General Knowledge Today

General Science-6: Everyday Chemistry

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States of Matter

Four States of Matter

Matter can exist in at least four fundamental states viz. solid, liquid, gas and plasma. There are other states also such as Bose–Einstein condensate, quark-gluon plasmas etc. which don't exist in our natural environment.

Basic difference between Solid, Liquid and Gas

In solids, the constituent particles are held very close to each other in an orderly fashion and there is not much freedom of movement. In liquids, the particles are close to each other but they can move around. In gases, the particles are far apart as compared to those present in solid or liquid states and their movement is easy and fast.

Because of such arrangement of particles, solids have definite volume and definite shape; the Liquids have definite volume but not the definite shape. They take the shape of the container in which they are placed. The Gases have neither definite volume nor definite shape. Gases completely occupy the container in which they are placed. These states of matter are interconvertible by changing the conditions of temperature and pressure.

Plasma

Plasma is one of the four fundamental states of matter. Plasma is basically *ionized molecules or atoms.* The Ionization can be induced by heat or strong electromagnetic field applied with a laser or microwave generator. When this is done, the molecular bonds dissociate to give rise to Plasma.

Difference between Gas and Plasma

Like gas, plasma *does not have a definite shape or a definite volume* unless enclosed in a container. However, unlike gas, plasma can form structures such as filaments, beams and double layers under the influence of a magnetic field.

Plasma in Universe

Plasma is most common state of matter in universe and most of it is found as rarefied inter-galactic plasma. It is found in stars and galaxies.

Plasma in appliances

In everyday life, plasma can be found in many electronic instruments such as Plasma TV, Neon Lights, Static Electric sparks etc. Further, *the area in front of a spacecraft's heat shield during re-entry into the atmosphere is a plasma.* The electric arc in an arc lamp, an arc welder or plasma torch is also plasma. Laser-produced plasmas (LPP) are created when high power lasers interact with materials. Magnetically induced plasmas (MIP) are typically produced using microwaves as a resonant coupling method.

Concepts Related to Atoms

Atomic Number and Mass Number

Atomic Number is the *number of Protons* in nucleus of an Atom. Mass number of an element is the number of nucleons viz. Neutrons and Protons. The atomic mass number is represented by a super index in left side such as ^{238}U. The number 238 denotes that it has total 238 of nucleons (neutrons and Protons).

Difference between Atomic Mass and Mass Number

While mass number is total number of nucleons, atomic mass is relative mass of an atom to another. Earlier, atomic mass of Hydrogen was fixed at 1 without any units and other atoms were assigned masses relative to it. Currently, atomic mass is defined as 1/12 of a mass of an atom of the carbon-12 (^{12}C) isotope. This is called atomic mass unit (amu) or a Dalton. On this basis, the mass of Hydrogen atom is 1.0080 amu. Mass of oxygen – 16 ($_{16}O$) atom is 15.995 amu.

Nuclear Binding Energy

All the protons have a similar charge that is positive charge. To keep all the protons together which are similarly charged (positive), a nuclear force exists which is a very short range force and works within the nucleus. This is called Nuclear Binding energy and is released when nucleus is broken apart via nuclear fission. Thus, the energy required to break apart or split the nucleus of the atom into its component nucleons viz. Neutrons and Protons is also called Nuclear Binding Energy.

Due to nuclear binding energy the *mass of the atomic nucleus is always less than the sum of the individual masses of the nucleons*. This gives an explanation to the non whole number of the atomic mass. For example the mass of 19F is 18.9984032 u. This mass difference is called *Mass defect*. Please note that nuclear binding energy is millions of times more than the electron binding energy.

Molecular Mass

Molecular mass is the sum of atomic masses of the elements present in a molecule. It is obtained by multiplying the atomic mass of each element by the number of its atoms and adding them together. For example, molecular mass of methane which contains one carbon atom and four hydrogen atoms can be obtained as follows:

Molecular mass of methane,

(CH4) = (12.011 u) + 4 (1.008 u)

= 16.043 u

Similarly, molecular mass of water (H2O)

= 2 atomic mass of hydrogen + 1 atomic mass of oxygen

= 2 (1.008 u) + 16.00 u

= 18.02 u

Mole

One mole is the amount of a substance that contains as many particles or entities as there are atoms in exactly 12 g (or 0.012 kg) of the ^{12}C isotope. It may be emphasised that the mole of a substance always contain the same number of entities, no matter what the substance may be. In order to determine this number precisely, the mass of a carbon-12 atom was determined by a mass spectrometer and found to be equal to $1.992648\ 10^{-23}$ g.

Chemical Reactions

Chemical and Physical Changes

In a physical change, substances don't change; only their molecules are rearranged. No new substance is formed in a physical change. In Chemical Change, a chemical reaction takes place and new substances are formed. Such reaction either takes energy or releases energy.

Examples of Physical Change

- Any change in state of matter in solid, liquid or vapour and vice versa is a physical change. For example, heating water would turn it into vapour while cooling it would turn it into ice.
- Sublimation of iodine or salt; melting of gold, silver or other metals.
- Absorption of water into a towel, Crumpling a piece of paper, Pulling copper into a thin wire, cutting wood, breaking glass, ripping a paper of tin foil etc.
- Dissolving sugar in water is also an example of Physical change because sugar molecules are dispersed within the water, but the individual sugar molecules are unchanged.

Examples of Chemical Changes

- Rusting of Iron (Iron reacts with Oxygen and turns into Iron Oxide)
- Burning of all kinds of fuels results in release of energy and gases such as CO2
- Cooking of egg would denature the protein molecules; which uncoil and create cross links to become solid white.
- Fermentation in which yeast converts Carbohydrates to alcohol, CO2 and other by products.
- Souring of Milk results in production of lactic acid from lactose sugar
- Burning of Camphor
- Explosive reaction of sodium with water and phosphorous with moist air
- Setting of cement

A change is considered to be chemical reaction only if chemical bonds are broken in reactants and new bonds are formed in products. *In other words, chemical reaction is a bond breaking and bond making process*. In some cases, the products of a reaction recombine to form the reactants back. These are called reversible reactions. Others are irreversible reactions.

During chemical changes, there is a rearrangement of atoms that makes or breaks chemical bonds. In a chemical reaction, bonds are broken and new bonds are formed between different atoms.

Dissolving salt into water is a Physical Change or Chemical Change?

Sometimes, changes are difficult to categorize into physical or chemical changes. One definition of

Physical change is that may result in re-arrangement of molecules but the molecules should not be broken apart. Although dissolving salt in water involves the breaking of chemical bonds, yet is described as physical change.

Burning of Candle is a Physical Change or Chemical Change?

Burning of candle is example of both physical and chemical change. Physical change is melting and solidifying of the wax. Chemical change is the production of heat by consuming oxygen.

Rate of Chemical Reaction

The rate of a chemical reaction is defined as the change in the concentration of the reactant or product per unit time. The Factors affecting the rate of reaction are summarized as below:

Concentration of Reactants

The rate of reaction generally increases with increase in concentration of the reactants.

Temperature

Generally increase in temperature increases the rate of reaction. When the temperature increases, the reactant molecules acquire higher energy and can easily form the products. Cooked food gets spoilt quickly during summer than winter. Souring of milk is faster in summer. These are all due to the fact that the chemical reactions responsible for these changes take place faster at higher temperatures.

Presence of Light

There are certain reactions which take place or are accelerated by the absorption of light by the reactants. Such reactions are known as photochemical reactions. These reactions do not occur if the reactants are shielded from light. The combination of hydrogen and chlorine to produce hydrogen chloride does not take place at measurable rate in the dark. The plants prepare starch from carbon dioxide and water in the presence of sunlight by the process of photosynthesis. This reaction is slow in dim sunlight but it is much faster in bright sunlight.

Presence of Catalyst

A catalyst is a substance which is added to a reaction mixture to alter the rate of chemical reaction where the mass and the chemical composition of the catalyst remain unchanged at the end of the reaction. Many industrially important reactions such as manufacture of ammonia, sulphuric acid, nitric acid and polythene are carried out using suitable catalysts.

Chemical Equilibrium

In reversible chemical reactions, there is a point when forward and backward reactions proceed simultaneously at the same rate. This is called Chemical Equilibrium. For instance when hydrogen and iodine are taken in a closed vessel maintained at 717 K, hydrogen molecule combines with iodine molecule to form hydrogen iodide.

$$H_2(g) + I_2(g) \longleftrightarrow 2HI(g)$$

Since the reaction is reversible in nature, the molecules of hydrogen iodide formed begin to dissociate to form hydrogen and iodine.

Exothermic and Endothermic Reactions

The chemical reactions which proceed with the evolution of heat energy are called exothermic reactions. Heat evolved is expressed in Joules (J) or kilo Joules (kJ).

All combustion reactions are exothermic. These reactions proceed with the evolution of heat energy. An important exothermic reaction occurs in our body cells which is nothing but respiration. During respiration, glucose in food burns in oxygen and gives out heat energy. Another example is formation of ammonia. When nitrogen combines with hydrogen in the presence of iron catalyst to form ammonia, a lot of heat is produced. Thus, the formation of ammonia is an exothermic reaction

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + \text{Heat}$

The chemical reactions which proceed with the absorption of heat energy are called endothermic reactions.

Why heat is evolved or absorbed in chemical reactions?

Chemical reaction involves the rearrangement of atoms. During the reaction, certain bonds are broken while certain new bonds are formed between the atoms. If the energy required to break the bonds is more than the energy released during the formation of bonds, then there is net absorption of energy and the reaction is endothermic. Both exothermic and endothermic reactions are due to the internal (intrinsic) energy that is stored within the structural units of every substance. When nitrogen and oxygen are heated to a very high temperature, they combine to form nitrogen monoxide and a lot of heat is absorbed in this reaction. Thus, the formation of nitrogen monoxide is an endothermic reaction.

$N_2(g) + O_2(g) + \text{Heat} \longleftrightarrow 2NO(g)$

What is impact of Temperature on Exothermic and Endothermic Reactions?

Increase in temperature favours endothermic reactions and decrease in temperature favours the exothermic reactions.

Acids and Bases

The term acid is derived from the Latin word *acidus* meaning sour. Bases are bitter in taste. An acid is a substance that has the tendency to lose a proton and a base is a substance that has the tendency to accept a proton. An acid in water gives hydrogen ions. A base in water gives Hydroxyl ion.

Key Features of Acids

Acids can be defined in many ways but generally their aqueous solutions have the following properties.

- They are sour in taste.
- They turn blue litmus red.

- They react with certain metals and liberate hydrogen gas.
- They react with oxides and hydroxides of metals forming salt and water.
- Their aqueous solutions conduct electricity

Key features of Bases

Bases are defined in various ways but generally substances having the following characteristics are called bases.

- They have a *bitter taste.*
- Their aqueous solutions have a soapy touch.
- They turn red litmus blue.
- They react with acids to form salt and water.
- Their aqueous solutions conduct electricity.

Weak and Strong acids and bases

- Acids such as Hydrochloric Acid (HCl), Sulphuric Acid (H_2SO_4) and Nitric Acid (HNO_3) which are almost *completely ionised* in aqueous solution are termed as strong acids. Acids such as acetic acid (CH_3COOH) is partially ionised and is called a weak acid.
- Similarly, bases like NaOH and KOH are almost completely ionised in aqueous solution and are therefore called strong bases. Ammonium Hydroxide is partially ionised and is called a weak base.

