

(1) **Xenon difluoride** (XeF_2) is formed when a mixture of Xenon and fluorine in the ratio 1 : 3 by volume is passed through a nickel tube at 673 *K*, $Xe + Fe \xrightarrow{\text{Ni, 673K}} XeF_2$

Structure : XeF_2 has trigonal bipyramid geometry due to sp^3d-hybridization of *Xe*. Three equatorial positions are occupied by lone pairs of electrons giving a linear shape to the molecule.

Properties : XeF_2 is a colourless crystalline solid, reacts with H_2 to give *Xe* and *HF*. It is hydrolysed completely by water,

$$2XeF_2 + 2H_2O \rightarrow 2Xe + O_2 + 4HF.$$

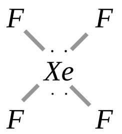
It also forms addition compounds with reactive pentafluorides like SbF_5, TaF_5 etc.

$$XeF_2 + 2SbF_5 \rightarrow XeF_2.2SbF_5$$

It is a mild fluorinating agent and hence reacts with benzene to give fluorobenzene.

(2) **Xenon tetrafluoride** (XeF_4) is prepared by heating a mixture of xenon and fluorine in the ratio 1 : 5 in a nickel vessel at 673 K and then suddenly cooling it in acetone. XeF_4 is also formed when an electric discharge is passed through a mixture of xenon and excess of fluorine, $Xe + 2F_2 \xrightarrow{\text{Ni, 673K}} XeF_4$

Structure : XeF_4 has square planar shape due to sp^3d^2 hybridization of *Xe* giving octahedral geometry with two trans positions occupied by lone pairs of electrons.



Properties : XeF_4 is a colourless, crystalline solid, soluble in anhydrous *HF*, reacts with H_2 to form *Xe* and *HF* and reacts with water to give highly explosive solid, XeO_3. (complete hydrolysis),

$$6XeF_4 + 12H_2O \rightarrow 4Xe + 2XeO_3 + 24HF + 3O_2$$

Partial hydrolysis yields $XeOF_2$,

$$XeF_4 + H_2O \xrightarrow{\text{193K}} XeOF_2 + 2HF$$

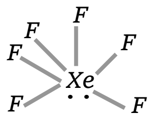
It also forms addition compounds with SbF_5, $XeF_4 + SbF_5 \rightarrow [XeF_3]^+[SbF_6]^-$.

It also acts as a strong fluorinating agent.

(3) **Xenon hexafluoride** (XeF_6) is prepared by heating a mixture of xenon and fluorine in the ratio 1 : 20 at 473—523*K* under a pressure of 50 atmospheres.

$$Xe + 3F_2 \xrightarrow{473-523\,K,\,50\,atm.} XeF_6$$

Structure : XeF_6 has pentagonal bipyramid geometry due to sp^3d^3 hybridization. One trans position is occupied by a lone pair giving a distorted octahedral shape.



Properties : It is colourless, crystalline solid, highly soluble in anhydrous *HF* giving solution which is a good conductor of electricity, $HF + XeF_6 \rightarrow XeF_5^+ + HF_2^-$.

It is the most powerful fluorinating agent and reacts with H_2 to give *Xe* and *HF*. Partial hydrolysis of XeF_6 yields $XeOF_4$ an complete hydrolysis yields xenon trioxide, XeO_3.

$$XeF_6 + H_2O \rightarrow XeOF_4 + 2HF$$

$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

It forms addition compounds with alkali metal fluorides (except *LiF*) of the formula $XeF_6.MF$ where M represents the alkali metal.

Oxides : Xenon forms two oxides such as xenon trioxide (XeO_3) and xenon tetraoxide (XeO_4).

(1) **Xenon trioxide (*XeO*₃)** is prepared by complete hydrolysis of XeF_4 and XeF_6

$$6XeF_4 + 12H_2 \rightarrow 2XeO_3 + 4Xe + 3O_2 + 24HF$$

$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

Structure : XeO_3 has tetrahedral geometry due to sp^3 hybridization of *Xe*. One of the hybrid orbitals contains a lone pair of electrons giving a trigonal pyramidal shape. The molecule has three *Xe* = O double bonds containing $p\pi - d\pi$ overlapping.

Properties : It is a colourless solid, highly explosive and powerful oxidizing agent.

(2) **Xenon tetraoxide (*XeO*₄)** is prepared by the action of conc. H_2SO_4 on sodium or barium xenate (Na_4XeO_6; Ba_2XeO_6) at room temperature,

$$Na_4XeO_6 + 2H_2SO_4 \rightarrow XeO_4 + 2Na_2SO_4\,2H_2O$$

$$Ba_2XeO_6 + 2H_2SO_4 \rightarrow XeO_4 + 2BaSO_4 + 2H_2O$$

XeO_4 is purified by vacuum sublimation at 195 *K*.

Structure : XeO_4 has tetrahedral structure due to sp^3 hybridization of *Xe*. There are four *Xe–O* double bonds containing $p\pi - d\pi$ overlapping.

Properties : It is quite unstable gas and decomposes to xenon and oxygen, $XeO_4 \rightarrow Xe + 2O_2$.

Oxyfluorides : Xenon forms three types of oxy fluorides such as xenon oxydifluoride ($XeOF_2$), xenon oxytetrafluoride $XeOF_4$ and xenon dioxydifluoride (XeO_2F_2).

(1) **Xenon oxydifluoride ($XeOF_2$)** is formed by partial hydrolysis of XeF_4 at 193 *K*,

$$XeF_4 + H_2O \xrightarrow{193\,K} XeOF_2 + 2HF.$$

Structure : $XeOF_2$ has trigonal bipyramid geometry due to $sp^3\,d$-hybridization of *Xe*. Two equatorial positions are occupied by lone pairs of electrons giving a T-shape to the molecule. There is one *Xe–O* double bond containing $p\pi - d\pi$ overlapping.

(2) **Xenon oxytetrafluoride ($XeOF_4$)** is prepared by partial hydrolysis of XeF_6; $XeF_6 + H_2O \rightarrow XeOF_4 + 2HF$. It can also be prepared by the reaction of SiO_2 with XeF_6,

$$2XeF_6 + SiO_2 \rightarrow 2XeOF_4 + SiF_4.$$

Structure : $XeOF_4$ has octahedral geometry due to sp^3d^2-hybridization of Xe. One trans position is occupied by a lone pair giving pyramid shape to the molecule. There is one *Xe–O* double bond containing $p\pi - d\pi$ overlapping.

Properties : It is a colourless volatile liquid which melts at 227 *K*. It reacts with water to give XeO_2F_2 and XeO_3,

$$XeOF_4 + H_2O \rightarrow XeO_2 + 2HF,$$

$$XeO_2F_2 + H_2O \rightarrow XeO_3 + 2HF.$$

It is reduced by H_2 to *Xe,*

$$XeOF_4 + 3H_2 \rightarrow Xe + H_2O + 4HF$$

(3) **Xenon dioxydifluoride (XeO_2F_2)** is formed by partial hydrolysis of $XeOF_4$ or XeF_6

$$XeOF_4 + H_2O \rightarrow XeO_2F_2 + 2HF$$

$$XeF_6 + 2H_2O \rightarrow XeO_2F_2 + 4HF$$

It can also be prepared by mixing XeO_3 and $XeOF_4$ at low temperature (195*K*). The product is purified by fractional distillation, $XeO_3 + XeOF_4 \xrightarrow{195\,K} 2XeO_2F_2$

Structure : XeO_2F_2 has trigonal bipyramid geometry due to sp^3d-hybridization of *Xe*. One equatorial position is occupied by a lone pair of electrons giving a see-saw structure (shape) to the molecule. There are two *Xe–O* double bonds containing $p\pi - d\pi$ overlapping.

Properties : It is a colourless solid which melts at 303*K*. It is easily hydrolysed to give XeO_3

$$XeO_2F_2 + H_2O \rightarrow XeO_3 + 2HF$$

Uses of noble gases

(1) He is used for filling of balloons and air ships because of its non-inflammability and high power (which is 92.6% to that of hydrogen).

(2) Oxygen-helium (1 : 4) mixture is used for treatment of asthma and for artificial respiration in deep sea diving because unlike nitrogen, helium is not soluble in blood even under high pressure.

(3) Helium is also used for creating inert atmosphere in chemical reactions.

(4) Liquid helium is used as a cryogenic fluid to produce and maintain extremely low temperatures for carrying out researches and as a coolant in atomic reactors and super conducting magnets.

(5) It is also used in low temperature gas thermometry and as a shield gas for arc welding.

(6) Argon is used for creating inert atmosphere in chemical reactions, welding and metallurgical operations and for filling in incandescent and fluorescent lamps. It is also used in filling Geiger-Counter tubes and thermionic tubes.

(7) Krypton and Xenon are also used in gas filled lamps. A mixture of Krypton and Xenon is also used in some flash tubes for high speed photography.

(8) Radon is used in radioactive research and therapeutics and in the non-surgical treatment of cancer and other malignant growths.

Tips & Tricks

✍ Among all the alkalimetals *Li* is the strongest and *Na* is the weakest reducing agent.

✍ Lindlar's catalyst is *Pd* poisoned with $BaSO_4$ in quinoline.

✍ *Keen's cement* : The setting of plaster of paris may be catalysed by sodium chloride while it is retard by borax or alum. Addition of alum to plaster of paris makes the setting very hard. The mixture is known as keen's cement.

✍ B_4C_3 (boron carbide) is one of the hardest known artificial substance and is called norbia.

- Bitter almonds contain *HCN* in free state. It is produced by the action of water on amygadatin (present in bitter almonds) in the presence of enzyme emulsion (also present in bitter almonds).
- Industrial lubricant oildag is a suspension of graphite in oil and colloidal solution of graphite is called aquadag.
- Broken glass pieces added during glass making is known as cullet.

Ordinary Thinking

Objective Questions

Alkali metals

1. As compared to potassium, sodium has **[MP PMT 1985]**

(a) Lower electronegativity

(b) Higher ionization potential

(c) Greater atomic radius

(d) Lower melting point

2. Potassium is kept in **[CPMT 1976]**

(a) Alcohol (b) Water

(c) Kerosene (d) Liquid ammonia

3. The product obtained on fusion of $BaSO_4$ and Na_2CO_3 is **[AFMC 2005]**

(a) $BaCO_3$ (b) BaO

(c) $Ba(OH)_2$ (d) $BaHSO_4$

4. Which of the following statement is correct regarding alkali metals **[NCERT 1981]**

(a) Cation is less stable than the atom

(b) Cation is smaller than the atom

(c) Size of cation and atom is the same

(d) Cation is greater in size than the atom

5. Valency electrons in alkali metals are **[CPMT 1972]**

(a) 1 (b) 7

(c) 4 (d) 2

6. Magnitude of which of the following property of alkali metals increases with the increase of atomic number **[MP PMT 1987]**

(a) Electronegativity (b) Ionic radius

(c) First ionization energy (d) Melting point

7. As compared to lithium, sodium reacts quickly with water because **[NCERT 1978, 80]**

(a) Its molecular weight is less

(b) It is stronger electronegative

(c) It is stronger electropositive

(d) It is a metal

8. Which is an ore of potassium **[DPMT 1984; CPMT 1986; Kurukshetra CEE 1998]**

(a) Carnellite (b) Cryolite

(c) Bauxite (d) Dolomite

9. Na_2CO_3 can be manufactured by Solvey's process but K_2CO_3 cannot be prepared because **[MP PMT 1993]**

(a) K_2CO_3 is more soluble

(b) K_2CO_3 is less soluble

(c) $KHCO_3$ is more soluble than $NaHCO_3$

(d) $KHCO_3$ is less soluble than $NaHCO_3$

10. Which of the following alkali metals is smallest in size **[CPMT 1990]**

(a) Rb (b) K

(c) Na (d) Li

11. When potassium dichromate crystal are heated with conc. HCl

(a) O_2 is evolved

(b) Chromyl chloride vapours are evolved

(c) Cl_2 is evolved

(d) No reaction takes place

12. Which of the following does not illustrate the anomalous properties of lithium **[MP PET 1993]**

(a) The melting point and boiling point of Li are comparatively high

(b) Li is much softer than the other group I metals

(c) Li forms a nitride Li_3N unlike group I metals

(d) The ion of Li and its compounds are more heavily hydrated than those of the rest of the group

13. Correct order of increasing activity is

(a) Cu, Mg, Na (b) Na, Mg, Cu

(c) Mg, Na, Cu (d) Cu, Na, Mg

14. On heating anhydrous Na_2CO_3, ... is evolved **[CPMT 1971, 79]**

(a) CO_2 (b) Water vapour

(c) CO (d) No gas

15. Chile saltpetre is **[DPMT 1984; CPMT 1986, 89; CET Pune 1998; MP PMT 2003]**

(a) $NaNO_3$ (b) Na_2SO_4

(c) KNO_3 (d) Na_2SO_3

16. A mixture of KCl and KF is added to sodium chloride

(a) To increase the conductivity of $NaCl$

(b) To decrease the melting point of $NaCl$

(c) To supress the degree of dissociation of $NaCl$

(d) To decrease the volatility of $NaCl$

17. A well known reagent which contains copper sulphate, sodium potassium tarterate and sodium hydroxide is

(a) Fenton's reagent (b) Schiff's reagent

(c) Fehling's solution (d) Nessler's reagent

18. Sodium metal can be stored under **[CPMT 1972, 85; BHU 1983]**

(a) Benzene (b) Kerosene

(c) Alcohol (d) Toluene

19. The most dangerous method of preparing hydrogen would be by the action of HCl and **[JIPMER 2000]**

(a) Al (b) K

(c) Fe (d) Zn

20. Based on lattice energy and other considerations which one of the following alkali metal chlorides is expected to have the highest melting point **[AIEEE 2005]**

(a) $LiCl$ (b) $NaCl$

(c) KCl (d) $RbCl$

21. The correct formula of hypo is

(a) $Na_2S_2O_3.5H_2O$ (b) Na_2SO_4

(c) $Na_2S_2O_3.4H_2O$ (d) $Na_2S_2O_3.3H_2O$

22. The reagent commonly used to determine hardness of water titrimetrically is **[AIIMS 2003]**

(a) Oxalic acid

(b) Disodium salt of $EDTA$

(c) Sodium citrate

(d) Sodium thiosulphate

23. K_2CS_3 can be called potassium **[CPMT 1972, 74]**

(a) Thiocyanate (b) Thiocarbonate

(c) Thiocarbide (d) Sulphocyanide

24. Which is most basic in character **[BHU 1982]**

(a) $RbOH$ (b) KOH

(c) $NaOH$ (d) $LiOH$

25. When washing soda is heated **[AFMC 2005]**

(a) CO is released

(b) $CO + CO_2$ is released

(c) CO_2 is released

(d) Water vapour is released

26. Which of the following is correct **[CPMT 1971]**

(a) All carbonates are soluble in water

(b) Carbonates of Na, K and NH_4 are soluble in water

(c) Carbonates of Ca, Sr, Ba are soluble in water

(d) All carbonates are insoluble

27. Nitre is **[CPMT 1986]**

(a) $AgNO_3$ (b) KNO_3

(c) NH_4NO_3 (d) $NaNO_3$

28. Nelson cell is used for the preparation of **[CPMT 1985]**

(a) Slaked lime (b) Baryta

(c) Sodium (d) Caustic soda

29. Potash alum is a **[CPMT 1986; MNR 1981]**

(a) Complex salt (b) Acid salt

(c) Double salt (d) Normal salt

30. The process of industrial manufacturing of sodium carbonate is known as **[CPMT 1978, 86; MP PMT 1995]**

(a) Castner process (b) Haber's process

(c) Le-blanc process (d) Chamber process

31. The colour of hydrogen is **[IIT 1980]**

(a) Black (b) Yellow

(c) Orange (d) None of these

32. Which one of the following salts gives aqueous solution which is weakly basic **[Bihar CEE 1995]**

(a) $NaHCO_3$ (b) $NaHSO_4$

(c) $NaCl$ (d) NH_4HCO_3

33. An example for a double salt is **[KCET 2002]**

(a) Silver nitrate (b) Mohr's salt

(c) Potassium ferricyanide (d)Cupromonium sulphate

34. The elements of group IA provide a colour to the flame of Bunson burner due to **[AIIMS 1987]**

(a) Low ionization potential

(b) Low melting point

(c) Softness

(d) Presence of one electron in the outermost orbit

35. Which of the following is the smallest cation **[MP PMT 1993]**

(a) Na^+ (b) Mg^{+2}

(c) Ca^{+2} (d) Al^{+3}

36. K, Ca and Li metals may be arranged in the decreasing order of their standard electrode potentials as **[CPMT 1990]**

(a) K, Ca, Li (b) Li, K, Ca

(c) Li, Ca, K (d) Ca, Li, K

37. Alkali metals lose electrons in **[CBSE PMT 1990]**

(a) *s*-orbitals (b) *p*-orbitals

(c) *d*-orbitals (d) *f*-orbitals

38. The alkali metal that reacts with nitrogen directly to form nitride is **[Roorkee 1992; MP PMT 2000; BHU 2000]**

(a) Li (b) Na

(c) K (d) Rb

39. Which of the following has density greater than water **[MP PET 1994]**

(a) Li (b) Na

(c) K (d) Rb

40. The reactivity of the alkali metal sodium with water, is made use of **[MP PMT 1994]**

(a) In drying of alcohols

(b) In drying of benzene

(c) In drying of ammonia solution

(d) As a general drying agent

41. Which of the following has smaller size **[RPET 2003]**

(a) H (b) He^+

(c) ${}_1H^2$ (d) Li^{2+}

42. KF combines with HF to form KHF_2. The compound contains the species **[IIT 1996]**

(a) K^+, F^- and H^+ (b) K^+, F^- and HF

(c) K^+ and $[HF_2]^-$ (d) $[KHF]^+$ and F^-

43. Which alkali metal is most metallic in character **[MH CET 2001]**

(a) K (b) Cs

(c) Na (d) Li

44. The property of hydrogen which distinguishes it from other alkali metals is **[MP PET 1996]**

(a) Its electropositive character

(b) Its affinity for non-metals

(c) Its reducing character

(d) Its non-metallic character

45. Which of the following reacts with water with high rate **[AFMC 1995]**

(a) Li (b) K

(c) Na (d) Rb

46. The valence shell electronic configuration of alkali metals is **[MP PET 1996; UPSEAT 2001]**

(a) ns^2np^1 (b) ns^1

(c) $(n-1)p^6ns^2$ (d) $(n-1)d^2ns^2$

47. Alkali metals are **[MP PMT 1996]**

(a) *Li, Na, Be, Mg, Cs* (b) *Li, Na, K, Rb, Cs*

(c) *Na, K, Mg, Ca, Rb* (d) *K, Rb, Cs, Ba, Sr*

48. The atomic number of an element is 11. Its oxide will be **[MP PMT 1996]**

(a) Acidic (b) Basic

(c) Acid and basic both (d) Neutral

49. The commercial production of sodium carbonate is done by **[CPMT 1982; MP PMT 1996]**

(a) Lead-chamber process

(b) Haber's process

(c) Solvay's process

(d) Castner's process

50. Alkali metals are strong reducing because

(a) These are monovalent

(b) Their ionisation potential are very high

(c) Their standard electrode potential are very much negative

(d) These are metals

51. Which of the following statement about $LiCl$ and $NaCl$ is correct **[Kurukshetra CEE 2002]**

(a) $LiCl$ has higher melting point than $NaCl$

(b) $LiCl$ dissolves in water whereas $NaCl$ does not

(c) $LiCl$ would ionize in water more than $NaCl$

(d) Fused $LiCl$ would be less conducting than fused $NaCl$

52. In the Castner's process for the extraction of sodium, the anode is made of.......metal. **[EAMCET 2003]**

(a) Copper (b) Iron

(c) Sodium (d) Nickel

53. Which of the following *s*-block elements forms nitride **[RPET 2003]**

(a) Ba (b) Be

(c) Ca (d) Li

54. Tincal is **[Pb. PMT 2001]**

(a) $Na_2CO_3.10H_2O$ (b) $NaNO_3$

(c) $NaCl$ (d) $Na_2B_4O_7.10H_2O$

55. Which has minimum solubility **[BHU 2003]**

(a) Br_2S_3 (b) Ag_2S

(c) CoS (d) PbS

56. Cryolite helps in **[BHU 2003]**

(a) Lowering the melting point

(b) Increasing the melting point

(c) Increasing the electrical conductivity

(d) Decreasing the electrical conductivity

57. In certain matters lithium differs from other alkali metals, the main reason for this is**[MP PET/PMT 199**

(a) Small size of Li atom and Li^+ ion

(b) Extremely high electropositivity of Li

(c) Greater hardness of Li

(d) Hydration of Li^+ ion

58. Acidified potassium permanganate solution is decolourised by

(a) Bleaching powder (b) Microcosmic salt

(c) Mohr salt (d) White vitriol

59. Which one of the following is used as a disinfectant in water treatment **[NDA 1999]**

(a) Alum (b) Charcoal

(c) Kieselguhr (d) Potassium permanganate

60. Sodium thiosulphate is used in photography **[UPSEAT 1999]**

(a) To convert metallic silver into silver salt

(b) $AgBr$ grain is reduced to non-metallic silver

(c) To remove reduced silver

(d) To remove undecomposed $AgBr$ in the form of $Na_3[Ag[S_2O_3)_2]$ (a complex salt)

61. Composition of borax is **[UPSEAT 2001;04]**

(a) $Na_2B_4O_7.4H_2O$ (b) $Na_2B_4O_7.10H_2O$

(c) $NaBO_2$ (d) Na_2BO_3

62. When sodium dicarbonate is heated strongly for calcined in a kiln, it forms **[CPMT 2000; KCET (Med.) 2000]**

(a) Na (b) Na_2CO_3

(c) $NaCO_3$ (d) $NaHCO_3$

63. The strongest reducing agent is **[MP PET 2001]**

(a) K (b) Al

(c) Mg (d) Br

64. The word 'alkali' is used for alkali metals indicates

[RPMT 1999]

(a) Ash of the plants (b) Metallic nature

(c) Silvery lusture (d) Active metal

65. Potassium nitrate is called **[RPMT 1999]**

(a) Mohr's salt (b) Gypsum

(c) Indian salt petre (d) Chile salt petre

66. Which of the following chemicals, in addition to water, are used for the manufacture of Na_2CO_3 by Solvay process

[Roorkee 1999]

(a) $NaCl, CO$ and NH_3

(b) $NaCl, CO_2$ and NH_3

(c) $NaCl, NH_4Cl$ and CO_2

(d) $NaHCO_3, CO$ and NH_3

67. Which metal forms amide with NH_3 at $300^o C$

[CPMT 1994]

(a) Mg (b) Pb

(c) Al (d) Na

68. When sodium is heated with moist air, then the product obtained is **[AIIMS 1999]**

(a) Na_2O (b) $NaOH$

(c) Na_2CO_3 (d) Na_2O_2

69. An inorganic compound first melts then resolidifies and then liberates a gas. It may be **[DPMT 2002]**

(a) MnO_2 (b) Al_2O_3

(c) $KMnO_4$ (d) $KClO_3$

70. On dissolving moderate amount of sodium metal in liquid NH_3 at low temperature, which one of the following does not occur **[AIIMS 2003]**

(a) Blue coloured solution is obtained

(b) Na^+ ions are formed in the solution

(c) Liquid NH_3 becomes good conductor of electricity

(d) Liquid ammonia remains diamagnetic

71. The solubility of the alkali metal carbonates

[Pune CET 1998]

(a) Increases at first and then decreases

(b) Does not show regular variation

(c) Increases as we go down the group

(d) Decreases as we go down the group

72. Which of the following properties is not true for an alkali metal **[Pune CET 1998]**

(a) Low atomic volume

(b) Low ionization energy

(c) Low density

(d) Low electronegativity

73. Which of the following alkali metals has the biggest tendency for the half reaction, $M(g) \rightarrow M^+(aq) + e^-$ **[DPMT 2001]**

(a) Lithium (b) Sodium

(c) Cesium (d) Potassium

74. Which one of the following metalic hydroxides does not dissolve in sodium hydroxide solution **[KCET (Me**

(a) $Zn(OH)_2$ (b) $Al(OH)_3$

(c) $Fe(OH)_3$ (d) $Pb(OH)_2$

75. Which one of the following on heating will not give CO_2

[NDA 1999; BHU 2000]

(a) $CaCO_3$ (b) Na_2CO_3

(c) $PbCO_3$ (d) Li_2CO_3

76. $NaOH$ is prepared by the method **[AFMC 2005]**

(a) Down's cell (b) Castner cell

(c) Solvay process (d) Castner Kellner cell

77. Sodium gives blue colour with NH_3 solution, this blue colour is due to

[UPSEAT 2000,02; AMU 2002; RPMT 2002]

(a) Ammoniated $Na^{\oplus}$ (b) Ammoniated $Na^{\ominus}$

(c) Ammoniated e^- (d) Na^+ / Na^- pair

78. The strongest reducing agent of the alkali metal is

[CPMT 1999; Pb.CET 2001]

(a) Li (b) Na

(c) K (d) Cs

79. With the increase in atomic weights, melting points of the alkali metals **[MP PMT 1995]**

(a) Increase

(b) Decrease

(c) Remain constant

(d) Do not show definite trend

80. The reaction of water with sodium and potassium is

[BHU 1999]

(a) Exothermic

(b) Endothermic

(c) Reversible

(d) Irreversible and endothermic

81. When potassium ferrocyanide crystals are heated with concentrated sulphuric acid, the gas evolved is **[CBSE PMT PMT 1999; KCET 2000]**

(a) Ammonia (b) Sulphur dioxide
(c) Carbon dioxide (d) Carbon monoxide

82. Characteristic feature of alkali metals is **[RPMT 2000; MP PMT 2004]**

(a) Good conductor of heat and electricity
(b) High melting points
(c) Low oxidation potentials
(d) High ionization potentials

83. A substance X is a compound of an element of group IA the substance X gives a violet colour in flame test, X is **[MP PMT 1980, 85, 86; CPMT 1985; DCE 2000]**

(a) $LiCl$ (b) $NaCl$
(c) KCl (d) None

84. Which of the following alkali metal ions has lowest ionic mobility in aqueous solution **[KCET 2000]**

(a) Rb^+ (b) Cs^+
(c) Li^+ (d) Na^+

85. Lithium shows similarities to magnesium in its chemical behaviour because **[Pb. PMT 2000]**

(a) Similar size, greater electronegativity and similar polarizing power.
(b) Similar size same electronegativity and lower polarizing power
(c) Similar size, same electronegativity and similar high polarizing power
(d) None of these

86. Which one of the following is the most electropositive element **[Pb. PMT 2000]**

(a) Calcium (b) Chlorine
(c) Potassium (d) Carbon

87. Electrolysis of molten sodium chloride leads to the formation of **[KCET 1990]**

(a) Na and H_2 (b) Na and O_2
(c) H_2 and O_2 (d) Na and Cl_2

88. When sodium bicarbonate is heated the product obtained is **[Pb. CET 2000; DCE 2004]**

(a) Na (b) Na_2CO_3
(c) $NaCO_3$ (d) $Na_2(HCO_3)$

89. Which of the following is a use of alum **[CPMT 2004]**

(a) Making explosives (b) Bleaching clothes
(c) Water softening (d) All of the above

90. Which of the following salt does not get hydrolysed in water **[CPMT 2004]**

(a) $KClO_4$ (b) NH_4Cl
(c) CH_3COONa (d) None of these

91. A fire of lithium, sodium and potassium can be extinguished by **[DCE 2003]**

(a) H_2O (b) Nitrogen
(c) CO_2 (d) Asbestos blanket

92. Which of the following metal has stable carbonates **[AFMC 2004]**

(a) Na (b) Mg
(c) Al (d) Si

93. Aluminium reacts with caustic soda to form **[DCE 2004]**

(a) Aluminium hydroxide
(b) Aluminium oxide
(c) Sodium meta-aluminate
(d) Sodium tetra aluminate

94. Alkaline earth metals are denser than alkali metals, because metallic bonding in alkaline earth's metal, is **[BHU 2004]**

(a) Stronger (b) Weaker
(c) Volatile (d) Not present

95. Which of the following is a false statement **[CPMT 2004]**

(a) Fluorine is more electronegative than chlorine
(b) Nitrogen has greater IE_1 than oxygen
(c) Lithium is amphoteric
(d) Chlorine is an oxidising agent

96. Which is most basic in character **[UPSEAT 2004]**

(a) $CsOH$ (b) KOH
(c) $NaOH$ (d) $LiOH$

97. Photoelectric effect is maximum in **[AFMC 2004]**

(a) Cs (b) Na
(c) K (d) Li

98. A metal M reacts with N_2 to give a compound 'A' (M_3N). 'A' on heating at high temperature gives back 'M' and 'A' *on* reacting with H_2O gives a gas 'B'. 'B' turns $CuSO_4$ solution blue on passing through it. A and B can be **[DCE 2003]**

(a) Al and NH_3 (b) Li and NH_3
(c) Na and NH_3 (d) Mg and NH_3

99. A solid compound 'X' on heating gives CO_2 gas and a residue. The residue mixed with water forms 'Y'. On passing an excess of CO_2 through 'Y' in water, a clear solution, 'Z' is obtained. On boiling 'Z', compound 'X' is reformed. The compound 'X' is **[CBSE PMT 2004]**

(a) Na_2CO_3 (b) K_2CO_3
(c) $Ca(HCO_3)_2$ (d) $CaCO_3$

100. mongst $LiCl, RbCl, BeCl_2$ and $MgCl_2$ the compounds with the greatest and least ionic character respectively are

[Pb. CET 2004]

(a) $LiCl$ and $RbCl$ (b) $MgCl_2$ and $BeCl_2$

(c) $RbCl$ and $BeCl_2$ (d) $RbCl$ and $MgCl_2$

101. Salt cake is

(a) Sodium sulphate

(b) Sodium chloride

(c) Sodium bisulphite

(d) Sodium sulphate and Sodium chloride

102. Globar salt is **[BHU 1983; CPMT 1988, 91; IIT 1985; MP PET 2000]**

(a) $MgSO_4.7H_2O$ (b) $CuSO_4.5H_2O$

(c) $FeSO_4.7H_2O$ (d) $Na_2SO_4.10H_2O$

103. The colour given to the flame by sodium salts is **[CPMT 1980; MP PET 1986]**

(a) Light red (b) Golden yellow

(c) Green (d) Pink

104. Solvay's process is used for the preparation of **[CPMT 1982; AIIMS 1987]**

(a) Ammonia (b) Sodium bicarbonate

(c) Sodium carbonate (d) Calcium carbonate

105. Sodium when heated in a current of dry ammonia gives **[NCERT 1981; KCET 2000]**

(a) Sodium nitrite (b) Sodium hydride

(c) Sodium amide (d) Sodium azide

106. Washing soda is **[CPMT 1982; DPMT 1982; CBSE PMT 1990; MP PMT 1987, 96]**

(a) $Na_2CO_3.10H_2O$ (b) $Na_2CO_3.H_2O$

(c) $Na_2CO_3.5H_2O$ (d) Na_2CO_3

107. The substance used to decolourise and purify oils is **[MP PMT 1987]**

(a) Sodium carbonate (b) Sodium chloride

(c) Sodium hydroxide (d) Sodium sulphate

108. The main salt soluble in sea water is**[MP PMT 1998]**

(a) $MgCl_2$ (b) $NaCl$

(c) $MgSO_4$ (d) $CaSO_4$

109. The metallic lustre exhibited by sodium is explained by **[IIT 1987]**

(a) Diffusion of sodium ions

(b) Oscillation of loose electrons

(c) Excitation of free protons

(d) Existence of body centred cubic lattice

110. The metal which reacts with water at room temperature is **[CPMT 1985; MP PMT 1996; MP PET 1998]**

(a) Copper (b) Iron

(c) Magnesium (d) Sodium

111. When $NaCl$ is dissolved in water, the sodium ion is **[CPMT 1989]**

(a) Oxidised (b) Reduced

(c) Hydrolysed (d) Hydrated

112. Sodium metal cannot be stored under **[CPMT 1985, 88, 94]**

(a) Benzene (b) Kerosene

(c) Alcohol (d) Toluene

113. Causticization process is used for the preparation of **[CPMT 1985; BHU 1986]**

(a) Caustic soda (b) Caustic potash

(c) Baryta (d) Slaked lime

114. When CO is passed over solid $NaOH$ heated to 200^oC, it forms **[MP PMT 1985]**

(a) Na_2CO_3 (b) $NaHCO_3$

(c) $HCOONa$ (d) None

115. $NaOH$ is manufactured by electrolysis of brine solution. The products of the reaction are**[KCET 1990]**

(a) Cl_2 and H_2 (b) Cl_2 and $Na-Hg$

(c) Cl_2 and Na (d) Cl_2 and O_2

116. Sodium carbonate is manufactured by Solvay process, the products that are recycled are**[KCET 1993; DC**

(a) CO_2 and NH_3 (b) CO_2 and NH_4Cl

(c) $NaCl, CaO$ (d) $CaCl_2, CaO$

117. The useful bye-products, obtained in the Solvay process of manufacturing sodium carbonate, are**[KCET 198**

(a) Quick lime and CO_2

(b) $NaHCO_3$ and NH_4Cl

(c) NH_4Cl solution and quick lime

(d) $NaHCO_3$ and CO_2

118. In the preparation of sodium carbonate, which of the following is used **[AFMC 1992]**

(a) Slaked lime (b) Quick lime

(c) Lime stone (d) $NaOH$

119. When $NaOH$ crystals are left in open air, they acquire a fluid layer around each crystal as**[CPMT 1974]**

(a) They start melting

(b) They absorb moisture from air

(c) They react with air to form a liquid compound

(d) They absorb CO_2 from air

120. Sodium carbonate reacts with SO_2 in aqueous medium to give **[MP PMT 1982, 85]**

(a) $NaHSO_3$ (b) Na_2SO_3

(c) $NaHSO_4$ (d) Na_2SO_4

121. Baking soda is **[CPMT 1974, 78, 79, 91; BHU 1979; Manipal MEE 1995; AIIMS 1996; CPMT 1973; RPET 1999; AFMC 2001, 05; Pb. CET 2002]**

(a) Na_2CO_3 (b) $NaHCO_3$

(c) Na_2SO_4 (d) K_2CO_3

122. Soda ash is **[KCET 1993]**

(a) $Na_2CO_3.H_2O$ (b) $NaOH$

(c) Na_2CO_3 (d) $NaHCO_3$

123. Soda lime is **[KCET 1993]**

(a) $NaOH$ (b) CaO

(c) $NaOH$ and CaO (d) Na_2CO_3

124. Molten sodium is used in nuclear reactors to**[KCET 1989]**

(a) Absorb neutrons in order to control the chain reaction

(b) Slow down the fast neutrons

(c) Absorb the heat generated by nuclear fission

(d) Extract radio-isotopes produced in the reactor

125. Squashes are stored by adding **[AFMC 1989]**

(a) Citric acid (b) KCl

(c) Na_2SO_3 (d) Sodium metabisulphite

126. Sodium thiosulphate $(Na_2S_2O_3.5H_2O)$ is used in photography to **[CPMT 1972, 74, 79; DPMT 1983; Bihar CEE 1995; MNR 1995]**

(a) Reduce silver bromide to metallic silver

(b) Convert metallic silver to silver salt

(c) Remove undecomposed $AgBr$ as a soluble silver thiosulphate complex

(d) Remove unreduced silver

127. Which of the following pair can't exist in solution **[IIT 1986; DCE 1999]**

(a) $NaHCO_3$ and $NaOH$ (b) Na_2CO_3 and $NaOH$

(c) Na_2CO_3 and $NaCl$ (d) $NaHCO_3$ and $NaCl$

128. Sodium thiosulphate is prepared by **[IIT 1996]**

(a) Reducing Na_2SO_4 solution with H_2S

(b) Boiling Na_2SO_3 solution with S in alkaline medium

(c) Neutralising $H_2S_2O_3$ solution with $NaOH$

(d) Boiling Na_2SO_3 solution with S in acidic medium

129. When $NaOH$ is prepared, the gas released is**[CPMT 1996]**

(a) Cl_2 (b) H_2

(c) O_2 (d) H_2O

130. What is lye **[BHU 1997]**

(a) 10% solution of $NaCl$

(b) 10% solution of KOH

(c) 10% solution of $Ca(OH)_2$

(d) 10% solution of Na_2CO_3

131. Na imparts yellow colour to Bunsen flame because of **[RPMT 1997]**

(a) Low ionisation potential

(b) Sensitivity

(c) Sublimation

(d) Absorbed high radiation

132. Sn is dissolved in excess of $NaOH$ solution, the compound obtained is **[RPMT 1997]**

(a) $Sn(OH)_2$ (b) Na_2SnO_3

(c) Na_2SnO_2 (d) SnO_2

133. Identify the correct statement **[CPMT 1997]**

(a) Elemental sodium can be prepared and isolated by electrolysing an aqueous solution of sodium chloride

(b) Elemental sodium is a strong oxidizing agent

(c) Elemental sodium is insoluble in ammonia

(d) Elemental sodium is easily oxidized

134. Calcium is obtained by **[CBSE PMT 1997]**

(a) Roasting of limestone

(b) Electrolysis of solution of calcium chloride in H_2O

(c) Reduction of calcium chloride with carbon

(d) Electrolysis of molten anhydrous calcium chloride

135. When sodium chloride solution is electrolysed, the gas that is liberated at the cathode is**[Kurukshetra CEE**

(a) Oxygen (b) Hydrogen

(c) Chlorine (d) Air

136. During the electrolysis of fused sodium chloride, the anodic reaction is **[KCET 1998]**

(a) Reduction of sodium ions

(b) Oxidation of sodium ions

(c) Reduction of chloride ions

(d) Oxidation of chloride ions

137. Which of the following does not participate in the Solvey's process for the manufacture of Na_2CO_3 **[EAMCET**

(a) NH_3 (b) $NaCl$ solution

(c) CO_2 (d) H_2SO_4

138. The colour of the precipitate produced by adding $NaOH$ solution to $HgCl_2$ is **[KCET 1998]**

(a) Yellow (b) Black

(c) Brown (d) White

139. The cell used for the electrolysis of fused $NaCl$ is **[AFMC 1999; Kerala (Mea.) 2002]**

(a) Down's cell (b) Castner cell

(c) Solvay cell (d) Nelson cell

140. Slaked lime $[Ca(OH)_2]$ is used in the manufacture **[UPSEAT 2000]**

(a) Cement (b) Fire bricks

(c) Pigment (d) Medicine

141. The alum used for purifying water is **[KCET (Med.) 2001]**

(a) Ferric alum (b) Chrome alum

(c) Potash alum (d) Ammonium alum

142. Which one of the following metalic hydroxides does not dissolve in sodium hydroxide solution**[KCET (Med.) 2001]**

(a) $Zn(OH)_2$ (b) $Al(OH)_3$

(c) $Fe(OH)_3$ (d) $Pb(OH)_2$

143. In which of the following processes, fused sodium hydroxide is electrolysed at a $330^\circ C$ temperature for extraction of sodium **[CBSE PMT 2000; AFMC 2001]**

(a) Castner's process (b) Down's process

(c) Cyanide process (d) Both (b) and (c)

144. Excess of Na^+ ions in our system causes **[KCET (Med.) 2001]**

(a) High B.P. (b) Low B.P.

(c) Diabetes (d) Anaemia

145. Ferric alum has the composition $(NH_4)_2SO_4.Fe_2(SO_4)_3.xH_2O$ **[Orissa JEE 2002]**

(a) 7 (b) 24

(c) 6 (d) 15

146. If Na is heated in presence of air, it forms **[AFMC 2002]**

(a) Na_2CO_3 (b) Na_2O_2

(c) Na_2O (d) Both (b) and (c)

147. Which of the following is most reducing agent**[RPMT 2002]**

(a) HNO_3 (b) Na

(c) Cl_2 (d) Cr

148. Pyrolusite is **[DPMT 2002]**

(a) Carbonate ore (b) Sulphur ore

(c) Silicon ore (d) None of these

149. In the manufacture of metallic sodium by the fused salt electrolysis (Down's process) a small amount of calcium chloride is added to**[MP PET 1993; MP PMT 1994]**

(a) Improve the electrical conduction

(b) Increase the temperature of electrolysis

(c) Bring down the melt temperature

(d) Stabilize the metallic sodium

150. Sodium metal is extracted by **[MP PMT 1996]**

(a) Electrolysis of aqueous solution of sodium chloride

(b) Electrolysis of fused sodium chloride

(c) Heating sodium oxide with carbon

(d) Heating sodium oxide with hydrogen

Alkaline earth metals

1. To remove last traces of water from alcohol, the metal used is

(a) Sodium (b) Potassium

(c) Calcium (d) Aluminium

2. **Plaster of Paris** is

[CPMT 1972, 76, 78, 83, 87, 88, 90, 91, 93, 94; JIPMER 2002; MP PET 1986, 2001; BHU 1992, 95, 2000; MNR 1982; DCE 2000; Manipal MEE 1995; NCERT 1976; Bihar MEE 1997; EAMCET 1978; AMU 1982, 84; DPMT 1982, 83]

(a) $CaSO_4.2H_2O$ (b) $CaSO_4.3H_2O$

(c) $CaSO_4.H_2O$ (d) $CaSO_4.\frac{1}{2}H_2O$

3. Which of the following substance is used as dehydrating agent in laboratory **[MP PMT 1987]**

(a) Calcium chloride (b) Sodium chloride

(c) Sodium carbonate (d) Potassium nitrate

4. The metal that is extracted from sea water is **[EAMCET 1978; CPMT 1988; CET Pune 1998; MP PET 2000]**

(a) Ba (b) Mg

(c) Ca (d) Sr

5. Which of the following ore contains both magnesium and calcium **[MDAT Bihar 1984; MP PET 2003]**

(a) Magnesite (b) Dolomite

(c) Carnellite (d) Phosphorite

6. Epsom salt is **[EAMCET 1978, 80; BHU 1979; MP PET 1999; CPMT 1988, 89, 90; Bihar MEE 1996]**

(a) $CaSO_4.2H_2O$ (b) $BaSO_4.2H_2O$

(c) $MgSO_4.2H_2O$ (d) $MgSO_4.7H_2O$

7. Setting of plaster of paris is**[MP PMT 1985; CPMT 1989]**

(a) Oxidation with atmospheric oxygen

(b) Combination with atmospheric CO_2

(c) Dehydration

(d) Hydration to yield another hydrate

8. To prevent magnesium from oxidation in electrolytic extraction process

(a) Some calcium fluoride is added

(b) Some chlorides are added

(c) Metal is taken out by spoons

(d) The whole process is done in an atmosphere of coal gas

9. Which of the following metal is found in green colouring pigment chlorophyll of plants **[KCET 1993; RPMT 1999; MP PET 2002]**

(a) Fe (b) Mg

(c) Na (d) Al

10. Which of the following metal carbonate is decomposed on heating **[MNR 1985; MP PET 1994; Pb. CET 2**

(a) $MgCO_3$ (b) Na_2CO_3

(c) K_2CO_3 (d) Rb_2CO_3

11. The outer electronic configuration of alkaline earth metal is

[BHU 1980; CPMT 1985, 93; MP PAT 1993]

(a) ns^2 (b) ns^1

(c) np^6 (d) nd^{10}

12. Metallic magnesium is prepared by

(a) Reduction of MgO by coke

(b) Electrolysis of aqueous solution of $Mg(NO_3)$

(c) Displacement of Mg by iron from $MgSO_4$ solution

(d) Electrolysis of molten $MgCl_2$

13. Of the metals Be, Mg, Ca and Sr of group II A. In the periodic table the least ionic chloride would be formed by

[NCERT 1980; CPMT 1980]

(a) Be (b) Mg

(c) Ca (d) Sr

14. Which one of the following is fluorspar

(a) CaF_2 (b) CaO

(c) H_2F_2 (d) $CaCO_3$

15. Which one is known as barytes **[CPMT 1987]**

(a) $BaSO_4$ (b) $BaCl_2.2H_2O$

(c) BaO (d) $BaCO_3$

16. Which of the following sulphates have the highest solubility in water **[EAMCET 1980,84,85; MP PMT 1994; Kurukshetra CEE 1998; AFMC 1990; MP PET 1994]**

(a) $MgSO_4$ (b) $BaSO_4$

(c) $CaSO_4$ (d) $BeSO_4$

17. The composition formulae of gypsum is

[CPMT 1975, 78, 82; DPMT 1982; IIT 1978; MNR 1981; MP PMT 1996; RPMT 1997]

(a) $(CaSO_4)_2.H_2O$ (b) $2CaSO_4$

(c) $CaSO_4.2H_2O$ (d) $2CaSO_4.H_2O$

18. Mortar is a mixture of **[EAMCET 1998; AIIMS 2000]**

(a) $CaCO_3$, sand and water

(b) Slaked lime and water

(c) Slaked lime, sand and water

(d) $CaCO_3$ and CaO

19. Gypsum $CaSO_4.2H_2O$ on heating to about $120^{o}C$ forms a compound which has the chemical composition represented by **[CPMT 1978, 82, 88, 90; EAMCET 1978; DPMT 1982, 83; NCERT 1979]**

(a) $CaSO_4$ (b) $2CaSO_4.H_2O$

(c) $CaSO_4.H_2O$ (d) $2CaSO_4.3H_2O$

20. The highly efficient method of obtaining beryllium is

[NCERT 1982]

(a) Dissociation of beryllium carbide

(b) Electrolysis of fused beryllium chloride

(c) Reduction of beryllium oxide with carbon

(d) Reduction of beryllium halide with magnesium **[BHU 1973, 77]**

21. Mark the incorrect statement

(a) Lithopone is cheap and possess good covering power

(b) Lithopone is yellow pigment

(c) Lithopone is prepared by mixing barium sulphide and zinc sulphate

(d) Lithopone is a mixture of barium sulphate and zinc sulphide

22. Pure anhydrous $MgCl_2$ can be prepared from the hydrated salt by **[CPMT 1986; MP PMT 1989]**

(a) Heating the hydrate with coke

(b) Heating the hydrate with Mg ribbon

(c) Melting the hydrate

(d) Heating the hydrate to red heat in an atmosphere of HCl gas

23. Bleaching powder is obtained by the interaction of chlorine and **[CPMT 1972, 78, 89; 2002; DPMT 1983]**

(a) Conc. solution of $Ca(OH)_2$

(b) Dilute solution of $Ca(OH)_2$

(c) Dry calcium oxide

(d) Dry slaked lime

24. Deep pink colour is given to flame by the salts of

(a) Strontium (b) Potassium

(c) Zinc (d) Barium

25. Calcium salts give which colour when put in a flame

(a) Brick red (b) Green

(c) White (d) Pink

26. Phosphine is obtained from the following ore

[Roorkee 1995]

(a) Calcium superphosphite (b) Calcium phosphide

(c) Potassium phosphide (d) Calcium hypophosphide

27. Calcium is obtained by

[DPMT 1980; IIT 1980; CPMT 1996; AIIMS 2001]

(a) Roasting of lime stone

(b) Reduction of $CaCl_2$ with carbon

(c) Electrolysis of a solution of $CaCl_2$ in water

(d) Electrolysis of molten $CaCl_2$

28. Which element possesses biggest atomic radii

(a) P (b) Si

(c) Al (d) Mg

29. Magnesia is

(a) $MgCO_3$ (b) MgO
(c) $MgSO_4$ (d) $MgCl_2$

30. Mixture of $MgCl_2$ and MgO is called **[DPMT 1984]**
(a) Double salt (b) Sorrel cement
(c) Portland cement (d) None of these

31. Lithopone is **[AFMC 1992; BHU 1983, 86, 95; JIPMER 1999; RPET/PMT 1999]**
(a) $BaO + ZnSO_4$ (b) $ZnO + BaSO_4$
(c) $BaS + ZnSO_4$ (d) $ZnS + BaSO_4$