Important Notes on Acids and Bases

- Acid-base indicators are dyes or mixtures of dyes which are used to indicate the presence of acids and bases.
- Acidic nature of a substance is due to the formation of H+(aq) ions in solution. Formation of OH–(aq) ions in solution is responsible for the basic nature of a substance.
- When an acid reacts with a metal, hydrogen gas is evolved and a corresponding salt is formed. When a base reacts with a metal, along with the evolution of hydrogen gas a salt is formed which has a negative ion composed of the metal and oxygen.
- When an acid reacts with a metal carbonate or metal hydrogen carbonate, it gives the corresponding salt, carbon dioxide gas and water.
- Both acidic and basic solutions in water conduct electricity because they produce hydrogen and hydroxide ions respectively.

pH Scale

The acidity or basicity of a solution is usually expressed in terms of function of the hydrogen ion concentration. This function is called pH of a solution. pH of a solution may be defined as the negative logarithm (to the base 10) of hydrogen ion concentration expressed in moles per litre.

$pH = -\log_{10} [H+]$

For pure water and neutral solutions, at 298 K, concentration of hydrogen ions is 1 x 10-7 mol L-1. These hydrogen ions are formed by ionisation of some of the water molecules.

H_2O (l) H(aq)$^+$ + OH(aq)$^-$

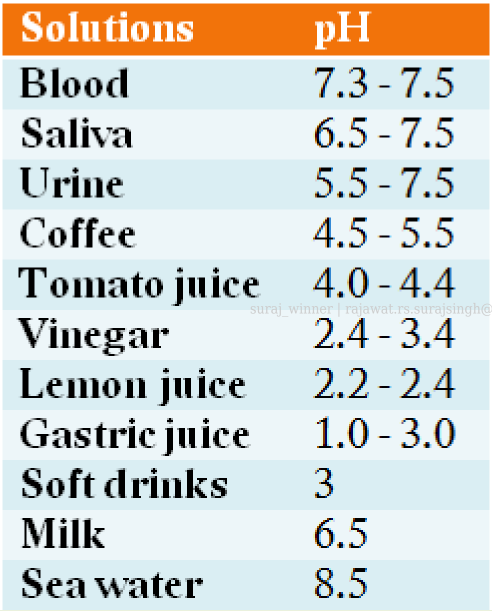
Thus, for pure water at 298 K,

[H+] = [OH-] = 1 x10^{-7} mol L-1

Sp pH of distilled water is :

-log (1 x 10^{-7}) = 7

The approximate values of pH for some familiar solutions are as follows:



Solutions	pH
Blood	7.3 - 7.5
Saliva	6.5 - 7.5
Urine	5.5 - 7.5
Coffee	4.5 - 5.5
Tomato juice	4.0 - 4.4
Vinegar	2.4 - 3.4
Lemon juice	2.2 - 2.4
Gastric juice	1.0 - 3.0
Soft drinks	3
Milk	6.5
Sea water	8.5

Red Cabbage Juice as Acid Base Indicator

Red cabbage juice is known as an acid/base indicator because it has pigments in it that react differently to acids and bases. These pigment change color when exposed to an acid or a base. Cabbage juice is naturally neutral and it has a purplish color. *When acid is added to it, it turns pink. If a base is added, it turns green.*

For example, the juice will turn pink when lemon juice is added to it. It changes to green when toothpaste is mixed with it, because toothpaste is basic in nature. *The tooth paste should be basic due to the reason, that some acids are formed by the bacteria in our mouth and these are neutralized by the bases present in the tooth paste.*

Periodic Table

Elements

Elements are pure chemical substances consisting of one type of atom. Elements can be metals, metalloids or non-metals. Examples: carbon, oxygen (non-metals), silicon, arsenic (metalloids), aluminium, iron, copper, gold, mercury, and lead (metals).

As of now, 118 elements have been defined of which 98 are known to occur naturally and 80 are stable. Others are either radioactive, decaying into lighter elements over various timescales from fractions of a second to billions of years or synthesized.

Most abundant elements

Hydrogen and helium are by far the most abundant elements in the universe. However, iron is the most abundant element (by mass) making up the Earth. Oxygen is the most common element in the Earth's crust.

Isotopes

Isotopes have different number of neutrons but same number of protons. The number of protons is called atomic number so all isotopes have same atomic number but different number of nucleons (neutron + proton) due to different number of neutrons. For example C_{12}, C_{13} & C_{14} are isotopes. Each of them has 6 protons. But they have 6, 7, 8 neutrons. So their atomic weights vary. The 80 elements with stable isotopes have atomic number of 1 to 82.

- The two elements between this atomic number range elements 43 and 61 (technetium and promethium) have no stable isotopes.
- 83rd element is Bismuth and from Bismuth onwards all undergo radioactive decay. They don't have stable nuclei but are found in nature.
- Remaining 24 are artificial or synthetic elements.

The first synthetic element was technetium. Technetium is found in trace amounts in nature and was discovered in 1925 but it was synthesized in 1937.

Allotropes

Some chemical elements are known to exist in two or more different forms because the atoms are bounded together in different manners. Most common example is Carbon which exists in Diamond, graphite, fullerenes etc. Allotropy is for elements and NOT for compounds. For example water and ice are not allotropes. The changes in state between solid, gas and liquid is NOT allotropy.

Oxygen has two allotropes viz. Oxygen and Ozone. These allotropes can stay in all the liquid, gaseous and solid phases. Phosphorus has many allotropes but when melted, all return to the P4 form. The different structural forms of the same element lead to the allotropes to show different physical properties and chemical behaviours.

Some allotropes

Allotropes of Carbon:

- Carbon has allotropes such as Diamond which is extremely hard, transparent crystal in which atoms are arranged in a tetrahedral lattice.
- Another allotrope is **Lonsdaleite** which is also known as hexagonal diamond. It has a hexagonal lattice in comparison to the diamond which has tetrahedral crystal structure. It is less hard than diamond (Diamond has Mohs hardness 10 while the Lonsdaleite has 7-8). It's a brown color substance.
- Another allotrope is Graphite which is soft, black and flaky and a moderate electrical conductor. In graphite the C atoms are bonded in flat hexagonal lattices layered in sheets. Each lattice is called a Graphene.
- Amorphous carbon is another allotrope. It has no crystalline structure.
- Fullerenes are other allotropes of Carbon. The fullerenes exist in various shapes such as hollow sphere, ellipsoid, or tubes. Accordingly they have been named buckyballs (for spherical) and buckeytubes for tube fullerenes. Tube fullerenes are the carbon nanotubes.
- The first fullerene discovered was **C60 in 1985** and it was called buckministerfullerene.
- Carbon nanotubes display extraordinary properties that make them potentially useful in many applications including in nanotechnology, electronics, optics and other fields of materials science. They exhibit extraordinary strength and unique electrical properties, and are efficient thermal conductors. They are either single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs).

Allotropes of Phosphorus

- The crystalline solid phosphorous is P_4 which is called white phosphorus.
- The Red phosphorus is polymeric.
- There are scarlet phosphorus, Violet Phosphorus, Black Phosphorus and Diphosphorus.
- Black Phosphorous is a semiconductor which is very much equivalent to Graphite.

Allotropes of Oxygen

- Oxygen has two allotropes Dioxygen O^2, which is colourless and Ozone O^3 which is blue.
- Apart from this there is tetraoxygen O_4 which is also called oxozone and it is metastable.
- The solid oxygen is Octaoxygen which exists in 6 phases under various pressures and temperatures; it is also called Red Oxygen.

Allotropes of Nitrogen

- N_2 is stable isotope. Another is unstable Polynitrogen molecule N_4.

Allotropes of Sulfur

- Sulfur is amorphous polymeric solid which is called **plastic Sulfur**, then there are S_8 molecules which are large crystalline structures called Rhombic Sulfur.
- Another form is fine needle like structures called monoclinic Sulfur.

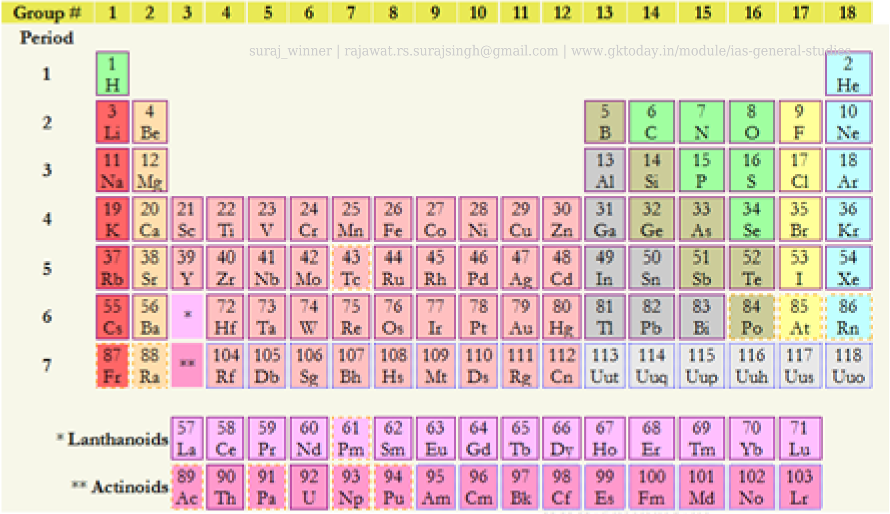
- Apart from that there are other ring molecules such as S_7 and S_{12}.

Periodic Table

Periodic classification attempts to arrange the chemical elements on the basis of fundamental properties. The practice started in 19th century when Dmitri Mendeleev propounded the Mendeleev law. This law states that the *physical and chemical properties of the elements are periodic functions of their atomic weights.* Thus, as per this law, if the elements are arranged in the order of increasing atomic weights; then after certain definite number there would be the elements which would have almost same properties.

He arranged the known elements in a table and created the Periodic table. Via this table, he predicted discovery of new elements and kept black space for them.

The periodic table of Mendeleev was modified several times later. Currently, periodic table has 7 horizontal rows (periods) and 18 vertical columns (groups). Please note that there is an extended version of the periodic table which contains 8th period. No element of the eighth period has yet been synthesized.



Group #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
* Lanthanoids			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
** Actinoids			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Periods

- When we go from left to right in a period
  - *size of atomic radius, metallic property* decrease.
  - Electron affinity, Electron negativity, ionization potential increase
  - Chemical reactiveness first decreases and then increases till halogens. However, this is not applicable to last group of Nobel gases.

Groups

When we move from top to bottom in a group:

- The metallic property in a group increases from top to bottom.
- The chemical reactiveness of the metallic elements increases from top to bottom, while decreases in the case of non-metallic elements.
- Valency is same in all groups (there are some exceptions)
- Values of the electron affinity decreases from top to bottom in a group.
- Values of ionization potential decreases from top to bottom.
- The size of the atomic radius increases from top to bottom.

Alkali metals

The metals of First group of periodic table are alkali metals. They include Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Caesium (Cs), And Francium (Fr). Hydrogen is also a member of group 1 but is not an alkali metal.