32. For bleaching powder, which is incorrect **[EAMCET 1984; CPMT 1985]**
(a) Reacts with dilute acid to release chlorine
(b) Oxidising agent
(c) Light yellow coloured powder
(d) Highly soluble in water

33. Bleaching powder is a compound having the molecular formula **[CPMT 1986, 89, 90, 93; MP PMT 1996; BHU 2005]**
(a) $CaOCl_3$ (b) $CaOCl_2$
(c) $CaClO$ (d) $CaClO_3$

34. Calcium cynamide is **[CPMT 1986, 93]**
(a) $CaCHNH_2$ (b) $CaCN_2$
(c) CaC_2N_2 (d) $Ca(CN)_2$

35. Which one of the following is a true peroxide **[RPET 1999; CPMT 1981; Roorkee 1995]**
(a) SO_2 (b) BaO_2
(c) MnO_2 (d) NO_2

36. Which of the following is not a water absorber and dehydrating substance**[CBSE 1989; JIPMER 2002]**
(a) Silica gel (b) P_2O_5
(c) Conc. H_2SO_4 (d) Aqueous $CaCl_2$

37. The dark red colour of bombs in fireworks is due to the presence of **[Roorkee 1989; DPMT 2001 MP PMT 1985; AFMC 1989; Roorkee 1989]**
(a) Na (b) Ba
(c) Sr (d) K

38. The most electropositive amongst the alkaline earth metals is **[MP PMT 1993]**
(a) Beryllium (b) Magnesium
(c) Calcium (d) Barium

39. Which of the following salts is insoluble in water at room temperature but soluble in boiling water**[MP PMT 1993]**
(a) $CaCl_2$ (b) $BaCl_2$
(c) $SrCl_2$ (d) $PbCl_2$

40. Electronegativity of beryllium is approximately equal to that of **[MP PMT 1993]**
(a) Aluminium (b) Boron
(c) Magnesium (d) Sodium

41. The right order of the solubility of sulphates of alkaline earth metals in water is **[MP PET 1993; Pb. CET 2000; DPMT 2004]**
(a) $Be > Ca > Mg > Ba > Sr$
(b) $Mg > Be > Ba > Ca > Sr$
(c) $Be > Mg > Ca > Sr > Ba$
(d) $Mg > Ca > Ba > Be > Sr$

42. Which of the following has highest electrode potential **[CPMT 1990]**
(a) Be (b) Mg
(c) Ca (d) Ba

43. The alkaline earth metals Ba, Sr, Ca and Mg may be arranged in the order of their decreasing first ionisation potential as
(a) $Mg, Ca, Sr, Ba,$ (b) Ca, Sr, Ba, Mg
(c) Sr, Ba, Mg, Ca (d) $Ba, Mg, Ca, Sr,$

44. Which of the following alkaline earth metals shows some properties similar to aluminium**[BHU 1983]**
(a) Be (b) Ca
(c) Sr (d) Ba

45. Which of the following ions forms highly soluble hydroxide in water **[CPMT 1974, 76, 79, 82]**
(a) K^+ (b) Zn^{++}
(c) Al^{+++} (d) Ca^{++}

46. Sodium sulphate is soluble in water whereas barium sulphate is sparingly soluble because **[IITJEE 1989**
(a) The hydration energy of Na_2SO_4 is less than its lattice energy
(b) The hydration energy of Na_2SO_4 is more than its lattice energy
(c) The lattice energy of $BaSO_4$ is more than its hydration energy
(d) The lattice energy has no role to play in solubility

47. Which one of the following is most basic **[CPMT 1977, 83]**
(a) Al_2O_3 (b) MgO
(c) SiO_2 (d) P_2O_5

48. Alloys of ...... metal are light and strong and so are used in the manufacture of aeroplane parts**[EAMCET 1**
(a) Cr (b) Sn
(c) Fe (d) Mg

49. In India at the occasion of marriages, the fire works used give green flame. Which one of the following radicals may be present**[CPMT 1980; AFMC 1989; MP PET 2002]**
(a) Na (b) K

(c) Ba (d) Ca

50. $CaCO_3 \rightleftharpoons CaO + CO_2$ reaction in a line goes to completion because **[AFMC 2005]**

(a) CaO does not react to CO_2 to give $CaCO_3$

(b) Backward reaction is very slow

(c) CO_2 formed escapes out

(d) None of these

51. The wire of flash bulb is made of **[CPMT 1988]**

(a) Mg (b) Cu

(c) Ba (d) Ag

52. Bone ash contains **[KCET 1992]**

(a) CaO (b) $CaSO_4$

(c) $Ca_3(PO_4)_2$ (d) $Ca(H_2PO_4)_2$

53. A substance absorbs CO_2 and violently reacts with water. That substance is

(a) $CaCO_3$ (b) CaO

(c) H_2SO_4 (d) ZnO

54. Setting of cement is an **[DPMT 1984]**

(a) Exothermic reaction

(b) Endothermic reaction

(c) Neither exothermic nor endothermic

(d) None of these

55. Which is quick lime **[EAMCET 1993]**

(a) $Ca(OH)_2$ (b) CaO

(c) $CaCO_3$ (d) $Ca(OH)_2 + H_2O$

56. A major constituent of portland cement except lime is

[CPMT 1982]

(a) Silica (b) Alumina

(c) Iron oxide (d) Magnesia

57. Portland cement is manufactured by using **[CPMT 1986]**

(a) Lime stone, clay and sand

(b) Lime stone, gypsum and sand

(c) Lime stone, gypsum and alumina

(d) Lime stone, clay and gypsum

58. Identify the correct statement **[CBSE PMT 1995]**

(a) Gypsum contains a lower percentage of plaster of calcium than plaster of paris

(b) Gypsum is obtained by heating plaster of paris

(c) Plaster of paris can be obtained by hydration of gypsum

(d) Plaster of paris is obtained by partial oxidation of gypsum

59. Which of the following decreases on going gradually from Be to Ba (in periodic table)

(a) Basic character of hydroxides

(b) Solubility of sulphates in water

(c) Solubility of hydroxides in water

(d) Strength of elements as reducing agent

60. Alkaline earth metals are **[MP PMT 1996]**

(a) Li, Be, K, Mg, Ca (b) Be, Mg, Ca, Sr, Ba

(c) Be, K, Mg, Ca, Sr (d) Be, Mg, Ca, K, Rb

61. Which of the following substances is used in the laboratory for fast drying of neutral gases **[AIIMS 1998; AF**

(a) Sodium phosphate

(b) Phosphorus pentoxide

(c) Sodium sulphate

(d) Anhydrous calcium chloride

62. Which of the following can be represented by the configuration $[Kr]5s^2$? **[MP PMT 1997]**

(a) Ca (b) Sr

(c) Ba (d) Ra

63. Point out the incorrect statement regarding Be (Group-IIA)

[MP PMT 1997]

(a) It forms an ionic carbide

[AFMC 1988]

(b) Its carbonate decomposes on heating

(c) Its halides are covalent

(d) It is easily attacked by water

64. Beryllium differs from rest of the members of its family (Group-IIA) in many ways. The reason for this is its

[MP PMT 1997]

(a) Small size and higher electronegativity

(b) Small size and lower electronegativity

(c) Large size and lower ionisation energy

(d) Large size and largest ionic radius

65. The oxide, which is best soluble in H_2O is **[BHU 2001]**

(a) $Ba(OH)_2$ (b) $Mg(OH)_2$

(c) $Sr(OH)_2$ (d) $Ca(OH)_2$

66. The property of the alkaline earth metals that increases with their atomic number is **[BHU 2001]**

(a) Ionisation energy

(b) Electronegativity

(c) Solubility of their sulphates

(d) Solubility of their hydroxides

67. In the Alkaline earth metals, the element forming predominantly covalent compound is **[BHU 2001]**

(a) Be (b) Mg

(c) Sr (d) Ca

68. A mixture of lime paste is sand, water and **[RPMT 1997]**

(a) Gypsum (b) Slacked lime

(c) Quick lime (d) Lime stone

69. The formula for calcium chlorite is **[CBSE PMT 1994, 96]**

(a) $Ca(ClO_4)_2$ (b) $Ca(ClO_3)_2$

(c) $CaClO_2$ (d) $Ca(ClO_2)_2$

70. Which pair of substances gives same gaseous product, when these react with water **[CBSE PMT 1994]**

(a) Ca and CaH_2 (b) Na and Na_2O_2

(c) K and KO_2 (d) Ba and BaO_2

71. Magnesium does not decompose the **[AFMC 1999]**

(a) Steam (b) Hot water

(c) Cold Water (d) Semi hot water

72. Alkaline earth metals are denser than alkali metals because metallic bonding is

(a) Stronger (b) Weaker

(c) Not present (d) Volatile

73. Property of the alkaline earth metals that increases with their atomic number is **[IIT 1997]**

(a) Ionisation energy

(b) Solubility of their hydroxides

(c) Solubility of their sulphates

(d) Electronegativity

74. A metal is burnt in air and the ash on moistening smells of NH_3. The metal is

(a) Na (b) Fe

(c) Mg (d) Al

75. Alkaline earth metals come under **[Bihar MEE 1996]**

(a) Halogens (b) Representative elements

(c) Transition elements (d) Inner transition elements

(e) None of these

76. Which of the following alkaline-earth metal hydroxides is the strongest base **[CPMT 1996]**

(a) $Be(OH)_2$ (b) $Mg(OH)_2$

(c) $Ca(OH)_2$ (d) $Ba(OH)_2$

77. Which one of the following is the strongest base **[Pb. PMT 1998]**

(a) $Be(OH)_2$ (b) $Mg(OH)_2$

(c) $Al(OH)_3$ (d) $Si(OH)_4$

78. Lime stone is **[RPMT 1997]**

(a) CaO (b) $Ca(OH)_2$

(c) Both (a) and (b) (d) None of these

79. Which of the alkaline earth metals is strongest reducing agent **[MP PMT 1995]**

(a) Ca (b) Sr

(c) Ba (d) Mg

80. Plaster of paris hardens by **[CPMT 1994]**

(a) Giving off CO_2 (b) Changing into $CaCO_3$

(c) Uniting with water (d) Giving out water

81. Which is not soluble in water **[CPMT 1994]**

(a) $CaCO_3$ (b) $BaCO_3$

(c) $SrCO_3$ (d) All of these

82. The correct order of the increasing ionic character is **[MNR 1991; AFMC 1998]**

(a) $BeCl_2 < MgCl_2 < CaCl_2 < BaCl_2$

(b) $BeCl_2 < MgCl_2 < BaCl_2 < CaCl_2$

(c) $BeCl_2 < BaCl_2 < MgCl_2 < CaCl_2$

(d) $BaCl_2 < CaCl_2 < MgCl_2 < BeCl_2$

83. $MgCl_2.6H_2O$ when heated gives **[CPMT 1997]**

[AIIMS 1999]

(a) Magnesium oxychloride

(b) Magnesium dichloride

(c) Magnesium oxide

(d) Magnesium chloride

84. Which of the following hydroxide is insoluble in water **[AIIMS 2001]**

(a) $Be(OH)_2$ (b) $Mg(OH)_2$

(c) $Ca(OH)_2$ (d) $Ba(OH)_2$

85. Which of the following statements is false **[BHU 2005]**

[KCET 1996]

(a) $CaOCl_2$ gives OH^-, Cl^- and OCl^- in aqueous solution

(b) Diamond and graphite are allotrops of carbon

(c) Bleaching action of Cl_2 in moist condition is not permanent

(d) Calomel is Hg_2Cl_2

86. A metal M readily forms its sulphate MSO_4 which is water-soluble. It forms its oxide MO which becomes inert on heating. It forms its insoluble hydroxide $M(OH)_2$ which is soluble in $NaOH$ solution. Then M is **[AIEEE 2002]**

(a) Mg (b) Ba

(c) Ca (d) Be

87. In the lime (kiln), the reaction $CaCO_3(s) \rightarrow CO_2(g)$ goes to completion because **[Kerala (Engg.) 2002]**

(a) Of high temperature

(b) CaO is more stable than $CaCO_3$

(c) CO_2 escapes simultaneously

(d) CaO is not dissociated

88. The ionic compound $BaSO_4$ is insoluble in water due to **[CPMT 1999]**

(a) High lattice energy (b) Low lattice energy

(c) Low hydration energy (d) Both (a) and (c)

89. which is used to reduced the acidity of soil **[DPMT 2001]**

(a) Calcium hydroxide (b) Ammonium sulphate

(c) Ammonium nitrate (d) Ammonium chloride

90. Alkaline earth metals belong to the **[KCET (Med.) 2001]**

(a) $s-$ block in periodic table

(b) $p-$ block in periodic table

(c) $d-$ block in periodic table

(d) $f-$ block in periodic table

91. The element having atomic number 56 belongs to **[AFMC 2002]**

(a) Actinides (b) Alkaline earth metals
(c) Transition series (d) Lanthanides

92. The thermal stability of alkaline earth metal carbonates $MgCO_3, CaCO_3$, $BaCO_3$ and $SrCO_3$ decreases as **[MP PMT 2002]**

(a) $CaCO_3 > SrCO_3 > MgCO_3 > BaCO_3$
(b) $BaCO_3 > SrCO_3 > MgCO_3 > CaCO_3$
(c) $BaCO_3 > SrCO_3 > CaCO_3 > MgCO_3$
(d) $MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$

93. A certain metal M is used to prepare an antacid, which is used as a medicine in acidity. This metal accidently catches fire which can not be put out by using CO_2 based extinguishers. The metal M is

(a) Ca (b) C
(c) Mg (d) All of these

94. $Be(OH)_2$ is insoluble in water while $Ba(OH)_2$ is highly soluble due to **[AMU 2002]**

(a) Bond order (b) Lattice energy difference
(c) Common ion effect (d) Hard acid

95. Which of the following gives a green colour to flame **[AFMC 2001]**

(a) Barium (b) Calcium
(c) Strontium (d) None of these

96. Sparingly soluble salt is **[RPMT 1999]**

(a) KCl (b) $NaCl$
(c) NH_4Cl (d) $BaSO_4$

97. Among the alkaline earth metals the element forming predominantly covalent compound is **[MP PET 1999]**

(a) Barium (b) Strontium
(c) Calcium (d) Berylium

98. Peroxide bond is present in **[RPET 2003]**

(a) MgO (b) CaO
(c) Li_2O (d) BaO_2

99. Least ionic character is found in **[CPMT 1993]**

(a) Mg (b) Sr
(c) Ca (d) Ra

100. The number of water molecules in gypsum and plaster of paris respectively are

(a) 1/2 and 2 (b) 2 and 1/2
(c) 2 and 1 (d) 5 and 2

101. Which of the following is formed when calcium combines with oxygen **[MH CET 2000]**

(a) Ca (b) CaO
(c) CaO_2 (d) Ca_2O_2

102. Slow acting nitrogenous fertilizer among the following is **[DCE 2003]**

(a) NH_2CONH_2 (b) NH_4NO_3
(c) $CaNCN$ (d) KNO_3

103. Plaster of paris is used **[Pb. CET 2000; CPMT 2000]**

(a) In surgery and dentistry
(b) As a white wash
(c) As a constituent of tooth paste
(d) For the preparation of RCC

104. Iron pipes lying under acidic soil are often attached to blocks of magnesium for protection from rusting. Magnesium offers protection to iron against corrosion because it **[DPMT 2004; BHU 2004]**

(a) Prevents air from reaching the surface of iron
(b) is more readily converted into positive ions **[BHU 2002]**
(c) Is higher than iron
(d) Forms a corrosion-resistance alloy with iron

105. Among $K, Ca, Fe,$ and Zn, the element which can form more than one binary compound with chlorine is **[CBSE PMT 2004]**

(a) K (b) Ca
(c) Fe (d) Zn

106. Li shows the diagonal relationship with **[Pb.CET 2001]**

(a) Mg (b) B
(c) Al (d) C

107. A sodium salt on treatment with $MgCl_2$ gives white precipitate only on heating. The anion of the sodium salt is **[IIT JEE Screening 2004]**

(a) HCO_3^- (b) CO_3^{2-}
(c) NO_3^- (d) SO_4^{2-}

108. $MgCl_2.6H_2O$. When heated gives **[MHCET 2003]**

(a) Magnesium oxide
(b) Magnesium oxychloride
(c) Magnesium dichloride
(d) Magnesium chloride

109. Mg burns in CO to produce **[Pb.PMT 2001]**

(a) MgO_2 (b) $MgCO_3$
(c) $MgO + CO$ (d) $MgO + C$

110. Sorel's cement is **[Pb. PMT 1999]** **[Pb.CET 2003]**

(a) Portland cement $+MgO$
(b) $MgCl_2.CaSiO_3.2H_2O$
(c) $CaSiO_3.MgCO_3$
(d) $MgCl_2.5MgO.xH_2O$

111. Colemnite is **[AFMC 2004]**

(a) $Ca[B_3O_4(OH)_2].2H_2O$
(b) $Ca_2B_6O_{11}.5H_2O$
(c) $Ca(OH)_2$

(d) $Na_2B_4O_7.2H_2O$

Boron family

1. Which of the following statements about H_3BO_3 is not correct **[CBSE PMT 1994]**

(a) It is a strong tribasic acid

(b) It is prepared by acidifying an aqueous solution of borax

(c) It has a layer structure in which planar BO_3 units are joined by hydrogen bonds

(d) It does not act as proton donor but acts as a Lewis acid by accepting hydroxyl ion

2. The type of hybridisation of boron in diborane is **[CPMT 1999]**

(a) *sp*-hybridisation

(b) sp^2 - hybridisation

(c) sp^3 - hybridisation

(d) sp^3d^2 - hybridisation

3. In the reaction $B_2O_3 + C + Cl_2 \rightarrow A + CO.$ The A is **[Pb. PMT 2000]**

(a) BCl_3 (b) BCl_2

(c) B_2Cl_2 (d) CCl_2

4. The molecular formula of felspar is **[MP PMT 2003]**

(a) $K_2O.Al_2O_3.6SiO_2$ (b) $K_2O.3Al_2O_3.6SiO_2$

(c) Na_3AlF_6 (d) $CaSO_4.2H_2O$

5. The most acidic of the following compounds is **[Bihar CEE 1995]**

(a) P_2O_3 (b) Sb_2O_3

(c) B_2O_3 (d) As_2O_3

6. Identify the statement that is not correct as far as structure of diborane is concerned **[Pb. PMT 1998]**

(a) There are two bridging hydrogen atoms in diborane

(b) Each boron atom forms four bonds in diborane

(c) The hydrogen atoms are not in the same plane in diborane

(d) All B - H bonds in diborane are similar

7. Soft heavy metal melts at 30^oC and is used in making heat sensitive thermometers the metal is **[RPET 2000]**

(a) Galium (b) Sodium

(c) Potassium (d) Caesium

8. Which of the following is formed when aluminium oxide and carbon is strongly heated in dry chlorine gas **[AFMC 2000]**

(a) Aluminium chloride

(b) Hydrate aluminium chloride

(c) Anhydrous aluminium chloride

(d) None of these

9. Which metal burn in air at high temperature with the evolution of much heat

(a) Cu (b) Hg

(c) Pb (d) Al

10. Aluminium hydroxide is soluble in excess of sodium hydroxide forming the ion **[AMU 2001]**

(a) AlO_2^{+3} (b) AlO_2^{-3}

(c) AlO_2^- (d) AlO_3^-

11. Boron form covalent compound due to **[Pb. PMT 2000]**

(a) Higher ionization energy

(b) Lower ionization energy

(c) Small size

(d) Both (a) and (c)

12. In diborane, the two $H - B - H$ angles are nearly **[AIIMS 2005]**

(a) 60°, 120° (b) 95°, 120°

(c) 95°, 150° (d) 120°, 180°

13. Which of the following is a non-metal **[MP PMT 1999]**

(a) Gallium (b) Indium

(c) Boron (d) Aluminium

14. Which of the following is most acidic **[BHU 1998]**

(a) Na_2O (b) MgO

(c) Al_2O_3 (d) CaO

15. When orthoboric acid (H_3BO_3) is heated, the residue left is **[Pb. PMT 2002]**

(a) Metaboric acid (b) Boron

(c) Boric anhydride (d) Borax

16. Which of the following form dimeric halides **[Roorkee Qualifying 1998]**

(a) Al (b) Mg

(c) In (d) Ga

17. The liquid field metal expanding on solidification is **[AIIMS 2004]**

(a) Ga (b) Al

(c) Zn (d) Cu

18. Aluminium chloride exists as dimer, Al_2Cl_6 in solid state as well as in solution of non-polar solvents such as benzene. When dissolved in water, it gives **[AIEEE 2004]**

(a) $[Al(OH)_6]^{3-} + 3HCl$ (b) $[Al(H_2O)_6]^{3+} + 3Cl^-$

(c) $Al^{3+} + 3Cl^-$ (d) $Al_2O_3 + 6HCl$

19. The hardest substance amongst the following is **[Kerala PMT 2004]**

(a) Be_2C (b) Graphite

(c) Titanium (d) SiC

(e) B_4C

20. Which of the following is known as inorganic benzene **[Pb. CET 2001]**

(a) Borazine (b) Boron nitride
(c) *p*-dichlorobenzene (d) Phosphonitrilic acid

21. Which of the following is only acidic in nature **[AIIMS 2004]**

(a) $Be(OH)_2$ (b) $Mg(OH)_2$
(c) $B(OH)_3$ (d) $Al(OH)_3$

22. Moissan boron is **[DCE 2003]**

(a) Amorphous boron of ultra purity
(b) Crystalline boron of ultra purity
(c) Amorphous boron of low purity
(d) Crystalline boron of low purity

23. Which of the following does not exist in free form **[Kerala PMT 2004]**

(a) BF_3 (b) BCl_3
(c) BBr_3 (d) BH_3
(e) None of these

24. Alumina is **[DCE 2002]**

(a) Acidic (b) Basic
(c) Amphoteric (d) None of these

25. The most abundant metal in the earth crust is **[Pb. CET 2004]**

(a) Al (b) Ca
(c) Fe (d) Na

26. Crystalline metal can be transformed into metallic glass by **[NCERT 1984]**

(a) Alloying
(b) Pressing into thin plates
(c) Slow cooling of molten metal
(d) Very rapid cooling of a spray of the molten metal

27. Which metal is protected by a layer of its own oxide **[NCERT 1981; DPMT 1983; BHU 1998]**

(a) Al (b) Ag
(c) Au (d) Fe

28. Aluminium is a self–preserving metal, because

(a) It is not tarnished by air
(b) A thin film of basic carbonate on its surface
(c) A non-porous layer of oxide is formed on its surface
(d) It is not affected by salt water

29. Anhydrous $AlCl_3$ cannot be obtained from which of the following reactions **[CPMT 1987]**

(a) Heating $AlCl_3.6H_2O$
(b) By passing dry HCl over hot aluminium powder
(c) By passing dry Cl_2 over hot aluminium powder
(d) By passing dry Cl_2 over a hot mixture of alumina and coke

30. An element A dissolves both in acid and alkali. It is an example of **[NCERT 1972]**

(a) Allotropic nature of A (b) Dimorphic nature of A
(c) Amorphous nature of A (d) Amphoteric nature of A

31. Hydrogen gas will not reduce **[IIT 1984]**

(a) Heated cupric oxide
(b) Heated ferric oxide
(c) Heated stannic oxide
(d) Heated aluminium oxide

32. Conc. HNO_3

(a) Reacts with aluminium vigrously
(b) Reacts with aluminium to form aluminium nitrate
(c) Does not react with aluminium
(d) Reacts with platinum

33. Anhydrous $AlCl_3$ is obtained from **[BHU 1980; CPMT 1982]**

(a) HCl and aluminium metal
(b) Aluminium and chlorine gas
(c) Hydrogen chloride gas and aluminium metal
(d) None of the above

34. Which is true for an element R present in III group of the periodic table **[EAMCET 1991]**

(a) It is gas at room temperature
(b) It has oxidation state of $+4$
(c) It forms R_2O_3
(d) It forms RX_2

35. When Al is added to KOH solution **[NCERT 1974, 76; CPMT 1977]**

(a) No action takes place
(b) Oxygen is evolved
(c) Water is produced
(d) Hydrogen is evolved

36. Aluminium is more reactive than iron. But aluminium is less easily corroded than iron because **[KCET 1993]**

(a) Aluminium is a noble metal
(b) Oxygen forms a protective oxide layer
(c) Iron undergoes reaction easily with water
(d) Iron forms mono and divalent ions

37. Aluminium vessels should not be washed with materials containing washing soda since **[KCET 1993]**

(a) Washing soda is expensive

(b) Washing soda is easily decomposed

(c) Washing soda reacts with aluminium to form soluble aluminate

(d) Washing soda reacts with aluminium to form insoluble aluminium oxide

38. Which of the statements about anhydrous aluminium chloride is correct **[IIT 1981]**

(a) It exists as $AlCl_3$ molecule

(b) It is not easily hydrolysed

(c) It sublimes at 100^oC under vacuum

(d) It is a strong Lewis base

39. Common alum is

[DPMT 1982; CPMT 1978; AMU 1982, 83]

(a) $K_2SO_4.Al_2(SO_4)_3.24H_2O$

(b) $K_2SO_4.Cr_2(SO_4)_3.24H_2O$

(c) $K_2SO_4.Fe_2(SO_4)_3.24H_2O$

(d) $(NH_4)_2SO_4.FeSO_4.6H_2O$

40. Which of the following is not true about potash alum

[MNR 1993; UPSEAT 2002]

(a) Its empirical formula is $KAl(SO_4)_2.12H_2O$

(b) Its aqueous solution is basic

(c) It is used in dyeing industries

(d) On heating it melts in its water of crystallization

41. Which one of the following is correct statement

(a) The hydroxide of aluminium is more acidic than that of boron

(b) The hydroxide of boron is basic, while that of aluminium is amphoteric

(c) The hydroxide of boron is acidic, while that of aluminium is amphoteric

(d) The hydroxide of boron and aluminium are amphoteric

42. $AlCl_3$ is **[AFMC 1995]**

(a) Anhydrous and covalent (b)Anhydrous and ionic

(c) Covalent and basic (d) Coordinate and acidic

43. Aluminium (III) chloride forms a dimer because

[CBSE PMT 1995]

(a) Higher coordination number can be achieved by aluminium

(b) Aluminium has high ionization energy

(c) Aluminium belongs to III group

(d) It cannot form a trimer

44. Aluminium has a great affinity for oxygen and its oxidation is an exothermic process. This fact is made use of in

[MP PMT 1997]

(a) Preparing thin foils of aluminium

(b) Making utensils

(c) Preparing duralumin alloy

(d) Thermite welding

45. Number of water molecules in Mohr's salt is

[CPMT 1997; AIIMS 2001; JIPMER 2001]

(a) 7 (b) 6

(c) 5 (d) 8

46. Which of the following is an amphoteric oxide

[BHU 2001]

(a) MgO (b) Al_2O_3

(c) Cl_2O_7 (d) Ti_2O_2

47. Aluminium oxide is not reduced by chemical reactions since

[KCET 2002]

(a) Aluminium oxide is reactive

(b) Reducing agents contaminate

(c) Aluminium oxide is highly stable

(d) The process pollutes the environment

48. Aluminium is not used **[DPMT 2002]**

(a) In silvery paints

(b) For making utensils

(c) As a reducing agent

(d) As oxidizer in metallurgy

49. In the thermite process the reducing agent is

[Pb. PMT 2002]

(a) Al (b) C

(c) Mg (d) Na

50. In Goldschmidt aluminothermic process, thermite contains

[KCET 2003]

(a) 3 parts of Al_2O_3 and 4 parts of Al

(b) 3 parts of Fe_2O_3 and 2 parts of Al

(c) 3 parts of Fe_2O_3 and 1 part of Al

(d) 1 part of Fe_2O_3 and 1 part of Al

51. Bauxite containing impurities of iron oxide is purified by

[CPMT 1987; AIIMS 1998]

(a) Hoop's process (b) Serpeck's process

(c) Baeyer's process (d) Electrolytic process

52. In the purification of bauxite by Hall's process

(a) Bauxite ore is heated with $NaOH$ solution at 50^oC

(b) Bauxite ore is fused with Na_2CO_3

(c) Bauxite ore is fused with coke and heated at 1800^oC in a current of nitrogen

(d) Bauxite ore is heated with $NaHCO_3$

53. Which one is used as a bye-product in Serpeck's process

(a) NH_3 (b) CO_2

(c) N_2 (d) PH_3

54. In the metallurgy of aluminium, cryolite is mixed in the molten state because it **[Roorkee 1995]**

(a) Increases the melting point of alumina

(b) Oxidises alumina

(c) Reduces alumina
(d) Decreases the melting point of alumina

55. In the electrolytic extraction of aluminium, cryolite is used

[NCERT 1981; CPMT 1989; RPMT 2000; MP PMT 2000, 02]

(a) To obtain more aluminium
(b) To decrease temperature to dissolve bauxite
(c) To protect the anode
(d) As reducing agent

56. In the extraction of aluminium, bauxite is dissolved in cryolite because

(a) It acts as a solvent
(b) It reduces melting point of aluminium oxide
(c) It increases the resistance of aluminium oxide
(d) Bauxite becomes active

57. In the extraction of aluminium the electrolyte is

[CBSE PMT 1989; AIEEE 2002]

(a) Fused cryolite with felspar
(b) Fused cryolite with fluorspar
(c) Pure alumina in molten cryolite
(d) Pure alumina with bauxite and molten cryolite

58. Aluminium is obtained by **[KCET 1992; RPMT 2002]**

(a) Reducing Al_2O_3 with coke
(b) Electrolysing Al_2O_3 dissolved in Na_3AlF_6
(c) Reducing Al_2O_3 with chromium
(d) Heating alumina and cryolite

59. In the electrolysis of alumina, cryolite is added to

[IIT 1986; BHU 1987]

(a) Increase the melting point of alumina
(b) Increase the electrical conductivity
(c) Minimise the anodic effect
(d) Remove impurities from alumina

60. The function of fluorspar in the electrolytic reduction of alumina dissolved in fused cryolite (Na_3AlF_6) is

[KCET 1993; IIT 1993]

(a) As a catalyst
(b) To lower the temperature of the melt and to make the fused mixture very conducting
(c) To decrease the rate of oxidation of carbon at the anode
(d) None of the above

61. For purification of alumina, the modern processes most useful when (i) the impurity present is a lot of iron oxides and (ii) the impurity present is a lot of silica, are

(a) For (i) Hall's process; for (ii) Baeyer's process
(b) For (i) Hall's process; for (ii) Serpeck's process
(c) For (i) Serpeck's process; for (ii) Baeyer's process
(d) For (i) Baeyer's process; for (ii) Serpeck's process

62. For the electrolytic production of aluminium, (i) the cathode and (ii) the anode are made of

(a) (i) Platinum and (ii) Iron
(b) (i) Copper and (ii) Iron
(c) (i) Copper and (ii) Carbon
(d) (i) Carbon and (ii) Carbon

63. In the commercial electrochemical process for aluminium extraction, the electrolyte used is**[IIT-JEE 1999**

(a) $Al(OH)_3$ in $NaOH$ solution
(b) An aqueous solution of $Al_2(SO_4)_3$
(c) A molten mixture of Al_2O_3 and Na_3AlF_6
(d) A molten mixture of $AlO(OH)$ and $Al(OH)_3$

64. In electrolysis of aluminium oxide which of the following is added to accelerate the process**[AFMC 1999; C**

(a) Silica (b) Cryolite
(c) Nickel (d) Silicate

65. The purification of alumina is called

[CPMT 1997; AFMC 1998; AIIMS 1999]

(a) Bosch process (b) Caster process
(c) Baeyer's process (d) Hoop's process

66. Electrolytic reduction of alumina to aluminium by Hall-Heroult process is carried out in the presence of

[IIT-JEE (Screening) 2000]

(a) $NaCl$
(b) Fluorite
(c) Cryolite which forms a melt with lower melting temperature
(d) Cryolite which forms a melt with higher melting temperature

67. In the electrolytic method of obtaining aluminium from purified bauxite, cryolite is added to the charge in order to

[KCET 2004]

(a) Minimize the heat loss due to radiation
(b) Protect aluminium produced from oxygen
(c) Dissolve bauxite and render it conductor of electricity
(d) Lower the melting point of bauxite

68. Hoop's process is used for the purification of the metal

[MP PET 1995; MP PMT 2001]

(a) Al (b) Zn
(c) Ag (d) Cu

69. Purification of aluminium done by electrolytic refining is known as

[CPMT 1989; CBSE PMT 1999; RPET 2003; BCECE 2005]

(a) Serpeck's process (b) Hall's process
(c) Baeyer's process (d) Hoop's process

70. In the Hoope's process for refining of aluminium, the fused materials form three different layers and they remain separated during electrolysis also. This is because

[MP PET 1996]

(a) The upper layer is kept attracted by the cathode and the lower layer is kept attracted by the anode

(b) There is special arrangement in the cell to keep the layers separate

(c) The 3 layers have different densities

(d) The 3 layers are maintained at different temperatures

71. During metallurgy of aluminium bauxite is dissolved in cryolite because

(a) Bauxite is non-electrolyte

(b) Cryolite is a flux

(c) Cryolite acts as an electrolyte

(d) All are correct

72. For the electrolytic refining of aluminium, the three fused layers consist of

	Bottom Layer	**Middle Layer**	**Upper Layer**
(a)	Cathode of pure *Al*	Cryolite and fluorspar	Anode of *Al* and *Cu* alloy
(b)	Cathode of *Al* and *Cu* alloy	Bauxite and cryolite	Anode of pure *Al*
(c)	Anode of *Al* and *Cu* alloy	Cryolite and barium fluoride	Cathode of pure *Al*
(d)	Anode of impure *Al*	Bauxite, cryolite and fluorspar	Cathode of pure *Al*

73. Heating an aqueous solution of aluminium chloride to dryness will give **[AIEEE 2005]**

(a) $AlCl_3$ (b) Al_2Cl_6

(c) Al_2O_3 (d) $Al(OH)Cl_2$

74. The structure of diborane (B_2H_6) contains **[AIEEE 2005]**

(a) Four 2c-2e bonds and two 3c-2e bonds

(b) Two 2c-2e bonds and four 3c-2e bonds

(c) Two 2c-2e bonds and two 3c-3e bonds

(d) Four 2c-2e bonds and four 3c-2e bonds

75. Which of the following is the electron deficient molecule

[CBSE PMT 2005]

(a) B_2H_6 (b) C_2H_6

(c) PH_3 (d) SiH_4

76. In Hall's process, the main reagent is mixed with **[AFMC 2005]**

(a) *NaF* (b) Na_3AlF_6

(c) AlF_3 (d) None of these

77. Acedic strength of Boron trihalide are in order of **[Kerala CET 2005]**

(a) $BF_3 < BCl_3 < BBr_3 < BI_3$

(b) $BI_3 < BBr_3 < BCl_3 < BF_3$

(c) $BBr_3 < BCl_3 < BF_3 < BI_3$

(d) $BF_3 < BI_3 < BCl_3 < BBr_3$

Carbon family

1. Carbon and silicon belong to (IV) group. The maximum coordination number of carbon in commonly occurring compounds is 4, whereas that of silicon is 6. This is due to

[CBSE PMT 1994]

(a) Large size of silicon

(b) More electropositive nature of silicon

(c) Availability of low lying *d*-orbitals in silicon

(d) Both (a) and (b)

2. The ionic carbide is **[JIPMER 2000]**

(a) ZnC

(b) TiC

(c) SiC

(d) CaC_2

3. PbO_2 is **[JIPMER 2000]**

(a) Basic

(b) Acidic

(c) Neutral

(d) Amphoteric

4. Lead pipes are not suitable for drinking water because

[JIPMER 2000]

(a) A layer of lead dioxide is deposited over pipes

(b) Lead reacts with air to form litharge

(c) Lead reacts with water containing air to form $Pb(OH)_2$

(d) Lead forms basic lead carbonate

5. Silicon dioxide is formed by the reaction of

[KCET (Med.) 2001]

(a) $SiCl_4 + 2H_2O$

(b) $SiO_2 + 4HF$

(c) $SiO_2 + NaOH$

(d) $SiCl_4 + NaOH$

6. Which alkali metal carbonate decomposes on heating to liberate CO_2 gas

(a) Li_2CO_3

(b) $CaCO_3$

(c) Na_2CO_3

(d) Al_2CO_3

7. Which of the following gives propyne on hydrolysis

[AIIMS 2005]

(a) Al_4C_3

(b) Mg_2C_3

(c) B_4C

(d) La_4C_3

8. Which one of the following statements is not correct

[CBSE PMT 1994]

(a) Zinc dissolves in sodium hydroxide solution

(b) Carbon monoxide reduces iron (III) oxide to iron

(c) Mercury (II) iodide dissolves in excess of potassium iodide solution

(d) Tin (IV) chloride is made by dissolving tin solution in concentrated hydrochloric acid

9. In laboratory silicon can be prepared by the reaction

[Pb. PMT 1999]

(a) By heating carbon in electric furnace

(b) By heating potassium with potassium dichromate

(c) Silica with magnesium

(d) None of these

10. Which of the following is the correct statement for red lead

[AIIMS 2000]

(a) It is an active form of lead

(b) Its molecular formula is Pb_2O_3

(c) It decomposes into Pb and CO_2

(d) It decomposes into PbO and O_2

11. Suppose you have to determine the percentage of carbon dioxide in a sample of a gas available in a container. Which is the best absorbing material for the carbon dioxide

[Pb. PMT 2001]

(a) Heated copper oxide

(b) Cold, solid calcium chloride

(c) Cold, solid calcium hydroxide

(d) Heated charcoal

12. The number and type of bonds between 2 carbon atoms in CaC_2 **[UPSEAT 2001]**

(a) One sigma (σ) and one pi (π) bond

(b) One sigma (σ) and two pi (π) bond

(c) One sigma (σ) and half pi (π) bond

(d) One sigma (σ) bond

13. Metalloid among the following is **[DPMT 2001]**

(a) Si

(b) C

[Pb. PMT 2000]

(c) Pb

(d) Ge

14. '*Lead pencil*' contains **[DPMT 2001; IIT 1990]**

(a) PbS

(b) Graphite

(c) FeS

(d) Pb

15. Nitrogen gas is absorbed by **[DPMT 2001]**

(a) Calcium hydroxide

(b) Ferrous sulphate

(c) Calcium carbide

(d) Aluminium carbide

16. In laboratory silicon can be prepared by the reaction

[Pb. PMT 1999; AFMC 2002]

(a) Silica with magnesium

(b) By heating carbon in electric furnace

(c) By heating potassium fluosilicate with potassium

(d) None of these

17. Formation of in-numberable compounds of carbon is due to its

(a) High reactivity

(b) Catenation tendency

(c) Covalent and ionic tendency
(d) Different valency

18. Colour is imported to glass by mixing **[Pb. PMT 2002]**
(a) Synthetic dyes (b) Metal oxide
(c) Oxides of non-metal (d) Coloured salt

19. Which of the following is insoluble in water **[MP PET 2002]**
(a) Na_2CO_3 (b) $CaCO_3$
(c) $ZnCO_3$ (d) $Al_2(CO_3)_3$

20. In which of the following the inert pair effect is most prominent **[MP PMT 2000]**
(a) C (b) Si
(c) Ge (d) Pb

21. Plumbosolvancy implies dissolution of lead in **[DCE 1999]**
(a) Bases (b) Acids
(c) Ordinary water (d) $CuSO_4$ sol

22. Which of the following glass is used in making wind screen of automobiles **[AIIMS 1999; Pb. CET 2000]**
(a) Crook's (b) Jena
(c) Safety (d) Pyrex

23. Glass reacts with HF to produce **[KCET 2000; CBSE PMT PMT 2000]**
(a) SiF_4 (b) H_2SiF_6
(c) H_2SiO_3 (d) Na_3AlF_6

24. The type of glass used in making lenses and prisms is **[JIPMER 1999]**
(a) A flint glass (b) Jena glass
(c) Pyrex glass (d) Quartz glass

25. When carbon monoxide is passed over solid caustic soda heated to $200^o C$, it forms **[KCET (Med.) 1999]**
(a) Na_2CO_3 (b) $NaHCO_3$
(c) $H-COONa$ (d) CH_3COONa

26. Which is used to produce smoke screens **[AFMC 2005]**
(a) Calcium phosphide (b) Zinc sulphide
(c) Sodium carbonate (d) Zinc phosphide

27. Sodium oxalate on heating with conc. H_2SO_4 gives **[Roorkee 2000]**
(a) CO only (b) CO_2 only
(c) CO and CO_2 (d) SO_2 and SO_3

28. Extraction of lead by reduction methods is done by **[AMU 2000]**
(a) Adding more galena into reverberatory furnace
(b) Adding more lead sulphate into reverberatory furnace
(c) Adding more galena and coke into the reverberatory furnace
(d) Self reduction of oxide from sulphide present in the furnace

29. Which gas is used in excess water **[BVP 2003]**
(a) CO_2 (b) SO_2
(c) CO (d) Water vapours

30. The compound which does not possess a peroxide linkage is
(a) Na_2O_2 (b) CrO_5
(c) H_2SO_5 (d) PbO_2

31. Silicon is an important constituent of **[MH CET 2001]**
(a) Rocks (b) Amalgams
(c) Chlorophyll (d) Haemoglobin

32. Carborundum is **[AFMC 2002; MH CET 2003; BHU 2003, 05]**
(a) SiC (b) $AlCl_3$
(c) $Al_2(SO_4)_3$ (d) $Al_2O_3.2H_2O$

33. SiF_4 gets hydrolysed giving ……. **[Orissa JEE 2002]**
(a) SiO_2 (b) $Si(OH)_2F_2$
(c) H_2SiF_6 (d) $Si(OH)_4$

34. Glass is a **[AIEEE 2003; RPET 2003]**
(a) Micro-crystaline solid
(b) Super cooled liquid
(c) Gel
(d) Polymeric mixture

35. H_2O_2 on reaction with PbS gives **[RPET 2003]**
(a) PbO (b) $PbSO_4$
(c) PbO_2 (d) $PbHSO_4$

36. Soldiers of Napolean army while at Alps during freezing winter suffered a serious problem as regards to the tin buttons of their uniforms. White metallic tin buttons got converted to grey powder. This transformation is related to **[AIEEE 2004]**
(a) A change in the partial pressure of oxygen in the air
(b) A change in the crystalline structure of tin
(c) An interaction with nitrogen of the air at very low to temperatures
(d) An interaction with water vapour contained in the humid air

37. Solid CO_2 is known as dry ice, because **[Pb. CET 2000]**
(a) It melts at 0°C
(b) It evaporates at 40°C
(c) It evaporates at $-78^{\circ}C$ without melting
(d) Its boiling point is more than 199°C

38. Which one of the following statements about the zeolites is false **[CBSE PMT 2004]**
(a) Zeolites are aluminosilicates having three dimensional network
(b) Some of the SiO_4^{-4} units are replaced by AlO_4^{-5} and AlO_6^{9-} ions in zeolites

(c) They are used as cation exchangers
(d) They have open structure which enables them to take up small molecules

39. Which of the following cuts ultraviolet rays **[AFMC 2004]**
(a) Soda glass (b) Crooke's glass
(c) Pyrax (d) None of these

40. In IIIA group, Tl (thalium) shows +1 oxidation state while other members show +3 oxidation state. Why **[JEE Orissa 2004]**
(a) Presence of lone pair of electron in Tl
(b) Inert pair effect
(c) Large ionic radius of Tl ion
(d) None of these

41. Carbon suboxide C_3O_2 has **[DCE 2003]**
(a) Linear structure
(b) Bent structure
(c) Trigonal planar structure
(d) Distorted tetrahedral structure

42. Which of the following is a mixed oxide **[Pb. CET 2003]**
(a) Fe_2O_3 (b) PbO_2
(c) Pb_3O_4 (d) BaO_2

43. Noble gases are absorbed on **[BVP 2004]**
(a) Anhydrous $CaCl_2$ (b) Charcoal
(c) Conc. H_2SO_4 (d) Coconut

44. Lapis lazuli is **[AFMC 2004]**
(a) Ferrous sulphate (b) Copper sulphate
(c) Sodium alumino silicate (d) Zinc sulphate

45. Which of the following statement is correct with respect to the property of elements in the carbon family with an increase in atomic number, their **[Pb. CET 2002]**
(a) Atomic size decreases
(b) Ionization energy increases
(c) Metallic character decreases
(d) Stability of +2 oxidation state increases

46. When tin is treated with concentrated nitric acid **[DCE 2004]**
(a) It is converted into stannous nitrate
(b) It is converted into stannic nitrate
(c) It is converted into metastannic acid
(d) It becomes passive

47. Solder is an alloy of **[Pb. CET 2003]**
(a) $Pb + Zn + Sn$ (b) $Pb + Zn$
(c) $Pb + Sn$ (d) $Sn + Zn$

48. A metal used in storage batteries is
(a) Copper (b) Lead
(c) Tin (d) Nickel

49. Name of the structure of silicates in which three oxygen atoms of $[SiO_4]^{4-}$ are shared is **[IIT 2005]**
(a) Pyrosilicate
(b) Sheet silicate
(c) Linear chain silicate
(d) Three dimensional silicate

50. *Red lead* is **[CPMT 1972, 74, 94; MNR 1985; DPMT 1982, 2002; Bihar CEE 1995; MP PET 1995]**
(a) Pb_3O_4 (b) PbO
(c) PbO_2 (d) Pb_4O_3

51. *White lead* is **[CPMT 1983, 93, 2002; MNR 1984; MP PMT 1995; UPSEAT 1999; DCE 2000]**
(a) $PbCO_3$ (b) $PbCO_3.PbO$
(c) $2PbCO_3.Pb(OH)_2$ (d) $2PbSO_4.PbO$

52. Lead pipes are corroded quickly by **[AFMC 1981]**
(a) Dil. H_2SO_4 (b) Conc. H_2SO_4
(c) Acetic acid (d) Water

53. In silicon dioxide **[AIEEE 2005]**
(a) Each silicon atom is surrounded by four oxygen atoms and each oxygen atom is bonded to two silicon atoms
(b) Each siliocn atom is surrounded by two oxygen atoms and each oxygen atom is bounded to two silicon atoms
(c) Silicon atom is bonded to two oxygen atoms
(d) There are double bonds between silicon and oxygen atoms

54. Litharge is chemically **[DPMT 1984; JIPMER 2001]**
(a) PbO (b) PbO_2
(c) Pb_3O_4 (d) $Pb(CH_3COO)_2$

55. The element of s^2p^2 configuration is of ..... group
(a) IV (b) III
(c) V (d) II

56. Which of the following compounds of elements in group IV would you expect to be most ionic in character **[NCERT 1978]**
(a) CCl_4 (b) $SiCl_4$
(c) $PbCl_2$ (d) $PbCl_4$

57. Which of the following compounds of lead is used in match industry
(a) PbO (b) PbO_2
(c) $PbCl_2$ (d) None of these

58. Type metal is an alloy of Pb, Sb and Sn. It consists of
(a) Equal amounts of the three metals
(b) More amount of lead
(c) More amount of antimony
(d) More amount of tin

59. Which is correct oxidation state of lead **[AFMC 1987]**
(a) + 2, + 4 (b) + 1, + 2
(c) + 3, + 4 (d) + 4

60. Sugar of lead is
(a) $2PbSO_4.PbO$ (b) $(CH_3COO)_2Pb$
(c) $PbCO_3$ (d) $PbCO_3.Pb(OH)_2$

61. Which of the following compounds has peroxide linkage

[CPMT 1988]

(a) Pb_2O_3
(b) SiO_2
(c) CO_2
(d) PbO_2

62. Percentage of lead in lead pencil is

[CBSE PMT 1999]