Key features:

- They are highly reactive and are never found in elemental forms in nature.
- They are usually stored immersed in mineral oil or kerosene (paraffin oil) because of their high reactive nature.

- They have low melting points and densities.
- All alkali metals have silver color except caesium which has a golden color.
- They react with halogens and make salts for example NaCl (table salt)
- They react with water and make Hydroxides for example NaOH
- Potassium and rubidium are naturally weakly radioactive elements and they each contain a long half-life radioactive isotope.
- Under standard conditions Lithium is the lightest metal and the least dense solid element.
- Lithium carbonate is used in use in psychiatry
- Organolithiums are also used in polymer synthesis and for creating carbon-carbon polymers.
- Lithium batteries are disposable (primary) batteries with lithium metal or lithium compounds as an anode, while the Lithium ion batteries are high energy-density rechargeable batteries.
- Al-Li alloys are used in aeronautics.
- The sodium vapour lamp uses sodium in an excited state to produce light.
- Alkali metal as the Na+ ion is vital to animal life.
- Molten sodium is used as a coolant in some types of nuclear reactors.
- It decreases in blood pressure and decreases in sodium concentration sensed within the kidney result in the production of rennin which in turn helps in secretion of ant diuretic hormones

- Animal cells, potassium ions are vital to cell function. They participate in the Na-K pump and in helping to restore the body's total amount of fluid.
- Sodium is the chief cation in fluid residing outside cells in the mammalian body
- Low sodium intake may lead to sodium deficiency which is known as hyponatremia.
- About 93% of the world potassium production is consumed by the fertilizer industry
- Potassium chloride is used in execution by lethal injection.
- Potassium vapour is used in several types of magnetometers
- Caesium is one among the five metals which are liquid at room temperature. These are Mercury (melting point −39 °C), Francium (27 °C) caesium (28 °C), Gallium (30 °C) & rubidium (39 °C)
- Caesium has been used in the petroleum Industry exploration as caesium formate.
- The caesium atomic clocks use the resonant vibration frequency of caesium-133 atoms as a reference point. Precise caesium clocks measure frequency with an accuracy of from 2 to 3 parts in 1014, which would correspond to a time measurement accuracy of 2 nanoseconds per day, or one second in 1.4 million years.

Alkaline Earth Metals

- Group 2 of the periodic table is known as Alkaline earth metals and it includes the Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra).
- Beryllium has very low absorption for X-rays and its most important applications are in radiation windows for X-ray tubes.
- Magnesium ions are essential to all living cells, where they play a major role in manipulating important biological polyphosphate compounds like ATP, DNA, and RNA. Hundreds of enzymes thus require magnesium ions to function.
- Magnesium is also the metallic ion at the center of chlorophyll, and is thus a common additive to fertilizers.
- Magnesium hydroxide is an inorganic compound with the chemical formula Mg(OH)2. As a suspension in water, it is often called milk of magnesia because of its milk-like appearance it is used as an antacid and laxative.
- Magnesium has three stable isotopes: 24Mg, 25Mg and 26Mg, all are in significant amount.
- Magnesium is the third most commonly used structural metal. The two most commonly used are iron and aluminum.
- It has a low weight and used in Electronic devices.
- Calcium has four stable isotopes (40Ca and 42Ca through 44Ca).
- New Rocks: The uplift of mountains exposes Ca-bearing rocks to chemical weathering and

releases Ca2+ into surface water. This Ca2+ eventually is transported to the ocean where it reacts with dissolved CO2 to form limestone. Some of this limestone settles to the sea floor where it is incorporated into new rocks.

- Dissolved CO2, along with carbonate and bicarbonate ions, are referred to as Dissolved Inorganic Carbon (DIC).
- Making of cheese, where calcium ions influence the activity of rennin in bringing about the coagulation of milk.
- Calcium plays an important role in building stronger, denser bones early in life and keeping bones strong and healthy later in life.
- Approximately ninety-nine percent of the body's calcium is stored in the bones and teeth.
- Vitamin D is added to some calcium supplements. Proper vitamin D status is important because vitamin D is converted to a hormone in the body which then induces the synthesis of intestinal proteins responsible for calcium absorption.
- Strontium is named after a village in Scotland where it was first discovered.
- The 90Sr isotope is present in radioactive fallout and has a half-life of 28.90 years
- Barium sulphate is used for its heaviness, insolubility, and X-ray opacity.

- 133Ba, is routinely used as a standard source in the calibration of gamma-ray detectors in nuclear physics studies
- Barium sulphate is used as a radio contrast agent for X-ray imaging of the digestive system ("barium meals)
- The most stable isotope of radium is 226Ra, has a half-life of 1601 years and decays into radon gas.
- Radium is over one million times more radioactive than the same mass of uranium, Handling of radium has been blamed for **Marie Curie's death due to aplastic anaemia.**

Metals versus Non-Metals

On the basis of their properties, the elements are broadly classified into metals and non-metals. The metals have been placed on the left hand side and in the centre of the periodic table, whereas non-metals have been placed on the right hand side. There are certain elements which show the properties of both metals and non-metals and these are called metalloids. The metals and non-metals in the periodic table are separated by a zig-zag line of metalloids. The metalloids are bismuth, silicon, germanium, arsenic, antimony, tellurium and polonium.

The following table differentiates between metals and non metals with their general properties.

Metals	Non Metals
Except mercury, all metals all solids at room temperature	Non-metals can be solids, liquids or gases. For example bromine is a liquid.
Metals are hard and malleable and can be beaten into thin sheets.	Non-metals are brittle
They are generally lustrous	They are generally not lustrous (Iodine, graphite and diamond are lustrous)
They are ductile and can be stretched into wires.	They are generally non ductile except some as Carbon fibre
They are sonorous and clang if they are hit.	Non-sonorous
They are good conductors of heat and electricity.	Except some examples such as Graphite, Non-metals are bad conductors of heat and electricity
Generally hard (except sodium and potassium) and have high tensile strength	Generally soft exception diamond.
Generally high density	Generally low density
Generally high melting and boiling points (except sodium and potassium)	Generally low melting and boiling points (exception graphite)
Metals react with oxygen and forms metal oxides. which are mostly basic in nature. Aluminium and zinc oxides exhibit acidic as well as basic properties. Such metal oxides are known as amphoteric oxides.	Non-metals react with oxygen and form acidic or neutral oxides. Carbon and sulphur form acidic oxides. Hydrogen forms a neutral oxide

Minerals

A mineral is a naturally occurring substance that is solid and stable at room temperature, representable by a chemical formula, usually abiogenic, and has an ordered atomic structure. It is different from a rock, which can be an aggregate of minerals or non-minerals, and does not have a specific chemical composition. There are around 5000 known minerals. The diversity and abundance of mineral species is controlled by the Earth's chemistry. Silicon and oxygen constitute approximately 75% of the Earth's crust, which translates directly into the predominance of silicate minerals. Minerals are distinguished by various chemical and physical properties. Differences in chemical composition and crystal structure distinguish various species, and these properties in turn are influenced by the mineral's geological environment of formation.

The general definition of a mineral encompasses the following criteria:

- Naturally occurring
- Stable at room temperature
- Represented by a chemical formula
- Usually abiogenic
- Ordered atomic arrangement

As the composition of the Earth's crust is dominated by silicon and oxygen, silicate elements are by far the most important class of minerals in terms of rock formation and diversity. However, non-silicate minerals are of great economic importance, especially as ores. Non-silicate minerals are subdivided into several other classes by their dominant chemistry, which included native elements, Sulfides, halides, oxides and hydroxides, carbonates and nitrates, borates, sulphates, phosphates, and organic compounds. The majority of non-silicate mineral species are extremely rare (constituting in total 8% of the Earth's crust), although some are relative common, such as calcite, pyrite, magnetite, and hematite.

Minerals versus Ores

The Inorganic elements or compounds of various metals found in nature, associated with their earthly impurities are called Minerals. For example, sodium chloride – NaCl, potassium chloride – KCl, calcium carbonate, – $CaCO_3$, magnesium carbonate – $MgCO_3$, zinc sulphide – ZnS, cuprous sulphide – Cu_2S etc., which are found in nature are minerals. Some minerals may contain a large percentage of metals whereas others may contain only a small percentage. All the minerals cannot be used to extract metals. Those minerals from which metals can be extracted profitably and conveniently are called Ores.

There are four types of Ores

- **Oxide ores:** Bauxite $Al_2O_3.2H_2O$, Cuprite Cu_2O, Zincite ZnO, Haematite Fe_2O_3, Pyrolusite MnO_2
- **Sulphide ores :** Copper pyrites $CuFeS_2$, Argentite Ag_2S, Zinc blende ZnS, Cinnabar HgS, Galena PbS and Copper glance Cu_2
- **Carbonate ores :** Limestone $CaCO_3$, Calamine $ZnCO_3$.
- **Halide ores :** Rock salt NaCl, Fluorspar CaF_2

Basics of Metallurgy

The process of extracting metals from their ores followed by refining is known as metallurgy. The four steps usually employed in metallurgy are :

- Concentration of ore (or enrichment of ore)
- Conversion of concentrated ore into metal oxide.
- Reduction of metal oxide to metal

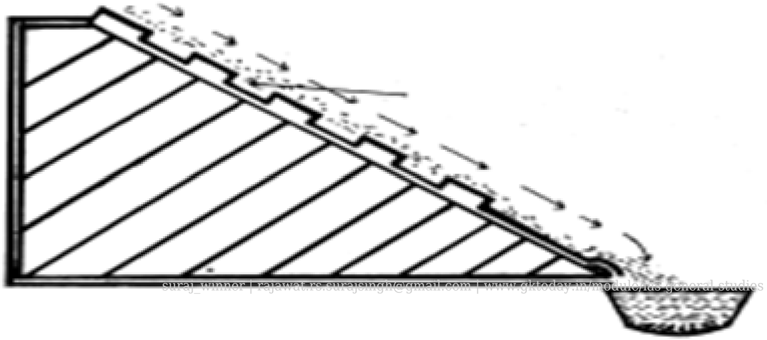
- Refining of impure metal.

Concentration of ores

Ores are usually associated with unwanted earthly matter called gangue (sand, clay etc.,) and the removal of this unwanted impurity is called concentration. Concentration of ores is generally carried out by any one of the following processes

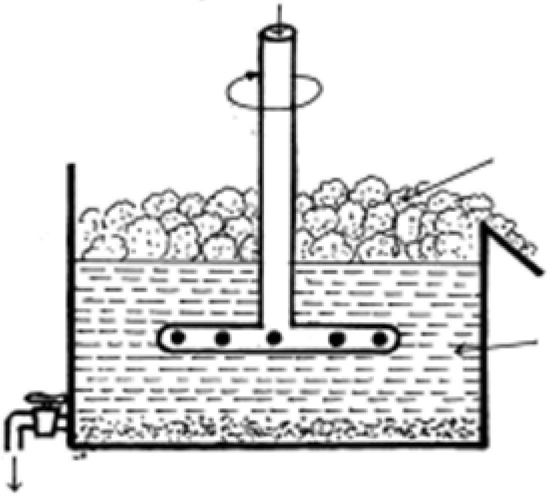
Gravity separation

The method is generally used for the concentration of oxide ores. The ore is thoroughly crushed, sieved and levigated in a stream of water. The heavier ore particles stay back while the lighter earthly impurities are washed away.



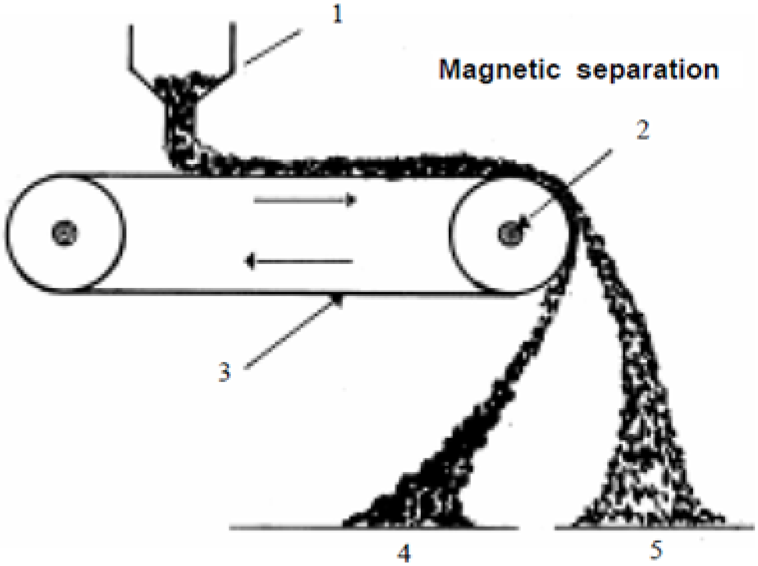
Froth floatation process

The process is commonly employed for the concentration of sulphide ores, which are preferentially wetted by oils. The well powdered ore is added to a mixture of pine or eucalyptus oil and water and agitated by flowing air into the mixture. The ore which is wetted by oil comes to the surface with the froth while the impurities go to the water layer below. *For example, Zinc sulphide and Galena are concentrated by this method.*



Electromagnetic separation

If one of the impurities present is magnetic in nature, it can be removed by this method. Thus, tinstone, an ore of tin, contains *Wolframite as an impurity, which is paramagnetic (i.e., attracted by a magnet).* To remove wolframite the powdered tinstone ore is dropped over a travelling belt passing over electromagnetic rollers. Wolframite being paramagnetic is attracted and collected in a heap near the magnets while tinstone is dropped away from the roller and forms another separate heap.



1. Powdered ore 2. Magnetic roller 3. Moving belt
4. Magnetic impurities 5. Non-magnetic ore particles

Conversion of concentrated ore into metal oxide

Calcination

It is the process of heating the concentrated ore in the controlled supply of air at a temperature sufficient to melt the ore.

$$FeCO_3 \xrightarrow{\Delta} FeO + CO_2 \uparrow$$

$$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \uparrow$$

During calcination process, the moisture and volatile impurities are removed from the concentrated ore and the mass becomes porous. Decomposition of the ores may also take place. Thus, in the case of oxide ores water is lost from the ores and Carbonate ores undergo decomposition with the evolution of carbon dioxide leaving behind a porous oxide ore.

Roasting

Roasting is the name of process of heating the concentrated ore strongly in the presence of excess air. Usually, sulphide ores are subjected to roasting. For example, zinc sulphide gives zinc oxide on roasting.

$$2\ ZnS + 3O_2 \xrightarrow{\Delta} 2\ ZnO + 2SO_2 \uparrow$$

Reduction of metallic oxide to the metal

Reduction is carried out either by electrolysis or by smelting.

Electrolysis

Electrolysis is the process employed for highly electropositive metals which cannot be reduced by reducing agents such as carbon, carbon monoxide, hydrogen etc., Electrolysis is carried out on fused metallic salts (halides or oxides) resulting in deposition of metal ions at cathode. Oxides of potassium, sodium, calcium, magnesium and aluminium are reduced to metals by electrolysis of their fused metallic salts.

Smelting

The calcined or roasted ore is reduced to the metallic form. The high temperature reduction process in which the metal is usually obtained in a molten state is called smelting. The smelting operations are usually carried out in the presence of a flux.

Metallic oxides are reduced to metals by coke, carbon monoxide or hydrogen. Zinc oxide is reduced by coke. Oxides of Iron, lead and copper are reduced by carbon, carbon monoxide or hydrogen. Oxides of Mercury and silver are reduced by thermal decomposition.

Refining of metals

The metals obtained by any of the methods described above need further purification as they may contain other metals, dissolved oxides, carbon, phosphorous etc. The following methods are employed for refining.

Distillation

This is employed for purifying volatile metals like zinc and mercury. On heating, pure metal is vaporised, condensed and gets collected and non-volatile impurities remain behind.

Liquation

It is used for refining easily fusible metals having low melting point like tin. Impure metal is placed on the inclined bed of a furnace and heated. When the metal melts, it flows down leaving the non-fusible impurities behind.

Oxidation

If the impurities present in a metal can be easily oxidised, then the metal is refined by stirring the molten mass thoroughly in the presence of air. During this process, the impurities come to the surface in the form of a scum and can be skimmed off.

Electrolytic refining

The impure metal to be refined is made as anode and the cathode consists of a piece of pure metal in an electrolyte which is a suitable salt of the impure metal. Pure metal gradually passes from the anode to the cathode while the impurities settle to the bottom. Copper, tin, lead, aluminium etc., are purified by this method.

Some basic terms related to Metallurgy

Gangue or matrix

The ore mined from the earth's crust contains some unwanted substances or impurities such as sand, rocky or clay materials. These substances are called gangue or matrix. The gangue has to be removed before the extraction of metals.

Flux

A flux is a substance that is added to the furnace charge (roasted or calcined ore and coke) during the process of smelting to remove the non-fusible impurities present in the ore.

Slag

Flux combines with non-fusible impurities to convert them into fusible substances known as slag. It is being light, floats over the molten metal and is removed from there. Impurities present in metal oxides may be acidic or basic. For acidic impurities, such as silica or phosphorus pentoxide (SiO2 or P2O5), calcium oxide is added as a flux to the mixture during smelting. If basic impurities such as manganese oxide are present, silica is added as a flux.

Important Inorganic Compounds

Sodium Carbonate / Washing Soda

Washing soda is sodium carbonate decahydrate, $Na_2CO_3.10H_2O$. Sodium carbonate was made from the ash of sea weeds, once upon a time. It was also found to occur as an efflorescent deposit (Trona, Na2CO3. NaHCO3.2H2O) in Egypt. In India, an efflorescent soil called **Sajimati**, which is a mixture of sodium carbonate, sodium bicarbonate, sodium sulphate and clay is found in places such as Dehradun, Mathura and Varanasi.

Sodium carbonate is one of the most important industrial chemicals. First, anhydrous sodium carbonate is manufactured by the Solvay process (ammonia-soda process) and then it is converted into sodium carbonate decahydrate which is called washing soda.

Why washing Soda Effloresce in water?

Washing soda is a transparent, crystalline solid, soluble in water and the solution is found to be alkaline as it turns red litmus blue. Washing soda, the decahydrate of sodium carbonate effloresces in air forming sodium carbonate monohydrate. Efflorescence is the process of losing water of crystallization from a hydrated salt when kept exposed to air for a long time.

Na2CO3.10H2O →Na2CO3.H2O+9H2O

The so formed monohydrate, Na2CO3.H2O is a white amorphous solid, which is stable in air.

How Soda Ash is obtained from Washing Soda?

On heating, washing soda gives **anhydrous sodium carbonate** called soda ash.

$Na_2CO_3 .10H_2O \rightarrow Na_2CO_3 + 10H_2O$

Major applications of Sodium Carbonate

Sodium carbonate is used

- In the manufacture of paper, soap, textiles, paints, etc.
- In laundry as washing soda and as a cleaning agent for domestic purposes.
- As an important laboratory reagent both in qualitative and quantitative analysis.
- In softening of hard water.

Role of Sodium Carbonate in Softening of hard water

Hardness of water is due to the presence of soluble salts of calcium and magnesium. When washing soda is dissolved in hard water, calcium and magnesium salts which cause hardness, react with washing soda and gets precipitated as insoluble solids, thus leaving the water soft.

Na2CO3 + MgSO4 →Na2SO4 + MgCO3

Baking Soda

Sodium Bicarbonate $NaHCO_3$ is known as baking soda. It is also manufactured by Solvay process. In Laboratory, it can be prepared by saturating aqueous solution of sodium carbonate with carbon dioxide.

$Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3$

Baking soda is a white solid. It is sparingly soluble in water and the solution is slightly alkaline which turn red litmus blue.

Baking powder is a mixture of sodium bicarbonate and tartaric acid. Baking powder is used in aerated drinks and as an additive in food stuff to make it soft. Sodium carbonate produced during baking is neutralised by tartaric acid present in baking powder.

How baking soda helps in baking?

When it is heated, it decomposes with the evolution of carbon dioxide gas. Hence, it is used as a constituent of baking powder to soften the dough and to aerate the drinks. The evolution of carbon dioxide also makes it useful for fire extinguishers.

$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2\uparrow + H_2O$$

It gives brisk effervescence with acids due to the liberation of carbon dioxide

$$NaHCO_3 + HCl \longrightarrow NaCl + CO_2 \uparrow + H_2O$$

Bleaching Powder

Bleaching powder is chemically, calcium oxychloride ($CaOCl_2$). Bleaching powder is manufactured using Backmann's plant in which slack lime and Chlorine are made to react to create Bleaching Powder.

Bleaching powder is a yellowish white powder with a strong smell of chlorine. When exposed to air, bleaching powder gives a smell of chlorine. This is because bleaching powder reacts with carbon dioxide from the atmosphere to produce calcium carbonate and chlorine.

$CaOCL_2 + CO_2 \rightarrow CaCO_3 + Cl_2$

Working of Bleaching Powder

In the presence of a very small amount of dilute acid, it gives nascent oxygen. Due to the evolution of nascent oxygen, it acts as an oxidising and a bleaching agent.

$2CaOCl_2 + H_2SO_4 \rightarrow CaCl_2 + CaSO_4 + 2HOCl$

$2HOCl \rightarrow 2HCl + 2\ [O]$

When it is treated with excess of dilute acids, chlorine is evolved. Chlorine gas produced in this way is known as, "available chlorine" which is responsible for the bleaching action of bleaching power. Available chlorine in bleaching powder is usually 35 – 38% by weight. The strength of bleaching powder is estimated on the basis of available chlorine content.

$CaOCl_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O + Cl_2$

$CaOCl_2 + 2HCl \rightarrow CaCl_2 + H_2O + Cl_2$

Bleaching powder is used to bleach cotton and linen in textile industry and wood pulp in paper industry. It is also used to bleach washed clothes in laundry. Bleaching powder is also used as a

disinfectant and germicide, ***since it liberates chlorine*** on exposure to the atmosphere which destroys the germs. It is also used for disinfecting water for the same reason. It is also used as an oxidising agent in many chemical industries

Plaster of Paris

Plaster of Paris is calcium sulphate hemihydrates. The formula is given as, $CaSO_4.^{1/2}H_2O$ or $(2CaSO_4).H2O$. The powder is called plaster of Paris, because the gypsum which was used to get the powder was mainly found in Paris. POP is prepared by heating gypsum at 373K in rotary kilns, where it gets **partially dehydrated**.

$$\underset{\text{gypsum}}{CaSO_4 . 2H_2O} \xrightarrow{373K} \underset{\text{plaster of Paris}}{CaSO_4 . \tfrac{1}{2}H_2O} + 1\tfrac{1}{2}\, H_2O$$

$$2(CaSO_4 . 2H_2O) \xrightarrow{373K} (2CaSO_4) . H_2O + 3H_2O$$

If the temperature is not maintained carefully, further dehydration will take place at higher temperature and setting property of the plaster will be partially reduced.