(a) Zero
(b) 20
(c) 80
(d) 70

63. Which of the following has most density

[CPMT 1996]

(a) Fe
(b) Cu
(c) B
(d) Pb

64. Red lead in an example of a/an .... oxide

[JIPMER 2001]

(a) Basic
(b) Super
(c) Mixed
(d) Amphoteric

65. Which of the following lead oxides is 'Sindhur'

[MP PET 2002]

(a) PbO
(b) PbO_2
(c) Pb_2O_3
(d) Pb_3O_4

66. Element showing the phenomenon of allotropy is

[MP PMT 1999]

(a) Aluminium
(b) Tin
(c) Lead
(d) Copper

67. Which of the following element is a metalloid

[CPMT 2004]

(a) Bi
(b) Sn
(c) Ge
(d) C

68. Which gas is liberated when Al_4C_3 is hydrolysed

[AFMC 2005]

(a) CH_4
(b) C_2H_2
(c) C_2H_6
(d) CO_2

69. Which of the following attacks glass

[NCERT 1976; AFMC 2005]

(a) HCl
(b) HF
(c) HI
(d) HBr

Nitrogen family

1. Which of the following elements does not form stable diatomic molecules

(a) Iodine
(b) Phosphorus
(c) Nitrogen
(d) Oxygen

2. Producer gas is a mixture of **[DPMT 1982; CPMT 1978]**

(a) CO and N_2
(b) CO_2 and H_2
(c) CO and H_2
(d) CO_2 and N_2

3. Which one of the following combines with $Fe(II)$ ions to form a brown complex

[AIIMS 1982, 83, 87; BHU 1998; CBSE PMT 2000; Pb. PMT 2000; AFMC 1988, 92; MP PET 1997, 2000, 01]

(a) N_2O
(b) NO
(c) N_2O_3
(d) N_2O_5

4. Metaphosphoric acid has the formula **[CPMT 1973, 89, 93]**

(a) H_3PO_4
(b) HPO_3
(c) H_2PO_3
(d) H_3PO_2

5. Which of the following is the most suitable drying agent for ammonia gas

[MP PMT 1989; CBSE PMT 1989; DPMT 1982; CPMT 1974, 78, 91; BHU 1986, 96; 2001; IIT (Screening) 2000]

(a) Calcium oxide
(b) Anhydrous calcium chloride
(c) Phosporus pentoxide
(d) Conc. sulphuric acid

6. Each of the following is true for white and red phosphorus except that they

(a) Are both soluble in CS_2
(b) Can be oxidised by heating in air
(c) Consists of same kind of atoms
(d) Can be converted into one another

7. Which of the following is a tetrabasic acid **[CPMT 1988]**

(a) Orthophosphorus acid
(b)Orthophosphoric acid
(c) Metaphosphoric acid
(d) Pyrophosphoric acid

8. Phosphine is prepared by the reaction of

[MP PET/PMT 1988]

(a) P and H_2SO_4
(b) P and $NaOH$
(c) P and H_2S
(d) P and HNO_3

9. Which of the following is not known **[MP PET/PMT 1988; NCERT 1982; CBSE PMT 1989; MP PET 1993]**

(a) NCl_5
(b) NI_3
(c) $SbCl_3$
(d) NCl_3

10. Chemical formula for the phosphorus molecule is

[CPMT 1976, 80, 84, 90; BHU 1984, 86; NCERT 1977]

(a) P
(b) P_4
(c) P_2
(d) P_5

11. White phosphorus (P_4) has **[IIT 1998]**

[CBSE PMT 1989, 94]

(a) Six P - P single bonds
(b) Four P - P single bonds
(c) Four lone pairs of electrons
(d) PPP angle of 60^o

12. Ammonium nitrate decomposes on heating into

[NCERT 1974,75; CPMT 1973, 78, 88, 94; AMU 1984]

(a) Ammonia and nitric acid
(b) Nitrous oxide and water
(c) Nitrogen, hydrogen and ozone

(d) Nitric oxide, nitrogen dioxide and hydrogen

13. In Birkeland-Eyde process, the raw material used is **[CPMT 1982, 86]**

(a) Air (b) NH_3

(c) NO_2 (d) HNO_3

14. Among the following nitrates, *Lead nitrate, Silver nitrate* and *Ammonium nitrate;* the one that decomposes without leaving any solid residue is**[NCERT 1983]**

(a) Lead nitrate (b) Ammonium nitrate

(c) Silver nitrate (d) Sodium nitrate

15. Of the different allotropes of phosphorus, the one which is most reactive is **[CPMT 1983; NCERT 1978; CBSE PMT 1999; Kurukshetra CEE 1998]**

(a) Violet phosphorus (b) Scarlet phosphorus

(c) Red phosphorus (d) White phosphorus

16. Phosphine is generally prepared in the laboratory **[CPMT 1983, 2003]**

(a) By heating phosphorus in a current of hydrogen

(b) By heating white phosphorus with aqueous solution of caustic potash

(c) By decomposition of P_2H_4 at $110^o C$

(d) By heating red phosphorus with an aqueous solution of caustic soda

17. Which of the following elements is most metallic **[CPMT 1983; MP PMT 1993]**

(a) Phosphorus (b) Arsenic

(c) Antimony (d) Bismuth

18. The basicity of orthophosphoric acid is**[CPMT 1984, 91]**

(a) 2 (b) 3

(c) 4 (d) 5

19. HNO_2 acts as **[AFMC 1992]**

(a) Oxidising agent (b) Reducing agent

(c) Both (a) and (b) (d) Its solution is stable

20. Nitrogen dioxide cannot be obtained by heating **[CPMT 1989; IIT 1985; CPMT 1993]**

(a) KNO_3 (b) $Pb(NO_3)_2$

(c) $Cu(NO_3)_2$ (d) $AgNO_3$

21. When heated NH_3 is passed over CuO gas evolved is **[BCECE 2005]**

(a) N_2 (b) N_2O

(c) HNO_3 (d) NO_2

22. Non-combustible hydride is **[CPMT 1979]**

(a) NH_3 (b) PH_3

(c) AsH_3 (d) SbH_3

23. On heating a mixture of NH_4Cl and KNO_2 we get **[CPMT 1972, 79; NCERT 1977]**

(a) NH_4NO_3 (b) N_2

(c) N_2O (d) NO

24. Which of the following oxide of nitrogen is the anhydride of HNO_3 **[CPMT 1979,80,89,97; MP PET/PMT 1988; KCET 1991; CBSE PMT 1989, 91,99; EAMCET 1991; NCERT 1975; MP PET 1989; MP PMT 1994]**

(a) NO (b) N_2O_3

(c) N_3O_4 (d) N_2O_5

25. Phosphorus is manufactured by heating in a electric furnace a mixture of**NCERT 1977; CPMT 1974, 78, 81**

(a) Bone ash and coke

(b) Bone ash and silica

(c) Bone ash, silica and coke

(d) None of these

26. A certain element forms a solid oxide which when dissolved in water forms an acidic solution, the element is **[CPMT 1972, 78]**

(a) Argon (b) Potassium

(c) Phosphorus (d) Sulphur

27. Dissociation of H_3PO_4 occurs in following stages **[CPMT 1976]**

(a) 1 (b) 2

(c) 3 (d) 4

28. Nitrogen forms how many oxides

(a) 3 (b) 4

(c) 5 (d) 6

29. The *P-P-P* bond angle in white phosphorus is **[MP PET 1991]**

(a) 120^o (b) $109^o28'$

(c) 90^o (d) 60^o

30. Ammonium dichromate on heating gives **[BHU 1973, 78; CBSE PMT 1993; MP PMT 1993]**

(a) Chromium oxide and ammonia

(b) Chromic acid and nitrogen

(c) Chromium oxide and nitrogen

(d) Chromic acid and ammonia

31. When concentrated nitric acid is heated, it decomposes to give

(a) O_2 and N_2 (b) NO

(c) N_2O_5 (d) NO_2 and O_2

32. The element which catches fire in air at $30^o C$ and is stored under water is**[BHU 1973; MP PET 1989,99]**

(a) Calcium (b) Sodium

(c) Phosphorus (d) Zinc

33. A solution of ammonia in water contains

[CBSE PMT 1991]

(a) H^+

(b) OH^-

(c) Only NH_4^+

(d) OH^-, NH_4^+ and NH_4OH molecules

34. Among the members of V A group (*N, P, As, Sb* and *Bi*), which of the following properties shows an increase as we go down from nitrogen to bismuth **[CPMT 1982]**

(a) Stability of +3 oxidation state

(b) Reducing character of hydrides

(c) Electronegativity

(d) Acidic nature of the pentoxide

35. The important method for the fixation of nitrogen is

[CPMT 1985, 94]

(a) Haber (b) Solvay

(c) Deacon (d) Fischer method

36. Which of the following is oxidised in air

[AFMC 1987; KCET 1991]

(a) White phosphorus (b) CH_4

(c) H_2O (d) $NaCl$

37. A pure sample of nitrogen is prepared by heating

(a) Calcium cyanamide (b) Barium azide

(c) Ammonium hydroxide (d) Ammonium nitrite

38. Nitrous oxide

(a) Is a mixed oxide

(b) Is an acidic oxide

(c) Is highly soluble in hot water

(d) Supports the combustion of sulphur

39. Which of the following represents **laughing gas**

[CPMT 1986, 89; Manipal MEE 1995;MP PMT 1990; MP PET 1995; RPMT 1999; AFMC 2002]

(a) NO (b) N_2O

(c) NO_2 (d) N_2O_3

40. NO_2 is a mixed oxide is proved by the first that with $NaOH$, it forms

(a) Nitrites salt

(b) Nitrates salt

(c) Mixture of nitrate and nitrite

(d) Ammonia

41. Which of the following metal produces nitrous oxide with dil. HNO_3

(a) Fe (b) Zn

(c) Cu (d) Ag

42. Which of the following acid exist in polymeric form

(a) HPO_3 (b) $H_4P_2O_7$

(c) H_3PO_4 (d) None of these

43. Superphosphate of lime is **[AMU 1985]**

(a) A mixture of normal calcium phosphate and gypsum

(b) A mixture of primary calcium phosphate and gypsum

(c) Normal calcium phosphate

(d) Soluble calcium phosphate

44. If phosphoric acid is allowed to react with sufficient quantity of $NaOH$, the product obtained is

[DPMT 1983; MP PMT 1983]

(a) $NaHPO_3$ (b) Na_2HPO_4

(c) NaH_2PO_4 (d) Na_3PO_4

45. White phosphorus contains

[CPMT 1978; KCET (Med.) 2000; MP PET 1990]

(a) P_5 molecules (b) P_4 molecules

(c) P_6 molecules (d) P_2 molecules

46. In the catalytic oxidation of ammonia an oxide is formed which is used in the preparation of HNO_3. This oxide is

[CPMT 1984; KCET 1990; AIIMS 1996]

(a) N_2O_5 (b) N_2O_4

(c) NO_2 (d) NO

47. Nitric acid oxidises phosphorus to

[CPMT 1984; JIPMER 2002]

(a) $H_2P_2O_7$ (b) H_3PO_3

(c) P_2O_5 (d) H_3PO_4

48. Which one of the following statements is true for HNO_2

[CPMT 1980, 84]

(a) It is very stable in aqueous solution

(b) It cannot act both as an oxidant and as a reductant

(c) It cannot act as an oxidising agent

(d) It cannot act as reducing agent

49. Which oxide is alkaline **[MP PET 1990]**

(a) P_2O_3 (b) Bi_2O_3

(c) As_2O_3 (d) B_2O_3

50. Which acid is formed by P_2O_3 **[MP PET 1991]**

(a) H_3PO_4 (b) H_3PO_3

(c) HPO_3 (d) $H_4P_2O_7$

51. Which nitrogen trihalides is least basic

[IIT 1987; Kurukshetra CEE 1998; CPMT 1999]

(a) NF_3 (b) NCl_3

(c) NBr_3 (d) NI_3

52. Dehydrated phosphorus trichloride in water gives

[MP PET 1990]

(a) HPO_3 (b) H_3PO_4

(c) H_3PO_2 (d) H_3PO_3

53. Which is used in the manufacture of safe matchsticks

[DPMT 1982, CPMT 1974, 75]

(a) White phosphorus (b) Sulphur

(c) Red phosphorus (d) Selenium

54. Which oxide of nitrogen is coloured gas **[IIT 1987; Kurukshetra CEE 1998]**

(a) N_2O (b) NO

(c) N_2O_5 (d) NO_2

55. Which oxide do not act as a reducing agent **[MP PET 1990]**

(a) NO (b) NO_2

(c) N_2O (d) N_2O_5

56. In NH_4NO_2, the oxidation number of nitrogen will be **[MP PET 1990]**

(a) + 3 (b) + 5

(c) – 3 and + 3 (d) + 3 and + 5

57. In which compound, the oxidation state of phosphorus is+4 **[MP PET 1991]**

(a) P_4O_{11} (b) P_4O_8

(c) P_4O_6 (d) H_3PO_4

58. In which compound, the oxidation state of nitrogen is −1 **[MP PMT 1989]**

(a) NO (b) N_2O

(c) NH_2OH (d) N_2H_4

59. Which of the following oxide is least acidic **[MP PMT 1990; CBSE PMT 1996]**

(a) P_4O_6 (b) P_4O_{10}

(c) As_4O_6 (d) As_4O_{10}

60. The basic character of hydrides of the *V*-group elements decreases in the order **[CBSE PMT 1996]**

(a) $SbH_3 > PH_3 > AsH_3 > NH_3$

(b) $NH_3 > SbH_3 > PH_3 > AsH_3$

(c) $NH_3 > PH_3 > AsH_3 > SbH_3$

(d) $SbH_3 > AsH_3 > PH_3 > NH_3$

61. Which is least stable **[MP PET 1989]**

(a) BiH_3 (b) SbH_3

(c) AsH_3 (d) PH_3

62. Which of the following is not hydrolysed **[DPMT 2005]**

(a) $AsCl_3$ (b) PF_3

(c) $SbCl_3$ (d) NF_3

63. Electrolysis temperature is maximum for **[MP PET 1990]**

(a) AsH_3 (b) NH_3

(c) PH_3 (d) SbH_3

64. Which of the following is kept in water? **[BCECE 2005]**

(a) White phosphorous (b) Sodium

(c) Potassium (d) Calcium

65. Which of the following substances is used as a fertilizer

(a) $K_2SO_4.Al_2(SO_4)_3.24H_2O$

(b) $Ca(H_3PO_4)_2H_2O + CaSO_4$

(c) $NaAlO_2$

(d) CaC_2

66. On adding water to $BiCl_3$ solution in HCl, the compound produced is

(a) Bi_2O_3 (b) $Bi(OH)_3$

(c) $BiOCl$ (d) $BiOCl_2$

67. V-A group precipitate was dissolved in HNO_3 and treated with excess of NH_4OH. It gives a white ppt. because of

(a) $Cu(OH)_2$ (b) $Cd(OH)_2$

(c) $Bi(OH)_3$ (d) $Hg(OH)_2$

68. *N, P, As, Sb, Bi* elements belong to **[DPMT 1982]**

(a) VA group (b) IVA group

(c) VIIA group (d) VB group

69. Which one of the following elements occur free in nature **[CPMT 1988]**

(a) Nitrogen (b) Phosphorus

(c) Arsenic (d) Antimony

70. Which of the following elements of group VA does not show allotropy **[CPMT 1980]**

(a) N (b) Bi

(c) P (d) As

71. Which does not form complex **[CPMT 1986]**

(a) N (b) P

(c) As (d) Bi

72. The strongest base is **[IIT 1989; CPMT 1997; MP PET 2001,03]**

(a) NH_3 (b) PH_3

(c) AsH_3 (d) SbH_3

73. The most stable hydride is **[EAMCET 1988]**

(a) NH_3 (b) PH_3

(c) AsH_3 (d) SbH_3

74. Which has the lowest boiling point **[CBSE PMT 1989]**

(a) NH_3 (b) PH_3

(c) AsH_3 (d) SbH_3

75. Which is the most explosive **[BHU 1984; Roorkee 1989; AIIMS 1996; MP PMT 1985, 2001]**

(a) NCl_3 (b) PCl_3

(c) $AsCl_3$ (d) All of these

76. Of the following, the most acidic is **[EAMCET 1980]**

(a) As_2O_3 (b) P_2O_3

(c) Sb_2O_3 (d) Bi_2O_3

77. Of the following, non-existent compound is **[NCERT 1975, 79]**

(a) PH_4I (b) As_2O_3

(c) $SbCl_2$ (d) As_2H_3

78. Pure N_2 gas is obtained from **[CBSE PMT 1991]**

(a) $NH_3 + NaNO_2$ (b) $NH_4Cl + NaNO_2$

(c) $N_2O + Cu$ (d) $(NH_4)_2Cr_2O_7$

79. Pure nitrogen can be prepared from

[KCET 1991; AFMC 1993; AMU 1985]

(a) NH_4OH (b) Ca_3N_2

(c) NH_4NO_2 (d) $Ba(NO_3)_2$

80. Nitrogen combines with metals to form **[CPMT 1981, 93]**

(a) Nitrites (b) Nitrates

(c) Nitrosyl chloride (d) Nitrides

81. Nitrogen is relatively inactive element because **[CBSE PMT 1992]**

(a) Its atom has a stable electronic configuration

(b) It has low atomic radius

(c) Its electronegativity is fairly high

(d) Dissociation energy of its molecule is fairly high

82. The cyanide ion, CN^- and N_2 are isoelectronic. But in contrast to CN^-, N_2 is chemically inert because of **[IIT 1992]**

(a) Low bond energy

(b) Absence of bond polarity

(c) Unsymmetrical electron distribution

(d) Presence of more number of electrons in bonding orbitals

83. Which statement is not correct for nitrogen **[AIIMS 1991]**

(a) It has a small size

(b) It does not readily react with O_2

(c) It is a typical non-metal

(d) *d*-orbitals are available for bonding

84. The element which is essential in nitrogen fixation is **[NCERT 1981]**

(a) Zinc (b) Copper

(c) Molybdenum (d) Boron

85. Laughing gas is prepared by heating **[EAMCET 1980]**

(a) NH_4Cl (b) $(NH_4)_2SO_4$

(c) $NH_4Cl + NaNO_3$ (d) NH_4NO_3

86. Nitrogen (I) oxide is produced by **[IIT 1989]**

(a) Thermal decomposition of ammonium nitrate

(b) Disproportionation of N_2O_4

(c) Thermal decomposition of ammonium nitrite

(d) Interaction of hydroxyl amine and nitrous acid

87. Which of the following is not correct for N_2O **[CPMT 1984]**

(a) It is called laughing gas

(b) It is nitrous oxide

(c) It is not a linear molecule

(d) It is least reactive in all oxides of nitrogen

88. Which of the following oxides of nitrogen is the anhydride of nitrous acid

(a) NO (b) N_2O_3

(c) N_2O_4 (d) N_2O_5

89. Which of the following is a true acidic anhydride **[NCERT 1977]**

(a) CO (b) NO

(c) ClO_2 (d) N_2O_5

90. On strongly heating $Pb(NO_3)_2$ crystals, the gas formed is **[NCERT 1980; CPMT 1997]**

(a) NO_2 (b) O_2

(c) $NO_2 + O_2$ (d) NO

91. Nitrogen dioxide is released by heating **[AFMC 1992]**

(a) $Pb(NO_3)_2$ (b) KNO_3

(c) $NaNO_2$ (d) $NaNO_3$

92. Nitric oxide is prepared by the action of HNO_3 on **[AFMC 1990]**

(a) Fe (b) Cu

(c) Zn (d) Sn

93. When lightning flash is produced, which gas may form **[EAMCET 1992; AFMC 1989]**

(a) Nitrous oxide (b) Nitrogen dioxide

(c) Dinitrogen pentoxide (d) Nitric oxide

94. Of the following, which has three electron bond in its structure **[CPMT 1986]**

(a) Nitrous oxide (b) Nitric oxide

(c) Dinitrogen trioxide (d) Nitrogen pentoxide

95. Which of the following oxides of nitrogen is neutral **[CPMT 1988]**

(a) N_2O_5 (b) N_2O_3

(c) N_2O_4 (d) N_2O

96. Oxidation of NO in air produces **[KCET 1992]**

(a) N_2O (b) N_2O_3

(c) NO_2 (d) N_2O_5

97. The reddish brown coloured gas formed when nitric oxide is oxidised by air is **[IIT 1979]**

(a) N_2O_5 (b) N_2O_4

(c) NO_2 (d) N_2O_3

98. When $AgNO_3$ is heated strongly, the products formed are **[Roorkee 1990]**

(a) NO and NO_2 (b) NO_2 and O_2

(c) NO_2 and N_2O (d) NO and O_2

99. Which of the nitrates on strong heating leaves the metal as the residue **[KCET 1990]**

(a) $AgNO_3$ (b) $Pb(NO_3)_2$

(c) $Cu(NO_3)_2$ (d) $Al(NO_3)_3$

[NCERT 1975; AIIMS 1991]

100. Nitrogen dioxide **[KCET 1989]**

(a) Dissolves in water forming nitric acid

(b) Does not dissolve in water

(c) Dissolves in water to form nitrous acid and gives off oxygen

(d) Dissolves in water to form a mixture of nitrous and nitric acids

101. Concentrated nitric acid oxidises cane sugar to **[CBSE PMT 1991]**

(a) CO_2 and H_2O (b) CO and H_2O

(c) CO, CO_2 and H_2O (d) Oxalic acid and water

102. A mixture of ammonia and air at about 800^oC in the presence of *Pt* gauze forms **[Pb. CET 1989]**

(a) N_2O (b) NO

(c) NH_2OH (d) N_2O_3

103. Which of the following acid possesses oxidising, reducing and complex forming properties **[MNR 1985]**

(a) HNO_3 (b) H_2SO_4

(c) HCl (d) HNO_2

104. Nitrogen is essential constituent of all **[MP PMT 1990]**

(a) Proteins (b) Fats

(c) Proteins and fats (d) None of these

105. Ammonia gas can be collected by the displacement of **[NCERT 1989, 90]**

(a) Conc. H_2SO_4 (b) Brine

(c) Water (d) Mercury

106. The chemical used for cooling in refrigeration is **[CPMT 1981, 88]**

(a) CO_2 (b) NH_4OH

(c) NH_4Cl (d) Liquid NH_3

107. A hydride of nitrogen which is acidic is **[NCERT 1978, 80; CPMT 1980; BHU 1986]**

(a) NH_3 (b) N_2H_4

(c) N_2H_2 (d) N_3H

108. PCl_5 exists but NCl_5 does not because **[EAMCET 1977, 82]**

(a) Nitrogen has no vacant orbitals

(b) NCl_5 is unstable

(c) Nitrogen atom is much smaller

(d) Nitrogen is highly inert

109. Phosphide ion has the electronic structure similar to that of **[CPMT 1988]**

(a) Nitride ion (b) Fluoride ion

(c) Sodium ion (d) Chloride ion

110. Which of the following phosphorus is most stable **[AFMC 1992]**

(a) Red (b) White

(c) Black (d) All stable

111. Red phosphorus can be obtained from white phosphorus by **[KCET 1989]**

(a) Heating it with a catalyst in an inert atmosphere

(b) Distilling it in an inert atmosphere

(c) Dissolving it in carbon disulphide and crystallizing

(d) Melting it and pouring the liquid into water

112. Bones glow in the dark because **[EAMCET 1980]**

(a) They contain shining material

(b) They contain red phosphorus

(c) White phosphorus undergoes slow combustion in contact with air

(d) White phosphorus changes into red form

113. Which of the following properties of white phosphorus are shared by red phosphorus **[NCERT 1973, 74]**

(a) It shows phosphorescenes in air

(b) It reacts with hot aqueous $NaOH$ to give phosphine

(c) It dissolves in carbon disulphide

(d) It burns when heated in air

114. Mixture used for the tips of match stick is **[DPMT 1984]**

(a) $S + K$

(b) Sb_2S_3

(c) $K_2Cr_2O_7 + S + \text{red } P$

(d) $K_2Cr_2O_7 + K + S$

115. In modern process phosphorus is manufactured by **[CPMT 1974, 78, 81]**

(a) Heating a mixture of phosphorite mineral with sand and coke in electric furnace

(b) Heating calcium phosphate with coke

(c) Heating bone ash with coke

(d) Heating the phosphate mineral with sand

116. White phosphorus when boiled with strong solution of caustic soda produces **[CPMT 1989,03]**

(a) Phosphine (b) Phosphoric acid

(c) Phosphorus acid (d) No reaction

117. White phosphorus reacts with caustic soda. The products are PH_3 and NaH_2PO_2. This reaction is an example of **[IIT 1980; KCET 1993]**

(a) Oxidation (b) Reduction

(c) Oxidation and reduction (d) Neutralisation

118. Phosphine is not obtained by the reaction **[MP PMT 1989]**

(a) White *P* is heated with $NaOH$

(b) Red *P* is heated with $NaOH$

(c) Ca_3P_2 reacts with water

(d) Phosphorus trioxide is boiled with water

119. $PH_4I + NaOH$ forms **[CBSE PMT 1991]**

(a) PH_3 (b) NH_3

(c) P_4O_6 (d) P_4O_{10}

120. Phosphine is produced by adding water to **[KCET 1991]**

(a) CaC_2 (b) HPO_3

(c) Ca_3P_2 (d) P_4O_{10}

121. When aluminium phosphide is treated with dil. sulphuric acid

[KCET 1989]

(a) SO_2 is liberated (b) PH_3 is evolved

(c) H_2S is evolved (d) H_2 is evolved

122. With reference to protonic acids, which of the following statements is correct

(a) PH_3 is more basic than NH_3

(b) PH_3 is less basic than NH_3

(c) PH_3 is equally basic as NH_3

(d) PH_3 is amphoteric while NH_3 is basic

123. One of the acid listed below is formed from P_2O_3 and the rest are formed from P_2O_5. The acid formed from phosphorus (III) oxide is

(a) HPO_3 (b) $H_4P_2O_7$

(c) H_3PO_4 (d) H_3PO_3

124. P_2O_5 is heated with water to give

[CBSE PMT 1991; DPMT 2000]

(a) Hypophosphorus acid (b)Orthophosphorus acid

(c) Hypophosphoric acid (d) Orthophosphoric acid

125. Hypophosphorus acid is **[NCERT 1977; MP PMT 1992]**

(a) A tribasic acid (b) A dibasic acid

(c) A monobasic acid (d) Not acidic at all

126. PCl_3 reacts with water to form

[KCET 1990; CBSE PMT 1991; CPMT 2003]

(a) PH_3 (b) H_3PO_3, HCl

(c) $POCl_3$ (d) H_3PO_4

127. H_3PO_3 is

[CPMT 1977, 79, 94; NCERT 1981; MP PMT 1980]

(a) A tribasic acid (b) A dibasic acid

(c) Neutral (d) A monobasic acid

128. Oxidation state of + 1 for phosphorus is found in

[MP PMT 1991; MP PET 2001]

(a) H_3PO_3 (b) H_3PO_4

(c) H_3PO_2 (d) $H_4P_2O_7$

129. Which is not an acid salt **[MNR 1989]**

(a) NaH_2PO_3 (b) NaH_2PO_2

(c) $Na_3HP_2O_6$ (d) $Na_4P_2O_7$

130. By the action of hot conc. H_2SO_4, phosphorus changes to

[Roorkee 1992]

(a) Phosphorus acid

(b) Orthophosphoric acid

(c) Metaphosphoric acid

(d) Pyrophosphoric acid

131. Cyanamide process is used in the formation of

[BHU 1995]

(a) N_2 (b) HNO_3

(c) NH_3 (d) PH_3

132. The number of hydroxyl group in pyrophosphoric acid is

[KCET 1993]

(a) 3 (b) 4

(c) 5 (d) 7

133. There is very little difference in acid strength in the series H_3PO_4, H_3PO_3, and H_3PO_2 because **[KCET 199**

[CPMT 1990]

(a) Phosphorus in these acids exists in different oxidation states

(b) The hydrogen in these acids are not all bounded to the phosphorus

(c) Phosphorus is not a highly electronegative element

(d) Phosphorus oxides are less basic

134. $BiCl_3$ on hydrolysis forms a white precipitate of

[NCERT 1975]

[CPMT 1988]

(a) Bismuthio acid

(b) Bismuth oxychloride

(c) Bismuth pentachloride

(d) Bismuth hydroxide

135. At high temperature nitrogen combines with calcium carbide (CaC_2) to give

[DPMT 1981, 85; AFMC 1998; MP PET 2000]

(a) Calcium cyanide (b) Calcium cyanamide

(c) Calcium carbonate (d) Calcium nitride

136. Calcium cyanamide on treatment with steam under pressure gives ammonia and **[EAMCET 1984, 88; CPM**

(a) Calcium carbonate (b) Calcium hydroxide

(c) Calcium oxide (d) Calcium bicarbonate

137. Which one has the highest percentage of nitrogen

[KCET 1991; CBSE PMT 1993;
AIIMS 1996, MP PET 2001; RPET 2003]

(a) Urea (b) Ammonium sulphate

(c) Ammonium nitrate (d) Calcium nitrate

138. Superphosphate of lime contains **[CPMT 1984]**

(a) $Ca_3(PO_4)_2$ (b) $CaHPO_4$

(c) $Ca_3(PO_4)_2 + H_3PO_4$ (d) $Ca(H_2PO_4)_2$

139. Thomas slag is **[CPMT 1988]**

(a) $Ca_3(PO_4)_2$ (b) $MnSiO_3$

(c) $CaSiO_3$ (d) $FeSiO_3$

140. When equal weights of the two fertilizers, urea and ammonium sulphate are taken, urea contains **[KCET 19**

(a) Less nitrogen than ammonium sulphate

(b) As much nitrogen as ammonium sulphate

(c) Twice the amount of nitrogen present in ammonium sulphate

(d) More than twice the amount of nitrogen present in ammonium sulphate

141. Which statement is wrong for NO **[DPMT 2005]**

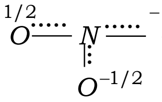
(a) It is anhydride of nitrous acid

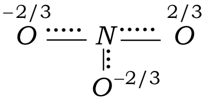
(b) Its dipole moment in 0.22 D

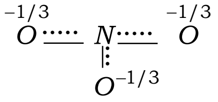
(c) It forms dimer

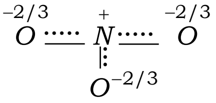
(d) it is paramagnetic

142. The resonance hybrid of nitrate ion is **[AFMC 2002]**

(a) 
$\overset{1/2}{O}\cdots\underset{\vdots\; O^{-1/2}}{N}\cdots\overset{-1/2}{O}$

(b) 
$\overset{-2/3}{O}\cdots\underset{\vdots\; O^{-2/3}}{N}\cdots\overset{2/3}{O}$

(c) 
$\overset{-1/3}{O}\cdots\underset{\vdots\; O^{-1/3}}{N}\cdots\overset{-1/3}{O}$

(d) 
$\overset{-2/3}{O}\cdots\underset{\vdots\; O^{-2/3}}{\overset{+}{N}}\cdots\overset{-2/3}{O}$

143. Blasting of TNT is done by mixing **[AFMC 1993]**

(a) NH_4Cl (b) NH_4NO_3

(c) NH_4NO_2 (d) $(NH_4)_2SO_4$

144. Sodium hydroxide solution reacts with phosphorus to give phosphine. To bring about this reaction, we need **[KCET 1989]**

(a) White phosphorus and dil. $NaOH$

(b) White phosphorus and conc. $NaOH$

(c) Red phosphorus and dil. $NaOH$

(d) Red phosphorus and conc. $NaOH$

145. Which of the following exhibits highest solubility in water **[MP PET 1994]**

(a) NH_3 (b) PH_3

(c) AsH_3 (d) SbH_3

146. Which of the following has highest boiling point **[MP PET 1994]**

(a) NH_3 (b) PH_3

(c) AsH_3 (d) SbH_3

147. In the following reaction

$P_4+3NaOH+3H_2O\rightarrow PH_3+3NaH_2PO_2$ **[MP PMT 1994]**

(a) Phosphorus is oxidised

(b) Phosphorus is oxidised and reduced

(c) Phosphorus is reduced

(d) Sodium is oxidised

148. HNO_3 in aqueous solution yields **[AMU 2000]**

(a) NO_3^- and H^+ (b) NO_3^- and H_3O^+

(c) NO_2^- and OH^- (d) N_2O_5 and H_2O

149. The oxyacid of phosphorus, in which phosphorus has the lowest oxidation state, is **[KCET (Med.) 2001]**

(a) Hypophosphorus acid (b)Orthophosphoric acid

(c) Pyrophosphoric acid (d) Metaphosphoric acid

150. Superphosphate is a mixture of **[KCET (Med.) 2001]**

(a) $Ca(H_2PO_4)_2H_2O+CaCl_2.2H_2O$

(b) $Ca_3(PO_4)_2.H_2O+CaCl_2.2H_2O$

(c) $Ca_3(PO_4)_2.H_2O+2CaSO_4.2H_2O$

(d) $Ca(H_2PO_4)_2.H_2O+2CaSO_4.2H_2O$

151. Solid PCl_5 exits as **[JIPMER 2002]**

(a) PCl_5 (b) PCl_4^+

(c) PCl_6^- (d) PCl_4^+ and PCl_6^-

152. In the reaction, $P_2O_5+3CaO\rightarrow Ca_3(PO_4)_2;P_2O_5$ acts as...... **[Orissa JEE 2002]**

(a) Acidic flux (b) Basic flux

(c) Basic impurity (d) Acidic impurity

153. Atoms in a P_4 molecule of white phosphorus are arranged regularly in space in which of the following way **[Kerala (Engg.) 2002]**

(a) At the corners of tetrahedron

(b) At the corners of a cube

(c) At the corners of a four membered ring

(d) At the centre and corners of an equilateral triangle

154. The most common minerals of phosphorus are **[Kerala (Med.) 2002]**

(a) Hydroxy apatite and kernite

(b) Colemanite and fluoraptite

(c) Borax and fluoraptite

(d) Hydroxy apatite and colemanite

(e) Hydroxy apatite and fluorapatile

155. The three important oxidation states of phosphorus are **[Kerala (Med.) 2002]**

(a) $-3,+3$ and $+5$ (b) $-3,+3$ and -5

(c) $-3,+4$ and -4 (d) $-3,+3$ and $+4$

156. In case of nitrogen, NCl_3 is possible but not NCl_5 while in case of phosphorous, PCl_3 as well as PCl_5 are possible. It is due to

(a) Availability of vacant d-orbital in P but not in N

(b) Lower electronegativity of P than N

(c) Lower tendency of H bond formation in P than N

(d) Occurrence of P in solid while N in gaseous state at room temperature

157. When ammonia is passed over heated copper oxide, the metallic copper is obtained. the reaction shows that ammonia is

(a) A dehydrating agent (b) An oxidising agent

(c) A reducing agent (d) A nitrating agent

158. Urea is preferred to ammonium sulphate as a nitrogeneous fertilizer because **[KCET 2003]**

(a) It is more soluble in water

(b) It is cheaper than ammonium sulphate

(c) It is quite stable
(d) It does not cause acidity in the soil

159. Liquid ammonia is used for refrigeration because **[MP PET 2002]**
(a) It has a high dipole moment
(b) It has a high heat of vapourisation
(c) It is basic
(d) It is a stable compound

160. Action of concentrated nitric acid (HNO_3) on metallic tin produces **[BHU 2002]**
(a) Stannic nitrate (b) Stannous nitrate
(c) Stannous nitrite (d) Meta stannic acid

161. How can you synthesize nitric oxide in the laboratory **[Orissa JEE 2003]**
(a) Zinc with cold and dilute HNO_3
(b) Zinc with concentrated HNO_3
(c) Copper with cold and dilute HNO_3
(d) Heating NH_4NO_3

162. What would happen when a solution of potassium chromate is treated with an excess of dilute nitric acid **[AIEEE 2003]**
(a) Cr^{3+} and $Cr_2O_7^{2-}$ are formed
(b) $Cr_2O_7^{2-}$ and H_2O are formed
(c) CrO_4^{2-} is reduced to $+3$ state of Cr
(d) CrO_4^{2-} is oxidized to $+7$ state of Cr

163. The pentavalence in phosphorus is more stable as compared to that of nitrogen even though they belong to the same group. It is due to
(a) Inert nature of nitrogen
(b) Reactivity of phosphorus
(c) Larger size of phosphorus atom
(d) Dissimilar electronic configuration

164. A neutral fertilizer among the following compounds is **[KCET 2002]**
(a) Urea
(b) Ammonium nitrate
(c) Ammonium sulphate
(d) Calcium ammonium nitrate

165. Which is true with regard to the properties of PH_3 **[BHU 2000]**
(a) PH_3 is not much stable
(b) PH_3 is neutral towards litmus
(c) PH_3 has fishy smell
(d) PH_3 is insoluble in water

166. Nitrogen is obtained when $NaNO_2$ reacts with **[UPSEAT 2003]**
(a) NH_4Cl (b) NH_4NO_3
(c) $(NH_4)_2CO_3$ (d) NH_4OH

167. N_2 combines with metal to form **[JIPMER 2000]**
(a) Nitride (b) Nitrate
(c) Nitrite (d) Nitrosyl chloride

168. The number of $P-O-P$ bridges in the structure of phosphorous pentoxide and phosphorous trioxide are respectively **[AIIMS 2005]**
(a) 6, 6 (b) 5, 5
(c) 5, 6 (d) 6, 5

169. Sodium pyrophosphate is **[CPMT 2003]**
(a) $Na_2P_2O_7$ (b) $Na_4P_2O_7$
(c) $NaPO_4$ (d) Na_2PO_2

170. Which of the following is solid in nature **[UPSEAT 2003; AFMC 2004]**
(a) NO (b) N_2O
(c) N_2O_3 (d) N_2O_5

171. Which of the following is a cyclic phosphate **[KCET 1996]**
(a) $H_5P_3O_{10}$ (b) $H_6P_4O_{13}$
(c) $H_5P_5O_{15}$ (d) $H_7P_5O_{16}$

172. The reaction, which forms nitric oxide, is **[KCET (Med.) 2001]**
(a) C and N_2O (b) Cu and N_2O
(c) Na and NH_3 (d) Cu and HNO_3

173. Which one of the following can be used as an anaesthetic **[EAMCET 1998]**
(a) N_2O (b) NO
[KCET 2002]
(c) NCl_3 (d) NO_2

174. Solution of sodium metal in liquid ammonia is strongly reducing due to the presence in the solution of the following **[KCET 2000; MP PMT 2001]**
(a) Sodium hydride (b) Sodium amide
(c) Sodium atoms (d) Solvated electrons

175. What may be expected to happen when phosphine gas is mixed with chlorine gas **[AIEEE 2003]**
(a) The mixture only cools down
(b) PCl_3 and HCl are formed and the mixture warms up
(c) PCl_5 and HCl are formed and the mixture cools down
(d) $PH_3.Cl_2$ is formed with warming up

176. P_4O_{10} is not used with to dry NH_3 gas because **[KCET 2001]**
(a) P_4O_{10} is basic and NH_3 is acidic
(b) P_4O_{10} is acidic and NH_3 is basic
(c) P_4O_{10} is not a drying agent
(d) P_4O_{10} reacts with moisture in NH_3

177. When ammonia reacts with sodium hypochlorite, product containing nitrogen is **[AFMC 2000]**

(a) N_2 (b) N_2O

(c) NH_2OH (d) $H_2N.NH_2$

178. P_2O_5 is used extensively as a **[BVP 2003]**

(a) Reducing agent (b) Oxidising agent

(c) Dehydrating agent (d) Preservative

179. Inertness of N_2 gas is due to **[DCE 2000; MP PET 2001]**

(a) No vacant *d*-orbital

(b) High dissociation energy

(c) High electronegativity

(d) None

180. Which show maximum valency **[CPMT 2003]**

(a) Phosphorus (b) Tin

(c) Antimony (d) Bismuth

181. Which is used in the Haber process for the manufacture of NH_3 **[MH CET 2001]**

(a) Pt (b) $Fe+Mo$

(c) CuO (d) Al_2O_3

182. On adding excess of ammonium hydroxide to a copper chloride solution.

(a) A deep blue solution is obtained

(b) No change is observed

(c) Blue precipitate of copper hydroxide is obtained

(d) Black precipitate of copper oxide is obtained

183. The product obtained by heating $(NH_4)_2SO_4$ and $KCNO$ is

[DPMT 2000]

(a) Hydrocyanic acid (b) Ammonia

(c) Ammonium cyanide (d) Urea

184. The number of $P-O-P$ bonds in cyclic metaphosphoric acid is **[IIT-JEE (Screening) 2000]**

(a) Zero (b) Two

(c) Three (d) Four

185. When HNO_3 is dropped into the palm and washed with water, it turns into yellow. It shows the presence of

[CPMT 1997]

(a) NO_2 (b) N_2O

(c) NO (d) N_2O_5

186. Which of the following is nitrogenous fertilizers

[CPMT 1999]

(a) Bone meal (b) Thomas meal

(c) Nitro phosphate (d) Ammonium sulphate

187. Which compound is related to Haber's process

[RPET 1999]

(a) CO_2 (b) H_2

(c) NO_2 (d) NH_3

188. Ammonia is dried over **[CPMT 2002; JIPMER 2002]**

(a) Quick lime (b) Slaked lime

(c) Anhy. $CaCl_2$ (d) None of these

189. Which of the following compounds is sparingly soluble in ammonia **[JIPMER 1999]**

(a) AgI (b) $AgBr$

(c) $AgCl$ (d) $CuCl_2$

190. The carbonate which does not leave a residue on heating is

[JIPMER 1999; DCE 1999]

(a) Na_2CO_3 (b) Ag_2CO_3

(c) $CuCO_3$ (d) $(NH_4)_2CO_3$

191. Which of the following has the highest dipole moment

[CBSE PMT 1997]

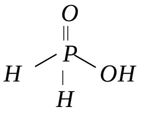
(a) NH_3 (b) PH_3

(c) SbH_3 (d) AsH_3

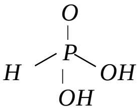
192. The structural formula of hypophosphorus acid is

[CBSE PMT 1997; AIIMS 2001; BCECE 2005; Pb. CET 2002]

(a)

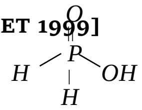


(b)

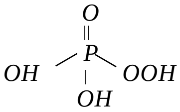


[MH CET 1999]

(c)



(d)



193. Repeated use of which of the following fertilizers would increase the acidity of the soil**[CBSE PMT 1998]**

(a) Urea (b) Potassium nitrate

(c) Ammonium sulphate (d) Superphosphate of lime

194. Aqua-regia is **[Orissa JEE 2005]**

(a) 1 : 3 conc. HNO_3 and conc. HCl

(b) 1 : 2 conc. HNO_3 and conc. HCl

(c) 3 : 1 conc. HNO_3 and conc. HCl

(d) 2 : 1 conc. HNO_3 and conc. HCl

195. Which oxide of nitrogen is obtained on heating ammonium nitrate at $250^{o}C$

(a) Nitric oxide (b) Nitrous oxide

(c) Nitrogen dioxide (d) Dinitrogen oxide

196. The oxidation number of phosphorus vary from

[Kurukshetra CEE 1998; DCE 2001]

(a) –1 to +3 (b) –3 to +3

(c) –3 to +5 (d) –5 to +1

197. Inorganic graphite is **[KCET 2003]**

(a) $B_3N_3H_6$ (b) B_3N_3

(c) SiC (d) $Fe(CO)_5$

198. Conc. HNO_3 can be stored in container of**[MH CET 2001]**

(a) Al (b) Sn

(c) Cu (d) Zn

199. Which of the following compounds does not exist

[JIPMER 1997]

(a) $SbCl_3$ (b) $BiCl_5$

(c) $SbCl_5$ (d) $AsCl_5$

200. The formula of an oxyacid of phosphorus is H_3PO_4. It is a

[MP PMT 1996; CPMT 1999; J & K CET 2005]

(a) Dibasic acid (b) Monobasic acid
(c) Tribasic acid (d) Tetrabasic acid

201. Which salt can be classified as an acid salt **[CPMT 1993]**

(a) Na_2SO_4 (b) $BiOCl$
(c) $Pb(OH)Cl$ (d) Na_2HPO_4

202. In NH_3 and PH_3, the common is **[AFMC 1995]**

(a) Odour (b) Combustibility
(c) Basic nature (d) None of these

203. Which one of the following hydrides is least stable

(a) AsH_3 (b) SbH_3
(c) NH_3 (d) PH_3

204. Which element from V group, gives most basic compound with hydrogen

(a) Nitrogen (b) Bismuth
(c) Arsenic (d) Phosphorus

205. The acid which forms two series of salts is **[KCET 1996]**

(a) H_3PO_4 (b) H_3PO_3
(c) H_3BO_3 (d) H_3PO_2

206. Which gas is obtained when urea is heated with HNO_2

[CPMT 1996]

(a) N_2 (b) H_2
(c) O_2 (d) NH_3

207. Atomic number of N is 7. The atomic number of IIIrd member of nitrogen family is **[CPMT 1996]**

(a) 23 (b) 15
(c) 33 (d) 43

208. Which of the following have least covalent $P-H$ bond

[CPMT 1996]

(a) PH_3 (b) P_2H_6
(c) P_2H_5 (d) PH_6^+

209. Sides of match box have coating of **[BHU 1995]**

(a) Potassium chlorate, red lead
(b) Potassium chlorate, antimony sulphide
(c) Antimony sulphide, red phosphorus
(d) Antimony sulphide, red lead

210. Which of the following compound is tribasic acid

[AIIMS 2002]

(a) H_3PO_2 (b) H_3PO_3
(c) H_3PO_4 (d) $H_4P_2O_7$

211. Which of the following is manufactured from the molecular nitrogen by bacteria **[MP PET 1999]**

(a) NO_3 (b) NO_2
(c) Amino acids (d) Ammonia

212. One mole of calcium phosphide on reaction with excess water gives **[IIT-JEE 1999]**

(a) One mole of phosphine
(b) Two moles of phosphoric acid
(c) Two moles of phosphine
(d) One mole of phosphorous pentoxide

213. On heating ammonium dichromate, the gas evolved is

[IIT-JEE 1999]

(a) Oxygen (b) Ammonia
(c) Nitrous oxide (d) Nitrogen

214. In compounds of type ECl_3, where $E = B,\ P,\ As$ or Bi, the angles $Cl-E-Cl$ for different E are in the order

[IIT-JEE 1999]

(a) $B > P = As = Bi$ (b) $B > P > As > Bi$
(c) $B < P = As = Bi$ (d) $B < P < As < Bi$

215. **[MP PMT 1995]** Ammonia on reaction with hypochlorite anion, can form

[IIT-JEE 1999]

(a) NO (b) NH_4Cl
(c) N_2H_4 (d) HNO_2

216. Orthophosphoric acid represents the molaysis condition due to

(a) Hydrogen bonding
(b) Phosphorous group
(c) Maximum oxygen group
(d) Tribasicity

217. Which of the following elements forms a strongly acidic oxide

(a) P (b) As
(c) Sb (d) Bi

218. In group V-A of the periodic table nitrogen forms only a trihalide but other elements form pentahalides also. The reason is

(a) Nitrogen has less affinity towards halogens
(b) Nitrogen halides are covalent
(c) Nitrogen undergoes d^2sp^3 hybridization
(d) Nitrogen does not have *d*-orbitals

219. In the nitrogen family the $H-M-H$ bond angle in the hydrides MH_3 gradually becomes closer to 90^o on going from N to Sb. This shows that gradually

[MP PET/PMT 1998; MP PMT 2000]

(a) The basic strength of hydrides increases
(b) Almost pure *p*-orbitals are used for $M-H$ bonding
(c) The bond energies of $M-H$ bond increase
(d) The bond pairs of electrons become nearer to the central atom

220. An element (X) forms compounds of the formula XCl_3, X_2O_5 and Ca_3X_2, but does not form XCl_5, which of the following is the element X **[MP PET 1997]**

(a) B (b) Al

(c) N (d) P

221. Which of the following tendencies remains unchanged on going down in the nitrogen family (Group-VA) ? **[MP PMT 1997]**

(a) Highest oxidation state
(b) Non-metallic character
(c) Stability of hydrides
(d) Physical state

222. Which of the following oxy acids of phosphorus is a reducing agent and monobasic

(a) H_3PO_2 (b) H_3PO_3
(c) H_3PO_4 (d) $H_4P_2O_6$

223. Bone black is a polymorphic form of **[DCE 2003]**

(a) Phosphorus (b) Sulphur
(c) Carbon (d) Nitrogen

224. Nitrous oxide is known as **[AFMC 2004]**

(a) Breathing gas (b) Laughing gas
(c) exercising gas (d) Laboratory gas

225. When lead nitrate is heated, it gives **[MH CET 2003]**

(a) NO_2 (b) NO
(c) N_2O_5 (d) N_2O

226. Which element exist as a solid at 25°C and 1 atmospheric pressure among the following **[DCE 2003]**

(a) Br (b) Cl
(c) Hg (d) P

227. In the reaction $HNO_3 + P_4O_{10} \rightarrow 4HPO_3 + x$, the product x is **[MH CET 2003; DPMT 2004]**

(a) N_2O_3 (b) N_2O_5
(c) NO_2 (d) H_2O

228. The number of hydrogen atom (s) attached to phosphorus atom in hypophosphorous acid is **[AIEEE 2005]**

(a) Zero (b) Two
(c) One (d) Three

229. Which blue liquid is obtained on reacting equimolar amounts of two gases at $-30°C$ **[IIT-JEE (Screening) 2005]**

(a) N_2O (b) N_2O_3
(c) N_2O_4 (d) N_2O_5

230. Which is the most thermodynamically stable allotropic form of phosphorus **[IIT-JEE (Screening) 2005]**

(a) Red (b) White
(c) Black (d) Yellow

231. $(NH_4)_2Cr_2O_7$ on heating liberates a gas. The same gas will be obtained by **[IIT JEE (Screening) 2004; BVP 2004]**

(a) Heating NH_4NO_2
(b) Heating NH_4NO_3
(c) Treating H_2O_2 with $NaNO_2$
(d) Treating Mg_3N_2 with H_2O

232. The element which forms oxides in all oxidation states $+I$ to $+V$ is **[AIIMS 2004]**

(a) N (b) P
(c) As (d) Sb

233. The boiling points of the following hydrides follow the order of **[DPMT 2004]**

(a) $NH_3 > AsH_3 > PH_3 > SbH_3$
(b) $SbH_3 > AsH_3 > PH_3 > NH_3$
(c) $SbH_3 > NH_3 > AsH_3 > PH_3$
(d) $NH_3 > PH_3 > AsH_3 > SbH_3$

[DCE 2004]

234. Which of the following halides is most acidic **[MP PMT 2004]**

(a) PCl_3 (b) $BiCl_3$
(c) $SbCl_3$ (d) CCl_4

235. In the electrothermal process, the compound displaced by silica from calcium phosphate is **[KCET 2004]**

(a) Calcium (b) Phosphine
(c) Phosphorus (d) Phosphorus pentoxide

236. Which of the following compound show sublimation **[AFMC 1995; Pb. CET 2000]**

(a) NH_4Cl (b) $CaCO_3$
(c) $BaSO_4$ (d) $CaHPO_3$

237. Number of $P-O$ bonds in P_4O_{10} is **[DCE 2002]**

(a) 17 (b) 16
(c) 15 (d) 6

238. Most acidic oxide is **[Pb. CET 2004]**

(a) Na_2O (b) ZnO
(c) MgO (d) P_2O_5

239. Which of the following is a mixed anhydride **[Pb. CET 2003]**

(a) NO (b) NO_2
(c) N_2O_5 (d) N_2O

240. Oxidation number of As in $H_2AsO_4^-$ is **[CPMT 2001]**

(a) 6 (b) 7
(c) 5 (d) 9

241. When plants and amimals decay, the organic nitrogen is converted into inorganic nitrogen. The inorganic nitrogen is in the form of **[KCET 2005]**

(a) Ammonia (b) Elements of nitrogen
(c) Nitrates (d) Nitrides

Oxygen family

1. Which element is found in free state **[CPMT 1972, 81, 91; DPMT 1986]**

(a) Iodine (b) Sulphur
(c) Phosphorus (d) Magnesium

2. Which of the elements listed below occurs in allotropic forms

[CPMT 1972]

(a) Iodine (b) Copper
(c) Sulphur (d) Silver

3. Which forms new compound in air **[AFMC 1987]**

(a) H_2O in air (b) O_2 in air
(c) N_2 in air (d) Phosphorus in air

4. Which of the following after burning at room temperature gives gaseous oxide

[NCERT 1973; CPMT 1981; DPMT 1982; JIPMER 2001]

(a) H (b) Na
(c) S (d) He

5. Sulphur molecule is converted into sulphur ion, when it

[DPMT 1980]

(a) Gains two electrons (b) Loses two electrons
(c) Gains two protons (d) Shares two electrons

6. The element which liberates oxygen gas from water is

[MP PMT 1993]

(a) P (b) Na
(c) F (d) I

7. The highest catenation ability is shown by

[AIIMS 1983; MP PET 1993; CPMT 1997]

(a) Oxygen (b) Sulphur
(c) Selenium (d) Tellurium

8. Ozone belongs to which group of the periodic table

(a) V group (b) VI group
(c) VII group (d) None of these

9. The number of unpaired electrons in the *p*-subshell of oxygen atom is

(a) 1 (b) 2
(c) 3 (d) 4

10. Most abundant element on earth is**[MP PET/PMT 1988]**

(a) O (b) S
(c) Se (d) Te

11. Which of the following is most electronegative**[BHU 1978]**

(a) O (b) S
(c) Te (d) Se

12. The ability of a substance to assume two or more crystalline structures is called

(a) Isomerism (b) Polymorphism
(c) Isomorphism (d) Amorphism

13. SO_2 is obtained when **[Roorkee 1995]**

(a) Oxygen reacts with dilute sulphuric acid
(b) Hydrolysis of dilute H_2SO_4
(c) Concentrated H_2SO_4 reacts with Na_2SO_3
(d) All of these

14. Which shows polymorphism**[BHU 1982; MP PMT 1985]**

(a) O (b) S
(c) Se (d) All the above

15. Bond angle is minimum for **[DPMT 1990]**

(a) H_2O (b) H_2S
(c) H_2Se (d) H_2Te

16. Oxygen was discovered by **[BHU 1987]**

(a) Priestley (b) Boyle
(c) Scheele (d) Cavandish

17. The compound which gives off oxygen on moderate heating is

[IIT-JEE 1986; MP PMT 1991; MADT Bihar 1995]

(a) Cupric oxide
(b) Mercuric oxide
(c) Zinc oxide
(d) Aluminium oxide

18. It is possible to obtain oxygen from air by fractional distillation because

(a) Oxygen is in a different group of the periodic table from nitrogen
(b) Oxygen is more reactive than nitrogen
(c) Oxygen has higher b.p. than nitrogen
(d) Oxygen has a lower density than nitrogen

19. Oxygen is denser than air so it is collected over

[CPMT 1980; MP PET 1999]

(a) H_2O (b) Ethanol
(c) Mercury (d) Kerosene oil

20. Oxygen molecule exhibits

[CPMT 1991, 99, 2002; AIIMS 1983; BHU 1986; NCERT 1980, 81; MP PMT 1985, 92; AFMC 2004]

(a) Paramagnetism (b) Diamagnetism
(c) Ferromagnetism (d) Ferrimagnetism

21. When oxygen is passed through a solution of Na_2SO_3 we get

(a) Na_2SO_4 (b) Na_2S
(c) $NaHSO_4$ (d) NaH

22. Oxygen does not react with **[CBSE PMT 1989]**

[Kurukshetra CEE 1991]

(a) P (b) Na
(c) S (d) Cl

23. The formula of ozone is O_3, it is

[CPMT 1989, 91; Manipal MEE 1995; RPET 1999, 2000]

(a) An allotrope of oxygen (b)Compound of oxygen
(c) Isotope of oxygen (d) None of these

24. Ozone is obtained from oxygen **[CPMT 1982]**

(a) By oxidation at high temperature
(b) By oxidation using a catalyst
(c) By silent electric discharge **[CBSE PMT 1989]**
(d) By conversion at high pressure

25. Which of the following statement is true about ozone layer

[NCERT 1980]

(a) It is harmful because ozone is dangerous to living organism
(b) It is beneficial because oxidation reaction can proceed faster in the presence of ozone
(c) It is beneficial because ozone cuts out the ultraviolet radiation of the sun

(d) It is harmful because ozone cuts out the important radiation of the sun which are vital for photosynthesis

26. Identify the incorrect statement with respect to ozone **[AIIMS 1992]**

(a) Ozone is formed in the upper atmosphere by a photochemical reaction involving dioxygen
(b) Ozone is more reactive than oxygen
(c) Ozone is diamagnetic whereas dioxygen is paramagnetic
(d) Ozone protects the earth's inhabitants by absorbing γ radiations

27. Which one of the following property is not correct for ozone **[CPMT 1984]**

(a) It oxidises lead sulphide
(b) It oxidises potassium iodide
(c) It oxidises mercury
(d) It cannot act as bleaching agent

28. Ozone with KI solution produces **[CPMT 1987]**

(a) Cl_2 (b) I_2
(c) HI (d) IO_3

29. The gases respectively absorbed by alkaline pyrogallol and oil of cinnamon is **[CBSE PMT 1989]**

(a) $O_{3,}$ CH_4 (b) O_2, O_3
(c) SO_2, CH_4 (d) N_2O, O_3

30. Ozone turns trimethyl paper **[CPMT 1989]**

(a) Green (b) Violet
(c) Red (d) Black

31. No. of atoms in one molecule of sulphur is **[AFMC 1987, 91; AMU 1985]**

(a) 8 (b) 4
(c) 3 (d) None of these

32. When H_2S is passed through acidified $KMnO_4$, we get **[CPMT 1979, 91; MP PMT 1987]**

(a) K_2SO_3 (b) MnO_2
(c) $KHSO_3$ (d) Sulphur

33. Copper turnings when heated with concentrated sulphuric acid will give **[AFMC 1987; BHU 1999; CBSE PMT 2000]**

(a) SO_2 (b) SO_3
(c) H_2S (d) O_2

34. Which of the following is used to absorb sulphur dioxide **[EAMCET 1980]**

(a) Conc. H_2SO_4 (b) KOH solution
(c) Water (d) Anhydrous $CaCl_2$

35. Which compound acts as an oxidising as well as reducing agent **[IIT 1991]**

(a) SO_2 (b) MnO_2
(c) Al_2O_3 (d) CrO_3

36. A solution of sulphur dioxide in water reacts with H_2S precipitating sulphur. Here sulphur dioxide acts as **[NCERT 1980; MP PMT 1994]**

(a) An oxidising agent (b) A reducing agent
(c) An acid (d) A catalyst

37. When SO_2 is passed through acidified $K_2Cr_2O_7$ solution **[CPMT 1989, 94]**

(a) The solution turns blue
(b) The solution is decolourised
(c) SO_2 is reduced
(d) Green $Cr_2(SO_4)_3$ is formed

38. When SO_2 is passed through cupric chloride solution **[CPMT 1979, 81, 89, 94]**

(a) A white precipitate is obtained
(b) The solution becomes colourless
(c) The solution becomes colourless and a white precipitate of Cu_2Cl_2 is obtained
(d) No visible change takes place

39. Which of the following is oxidised by SO_2 **[BHU 1986]**

(a) Mg (b) $K_2Cr_2O_7$
(c) $KMnO_4$ (d) All of these

40. Bleaching action of SO_2 is due to **[CPMT 1971, 79, 86]**

(a) Reduction (b) Oxidation
(c) Hydrolysis (d) Its acidic nature

41. A salt of sulphurous acid is called **[NCERT 1978]**

(a) Sulphate (b) Sulphurate
(c) Sulphite (d) Sulphide

42. Which of the following is acidic **[AFMC 1990; JIPMER 1997]**

(a) SO_3 (b) N_2O
(c) BeO (d) HgO

43. The final acid obtained during the manufacture of H_2SO_4 by contact process is

(a) H_2SO_4 (conc.) (b) H_2SO_4 (dil.)
(c) H_2SO_4 (d) $H_2S_2O_7$

44. About H_2SO_4 which is incorrect **[CPMT 1985]**

(a) Reducing agent (b) Dehydrating agent
(c) Sulphonating agent (d) Highly viscous

45. In the reaction

$$2Ag + 2H_2SO_4 \rightarrow Ag_2SO_4 + 2H_2O + SO_2$$

H_2SO_4 acts as **[CPMT 1981]**

(a) Reducing agent (b) Oxidising agent
(c) Catalytic agent (d) Dehydrating agent

46. In the reaction $HCOOH \xrightarrow{H_2SO_4} CO + H_2O$; H_2SO_4 acts as

(a) Dehydrating agent (b) Oxidising agent
(c) Reducing agent (d) All of these

47. When conc. H_2SO_4 comes in contact with sugar, it becomes black due to **[CPMT 1989; BHU 1986; MDAT Bihar 1980]**

(a) Hydrolysis (b) Hydration

(c) Decolourisation (d) Dehydration

48. Oxalic acid when heated with conc. H_2SO_4, gives out **[DPMT 1981; AFMC 1998]**

(a) H_2O and CO_2 (b) CO and CO_2

(c) Oxalic sulphate (d) CO_2 and H_2S

49. Which one is known as **oil of vitriol** **[CPMT 1988; MP PMT 2004]**

(a) H_2SO_3 (b) H_2SO_4

(c) $H_2S_2O_7$ (d) $H_2S_2O_8$

50. The acid used in lead storage cells is **[NCERT 1971; Roorkee 1989]**

(a) Phosphoric acid (b) Nitric acid

(c) Sulphuric acid (d) Hydrochloric acid

51. Which one of the gas dissolves in H_2SO_4 to give oleum **[CPMT 1988]**

(a) SO_2 (b) H_2S

(c) S_2O (d) SO_3

52. Oleum is **[CBSE PMT 1991; MP PMT 2002; CPMT 2004]**

(a) Castor oil (b) Oil of vitriol

(c) Fuming H_2SO_4 (d) None of them

53. There is no $S-S$ bond in **[IIT 1991; CPMT 1999; DCE 2000]**

(a) $S_2O_4^{2-}$ (b) $S_2O_5^{2-}$

(c) $S_2O_3^{2-}$ (d) $S_2O_7^{2-}$

54. Which of the following sulphate is insoluble in water **[MP PMT 2000]**

(a) $CuSO_4$ (b) $CdSO_4$

(c) $PbSO_4$ (d) $Bi_2(SO_4)_3$

55. When sulphur is boiled with Na_2SO_3 solution, the compound formed is **[CPMT 1979; Roorkee 1992]**

(a) Sodium sulphide (b) Sodium sulphate

(c) Sodium persulphate (d) Sodium thiosulphate

56. The products of the chemical reaction between $Na_2S_2O_3$, Cl_2 and H_2O are **[EAMCET 1989]**

(a) $S+HCl+Na_2S$ (b) $S+HCl+Na_2SO_4$

(c) $S+HCl+Na_2SO_3$ (d) $S+NaClO_3+H_2O$

57. Hypo is used in photography for **[Roorkee 1989]**

(a) Developing a picture

(b) Picture printing

(c) The colour of picture

(d) The fixation of the picture

58. Hypo is used in photography to **[CBSE PMT 1988; Pb. CET 1989]**

(a) Reduce $AgBr$ grains to metallic silver

(b) Convert the metallic silver to silver salt

(c) Remove undecomposed silver bromide as a soluble complex

(d) Remove reduced silver

59. Hypo is used in photography because of its **[IIT 1981; EAMCET 1988; MADT Bihar 1995]**

(a) Reducing behaviour

(b) Oxidising behaviour

(c) Complex forming behaviour

(d) Reaction with light

60. Aqueous solutions of hydrogen sulphide and sulphur dioxide when mixed together, yield **[KCET 2002]**

(a) Sulphur and water

(b) Sulphur trioxide and water

(c) Hydrogen peroxide and sulphur

(d) Hydrogen and sulphurous acid

61. An example of a neutral oxide is **[KCET 2003]**

(a) NO (b) CO_2

(c) CaO (d) ZnO

62. Which of the following is the best scientific method to test presence of water in a liquid **[AIIMS 1999]**

(a) Taste

(b) Smell

(c) Use of litmus paper

(d) Use of anhydrous copper sulphate

63. H_2S react with O_2 to form **[AFMC 1995]**

(a) H_2O+S (b) H_2O+SO_2

(c) H_2O+SO_3 (d) H_2SO_4+S

64. Which of the following mixture is chromic acid **[Pb. PMT 2000]**

(a) $K_2Cr_2O_7$ and conc. H_2SO_4

(b) $K_2Cr_2O_7$ and HCl

(c) K_2SO_4 and conc. H_2SO_4

(d) H_2SO_4 and HCl

65. At room temperature H_2O is a liquid while H_2S is a gas. The reason is **[RPET 1999]**

(a) Electronegativity of O is greater than S

(b) Difference in the bond angles of both the molecules

(c) Association takes place in H_2O due to H-bonding while no H- bonding in H_2S

(d) O and S belong to different periods

66. Which of the following products is formed on boiling tin with an alkali solution **[Roorkee 2000]**

(a) $Sn(OH)_2$ (b) $Sn(OH)_4$

(c) SnO_3^{2-} (d) SnO_2

67. Amongst H_2O, H_2S, H_2Se and H_2Te the one with the highest boiling point is **[IIT-JEE (Screening) 2000]**

(a) H_2O because of hydrogen bonding

(b) H_2Te because of higher molecular weight

(c) H_2S because of hydrogen bonding

(d) H_2Se because of lower molecular weight

68. Among the hydrides formed by the group VI-A elements, only H_2O has an abnormally low volatility (high boiling point). This is so because

(a) H_2O molecules are associated due to intermolecular hydrogen bonds

(b) H_2O is covalent in nature

(c) The $O-H$ bond in H_2O is very strong

(d) The electronegativity difference of H and O is very large

69. Sulphuric acid reacts with PCl_5 to give

[KCET 1996; JIPMER 2000]

(a) Thionyl chloride (b) Sulphur monochloride

(c) Sulphuryl chloride (d) Sulphur tetrachloride

70. Carbogen is **[EAMCET 1998]**

(a) Pure form of carbon

(b) $COCl_2$

(c) Mixture of CO and CO_2

(d) Mixture of O_2 and CO_2

71. Which of the following dissociates to give H^+ most easily

[MP PET 1994]

(a) H_2O (b) H_2S

(c) H_2Te (d) H_2Se

72. Superphosphate is the mixture of **[CPMT 1993]**

(a) Calcium phosphate and dil. H_2SO_4

(b) Sodium phosphate and dil. H_2SO_4

(c) Potassium phosphate and dil. H_2SO_4

(d) None of these

73. Among KO_2, NO_2^-, BaO_2 and NO_2^+ unpaired electron is present in **[IIT 1997]**

(a) NO_2^+ and BaO_2 (b) KO_2 and BaO_2

(c) KO_2 only (d) BaO_2 only

74. Which is not easily soluble in water **[CPMT 1994]**

(a) H_2 (b) O_2

(c) SO_2 (d) CO_2

75. Point out in which of the following properties oxygen differs from the rest of the members of its family (Group-VIA)

[MP PMT 1997]

(a) High value of ionisation energies

(b) Oxidation states (2, 4, 6)

(c) Polymorphism

(d) Formation of hydrides

76. In the preparation of sulphuric acid, V_2O_5 is used in the reaction, which is **[CBSE PMT 2001; AFMC 2001]**

(a) $S + O_2 \rightarrow SO_2$

(b) $2SO_2 + O_2 \rightarrow 2SO_3$

(c) $SO_2 + H_2O \rightarrow H_2SO_4$

(d) $N_2 + 3H_2 \rightarrow 2NH_3$

77. Which of the following hydrides has the lowest boiling point

[MP PET 1997]

(a) H_2O (b) H_2S

(c) H_2Se (d) H_2Te

78. The catalyst used in the manufacture of H_2SO_4 by contact process is **[UPSEAT 1999]**

(a) Al_2O_3 (b) Cr_2O_3

(c) V_2O_5 (d) MnO_2

79. The molecular formula of sulphur is

[MP PMT 1996; MP PET/PMT 1998]

(a) S (b) S_2

(c) S_4 (d) S_8

80. Which of the following is not suitable for use in a descicator to dry substances

(a) Conc. H_2SO_4 (b) Na_2SO_4

(c) $CaCl_2$ (d) P_4O_{10}

81. Which shows polymorphism **[DCE 2000]**

(a) O (b) S

(c) Se (d) All

82. All the elements of oxygen family are **[MP PET/PMT 1998]**

(a) Non-metals (b) Metalloids

(c) Radioactive (d) Polymorphic

83. The triatomic species of elemental oxygen is known as

[Kerala (Med.) 2002]

(a) Azone (b) Polyzone

(c) Triozone (d) Ozone

84. When H_2S gas is passed through nitric acid, the product is

[Kerala (Engg.) 2002]

(a) Rhombic S (b) Prismatic S

(c) Amorphous S (d) Monoclinic S

(e) None of these

85. Shape of O_2F_2 is similar to that of **[AIIMS 2004]**

(a) C_2F_2 (b) H_2O_2

(c) H_2F_2 (d) C_2H_2

86. Which of the following bonds has the highest energy

[CBSE PMT 1996]

(a) $Se - Se$ (b) $Te - Te$

(c) $S - S$ (d) $O - O$

87. Which of the following is not a chalcogen **[CPMT 1999]**

(a) O (b) S

(c) Se (d) Na

88. Which of the following is a suboxide **[DPMT 2001]**

(a) Ba_2O (b) Pb_2O

(c) C_3O_2 (d) ZnO

89. In the manufacture of sulphuric acid by contact process, Tyndall box is used to **[KCET 2003]**

(a) Filter dust particles

(b) Remove impurities

(c) Convert SO_2 to SO_3

(d) Test the presence of dust particles

90. Permono sulphuric acid is known as **[Bihar CEE 1995]**

(a) Marshell's acid (b) Caro's acid

(c) Sulphuric acid (d) None of these

91. $KO_2 + CO_2 \rightarrow ?$ (gas) **[CPMT 1997]**

(a) H_2 (b) N_2

(c) O_2 (d) CO

92. H_2SO_4 acts as dehydrating agent in its reaction with

[JIPMER 2001]

(a) $H_2C_2O_4$ (b) $Ba(OH)_2$

[AIIMS 1996]

(c) KOH (d) Zn

93. Which of the following group shows the highest boiling point

[MP PET 2002]

(a) H_2O (b) H_2S

(c) H_2Se (d) H_2Te

94. In presence of moisture, SO_2 can **[BVP 2003]**

(a) Act as oxidant (b) Lose electron

(c) Gain electron (d) Not act as reductant

95. A gas that cannot be collected over water is

[Kurukshetra CEE 1998]

(a) N_2 (b) O_2

(c) SO_2 (d) PH_3

96. Which of the following is formed by the action of water on sodium peroxide

(a) H_2 (b) N_2

(c) O_2 (d) CO_2

97. Sulphur on boiling with $NaOH$ solution gives

[Roorkee 1999]

(a) $Na_2S_2O_3 + NaHSO_3$ (b) $Na_2S_2O_3 + Na_2S$

(c) $Na_2SO_3 + H_2S$ (d) $Na_2SO_3 + SO_2$

98. Quartz is a crystalline variety of

[Pb. CET 2002; Pb. PMT 2000, 04]

(a) Silicon carbide (b) Sodium silicate

(c) Silica (d) Silicon

99. The most efficient agent for the absorption of SO_3 is

[BHU 2004; DPMT 2004]

(a) 80% H_2SO_4 (b) 98% H_2SO_4

(c) 50% H_2SO_4 (d) 20% $H_2S_2O_7$

100. Conc. H_2SO_4 is diluted **[Pb. CET 2001]**

(a) By adding water in H_2SO_4

(b) By adding H_2SO_4 in water

(c) By adding glacial acetic acid in H_2SO_4

(d) None of the above

101. The smog is essentially caused by the presence of **[AIEEE 2004]**

(a) Oxides of sulphur and nitrogen

(b) O_2 and N_2

(c) O_2 and O_3

(d) O_3 and N_2

102. Bleaching action of SO_2 is due to its **[CPMT 2004]**

(a) Oxidising property (b) Acidic property

(c) Basic property (d) Reducing property

103. Oxygen is not evolved on reaction of ozone with **[Pb. PMT 2004]**

(a) H_2O_2 (b) SO_2

(c) Hg (d) KI

104. When PbO_2 reacts with conc. HNO_3 the gas evolved is **[IIT-JEE (Screening) 2005]**

(a) NO_2 (b) O_2

(c) N_2 (d) N_2O

105. Sulphur in +3 oxidation state is present in **[DCE 2003]**

(a) Sulphurous acid (b) Pyrosulphuric acid

(c) Dithionous acid (d) Thiosulphuric acid

106. $SO_2 + H_2S \rightarrow$ product. the final product is **[Orissa JEE 2005]**

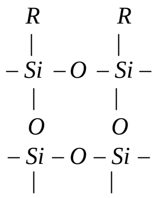
(a) $H_2O + S$ (b) H_2SO_4

(c) H_2SO_3 (d) $H_2S_2O_3$

107. Oncontrolled hydrolysis and condensation, R_3SiCl yields **[Orissa JEE 2005]**

(a) $R_3Si - O - SiR_3$ (b) $\left(R_3Si - O - SiR_3 \right)_n$

(c) R_3SiOH (d)



108. Ozone deplict due to the formation of following compound in Antarctica **[Kerala CET 2005]**

(a) Acrolein (b) Peroxy acetyl nitrate

(c) SO_2 and SO_3 (d) Chlorine nitrate

(e) Formaldehyde

Halogen family

1. The correct order of the thermal stability of hydrogen halides (H –X) is **[AIEEE 2005]**

(a) $HI > HBr > HCl > HF$

(b) $HF > HCl > HBr > HI$

(c) $HCl < HF < HBr < HI$

(d) $HI > HCl < HF < HBr$

2. **Phosgene** is the common name of **[CPMT 1974, 86; DPMT 1989; MP PMT 1994]**

(a) Carbonyl chloride (b) Phosphine

(c) Phosphorus oxychloride (d)Phosphorus trichloride

3. The solubility of iodine in water increases in the presence of **[CPMT 1973, 74, 78, 86, 89, 91; NCERT 1973; AFMC 1995]**

(a) Alcohol (b) Chloroform

(c) Sodium hydroxide (d) Potassium iodide

4. When thiosulphate ion is oxidised by iodine, which one of the following ion is produced **[CPMT 1989; AFMC 1990; CBSE PMT 1996]**

(a) SO_3^{2-} (b) SO_4^{2-}

(c) $S_4O_6^{2-}$ (Tetrathionate) (d) $S_2O_6^{2-}$

5. Bromine is liberated when an aqueous solution of potassium bromide is treated with **[CBSE PMT 1989]**

(a) Cl_2 (b) I_2

(c) Dilute H_2SO_4 (d) SO_2

6. Which of the following has greatest reducing power **[CPMT 1984, 88, 89, 94]**

(a) HI (b) HBr

(c) HCl (d) HF

7. Chlorine was discovered by **[BHU 1988]**

(a) Davy (b) Priestley

(c) Rutherford (d) Sheele

8. Bad conductor of electricity is **[MP PET/PMT 1988]**

(a) H_2F_2 (b) HCl

(c) HBr (d) HI

9. Which of the following will not occur **[MP PET/PMT 1988]**

(a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

(b) $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$

(c) $2KBr + I_2 \rightarrow 2KI + Br_2$

(d) $CuO + H_2 \rightarrow Cu + H_2O$

10. Bromine is obtained on commercial scale from **[CPMT 1985]**

(a) Caliche (b) Carnellite

(c) Common salt (d) Cryolite

11. Which one of the halogen acids is a liquid **[MP PMT 1985]**

(a) HF (b) HCl

(c) HBr (d) HI

12. Which one of the following acids is the weakest **[MP PMT 1985]**

(a) $HClO$ (b) HBr

(c) $HClO_3$ (d) HCl

13. Chlorine reacts with sodium hydroxide under various condition to give

(a) Sodium chloride (b) Sodium hypochlorite
(c) Sodium chlorate (d) All of these

14. Br_2 gas turns starch iodide paper **[CPMT 1987; AFMC 1987; AMU 1999]**

(a) Blue (b) Red
(c) Colourless (d) Yellow

15. When Cl_2 gas is passed through hot and conc. solution of KOH, following compound is formed **[CPMT 1971, 79; BVP 2003]**

(a) KCl (b) $KClO_3$
(c) $KClO_2$ (d) $KClO_4$

16. Deacon's process is used in the manufacture of **[BHU 1979]**

(a) Bleaching powder (b) Sulphuric acid
(c) Nitric acid (d) Chlorine

17. Which of the following is the weakest acid **[BHU 1984, 86; CPMT 1988, 2000; MP PMT 1995; MP PET 1989, 90; Kurukshetra CEE 1998; Roorkee 2000; RPMT 2000]**

(a) HF (b) HCl
(c) HBr (d) HI

18. Which is the most volatile compound **[CPMT 1979; AIIMS 1980; DPMT 1982; Kurukshetra CEE 1998; J & K CET 2005; DPMT 2002]**

(a) HF (b) HCl
(c) HBr (d) HI

19. On boiling an aqueous solution of $KClO_3$ with iodine, the following product is obtained **[NCERT 1980]**

(a) KIO_3 (b) $KClO_4$
(c) KIO_4 (d) KCl

20. Colour of iodine solution is disappeared by shaking it with aqueous solution of **[CPMT 1979, 81; MP PET/PMT 1988; MP PMT 1986; RPMT 1997, 2002]**

(a) H_2SO_4 (b) Na_2S
(c) $Na_2S_2O_3$ (d) Na_2SO_4

21. A quick supply of Cl_2 gas may be made by reacting crystals of $KMnO_4$ with a concentrated solution of **[CPMT 1973]**

(a) Potassium chloride (b) Sodium chloride
(c) Bleaching powder (d) Hydrochloric acid

22. The strongest acid amongst the following is **[IIT 1989]**

(a) $HClO_4$ (b) $HClO_3$
(c) $HClO_2$ (d) $HClO$

23. Iodine deficiency in diet causes

(a) Nightblindness (b) Rickets
(c) Goitre (d) Beri-beri

24. Which of the following is correct **[CPMT 1985]**

(a) Iodine is a solid
(b) Chlorine is insoluble in water
(c) Iodine is more reactive than bromine
(d) Bromine is more reactive than chlorine

[NCERT 1973]

25. When KBr is treated with concentrated H_2SO_4 redish brown gas evolved, gas is **[Pb. CET 2003]**

(a) Mixture of bromine and HBr
(b) HBr
(c) Bromine
(d) None of these

26. Sea weed is employed as a source of manufacture of **[CPMT 1982, 86, 2002; MP PET 2002]**

(a) F (b) I
(c) Br (d) Cl

27. Which of the following is most active halogen **[MP PET 1990]**

(a) Cl_2 (b) Br_2
(c) I_2 (d) F_2

28. Which of the following represents clear electropositive properties **[MP PET/PMT 1988; MP PMT 1991]**

(a) F (b) Cl
(c) Br (d) I

29. Which statement is false **[MP PET 1991]**

(a) Electronegativity of fluorine is maximum
(b) Electron affinity of fluorine is maximum
(c) Melting point of fluorine is minimum
(d) Boiling point of fluorine is maximum

30. Strongest reducing agent is **[MP PMT 1990]**

(a) F^- (b) Cl^-
(c) Br^- (d) I^-

31. Which of the following represents outermost shell electronic configuration of halogens **[MP PET 1991; Manipal MEE 1995; MP PMT 1996]**

(a) s^2p^3 (b) s^2p^6
(c) s^2p^4 (d) s^2p^5

32. Chlorine can remove **[MP PET 1990]**

(a) Br from $NaBr$ solution
(b) F from NaF solution
(c) Cl from $NaCl$ solution
(d) F from CaF_2 solution

33. Hydrolysis of which of the following does not occur **[AIIMS 1982]**

(a) VCl_4 (b) $TiCl_4$
(c) $SiCl_4$ (d) CCl_4

34. Nitric acid converts iodine into **[MP PMT 1990]**

(a) Iodic acid (b) Hydroiodic acid
(c) Iodine nitrate (d) Iodine pentaoxide

35. In KI solution, I_2 readily dissolves and forms **[MP PMT 1989; EAMCET 1992]**

(a) I^- (b) KI_2
(c) KI_2^- (d) KI_3

36. Which reaction cannot be used for the production of halogen acid **[MP PMT 1989]**

(a) $2KBr + H_2SO_4 \rightarrow K_2SO_4 + 2HBr$

(b) $NaHSO_4 + NaCl \rightarrow Na_2SO_4 + HCl$

(c) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

(d) $CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$

37. In dark, which of the following reacts with hydrogen **[MP PMT/PET 1988; Kurukshetra CEE 1998]**

(a) Br_2 (b) F_2

(c) I_2 (d) Cl_2

38. The more activeness of fluorine is due to **[MP PMT 1990]**

(a) F-F bond has less energy

(b) F_2 is gas at normal temperature

(c) Its electronic bond is maximum

(d) F-F bond has more energy

39. Which of the following after reacting with KI do not remove iodine **[MP PET 1989]**

(a) $CuSO_4$ (b) $K_2Cr_2O_7$

(c) HNO_3 (d) HCl

40. Aqueous solution of which of the following acids cannot be kept in a bottle of glass **[MP PET 1989]**

(a) HF (b) HCl

(c) HBr (d) HI

41. Which of the following pairs is not correctly matched **[MP PET 1993]**

(a) A halogen which is liquid at room temperature—*Bromine*

(b) The most electronegative element—*Fluorine*

(c) The most reactive halogen—*Fluorine*

(d) The strongest oxidizing halogen—*Iodine*

42. Iodine is formed when potassium iodide reacts with a solution of **[MNR 1984; MP PET/PMT 1998]**

(a) $ZnSO_4$ (b) $CuSO_4$

(c) $(NH_4)_2SO_4$ (d) Na_2SO_4

43. As the atomic number of halogens increases, the halogens **[MP PMT 1991]**

(a) Lose the outermost electrons less readily

(b) Become lighter in colour

(c) Become less denser

(d) Gain electrons less readily

44. Which statement is correct about halogens **[EAMCET 1991]**

(a) They are all diatomic and form univalent ions

(b) They are all capable of exhibiting several oxidation states

(c) They are all diatomic and form divalent ions

(d) They can mutually displace each other from the solution of their compounds with metals

45. Mark the smallest atom **[CPMT 1984, 89]**

(a) F (b) Cl

(c) Br (d) I

46. Mark the element which shows only one oxidation state **[BHU 1988; MP PET 2002]**

(a) F (b) Cl

(c) Br (d) I

47. Which of the following arrangement for the three halogens Cl, Br and I when placed in the order of their increasing electron affinity is correct **[CPMT 1990]**

(a) $Cl,\ Br,\ I$ (b) I, Br, Cl

(c) $Br,\ Cl,\ I$ (d) $I,\ Cl,\ Br$

48. Which of the following is strongest oxidising agent **[CPMT 1978, 91, 94; MNR 1990; AMU 1983, 84; MP PMT 1991, 92, 96; IIT 1992; UPSEAT 2000]**

(a) F_2 (b) Cl_2

(c) Br_2 (d) I_2

49. Fluorine is a better oxidising agent than Br_2. It is due to **[EAMCET 1992]**

(a) Small size of fluorine

(b) More electron repulsion in fluorine

(c) More electronegativity of fluorine

(d) Non-metallic nature of fluorine

50. Fluorine is a stronger oxidising agent than chlorine in aqueous solution. This is attributed to many factors except **[Pb. CET 1989]**

(a) Heat of dissociation (b) Electron affinity

(c) Heat of hydration (d) Ionisation potential

51. Mark the element which displaces three halogens from their compounds **[MP PMT 1980, 82; BHU 1984; NCERT 1987]**

(a) F (b) Cl

(c) Br (d) I

52. Which one of the following is the most basic **[CPMT 1975, 77; MP PMT 2001]**

(a) I (b) Br

(c) Cl (d) F

53. Which of the following will displace the halogen from the solution of the halide **[EAMCET 1979]**

(a) Br_2 added to $NaCl$ solution

(b) Cl_2 added to KCl solution

(c) KCl added to NaF solution

(d) Br_2 added to KI solution

54. Fluorine does not form positive oxidation states because **[AIIMS 1987]**

(a) It is most electronegative element

(b) It forms only anions in ionic compounds

(c) It cannot form multiple bonding

(d) It shows non-bonded electron pair repulsion due to small size

55. In the isolation of fluorine, a number of difficulties were encountered. Which statement is correct

[NCERT 1983, 86]

(a) The potential required for the discharge of the fluoride ions is the lowest

(b) Fluorine reacts with most glass vessels

(c) Fluorine has great affinity for hydrogen

(d) Electrolysis of aqueous HF gives ozonised oxygen

56. Fluorine reacts with water to give **[BHU 1988, 89]**

(a) HF and O_2 (b) HF and OF_2

(c) HF and O_3 (d) HF, O_2 and O_3

57. In which of the following, oxygen has + 2 oxidation number **[EAMCET 1986]**

(a) F_2O (b) Cl_2O

(c) Na_2O_2 (d) Na_2O

58. The electrolysis of a certain liquid resulted in the formation of hydrogen at the cathode and chlorine at the anode. The liquid is

(a) Pure water

(b) H_2SO_4 solution

(c) $NaCl$ solution in water

(d) $CuCl_2$ solution in water

59. In the preparation of chlorine from HCl, MnO_2 acts as

[CPMT 1981]

(a) Oxidising agent (b) Reducing agent

(c) Catalytic agent (d) Dehydrating agent

60. Chlorine gas is dried over **[CPMT 1980]**

(a) CaO (b) $NaOH$

(c) KOH (d) Conc. H_2SO_4

61. Chlorine can be manufactured from **[CPMT 1989]**

(a) Electrolysis of $NaCl$

(b) Electrolysis of brine

(c) Electrolysis of bleaching powder

(d) All of these

62. When chlorine water is exposed to sunlight, O_2 is liberated. Hence **[AFMC 1989]**

(a) Hydrogen has little affinity to O_2

(b) Hydrogen has more affinity to O_2

(c) Hydrogen has more affinity to Cl_2

(d) It is a reducing agent

63. When cold $NaOH$ reacts with Cl_2 which of the following is formed **[AFMC 1992]**

(a) $NaClO$ (b) $NaClO_2$

(c) $NaClO_3$ (d) None of these

64. Chlorine is used in water for **[CBSE PMT 1988]**

(a) Killing germs (b) Prevention of pollution

(c) Cleansing (d) Removing dirt

65. Chlorine cannot be used **[MP PET/PMT 1988]**

(a) As bleaching agent

(b) In sterilisation

(c) In preparation of antiseptic

(d) For extraction of silver and copper

66. Chlorine acts as a bleaching agent only in presence of

[IIT 1983; DCE 2002]

(a) Dry air (b) Moisture

(c) Sunlight (d) Pure oxygen

67. Euchlorine is a mixture of **[CPMT 1988]**

(a) Cl_2 and SO_2 (b) Cl_2 and ClO_2

(c) Cl_2 and CO (d) None of these

68. A gas reacts with CaO, but not with $NaHCO_3$. The gas is

[AFMC 1987]

(a) CO_2 (b) Cl_2

(c) N_2 (d) O_2

[EAMCET 1979]

69. When chlorine is passed over dry slaked lime at room temperature, the main reaction product is

[CBSE PMT 1992]

(a) $Ca(ClO_2)_2$ (b) $CaCl_2$

(c) $CaOCl_2$ (d) $Ca(OCl_2)_2$

70. Bromine is obtained commercially from sea water by adding **[CPMT 1988]**

(a) $AgNO_3$ solution (b) Crystals of $NaBr$

(c) Cl_2 (d) C_2H_4

71. In the manufacture of bromine from sea water, the mother liquor containing bromides is treated with

[CBSE PMT 1992; MP PMT 2001; BHU 2002; JIPMER 2002]

(a) CO_2 (b) Cl_2

(c) I_2 (d) SO_2

72. Br^- is converted into Br_2 by using **[CPMT 1987]**

(a) Cl_2 (b) Conc. HCl

(c) HBr (d) H_2S

73. A salt, which on heating with conc. H_2SO_4 gives violet vapours, is **[CPMT 1971]**

(a) Iodide (b) Nitrate

(c) Sulphate (d) Bromide

74. When I_2 is dissolved in CCl_4, the colour that results is

[AFMC 1993]

(a) Brown (b) Violet

(c) Colourless (d) Bluish green

75. Which of the following halogen oxides is ionic**[CPMT 1989**

(a) ClO_2 (b) BrO_2

(c) I_2O_5 (d) I_4O_9

76. KI when heated with conc. H_2SO_4 gives **[MP PET/PMT 1988]**

(a) HI (b) I_2

(c) HIO_3 (d) KIO_3

77. The type of bonding in HCl molecule is **[AIIMS 1992]**

(a) Pure covalent (b) Polar covalent

(c) Highly covalent (d) H-bonding

78. HCl is a gas, but HF is a low boiling liquid. This is because **[EAMCET 1981, 89]**

(a) $H-F$ bond is strong

(b) $H-F$ bond is weak

(c) The molecules aggregate because of hydrogen bonding in HF

(d) HF is a weak acid

79. HI cannot be prepared by the action of conc. H_2SO_4 on KI because **[MNR 1984]**

(a) HI is stronger than H_2SO_4

(b) HI is more volatile than H_2SO_4

(c) H_2SO_4 is an oxidising agent

(d) H_2SO_4 forms complex

80. A solution of HCl in water is good conductor while gaseous hydrogen chloride is not. This is due to the reason that **[NCERT 1980]**

(a) Water is a good conductor of electricity

(b) HCl in water ionises

(c) Gas can not conduct electricity but water can

(d) None of these

81. Sodium chloride when heated with conc. H_2SO_4 and solid potassium dichromate gives **[CPMT 1981, 84]**

(a) Chromic chloride (b) Chromyl chloride

(c) Chromous chloride (d) None of these

82. Hydrogen bonding does not play any role in boiling of **[AFMC 1992]**

(a) NH_3 (b) H_2O

(c) HI (d) C_2H_5OH

83. HBr and HI reduce sulphuric acid, HCl can reduce $KMnO_4$ and HF can reduce **[IIT 1981; MP PET 1993]**

(a) H_2SO_4 (b) $KMnO_4$

(c) $K_2Cr_2O_7$ (d) None of these

84. Which has the highest molar heat of vaporisation **[CPMT 1991]**

(a) HF (b) HCl

(c) HBr (d) HI

85. Mark the strongest acid **[Bihar MEE 1996; MP PET/PMT 1998; NCERT 1974; CPMT 1976, 90]**

(a) HF (b) HCl

(c) HBr (d) HI

86. Which of the following hydrogen halides has the highest boiling point **[AIIMS 1980; DPMT 1983; MP PMT 198**

(a) HF (b) HCl

(c) HBr (d) Hi

87. Hydrogen bonding is present in **[MP PMT 1989; DPMT 1990; Roorkee 1995]**

(a) HF (b) HCl

(c) HBr (d) HI

88. The type of hybrid orbitals used by chlorine atom in ClO_2^- is

(a) SP^3 (b) SP^2

(c) SP (d) None of these

89. Which one is the anhydride of $HClO_4$ **[AIIMS 1983; BHU 1983; AMU 1984]**

(a) Cl_2O (b) ClO_2

(c) Cl_2O_6 (d) Cl_2O_7

90. Which of the following halogens is solid at room temperature **[MP PET 1999; AFMC 1999]**

(a) Chlorine (b) Iodine

(c) Bromine (d) Fluorine

91. Which of the following chemical contains chlorine **[MP PET 1999]**

(a) Fischer salt (b) Epsom salt

(c) Fremy's salt (d) Spirit of salt

92. The element which never acts as reducing agent in a chemical reaction is **[Bihar CEE 1995]**

(a) O (b) Li

(c) F (d) C

93. Concentrated HNO_3 reacts with I_2 to give **[IIT 1989; Roorkee 1995; JIPMER 2001]**

(a) HI (b) HOI

(c) $HOIO_3$ (d) $HOIO_3$

94. The formula of some fluorides are given below. Which of them will combine further with fluorine **[NCERT**

(a) IF_5 (b) NaF

(c) CaF_2 (d) SF_5

95. Which one below is a pseudohalide **[AIIMS 1982]**

(a) CN^- (b) ICl

(c) IF_5 (d) I_3^-

96. Which one is highest melting halide **[AIIMS 1982; BHU 1999]**

(a) $NaCl$ (b) $NaBr$

(c) NaF (d) NaI

97. The above answer is correct because the chosen halide has **[AIIMS 1982]**

(a) Minimum ionic character

(b) Maximum ionic character

(c) Highest oxidising power
(d) Lowest polarity

98. Which of the following oxidizes H_2O to oxygen **[MP PET 1994]**
(a) Chlorine (b) Fluorine
(c) Bromine (d) Iodine

99. The bleaching action of the bleaching powder is due to the liberation of **[MP PMT 1994]**
(a) Chlorine (b) Molecular oxygen
(c) Nascent oxygen (d) Calcium carbonate

100. Which of the following element is extracted commercially by the electrolysis of an aqueous solution of its compound **[KCET 2002]**
(a) Chlorine (b) Bromine
(c) Aluminium (d) Calcium

101. The effective component of bleaching powder is ..... of calcium **[Kerala (Engg.) 2002]**
(a) Chlorine (b) Bromine
(c) Aluminium (d) Calcium

102. $Na_2S_2O_3 + I_2 \rightarrow$ Product is **[BHU 2003]**
(a) Na_2S (b) NaI
(c) $Na_2S_4O_6$ (d) S_2

103. Which of the following is prepared by electrolytic method **[CBSE PMT 2001]**
(a) Ca (b) Sn
(c) S (d) F_2

104. Beilstein test is used for **[AFMC 1995]**
(a) N_2 (b) Cl
(c) Na (d) CO_2

105. Which one will liberate Br_2 from KBr **[BVP 2003]**
(a) I_2 (b) SO_2
(c) HI (d) Cl_2

106. Chlorine dioxide is best prepared by passing dry **[Kerala PMT 2003]**
(a) Chlorine gas over hot HgO
(b) Chlorine and oxygen gas over hot pt catalyst
(c) Hydrogen chloride and oxygen over silver oxide
(d) Hydrogen chloride over phosphorus pentoxide
(e) Chlorine over hot silver chlorate

107. The mixture of concentrated HCl and HNO_3 made in 3 : 1 ratio contains **[AIIMS 2003]**
(a) ClO_2 (b) $NOCl$
(c) NCl_3 (d) N_2O_4

108. On exciting Cl_2 molecule by UV light, we get **[UPSEAT 2003]**
(a) Cl (b) Cl^+
(c) Cl^- (d) All

109. Which of the following statements is not true **[CBSE PMT 2003]**
(a) HF is a stronger acid than HCl
(b) Among halide ions, iodide is the most powerful reducing agent
(c) Fluorine is the only halogen that does not show a variable oxidation state
(d) $HOCl$ is a stronger acid than $HOBr$

110. The correct order of acidic strength **[Pb. CET 2004]**
(a) $Cl_2O_7 > SO_2 > P_4O_{10}$ (b) $K_2 > CaO > MgO$
(c) $CO_2 > N_2O_5 > SO_3$ (d) $Na_2O > MgO > Al_2O_3$