$CaSO_4.2H_2O \rightarrow CaSO_4 + 2H_2O$

How POP works?

Plaster of Paris is a white powder. When it is mixed with water (1/3rd of its mass), gypsum is obtained back. It initially forms a plastic mass with the evolution of heat and then sets to a hard solid mass within 5 to 15 minutes. Setting of plaster of Paris is accompanied by a slight expansion (about 1%) in volume which makes it suitable for making casts for statues, toys, etc. The setting of plaster of Paris can be catalysed by adding sodium chloride to it.

Cement

Cement was first discovered by an English brick layer named Joseph Aspdin in 1824. He called it Portland cement for the reason that the cement he discovered, resembled the limestone found in Portland. The approximate composition of Portland cement is given below

- Lime (CaO) : 60 – 70%
- Silica (SiO_2): 20 – 25%
- Alumina (Al_2O_3): 5 – 10%
- Ferric oxide (Fe_2O_3): 2 – 3 %

The raw materials used for the manufacture of Portland cement are limestone (provides CaO) and clay (provides SiO2 , Al2O3 and Fe2O3) which are finely powdered and then mixed in the ratio 3 : 1 by mass. The mixture is again ground to a fine powder and water is added. The finely ground powder called **slurry** is heated to 1773 K in a rotary kiln. On heating, lime, silica, alumina and ferric oxide react together and produces a mixture of dicalcium silicate, tricalcium silicate and tricalcium aluminate called **clinker**. The clinker is cooled and a small amount of gypsum (2 – 5%) is added to it**, to delay the setting time of cement.** The mixture of clinker and gypsum is then ground to a fine powder which is called cement. It is stored in tall structures called silos. The cement is then packed in water-proof bags and sold in markets.

When cement is mixed with water, it becomes hard over a period of time. This is called setting of cement. Gypsum is often added to Portland cement to prevent early hardening or "flash setting", allowing a longer working time.

Glass

The approximate composition of ordinary glass is given by the formula, Na_2O. $CaO.6SiO_2$. The raw materials required for the manufacture of ordinary glass are sodium carbonate, calcium carbonate and silica. The raw materials are ground separately to a fine powder, weighed accurately and mixed in a definite proportion. The mixture is called batch.

A specific amount of cullet (broken pieces of glass) is added to increase the fusibility of the glass produced The mixture is heated in fire clay pots or in a tank furnace. The pots (or tanks) are heated by using producer gas. The burning of gases produces a high temperature of about 1673 K in the furnace. The raw materials present in the batch melt at this high temperature and react with one another to form glass. **Carbon dioxide is evolved during the reaction**.

Annealing of Glass

The **slow and uniform cooling** of Glass is called Annealing. The glass articles are made by pouring molten glass into moulds and then cooling. If the glass is cooled rapidly, it becomes very brittle and cracks easily and if it is cooled very slowly, it becomes opaque. Therefore, it should be cooled neither very slowly nor very quickly. In the annealing process, the hot glass articles are placed on a slow moving belt which passes through a long narrow chamber in which the temperature is regulated carefully so that it is hot at the starting point and at room temperature at the other end. It takes several days for completion.

Soda glass or soda-lime glass

It is the most common variety of glass. It is prepared by heating sodium carbonate and silica. It is used for making windowpanes, tableware, bottles and bulbs.

Coloured Glass

Small amounts of metallic oxides are mixed with the hot molten mixture of sand, sodium carbonate and limestone. The desired color determines the choice of the metallic oxide to be added, as different metallic oxides give different colors to the glass.

Chemicals Used in Making of Colored Glass

- Iron oxide is used to produce bluish-green glass (used in beer bottles). Chromium along with

Iron Oxide gives richer green color, used for wine bottles.

- Sulfur + Carbon + Iron salts make iron polysulfides, which give amber glass ranging from yellowish to almost black.
- In borosilicate glasses rich in boron, sulfur imparts a blue color. With calcium it yields a deep yellow color
- Manganese is added to remove the green tint given by iron. Manganese dioxide, which is black, is used to remove the green color from the glass; in a very slow process this is converted to sodium permanganate, a dark purple compound.
- In New England some houses built more than 300 years ago have window glass which is lightly tinted violet because of the above chemical change; and such glass panes are prized as antiques
- Small concentrations of cobalt (0.025 to 0.1%) yield blue glass.
- 2 to 3% of copper oxide produces a turquoise color.
- Nickel, depending on the concentration, produces blue, or violet, or even black glass.
- Lead crystal with added nickel acquires purplish color.
- Nickel together with a small amount of cobalt was used for decolorizing of lead glass.
- Uranium (0.1 to 2%) can be added to give glass a fluorescent yellow or green color. Uranium glass is typically not radioactive enough to be dangerous, but if ground into a powder, such as by polishing with sandpaper, and inhaled, it can be carcinogenic. When used with lead glass with very high proportion of lead, produces a deep red color.

Safety glass

It is made by placing a sheet of plastic such as celluloid between sheets of glass.

Laminated glass

It can also be called bulletproof glass. Several layers of safety glass are bound together with a transparent adhesive.

Flint Glass

Optical glass is softer than any other glass. It is clear and transparent. Potassium and lead silicates are used in making optical glass. It is also called flint glass. The main use of flint glass is in the manufacture of lenses, prisms and other optical instruments.

Pyrex glass

Pyrex glass is highly heat resistant. In ordinary glass, silica is the main constituent. In pyrex glass some of the silica is replaced by boron oxide. **Boron oxide expands very little when heated, thus, pyrex glass does not crack on strong heating**. Pyrex glass is also called borosilicate glass. It has a high melting point and is resistant to many chemicals. Laboratory equipment and ovenware are made of pyrex glass.

Photo-chromatic glass

Photochromatic pr Photochromic glass acquires a darker shade when exposed to bright light and returns to its original lighter shade in dim light. This happens because **silver halides (iodide or chloride) is added to this glass**. Plastic photochromic lenses rely on organic photochromic molecules (such as oxazines and naphthopyrans) to achieve the reversible darkening effect.

Lead crystal glass

Lead crystal glass has high refractive index, and so has the maximum brilliance. It sparkles and is used for high quality art objects and for expensive glassware. It is also called cut glass because the surface of the glass objects is often cut into decorative patterns to reflect light. In order to increase the refractive index, **lead oxide is used as flux in crystal glass**, therefore it is also called **lead crystal glass.**

Organic Compounds

Carbon Compounds

Cells in our body are made of proteins. The fossil fuels are the important energy resources. The life saving antibiotics and drugs play a vital role in our day to day life. In recent years, many synthetic polymer products like polyethylene terephthalate (PET) polyethylene, nylon, terylene, bakelite, etc. are widely used in various fields.. Soaps, detergents and many cleansing agents are useful for domestic and industrial purposes. The above mentioned products namely, proteins, fossil fuels, antibiotics, drugs, synthetic polymers, soaps and detergents are compounds of carbon. Carbon exhibits a characteristic property called catenation by which carbon atoms can attach themselves with one another and due to this property, a large number of carbon compounds are existing. The role of carbon and its compounds in our daily life shows the importance of the study of these compounds.

Carbon forms a large number of compounds with hydrogen. Compounds containing only carbon and hydrogen are called Hydrocarbons. Many carbon compounds, in addition to hydrogen, also contain some elements like oxygen, nitrogen, halogens (chlorine, bromine and iodine) and sulphur.

Defining Organic Molecule

The difference between organic and inorganic molecules has been a subject of debate. An organic molecule is considered to be a molecule that plays role in organic activities.

- All organic molecules have Carbon.
- Oxygen may or may not be present, for example CH3 (methane) is organic despite not having Oxygen.
- The presence of C–C and C–H bonds are also not needed in some important molecules to call them organic. For example, Urea has no C–H bond. The same is with Oxalic Acid.

- Then C–C bond is neither present in methane, nor in Carbon Tetra Chloride.

Thus, there is no “official” definition of an organic compound. Some textbooks define an organic compound as one containing one or more C-H bonds; others include C-C bonds in the definition. Others state that if a molecule contains carbon-it is organic. One more definition is that except hydrocarbons, **organic compounds** consists of two parts, namely a reactive part which is known as Functional group and a skeleton of carbon and hydrogen atoms called alkyl radical. **Functional group** may be defined as an atom or group of atoms which is responsible for the characteristic properties of the compound. The chemical properties of an organic compound are determined by the functional group and the physical properties of an organic compound are determined by the remaining part of the molecule.

Classification of organic compounds based on functional groups

Alcohols

Organic compounds containing -OH as the functional group are known as Alcohols. For example, methanol (CH_3OH), ethanol (C_2H_5OH), propanol (C_3H_7OH), Butanol (C_4H_9OH) etc., are alcohols. Most of the characteristic properties of alcohols are due to the presence of the -OH group.

Aldehydes

Organic compounds containing –CHO as the functional group are known as aldehydes. For example, methanal (HCHO), ethanal (CH_3CHO), propanal (CH_3CH_2CHO), butanal ($CH_3CH_2CH_2CHO$) etc., are aldehydes.

Ketones (>C=O)

Organic compounds containing >C=O as the functional group are known as ketones. For example, propanone (CH_3COCH_3), Butanone ($CH_3CH_2COCH_3$) are ketones.

Carboxylic acids

Organic compounds containing carboxyl group (-COOH) as the functional group are known as carboxylic acids. For example, methanoic acid (HCOOH), ethanoic acid (CH_3COOH), propanoic acid (CH_3CH_2COOH), butanoic acid ($CH_3CH_2CH_2COOH$) etc., are carboxylic acids.

Saturation in Organic Chemistry

In organic chemistry, a saturated compound has **no double or triple bonds or ring**. In saturated hydrocarbons, every carbon atom is attached to two hydrogen atoms, except those at the ends of the chain, which bear three hydrogen atoms. In the case of saturated ethane, each carbon centre has four single bonds as is characteristic of other saturated hydrocarbons, alkanes.

In contrast, in alkenes such as ethylene (C2H4), double bonds are common. Thus, like other alkenes, ethylene is unsaturated. The degree of unsaturation specifies the amount of hydrogen that a compound can bind. The term is applied similarly to the fatty acid constituents of fats, which can be either saturated or unsaturated, depending on whether the constituent fatty acids contain carbon-

carbon double bonds. Unsaturated is used when any carbon structure contains double or occasionally triple bonds. Many vegetable oils contain fatty acids with one (monounsaturated) or more (polyunsaturated) double bonds in them. The bromine number is an index of unsaturation.

Alkanes

Chain compounds in which all carbon-to-carbon bonds are only simple single bonds (C-C) are called ALKANES. They are also called saturated hydrocarbons, because each carbon-to-carbon bond is a single bond, and the valence of the carbon atom is, therefore, saturated.