111. Halogen acid used in the preparation of aqua regia is **[DPMT 2002]**
(a) HBr (b) HI
(c) HCl (d) HF

112. $NaOCl$ is used as a bleaching agent and sterilising agent. It can be synthesized by the action of **[RPET 2003]**
(a) $NaCl$ with H_2O
(b) NH_4Cl with $NaOH$
(c) Cl_2 with cold and dilute $NaOH$
(d) Cl_2 with hot and concentrated $NaOH$

113. Metal halide which is insoluble in water is **[AIIMS 1996]**
(a) AgI (b) KBr
(c) $CaCl_2$ (d) AgF

114. Which one among the following non-metals liquid at $25^o C$ **[MP PMT 1999]**
(a) Bromine (b) Carbon
(c) Phosphorus (d) Sulphur

115. Bleaching action of chlorine is due to **[Bihar CEE 1995]**
(a) Oxidation (b) Reduction
(c) Hydrolysis (d) Its acidic nature

116. Hydrogen iodide cannot be prepared by the action of conc. H_2SO_4 on potassium iodide because **[Bihar CEE 19**
(a) HI is stronger than H_2SO_4
(b) HI is more volatile than H_2SO_4
(c) H_2SO_4 is an oxidising agent
(d) H_2SO_4 forms complex

117. White enamel of our teeth is **[Bihar CEE 1995]**
(a) $Ca_3(PO_4)_2$ (b) CaF_2
(c) $CaCl_2$ (d) $CaBr_2$

118. The least active halogen with hydrogen is **[DPMT 1996]**
(a) Cl (b) I
(c) Br (d) F

119. Iodine dissolves readily in **[BHU 1996]**
(a) Water (b) Potassium iodide
(c) Carbon tetrachloride (d) Alcohol

120. Which one of the following compounds in aqueous solution gives a white precipitate with perchloric acid **[EAMCET 1997]**

(a) $NaCl$ (b) KCl

(c) $MgCl_2$ (d) $FeCl_3$

121. Which of the following sequence is correct with reference to the oxidation number of iodine **[EAMCET 1997]**

(a) $I_2 > ICl < HI < HIO_4$ (b) $HIO_4 < ICl < I_2 < HI$

(c) $I_2 < HI < ICl < HIO_4$ (d) $HI < I_2 < ICl < HIO_4$

122. The correct order of acidic strength is **[Pb. PMT 1998; AFMC 1998;KCET 2000; Orissa JEE 2005]**

(a) $HF < HCl < HBr < HI$

(b) $HCl < HBr < HF < HI$

(c) $HBr < HCl < HI < HF$

(d) $HI < HBr < HCl < HF$

123. The chief source of iodine in which it is present as sodium iodate is **[JIPMER 1997]**

(a) Sea weeds

(b) Caliche

(c) Carnallite

(d) Iodine never exists as sodium iodate

124. The lattice energy of the lithium halides is in the following order **[Roorkee Qualifying 1998]**

(a) $LiF > LiCl > LiBr > LiI$

(b) $LiCl > LiF > LiBr > LiI$

(c) $LiBr > LiCl > LiF > LiI$

(d) $LiI > LiBr > LiCl > LiF$

125. Which has the strong bond **[DCE 2001]**

(a) $F - F$ (b) $F - Cl$

(c) $F - Br$ (d) $Cl - B$

126. Iodine and hypo react to produce **[DPMT 2001]**

(a) Na_2S (b) Na_2SO_4

(c) $Na_2S_4O_6$ (d) Na_2SO_3

127. Bleaching powder is correctly represented as **[RPMT 1997]**

(a) $CaOCl_2$ (b) CaO

(c) $CaO(Cl)$ (d) $CaCl(OCl)$

128. When chlorine reacts with cold and dilute solution of sodium hydroxide, the products obtained are **[CBSE PMT 1998]**

(a) $Cl^- + ClO^-$ (b) $Cl^- + ClO_2^-$

(c) $Cl^- + ClO_3^-$ (d) $Cl^- + ClO_4^-$

129. A one litre flask is full of brown bromine vapour. The intensity of brown colour of vapour will not decrease appreciably on adding to the flask some **[CBSE PMT 1998]**

(a) Pieces of marble (b) Carbon disulphide

(c) Carbon tetrachloride (d) Animal charcoal powder

130. Which of the following statements is correct **[BHU 1997]**

(a) Only chlorine and bromine form oxy acids

(b) All halogens form oxy acids

(c) All halogens except fluorine form oxy acids

(d) Only iodine form oxy acids

131. When iodine reacts with NaF, $NaBr$ and $NaCl$ **[CPMT 1997]**

(a) It gives mixture of F_2, Cl_2 and Br_2

(b) It gives chlorine

(c) It gives bromine

(d) None of these

132. Which is the strongest of the following acids **[JIPMER 1999]**

(a) $HClO_4$ (b) H_2SO_4

(c) HCl (d) HNO_3

133. Hydrogen has a tendency to gain one electron to acquire helium configuration. In this respect it resembles **[JIPMER 1999]**

(a) Halogens (b) Actinides

(c) Transition elements (d) Alkali metals

134. What is the product obtained in the reaction of $HgCl_2$ and $Hg(CN)_2$ **[MP PET 2002]**

(a) $(CN)_2$

(b) Addition compound $HgCl_2.Hg(CN)_2$

(c) $Hg(CN)Cl$

(d) $Hg[Hg(CN)_2Cl_2]$

135. The weakest acid HX ($X = F, Cl, Br, I$) is **[BHU 2000]**

(a) HF (b) HCl

(c) HBr (d) HI

136. Bleaching powder is obtained by passing chlorine on **[KCET 2002]**

(a) Lime stone (b) Quick lime

(c) Slaked lime (d) Pure lime

137. Chlorine is liberated, when we heat **[AFMC 1998]**

(a) $KMnO_4 + NaCl$ (b) $K_2Cr_2O_7 + MnO_2$

(c) $Pb_2(NO_3)_4 + MnO_2$ (d) $K_2Cr_2O_7 + HCl$

138. Which of the following silver compounds finds maximum use in photography

(a) $AgCl$ (b) $AgBr$

(c) AgI (d) $AgNO_3$

139. Which of the following halogen does not exhibit positive oxidation state in its compounds **[EAMCET 1997; AIIMS 2000]**

(a) Cl (b) Br

(c) I (d) F

140. Acid strength of oxy acids of chlorine follows the order **[AIIMS 2000; CBSE PMT 2005]**

(a) $HClO < HClO_2 < HClO_3 < HClO_4$

(b) $HClO_4 < HClO_3 < HClO_2 < HClO$

(c) $HClO_4 < HClO_3 < HClO < HClO_2$

(d) None of these

141. Bleaching powder is obtained by treating chlorine with

[Pb. PMT 1999]

(a) CaO (b) $CaCO_3$

(c) $CaSO_4$ (d) $Ca(OH)_2$

142. Which statement is not true **[MP PET 2000]**

(a) $Ni(CO)_4$ is diamagnetic

(b) BI_3 is a stronger Lewis acid than BF_3

(c) Graphite conducts electricity whereas diamond does not

(d) CCl_4 is hydrolysed whereas BCl_3 is inert

143. Bleaching powder loses its power on keeping for a long time because **[KCET 2000]**

(a) It changes into calcium hypochlorate

(b) It changes into calcium chloride and calcium hydroxide

(c) It absorbs moisture

(d) It changes into calcium chloride and calcium chlorate

144. The compound which forms a dative bond with ammonia

[JIPMER 2001]

(a) CCl_4 (b) BCl_3

(c) $MgCl_2$ (d) $NaCl$

145. The bleaching action of bleaching powder is due to the formation of **[Roorkee 1999]**

(a) $CaCl_2$ (b) $CaSO_4$

(c) $HClO$ (d) $Ca(ClO_3)_2$

146. Fluorine with dilute $NaOH$ gives **[MH CET 2000]**

(a) OF_2 (b) O_3

(c) O_2 (d) HF and O_2

147. Which is not oxidised by MnO_2 **[DCE 2003]**

(a) F (b) Cl

(c) I_2 (d) I

148. Bromine water reacts with SO_2 to form **[AFMC 1995]**

(a) H_2O and HBr (b) H_2SO_4 and HBr

(c) HBr and S (d) S and H_2O

149. Which of the following reaction is not feasible

[CBSE PMT PMT 2002]

(a) $2KI + Br_2 \rightarrow 2KBr + I_2$

(b) $2H_2O + 2F_2 \rightarrow 2HF + O_2$

(c) $2KBr + I_2 \rightarrow 2KI + Br_2$

(d) $2KBr + Cl_2 \rightarrow 2KCl + Br_2$

150. Which of the following has the lowest solubility

[Roorkee 2000]

(a) CaF_2 (b) $CaCl_2$

(c) $CaBr_2$ (d) CaI_2

151. Which one of the following pairs of substances when mixed, produces chlorine gas at room temperature **[IIT 1995]**

(a) $NaCl$ and MnO_2

(b) $NaCl$ and HNO_3 (conc.)

(c) $NaCl$ and H_2SO_4 (conc.)

(d) HCl (conc.) and $KMnO_4$

152. Concentrated H_2SO_4 cannot be used to prepare HBr from $NaBr$, because it

(a) Reduces HBr (b) Oxidises HBr

(c) Disproportionates HBr (d)Reacts slowly with $NaBr$

153. Which of the following halides is least stable and has doubtful existence **[IIT 1996]**

(a) CI_4 (b) GeI_4

(c) SnI_4 (d) PbI_4

154. Chlorine cannot displace **[MP PET 1996]**

(a) Fluorine from NaF (b) Iodine from NaI

(c) Bromine from $NaBr$ (d) None of these

155. When fluoride is heated with conc. H_2SO_4 and MnO_2 the gas evolved is **[DPMT 2000]**

(a) F_2 (b) SF

(c) HF (d) None

156. Cl_2 reacts with CS_2 in presence of I_2 catalyst to form

[AFMC 1995]

(a) $CHCl_3$ (b) CCl_4

(c) C_2H_5Cl (d) C_2H_6

157. Amongst $LiCl, RbCl, BeCl_2$ and $MgCl_2$. Maximum and minimum ionic character will be shown by the compounds

[RPMT 1999]

(a) $LiCl, MgCl_2$ (b) $RbCl, BeCl_2$

(c) $RbCl, MgCl_2$ (d) $MgCl_2, BeCl_2$

158. Which is formed when fluorine react with hot and concentrated sodium hydroxide

(a) O_2 (b) O_3

(c) NaO (d) HF

159. Which of the following condition is used to find atomic Cl_2 from molecular Cl_2 **[CPMT 1996]**

(a) High temperature, high pressure

(b) Low temperature, high pressure

(c) High temperature, low pressure

(d) Low temperature, low pressure

160. Which one is least basic **[JIPMER 2000]**

(a) BI_3 (b) BBr_3

(c) BCl_3 (d) BF_3

161. On heating $NaCl + K_2Cr_2O_7 + \text{conc.}\, H_2SO_4$, the gas comes out is **[JIPMER 2000]**

(a) O_2 (b) Cl_2
(c) $CrOCl_2$ (d) CrO_2Cl_2

162. Aqua regia is a mixture of **[KCET (Med.) 2001]**
(a) $3HCl + 1HNO_3$ (b) $H_3PO_4 + H_2SO_4$
(c) $3HNO_3 + 1HCl$ (d) $HCl + CH_3COOH$

163. Unlike other halogens fluorine does not show higher oxidation states because **[MP PET 1997]**
(a) It is highly electronegative
(b) It has no *d*-orbitals
(c) Its atomic radius is very small
(d) The F^- ion is stable and isoelectronic with neon

164. Which halogen does not show variable oxidation state
[UPSEAT 2003]
(a) F_2 (b) Cl_2
(c) Br_2 (d) I_2

165. To purify fluorine gas, fumes of HF are removed by
[MH CET 2002]
(a) Solid NaF (b) H_2 gas
(c) Solid KHF_2 (d) None of these

166. Fluorine is prepared by
(a) Oxidation of HF
(b) Electrolysis of KF
(c) Electrolysis of fused KHF_2
(d) Decomposition of HgF_2

167. Amongst halogens fluorine is most oxidising because
(a) Fluorine has highest electron affinity
(b) Fluorine is most electronegative
(c) Dissociation energy for fluorine molecule is lowest
(d) All are correct

168. The alkali metal halides are soluble in water but LiF is insoluble because
(a) It is amphoteric
(b) The $Li-F$ bond is highly ionic
(c) Its lattice energy is high
(d) Li^+ ion is least hydrated

169. In which of the following pairs does the first gas bleaches flowers by reduction while the second gas does so by oxidation **[Manipal MEE 1995]**
(a) CO and Cl_2 (b) SO_2 and Cl_2
(c) H_2 and Br_2 (d) NH_3 and SO_2

170. Which of the following halogens does not form oxyacid
[MP PET 1997]
(a) Fluorine (b) Chlorine
(c) Bromine (d) Iodine

171. Which of the following molecule is theoritically not possible
[BHU 2002]
(a) OF_4 (b) OF_2
(c) SF_4 (d) O_2F_2

172. Iodine is released when potassium iodide reacts with
[UPSEAT 1999]
(a) $ZnSO_4$ (b) $CuSO_4$
(c) $FeSO_4$ (d) $(NH_4)_2SO_4$

173. Which of the following is used in the preparation of chlorine
[CBSE PMT 1999]
(a) Only MnO_2
(b) Only$KMnO_4$
(c) Both MnO_2 and $KMnO_4$
(d) Either MnO_2 or $KMnO_4$

174. Among Cl^-, Br^-, I^-, the correct order for being oxidise to dihalogen is **[CPMT 1999]**
(a) $I^- > Cl^- > Br^-$ (b) $Cl^- > Br^- > I^-$
(c) $I^- > Br^- > Cl^-$ (d) $Br^- > I^- > Cl^-$

175. On heating $KClO_3$, we get **[CPMT 1999]**
(a) Cl_2O (b) ClO_2
(c) ClO_3 (d) Cl_2O_7

176. For which one of the following properties of halogens the sequence $F > Cl > Br > I$ holds good**[MP PET/**
(a) Electron affinity (b) Electronegativity
(c) Atomic radius (d) Boiling point

177. Which of the following properties increases on going down from F to I in Group VII-A of the periodic table ?
[MP PMT 1997]
(a) Electronegativity (b) Volatile nature
(c) Ionic radius (d) Oxidising power

178. Among the halogens, the one which is oxidised by nitric acid is
[KCET 2004]
(a) Fluorine (b) Iodine
(c) Chlorine (d) Bromine

179. The reaction of the type $2X_2 + S \rightarrow SX_4$ is shown by sulphur when X is **[DCE 2003]**
(a) Fluorine or chlorine
(b) Chlorine only
(c) Chlorine and bromine only
(d) F, Cl, Br all

180. When I_2 is passed through KCl, KF and KBr solutions
[CPMT 2004]
(a) Cl_2 and Br_2 are evolved
(b) Cl_2 is evolved

(c) Cl_2, Br_2 and F_2 are evolved

(d) None of these

181. The solubility of I_2 increases in water in the presence of **[Pb. CET 2002]**

(a) KI (b) H_2SO_4

(c) $KMnO_4$ (d) NH_3

182. Which of the hydrogen halides forms salts like KHX_2 (where X is a halogen atom) **[Kerala PMT 2004]**

(a) HF (b) HCl

(c) HI (d) HBr

(e) All of these

183. With cold and dilute sodium hydroxide fluorine reacts to give **[MH CET 2004]**

(a) NaF and OF_2 (b) $NaF + O_3$

(c) O_2 and O_3 (d) $NaF + O_2$

184. Which one of the following oxides is expected exhibit paramagnetic behaviour

(a) CO_2 (b) SO_2

(c) ClO_2 (d) SiO_2

185. Of the following acids, the one that is strongest is **[DPMT 2004]**

(a) $HBrO_4$ (b) $HOCl$

(c) HNO_2 (d) H_3PO_3

186. Which of the following is anhydride of perchloric acid **[CPMT 2004]**

(a) Cl_2O_7 (b) Cl_2O_5

(c) Cl_2O_3 (d) $HClO$

187. I_2 dissolves in KI solution due to the formation of **[CPMT 2004]**

(a) KI_2 and I^- (b) K^+, I^- and I_2

(c) KI_3^- (d) None of these

Noble gases

1. Which of the following outer electronic configuration represents argon **[DPMT 1982; CPMT 1976; NCERT 1987; Kurukshetra CEE 1998]**

(a) ns^2 (b) ns^2np^6

(c) ns^2np^5 (d) ns^2np^4

2. Which mineral was used in isolation of radium **[CPMT 1978, 81, 91]**

(a) Lime stone (b) Pitch blende

(c) Rutile (d) Haematite

3. Which is the lightest gas

(a) Hydrogen (b) Oxygen

(c) Helium (d) Nitrogen

4. The valency of inert gases is

(a) 5 (b) 1

(c) 0 (d) None of these

5. Helium was discovered by

(a) Crooks (b) Rutherford

(c) Frankland and Lockyer (d) Dorn

6. The inert gases are **[CPMT 1984]**

(a) Polyatomic (b) Triatomic

(c) Diatomic (d) Monoatomic

7. The charcoal maintained at $100^o C$ absorbs

(a) Ne and Kr (b) He and Ar

(c) Ar, Kr, Xe (d) He and Ne

8. Every inert gas atom

(a) Has a saturated outermost shell

(b) Has one electron in outermost shell

(c) Has eight electrons in outermost shell

(d) Has two electrons in outermost shell

9. Argon was discovered by **[CPMT 1991]**

(a) Rayleigh (b) Frakland and Lockyer **[CBSE PMT 2005]**

(c) Jansen (d) Ramsay

10. Deep sea divers used to respirate is a mixture of

(a) Oxygen and argon (b) Oxygen and helium

(c) Oxygen and nitrogen (d) Oxygen and hydrogen

11. The noble gas which forms maximum number of compounds is **[NCERT 1976; BHU 1980; CPMT 1982, 91; AMU 1985; DPMT 1996; MP PMT 2001; Pb.CET 2003]**

(a) Ar (b) He

(c) Xe (d) Ne

12. Which of the following gases exist more abundantly in nature than the others **[BHU 1982; DPMT 1982,02; CPMT 1983, 89; EAMCET 1993; Manipal MEE 1995; MHCET 2003]**

(a) Helium (b) Neon

(c) Argon (d) Krypton

13. Which of the following is monoatomic **[NCERT 1976, 77; CPMT 1983, 86, 90]**

(a) Nitrogen (b) Fluorine

(c) Neon (d) Oxygen

14. Nuclear fusion produces

(a) Argon (b) Deuterium

(c) Helium (d) Krypton

15. Among the fluorides below, the one which does not exist is **[NCERT 1977; CPMT 1988]**

(a) XeF_4 (b) HeF_4

(c) SF_4 (d) CF_4

16. The last orbit of argon would have electrons **[CPMT 1971, 78]**

(a) 6 (b) 2

(c) 18 (d) 8

17. The electronic configuration of neon is **[CPMT 1974, 80, 81; DPMT 1982; MNR 1995]**

(a) $1s^2,\ 2s^2 2p^2$
(b) $1s^2,\ 2s^2 2p^6$
(c) $1s^2,\ 2s^2$
(c) $1s^2$

18. The colour discharge tubes for advertisement mainly contain **[CPMT 1980, 89; MP PET 2002]**
(a) Argon
(b) Neon
(c) Helium
(d) Xenon

19. Least chemical activity is shown by **[CPMT 1973, 79]**
(a) Nitrogen
(b) Argon
(c) Methane
(d) Ammonia

20. Noble gases do not react with other elements because **[CPMT 1981]**
(a) They have completely paired up and stable electron shells
(b) The sizes of their atoms are very small
(c) Are not found in abundance
(d) Are monoatomic

21. Monazite is source of
(a) He
(b) Kr
(c) Ar
(d) Ne

22. Which of the following fluorides of Xenon is impossible **[CPMT 1982; Kurukshetra CEE 1998;RPET 1999]**
(a) XeF_6
(b) XeF_4
(c) XeF_3
(d) XeF_2

23. XeF_2 molecule is
(a) Square planer
(b) Trigonal bipyramidal
(c) Trigonal planer
(d) Linear

24. XeF_4 on partial hydrolysis produces **[AFMC 1995]**
(a) XeF_2
(b) $XeOF_2$
(c) $XeOF_4$
(d) XeO_3

25. In XeF_2 hybridisation of Xe is
(a) sp^2
(b) sp^3d
(c) sp^3
(d) sp^3d^2

26. Which one of the following noble gases is the least polarizable **[AIIMS 1983; MP PET 1999; Pb. PMT 2001; JIPMER (Med.) 2002]**
(a) Xe
(b) Ar
(c) Ne
(d) He

27. Which one of the following noble gases is not found in the atmosphere **[MP PMT 1993]**
(a) Rn
(b) Kr
(c) Ne
(d) Ar

28. Helium is added to the oxygen supply used by deep sea divers because **[MP PMT 1993; MP PET 1997]**
(a) It is less soluble in blood than nitrogen at high pressure
(b) It is lighter than nitrogen
(c) It is readily miscible with oxygen
(d) It is less poisonous than nitrogen

29. Which of the following statements is not correct for a noble gas
(a) Ar is used in electric bulbs
(b) Kr is obtained during radioactive disintegration
(c) Half life of Rn is only 3.8 days
(d) He is used in producing very low temperature

30. Which one of the following configuration represents a noble gas **[CPMT 1976, 83, 89; BHU 1982; Pb. CET 2000 NCERT 1979; IIT Screening 1993; EAMCET 1993]**
(a) $1s^2,\ 2s^2 2p^6,\ 3s^2$
(b) $1s^2,\ 2s^2 2p^6,\ 3s^1$
(c) $1s^2,\ 2s^2 2p^6$
(d) $1s^2,\ 2s^2 2p^6,\ 3s^2 3p^6,\ 4s^2$

31. Which of the following has zero valency **[DPMT 1985]**
(a) Sodium
(b) Beryllium
(c) Aluminium
(d) Krypton

32. The forces acting between noble gas atoms are **[NCERT 1989]**
(a) Vander Waals forces
(b) Ion-dipole forces
(c) London dispersion forces
(d) Magnetic forces

33. Which of the following is the correct sequence of the noble gases in their group in the periodic table **[Manipal MEE 1995]**
(a) *Ar, He, Kr, Ne, Rn, Xe*
(b) *He, Ar, Ne, Kr, Xe, Rn*
(c) *He, Ne, Ar, Kr, Xe, Rn*
(d) *He, Ne, Kr, Ar, Xe, Rn*

34. Which of the following represent nobel gas configuration **[BHU 1995]**
(a) $1s^2,\ 2s^2 2p^6,\ 3s^2 3p^6 3d^{10},\ 4s^2 4p^6 4d^{10},\ 5s^2 5p^6$
(b) $1s^2,\ 2s^2 2p^6,\ 3s^2 3p^6 3d^{10},\ 4s^2 4p^6 4d^{10} 4f^{14},\ 5s^2 5p^6 5d^1, 6s^2$
(c) $1s^2,\ 2s^2 2p^6,\ 3s^2 3p^6 3d^{10},\ 4s^2 4p^6 4d^{10},\ 5s^2 5p^6 5d^1,\ 6s^2$
(d) $1s^2,\ 2s^2 2p^6,\ 3s^2 3p^6 3d^{10},\ 4s^2 4p^6 4d^{10}$

35. XeF_6 on hydrolysis gives **[MP PET 2000; Pb. PMT 2000; DCE 2002]**
(a) XeO_3
(b) XeO
(c) XeO_2
(d) Xe

36. The correct order of solubility in water for $He, Ne, Ar, Kr, Xe,$ is **[AIIMS 2002]**
(a) $He > Ne > Ar > Kr > Xe$

(b) $Ne > Ar > Kr > He > Xe$

(c) $Xe > Kr > Ar > Ne > He$

(d) $Ar > Ne > He > Kr > Xe$

37. In XeF_2, XeF_4, XeF_6 the number of lone pairs on Xe is respectively **[AIEEE 2002]**

(a) 2, 3, 1 (b) 1, 2, 3

(c) 4, 1, 2 (d) 3, 2, 1

38. Noble gases are group of elements which exhibit very **[Kerala (Med.) 2002]**

(a) High chemical activity

(b) Low chemical activity

(c) Minimum electronegativity

(d) Much paramagnetic properties

39. Which noble gas is most soluble in water **[CPMT 2002]**

(a) He (b) Ar

(c) Ne (d) Xe

40. Gradual addition of electronic shells in the noble gases causes a decrease in their **[MP PET 1997]**

(a) Ionization energy (b) Atomic radius

(c) Boiling point (d) Density

41. Which of the following noble gas does not have an octet of electrons in its outermost shell**[MP PET 1996]**

(a) Neon (b) Radon

(c) Argon (d) Helium

42. The low chemical reactivity of the rare gases can be attributed to their **[Pune CET 1998]**

(a) Being non-metals

(b) Having high ionization energies

(c) Being gases

(d) Found in nature in small quantities

43. Percentage of Ar in air is about **[CPMT 1989]**

(a) 1% (b) 2%

(c) 3% (d) 4%

44. Which of the following is not obtained by direct reaction of constituent elements **[MP PET 1994]**

(a) XeF_2 (b) XeF_4

(c) XeO_3 (d) XeF_6

45. Fluorine forms chemical compounds with**[MP PMT 1994]**

(a) He (b) Ne

(c) Ar (d) Xe

46. Which of the following has sp^3 hybridisation**[DCE 2001]**

(a) XeO_3 (b) BCl_3

(c) XeF_4 (d) BBr_3

47. Which element out of He, Ar, Kr, and Xe forms least number of compounds **[MP PMT 1995]**

(a) He (b) Ar

(c) Kr (d) Xe

48. Which of the following exhibits the weakest intermolecular forces **[KCET (Med.) 2001]**

(a) He (b) HCl

(c) NH_3 (d) H_2O

49. Which of the following are formed by Xenon **[Roorkee 2000]**

(a) XeF_3 (b) XeF_4

(c) XeF_5 (d) XeF_6

50. Among the following molecule

(i) XeO_3 (ii) $XeOF_4$ (iii) XeF_6

Those having same number of lone pairs on Xe are **[AIIMS 2005]**

(a) (i) and (ii) only (b) (i) and (iii) only

(c) (ii) and (iii) only (d) (i),(ii) and (iii)

51. Who among the following first prepared a stable compound of noble gas **[MP PET 1999]**

(a) Rutherford (b) Rayleigh

(c) Ramsay (d) Neil Bartlett

52. The last member of inert gas elements is**[MP PMT 1999]**

(a) Helium (b) Neon

(c) Argon (d) Radon

53. Which of the following gas is/are called rare gas **[CPMT 2000; Pb. CET 2002]**

(a) Ne (b) He

(c) Kr (d) All of these

54. Which one of the following statements regarding helium is incorrect **[AIEEE 2004]**

(a) It is used to produce and sustain powerful superconducting magnets

(b) It is used as a cryogenic agent for carrying out experiments at low temperatures

(c) It is used to fill gas balloons instead of hydrogen because it is lighter and non-inflammable

(d) It is used in gas-cooled nuclear reactors

55. Which of the following inert gas liquifies easily **[Pb. CET 2002]**

(a) Kr (b) He

(c) Ne (d) Ar

56. The oxidation number of xenon in $XeOF_2$ is**[J & K 2005]**

(a) Zero (b) 2

(c) 4 (d) 3

57. Which inert gas having highest boiling point**[BCECE 2005]**

(a) Xe (b) Ar

(c) Kr (d) He

58. Which of the following is an inert gas **[AFMC 2005]**

(a) H_2 (b) O_2

(c) N_2 (d) Argon

59. Which of the following is most polarised**[DPMT 2005]**

(a) Kr (b) He

(c) Ar (d) Xe

60. Which of the following is planar **[J & K 2005]**

(a) XeF_2 (b) XeO_3F

(c) XeO_2F_2 (d) XeF_4

CT Critical Thinking

Objective Questions

1. The correct sequence in decreasing order of the percentage of nitrogen in the given compounds is **[NDA 1999]**

(a) Urea > Ammonium chloride > Ammonium nitrate > Ammonium nitrite

(b) Urea > Ammonium nitrate > Ammonium nitrite > Ammonium chloride

(c) Urea > Ammonium nitrite > Ammonium nitrate > Ammonium chloride

(d) Urea > Ammonium nitrite > Ammonium chloride > Ammonium nitrate

2. As the alkaline earth metals (except Be) tend to lose their valence electrons readily they act as **[Kerala (Med.) 2002]**

(a) Weak oxidising agent (b) Weak reducing agent

(c) Strong oxidising agent (d) Strong reducing agent

3. The first ionisation energies of alkaline earth metals are higher than those of the alkali metals. This is because **[UPSEAT 2001]**

(a) There is increases in the nuclear charge of the alkaline earth metals

(b) There is decreases in the nuclear charge of the alkaline earth metals

(c) There is no change in the nuclear charge

(d) None of these

4. Lead is maximum in **[BVP 2004]**

(a) Soda glass (b) Jena glass

(c) Pyrex glass (d) Flint glass

5. $BaSO_4$ and carbon on heating reacts to produce **[Pb. PMT 2004]**

(a) $Ba+SO_2+CO_2$ (b) $BaS+CO$

(c) $BaS+O_2+SO_2$ (d) $BaCO_3+S+O_2$

6. The atomic radii of alkali metals (M) lie in the order $Li<Na<K<Rb$ but the radii of M^+ ions in aqueous solution lie in the reverse order $Li^+>Na^+>K^+>Rb^+$. What is the reason for this reverse order (on going from Li to Rb)? **[MP PMT 1997]**

(a) Gradual increase in ionisation energy

(b) Increasing weakness of the metallic bond

(c) Increasing electropositive character

(d) Decreasing degree of hydration

7. Fusion mixture is **[CPMT 2002]**

(a) $Na_2CO_3+K_2CO_3$ (b) $Na_2CO_3+NaHCO_3$

(c) Na_2CO_3+NaOH (d) $Na_2CO_3+K_2SO_4$

8. Concentrated hydrochloric acid when kept in open air sometimes produces a cloud of white fumes. The explanation for it is that

(a) Concentrated hydrochloric acid emits strongly smelling HCl gas all the time

(b) Oxygen in air reacts with the emitted HCl gas to form a cloud of chlorine gas

(c) Strong affinity of HCl gas for moisture in air results in forming of droplets of liquid solution which appears like a cloudy smoke

(d) Due to strong affinity for water, concentrated hydrochloric acid pulls moisture of air towards itself. This moisture forms droplets of water and hence the cloud

9. Match List I with List II and select the correct answer using the codes given below the lists

List I	**List II**
(a) Peroxide	(1) C_3O_2
(b) Superoxide	(2) PbO_2
(c) Dioxide	(3) KO_2
(d) Suboxide	(4) H_2O_2

Codes : **[NDA 1999]**

	A	B	C	D
(a)	4	3	2	1
(b)	3	2	1	4
(c)	4	2	3	1
(d)	4	1	2	3

10. The most efficient agent for the absorption of SO_3 is **[KCET 1998]**

(a) $98\% H_2SO_4$ (b) $80\% H_2SO_4$

(c) 20% oleum (d) $90\% H_2SO_4$

11. Mark the oxide which is amphoteric in character **[MP PMT 2000]**

(a) CO_2 (b) SiO_2

(c) SnO_2 (d) CaO

12. Concentrated aqueous sodium hydroxide can separate mixture of **[MNR 1995]**

(a) Al^{3+} and Sn^{2+} (b) Al^{3+} and Fe^{3+}

(c) Al^{3+} and Zn^{2+} (d) Zn^{2+} and Pb^{2+}

13. The composition of the common glass is **[DCE 2004]**

(a) $Na_2O.CaO.6SiO_3$ (b) $Na_2O.Al_2O_3.SiO_2$

(c) $CaO.Al_2O_3.SiO_2$ (d) $Na_2O.CaO.6SiO_2$

14. The metal which does not form ammonium nitrate by reaction with dilute nitric acid is

(a) Al (b) Fe

(c) Pb (d) Mg

15. Total number of lone pair of electrons in $XeOF_4$ is

[IIT-JEE (Screening) 2004]

(a) 0 (b) 1

(c) 2 (d) 3

16. What is the correct relationship between the pHs of isomolar solutions of sodium oxide (pH_1), sodium sulphide (pH_2), sodium selenide (pH_3) and sodium telluride (pH_4)

[CBSE PMT 2005]

(a) $pH_1 > pH_2 = pH_3 > pH_4$

(b) $pH_1 < pH_2 < pH_3 < pH_4$

(c) $pH_1 < pH_2 < pH_3 = pH_4$

(d) $pH_1 > pH_2 > pH_3 > pH_4$

17. Which one of the following is not an amphoteric substance

[KCET 2004]

(a) HNO_3 (b) HCO_3^-

(c) H_2O (d) NH_3

18. Which group is called buffer group of the periodic table

[Pb. CET 2004]

(a) I (b) VII

(c) VIII (d) Zero

19. Which of the following salt is insoluble in water

[MP PET 2004]

(a) $CuSO_4$ (b) $CdSO_4$

(c) $PbSO_4$ (d) $Bi_2(SO_4)_3$

20. Which of the following oxides is the most acidic

[CBSE PMT 1999; MP PMT 2002]

(a) N_2O_5 (b) P_2O_5

(c) As_2O_5 (d) Sb_2O_5

21. Whose bond energy is maximum

[CPMT 1988; MP PMT 1990]

(a) F_2 (b) Cl_2

(c) Br_2 (d) I_2

22. Calcium cyanide on treatment with steam under pressure gives NH_3 and **[DPMT 2002]**

(a) $CaHCO_3$ (b) CaO

(c) $Ca(OH)_2$ (d) $CaCO_3$

23. Six volumes of oxygen, on complete ozonisation, form ...... volumes of ozone

(a) 4 (b) 3

(c) 2 (d) 6

24. The substance not likely to contain $CaCO_3$ is

[AIEEE 2003]

(a) A marble statue (b) Calcined gypsum

(c) Sea shells (d) Dolomite

[KCET 2004]

25. Which of the following statements is false for alkali metals

[MNR 1994; MP PET 2001]

(a) Lithium is the strongest reducing agent

(b) Na is amphoteric in nature

(c) Li^+ is exceptionally small

(d) All alkali metals give blue solution in liquid ammonia

26. Solubility of iodine in water is greatly increased by the addition of iodide ions because of the formation of ......

[IIT 1994]

(a) I_2 (b) I_3

(c) I_3^- (d) I^-

27. The solubility in water of sulphates down the Be group is $Be > Mg >> Ca > Sr > Ba$. This is due to

[CBSE PMT 1995]

(a) High heat of solvation for smaller ions like Be^{2+}

(b) Increasing molecular weight

(c) Decreasing lattice energy

(d) Increase in melting points

28. Magnesium burns in air to give

[CPMT 1988, 89; AFMC 1987]

(a) MgO (b) Mg_3N_2

(c) $MgCO_3$ (d) MgO and Mg_3N_2 both

29. Philospher's wool when heated with BaO at $1100\,^oC$ gives a compound. Identify the compound**[CPMT 1**

(a) $BaZnO_2$ (b) $Ba + ZnO_2$

(c) $BaCdO_2$ (d) $BaO_2 + Zn$

30. Which of the following oxide is diamagnetic

[MP PET 1990]

(a) NO (b) N_2O_4

(c) NO_2 (d) N_2O_5

31. Which of the following salt becomes plaster of paris on being appropriately hydrated **[CPMT 1985]**

(a) $ZnCO_3$ (b) $CaSO_4$

(c) $MgSO_4$ (d) $CaCO_3$

32. The number of electron and proton in the third alkaline earth metal ion will be

(a) $\frac{e}{20}, \frac{p}{20}$ (b) $\frac{e}{18}, \frac{p}{20}$

[DPMT 2000]

(c) $\frac{e}{18}, \frac{p}{18}$ (d) $\frac{e}{19}, \frac{p}{20}$

33. The compounds of alkaline earth metals have the following magnetic nature

[MP PET/PMT 1998; RPMT 2000; JIPMER 2002]

(a) Diamagnetic (b) Paramagnetic

(c) Ferromagnetic (d) Diaferromagnetic

34. Which of the following is the life saving mixture for an asthma patient **[MP PMT 2001]**

(a) Mixture of helium and oxygen
(b) Mixture of neon and oxygen
(c) Mixture of xenon and nitrogen
(d) Mixture of argon and oxygen

35. Which would quickly absorbs oxygen **[CBSE PMT 1992; MP PET 1995]**

(a) Alkaline solution of pyrogallol
(b) Conc. H_2SO_4
(c) Lime water
(d) Alkaline solution of $CuSO_4$

36. Nitrogen is liberated by the thermal decomposition of only **[IIT 1991]**

(a) NH_4NO_2 (b) NaN_3
(c) $(NH_4)_2Cr_2O_7$ (d) All the three

37. Red phosphorus is less reactive than yellow phosphorus because **[DPMT 1982; JIPMER 1999;CBSE PMT 1999; RPET 2003]**

(a) Its colour is red
(b) It is highly polymerised
(c) It is hard
(d) It is insoluble in C_2H_5OH

38. Carbon differs from other elements of the group. Which is the false statement

(a) Due to its marked tendency to form long chains (catenation)
(b) Due to its unique ability to form multiple bonds
(c) Due to *d*-orbital in penultimate shell
(d) Due to its limitation of co-ordination number 4

39. Which of the following oxide does not form acidic aqueous solution **[CPMT 2004]**

(a) N_2O_3 (b) NO_2
(c) N_2O_5 (d) NO

40. Which of the following is in the increasing order of the ionic character **[JIPMER 2002]**

(a) $PbCl_4 < PbCl_2 < CaCl_2 < NaCl$
(b) $PbCl_2 < PbCl_4 < CaCl_2 < NaCl$
(c) $PbCl_2 < PbCl_4 < NaCl < CaCl_2$
(d) $PbCl_4 < PbCl_2 < NaCl < CaCl_2$

41. Silicon chloroform is prepared by **[MH CET 1999]**

(a) $Si + HCl$ (b) $SiCl_4 + H_2O$
(c) $SiF_4 + NaF$ (d) $H_2SiF_6 + Cl_2$

42. KO_2 (potassium superoxide) is used in oxygen cylinders in space and submarines because it **[AIEEE 2002**

(a) Absorbs CO_2 and increases O_2 content
(b) Eliminates moisture
(c) Absorbs CO_2
(d) Produces ozone

43. **Fire extinguishers** contain H_2SO_4 and**[AFMC 1980]**

(a) $CaCO_3$ (b) Na_2CO_3
(c) $NaHCO_3$ (d) $NaHCO_3$ and Na_2CO_3

44. Which is insoluble in water **[CPMT 2003]**

(a) H_2S (b) $HgCl_2$
(c) $Ca(NO_3)_2$ (d) CaF_2

45. Which of the following halides is most acidic**[KCET 1996]**

(a) PCl_3 (b) $SbCl_3$
(c) $BiCl_3$ (d) CCl_4

46. The stability of the following alkali metal chlorides follows the order

(a) $LiCl > KCl > NaCl > CsCl$
(b) $CsCl > KCl > NaCl > LiCl$
(c) $NaCl > KCl > LiCl > CsCl$
(d) $KCl > CsCl > NaCl > LiCl$

47. The reaction of $Na_2S_2O_3$ with iodine gives **[CPMT 1971, 80, 81; DPMT 1983, 90; MP PMT 1985; EAMCET 1990; BHU 1980] [DPMT 2000]**

(a) Sodium sulphide (b) Sodium sulphite
(c) Sodium sulphate (d) Sodium tetrathionate

48. Which one of the following is the true covalent oxide of iodine **[MP PET/PMT 1988]**

(a) I_2O_4 (b) I_2O_5
(c) I_2O_7 (d) I_2O_9

49. Lithium aluminium hydride acts as **[CPMT 1994]**

(a) Oxidising agent (b) Reducing agent
(c) Both the above (d) None of these

50. The mixture of conc. HCl and potassium chlorate on heating gives **[Roorkee 2000]**

(a) Cl_2 only (b) ClO_2 only
(c) $Cl_2 + ClO_2$ (d) $Cl_2 + ClO_2 + ClO_3$

51. When SO_2 is passed through acidified solution of H_2S **[CPMT 1973, 81, 93]**

(a) H_2SO_4 is formed (b) H_2SO_3 is formed
(c) Sulphur is precipitated (d) None of these

52. Four reactions are given below

(i) $2Li + 2H_2O \rightarrow 2LiOH + H_2$
(ii) $2Na + 2H_2O \rightarrow 2NaOH + H_2$
(iii) $2LiNO_3 \xrightarrow{Heat} 2LiNO_2 + O_2$

(iv) $2NaNO_3 \xrightarrow{Heat} 2NaNO_2 + O_2$

Which of the above, if any, is wrong

(a) (iv) (b) (iii)

(c) (i) (d) None of these

53. Increasing order of solubility is **[AFMC 1987]**

(a) $CaCO_3, KHCO_3, NaHCO_3$

(b) $NaHCO_3, KHCO_3, CaCO_3$

(c) $KHCO_3, NaHCO_3, CaCO_3$

(d) $CaCO_3, NaHCO_3, KHCO_3$

54. **Nitrolim** is **[CPMT 1976, 78, 2000; BHU 1987; DCE 1999; RPMT 2000]**

(a) $Ca(NO_3)_2$ (b) $Ca(CN)_2$

(c) $CaCN_2 + C$ (d) $CaCN_2$

55. The following acids have been arranged in the order of decreasing acid strength. Identify the correct order.

(I) $ClOH$ (II) $BrOH$ (III) IOH

(a) $I > II > III$ (b) $II > I > III$

(c) $III > II > I$ (d) $I > III > II$

56. Which of the following element does not belong to the family of elements indicated **[Orissa JEE 1997]**

(a) Rubidium (*Rb*, *Z* = 37) : Alkali metals

(b) Barium (*Ba*, *Z* = 56) : Alkaline earth metals

(c) Iridium (*I*, *Z* = 77) : Nobel gases

(d) Argon (*Ar*, *Z* = 18) : Nobel gases

57. H_3PO_2 is the formula for one of the phosphorus acid. Its name and basicity are respectively **[CBSE PMT 1992; BHU 1999; KCET 1999]**

(a) Phosphorus acid and two

(b) Hypophosphorus acid and two

(c) Hypophosphorus acid and one

(d) Hypophosphoric acid and two

58. Which of the following oxides of nitrogen is paramagnetic **[CPMT 1984; CBSE PMT 1994; AIIMS 2000]**

(a) N_2O_3 (b) N_2O

(c) NO_2 (d) N_2O_5

59. Nessler's reagent is **[CPMT 2002]**

(a) Potassium in mercuric iodide

(b) $TiCl_4$

(c) Anhydrous $AlCl_3$

(d) Al_2O_3 / Cr_2O_3

60. The noble gas was first time discovered by

(a) Cavandish (b) William Ramsay

(c) Rayleigh (d) Frankland

61. The ratio of $\frac{C_p}{C_v}$ for inert gases is **[DCE 1999]**

(a) 1.99 (b) 2.13

(c) 1.66 (d) 1.33

62. White *P* reacts with caustic soda, the products are PH_3 and NaH_2PO_2. This reaction is an example of **[DCE 20**

(a) Oxidation (b) Reduction

(c) Disproportionation (d) Neutralisation

63. The oxide, which cannot act as a reducing agent, is **[Pb. CET 2002]**

(a) NO_2 (b) SO_2

(c) CO_2 (d) ClO_2

64. Which of the following product is formed when SiF_4 reacts with water **[Pb. CET 2003]**

(a) SiF_3 (b) H_4SiO_4

(c) H_2SO_4 (d) H_2SiF_4

65. Ozone with dry iodine give **[Pb. CET 2003]**

(a) I_4O_4 (b) I_2O_3

[IIT 1996] (c) IO_2 (d) I_2O_4

66. The microcosmic salt is **[Pb.CET 2004; Pb. PMT 2004]**

(a) $Na(NH_4)H_2O$ (b) $K(NH_4)HPO_3 2H_2O$

(c) $Na(NH_4)HPO_4 4H_2O)$ (d) $Na(NH_3)HPO_4 4H_2O$

67. Thermite is a mixture of **[Pb. CET 2004]**

(a) $Cr_2O_3 + Al_2O_3$ (b) $Fe_2O_3 + Al$

(c) $Fe_2O_3 + Al_2O_3$ (d) $Al_2O_3 + 2Cr$

68. The colour of liquid O_2 is **[BVP 2004]**

(a) Red (b) Dark blue

(c) Pale yellow (d) Pale blue

69. Which of the following gas mixture is used by the divers inside the sea **[AFMC 2004]**

(a) $O_2 + He$ (b) $O_2 + Xe$

(c) $O_2 + Ar$ (d) $O_2 + N_2$

70. One mole of magnesium nitride on the reaction with an excess of water gives

(a) Two moles of ammonia (b)One mole of nitric acid

(c) One mole of ammonia (d)Two moles of nitric acid

71. Calcium cyanamide on treatment with steam produce **[Pb. PMT 2004]**

(a) $CaCO_3 + NH_3$ (b) $CaHCO_3 + NH_3$

(c) $CaO + NH_3$ (d) $Ca(OH)_2 + NH_3$

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Sulphate is estimated as $BaSO_4$ and not as $MgSO_4$.
Reason : Ionic radius of Mg^{2+} is smaller than that of Ba^{2+}. **[IIT 1998]**

2. Assertion : Amongst the halogens fluorine can oxidise the elements to highest oxidation state.
Reason : Due to small size of fluoride ion, it is difficult to oxidise fluoride ion to fluorine. Hence reverse reaction takes place more easily. **[IIT 1996]**

3. Assertion : HNO_3 is a stronger acid than HNO_2.
Reason : In HNO_3 there are two nitrogen-to-oxygen bonds whereas in HNO_2 there is only one.

4. Assertion : The Value of Vander Waal's constant 'a' is larger for ammonia than for nitrogen.
Reason : Hydrogen bonding is present in ammonia. **[IIT 1998]**

5. Assertion : Xenon forms fluorides.
Reason : Due to the strong electronegativity of fluorine . **[AIIMS 2001]**

6. Assertion : Chlorine and sulphur dioxide both are bleaching agents.
Reason : The bleaching action of chlorine and sulphur dioxide is performed through the process of oxidation. **[AIIMS 2000]**

7. Assertion : Nitrogen is unreactive at room temperatures but becomes reactive at elevated temperatures (On heating) or in presence of catalysts.
Reason : In nitrogen molecule, there is extensive delocalization of electrons.

8. Assertion : Covalency of oxygen is three.
Reason : Dinegative anion of oxygen (O^{2-}) is quite common but dinegative anion of sulphur (S^{2-}) is less common. **[AIIMS 2001]**

9. Assertion : At room temperature, oxygen exists as a diatomic gas, whereas sulphur exists as solid.
Reason : The catenated $-O-O-O-$ changes are less stable as compared to $O=O$ molecule. **[AIIMS 2001]**

10. Assertion : Potassium and caesium are used in photo-electric cells.
Reason : Potassium and caesium emit electrons on exposure to light. **[AIIMS 2002]**

11. Assertion : The fluorine has lower reactivity.
Reason : $F-F$ bond has low bond dissociation energy. **[AIIMS 2002]**

12. Assertion : Halogens do not occur in free state.
Reason : Halogens are highly reactive. **[AIIMS 1994]**

13. Assertion : Lithium forms Lithium oxide (LiO_2).
Reason : N_2 molecule have unpaired electrons. **[AIIMS 1995]**

14. Assertion : Liquid NH_3 is used for refrigeration.
Reason : Liquid NH_3 quickly vaporises. **[AIIMS 1995]**

15. Assertion : $Al(OH)_3$ is insoluble in NH_4OH but soluble in $NaOH$.
Reason : $NaOH$ is strong alkali. **[AIIMS 1997]**

16. Assertion : Boron is metalloid.
Reason : Boron shows metallic nature. **[AIIMS 1997]**

17. Assertion : Inert gases are monoatomic.
Reason : Inert gases have stable configuration. **[AIIMS 1999]**

18. Assertion : Magnesium continue to burn in nitric oxide.
Reason : During burning heat evolved do not decompose NO. **[AIIMS 2001]**

19. Assertion : Anhydrous BaO_2 is used for preparing H_2O_2.
Reason : Hydrated BaO_2 is not available. **[AIIMS 2001]**

20. Assertion : Benzene is reactive while inorganic benzene is unreactive compound.
Reason : Inorganic benzene is, borazine, $B_3N_3H_6$. **[AIIMS 2002]**

21. Assertion : Halogens absorb visible light.
Reason : All halogens are coloured. **[AIIMS 2002]**

22. Assertion : Barium is not required for normal biological function in human.
Reason : Barium does not show variable oxidation state. **[AIIMS 2003]**

23. Assertion : The $O-O$ bond length in H_2O_2 is shorter than that of O_2F_2.
Reason : H_2O_2 is an ionic compound. **[AIIMS 2003]**

24. Assertion : PbI_4 is a stable compound.

Reason : Iodide stabilizes higher oxidation state.

[AIIMS 2003]

25. Assertion : *Mg* is not present in enamel of human teeth.

Reason : *Mg* is an essential element for biological functions of human. **[AIIMS 2004]**

26. Assertion : Radium is most abundant *s*-block element.

Reason : *s*-block elements are non-radioactive in nature.

27. Assertion : *LiCl* is predominantly a covalent compound.

Reason : Electronegativity difference between *Li* and *Cl* is too small.

28. Assertion : The first ionization energy of *Be* is greater than that of *B*.

Reason : 2*p*-orbital is lower in energy than 2*s*-orbital.

29. Assertion : The alkali metals can form ionic hydrides which contains the hydride ion.

Reason : The alkali metals have low electronegativity, their hydrides conduct electricity when fused and liberate hydrogen at the anode.

30. Assertion : *Be* does not impart any characteristic colour to the bunsen flame.

Reason : Due to its very high ionization energy, beryllium requires a large amount of energy for excitation of the electrons.

31. Assertion : Potassium is not obtained by the electrolysis of fused *KCl*.

Reason : Potassium vapourises at the melting point of *KCl*.

32. Assertion : Helium and beryllium have similar outer electronic configuration of the type ns^2 .

Reason : Both are chemically inert.

33. Assertion : Na_2SO_4 is soluble while $BaSO_4$ is insoluble.

Reason : Lattice energy of $BaSO_4$ exceeds its hydration energy.

34. Assertion : Alkali metals impart colour to the flame.

Reason : Their ionisation energies are low.

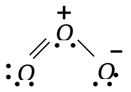
35. Assertion : Superoxides of alkali metals are paramagnetic.

Reason : Superoxides contain the ion O^{-2} which has one unpaired electron.

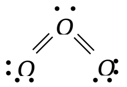
36. Assertion : Although PF_5, PCl_5 and PBr_3 are known, the pentahalides of nitrogen have not been observed.

Reason : Phosphorus has lower electronegativity than nitrogen.

37. Assertion : The electronic structure of O_3 is



Reason :



Structure is not allowed because octet around *O* cannot be expanded.

38. Assertion : Sulphuric acid is more viscous than water.

Reason : Concentrated sulphuric acid has a great affinity for water.

39. Assertion : PCl_5 is covalent in gaseous and liquid states but ionic in solid state.

Reason : PCl_5 in solid state consists of tetrahedral PCl_4^+ cation and octahedral PCl_6^- anion.

40. Assertion : Among nitrogen halides NX_3, the dipole moment is highest for NI_3 and lowest for NF_3.

Reason : Nitrogen halides NX_3, have trigonal pyramidal structure.

41. Assertion : White phosphorus is stored under water.

Reason : White phosphorous is highly reactive and catches fire spontaneously in air.

42. Assertion : *Al* forms $[AlF_6]^{3-}$ but *B* does not form $[BF_6]^{3-}$.

Reason : *B* does not react with F_2.

43. Assertion : NO_3^- is planar while NH_3 is pyramidal.

Reason : *N* in NO_3^- is sp^2 hybridized but in NH_3 it is sp^3 – hybridized.

44. Assertion : $Si-Si$ bonds are much stronger then $Si-O$ bonds.

Reason : Silicon forms double bonds with itself.

45. Assertion : The $S-S-S$ bond angle in S_8 molecule is 105°.

Reason : S_8 has a *V*-shape.

46. Assertion : Caro's acid has S atom in +6 oxidation state.

Reason : Caro's acid contains one peroxo O_2^{2-} group.

47. Assertion : The m.p./b.p. of noble gases are quite high.

Reason : The interparticle forces among noble gases in their liquid state are covalent forces.

48. Assertion : In SO_2, the bond angle is 119° whereas in SO_3, the bond angle is 120°.

Reason : S atom in both SO_2 and SO_3 is sp^2 – hybridized.

49. Assertion : Calcium carbide on hydrolysis gives methane.

Reason : Calcium carbide contains C^{4-} anions.

50. Assertion : Xenon forms fluorides.

Reason : Because 5 *d*-obitals are available for valence shell expansion.

51. Assertion : Hydrogen cannot be prepared in laboratory.

Reason : Hydrogen of high purity is obtained by electrolysing warm aqueous barium hydroxide between nickel electrodes.

52. Assertion : Diprotium shows relatively inert behaviour at room temperature.

Reason : The values of melting point and boiling point for dideuterium are higher as compared to diprotium.

53. Assertion : Water can be transformed from liquid to solid state only.

Reason : The distribution of water over the earth surface is uniform.

54. Assertion : Ice is less dense than water.

Reason : Ice is a solid whereas water is liquid.

55. Assertion : HF, NH_3 and H_2O form intermolecular hydrogen bonding.

Reason : HF, NH_3 and H_2O molecules are bonded in same manner.

56. Assertion : Hard water does not lather with soap.

Reason : In hard water, the sodium stearate of soap changes to the corresponding calcium magnesium salt which precipitates out.

57. Assertion : H_2O_2 is stored in wax-lined glass.

Reason : Presence of metal surfaces, traces of alkali (present in glass) etc. increases its decomposition.

58. Assertion : A nearly tetrahedral arrangement of the orbitals about the oxygen atom allows each water molecule to form hydrogen bonds with as many as four neighbouring water molecules.

Reason : In ice each water molecule form four hydrogen bond as each molecule is fixed in the space.

59. Assertion : Calgon is used for removing Ca^{2+} and Mg^{2+} ions from hard water.

Reason : Calgon forms precipitate with Ca^{2+} and Mg^{2+} ions.

60. Assertion : Reaction of SO_2 and H_2S in the presence of Fe_2O_3 catalyst gives elemental sulphur.

Reason : SO_2 is a reducing agent. **[AIIMS 2005]**

61. Assertion : SiF_6^{2-} is known but $SiCl_6^{2-}$ is not.

Reason : Size of fluorine is small and its lone pair of electrons interacts with *d*-orbitals of *Si* strongly. **[AIIMS 2005]**

62. Assertion : Borax bead test is not suitable for *Al*(III).

Reason : Al_2O_3 is insoluble in water. **[AIIMS 2005]**

63. Assertion : $SeCl_4$, does not have a tetrahedral structure.

Reason : *Se* in $SeCl_4$ has two lone pairs.

[AIIMS 2005]

64. Assertion : Ozone is a powerful oxidizing agent in comparison to O_2.

Reason : Ozone is diamagnetic but O_2 is paramagnetic. **[AIIMS 2005]**

Answers

Alkali metals

1	b	2	c	3	a	4	b	5	a
6	b	7	c	8	a	9	c	10	d
11	c	12	b	13	a	14	d	15	a
16	b	17	c	18	b	19	b	20	b
21	a	22	b	23	b	24	a	25	d
26	b	27	b	28	d	29	c	30	c
31	d	32	a	33	b	34	a	35	d
36	b	37	a	38	a	39	d	40	b
41	d	42	c	43	b	44	d	45	d

46	b	47	b	48	b	49	c	50	c
51	d	52	c	53	d	54	d	55	a
56	c	57	a	58	c	59	d	60	a
61	b	62	b	63	a	64	a	65	c
66	b	67	d	68	a	69	d	70	d
71	c	72	a	73	a	74	c	75	b
76	d	77	c	78	a	79	b	80	a
81	d	82	a	83	c	84	b	85	c
86	c	87	d	88	b	89	c	90	a
91	c	92	a	93	c	94	a	95	c
96	a	97	a	98	b	99	d	100	c
101	a	102	d	103	b	104	c	105	c
106	a	107	c	108	b	109	b	110	d
111	d	112	c	113	a	114	c	115	a
116	a	117	c	118	c	119	b	120	a
121	b	122	c	123	c	124	c	125	d
126	c	127	a	128	b	129	a,b	130	b
131	d	132	b	133	d	134	d	135	b
136	d	137	d	138	a	139	a	140	b
141	c	142	c	143	a	144	a	145	b
146	d	147	b	148	d	149	c	150	b

Alkaline earth metals

1	c	2	d	3	a	4	b	5	b
6	d	7	d	8	d	9	b	10	a
11	a	12	d	13	a	14	a	15	a
16	d	17	c	18	c	19	b	20	b
21	b	22	d	23	d	24	a	25	a
26	bc	27	d	28	d	29	b	30	b
31	d	32	d	33	b	34	b	35	b
36	d	37	c	38	d	39	d	40	a
41	c	42	a	43	a	44	a	45	a
46	c	47	b	48	d	49	c	50	c
51	a	52	c	53	b	54	a	55	b
56	a	57	d	58	a	59	b	60	b
61	d	62	b	63	d	64	a	65	a
66	d	67	a	68	c	69	d	70	a
71	c	72	a	73	b	74	c	75	b
76	d	77	b	78	d	79	c	80	c
81	d	82	a	83	c	84	a	85	c
86	d	87	c	88	d	89	a	90	a
91	b	92	c	93	c	94	b	95	a
96	d	97	d	98	d	99	a	100	b

101	b	102	c	103	a	104	b	105	c
106	a	107	a	108	c	109	d	110	d
111	b								

Boron family

1	a	2	c	3	a	4	a	5	c
6	d	7	a	8	c	9	d	10	c
11	d	12	b	13	c	14	c	15	c
16	acd	17	a	18	d	19	e	20	a
21	c	22	c	23	d	24	c	25	a
26	d	27	a	28	c	29	a	30	d
31	d	32	c	33	c	34	c	35	d
36	b	37	c	38	c	39	a	40	a
41	c	42	a	43	a	44	d	45	b
46	b	47	c	48	d	49	a	50	c
51	c	52	b	53	a	54	d	55	b
56	b	57	c	58	b	59	b	60	b
61	d	62	d	63	c	64	b	65	c
66	c	67	c	68	a	69	d	70	c
71	c	72	c	73	c	74	a	75	a
76	b	77	a						

Carbon family

1	c	2	d	3	d	4	c	5	a
6	a	7	b	8	d	9	c	10	d
11	c	12	b	13	d	14	b	15	c
16	a	17	b	18	b	19	d	20	d
21	c	22	c	23	a	24	a	25	c
26	a	27	c	28	a	29	a	30	d
31	a	32	a	33	d	34	b	35	b
36	b	37	c	38	b	39	b	40	b
41	a	42	c	43	b	44	c	45	d
46	c	47	c	48	b	49	d	50	a
51	c	52	c	53	a	54	a	55	a
56	c	57	b	58	b	59	a	60	b
61	d	62	a	63	d	64	c	65	d
66	b	67	c	68	a	69	b		

Nitrogen family

1	b	2	a	3	b	4	b	5	a
6	a	7	d	8	b	9	a	10	b
11	ad	12	b	13	a	14	b	15	d

16	b	17	d	18	b	19	c	20	a
21	a	22	a	23	b	24	d	25	c
26	c	27	c	28	c	29	d	30	c
31	d	32	c	33	d	34	ab	35	a
36	a	37	b	38	d	39	b	40	c
41	b	42	a	43	b	44	d	45	b
46	d	47	d	48	a	49	b	50	b
51	a	52	d	53	c	54	d	55	d
56	c	57	b	58	c	59	c	60	c
61	a	62	d	63	b	64	a	65	b
66	c	67	c	68	a	69	a	70	b
71	a	72	a	73	a	74	b	75	a
76	b	77	c	78	b	79	c	80	d
81	d	82	d	83	d	84	c	85	d
86	d	87	c	88	b	89	d	90	c
91	a	92	b	93	d	94	b	95	d
96	c	97	c	98	b	99	a	100	d
101	d	102	b	103	d	104	a	105	d
106	d	107	d	108	a	109	d	110	a
111	a	112	c	113	d	114	c	115	a
116	a	117	c	118	b	119	a	120	c
121	b	122	b	123	d	124	d	125	c
126	b	127	b	128	c	129	d	130	b
131	c	132	b	133	b	134	b	135	b
136	a	137	a	138	d	139	a	140	d
141	a	142	c	143	b	144	a	145	a
146	d	147	b	148	b	149	a	150	d
151	d	152	d	153	a	154	e	155	a
156	a	157	c	158	d	159	b	160	d
161	c	162	b	163	c	164	b	165	d
166	a	167	a	168	a	169	b	170	d
171	c	172	d	173	a	174	d	175	c
176	b	177	d	178	c	179	b	180	a
181	b	182	a	183	d	184	c	185	a
186	d	187	d	188	a	189	a	190	d
191	a	192	a	193	c	194	a	195	b
196	c	197	b	198	a	199	b	200	c
201	d	202	c	203	b	204	a	205	b
206	a	207	c	208	d	209	c	210	c
211	a	212	c	213	d	214	b	215	b,c
216	b	217	a	218	d	219	d	220	c
221	a	222	a	223	a	224	b	225	a
226	d	227	b	228	b	229	b	230	c
231	a	232	a	233	c	234	a	235	d
236	a	237	b	238	d	239	b	240	c
241	a								

Oxygen family

1	b	2	c	3	b	4	c	5	a
6	c	7	b	8	d	9	b	10	a
11	a	12	b	13	bc	14	d	15	d
16	a	17	b	18	c	19	a	20	a
21	a	22	d	23	a	24	c	25	c
26	d	27	d	28	b	29	b	30	b
31	a	32	d	33	a	34	b	35	a
36	a	37	d	38	c	39	a	40	a
41	c	42	a	43	d	44	a	45	b
46	a	47	d	48	b	49	b	50	c
51	d	52	c	53	d	54	c	55	d
56	b	57	a	58	c	59	c	60	a
61	a	62	d	63	a	64	a	65	c
66	c	67	a	68	a	69	c	70	d
71	c	72	a	73	c	74	c	75	b
76	b	77	b	78	c	79	d	80	a
81	d	82	d	83	d	84	e	85	b
86	c	87	d	88	c	89	d	90	b
91	c	92	a	93	a	94	b	95	c
96	c	97	b	98	c	99	b	100	b
101	a	102	d	103	b	104	b	105	c
106	a	107	a	108	d				

Halogen family

1	b	2	a	3	d	4	c	5	a
6	a	7	a	8	a	9	c	10	b
11	a	12	a	13	d	14	a	15	b
16	d	17	a	18	b	19	a	20	c
21	d	22	a	23	c	24	a	25	c
26	b	27	d	28	d	29	bd	30	d
31	d	32	a	33	d	34	a	35	d
36	a	37	b	38	a	39	d	40	a
41	d	42	b	43	d	44	a	45	a
46	a	47	b	48	a	49	d	50	b
51	a	52	a	53	d	54	a	55	a
56	d	57	a	58	c	59	a	60	d
61	b	62	c	63	a	64	a	65	d
66	b	67	b	68	b	69	c	70	c

71	b	72	a	73	a	74	b	75	d
76	b	77	b	78	c	79	c	80	b
81	b	82	c	83	d	84	d	85	d
86	a	87	a	88	a	89	d	90	b
91	d	92	c	93	c	94	a	95	a
96	c	97	b	98	b	99	c	100	a
101	a	102	c	103	d	104	b	105	d
106	e	107	b	108	a	109	a	110	a
111	c	112	c	113	a	114	a	115	a
116	c	117	b	118	b	119	b	120	b
121	d	122	a	123	b	124	a	125	a
126	c	127	d	128	a	129	a	130	c
131	d	132	a	133	a	134	a	135	a
136	c	137	d	138	b	139	d	140	a
141	d	142	d	143	d	144	b	145	a
146	a	147	a	148	b	149	c	150	a
151	d	152	b	153	d	154	a	155	c
156	b	157	b	158	a	159	c	160	d
161	d	162	a	163	b	164	a	165	a
166	c	167	c	168	c	169	b	170	a
171	a	172	b	173	c	174	c	175	b
176	b	177	c	178	b	179	a	180	d
181	a	182	a	183	a	184	c	185	a
186	a	187	c						

Noble gases

1	b	2	b	3	a	4	c	5	c
6	d	7	c	8	a	9	d	10	b
11	c	12	c	13	c	14	c	15	b
16	d	17	b	18	b	19	b	20	a
21	a	22	c	23	d	24	b	25	b
26	d	27	a	28	a	29	b	30	c
31	d	32	a	33	c	34	a	35	a
36	c	37	d	38	b	39	d	40	a
41	d	42	b	43	a	44	c	45	d
46	a	47	a	48	a	49	b	50	d
51	d	52	d	53	d	54	c	55	a
56	c	57	a	58	d	59	d	60	d

Critical Thinking Questions

1	c	2	d	3	a	4	d	5	b
6	d	7	a	8	b	9	a	10	a
11	c	12	b	13	d	14	c	15	b

16	d	17	a	18	d	19	c	20	a
21	b	22	d	23	a	24	b	25	b
26	c	27	a	28	d	29	a	30	b
31	b	32	b	33	a	34	a	35	a
36	d	37	b	38	c	39	d	40	a
41	a	42	a	43	d	44	d	45	a
46	b	47	d	48	b	49	b	50	c
51	c	52	b	53	d	54	c	55	a
56	c	57	c	58	c	59	a	60	b
61	c	62	c	63	c	64	b	65	a
66	c	67	b	68	d	69	a	70	a
71	a								

Assertion and Reason

1	b	2	b	3	a	4	a	5	a
6	c	7	b	8	e	9	a	10	a
11	e	12	a	13	a	14	a	15	a
16	c	17	b	18	c	19	d	20	d
21	a	22	b	23	d	24	d	25	b
26	d	27	c	28	c	29	a	30	a
31	a	32	c	33	b	34	a	35	a
36	b	37	a	38	b	39	b	40	b
41	a	42	c	43	a	44	d	45	c
46	a	47	d	48	b	49	d	50	a
51	e	52	b	53	d	54	b	55	c
56	a	57	a	58	a	59	d	60	b
61	a	62	b	63	c	64	b		

Answers and Solutions

Alkali metals

1. (b)

Element	Na	K
IE_1	496	419
IE_2	4562	3051

Sodium has higher I.E. because of smaller atomic size.

2. (c) Alkali metals are highly reactive metals. They react with

Alcohol – $2C_2H_5OH + 2K \rightarrow 2C_2H_5OK + H_2$

Water – $2K + 2H_2O \rightarrow 2KOH + H_2$

Ammonia – $K + (x+y)NH_3 \rightarrow \underset{\text{Ammoniated cation}}{[K(NH_3)_x]^+} + \underset{\text{Ammoniated electron}}{[e(NH_3)_y]^-}$

But they do not react with kerosene.

4. (b) After removal of an electron the effective nuclear charge per electron increases hence the size decreases.

5. (a) Alkali metals valence shell configuration $= ns^1$

6. (b)

Element –	Li	Na	K	Rb	Cs
Ionic radius – (pm)	76	102	138	152	167

as the atomic no. increases the no. of shells increases hence, atomic radius increases.

7. (c) On moving down the group electropositive character increases.

8. (a) Carnellite – $KCl.\ MgCl_2.\ 6H_2O$

Cryolite – Na_3AlF_6

Bauxite – ($Al_2O_3.2H_2O$)

Dolomite – $MgCO_3.\ CaCO_3$

10. (d)

Element –	Li	Na	K	Rb
Atomic radius (pm) –	152	186	227	248

12. (b) Li is much softer than the other group I metals. Actually Li is harder then other alkali metals

13. (a) $Cu^{+2} + 2e^- \rightarrow Cu\ , E^o = +0.34\ V$

$Mg^{+2} + 2e^- \rightarrow Mg\ , E^o = -2.37\ V$

$Na^+ + e^- \rightarrow Na\ , E^o = -2.71\ V$

14. (d) Anhydrous form of Na_2CO_3 does not decompose on heating even to redness. It is a amorphous powder called soda ash.

17. (c) Fehling's solution is a mixture of Alk. $CuSO_4 + Na - K$ tartarate (Rochelle salt)

19. (b) $2K + 2HCl \rightarrow 2KCl + H_2$ (violent reaction).

20. (b) Although lattice energy of $LiCl$ higher than $NaCl$ but $LiCl$ is covalent in nature and $NaCl$ ionic there after, the melting point decreases as we move $NaCl$ because the lattice energy decreases as a size of alkali metal atom increases (lattice energy $\propto$ melting point of alkali metal halide)

22. (b) It form calcium and magnesium complex with EDTA salt.

24. (a) $\underset{\xrightarrow{\hspace{6cm}}}{LiOH < NaOH < KOH < RbOH}$

Down the group basic character increases

25. (d) $\underset{\text{washing powder}}{Na_2CO_3\ .\ 10H_2O} \xrightarrow{\Delta} Na_2CO_3\ .\ H_2O \xrightarrow{\Delta}$

$Na_2CO_3 + H_2O \uparrow$

26. (b) Na_2CO_3, K_2CO_3 and $(NH_4)_2CO_3$ are soluble in water because hydration energy is more than lattice energy

29. (c) $K_2SO_4.Al_2(SO_4)_3.24H_2O$ potash alum it is a double salt.

31. (d) It is a colourless gas.

32. (a) $\underset{\text{(Salt of strong base \& weak acid)}}{NaHCO_3} \rightarrow Na^+ + \underset{OH^- + CO_2}{\underset{\downarrow}{HCO_3^-}}$

33. (b) $FeSO_4.(NH_4)_2SO_4.6H_2O$ Mohr's salt.

35. (d) $Ca^{+2} > Na^+ > Mg^{+2} > Al^{+3}$

36. (b) $Li^+ + e^- \rightarrow Li\ ,\ E^o = -3.05\ V$

$K^+ + e^- \rightarrow K\ ,\ E^o = -2.93\ V$

$Ca^{+2} + 2e^- \rightarrow Ca\ ,\ E^o = -2.87\ V$

37. (a) Because their valence electrons are present in s- orbitals.

38. (a) $6Li + N_2 \rightarrow 2Li_3N$ Lithium nitride.

39. (d) Li, Na, K are lighter than water but Rb is heavier than water.

42. (c) $KF + HF \rightarrow KHF_2 \rightleftharpoons K^+ + HF_2^-$

43. (b) $Cs > Rb > K > Na > Li$
Metallic character decreasing order.

45. (d) $2Rb + 2H_2O \rightarrow 2RbOH + H_2$

$$\xrightarrow{Li < Na < K < Rb < Cs}$$

As we go down the group reactivity with H_2O increases.

48. (b) Atomic number $11 \rightarrow Na \rightarrow Na_2O$

$$Na_2O + H_2O \rightarrow \underset{\text{(base)}}{2NaOH}$$

51. (d) Generally ionic character decreasing from $LiCl$ to $NaCl$.

52. (c) In castner process Na metal is made of anode.

55. (a) Fajan's rule is applied.

57. (a) Small atomic and ionic size leads to high electronegativity and hydration energy. Small atomic and ionic size leads to high electronegativity and hydration energy.

58. (c) Mohr salt is $(FeSO_4)(NH_4)_2SO_4.6H_2O$.

60. (a) Sodium thiosulphate is a reducing agent which convert metalic silver into silver salt.

64. (a) In alkali metal group elements alkali means plant ash.

67. (d) $2Na + 2NH_3 \xrightarrow{\text{heat}} 2NaNH_2 + H_2$

68. (a,b) $2Na + \frac{1}{2}O_2 \xrightarrow{\text{moist air}} Na_2O$

$$Na_2O + 2H_2O \longrightarrow 2NaOH + H_2.$$

69. (d) $2KClO_3 \rightarrow 2KCl + 3O_2$.

70. (d) Due to free electron liquid ammonia becomes paramagnetic.

72. (a) They possess highest atomic volume in their respective periods.

74. (c) $Fe(OH)_3$ is soluble in sodium hydroxide solution.

76. (d) The cell involves the following reaction,

$NaCl \rightleftharpoons Na^+ + Cl^-$

At anode : $2Cl^- \rightarrow 2Cl + 2e \rightarrow Cl_2$

At cathode : $Na^+ + e \rightarrow Na$

$Na + Hg \rightarrow$ amalgam

At anode : $Na -$ amalgam $\rightarrow Na^+ + Hg + e$

At cathode : $2H_2O + 2e \rightarrow H_2 \uparrow + 2OH^-$

78. (a) *Li* is a more reducing agent compare to other element.

79. (b) Element – *Li* *Na* *K* *Rb* *Cs*
M.pt in K – 4535 370.8 336.2 312 301.5

80. (a) $2Na + 2HOH \rightarrow 2NaOH + H_2 \uparrow$

$$2K + 2HOH \rightarrow 2KOH + H_2 \uparrow$$

82. (a) Alkali metal are good conductor of heat and electricity.

83. (c) Potassium react with halogens (chlorine) to gives violet colour flame.

84. (b) Mobility decreases from top to bottom because of the atomic size is increases.

85. (c) Lithium shows digonal relationships with *Mg*.

86. (c) $K > Ca > C > Cl$
Electropositive character in decreasing order.

87. (d) $\underset{\text{Molten}}{2NaCl} \xrightarrow{\text{Electrolysis}} \underset{\text{Cathode}}{2Na} + \underset{\text{Anode}}{Cl_2}$

88. (b) When sodium bicarbonate $(NaHCO_3)$ is heated, sodium carbonate, CO_2 and water are formed.

$$2NaHCO_3 \xrightarrow{\Delta} \underset{\text{Sodium carbonate}}{Na_2CO_3} + CO_2 \uparrow + H_2O$$

89. (c) Alum is used for softning of water.

90. (a) Only salts of (weak acid + strong base) and (strong acid + weak base) get hydrolysed (*i.e.,* show alkalinity or acidity in water). $KClO_4$ is a salt of strong acid and strong base therefore it does not get hydrolysed in water.

$$KClO_4 \rightleftharpoons K^+ + ClO_4^-;\ H_2O \rightleftharpoons \underset{\substack{\rightleftharpoons\\ KOH\\ \text{Strong}}}{OH^-} + \underset{\substack{\rightleftharpoons\\ HClO_3\\ \text{Strong}}}{H^+}$$

91. (c) Carbon dioxide does not help in burning, also it forms carbonate with alkali metals.

92. (a) When carbonate are heated they decompose to form the oxide. Sodium carbonate and potassium carbonate do not decompose. The carbonate become more difficult to decompose as we go down the group.

93. (c) Aluminium reacts with caustic soda to form sodium meta aluminate.

$$2Al + 2NaOH + 2H_2O \rightarrow \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2 \uparrow$$

94. (a) Alkaline earth metals (ns^2) are denser than alkali metal (ns^1) because metallic bonding in alkaline earth metal is stronger.

95. (c) Lithium is basic in nature and hence it is not amphoteric.

96. (a) $CsOH$ of the following is most basic in character due to increase electropositive character in a group of alkali.

97. (a) Group I element are so highly electropositive that they emit electrons even when exposed to light (Photoelectric effect) and this character increase on moving down the group from lithium towards cesium.

98. (b) Lithium form nitride on heating with nitrogen. Lithium nitride gives ammonia when heated with H_2O. Ammonia gas form tetrammine copper complex with $CuSO_4$ solution.

$$6Li + N_2 \rightarrow 2Li_3N$$

$$Li_3N + 3H_2O \rightarrow 3LiOH + NH_3$$

$$CuSO_4 + 4NH_3 \rightarrow [Cu(NH_3)_4]SO_4$$

99. (d) The given compound *x* must be $CaCO_3$. It can be explained by following reactions,

$$\underset{(x)}{CaCO_3} \xrightarrow{\Delta} \underset{\text{Residue}}{CaO} + CO_2 \uparrow ;$$

$$Ca(OH)_2 + CO_2 + H_2O \rightarrow \underset{z}{Ca(HCO_3)}$$

$$Ca(HCO_3)_2 \xrightarrow{\Delta} \underset{(x)}{CaCO_3} + CO_2 \uparrow + H_2O$$

100. (c) According to Fajan's rule *RbCl* has greatest ionic character due to large ionic size of Rb^+ ion. $BeCl_2$ has least ionic (Maximum covalent) due to small size of Be^{+2} ion which has highly polarising.

105. (c) $2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$

110. (d) $2Na + 2H_2O \rightarrow 2NaOH + H_2$

112. (c) It reacts with alcohol to form sodium alkoxide

$$2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$$

113. (a) Causticizing process (Gossage process) it is an old process and involves heating of 10% solution of Na_2CO_3 with a little excess of milk of lime $Ca(OH)_2$

$$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + 2NaOH$$

114. (c) $NaOH + CO \xrightarrow[5-10\text{ atm}]{150°-200°C} HCOONa$

115. (a) $2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$

119. (b) $NaOH$ is a deliquescent white crystalline solid. It absorbs moisture from the atmosphere.

120. (a) $Na_2CO_3 + H_2O + 2SO_2 \rightarrow 2NaHSO_3 + CO_2$

123. (c) $NaOH + CaO$ is called soda lime 3 : 1

124. (c) Molten sodium is used as a coolant

126. (c) $AgBr + 2Na_2S_2O_3 \rightarrow Na_3[Ag(S_2O_3)_2] + NaBr$

128. (b) $Na_2SO_3 + S \xrightarrow{NaOH} \underset{\text{Sod. thiosulph ate}}{Na_2S_2O_3}$

129. (a,b) $2NaCl + 2H_2O \rightarrow 2NaOH + \underset{\text{Anode}}{Cl_2} + \underset{\text{Cathode}}{H_2}$

132. (b) $Sn + 2NaOH + H_2O \rightarrow Na_2SnO_3 + 2H_2$

135. (b) $2NaCl + 2H_2O \xrightarrow{\text{Electroly sis}} 2NaOH + \underset{\text{Anode}}{Cl_2} + \underset{\text{Cathode}}{H_2}$

136. (d) $2NaCl \xrightarrow{\text{Electriccurrent}} \underset{\text{Cation}}{2Na^+} + \underset{\text{Anion}}{2Cl^-}$

138. (a) $HgCl_2 + 2NaOH \rightarrow HgO + 2NaCl + H_2O$

139. (a) Down's cell is used for the electrolysis of fused $NaCl$

142. (c) $Fe(OH)_3$ does not dissolve in $NaOH$

143. (a) Castner's process used to obtain Na, by electrolysis of sodium hydroxide.

144. (a) Excess of Na^+ ion causes high B.P.

145. (b) Ferric alum is $(NH_4)_2SO_4.Fe_2(SO_4)_3.24H_2O$

146. (d) When Na is heated in presence of air or oxygen, Na burns to form sodium oxide and sodium peroxide.

$$CaO + H_2O \rightarrow \underset{(y)}{Ca(OH)_2}$$

148. (d) Pyrolusite or Manganese dioxide (MnO_2) is a mineral of manganese.

149. (c) $CaCl_2$ bring down the melt temperature from 1075 *K* to 850 *K*

Alkaline earth metals

2. (d) $CaSO_4.\frac{1}{2}H_2O$ or $(CaSO_4)_2.H_2O$

3. (a) $CaCl_2$ because it is hygroscopic

7. (d) Setting of plaster of paris is exothermic process

$$CaSO_4.\frac{1}{2}H_2O \xrightarrow{H_2O} \underset{\text{Orthorhomb ic}}{CaSO_4.2H_2O}$$

$$\xrightarrow{\text{Hardening}} \underset{\substack{\text{Mono orthorhomb ic}\\ \text{Gy psum}}}{CaSO_4.2H_2O}$$

The setting is due to formation of another hydrate

10. (a) $MgCO_3 \xrightarrow{\text{Heat}} MgO + CO_2$

The metal whose oxide is stable, it's carbonate is unstable

12. (d) $\underset{\text{(Molten)}}{MgCl_2} \xrightarrow{Electrolysis} \underset{\text{Cation}}{Mg^{+2}} + \underset{\text{Anion}}{2Cl}$

Anode – $2Cl^- \rightarrow 2Cl + 2e^-, Cl + Cl \rightarrow Cl_2$

Cathode – $Mg^{+2} + 2e^- \rightarrow Mg$

13. (a) Because of small atomic size and high I.E. Be forms covalent chloride.

16. (d) $BeSO_4$ is most soluble because hydration energy is more than lattice energy.

$$\overrightarrow{BeSO_4 > MgSO_4 > CaSO_4 > SrSO_4 > BaSO}$$

Hydration energy decreases hence, solubility decreases.

19. (b) $\underset{\text{Gypsum}}{2(CaSO_4.2H_2O)} \xrightarrow[\text{Dehydration}]{120°C} \underset{\text{Plaster of paris}}{2CaSO_4.H_2O} + 3H_2O$

21. (b) Lithopone $(ZnS + BaSO_4)$ is used as a white pigment.

23. (d) $\underset{\text{Slaked lime}}{Ca(OH)_2} + Cl_2 \rightarrow \underset{\substack{\text{Bleaching}\\ \text{powder}}}{CaOCl_2} + H_2O$

24. (a) Strontium → Crimson or pink colour

26. (b,c)

$Ca_3P_2 + 6H_2O \to 3Ca(OH)_2 + 2PH_3$

$K_3P + 3H_2O \to 3KOH + PH_3$

27. (d) $CaCl_2 \to \underset{\text{Cathode}}{Ca^{+2}} + \underset{\text{Anode}}{2Cl^-}$

Cathode : $Ca^{+2} + 2e^- \to Ca$

Anode : $2Cl^- \to 2e^- + Cl_2$

28. (d)

Element –	Mg	Al	Si	P
Atomic radii (Å)–	1.60	1.43	1.32	1.28

as we move across the period nuclear charge increases, hence, size decreases.

30. (b) $MgCl_2.6H_2 + 5MgO + xH_2O \to$

$\underset{\text{Magnesia cement or sorrel cement}}{MgCl_2.5MgO.xH_2O}$

31. (d) $ZnS + BaSO_4$ is lithopone used as white pigment.

36. (d) Aqueous $CaCl_2$ or hydrated $CaCl_2$ can not act as dehydrating agent.

38. (d) As we go down the group electropositive character increases because I.E. decreases.

Ba is most electropositive element in the group.

39. (d) Due to the inert pair effect.

40. (a)

Element –	Be	Al
Electronegativity –	1.5	1.5

41. (c) $Be > Mg > Ca > Sr > Ba$

On moving down the group lattice energy remains almost constant as the sulphate is so big that small increase in the size of the cations from Be to Ba does not make any difference. However the hydration energy decreases from Be^{+2} to Ba^{+2}. This causes decrease in the solubility of the sulphates as the ionic size increases.

42. (a)

Element –	Be	Mg	Ca	Sr	Ba
Electrode potential	– 1.70	– 2.37	– 2.87	– 2.89	–2.90

43. (a)

Element –	Mg	Ca	Sr	Ba
I.E –	737	590	549	503

44. (a) Be due to diagonal relationship

45. (a) K^+ is highly soluble because of high hydration energy.

47. (b) $\underbrace{MgO}_{\text{Basic}} \ \underbrace{Al_2O_3}_{\text{Amphoteric}} \ \underbrace{SiO_2 \quad P_2O_5}_{\text{Acidic}}$

$MgO + H_2O \to Mg(OH)_2$ Base or alkali

48. (d)

Duralium $(Al = 95\%,\ Cu = 4\%,\ Mn = 0.5\%,\ Mg = 0.5\%)$

being light, tough and durable is used for the manufacture of aeroplanes and automobile parts.

49. (c)

Na	K	Ba	Ca	Sr
Yellow	Pale violet	Apple green	Brick red	Crimson

51. (a) Magnesium burns with an intense light. Therefore Mg is used in flash bulbs for photography, fireworks and signal fires.

53. (b) $CaO + CO_2 \to CaCO_3$

$CaO + H_2O \to Ca(OH)_2$

54. (a) When water is added to cement an exothermic reaction occurs. During this process, the cement reacts with water to form a gelatinous mass which slowly sets into a hard mass having three dimensional network structure involving $-Si-O-Si-$ and $-Si-O-Al-$ chains.

55. (b) CaO – (quick lime)

$Ca(OH)_2$ – (slaked lime)

$Ca(OH)_2 + H_2O$ – an aqueous suspension of $Ca(OH)_2$ in water is called lime water.

$CaCO_3$ (lime stone).

57. (d) Lime stone – $CaCO_3$

Clay – silica and alumina

Gypsum – $CaSO_4.2H_2O$

59. (b) Because hydration energy decreases down the group.

63. (d) Be does not react with water.

64. (a) (i) Small atomic size.

(ii) High electronegativity

(iii) Absence of *d* orbitals

65. (a) $\underrightarrow{Ba(OH)_2 > Sr(OH)_2 > Ca(OH)_2 > Mg(OH)_2}$

Solubility decreasing order.

66. (d) Solubility increasing top to bottom.

67. (a) Be to Ba ionic character increasing.

70. (a) $Ca + 2H_2O \to Ca(OH)_2 + H_2$

$CaH_2 + 2H_2O \to Ca(OH)_2 + 2H_2$

72. (a) They are denser than alkali metals because they can be packed more tightly to their greater charge and smaller radii.

76. (d) $Be(OH)_2 < Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$

On moving down the group basic character increases.

77. (b) $Mg(OH)_2$ Mg is most electropositive element amongst the given elements.

78. (d) Lime stone = $CaCO_3$

Quick lime = CaO

Slaked lime = $Ca(OH)_2$

79. (c) As we go down the group I.E. decreases. Hence, *Ba* can easily give electrons. Therefore strongest reducing agent.

80. (c) $\underset{\text{Plaster of paris}}{CaSO_4.\frac{1}{2}H_2O}+\frac{1}{2}H_2O \rightarrow \underset{\text{Hard mass}}{CaSO_4.2H_2O}$

82. (a) $BeCl_2 < MgCl_2 < CaCl_2 < BaCl_2$

As we go down the group I.E. decreases. Hence ionic character increases.

83. (c) $MgCl_2.6H_2O \xrightarrow{\text{heat}} MgO + 5H_2O + 2HCl$

84. (a) The solubility of hydroxides of alkaline earth metals in water increases on moving down the group.

85. (c) Bleaching action of Cl_2 in moist condition is permanent.

$Cl_2 + H_2O \rightarrow HCl + HClO$

$HClO \rightarrow HCl + O$

$Cl_2 + H_2O \rightarrow 2HCl + O$

Coloured matter + nascent oxygen → colourless matter

86. (d) The solubility of hydroxides of alkaline earth metals in water increases on moving down the group.

87. (c) CO_2 escapes simultaneously.

88. (d) It consist of high lattice energy and lowest hydration energy.

90. (a) It is a *s*-block elements.

91. (b) Barium Ba_{56} is a alkali earth metal.

92. (c) Thermal stability increasing from top to bottom.

94. (b) On moving down the group; Lattice energy decreases with increase in size of cation.

96. (d) $BaSO_4$ is sparingly soluble in water because the solubility of second group sulphates decreases with increasing atomic size. Because of hydration energy decreases.

97. (d) Berylium because of small atomic size and high ionization energy.

99. (a) $\xrightarrow[\text{Ionic nature increases}]{Mg < Ca < Sr < Ba < Ra}$

as we go down the group ionic nature increases because I.E. decreases.

100. (b) $CaSO_4.2H_2O$ – Gypsum

$CaSO_4.\frac{1}{2}H_2O$ – Plaster of paris

101. (b) $Ca + \frac{1}{2}O_2 \rightarrow CaO$.

102. (c) Calcium cyanamide is the slow acting nitrogenous fertilizer as it decompose very slowly.

$CaNCN + 2H_2O \rightarrow CaCO_3 + \underset{\text{Urea}}{NH_2CONH_2}$

$NH_2CONH_2 + H_2O \rightarrow CO_2 + 2NH_3$

$NH_3 \xrightarrow[\text{bacteria}]{\text{Nitrifying}} \text{Soluble nitrates} \rightarrow \text{Plants}$

103. (a) Plaster of paris $[(CaSO_4)_2H_2O]$ is used in surgery for setting of bones, dentistry and manufacturing of statues. It is prepared as follows,

$2CaSO_4.2H_2O \xrightarrow{125°C} \underset{\text{Plaster of paris}}{(CaSO_4)_2.H_2O}+3H_2O$

104. (b) Due to electropositive and reactive in nature, magnesium is readily converted into positive ions on contact with iron pipes and hence, iron pipes remains as it is.

105. (c) A binary compound is one made of two different elements. These can be one of each element such as *CuCl* or *FeO*. These can also be several of each element such as Fe_2O_3 or $SnBr_4$. Metal which have variable oxidation number can form more than one type of binary compound like *Fe* shows the oxidation state +2 and +3. Hence it forms two type of binary compound *e.g.,* $FeCl_2, FeCl_3$.

106. (a) Diagonal relationship: elements of 2nd period often show resemblance to the element of the IIIrd period diagonaly placed to it. This type of behaviour is called as diagonal relationship *Li* shows the diagonal relationship with *Mg*.

107. (a) $MgCl_2 + 2NaHCO_3 \rightarrow Mg(HCO_3)_2(aq) + 2NaCl$

$Mg(HCO_3)_2(aq) \xrightarrow{\Delta} \underset{\text{(White ppt.)}}{MgCO_3\downarrow} + H_2O + CO_2\uparrow$

108. (c) We know that

$MgCl_2.6H_2O \xrightarrow{Heat} MgCl_2 + 6H_2O$

Thus in this reaction magnesium dichloride is produced.

109. (d) Magnesium burns in *CO* to produce

$Mg + CO \rightarrow MgO + C$

110. (d) Sorel's cement is, $MgCl_2.5MgO.xH_2O$

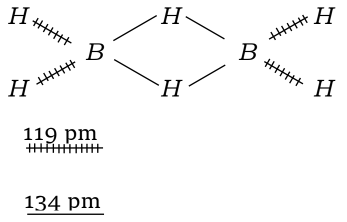
111. (b) Colemnite is a mineral of boron having composition as $Ca_2B_6O_{11}.5H_2O$.

Boron family

3. (a) $B_2O_3 + 3C + 3Cl_2 \rightarrow 2BCl_3 + 3CO$

BCl_3 is obtained by passing chlorine over the heated mixture of B_2O_3 and powdered charcoal.

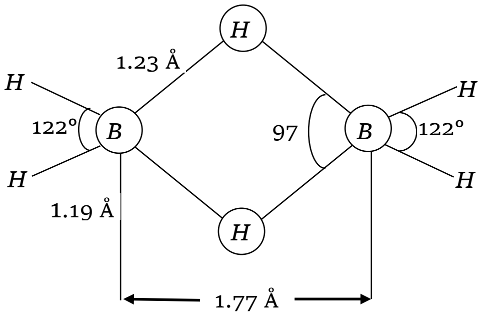
6. (d) B_2H_6 has two types of $B-H$ bonds



B H (Terminal bond)

B H (Bridge bond)

12. (b) Dilthey in 1921 proposed a bridge structure for diborane. Four hydrogen atoms, two on the left and two on the right, known as terminal hydrogens and two boron atoms lie in the same plane. Two hydrogen atoms forming bridges, one above and other below, lie in a plane perpendicular to the rest of molecule.



15. (c) $2H_3BO_3 \rightarrow B_2O_3 + 3H_2O$.

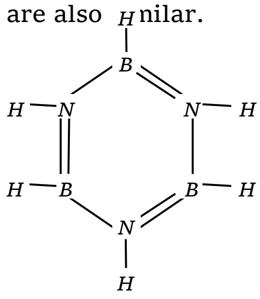
16. (a,c,d) Al_2Cl_6, In_2Cl_6, Ga_2Cl_6

17. (a) Liquified Ga expand on solidification Ga is less electropositive in nature, It has the weak metallic bond so it expand on solidification.

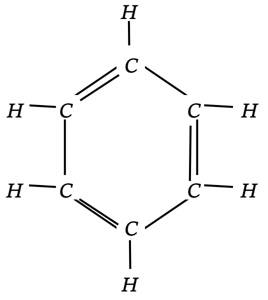
18. (d) $Al_2Cl_6 + 12H_2O \rightleftharpoons 2[Al(H_2O)_6]^{3+} + 6Cl^-$

19. (e) B_4C is the hardest substance along with diamond.

20. (a) Borazine $B_3N_3H_6$, is isoelectronic to benzene and hence, is called inorganic benzene some physical properties of benzene and borazine are also similar.



Borazine



Benzene

21. (c) Except $B(OH)_3$ all other hydroxide are of metallic hydroxide having the basic nature $B(OH)_3$ are the hydroxide of nonmetal showing the acidic nature.

22. (c) Moissan boron is amorphous boron, obtained by reduction of B_2O_3 with Na or Mg. It has 95-98% boron and is black in colour.

23. (d) Boron form different hydride of general formula B_nH_{n+4} and B_nH_{n+6} but BH_3 is unknown.

24. (c) Alumina is amphoteric oxide, which reacts acid as well as base.

25. (a) Al is the most abundant metal in the earth crust.

29. (a) $AlCl_3.6H_2O \xrightarrow{\Delta} Al(OH)_3 + 3HCl + 3H_2O$

Thus $AlCl_3$ can not be obtained by this method

30. (d) Amphoteric substance can react with both acid and base.

33. (c) $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

34. (c) $Al \rightarrow$ III group $\rightarrow$ Forms Al_2O_3

35. (d) $2KOH + 2Al + 2H_2O \rightarrow 2KAlO_2 + 3H_2$

37. (c) $Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$

$2NaOH + 2Al + 6H_2O \rightarrow 2Na[Al(OH)_4] + 3H_2$

41. (c) $B(OH)_3 \Rightarrow H_3BO_3$ Boric acid

$Al(OH)_3 \Rightarrow$ Amphoteric

45. (b) $FeSO_4.(NH_4)_2SO_4.6H_2O$

46. (b) Al_2O_3 is an amphoteric oxide.

47. (c) Aluminium oxide is highly stable therefore, it is not Reduced by chemical reactions.

48. (d) Aluminium is used as reducing agent in metallurgy.

49. (a) Al is used as reducing agent in thermite process.

50. (c) In Goldschmidt aluminothermic process, thermite contains 3 parts of Fe_2O_3 and 1 part of Al.

51. (c) For the purification of red bauxite which contains iron oxide as impurity → Baeyer's process. For the purification of white bauxite which contains silica as the main impurity Serpeck's process.

52. (b) In Hall's process

$Al_2O_3.2H_2O + Na_2CO_3 \rightarrow 2NaAlO_2 + CO_2 + 2H_2O$

$2NaAlO_2 + 3H_2O + CO_2 \xrightarrow{333\ K}$

$2Al(OH)_3 \downarrow + Na_2CO_3$

$2Al(OH)_3 \xrightarrow{1473\ K} Al_2O_3 + 3H_2O$

54. (d) Cryolite Na_3AlF_6

(1) Decreases the melting point of alumina

(2) Increases conductivity of the solution

55. (b) Cryolite Na_3AlF_6 is added

(1) To decrease the melting temp from $2323\ K$ to $1140\ K$

(2) To increase the electrical conductivity of solution

61. (d) Iron oxide impurity – Baeyer's process

Silica impurity – Serpeck's process

64. (b) Cryolite is added to lower the melting point of alumina and to increase the electrical conductivity.