No more atoms can be bonded to the atoms in the compound, without breaking the compound into two or more fragments. If it contains one or more bonds which can react with hydrogen it is called an unsaturated hydrocarbon. Almost all other organic compounds can be named as derivatives of these simple hydrocarbons. Alkanes which have long carbon chains are often called paraffins in chemical industry. The general formula of alkanes is $C_nH_{2n+2.}$

The simplest alkane is the gas methane, whose molecular formula is CH4. Methane exists as a tetrahedral shape, but it is often represented by a flattened structure as are most organic compounds.

Flattened structures for the three simplest alkanes are given in the adjacent figure. In many cases the structures can be further simplified without loss of information by omitting all single bonds and writing the letter symbol of the element close to the letter symbol of the element to which it is attached.

Thus the representation of methane as CH4, ethane as H3CCH3 (rather than as C2H6), and propane as H3CCH2CH3 (rather than as C3H8) is a representation of structure as well as of molecular composition.

The alkanes above propane are named by giving the number of carbons (in Greek) with the ending -ane added. If an alkane is not a straight chain, then the longest straight chain in it is used as the basis of the name and the shorter side chains are considered to be substituents; thus names such as methylpropane and methylbutane are derived.

Name	Molecular Formula	Structural Formula	Boiling Point (°C)
Methane	CH_4	CH_4	-161.0
Ethane	C_2H_6	CH_3CH_3	-88.5
Propane	C_3H_8	$CH_3CH_2CH_3$	-42.0
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$	0.5
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	36.0
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	68.7
Heptane	C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	98.5
Octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$	125.6
Nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$	150.7
Decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$	174.1

Saturated hydrocarbons occur in three forms: **straight-chain forms** , **branched chain forms** and cyclic forms which are known as cycloalkanes. The cycloalkanes contain only single bonds, and have the general formula C_nH_{2n}. Cyclomethane and cycloethane obviously cannot exist, but cyclopropane can; it is a triangular stable structure, though somewhat reactive because the bond angles are somewhat strained to form the triangular structure. The bond angles in cyclopropane are those of an equilateral triangle, 60 degrees, as compared to the tetrahedral bond angle of 109.5 degrees.

Cyclobutane is a square structure; it is less reactive than cyclopropane because the bond angle strain is less, 90 degrees compared to the tetrahedral bond angle of 109.5 degrees. Cyclopentane and larger cycloalkanes are, like the normal alkanes, quite unreactive; there is no significant bond angle strain in these molecules.

Notable Observations about Alkanes

- Alkanes occur in nature in various ways; biologically they are not among the essential materials.
- Musk of the Musk dear contains Cycloalkanes with 14 to 18 carbon atoms.
- Methanogens are the bacteria that are found in the guts of cows, produce large quantities of methane by the metabolism of carbon dioxide or other oxidized organic compounds. The energy is released by the oxidation of hydrogen as follows:

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

- First four alkanes are used mainly for heating and cooking purposes and in some countries for electricity generation. Methane and ethane are the main components of natural gas; they are normally stored as gases under pressure. It is, however, easier to transport them as liquids: This requires both compression and cooling of the gas.
- Propane and butane can be liquefied at fairly low pressures, and are well known as liquefied petroleum gas (LPG). Propane, for example, is used in the propane gas burner and as a fuel

for cars, butane in disposable cigarette lighters. The two alkanes are used as propellants in aerosol sprays.

- From pentane to octane the alkanes are reasonably volatile liquids. They are used as fuels in internal combustion engines, as they vaporise easily on entry into the combustion chamber without forming droplets, which would impair the uniformity of the combustion. Branched-chain alkanes are preferred as they are much less prone to premature ignition, which causes knocking, than their straight-chain homologues. This propensity to premature ignition is measured by the **octane rating** of the fuel, where 2,2,4-trimethylpentane (isooctane) has an arbitrary value of 100, and heptane has a value of zero.
- Apart from their use as fuels, the middle alkanes are also good solvents for nonpolar substances.
- Alkanes from nonane to hexadecane (C_{16}) are liquids of higher viscosity, less and less suitable for use in gasoline. They form instead the major part of diesel and aviation fuel. Diesel fuels are characterized by their **cetane number**, cetane being an old name for hexadecane. However, the higher melting points of these alkanes can cause problems at low temperatures and in Polar Regions, where the fuel becomes too thick to flow correctly.

- Alkanes from hexadecane upwards form the most important components of fuel oil and lubricating oil. In the latter function, they work at the same time as anti-corrosive agents, as their hydrophobic nature means that water cannot reach the metal surface. Many solid alkanes find use as paraffin wax, for example, in candles. This should not be confused however with true wax, which consists primarily of esters.
- Alkanes with a chain length of approximately 35 or more carbon atoms are found in bitumen, used, for example, in road surfacing. However, the higher alkanes have little value and are usually split into lower alkanes by cracking.
- Some synthetic polymers such as polyethylene and polypropylene are alkanes with chains containing hundreds of thousands of carbon atoms. These materials are used in innumerable applications, and billions of kilograms of these materials are made and used each year.

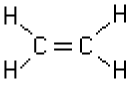
Alkenes

An alkene, olefin, or olefine is an unsaturated chemical compound containing at least one carbon-to-carbon double bond.. Thus, Alkenes are the simplest of the unsaturated hydrocarbons, hydrocarbons which will react with hydrogen.

<blockquote>An alkene may be distinguished from an alkane by shaking the hydrocarbon with **bromine water.** Bromine water is reddish-brown, and will decolorize with an alkene but not with an alkane. Bromine adds across the double bond of an alkene to form a colourless dibromo alkane.

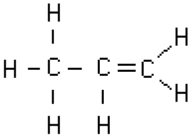
This is an example of an addition reaction. An addition reaction occurs when two or more reactants join together to form a single product.

Alkenes contain one or more reactive double bonds between carbon atoms, and are easily indicated by the symbol =. Since a double bond requires two carbon atoms, the simplest alkene is C_2H_4 or $H_2C{=}CH_2$, ethene. The presence of a double bond is indicated by the change of ending from -ane to -ene. An older form of the name, ethylene, is used in chemical industry. The general formula is C_nH_{2n}. All alkenes have at least one double bond.



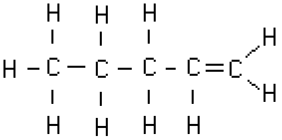
Ethene

C_2H_4



Propene

C_3H_6



Pentene

C_5H_{10}

Alkenes and Cycloalkanes have the same general formula, CnH2n. Therefore, the general formula does not identify the structure as an alkene nor a cycloalkane. To further become problematic there are alkenes which contain more than one double bond. Those with two double bonds have the formula, CnH2n-2.

The physical properties of alkenes are comparable with those of alkanes. The main differences between the two are that the acidity levels of alkenes are much higher than the ones in alkanes. The physical state depends on molecular mass. The simplest alkenes, ethene, propene and butene are gases. Linear alkenes of approximately five to sixteen carbons are liquids, and higher alkenes are waxy solids.

Alkenes are relatively stable compounds, but are more reactive than alkanes. Some common reactions related to alkenes are as follows:

Hydrogenation

Hydrogenation of alkenes produces the corresponding alkanes. The reaction is carried out under pressure at a temperature of 200 °C in the presence of a metallic catalyst. Common industrial catalysts are based on platinum, nickel or palladium.

Oxidation

Alkenes are oxidized with a large number of oxidizing agents. In the presence of oxygen, alkenes burn with a bright flame to produce carbon dioxide and water.

Ozonolysis

Ozonolysis is the cleavage of an alkene or alkyne with ozone to form organic compounds in which the multiple carbon–carbon bond has been replaced by a double bond to oxygen. The outcome of the reaction depends on the type of multiple bond being oxidized and the workup conditions. Alkenes can be oxidized with ozone to form alcohols, aldehydes or ketones, or carboxylic acids.

Notable Points about Alkenes

Alkenes are unsaturated hydrocarbons with one double bond (R-C=C-R). They are from a homologous series with the general formula CnH2n. The 1st member to possess this functional group is ethane, C2H4. Ethene is an important raw material for the petrochemical industry.

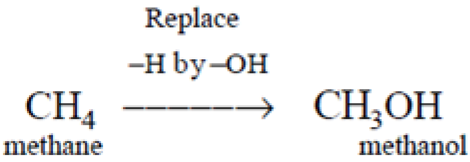
Alkenes are extremely important in the manufacture of plastics. All plastics are in some way related to alkenes. The names of some plastics (Polythene or Poly Ethene, Polypropene), relate to their alkene partners. Plastics are used for all kinds of tasks, from packaging and wrapping, to clothing and outdoor apparel.

- Lower alkenes are used as fuel and illuminant. These may be obtained by the cracking of kerosene or petrol.
- For the manufacture of a wide variety of polymers, e.g., polyethene, polyvinylchloride (PVC) and teflon etc.
- As raw materials for the manufacture of industrial Chemicals such as alcohols, aldehydes, and etc.

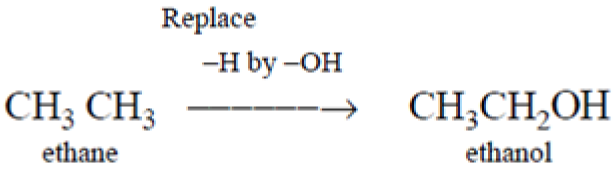
Besides, alkenes also used for artificial ripening of fruits, as a general anesthetic, for making poisonous mustard gas (War gas) and ethylene-oxygen flame.

Alcohols

Alcohols are compounds which contain carbon, hydrogen and oxygen. Alcohols can be derived from alkanes, if a hydrogen (–H) in alkane is replaced by a hydroxyl group (–OH). For example,



$$\underset{\text{methane}}{CH_4} \xrightarrow[\text{-H by -OH}]{\text{Replace}} \underset{\text{methanol}}{CH_3OH}$$



$$\underset{\text{ethane}}{CH_3\,CH_3} \xrightarrow[\text{-H by -OH}]{\text{Replace}} \underset{\text{ethanol}}{CH_3CH_2OH}$$

Generally alcohols are represented as R–OH where R is an alkyl group and –OH is the functional group and the general formula of alcohol is given as CnH2n + 1 OH, where 'n' is the number of carbon atoms. There are two ways of naming organic compounds namely Common and IUPAC system. The common names of alcohols are derived when the last letter '-ane' in the name of the parent hydrocarbon is replaced by '-yl' and it is combined with the word 'alcohol'.

According to IUPAC system, the last letter '-e' in the name of the parent hydrocarbon is replaced by 'ol'.

Alcohols are classified into primary, secondary (sec), and tertiary (tert), based upon the number of carbon atoms connected to the carbon atom that bears the hydroxyl group. The primary alcohols have general formulas RCH2OH; secondary ones are RR'CHOH; and tertiary ones are RR'R"COH, where R, R', and R" stand for alkyl groups. Ethanol and n-propyl alcohol are primary alcohols; isopropyl alcohol is a secondary one.