65. (c) The purification of alumina can be done by Baeyer's process.

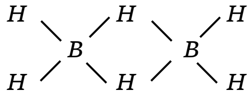
67. (c) In electrolytic method of obtaining aluminium from purified bauxite, cryolite is added to charge because it reduces the melting point of Bauxite (from 1200^oC to 800^o-900^oC) and also it increases electrical conductivity of mixture.

68. (a) Hoop's process ⇒ Purification of Al

Hall and Heroult process ⇒ Reduction of Al_2O_3

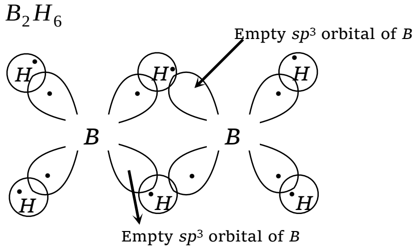
Baeyer's and Serpeck's process ⇒ Concentration of Bauxite ore

74. (a)



$3c-2e: B-H-B$; $\quad 2c-2e: H-B-H$

75. (a) B_2H_6



76. (b) Pure alumina is a bad conductor of electricity and the fusion temperature of pure alumina is about 2000°C and at this temperature when the electrolysis is carried of fused mass the metal formed vapoureses as the boiling point of Al is 1800°C.

To overcome this difficulty, Na_3AlF_6 and CaF_2 are mixed with alumina.

77. (a) Concentration of Lewis acid of boron tri halides is increased in following order. $BF_3 < BCl_3 < BBr_3 < BI_3$.

Carbon family

3. (d) It react with alkali as well as acid.

6. (a) Among alkali metal carbonates only Li_2CO_3 decomposes. $Li_2CO_3 \xrightarrow{\Delta} Li_2O + CO_2\uparrow$

7. (b) Propyne can be prepared by the hydrolysis of magnesium carbide.

$Mg_2C_3 + 4H_2O \rightarrow CH_3C \equiv CH + 2Mg(OH)_2$

10. (d) Generally red lead decompose into PbO and O_2.

11. (c) CO_2 is acidic oxide and thus more effectively absorbed by an alkali.

12. (b) CaC_2 have one sigma and two π bond.

13. (d) C and Si are non-metal and Pb is a metal.

16. (a) $SiO_2 + 2Mg \rightarrow Si + 2MgO$.

17. (b) Generally IV group element shows catenation tendency and carbon has more catenation power.

18. (b) Metal oxides or some salts are fused with glass to imported colour of glass.

19. (d) $Al_2(CO_3)_3$ is less soluble in water than Na_2CO_3, $ZnCO_3$.

20. (d) The inert pair effect is most prominent in Pb because from top to bottom due to increase in number of shells.

25. (c) $Co + NaOH \xrightarrow{200^\circ C} \underset{\text{Sod. formate}}{HCOONa}$

27. (c) Sodium oxalate react with conc. H_2SO_4 to form CO and CO_2 gas.

33. (d) It is hydrolysed with water to form a $Si(OH)_4$.

35. (b) When hydrogen peroxide react with PbS then they form $PbSO_4$.

36. (b) Grey tin is very brittle and easily crumbles down to a powder in very cold climates.

$\underset{\text{(Cubic)}}{\text{Grey tin}} \rightleftharpoons \underset{\text{(Tetragonal)}}{\text{White tin}}$

The change of white tin to grey tin is accompanied by increase in volume. This is called tin disease or tin plague.

37. (c) Solid CO_2 is knows as dry ice because it evaporates at –78°C without changing in the liquid state.

38. (b) Zeolite have SiO_4 and AlO_4 tetrahedrons linked together in a three dimensional open structure in which four or six membered ring predominate. Due to open chain structure they have cavities and can take up water and other small molecules.

39. (b) Crook's glass is a special type of glass containing cerium oxide. It does not allow the passage of ultra violet ray and is used for making lenses.

40. (b) Inert pair effect become significant for the 6th and 7th period of p-block element.

41. (a) Carbon suboxide has linear structure with $C-C$ bond length equal to $130\ Å$ and $C-O$ bond length equal to $120\ Å$.

$O=C=C=C=O \leftrightarrow O^- - C \equiv C - C \equiv O^+$

42. (c) Pb_3O_4 is a mixed oxide. It can be represented as $2PbO - PbO_2$.

43. (b) Noble gases are found in very minute amount in atmosphere. These are separated from each other by using coconut charcoal. Which adsorb different gas at different temperature.

44. (c) Lapis Lazuli is a rock composed mainly of the following mineral, lazurite, hauynite sodalite, nosean, calcite, pyrite, lapis lazuli is actually sulphur containing, sodium aluminium silicate having chemical composition $3Na_2O.3Al_2.6SiO_2.2Na_2S$.

45. (d) In carbon family stability +2 oxidation state increases on moving down the group in the periodic table with an increase in atomic number due to screening effect.

46. (c) Tin is oxidised to meta stannic acid when it is treated with nitric acid.

$Sn + 4HNO_3 \rightarrow H_2SnO_3 + 4NO_2 + H_2O$

47. (c) $Pb + Sn$

49. (d) Three dimensional sheet structures are formed when three oxygen atoms of each $[SiO_4]^{4-}$ tetrahedral are shared.

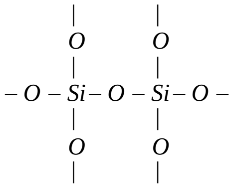
50. (a) $Pb_3O_4 \Rightarrow$ Red lead (Sindhur)

51. (c) White lead $\Rightarrow 2PbCO_3.Pb(OH)_2$

52. (c) Organic acids dissolve lead in presence of oxygen

$$Pb + 2CH_3COOH + \frac{1}{2}O_2 \rightarrow Pb(CH_3COO)_2 + H_2O$$

53. (a)



$$\begin{array}{ccccc} & | & & | & \\ & O & & O & \\ & | & & | & \\ -O- & Si & -O- & Si & -O- \\ & | & & | & \\ & O & & O & \\ & | & & | & \end{array}$$

55. (a) S^2P^2 Total 4 valence electrons $\Rightarrow$ IV group

56. (c) $PbCl_2$ is most ionic because on going down the group the metallic character increases and also the inert pair effect predominates.

58. (b) Type metal Pb = 82%, Sb = 15%, Sn = 3%

60. (b) Sugar of lead $(CH_3COO)_2Pb \Rightarrow$ lead acetate

63. (d) $Pb \Rightarrow$ 11.34 g/ml Heaviest

64. (c) Pb_3O_4 is a mixed oxide of $2PbO + PbO_2$

67. (c) Boron (B), Si, Ge, As, Sb, and At are the metalloid elements. Bismuth (Bi) and tin (Sn) are metals while carbon (C) is non-metal.

68. (a) $Al_4C_3 + 12H_2O \rightarrow 3CH_4 + 4Al(OH)_3$

69. (b) Glass being a mixture of sodium and calcium silicates reacts with hydrofluoric acid forming sodium and calcium fluorosilicates respectively.

$Na_2SiO_3 + 3H_2F_2 \rightarrow Na_2SiF_4 + 3H_2O$

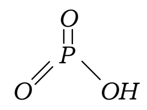
$CaSiO_3 + 3H_2F_2 \rightarrow CaSiF_4 + 3H_2O$

The etching of glass is based on these reactions.

Nitrogen family

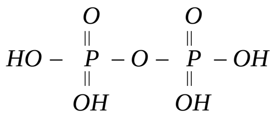
3. (b) $FeSO_4 + NO \rightarrow \underset{\text{(Brown)}}{FeSO_4.NO}$

4. (b) HPO_3, metaphosphoric acid



6. (a) White phosphorus is soluble in CS_2 whereas red phosphorus is insoluble in it.

7. (d) $H_4P_2O_7$ pyrophosphoric acid



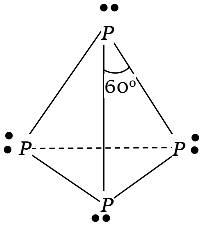
$$\begin{array}{ccccc} & O & & O & \\ & \| & & \| & \\ HO- & P & -O- & P & -OH \\ & \| & & \| & \\ & OH & & OH & \end{array}$$

Tetrabasic ($4-OH$ groups)

8. (b) $\underset{\text{(White)}}{P_4} + 3NaOH + 3H_2O \rightarrow \underset{\text{Phosphine}}{PH_3} + 3\underset{\text{Sod. hypophosphite}}{NaH_2PO_2}$

9. (a) NCl_5 is not known because of absence of d-orbitals in nitrogen.

11. (a,d) P_4 molecule



Bond angle $= 60^o$

Six P–P = Single bonds

Lone pairs = 4

12. (b) $\underset{(S)}{NH_4NO_3} \xrightarrow{\Delta} 2H_2O\uparrow + \underset{\substack{\text{Nitrous oxide}\\ \text{(Laughing gas)}}}{N_2O}\uparrow$

13. (a) Birkeland – Eyde process

Dinitrogen is prepared commercially from air by liquification and fractional distillation. When liquid air is allowed to distil, dinitrogen having lower b.pt (77K) distils over first leaving behind liquid oxygen (bpt 90K). World wide production of dinitrogen from liquid air is more than 50 million tonns per year.

14. (b) $\underset{(s)}{NH_4NO_3} \xrightarrow{\Delta} 2H_2O\uparrow + N_2O\uparrow$

$\underset{(s)}{NaNO_3} \xrightarrow{\Delta} \underset{(s)}{NaNO_2} + O_2\uparrow$

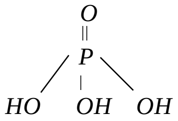
$2\underset{\text{Lunar caustic}}{AgNO_3}(s) \rightarrow 2Ag(s) + 2NO_2(g) + O_2(g)$

$2Pb(NO_3)_2 \rightarrow 2\underset{(s)}{PbO} + 4NO_2\uparrow + O_2\uparrow$

16. (b) $\underset{\text{White}}{P_4} + 3NaOH + 3H_2O \rightarrow \underset{\text{Phosphine}}{PH_3} + 3NaH_2PO_2$

17. (d) $\underbrace{N \quad P}_{\text{Non-metals}} \quad \underbrace{As \quad Sb}_{\text{Metalloids}} \quad \underbrace{Bi}_{\text{Meta}}$

18. (b)



3 - OH groups are present hence it is tribasic.

19. (c) Nitrous acid behaves as reducing as well as an oxidising agent. It reduces potassium permanganate, potassium dichromate, H_2O_2 and other strong oxidising agents. It oxidises strong reducing agents such as hydroiodic acid, sulphurous acid etc.

It oxidises Fe^{+2} into Fe^{+3} in acidic medium;

$Fe^{+2} + HNO_2 + H^+ \rightarrow Fe^{+3} + NO + H_2O$

It reduces acidified $KMnO_4$.

$$2KMnO_4 + 3H_2SO_4 + 5HNO_2 \rightarrow$$
$$K_2SO_4 + 2MnSO_4 + 3H_2O + 5HNO_3$$

20. (a) $\underset{(S)}{2KNO_3} \xrightarrow{\Delta} \underset{(S)}{2KNO_2} + O_2$

23. (b) $NH_4Cl + KNO_2 \rightarrow NH_4NO_2 + KCl$

$\downarrow$

$N_2 + 2H_2O$

24. (d) $\underset{\text{Nitric acid}}{2HNO_3} \rightarrow N_2O_5 + H_2O$

25. (c) $2Ca_3(PO_4)_2 + 6SiO_2 \xrightarrow{1770\text{K}} 6CaSiO_3 + P_4O_{10}$

$P_4O_{10} + 10C \xrightarrow{1770\text{K}} \underset{\text{White}}{P_4} + 10CO$

26. (c) $P_4 + 5O_2 \rightarrow 2P_2O_5$

$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$

27. (c) $H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$

$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$

$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$

28. (c) (i) $\underset{\text{Nitric oxide Colourless gas}}{NO}$ (ii) $\underset{\text{Nitrous oxide Colourless gas}}{N_2O}$ (iii) $\underset{\text{Dinitrogen trioxide Blue liquid}}{N_2O_3}$

(iv) $\underset{\text{Dinitrogen tetraoxide colourless liquid}}{N_2O_4}$ (v) $\underset{\text{Dinitrogen pentaoxide colourless gas}}{N_2O_5}$

30. (c) $(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} Cr_2O_3 + N_2 + 4H_2O$

31. (d) $4HNO_3 \rightarrow 4NO_2 + O_2 + 2H_2O$

32. (c) Because of its very low ignition temperature (303K) it is always kept under water.

33. (d) NH_3 when dissolved in water forms

$NH_3 + H_2O \rightarrow NH_4^+ + OH^- \rightleftharpoons NH_4OH$

34. (a,b) Stability of + 3 oxidation states increases on account of inert pair effect.

Reducing character of hydrides increases down the group because bond dissociation energy decreases down the group.

35. (a) Haber's process →Industrial process

$N_2 + 3H_2 \underset{\substack{650-800\,K \\ 200-350\,atm}}{\overset{Fe\text{ - }Mo}{\rightleftharpoons}} 2NH_3$

36. (a) $P_4 + 5O_2 \rightarrow P_4O_{10}$; white phosphorus gets easily oxidized because it is highly reactive.

38. (d) N_2O is itself non-combustible but supports combustion.

$S + 2N_2O \rightarrow SO_2 + 2N_2$

39. (b) When N_2O is inhaled in moderate quantities, it produces hysterical laughter, hence the name laughing gas.

40. (c) $2NO_2 + H_2O$

$\rightleftharpoons HNO_2 + HNO_3$

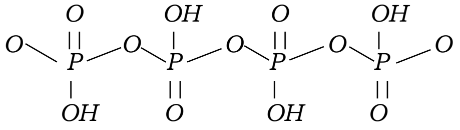
When dissolved in water, gives a mixture of nitrous acid and nitric acid.

$N_2O_4 + H_2O \rightarrow HNO_2 + HNO_3$

$HNO_3 + HNO_2 + 2NaOH \rightarrow NaNO_2 + NaNO_3 + 2H_2O$

41. (b) $4Zn + \underset{\text{hot \& dil.}}{10HNO_3} \rightarrow 4Zn(NO_3)_2 + 5H_2O + N_2O$

42. (a) $(HPO_3)_n$ Polymetaphosphoric acid



43. (b) Superphosphate of lime – It is a mixture of calcium dihydrogen phosphate and gypsum and is obtained by treating phosphatic rock will conc. H_2SO_4

$Ca_3(PO_4)_2 + 2H_2SO_4 + 5H_2O \rightarrow$

$\underset{\text{Superphosp hate of lime}}{Ca(H_2PO_4)_2.2H_2O + 2CaSO_4.2H_2O}$

44. (d) $3NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O$

46. (d) $4NH_3 + 5O_2 \xrightarrow[1100\,K]{Pt} 4NO + 6H_2O$

NO is used in the preparation of HNO_3

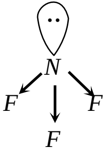
$2NO + O_2 \rightarrow 2NO_2$; $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

47. (d) $P_4 + 20HNO_3 \rightarrow 4H_3PO_4 + 20NO_2 + 4H_2O$

49. (b) $\underbrace{P_2O_3 \quad A_2O_3 \quad B_2O_3}_{\text{Acidic}} \quad \underbrace{Bi_2O_3}_{\text{Alkalin}}$

50. (b) $P_2O_3 + 3H_2O \rightarrow 2H_3PO_3$

51. (a) NF_3



It is least basic because of the high electronegativity of $3F$ atoms. The lone pair present on nitrogen atom is not easily available for donation.

52. (d) $3H_2O + PCl_3 \rightarrow H_3PO_3 + 3HCl$

53. (c) Due to less reactivity of red phosphorus

54. (d) NO_2 brown coloured gas.

55. (d) N_2O_5 is an anhydride of HNO_3

$2HNO_3 \rightarrow N_2O_5 + H_2O$

Therefore, it can act only as oxidising agent.

56. (c) $\underset{\text{(Oxidation number)}}{NH_4NO_2} \rightleftharpoons \overset{*}{N}H_4^+ + \overset{*}{N}O_2^-$

$x + 4 = +1 \qquad x - 4 = -1$

$x = 1 - 4 = -3 \qquad x = +3$

57. (b) $\overset{*}{P}_4 O_8$

$4x + (-2 \times 8) = 0$

$4x - 16 = 0$

$x = \frac{16}{4} = +4$

58. (c) $\overset{*}{N}H_2OH$

$x+2+(-2)+1=0$

$x+2-2+1=0$

$x=-1$

60. (c) $NH_3 > PH_3 > AsH_3 > SbH_3$

On moving down the group atomic size increases and availability of lone pair decreases. Hence, basic character decreases.

61. (a) $PH_3 > AsH_3 > SbH_3 > BiH_3$

On moving down the group bond energy decreases. Hence, stability decreases.

62. (d) Due to absence of *d*-orbitals in N atom, it cannot accept electrons from H_2O for hydrolysis of NF_3.

63. (b) NH_3 is most thermally stable hydride. Hence, electrolysis temperature is maximum.

64. (a) Phosphorus is kept in water due to it burt at 30^oC.

66. (c) $BiCl_3 + H_2O \rightarrow BiOCl + 2HCl$

67. (c) When the black ppt. of Bi_2S_3 is dissolved in 50% HNO_3 and a solution of NH_4OH is added. A white ppt. of $Bi(OH)_3$ is obtained.

69. (a) Atmospheric nitrogen is inert and unreactive because of very high bond energy $(945\ kJ/mole)$.

70. (b) Bismuth does not show allotropy other elements show allotropy.

Nitrogen → α-nitrogen and β-nitrogen (solid crystalline forms)

Phosphorus → White, Red and Black forms

Arsenic → Yellow and Grey forms

Antimony → Yellow and Grey forms

71. (a) Nitrogen does not form complexes because of the absence of *d*-orbitals.

72. (a) NH_3 is a strongest base because Lone pair is easily available for donation.

74. (b)

Hydride	NH_3	PH_3	AsH_3	SbH_3	BiH_3
Boling point	238.5	185.5	210.6	254.6	290

75. (a) NCl_3 is highly reactive and unstable. Hence it is explosive.

76. (b) $$\underbrace{N_2O_3 \quad P_2O_3 \quad As_2O_3}_{\text{Acidic Oxides}} \quad \underbrace{Sb_2O_3}_{\text{Amphoteri}} \quad \underbrace{Bi_2O_3}_{\text{Basic}}$$

$\xrightarrow{\hspace{6cm}}$

Acidic character decreases down the group

77. (c) $SbCl_2$ is not exists because

Vth group elements normally show +3 and +5 oxidation state.

78. (b) $\underset{(aq)}{NH_4Cl} + \underset{(aq)}{NaNO_2} \rightarrow NH_4NO_2 + NaCl$

$NH_4NO_2 \xrightarrow{\text{heat}} \underset{(g)}{N_2} + \underset{(l)}{2H_2O}$

79. (c) $NH_4NO_2 \rightarrow N_2 + 2H_2O$

80. (d) $6Li + N_2 \rightarrow 2Li_3N$ Lithium nitride

$3Mg + N_2 \rightarrow Mg_3N_2$ Magnesium nitride

81. (d) $N \equiv N$ bond energy is very high $945\ kJ\ mol^{-1}$.

83. (d) $N_7 \rightarrow 1s^2, 2s^2, 2p^3$

d-orbitals are absent in nitrogen.

85. (d) $NH_4NO_3 \xrightarrow{\text{heat}} \underset{\text{(Laughing gas)}}{N_2O} + 2H_2O$

86. (d) $NH_2OH + HNO_2 \rightarrow H_2\overset{+1}{N_2}O_2 + H_2O$

87. (c) N_2O is a linear molecule

88. (b) $2HNO_2 \rightarrow H_2O + N_2O_3$

89. (d) $2HNO_3 \rightarrow H_2O + N_2O_5$

90. (c) $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$

91. (a) $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$

92. (b) $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$

93. (d) In upper atmosphere *NO* is formed by lightning flash.

$N_2 + O_2 \rightleftharpoons 2NO$

96. (c) $2NO + O_2 \rightarrow 2NO_2$

98. (b) $2AgNO_3 \rightarrow 2AgNO_2 + O_2$

$\downarrow$

$2Ag + 2NO_2$

100. (d) $2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$

101. (d) $C_{12}H_{22}O_{11} \xrightarrow{\text{conc. } HNO_3} \underset{\text{Oxalic acid}}{\begin{matrix} COOH \\ | \\ COOH \end{matrix}} + H_2O$

102. (b) $4NH_3 + 5O_2 \xrightarrow[800^oC]{Pt} 4NO + 6H_2O$

103. (d) HNO_2 can be either reduced to nitric oxide (NO) or oxidised to nitric acid and hence it acts both as an oxidising as well as a reducing agent.

$2HNO_2 \rightarrow 2NO + H_2O + [O]$

$HNO_2 + [O] \rightarrow HNO_3$

106. (d) NH_3 is highly volatile compound. When vapourized, liquid ammonia causes intense cooling. Hence used as a coolant in ice factories and cold storages.

107. (d) $\underset{\text{Hydrazoic acid}}{N_3H} \rightleftharpoons N_3^- + H^+$

108. (a) *d*-orbitals are absent in nitrogen.

109. (d)

	Phosphide ion (P^{3-})	Chloride ion (Cl^-)
Total electrons	18	18

P^{3-} and Cl^- are isoelectronic.

110. (a) Due to the less reactivity.

116. (a) $P_4 + 3H_2O + 3NaOH \rightarrow \underset{\text{Phosphine}}{PH_3} + \underset{\text{Sod. hypophosphite}}{3NaH_2PO_2}$

117. (c) Both oxidation and reduction (Disproportionation)

Reduction

Oxidation

$$\overset{0}{P}_4 + 3H_2O + 3NaOH \rightarrow \overset{-3}{P}H_3 + 3NaH_2\overset{+1}{P}O_2$$

118. (b) $\underset{\text{Red}}{P_4} + NaOH \rightarrow$ No reaction

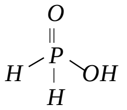
120. (c) $Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$

122. (b) PH_3 is less basic because lone pair is not easily available for donation.

123. (d) $P_2O_3 + 3H_2O \rightarrow 2H_3PO_3$

124. (d) $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$ orthophosphoric acid.

125. (c) H_3PO_2 Monobasic acid

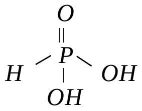


$$H-\overset{\overset{O}{\|}}{\underset{\underset{H}{|}}{P}}-OH$$

Only one $-OH$ group

126. (b) $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$

127. (b) H_3PO_3



$$H-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-OH$$

128. (c) $H_3\overset{*}{P}O_2$

$3 + x + (-2 \times 2) = 0$

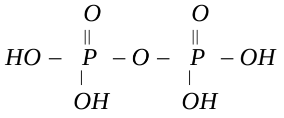
$x = +1$

129. (d) $Na_4P_2O_7$ Salt of strong acid and strong base.

130. (b) $P_4 + 6H_2SO_4 \rightarrow 4H_3PO_4 + 6SO_2$

131. (c) $CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$

132. (b) $H_4P_2O_7$



$$HO-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-OH$$

Tetrabasic

$4-OH$ group are present.

134. (b) $BiCl_3 + H_2O \rightarrow BiOCl + 2HCl$

135. (b) $CaC_2 + N_2 \xrightarrow[6-8\text{ atm}]{500-600^oC} CaCN_2 + C$

136. (a) $CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$

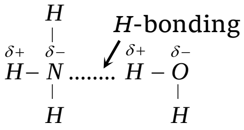
137. (a) NH_2CONH_2

% of N $= \dfrac{\text{Mass of } N}{\text{Mass of compound}} \times 100 = \dfrac{28}{60} \times 100 =$ 46%.

141. (a) Anhydride of nitrous acid is N_2O_3.

144. (b) $P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + NaH_2PO_4$

145. (a) NH_3 is highly soluble due to H-bonding.



$$\underset{\delta+}{H}-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{\overset{\delta-}{N}}} \cdots\cdots \overset{\delta+}{H}-\underset{\underset{H}{|}}{\overset{\delta-}{O}}$$

146. (d)

	NH_3	PH_3	AsH_3	SbH_3
B.pt in (K)	238.5	185.5	210.6	254.6

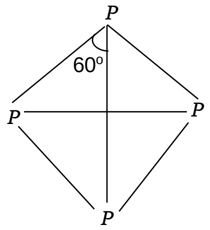
149. (a) $H_3\overset{*}{P}O_2$

$3 + x - 4 = 0$

$x = +1$

151. (d) Solid PCl_5 exists as PCl_4^+ and PCl_6^-.

153. (a)



154. (e) Phosphorus minerals is called as hydroxy apatite and fluorapatite.

156. (a) Nitrogen does not have d-orbitals.

157. (c) $3CuO + 2NH_3 \rightarrow 3Cu + N_2 + 3H_2O$.

159. (b) Liquid ammonia is used in refrigeration because it has high heat of vaporisation.

160. (a) $Sn + \text{conc. } 4NHO_3 \rightarrow \underset{\text{Meta stannic acid}}{H_2SnO_3} + 4NO_2 + H_2O$

161. (c) $3Cu + 8NHO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + \underset{\text{Nitric oxide}}{2NO}$

163. (c) Pentavalency in phosphorus is more stable that of nitrogen due to large size of phosphorus atom.

164. (b) Ammomium nitrate is neutral fertilizer.

165. (d) PH_3 insoluble in water because does not consist of hydrogen bond.

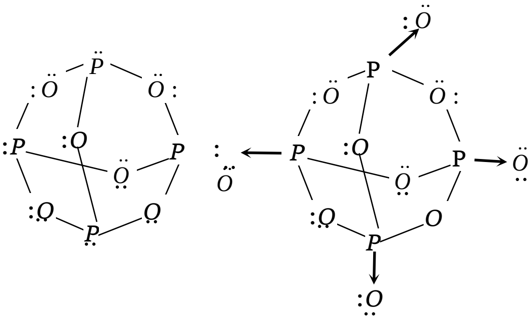
166. (a) $NH_4Cl + NaNO_2 \xrightarrow{\Delta} NH_4NO_2$

$NH_4NO_2 \longrightarrow N_2 + 2H_2O$

167. (a) Nitrogen react with metal to form a nitride.

$6Li + N_2 \xrightarrow{450^oC} 2Li_3N$ (Lithium nitride)

168. (a)



P_4O_6 P_4O_{10}

169. (b) It is a salt of pyrophosphoric acid $H_4P_2O_7$.

172. (d) Copper react with conc. nitric acid to form a nitric oxide.

173. (a) N_2O on account of stimulating effect on nervous system.

174. (d) Sodium metal in liq. NH_3 solution shows strong reducing power due to solvated electron.

$$Na+(x+y)NH_3 \rightleftharpoons [Na(NH_3)_x]^+ + \underset{\text{solvated electron}}{[e(NH_3)_y]^-}$$

175. (c) $PH_3 + 4Cl_2 \to PCl_5 + 3HCl$

178. (c) Generally P_2O_5 are used as a dehydrating agent.

180. (a) Phosphorus show + 5 valency.

181. (b) In the Haber process for the manufacture of NH_3, Fe is used catalyst and Mo as a promotre.

182. (a) On adding excess of ammonium hydroxide to a copper chloride solution a deep blue solution of $[Cu(NH_3)_4]^{2+}$ ion is formed.

183. (d) $(NH_4)_2SO_4 + KCNO \to$

$$NH_4CNO + K_2SO_4 \to \underset{\text{Urea}}{NH_2-CO-NH_2}$$

185. (a) Nitric acid turns the skin yellow because it reacts with protein giving a yellow compound called xanthoprotein.

186. (d) Ammonium sulphate is a nitrogenous fertilizers.

187. (d) Ammonia generally prepared by the Haber's process.

192. (a) H_3PO_2 is hypophosphorus acid

193. (c) $(NH_4)_2SO_4$ is a salt of weak base & strong acid

$$(NH_4)_2SO_4 + 2H_2O \to \underset{\text{Weak base}}{2NH_4OH} + \underset{\text{Strong acid}}{H_2SO_4}$$

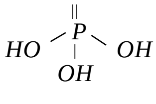
194. (a) One part of concentrated HNO_3 and 3 parts concentrated HCl form aquaregia.

196. (c) –3 to +5 $PH_3(-3)$ and $H_3PO_4(+5)$

199. (b) $BiCl_5$ does not exist because +3 oxidation state of Bi s more stable than +5 due to inert pair effect.

200. (c) $H_3PO_3 \to$ Tribasic acid$\to$ $3-OH$ groups are present

$$H_3PO_4 \to 3H^+ + PO_4^{3-}$$



201. (d) $Na_2HPO_4 \to Na_2PO_4^- + H^+$

It can give H^+ ion in solution.

202. (c) $\overset{\bullet\bullet}{N}H_3$ and $\overset{\cdot\cdot}{P}H_3$ both are basic because of the presence of lone pair of electrons.

203. (b) $\xrightarrow{NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3}$

Stability decreases down the group because bond energy decreases down the group.

204. (a) Nitrogen forms NH_3 which is most basic.

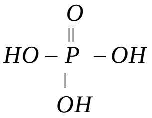
205. (b) H_3PO_3 is a diabasic acid. It forms two types of salts NaH_2PO_3 and Na_2HPO_3.

206. (a) $NH_2-CO-NH_2 + 2HNO_2 \to CO_2 + 3H_2O + 2N_2$

207. (c) I II III IV V

Element – N	P	As	Sb	Bi
Atomic no. 7	15	33	51	83

210. (c)



$HO-\underset{OH}{\overset{O}{\overset{\|}{P}}}-OH$ it is ionizes in three steps because three $-OH$ group are present.

212. (c) $Ca_3P_2 + 3H_2O \to 3Ca(OH)_2 + 2PH_3$

213. (d) $(NH_4)_2Cr_2O_7 \to N_2 + Cr_2O_3 + 4H_2O$

214. (b) $B > P > As > Bi$

As we go down the group bond angle decreases because repulsion between bonded pairs of electron decreases.

215. (b,c) $3NH_3 + OCl^- \to NH_2-NH_2 + NH_4Cl + OH^-$

217. (a) Acidic character of oxides decreases down the group.

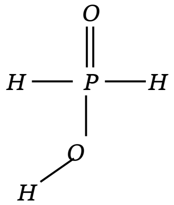
218. (d) $N_7 -\ 1s^2, 2s^2, 2p^3$

d-orbitals absent in second sub-shell.

220. (c) N_2 can form NCl_3, N_2O_5 and Ca_3N_2 but does not form NCl_5.

221. (a) Highest oxidation state is +5 which remains unchanged.

222. (a) Hypophosphorus acid (H_3PO_2) is a monobasic acid which act as reducing agent. In this molecule two $P-H$ bonds are responsible for its reducing character and one $O-H$ bond is responsible for its monobasic acid character.



223. (a) Bone black is the polymorphic form of phosphorus.

224. (b) Nitrous oxide is known as Laughing gas.

225. (a) We know that,

$$2Pb(NO_3)_2 \to 2PbO + 4NO_2 + O_2$$

So nitric oxide (NO_2) is produced.

226. (d) Phosphorus exist as solid at 27°C and 1 atmospheric pressure (m.p. of white phosphorus = 44°C)

227. (b) We know that, $4HNO_3 + P_4O_{10} \to 4HPO_3 + 2N_2O_5$

The product is dinitrogen pentaoxide (N_2O_5).

228. (b) Hypophosphorous acid is H_3PO_2.

229. (b) $NO(g) + NO_2(g) \xrightarrow{-30°C} \underset{\text{(Blue)}}{N_2O_3(l)}$

230. (c) The ignition temperature of black phosphorus is highest among all allotropes.

231. (a) $(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2\uparrow + Cr_2O_3 + 4H_2O$

$NH_4NO_2 \xrightarrow{\Delta} N_2\uparrow + 2H_2O$

232. (a) Nitrogen shows $+I$ to $+V$, all oxidation states.

233. (c) Boiling points of $SbH_3(254\ K)$, $NH_3(238\ K)$, $AsH_3(211\ K)$ and $PH_3\ (185\ K)$ therefore boiling points are of the order $SbH_3 > NH_3 > AsH_3 > PH_3$.

234. (a) Because phosphorous is most electronegative element out of P, Bi, Sb and C.

235. (d) $Ca_3(PO_4)_2 + 3SiO_2 \rightarrow 3CaSiO_3 + P_2O_5$

236. (a) When a solid compound on heating change into gaseous state without changing into liquid state, the phenomenon is known as sublimation. *e.g.,* I_2, NH_4Cl and camphor.

237. (b) 16 bond by its structure.

238. (d) Phosphorus is a non-metallic element. It form's acidic oxide.

239. (b) $\underset{\text{Mixed acid anhydride}}{2\overset{+4}{N}O_2} + H_2O \rightarrow HNO_2 + H\overset{+5}{N}O_3$

240. (c) Oxidation number of As in $H_2AsO_4^-$

$2 + x - 8 = -1$

$x - 6 = -1$

$x = 5$

241. (a) The inorganic nitrogen exists in the form of ammonia, which may be lost as gas to the atmosphere, may be acted upon by nitrifying bacteria, or may be taken up directly by plants.

Oxygen family

2. (c) Sulphur –

(1) Monoclinic (2) Rhombic (3) Plastic

4. (c) $S + O_2 \rightarrow SO_2$

5. (a) $\frac{1}{8}S_8 + 2e^- \rightarrow S^{2-}$

6. (c) $2H_2O + 2F_2 \rightarrow 4HF + O_2$

9. (b) O_8 – $\underset{\boxed{\uparrow\downarrow}}{1s^2}\quad \underset{\boxed{\uparrow\downarrow}}{2s^2}\quad \underset{\boxed{\uparrow\downarrow}\underbrace{\boxed{\uparrow}\boxed{\uparrow}}_{\text{2 unpaired electrons}}}{2p^4}$

11. (a) Element – *O* *S* *Sc* *Te* *Po*

Electronegativity – 3.5 2.5 2.4 2.1 2.0

13. (b,c)

$\underset{(S)}{Na_2SO_3} + \underset{(aq)}{H_2SO_4} \rightarrow \underset{(aq)}{Na_2SO_4} + \underset{(l)}{H_2O} + \underset{(g)}{SO_2}$

15. (d) H_2O H_2S H_2Se H_2Te

104.5^o 92.1^o 91^o 90^o

As we go down the group electronegativity decreases due to which repulsion between bonded pairs of electron also decreases. Hence, bond angle decreases.

20. (a) Paramagnetism because of two unpaired electrons in the antibonding molecular orbitals.

21. (a) $2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4$

24. (c) $3O_2 \underset{\text{electric discharge}}{\overset{\text{silent}}{\rightleftharpoons}} 2O_3$

28. (b) $O_3 \rightarrow O_2 + [O]$

$$\frac{2KI + H_2O + [O] \rightarrow 2KOH + I_2}{2KI + H_2O + O_3 \rightarrow 2KOH + I_2 + O_2}$$

32. (d) $2KMnO_4 + 3H_2SO_4 + 5H_2S \rightarrow$

$K_2SO_4 + 2MnSO_4 + 8H_2O + 5S$

33. (a) $Cu + 2H_2SO_4 \rightarrow CuSO_4 + 2H_2O + SO_2$

35. (a) The minimum and maximum oxidation number of S are –2 and +6 respectively. Since the oxidation number of S in SO_2 is +4, therefore it can be either increased or decreased. Therefore SO_2 behaves both as an oxidising as well as reducing agent.

36. (a) $\underset{\text{reducing agent}}{2H_2S} + \underset{\text{oxidising agent}}{SO_2} \rightarrow 2H_2O + 3S$

37. (d) $K_2Cr_2O_7 + H_2SO_4 + 3SO_2 \rightarrow$

$K_2SO_4 + \underset{\text{Green}}{Cr_2(SO_4)_3} + 3H_2O$

39. (a) $SO_2 + 2Mg \rightarrow 2MgO + S$

40. (a) $2H_2O + SO_2 \rightarrow H_2SO_4 + 2[H]$ (nascent hydrogen)

Coloured flower $+ 2[H] \rightarrow$ Colourless flower

41. (c) $H_2SO_3 + 2NaOH \rightarrow \underset{\text{Sodium sulphite}}{Na_2SO_3} + 2H_2O$

42. (a) $H_2O + SO_3 \rightarrow H_2SO_4$

43. (d) $H_2SO_4 + SO_3 \rightarrow \underset{\text{(oleum)}}{H_2S_2O_7}$

45. (b) $\underset{\text{Reducing agent}}{2Ag} + \underset{\text{Oxidising agent}}{2H_2SO_4} \rightarrow Ag_2SO_4 + 2H_2O + SO_2$

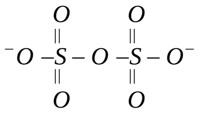
46. (a) Only dehydrating agent

$HCOOH \xrightarrow{H_2SO_4} CO + H_2O$

48. (b) 
$$\begin{array}{c}COOH\\ |\\ COOH\end{array} \xrightarrow{\text{conc. } H_2SO_4} H_2O + CO + CO_2$$

51. (d) $H_2SO_4 + SO_3 \rightarrow \underset{(\text{Oleum or Fuming } H_2SO_4)}{H_2S_2O_7}$

53. (d) $S_2O_7^{2-}$


$$\begin{array}{c}\quad O \qquad O\\ \quad \| \qquad \|\\ {}^-O-S-O-S-O^-\\ \quad \| \qquad \|\\ \quad O \qquad O\end{array}$$

55. (d) $Na_2SO_3 + S \rightarrow Na_2S_2O_3$

56. (b) $Na_2S_2O_3 + Cl_2 + H_2O \rightarrow Na_2SO_4 + 2HCl + S$

58. (c) $AgBr + 2Na_2S_2O_3 \rightarrow Na_3[Ag(S_2O_3)_2] + NaBr$

60. (a) $SO_2 + 2H_2S \rightarrow 3S + 2H_2O$

63. (a) $2H_2S + O_2 \rightarrow 2H_2O + 2S$

64. (a) Mixture of $K_2Cr_2O_7$ and conc. H_2SO_4 is known as chromic acid.

65. (c) H_2O contain hydrogen bond while no hydrogen bonding is present in H_2S.

67. (a) H_2O containing hydrogen bond.

69. (c) $HO-SO_2-OH + PCl_5 \rightarrow Cl-SO_2-OH + POCl_3 + HCl$

$HO-SO_2-OH + 2PCl_5 \rightarrow \underset{\text{Sulphuryl chloride}}{Cl-SO_2-Cl} + 2POCl_3 + 2HCl$

70. (d) Mixture of O_2 and CO_2.

71. (c) The bond between (H_2Te) is weakest hence it gives H^+ ion easily.

73. (c) KO_2 because in O_2^- (superoxide ion)

One unpaired electron is present in the antibonding orbital.

75. (b) Oxidation states are 2, 4, 6

77. (b)

H_2O	H_2S	H_2Se	H_2Te
373K	213K	269K	232K

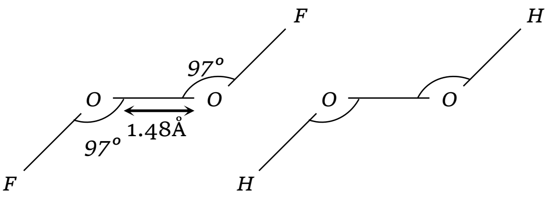
H_2S has lowest boiling point and H_2O has highest boiling point because if any compound has hydrogen bond. Its boiling point is high.

78. (c) V_2O_5 catalyst are used for the manufacture of H_2SO_4 by Contact process.

81. (d) O, S, Se shows polymorphism.

84. (e) $H_2S + 2HNO_3 \rightarrow 2NO_2 + S + 2H_2O$.

85. (b) O_2F_2 is similar to that of H_2O_2



87. (d) 16th group called chalcogens (oxygen family) while *Na* is a Ist group element which is called alkali metal.

90. (b) Caro's acid (H_2SO_5)

91. (c) $2KO_2 + CO_2 \rightarrow K_2CO_3 + \frac{3}{2}O_2$

93. (a) H_2O consist of highest boiling point than other hydride (Due to presence of the hydrogen bonding).

94. (b) Lose of electron.

95. (c) SO_2 is soluble in water

$H_2O + SO_2 \rightarrow \underset{\text{Sulphurus acid}}{H_2SO_3}$

96. (c) $2Na_2O_2 + 2H_2O \rightarrow 4NaOH + O_2$.

In this reaction oxygen (O_2) is formed.

97. (b) $3S + 4NaOH \xrightarrow{\text{boiling}} Na_2S_2O_3 + Na_2S$

98. (c) Quartz is a crystalline variety of silica.

99. (b) 98% H_2SO_4 is used for absorbing dense fog of acid which is formed by dissolving SO_3 in water. Hence 98% H_2SO_4 is the most efficient agent for the absorption of SO_3.

100. (b) Concentrated H_2SO_4 is diluted by adding the conc. H_2SO_4 in the water drop by drop with constant stirring because it is an exothermic reaction and by doing so heat is generated slowly and dissipated in the atmosphere.

101. (a) Photochemical smog is caused by oxides of sulphur and nitrogen.

102. (d) SO_2 act as bleaching agent due to its reducing property.

$SO_2 + 2H_2O \rightarrow H_2SO_4 + 2H$

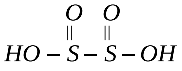
Coloured matter $+H \rightarrow$ Colourless matter

103. (b) Ozone on treatment with SO_2 produce SO_3.

$3SO_2 + O_3 \rightarrow 3SO_3$

104. (b) PbO_2 is a powerful oxidizing agent and liberate O_2 when treated with acids SO, O_2 gas will be evolved.

105. (c) Dithionous acid $(H_2S_2O_4)$ has sulphur in +3 oxidation state.


$$\begin{array}{c}\quad O \;\; O\\ \quad \| \;\; \|\\ HO-S-S-OH\end{array} \; ; \; 2(+1) + 2x + 4(-2) = 0$$

$2x = 8 - 2 = 6$; $x = +3$

106. (a) SO_2 acts as an oxidising agent particularly when treated with stronger reducing agents. SO_2 oxidises H_2S into S.

107. (a) R_3SiCl on hydrolysis forms only a dimer.

$R_3SiOH + HOSiR_3 \rightarrow R_3Si-O-SiR_3$.

108. (d) Formation of chlorine nitrate is the main cause of ozone depliction.

Halogen family

1. (b) $HF > HCl > HBr > HI$ (Thermal stability).

2. (a) $CHCl_3 + \frac{1}{2}O_2 \rightarrow \underset{\text{Phosgene or carbonyl chloride}}{COCl_2} + HCl$

3. (d) Iodine has the least affinity for water and is only slightly soluble in it. However, it dissolves in 10% *aq*. solution of *KI* due to the formation of a complex ion *i.e.* I_3^-.

$I_2 + KI \rightleftharpoons KI_3$ or $I_2 + I^- \rightleftharpoons I_3^-$ (complex ion)

4. (c) $2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$

5. (a) $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$

A more electronegative halogen can displaces less electronegative halogen.

6. (a) *HI* is the strongest reducing agent among halogen acids because of lowest bond dissociation energy.

8. (a) Due to H-Bonding free ions are not present in aq. solution. Hence, bad conductor.

9. (c) Electronegativity of I_2 is less than Br_2. Therefore unable to displace bromine.

10. (b) Carnellite is $KCl.MgCl_2.6H_2O$. The mother liquor life after crystallisation of *KCl* from carnellite contain about 0.25% of bromine as $MgBr_2$ and *KBr*.

11. (a) *HF* is liquid because of intermolecular H-Bonding.

12. (a) $\underset{\text{Weak acid}}{HClO} \rightleftharpoons H^+ + \underset{\text{Strong conjugate base}}{ClO^-}$

13. (d) $\underset{\text{(dil.)}}{2NaOH} + Cl_2 \xrightarrow{\text{Cold}} NaCl + \underset{\text{Sod. hypochlorite}}{NaClO} + H_2O$

$\underset{\text{(conc.)}}{6NaOH} + 3Cl_2 \xrightarrow{\text{heat}} 5NaCl + \underset{\text{Sodium chlorate}}{NaClO_3} + 3H_2O$

15. (b) $6KOH + 3Cl_2 \rightarrow 5KCl + KClO_3 + 3H_2O$.

17. (a) *HF* is the weakest acid. Since it is unable to give H^+ ions which are trapped in H-Bonding.

18. (b)

Hydride –	*HF*	*HCl*	*HBr*	*HI*
B.pt (in *K*) –	293	189	206	238

Becouse of having low b.p. *HCl* is more volatile.

19. (a) $2KClO_3 + I_2 \rightarrow 2KIO_3 + Cl_2$

20. (c) $2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$

21. (d) $2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 5Cl_2 + 8H_2O$

22. (a) $\overset{+7}{HClO_4} > \overset{+5}{HClO_3} > \overset{+3}{HClO_2} > \overset{+1}{HClO}$

As the oxidation no. of halogen increases acidic character increases.

25. (c) $2KBr + 3H_2SO_4 + MnO_2 \xrightarrow{\Delta}$

$2KHSO_4 + MnSO_4 + 2H_2O + Br_2$

29. (b,d) Electron affinity of Cl_2 is maximum

Element –	*F*	*Cl*	*Br*	*I*
E.A. *kJ/mole* –	332.6	348.5	324.7	295.5
Boiling pt (°*C*)	–188.1	–34.6	59.5	185.2

32. (a) $Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$

33. (d) $CCl_4 + H_2O \rightarrow$ No reaction

d-orbitals are absent in carbon atom.

34. (a) $I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$

35. (d) $KI + I_2 \rightarrow KI_3$

36. (a) $2KBr + H_2SO_4 \rightarrow K_2SO_4 + 2HBr$

37. (b) $H_2 + F_2 \rightarrow 2HF$

42. (b) $CuSO_4 + 2KI \rightarrow CuI_2 + K_2SO_4$

$2CuI_2 \rightarrow \underset{\text{Cuprous iodide}}{2CuI} + I_2$

43. (d) As the atomic number increases electronegativity decreases. Hence, tendency to gain electron decreases.

51. (a) $F_2 + 2Cl^- \rightarrow Cl_2 + 2F^-$

$F_2 + 2Br^- \rightarrow Br_2 + 2F^-$

$F_2 + 2I^- \rightarrow I_2 + 2F^-$

53. (d) $Br_2 + 2KI \rightarrow I_2 + 2KBr$

56. (d) $2F_2 + 2H_2O \rightarrow 4HF + O_2$

$3F_2 + 3H_2O \rightarrow 6HF + O_3$

58. (c) $2NaCl + 2H_2O \rightarrow 2NaOH + \underset{\text{(anode)}}{Cl_2} + \underset{\text{(cathode)}}{H_2}$

Reduction

59. (a) $\overset{+4}{Mn}O_2 + 4HCl \rightarrow \overset{+2}{Mn}Cl_2 + 2H_2O + Cl_2$

61. (b) $2NaCl + 2H_2O \xrightarrow{\text{Electrolysis}} \underset{\text{(aq)}}{2NaOH} + \underset{(g)}{Cl_2} + \underset{(g)}{H_2}$

62. (c) $H_2O + Cl_2 \rightarrow HCl + HClO$

Exposed to air

$HClO \rightarrow HCl + [O]$ or $2HClO \rightarrow 2HCl + O_2$

63. (a) $2NaOH + Cl_2 \rightarrow NaClO + NaCl + H_2O$

66. (b) $Cl_2 + H_2O \rightarrow 2HCl + [O]$ Nascent oxygen

$\underset{\text{flower}}{\text{Coloured}} + [O] \xrightarrow[\text{agent}]{\text{Bleaching}} \underset{\text{(Oxidized)}}{\text{Colourless flower}}$

68. (b) $CaO + Cl_2 \rightarrow CaOCl_2$

$NaHCO_3 + Cl_2 \rightarrow$ No reaction

69. (c) $\underset{\text{Slaked lime}}{Ca(OH)_2} + Cl_2 \rightarrow CaOCl_2 + H_2O$

71. (b) $MgBr_2 + Cl_2 \rightarrow MgCl_2 + Br_2$

72. (a) $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

73. (a) $KI + \underset{\text{Conc.}}{H_2SO_4} \xrightarrow{\Delta} KHSO_4 + HI$

Conc. $H_2SO_4 + 2HI \rightarrow 2H_2O + \underset{\substack{\text{Violet}\\\text{vapour}}}{I_2} + SO_2 \uparrow$

74. (b) $2NaI + Cl_2 \rightarrow 2KCl + I_2$

$CCl_4 + I_2 \rightarrow$ Violet colour

76. (b) $KI + H_2SO_4 \xrightarrow{\Delta} KHSO_4 + HI$

$H_2SO_4 + 2HI \rightarrow 2H_2O + \underset{\text{Violet vapour}}{I_2} + SO_2 \uparrow$

79. (c) $KI + H_2SO_4 \rightarrow KHSO_4 + HI$

HI is formed but it is further oxidised by conc. H_2SO_4 into I_2

$2HI + H_2SO_4 \rightarrow 2H_2O + \underset{\text{Violet vapour}}{I_2} + SO_2 \uparrow$

80. (b) $HCl \xrightarrow{H_2O} \underset{(aq)}{H^+} + \underset{(aq)}{Cl^-}$

81. (b) $4NaCl + K_2Cr_2O_7 + 3H_2SO_4 \rightarrow$

$K_2SO_4 + 2Na_2SO_4 + \underset{\text{Chromyl chloride}}{2CrO_2Cl_2} + 3H_2O$

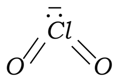
82. (c) Hydrogen bonding is absent in *HI* while it is present in NH_3, H_2O and C_2H_5OH.

84. (d) In case of *HI* due to large size of iodine strong Vander Waal forces are present. Hence, it has highest molar heat of vaporisation.

85. (d) *HI* is strongest acid because $H-I$ bond is weakest among halogen acids.

86. (a) In *HF* the molecules aggregate because of intermolecular hydrogen bonding. Hence, it has highest boiling point.

88. (a) ClO_2^- has sp^3-hybridization and two lone pairs on halogen which produces V-shape Bent structure



89. (d) $2HClO_4 \rightarrow H_2O + Cl_2O_7$.

90. (b) $\left.\begin{matrix}F_2\\Cl_2\end{matrix}\right\}$ gases

$Br_2 \}$ liquid

$I_2 \}$ solid

As we go down the group Vander Waal forces increases. Hence, physical state changes.

92. (c) *F* can not act as reducing agent because it has highest reduction potential

$F_2 + 2e^- \rightarrow 2F^-; E^o = +2.87\ V$

93. (c) $I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$

94. (a) $IF_5 + F_2 \rightarrow IF_7$.

95. (a) Pseudohalide ions and Pseudohalogens

There are certain monovalent negative ions made up of two or more electronegative atoms which exhibit properties similar to these of halide ions. Such ions are known as pseudo halide ions just as halide ions, pseudo halide ions have also corresponding dimoric molecules. These are called pseudo halogens and show properties similar to those of halogens.

Pseudohalide	Pseudohalogens
CN^- cyanide	$(CN)_2$ Cyanogen
SCN^- Thiocyanate	$(SCN)_2$ Thiocyanogen

96. (c) *NaF* is highest melting halide because it is most ionic in nature.

98. (b) $2F_2 + 2H_2O \rightarrow 4HF + O_2$

99. (c) $CaOCl_2 \rightarrow CaCl_2 + [O]$ Nascent oxygen

100. (a) Generally alkali metals and alkali earth metals elements extracted by the fused electrolysis method.

102. (c) $2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$.

104. (b) Beilstein test – In this test organic compound is heated on a copper wire in a flame. The appearance of a green or bluish green flame due to the formation of volatile cupric halides indicate the presence of halogens in the organic compound. (It does not tell which halogen is actually present).

105. (d) $\overbrace{\overset{0}{Cl_2} + 2K\underbrace{Br \rightarrow Br}_{\text{Oxidation}}{}_2 + 2K\overset{-1}{Cl}}^{\text{Reduction}}$

107. (b) $3HCl + HNO_3 \rightarrow NOCl + 2H_2O + Cl_2$.

108. (a) $Cl - Cl \xrightarrow{\text{U.V}} \underset{\text{Free radical}}{Cl + Cl}$

109. (a) *HF* is a weak acid due to intermolecular hydrogen bonding.

110. (a) Acidic nature of oxide ∝ Non metallic nature of element

Non metallic nature decrease in the order $Cl > S > P$.

111. (c) Aqua regia is 1 part of HNO_3 and 3 part of *HCl*.

113. (a) *AgI* is a covalent compound.

114. (a) Bromine is a liquid at room temperature.

115. (a) $Cl_2 + H_2O \rightarrow 2HCl + \underset{\text{Nascent oxygen}}{[O]}$

117. (b) The enamel of our teeth is the hardest substance in the body made up of CaF_2 and dentine below it made of $Ca_3(PO_4)_2$.

118. (b) As the electronegativity decreases reactivity also decreases.

119. (b) $KI + I_2 \rightarrow \underset{\text{(soluble complex)}}{KI_3}$

121. (d) $\underset{-1}{HI} < \underset{0}{I_2} < \underset{+1}{ICl} < \underset{+7}{HIO_4}$

122. (a) $HF < HCl < HBr < HCl$

As we go down the group bond energy decreases hence, acidic nature increases.

123. (b) Caliche is crude chile salt petre $(NaNO_3)$ which contains about 0.02% iodine as sodium iodate $(NaIO_3)$.

124. (a) $LiF > LiCl > LiBr > LiI$

Lattice energy depends on the size and charge of the ion.

125. (a) *F-F* more strong bond compare to *F-Cl*, *F-Br* and *Cl-Br* bond.

126. (c) $2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$.

127. (d) $CaCl(OCl) \Rightarrow Ca \left\langle \begin{matrix} Cl \\ O-Cl \end{matrix} \right.$

128. (a) $2NaOH + Cl_2 \rightarrow \underset{Na^+ + Cl^-}{\underset{\downarrow}{NaCl}} + \underset{Na^+ + OCl^-}{\underset{\downarrow}{NaOCl}} + H_2O$

131. (d) $\left.\begin{array}{l} I_2 + NaF \longrightarrow \\ I_2 + NaBr \longrightarrow \\ I_2 + NaCl \longrightarrow \end{array}\right\}$ No reaction

Because I_2 is least electronegative among halogens.

132. (a) $HClO_4 > HCl > H_2SO_4 > HNO_3$

Decreasing order of acidic character.

134. (a) $\underset{\text{Mercuric chloride}}{HgCl_2} + \underset{\text{Mercuric cyanide}}{Hg(CN)_2} \rightarrow HgCl_2 . Hg(CN)_2$

135. (a) $\underrightarrow{HI > HBr > HCl > HF}$

Acidic character decreasing order.

136. (c) $\underset{\text{Slaked lime}}{Ca(OH)_2} + Cl_2 \rightarrow \underset{\text{Bleaching poeder}}{CaOCl_2} + HOCl$

137. (d) $K_2Cr_2O_7 + 14HCl \rightarrow 2KCl + 2CrCl_3 + 7H_2O + 3Cl_2$

139. (d) Fluorine does not gives positive oxidation state it is always show –1 oxidation state.

140. (a) $\overset{+7}{HClO_4} > \overset{+5}{HClO_3} > \overset{+3}{HClO_2} > \overset{+1}{HCl}$

141. (d) $Ca(OH)_2 + Cl_2 \rightarrow \underset{\text{bleaching powder}}{CaOCl_2} + H_2O$

146. (a) $F_2 + (dil.)2NaOH \rightarrow 2NaF + OF_2 + H_2O$

147. (a) Fluorine can not be oxidised by even strongest oxidising agent.

148. (b) $Br_2 + 2H_2O + SO_2 \rightarrow H_2SO_4 + 2HBr$

149. (c) $2KBr + I_2 \rightarrow 2KI + Br_2$

Iodine is a less electronegative compare to Bromine hence iodine does not change Br^- to Br_2.

150. (a) CaI_2 are show covalent properties than other CaF_2, $CaCl_2$, $CaBr_2$ compound.

151. (d) $2KMnO_4 + 3H_2SO_4 + 10HCl \rightarrow$

$K_2SO_4 + 2MnSO_4 + 8H_2O + 5Cl_2$

153. (d) PbI_4 is least stable because of two reasons

(1) Size of iodine is biggest.

(2) +2 oxidation state of Pb is more stable than +4 state because of inert pair effect.

154. (a) $Cl_2 + NaF \rightarrow$ No reaction

Since Cl_2 is less electronegative then F_2. Therefore unable to displace fluorine from its salt.

156. (b) $CS_2 + 3Cl_2 \xrightarrow{I_2} CCl_4 + S_2Cl_2$

157. (b) According to the Fajan's rule largest cation and smallest anion.

158. (a) $2F_2 + 4NaOH \rightarrow 4HF + 2H_2O + O_2$

159. (c) $\underbrace{Cl_2}_{\text{1 mole}} \rightarrow \underbrace{2Cl}_{\text{2 moles}} \Delta H = +ve$

High temperature and low pressure is favourable.

160. (d) BF_3 accept lone pair of electrons.

161. (d) CrO_2Cl_2 is a orange red gas.

164. (a) Florine always show -1 oxidation state.

165. (a) Solid *NaF* is used to purify fluorine *i.e.* by removing of *HF* fumes.

166. (c) $KHF_2 \rightarrow KF + HF$

$KF \rightarrow K^+ + F^-$

At cathode : $K^+ + e^- \rightarrow K$

$2K + 2HF \rightarrow 2KF + H_2$

At anode : $F^- \rightarrow F + e^-$

$F + F \rightarrow F_2$

168. (c) Small atomic size of *Li* and *F* lattice energy is highest.

169. (b) SO_2 bleaches flower by reduction

$2H_2O + SO_2 \rightarrow H_2SO_4 + 2[H]$

$2[H] + \underset{\text{flower}}{\text{Coloured}} \xrightarrow{\text{Reduction}} \underset{\text{reduced flower}}{\text{Colourless}}$

This bleaching is temporary because reduced flower again oxidised by air to form coloured flower

$Cl_2 + H_2O \rightarrow 2HCl + [O]$

$[O] + \underset{\text{flower}}{\text{Coloured}} \xrightarrow{\text{Oxidation}} \underset{\text{Oxidised flower}}{\text{Colourless}}$

This bleaching is permanent because oxidised flower remains colourless.

170. (a) Fluorine does not form oxyacids because it is more electronegative than oxygen.

173. (c) $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

$2KMnO_4 + 3H_2SO_4 + 10HCl \rightarrow$

$K_2SO_4 + 2MnSO_4 + 8H_2O + 5Cl_2$

175. (b) $3KClO_3 + 3H_2SO_4 \xrightarrow{\text{Heat}}$

$$3KHSO_4 + HClO_4 + 2ClO_2 + H_2O$$

176. (b) $F > Cl > Br > I$. As the size increases electronegativity decreases.

177. (c) Ionic radius increases on going down the group because no. of shells increases.

178. (b) Reducing properties increase from F to I so it oxidise by nitric acid.

$$I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$$

179. (a) Fluorine and chlorine are more electronegative than sulphur.

180. (d) Upper halogen can replace lower halogen from their compounds solution.

181. (a) Iodine (I_2) is slightly soluble in water but it dissolves in 10% aqueous solution of KI due to the formation of potassium triodide (KI_3).

182. (a) Due to highest electronegativity of fluorine the anion $[F---H-F]^-$ exists as a result of strong hydrogen bond by which K^+ associate to form KHF_2.

183. (a) Fluorine is the most electronegative element. It does not form oxyfluoxides like other halogens. If reacts with NaOH to form sodium fluoride and oxygen fluoride.

$$2NaOH + 2F_2 \rightarrow 2NaF + OF_2 + H_2O$$

184. (c) Due to unpaired e^- ClO_2 is paramagnetic.

185. (a) Oxidation number of $HBrO_4$ is more than that of $HOCl, HNO_2$ and H_3PO_3 so it is the strongest acid among these.

186. (a) Chlorine heptachloride (Cl_2O_7) is the anhydride of perchloric acid.

$$2HClO_4 \xrightarrow{\Delta} Cl_2O_7 + H_2O$$

187. (c) I_2 forms complex ion I_3^- in KI solution due to which it dissolves in it.

Noble gases

3. (a)

Gas –	H_2	O_2	He	N_2
Mol. mass –	2	32	4	28

5. (c) Helium (In Greek Helios = Sun)

6. (d) All the noble gases are monoatomic, colourless and odourless gases. Their monoatomic nature is due to the stable outer configuration ns^2np^6 of their atoms. As a result, they do not enter into chemical combination even amongst themselves.

7. (c) Except He, all other noble gases are adsorbed by coconut charcoal at low temperatures. The extent of adsorption increases as the atomic size of the noble gas increases.

10. (b) An oxygen-helium mixture is used artificial respiration in deep sea diving instead of air because nitrogen present in air dissolves in blood under high pressure when sea diver goes into deep sea. When he comes to the surface, nitrogen bubbles out of the blood due to decrease in pressure, causing pains. This disease is called “bends”.

11. (c) $XeF_2, XeOF_2$. $XeF_4, XeOF_4$. XeF_6, XeO_3.

12. (c)

Gas	(Abundance in air by volume (ppm))
Helium	5.2
Neon	18.2
Argon	93.4
Krypton	1.1
Xenon	0.09

13. (c) Neon → Ne is monoatomic and others are diatomic N_2, F_2 and O_2.

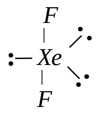
14. (c) $_1H^2 +_1 H^2 \rightarrow {}_2He^4$

15. (b) HeF_4 does not exist.

16. (d) $Ar_{18} \rightarrow 2, 8, 8$

17. (b) $Ne_{10} \rightarrow 1s^2\,2s^2\,2p^6$

23. (d) XeF_2 has sp^3d –hybridization with linear shape



24. (b) Partial hydrolysis; $XeF_4 + H_2O \rightarrow XeOF_2 + 2HF$

Complete hydrolysis;

$$2XeF_4 + 3H_2O \rightarrow Xe + XeO_3 + F_2 + 6HF$$

26. (d) He is least polarizable because of small atomic size.

27. (a) Rn because it is radioactive element obtained by the disintegration of radium

$$_{88}Ra^{206} \rightarrow {}_{86}Rn^{202} +_2 He^4$$

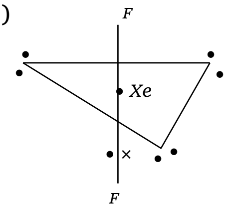
30. (c) $1s^2\,2s^2\,2p^6 \rightarrow \text{Neon}$

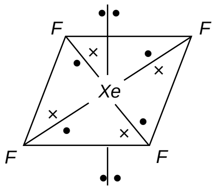
35. (a) $XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$

36. (c) $Xe > Kr > Ar > Ne > He$

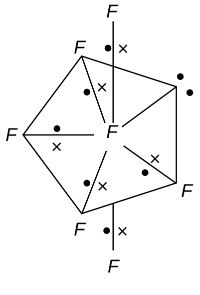
Solubility in decreasing order.

37. (d)





sp^3 hybridization



sp^3d^2 hybridization sp^3d^3 hybridization

38. (b) Zero group element are show less chemically activity because this group element have 8 electron.

39. (d) Xe is formed following compounds.

XeF_2, XeF_4, XeF_6.

40. (a) As the number of shells increases, size increases and the effective nuclear charge on the outermost electron decreases. Thus, I.E. decreases.

44. (c) XeF_2, XeF_4 & XeF_6 can be directly prepared

$$Xe + F_2 \xrightarrow[673K]{Ni\text{ tube}} XeF_2 \; ; \; Xe + 2F_2 \xrightarrow[6\text{ atm}]{673K} XeF_4$$

$$Xe + 3F_2 \xrightarrow[50-60\text{ atm}]{523-573K} XeF_6$$

XeO_3 is obtained by the hydrolysis of XeF_6

$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

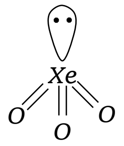
46. (a) XeO_3 shows sp^3 hybridization.

47. (a) It is because
(1) Small atomic size
(2) High Ionization energy
(3) Absence of *d*-orbitals

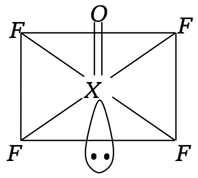
48. (a) Zero group element are attached with weak intermolecular force.

49. (b) XeF_2, XeF_4, XeF_6.

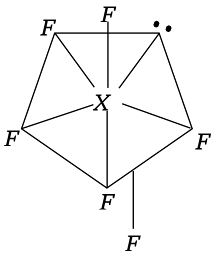
50. (d) XeO_3 :



$XeOF_4$:



XeF_6 :



51. (d) Neil Bartlett prepared first noble gas compound. Xenon hexafluoroplatinate (IV).

53. (d) He, Ne, and Kr all are found in very little amount in atmosphere, so all are called rare gas.

54. (c) Helium is twice as heavy as hydrogen, its lifting power is 92% of that of hydrogen. Helium has the lowest melting and boiling point of any element which makes liquid helium an ideal coolant for many extremely low temperature application such as super conducting magnet and cryogenic research where temperature close to absolute zero are needed.

55. (a) The maximum temperature at which gas can be liquified is called its critical temperature. The gas which have high boiling point will change into liquid first and so critical temperature of the gas will be more.

$T_C \propto$ B.P. and B.P. $\propto$ Molecular weight

So Kr liquifies first.

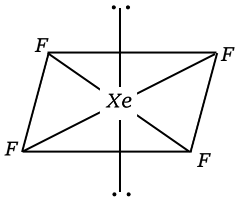
56. (c) Suppose the oxidation state of Xe is x. $XeOF_2$

$x + (-2) + 2(-1) = 0 \Rightarrow x - 2 - 2 = 0 \Rightarrow x = 4$.

57. (a) He Ne Ar Kr Xe Rn
Boiling point of – 269 –246 – 186 –153.6 – 108.1 –62
Inert gases

59. (d) Xe is highly polar since the ionisation potential of xenon is quite close to the ionisation potential of oxygen.

60. (d) In the formation of XeF_4, sp^3d^2 hybridisation occurs which gives the molecule an octahedral structure. The xenon and four fluorine atoms are coplanar while the two equatorial positions are occupied by the two lone pairs of electrons.



Critical Thinking Questions

1. (c) Correct sequence is

$NH_2CONH_2 > NH_4N_3 > NH_3NO_3 > NH_4Cl$.

2. (d) Second group elements are show strong reducing properties but less Ist group element show less.

3. (a) The size of alkaline earth metals is smaller as compared to its corresponding alkali metals and its effective nuclear charge is also more than that of its corresponding alkali metals.

4. (d) Lead is maximum in flint glass.

5. (b) $BaSO_4 + 4C \xrightarrow{\text{Heat}} BaS + 4CO$

Thus, on heating they produce $BaS + 4CO$.

6. (d) Smaller the atomic size tendency of hydration is more as the size increases tendency for hydration also decreases.

7. (a) Fusion mixture is $Na_2CO_3 + K_2CO_3$.

8. (b) HCl is a gas.

9. (a) (A) Peroxide is $H_2O_2(4)$; (B) Super oxide is $KO_2(3)$

(C) Dioxide is $PbO_2(2)$; (D) Suboxide is $C_3O_2(1)$

10. (a) $\underset{98\%}{H_2SO_4} + SO_3 \rightarrow \underset{\text{(Fuming } H_2SO_4)}{\underset{\text{Oleum}}{H_2S_2O_7}}$

11. (c) $SnO_2 + 2NaOH \rightarrow Na_2SnO_3 + H_2O$

$SnO_2 + 4HCl \rightarrow SnCl_4 + 2H_2O$

12. (b) $NaOH + Al^{+3} \rightarrow \underset{\text{(Soluble in } NaOH)}{\underset{\text{Sod. metaaluminate}}{NaAlO_2}}$

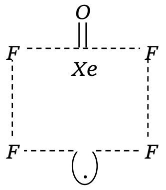
$NaOH + Fe^{+3} \rightarrow$ No reaction (Insoluble in $NaOH$)

13. (d) The composition of the common glass is $Na_2O.CaO.6SiO_2$.

14. (c) Lead form nitric oxide with dil. HNO_3

$3Pb + 8HNO_3 \rightarrow 3Pb(NO_3)_2 + 2NO + 4H_2O$

15. (b)



Therefore, total number of lone pair of electron on central atom *Xenon* =1

16. (d) Order of acidic strength is $H_2Te > H_2Se > H_2S > H_2O$

Na_2O is a salt of $NaOH + H_2O$ and H_2O is least acidic among given acids hence *pH* in this case will be maximum.

17. (a) HNO_3 is the strong oxidising acid so it react with alkali while rest can be react with both and alkali.

18. (d) Zero group is called a buffer group because it lies between highly electronegative halogens and highly electropositive alkali metal element.

19. (c) $PbSO_4$ is insoluble in water.

20. (a) N_2O_5 is most acidic.

21. (b) Element – Fluorine Chlorine Bromine Iodine

B.E. in *kJ mole*$^{-1}$ – 158.8 242.6 192.8 151.1

22. (d) $CaCN_2 + 3H_2O \xrightarrow[\text{pressure}]{\text{under}} CaCO_3 + 2NH_3$.

23. (a) $6O_2 \xrightarrow{\text{Ozonolysis}} 4O_3$

Complete ozonalysis gives 4 volume of ozone.

24. (b) Marble statue $\rightarrow CaCO_3$; Calcinated Gypsum $\rightarrow CaSO_4.2H_2O$; Sea shell $\rightarrow CaCO_3$; Dalomite $\rightarrow CaCO_3.MgCO_3$.

25. (b) Sodium is basic in nature.

26. (c) $I_2 + I^- \rightarrow I_3^-$

27. (a) The hydration energy decreases from Be^{+2} to Ba^{+2}. This causes the decrease in the solubilities of the sulphates in this order. In other words, the solubilities decreases with increase in the ionic size.

28. (d) $2Mg + O_2 \rightarrow 2MgO$

$3Mg + N_2 \rightarrow Mg_3N_2$

29. (a) $ZnO + BaO \xrightarrow{1100^oC} BaZnO_2$

30. (b) There are no free electron in N_2O_4, so it is dimagnetic in nature.

31. (b) $\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow{120^oC} \underset{\text{Ploster of paris}}{CaSO_4.\frac{1}{2}H_2O} + 1\frac{1}{2}H_2O$

32. (d) Third alkaline earth metal is calcium $_{20}Ca^{40}$.

No. of electron are 20 & No. of proton are 20; e/20, p/20.

33. (a) In the compounds of alkaline earth metals all the electrons are paired. Hence, they are diamagnetic in nature.

34. (a) Mixture of helium and oxygen is used in artificial respiration.

35. (a) Alkaline solution of pyrogallol quickly absorbs oxygen.

36. (d) $NH_4NO_2 \rightarrow N_2 + 2H_2O$

$2NaN_3 \rightarrow 2Na + 3N_2$

$(NH_4)_2Cr_2O_7 \rightarrow N_2 + Cr_2O_3 + 4H_2O$

37. (b) Because yellow phosphorus is most reactive form of phosphorus and is highly polymerised.

38. (c) Carbon has 2 electrons in their penultimate shell configuration so due to *d*-orbital in penultimate shell is false statement.

39. (d) All other oxides of nitrogen except N_2O and NO are acidic in nature.

40. (a) $PbCl_4 < PbCl_2 < CaCl_2 < NaCl$ is the increasing order of ionic character.

41. (a) $Si + 3HCl \rightarrow \underset{\text{silicon chloroform}}{SiHCl_3} + H_2$

42. (a) KO_2 is used in oxygen cylinder because it absorbs CO_2 and increases O_2 content. Super oxides reacts with water to give H_2O_2 & O_2.

43. (d) $NaHCO_3$ and Na_2CO_3 decomposes to give CO_2 which extinguish fire.

44. (d) CaF_2 is insoluble in water.

45. (a) PCl_3 is most acidic.

46. (b) $CsCl > KCl > NaCl > LiCl$

47. (d) $2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_8 + 2NaI$.

48. (b) In general, higher the oxidation state, more is the covalent character of the oxide. I_2O_7 & I_2O_5 do not exist. I_2O_4 is ionic in nature. It is infact iodyl iodate $[IO]^+[IO_3]^-$. The only covalent oxide is I_2O_5.

49. (b) $LiAlH_4$ act as reducing agent

$$CH_3CHO + 2H \xrightarrow{LiAlH_4} CH_3CH_2OH$$

50. (c) When conc. *HCl* react with potassium chlorate to gives $Cl_2 + ClO_2$.

51. (c) $2H_2S + SO_2 \rightarrow 2H_2O + 3S$

52. (b) Lithium nitrate on heating gives

$$\underset{(S)}{4LiNO_3} \xrightarrow{\Delta} \underset{(S)}{2Li_2O} + 4NO_2 \uparrow + O_2 \uparrow$$

53. (d) $CaCO_3 > NaHCO_3 > KHCO_3$ is the Increasing order of solubility.

54. (c) Nitrolim is $CaCN_2 + C$.

55. (a) The oxidation state of halogens is same +1. Therefore the acidic character depends only upon the electronegativity. Higher the electronegativity of the halogen more easily if will pull the electrons of $O-H$ bond toward itself and hence, stronger is the acid.

56. (c) Iridium $[I, Z = 77]$ is not belong to noble gas.

57. (c) Name and basicity of H_3PO_2 is hypophosphorus acid & one.

58. (c) In NO_2 there are free electron so it is paramagnetic in nature.

59. (a) Nessler's reagent is K_2HgI_4.

60. (b) Helium was firstly discovered by willium Ramsay.

61. (c) 1.66 Since inert gases are monoatomic.

62. (c) In this reaction, phosphorus is simultaneously oxidised to NaH_2PO_2 and reduced to PH_3. Hence this reaction is an example of disproportionation.

$$\overset{o}{P}_4 + 3NaOH + 3H_2O \rightarrow 3NaH_2\overset{+1}{P}O_2 + \overset{-3}{P}H_3$$

63. (c) Reduction is accompanied by an increase in oxidation number of the reducing agent. *C* belong to IVA so the max-O.N. is +4. In CO_2 the oxidation number of *C* is +4, which cannot be further increased. Hence, CO_2 can not act as reducing agent.

64. (b) When silicon tetra fluoride reacts with water H_2SiF_6 and H_4SiO_6 are formed

$$\underset{\text{Silicon tetrafluoride}}{3SiF_4} + \underset{\text{Water}}{4H_2O} \rightarrow 2H_2SiF_6 + \underset{\text{White silicic acid}}{H_4SiO_4}$$

65. (a) $4O_3 + 6I_2(dry) \rightarrow 3I_4O_4$

66. (c) $Na(NH_4)HPO_4.4H_2O$ (Microcosmic salt)

67. (b) Thermite mixture $Fe_2O_3 + Al$

68. (d) The colour of liquid O_2 is pale blue.

69. (a) Helium is not soluble in blood even under high pressure, a mixture of 80% helium and 20% oxygen is used instead of ordinary air by sea divers for respiration.

70. (a) $Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$

71. (a) Calcium cyanamide on treatment with steam produce $CaCO_3 + NH_3$.

Assertion & Reason

1. (b) Sulphate is estimated as $BaSO_4$ because of high lattice energy in a group.

2. (b) Fluorine is a strong oxidising agent than other halogens due to highest electronegativety..

3. (a) In HNO_3 due to presence of two *N-O* bonds it is a stronger acid than HNO_2.

6. (c) Bleaching action of chlorine carried by oxidation while bleaching action of SO_2 carried by reduction.

7. (b) On heating its outermost electron transite to next energy level by which it become more reactive.

10. (a) *K* and *Cs* emit electrons on exposure of light due to low ionisation potential.

11. (e) The lower value of bond dissociation energy of *F-F* bond due to longer inter electronic (electron - electron) repulsion between the non-bonding electrons in the 2*p* orbitals of fluorine atom.

12. (a) It is fact that halogens are highly reactive as they have seven electrons in their outermost orbit and they want to stabilize by acquiring an electron. Therefor, they do not occur in free state. Here both assertion and reason are true and the reason is the correct explanation of assertion.

13. (a) Lithium forms lithium oxide. This is due to the fact that Li^+ ion has smallest size and it has a strong positive field around it. Therefore, it stabilize O^{2-} ion with strong negative field around it. Thus, both assertion as well as reason are true.

14. (a) Liquid NH_3 is used for refrigeration is true and it is due to the fact that is vaporises quickly and for vaporisation it takes up heat and cool the refrigerator. Hence assertion and reason both are true.

15. (a) It is true that $Al(OH)_3$. The reason is that *NaOH* is a strong alkali, it dissolves $Al(OH)_3$. Which is amphoteric in nature and forms $NaAlO_2$.

$$Al(OH)_3 + NaOH \rightarrow \underset{\text{Sodium meta aluminate}}{NaAlO_2} + 2H_2O$$

16. (c) Boron is metalloid. Thus assertion is correct. Metalloids possess, metallic as well as non-metallic nature. Hence, reason is false.

17. (b) It is correct that inert gases are monoatomic because for inert gases $C_p / C_v = 1.66$.

18. (c) When *Mg* is burnt in nitric oxide it continue to burn because during burning the heat evolved decompose NO to N_2 and O_2. Oxygen thus, produced helps *Mg* to burn.

Here assertion is true but reason is false.

19. (d) Anhydrous BaO_2 is not used for preparing H_2O_2 because it reacts with H_2SO_4 and the reaction ceases after some time due to formation of $BaSO_4$ on BaO_2. Therefore, assertion and reason both are false.

20. (d) Inorganic benzene, borazine is highly reactive while benzene is much less reactive.

Here, assertion is false, but reason is true.

21. (a) The halogens absorb visible light due to which all halogens are coloured. Hence, both assertion and reason are true and reason is correct explanation.

22. (b) It is true that barium is not required for normal biological function in human beings and it is also true that it does not show variable oxidation state. It only shows +2 oxidation state.

23. (d) The $O-O$ bond length is shorter in O_2F_2 than in H_2O_2 due to higher electronegativity. H_2O_2 is a non ionic compound. Here both assertion and reason are false.

24. (d) Here both assertion and reason are false because PbI_4 is not a stable compound and iodine can not stabilize higher oxidation states. *Pb* shows (II) oxidation state more frequently than *Pb* (IV) due to inert pair effect.

25. (b) Both assertion and reason are true but reason is not correct explanation of the assertion. Enamel the hardest substance of the body is composed of fluorine not magnesium. Magnesium is an essential element as it acts as a factor of many enzymes of glycolysis and a number of other metabolic reactions dependent upon ATP.

26. (d) Both assertion and reason are false.

Radium is the rarest of all *s*-block elements comprising only 10^{-10} percent of igneous rocks. Francium (*s*-block member) is radioactive; its long lived isotope ^{223}Fr has a half life of only 21 minutes.

27. (c) Assertion is true but reason is false.

Due to high polarizing power of $Li^+, LiCl$ is a covalent compound.

28. (c) Assertion is true but reason is false.

Be has fully filled $2s^2-$orbital which gives a relatively more stable electronic configuration.

29. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

30. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

31. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

32. (c) Assertion is true but reason is false.

Helium is a noble gas (Chemically inactive) but beryllium is a member of alkaline earth metals (Chemically active).

33. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

Lattice energy of Na_2SO_4 is less than its hydration energy but the lattice energy of $BaSO_4$ exceeds its hydration energy.

34. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

35. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

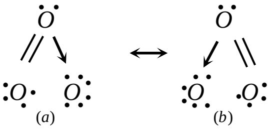
Presence of unpaired electrons in super oxides of alkali metals make them paramagnetic.

36. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

Nitrogen can not expand its octet due to the non availability of *d*-orbital.

37. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

Ozone is considered to be a resonance hybrid of the following two forms.



38. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

Molecules of sulphuric acid are associated due to large number of intermolecular hydrogen bonding.

39. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

PCl_5 is trigonal bipyramidal containing sp^3d hybridized *P* atom in liquid and gaseous state. Whereas in solid state it consists of tetrahedral PCl_4^+ cation and octahedral PCl_6^- anion.

40. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

In case of NI_3, the lone pair moment adds on the resultant of the $N-I$ moments but in case of NF_3, the lone pair moment on partly cancels the resultant $N-F$ moments.

41. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

The ignition temperature of white phosphorus is low (About 30°C). In air it readily catches fire giving dense fumes of phosphorus pentoxide. It is therefore, kept in water.

42. (c) Assertion is true but reason is false.

B does not have vacant d-orbitals as second shell is the outermost shell.

43. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

44. (d) Both assertion and reason are false.

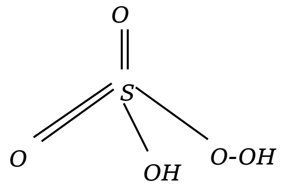
$Si-Si$ bonds are weaker than $Si-O$ bonds Si has no tendency to form double bonds with itself.

45. (c) Assertion is true but reason is false.

S atoms in S_8 molecule undergo sp^3 hybridization and contain two lone pairs of electrons on each and exists as staggered 8 atom rings.

46. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

This can be explained through structure of Caro's acid (Peroxomonosulphuric acid).



Oxidation no. of $S=x$, oxidation no. of $H=+1$,

Oxidation no. of oxygen in peroxo linkage = –1,

Oxidation no. of other oxygen atoms $=-2$ (each) $2+x-6-2=0$ or $x=+6$.

47. (d) Both assertion and reason are false.

The melting point / boiling point of noble gases are quite low. The inter particle forces among noble gases are weak Vander Waal's forces.

48. (b) If both assertion and reason are true and reason is the correct explanation of assertion.

S atom in both SO_2 and SO_3 is sp^2 hybridized but it contains a lone pair of electrons in SO_2.

49. (d) Both assertion and reason are false.

Calcium carbide on hydrolysis gives acetylene. Calcium carbide contains C_2^{2-} anion.

50. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

51. (e) Assertion is false but reason is true.

In lab, hydrogen is generally prepared by the reaction of zinc with dilute hydrochloric acid.

52. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

The relatively inert behaviour of diprotium at room temperature is due to the high enthalpy of $H-H$ bond, being the highest for a single bond between any two elements.

53. (d) Both assertion and reason are false.

Water can be easily transformed from liquid solid and to gaseous states. The distribution of water over the earth's surface is not uniform. The desert region have no permanent surface water while the oceans cover vast areas.

54. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

The structure of ice is open due to hydrogen bonding which makes ice less dence than liquid water at the same temperature.

55. (c) Assertion is true but reason is false.

The water molecules are joined together in an extensive three dimensional network in which each oxygen atom is bonded to four hydrogen atoms two by hydrogen bonds and two by normal covalent bonds in a near tetrahedral configuration. This situation does not exist for molecules like NH_3 and HF.

56. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

Hard water contain soluble calcium and magnesium salt like bicarbonates, chlorides and sulphates.

57. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

To stop decomposition H_2O_2 is stored in wax-lined glass or plastic vessels in the presence of stabilizers like urea.

58. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

At any given instant in liquid water at room temperature, each water molecule forms hydrogen bonds with an average 3.4 other water molecules. The H_2O molecules are in continuous motion so hydrogen bonds are constantly and rapidly broken and formed. In ice H_2O molecules are, however fixed in the space lattice.

59. (d) Both assertion and reason are false.

Calgon is used for making Ca^{2+} and Mg^{2+} ions present in hard water ineffective. It forms soluble complex with Ca^{2+} and Mg^{2+} ions.

60. (b) SO_2 shows both oxidising as well as reducing nature.

The reaction given in assertion is due to oxidising nature of SO_2.

$$2H_2S + SO_2 \rightarrow 2H_2O + 3S$$

61. (a) (i) Due to smaller size of F; steric repulsions will be less in SiF_6^{2-}.

(ii) Interaction of F lone pair electrons with Si is stronger than that of chlorine lone pairs.

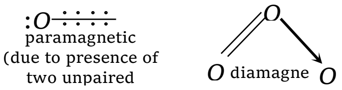
62. (b) Borax bead test is not suitable for Al(III) because its oxidising as well as reducing flame is colourless in both hot as well as cold.

Alumina is insoluble in water as they exist in hydrated form like $Al_2O_3.2H_2O$, $Al_2O_3.H_2O$ etc.

63. (c) $SeCl_4$ possess see saw geometry, which can be regarded as a distorted trigonal bipyramidal structure laving one lone pair (lp) of electrons in the basal position of the trigonal bipyramidal. See-saw geometry of $SeCl_4$ molecules arises due to the sp^3d hybridisation of the central atom. The distortion in shape is due to the presence of one lone pair of electrons.

64. (b) Due to the ease with which it can liberate nascent oxygen, O_3 acts as a powerful oxidising agent.

$$O_3 \rightarrow O_2 + O$$



s and p-Block Elements

SET Self Evaluation Test -18

1. Nitrogen can be obtained from air by removing **[AFMC 1998]**

(a) Oxygen

(b) Hydrogen

(c) Carbon dioxide

(d) Both (a) and (c)

2. SO_2 acts as temporary bleaching agent but Cl_2 acts as permanent bleaching agent. Why **[JEE Orissa 2004]**

(a) Cl_2 bleaches due to reduction but SO_2 due to oxidation

(b) Cl_2 bleaches due to reduction but SO_2 due to reduction

(c) Both of these

(d) None of these

3. Caro's acid is **[DCE 2002]**

(a) H_2SO_3

(b) $H_3S_2O_5$

(c) H_2SO_5

(d) $H_2S_2O_8$

4. Inorganic benzene is **[Pb. CET 2004]**

(a) $B_3H_3N_3$

(b) BH_3NH_3

(c) $B_3H_6N_3$

(d) $H_3B_3N_6$

5. Which of the following ions, will have maximum hydration energy **[Pb. CET 2003]**

(a) Sr^{2+}

(b) Ba^{2+}

(c) Ca^{2+}

(d) Mg^{2+}

6. When orthophosphoric acid is heated to $600\,^oC$, the product formed is

(a) Phosphine, PH_3

(b) Phosphorus pentoxide, P_2O_5

(c) Phosphorus acid, H_3PO_3

(d) Metaphosphoric acid, HPO_3

7. The statement true for N_3^- is **[AIIMS 2004]**

(a) It has a non-linear structure

(b) It is called pseudohalogen

(c) The formal oxidation state of nitrogen in this anion is -1

(d) It is isoelectronic with NO_2

8. $P_4 + 3NaOH + 3H_2O \rightarrow A + 3NaH_2PO_2$ here, 'A' is **[BVP 2004]**

(a) NH_3

(b) PH_3

(c) H_3PO_4

(d) H_3PO_3

9. A hydride of nitrogen which is acidic is **[MP PMT 2004]**

(a) NH_3

(b) N_2H_2

(c) N_3H

(d) N_2H_4

10. The ONO angle is maximum in **[AIIMS 2004]**

(a) NO_3^-

(b) NO_2^-

(c) NO_2

(d) NO_2^+

11. When ammonia is passed over heated CuO, it is oxidised to

(a) N_2

(b) NO_2

(c) N_2O

(d) HNO_2

12. Slaked lime is used in the manufacture of **[MNR 1985]**

(a) Cement

(b) Fire bricks

(c) Pigment

(d) Medicine

13. Which of the following is the most stable **[Roorkee Qualifying 1998]**

(a) Pb^{2+}

(b) Ge^{2+}

(c) Si^{2+}

(d) Sn^{2+}

14. When CO_2 is bubbled through a solution of barium peroxide in water **[AFMC 2005]**

(a) O_2 is released

(b) Carbonic acid is formed

(c) H_2O_2 is formed

[CBSE PMT 1989]

(d) No reaction occurs

15. The lightest metal is **[MP PET 2001]**

(a) Li

(b) Mg

(c) Ca

(d) Na

16. Which of the following will not undergo hydrolysis in water **[DPMT 2001]**

(a) Ammonium sulphate

(b) Sodium sulphate

(c) Calcium sulphate

(d) All the salts will hydrolyse

17. The species that does not contain peroxide ion is

[DCE 2003]

(a) PbO_2 (b) H_2O_2

(c) SrO_2 (d) BaO_2

18. The number of hydroxide ions produced by one molecule of sodium carbonate (Na_2CO_3) on hydrolysis is

[AFMC 2000]

(a) 1 (b) 2

(c) 3 (d) 4

19. Lead is soluble in **[BVP 2004]**

(a) CH_3COOH (b) H_2SO_4

(c) HCl (d) HNO_3

20. The difference of water molecules in gypsum and plaster of paris is **[CPMT 1997]**

(a) $\frac{5}{2}$ (b) 2

(c) $\frac{1}{2}$ (d) $1\frac{1}{2}$

21. When burning magnesium ribbon is introduced into a jar of oxygen, it produces **[MH CET 1999]**

(a) Mg (b) MgO

(c) MgO_2 (d) Mg_2O_2

22. Which of the following compounds transform baking soda into baking powder **[AIIMS 2001]**

(a) KCl (b) $KHCO_3$

(c) $NaHCO_3$ (d) $KHC_4H_4O_6$

23. Hydrated $AlCl_3$ is used as **[RPET 2003]**

(a) Catalyst in cracking of petroleum

(b) Catalyst in Friedel Craft reaction

(c) Mordant

(d) All of these

24. Which of the following ions has largest heat of hydration

[MP PET 2001]

(a) Ba^{2+} (b) K^+

(c) Li^+ (d) Be^{2+}

25. The hydroxides which sublime on heating are

[Roorkee 1999]

(a) $LiOH$ (b) KOH

(c) $RbOH$ (d) $Mg(OH)_2$

26. Electrolysis of $KCl.MgCl_2.6H_2O$ gives **[KCET 1993]**

(a) Mg Only

(b) Potassium only

(c) Mg and Cl_2

(d) P and Mg

27. Which species does not exist **[JIPMER 2000]**

(a) $(SiCl_6)^{2-}$ (b) $(CCl_6)^{2-}$

(c) $(GeCl_6)^{2-}$ (d) $(SnCl_6)^{2-}$

28. Al_2O_3 formation involves evolution of a large quantity of heat, which makes its use in **[DPMT 2002]**

(a) Deoxidiser

(b) Indoor photography

(c) Confectionary

(d) Thermite welding

29. Nitrates of all metals are **[DCE 2000]**

(a) Unstable (b) Stable

(c) Coloured (d) Soluble

30. The density of Neon will be highest at **[JIPMER 2002]**

(a) STP

(b) $0^oC, 2$ atmosphere

(c) $273^oC, 1$ atmosphere

(d) $273^oC, 2$ atmosphere

31. When chlorine water is exposed to sunlight the colour change that occurs is

(a) Colourless to brown

(b) Brown to colourless

(c) Light blue to colourless

(d) Colourless to greenish yellow

(e) Greenish yellow to colourless

32. Sodium nitrate $(NaNO_3)$ decomposes above $\sim 800^oC$ to give

(a) N_2 (b) O_2

(c) NO_2 (d) Na_2O

33. N_2 forms NCl_3, whereas P can form both PCl_5 and PCl_5. Why **[JEE Orissa 2004]**

(a) P has low lying $3d$ orbitals, which can be used for bonding but N_2 does not have low lying $3d$ orbital

(b) N_2 atom is larger than P in size

(c) P is more reactive towards Cl than N_2

(d) None of these

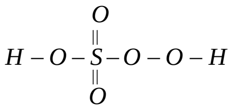
Answers and Solutions

(SET -18)

1. (d) Nitrogen can be obtained from air by removing oxygen and Hydrogen.

2. (b) Cl_2 bleaches due to oxidation which is permanent bleaching while SO_2 bleach due to reduction which is temporary bleach and convert in original by atmospheric oxygen.

3. (c) Caro's acid is H_2SO_5



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-O-H$$

4. (c) Inorganic benzene is $B_3H_6N_3$

5. (d) Hydration energy of smaller cations are higher than those of larger cations, hence Mg^{+2} has maximum hydration energy among these.

6. (d) $H_3PO_4 \xrightarrow[\Delta]{600^oC} \underset{\text{Metaphosphoric acid}}{HPO_3} + H_2O$

7. (c) N_3^- derived from N_3H in which nitrogen shows –1 oxidation state.

8. (b) This is the laboratory method of preparing phosphine gas.

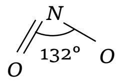
$P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$

In this reaction, phosphorus disproportionate into phosphine and sodium hydrogen phosphite.

9. (c) Hydrazoic acid N_3H is a fairly strong acid which is strong than CH_3COOH but weak than mineral acid.

$N_3H \rightarrow H^+ + N_3^-$

10. (d) NO_2 have 132° bond angle



increase of electron or increase of more electronegative atom in it decrease its bond angle since NO_2^+ loose a electron by which its bond angle increase from 132°.

11. (a) $3CuO + 2NH_3 \xrightarrow{\text{heat}} N_2 + 3Cu + 3H_2O$

12. (a) Composition of portland cement is

Lime (CaO)	50-60%
MgO	2-3%
SiO_2	20-25%
Fe_2O_3	1-2%
Alumina (Al_2O_3)	5-10%
SO_3	1-2%

13. (a) Pb^{+2} on going down the group due to inert pair effect + 2 state is more stable than + 4.

14. (c) When CO_2 is bubbled through a cold pasty solution of barium peroxide in water, H_2O_2 is obtained.

$BaO_2 + CO_2 + H_2O \rightarrow BaCO_3 + H_2O_2$

Barium carbonate being insoluble is filtered off. This is known as Merck's process.

15. (a) Lithium is the Lightest metal with atomic No. 3.

16. (b) Sodium sulphate is a salt of strong acid (H_2SO_4) and strong base $(NaOH)$. As we know that salt of strong acid and strong base do not hydrolyse in water but will ionised.

$Na_2SO_4 + [H_2O] \rightarrow 2Na^+(aq) + SO_4^{-2}(aq)$

17. (a) PbO_2 (Lead dioxide) is not a peroxide. All other are peroxides as they have $(-O-O-)$ linkage.

18. (b)

19. (d) Lead is soluble in dil. HNO_3. However, it becomes passive towards conc. HNO_3.

20. (d) $CaSO_4.2H_2O \xrightarrow{120^oC} CaSO_4.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O$.

21. (b) $2Mg + O_2 \longrightarrow 2MgO$

22. (d) $KHC_4H_4O_6$ transform baking soda into baking powder.

23. (c) Hydeated $AlCl_3$ in used as mordant.

24. (d) $\underrightarrow{Be^{2+} > Li^{+} > Ba^{2+} > K^{+}}$

decreasing order of heat of hydration.

25. (d) $Mg(OH)_2$ sublimes on heating.

26. (c) $KCl.MgCl_2.6H_2O \xrightarrow{\text{Electrolysis}} Mg$ & Cl_2

$K^{+} + e^{-} \rightarrow K$; $E^{o} = -2.93\ V$

$Mg^{+2} + 2e^{-} \rightarrow Mg$; $E^{o} = -2.37\ V$

Since, reduction potential of Mg is higher. Hence it gets reduced easily.

27. (b) CCl_6 does not exist because carbon has a valancy of 4.

28. (a) In thermite welding large quantity of heat is used which is evolved during Al_2O_3 formation.

29. (b) Generally all metal nitrates are stable.

30. (b) Density of Neon will be highest as $0^{o}C$, 2 atmosphere.

31. (e) $\underset{\text{Greenish yellow}}{Cl_2 + H_2O} \longrightarrow \underset{\text{Colourless}}{\text{Product}}$.

32. (a) $2NaNO_3 \xrightarrow{800^{o}C} 2NaNO_2 + O_2(g)$

33. (a) P has low lying 3d orbitals, which can be used for bonding, where as N_2 does not have low lying 3d orbitals.