Chemical Formula	IUPAC Name	Common Name
CH3OH	Methanol	Wood alcohol
C2H5OH	Ethanol	Grain alcohol
C3H7OH	Isopropyl alcohol	Rubbing alcohol
C4H9OH	Butyl alcohol	Butanol
C5H11OH	Pentanol	Amyl alcohol
C16H33OH	Hexadecan-1-ol	Cetyl alcohol
C2H4(OH)2	Ethane-1,2-diol	Ethylene glycol
C3H6(OH)2	Propane-1,2-diol	Propylene Glycol
C3H5(OH)3	Propane-1,2,3-triol	Glycerol
C4H6(OH)4	Butane-1,2,3,4-tetraol	Erythritol, Threitol
C5H7(OH)5	Pentane-1,2,3,4,5-pentol	Xylitol
C6H8(OH)6	Hexane-1,2,3,4,5,6-hexol	Mannitol, Sorbitol
C7H9(OH)7	Heptane-1,2,3,4,5,6,7-heptol	Volemitol
C3H5OH	Prop-2-ene-1-ol	Allyl alcohol
C10H17OH	3,7-Dimethylocta-2,6-dien-1-ol	Geraniol

Chemical Formula	IUPAC Name	Common Name
C3H3OH	Prop-2-in-1-ol	Propargyl alcohol
C6H6(OH)6	Cyclohexane-1,2,3,4,5,6-hexol	Inositol
C10H19OH	2 – (2-propyl)-5-methyl-cyclohexane-1-ol	Menthol

Common Applications of Alcohols

Alcoholic beverages

Alcoholic beverages, typically containing 5% to 40% ethanol by volume, have been produced and consumed by humans since pre-historic times.

Antifreeze

A 50% v/v (by volume) solution of ethylene glycol in water is commonly used as an antifreeze.

Antiseptics

Ethanol can be used as an antiseptic to disinfect the skin before injections are given, often along with iodine. Ethanol-based soaps are becoming common in restaurants and are convenient because they do not require drying due to the volatility of the compound. Alcohol based gels have become common as hand sanitizers.

Fuels

Some alcohols, mainly ethanol and methanol, can be used as an alcohol fuel. Fuel performance can be increased in forced induction internal combustion engines by injecting alcohol into the air intake after the turbocharger or supercharger has pressurized the air. This cools the pressurized air, providing a denser air charge, which allows for more fuel, and therefore more power.

Preservative

Alcohol is often used as a preservative for specimens in the fields of science and medicine.

Solvents

Alcohols have applications in industry and science as reagents or solvents. Because of its relatively low toxicity compared with other alcohols and ability to dissolve non-polar substances, ethanol can be used as a solvent in medical drugs, perfumes, and vegetable essences such as vanilla. In organic synthesis, alcohols serve as versatile intermediates.

Methanol

Methanol or methyl alcohol, **wood alcohol**, **wood naphtha** or **wood spirits**, is a chemical with the formula CH_3OH. Methanol acquired the name "wood alcohol" because it was once produced chiefly as a by-product of the destructive distillation of wood. Modern methanol is produced in a catalytic industrial process directly from carbon monoxide, carbon dioxide, and hydrogen. It smells slightly sweeter than Ethanol. Methanol is produced naturally in the anaerobic metabolism of many varieties of bacteria, and is ubiquitous in small amounts in the environment.

As a result, there is a small fraction of methanol vapour in the atmosphere. Over the course of several days, atmospheric methanol is oxidized with the help of sunlight to carbon dioxide and water. Methanol burns in oxygen (including open air), forming carbon dioxide and water:

$2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$

Methanol ingested in large quantities is metabolized to formic acid or formate salts, which is poisonous to the central nervous system, and may cause blindness, coma, and death. Because of these toxic properties, methanol is frequently used as a denaturant additive for ethanol manufactured for industrial uses.

Applications of Methanol

- Methanol is a common laboratory solvent.
- The largest use of methanol by far is in making other chemicals. About 40% of methanol is converted to formaldehyde, and from there into products as diverse as plastics, plywood, paints, explosives, and permanent press textiles.
- Methanol is used to produce a gasoline additive methyl tert-butyl ether (MTBE).
- In addition to direct use as a fuel, methanol (or less commonly, ethanol) is used as a component in the transesterification of triglycerides to yield a form of biodiesel.

- Methanol derived Dimethyl ether (DME) has replaced chlorofluorocarbons as an aerosol spray propellant. Dimethyl ether (DME) also can be blended with liquified petroleum gas (LPG) for home heating and cooking, and can be used as a diesel replacement for transportation fuel.
- Methanol is used on a limited basis to fuel internal combustion engines. It is not widely used as a fuel because , using high concentrations of methanol (and other alcohols, such as ethanol) in fuel is the corrosivity to some metals, particularly to aluminium. Methanol, although a weak acid, attacks the oxide coating that normally protects the aluminum from corrosion
- Methanol is a traditional denaturant for ethanol, the product being known as “denatured alcohol” or “methylated spirit”. This was commonly used during the Prohibition to discourage consumption of bootlegged liquor, and ended up causing several deaths.
- As an antifreeze in pipelines and windshield washer fluid.In some wastewater treatment plants, a small amount of methanol is added to wastewater to provide a carbon food source for the denitrifying bacteria, which convert nitrates to nitrogen to reduce the nitrification of sensitive aquifers.
- Methanol is also a widely used fuel in camping and boating stoves. Methanol burns well in an unpressurized burner, so alcohol stoves are often very simple, sometimes little more than a cup to hold fuel. This lack of complexity makes them a favorite of hikers who spend extended

time in the wilderness.

- Methanol is mixed with water and injected into high performance diesel and gasoline engines for an increase of power and a decrease in exhaust gas temperature in a process known as water methanol injection.

Ethanol

Ethanol is the second member of the alcoholic series. Ethanol is commonly known as alcohol. It is a constituent of all alcoholic beverages namely beer, wine, whisky, some cough syrups, digestive syrups etc. In industries, alcohol is produced by the fermentation of sugar present in molasses. Molasses is a by-product of sugar industry in India. In our country, most of the ethanol is prepared from molasses.

Fermentation

The slow chemical change taking place in an organic compound by the action of enzymes leading to the formation of smaller molecules is called Fermentation. In our daily life, there are many instances of fermentation. For example, the change of milk into curd, souring of kneaded flour, etc., are due to fermentation. The fermentation of sugar is a process in which the sugar molecules are broken down into ethanol and carbon dioxide by the action of enzymes called invertase and zymase present in yeast.

Manufacture of Ethanol from Molasses

Molasses is a dark colored syrupy liquid left after the crystallization of sugar from the concentrated sugar cane juice. Molasses still contain about 30% sucrose which could not be separated by crystallization. Molasses is converted into ethanol by the following steps.

Dilution

Molasses is first diluted with water to bring down the concentration of sugar to about 8 to 10 percent.

Addition of Ammonium salts

Molasses usually contains enough nitrogenous matter to act as food for yeast during fermentation. If the nitrogen content of the molasses is poor, it may be fortified by the addition of ammonium sulphate or ammonium phosphate.

Addition of yeast

The solution from step (2) is collected in large ‘fermentation tanks’ and yeast is added to it. The mixture is maintained at about 303K for a few days. During this period, the enzymes invertase and zymase present in yeast bring about the conversion of sugar into ethanol. During this process, the liquor froths owing to the evolution of CO_2 which is recovered and used for preparing aerated drinks. The fermented liquid is technically called **wash**.

Distillation of wash

The fermented liquid containing 15 to 18 percent alcohol and the rest water is now subjected to fractional distillation. The main fraction drawn is an aqueous solution of ethanol which contains

95.6% ethanol and 4.4% water. This is called Rectified spirit. This mixture is then heated under reflux over quicklime for about 5 to 6 hours and then allowed to stand for 12 hours. On distillation of this mixture, pure alcohol (C_2H_5OH = 100%) is obtained. This is called Absolute alcohol.

Physical Properties of Ethanol

- Ethanol is a colorless liquid having a pleasant smell and a burning taste.
- It is a volatile liquid having a low boiling point of 78° C (351 K).
- It is miscible with water in all proportions.
- Ethanol does not contain any ions, as it is a covalent compound and has no effect on litmus paper.
- The boiling point of alcohols is, in general, much higher than the corresponding alkanes. This is because in alcohols there is intermolecular association of a large number of molecules due to Hydrogen bonding which is absent in alkanes.

Chemical Reactions of Ethanol

Reaction with oxygen or combustion

Ethanol is a highly inflammable liquid (it catches fire easily). It burns with a blue flame to form carbon dioxide and water.

$C_2H_5OH + 3O_2 \rightarrow 2CO_2\uparrow + 3H_2O\uparrow$

Reaction with Sodium Metal

When a small piece of sodium metal is put into ethanol in a dry test tube, brisk effervescence is produced. When a burning splinter is brought near the mouth of the test tube, the gas burns with a 'pop' sound, which is a characteristic property of hydrogen gas. This shows that the gas produced by the action of sodium metal on ethanol is hydrogen. Ethanol reacts with sodium to produce sodium ethoxide and hydrogen.

$2C_2H_5OH + Na \rightarrow 2C_2H_5ONa + H_2\uparrow$

Esterification

Ethanol reacts with acetic acid in the presence of Concentrated Sulphuric Acid H_2SO_4 to form an ester, ethyl ethanoate and water. The ester formed has sweet smell and the reaction is known as esterification

Inflammability

An ethanol-water solution that contains 40% ABV (alcohol by volume) will catch fire if heated to about 26 °C (79 °F) and if an ignition source is applied to it. This is called its flash point. The flash point of pure ethanol is 16.60 °C (61.88 °F), less than average room temperature.

Applications of Ethanol

Ethanol is used in the following:

- Manufacture of paints, varnishes, lacquers and medicines.

- In the preparation of organic compounds like ether, chloroform and iodoform.
- As an antiseptic to sterilize wounds and syringes in hospitals and dispensaries.
- In alcoholic drinks (beverages) like whisky, wine, beer and other liquors. Beer contains around 3 to 6% ethanol, whisky contains 30% ethanol and wine contains 8 to 10% ethanol.
- In spirit lamps as methylated spirit (contains ethanol mixed with a small amount of methanol and water).
- As power alcohol to generate power in internal combustion engines. Power alcohol is a mixture of 25% absolute alcohol and 75% petrol and it is a good fuel for motor cars. In the present days, due to scarcity of petrol and petrolatum products, power alcohol can be used as a substitute for petrol in motor cars which may also reduce pollution of air.

Carbonyl Compounds

Aldehydes and ketones are called carbonyl compounds as they contain the carbonyl group, >C=O. The functional group of an Aldehydes is -CHO and that of the ketones is >C=O. Both Aldehydes and ketones have the same general formula, CnH2nO. The general formula for Aldehydes is R-CHO, where R is an alkyl group and the general formula for ketones is R-CO-R¢, where R and R' are alkyl group which may or may not be the same.

Aldehydes

The common names assigned to Aldehydes are based on the names of acids produced by their oxidation. For example, formaldehyde and acetaldehyde are so called because on oxidation they produce formic acid and acetic acid respectively.

Formaldehyde

Formaldehyde or Methanal is the first member of the aldehyde series. The chemical formula of methanal is HCHO. It is prepared by the controlled oxidation of methanol (CH_3OH) at 873 – 923K using silver, iron oxide or molybdenum oxide as catalyst

$$\underset{\text{methanol}}{2CH_3OH} + O_2 \xrightarrow{\text{873 – 923 K catalyst}} \underset{\text{formaldehyde}}{2HCHO} + 2H_2O$$

Properties of Formaldehyde

Formaldehyde is a colorless, pungent smelling gas. It is highly soluble in water. It can be easily condensed into liquid. The liquid HCHO boils at 252K. It causes irritation of skin, eyes, nose and throat. Its solution acts as an antiseptic and a disinfectant.

Applications of Formaldehyde

- Formaldehyde is oxidized to methanoic (Formic) acid in the presence of oxidizing agents like alkaline potassium permanganate or Ammoniacal silver nitrate. **Formic Acid occurs**

naturally, most notably in the venom of bee and ant stings.

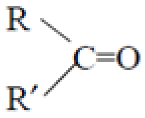
- A major use of formic acid is as a preservative and antibacterial agent in livestock feed
- An aqueous solution of formaldehyde is called Formalin which contains about 40% HCHO. It is a powerful disinfectant and antiseptic. It is used for preserving dead bodies, biological specimens and sterilising surgical instruments.
- It is used in the manufacture of paints and dyes.
- Formaldehyde is condensed with phenol in the manufacture of bakelite, a plastic which is used for making electrical switches.
- Formaldehyde is condensed with ammonia to produce urotropine, (CH2)6N4 which is an important medicine in urinary ailments.

Acetaldehyde

Acetaldehyde or ethanal occurs widely in nature and being produced on a large scale industrially. Acetaldehyde occurs naturally in coffee, bread, and ripe fruit, and is produced by plants as part of their normal metabolism. It is also produced by metabolism of Alcohol in our body and is popularly believed to be a cause of hangovers from alcohol consumption. Pathways of exposure include air, water, land or groundwater as well as drink and smoke. Acetaldehyde derived from the consumption of ethanol binds to proteins to form DNA adducts. This DNA adduct is what causes Cancer linked to alcohol overuse. Acetaldehyde is a probable or possible carcinogen in humans. Many microbes produce acetaldehyde from ethanol in our body which lead to stomach and colon cancer.

Ketones

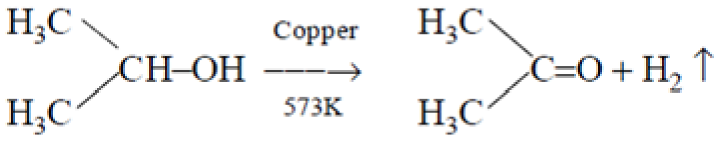
Like aldehydes, ketones also contain carbonyl group, >C=O. Therefore, ketones are also known as carbonyl compounds. Ketones have two alkyl groups attached to carbonyl carbon



where R and R' are alkyl groups.

Acetone

Acetone is the first member of the ketone series. Its IUPAC name is propanone. The chemical formula of acetone is CH3COCH3. It is prepared by the dehydrogenation of isopropyl alcohol using heated copper.

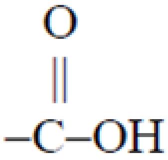


Properties & Applications of Acetone

- Acetone is a colourless, inflammable, volatile liquid with characteristic pleasant smell. Its boiling point is 329 K. It is miscible with water, alcohol and ether in all proportions. It specific gravity is 0.792 g/ml at 293K
- About a third of the world's acetone is used as a solvent, and a quarter is consumed as acetone cyanohydrin a precursor to methyl methacrylate, which is further used to create plastic called polymethyl methacrylate (PMMA)
- Acetone is a good solvent for most plastics and synthetic fibers including those used in laboratory bottles made of polystyrene, polycarbonate and some types of polypropylene. It is ideal for thinning fiberglass resin, cleaning fiberglass tools and dissolving two-part epoxies and superglue before hardening. It is used as a volatile component of some paints and varnishes. As a heavy-duty degreaser, it is useful in the preparation of metal prior to painting; it also thins polyester resins, vinyl and adhesives. It is also useful for high reliability soldering applications to remove solder rosin after soldering is complete. This helps to prevent the Rusty bolt effect from occurring due to dirty solder contacts.
- It is also used in the synthesis of rubber, in the manufacture of artificial leather, to clean and dry the parts of precious equipments and as a nail polish remover.

Carboxylic Acids

Carboxylic acids are a class of organic compounds which contain carboxyl group (–COOH) as the functional group. This group is structurally represented as follows:



Common names of monocarboxylic acids have been derived from the Latin name of the products / organisms in which they are found naturally. For example,

- Formic Acid HCOOH is found in the sting of Ants. Ants are called Formica in Latin.
- Acetic Acid CH_3COOH is found in Vinegar. Vinegar is called Acetum in Latin.
- Butyric Acid $CH_3CH_2CH_2COOH$ is found in Butter. Butter is called butyrum in Latin

Acetic Acid

Acetic acid is the second member of the carboxylic acid series after Formic Acid. The formula of acetic acid is CH3COOH and the IUPAC name of acetic acid is ethanoic acid. A dilute solution of acetic acid in water is called vinegar. Vinegar contains 6 to 10% acetic acid. Acetic acid is manufactured in the form of vinegar by the bacterial oxidation of ethanol. Ethanol is oxidised by the oxygen in air in the presence of Bacterium *Mycoderma aceti* to form a dilute solution of acetic acid called vinegar.

$CH_3CH_2OH + O_2 \rightarrow CH_3COOH + H_2O$

Acetic Acid is an important chemical reagent and industrial chemical, mainly used in the production of cellulose acetate mainly for photographic film and polyvinyl acetate for wood glue, as well as synthetic fibres and fabrics. In households, diluted acetic acid is often used in descaling agents. In the food industry, acetic acid is used under the food additive code E260 as an acidity regulator and as a condiment. The major use of acetic acid is for the production of vinyl acetate monomer (VAM). VAM is further polymerized to polyvinyl acetate or to other polymers, which are components in paints and adhesives. The acetates of metals such as Sodium, Magnesium etc. have wide usage such as preservatives, food inudustry, fungicides, dyes etc.

Soaps & Detergents

Soaps are sodium or potassium salts of some long chain carboxylic acids. Sodium salts of fatty acids are known as hard soaps and potassium salts of fatty acids are known as soft soaps. Hard soaps are prepared from cheap oils, fats and sodium hydroxide. They contain free alkali and are used for washing purposes. Soft soaps are prepared from good oils and potassium hydroxide. They do not contain free alkali, produce more lather and are used as toilet soaps, shaving creams and shampoos.

Soap is prepared by heating vegetable oil or animal fat containing Glyceryl stearate with concentrated sodium hydroxide solution. Hydrolysis of fat takes place and a mixture of sodium salts of fatty acids and glycerol is formed. The salts of fatty acids thus formed are used as soap. The alkaline hydrolysis of oils and fats forming soaps is commonly known as saponification.

$$\underset{\text{(animal fat)}}{\text{Glyceryl stearate}} + \text{sodium hydroxide} \longrightarrow \underset{\text{(soap)}}{\text{Sodium stearate}} + \text{Glycerol}$$

Hardness of water and soaps

The big disadvantage of soapy detergents is that their washing action is reduced by hardness in water. Water that contains calcium and magnesium compounds is said to be hard. These compounds destroy the soap **by reacting with it and converting into insoluble compounds called scums that float to the surface**. In hard water, a lot of soap is needed to get a good lather and a lot of scum is formed as well. This difficulty is overcome by detergents.

Detergents are sodium salts of benzene sulphonic acids. Thus instead of -COOH group in soaps, detergents contain -SO3H group. **The detergents do not form precipitates with metal ions such as Ca2+ and Mg2+ present in hard water**. Therefore, the cleansing action of detergents is better than soaps. Detergents are prepared by treating hydrocarbons obtained from petroleum with conc. sulphuric acid. The corresponding sulphonic acids are then converted into their sodium salts. Washing powders available in the market contain about 15 to 30 percent of detergents by weight. Some other chemicals which are added to detergents for specific cause are as follows:

- Sodium sulphate and sodium silicate added to keep the washing powder dry.
- Sodium carbonate is added to maintain alkalinity which helps in removing dirt and also in softening water.
- Carboxy-methyl cellulose (CMC) added to keep the dirt suspended in water.
- A mild bleaching agent such as sodium perborate is added to produce whiteness in clothes.

Soaps Versus Detergents

Soap	Detergents
Soaps are sodium salts of long chain fatty acids	Detergents are sodium salts of sulphonic acids.
The ionic part of a soap is -COO- Na+	The ionic part in a detergent is -SO3 – Na+
They are biodegradable	Some detergents are not biodegradable.
They are prepared from animal fats or vegetable oils.	They are prepared from hydrocarbons obtained from coal and petroleum.
Soaps form insoluble salts called scums with calcium and magnesium ions which are present in hard water and hence cannot be used in hard water.	Calcium and magnesium salts of detergents are soluble in water and therefore can be used even in hard water.

How soaps work?

When used for cleaning, soap allows otherwise insoluble particles to become soluble in water and then be rinsed away. A soap molecule contains two chemically distinct parts that interact differently with water. One part is a long hydrocarbon chain, which is non-polar and water hating (hydrophobic), while the other part is charged carboxylate group -COONa which is polar and water-loving (hydrophilic). The hydrophilic part makes the soap soluble in water. So, a soap molecule can be thought of as one having a long tail made of hydrocarbon and a short head made of carboxylate group. The long tail is dirt-loving and water-hating and the short head is water-loving. The hydrophobic part of the soap

molecule traps the dirt and the hydrophilic part makes the entire molecule soluble in water. When a soap or detergent is dissolved in water, the molecules join together as clusters called miscelles. Their long hydrocarbon chains attach themselves to the oil and dirt. The dirt is thus surrounded by the non-polar end of soap molecules. The charged carboxylate end of the soap molecules make the miscelles soluble in water. Thus, the dirt is washed away with soap.

Advantages of Detergents over Soap

Detergents can be used even in hard water whereas certain amount of soap gets wasted if water is hard. Detergents can be used even in acidic medium as they are the salts of strong acids and are not decomposed in acidic medium.

For example: oil/fat is insoluble in water, but when a couple of drops of dish soap are added to the mixture the oil/fat apparently disappears. The insoluble oil/fat molecules become associated inside micelles, tiny spheres formed from soap molecules with polar hydrophilic (water-loving) groups on the outside and encasing a lipophilic (fat-loving) pocket, which shielded the oil/fat molecules from the water making it soluble. Anything that is soluble will be washed away with the water. Synthetic detergents operate by similar mechanisms to soap. The type of alkali metal used determines the kind of soap produced. Sodium soaps, prepared from sodium hydroxide, are firm, whereas potassium soaps, derived from potassium hydroxide, are softer or often liquid. Historically, potassium hydroxide was extracted from the ashes of bracken or other plants. Lithium soaps also tend to be hard—these are used exclusively in greases.

Soaps are derivatives of fatty acids. Traditionally they have been made from triglycerides (oils and fats). Triglyceride is the chemical name for the triesters of fatty acids and glycerin. Tallow, i.e., rendered beef fat, is the most available triglyceride from animals. Its saponified product is called sodium tallowate. Typical vegetable oils used in soap making are palm oil, coconut oil, olive oil, and laurel oil. Each species offers quite different fatty acid content and, hence, results in soaps of distinct feel. The seed oils give softer but milder soaps. Soap made from pure olive oil is sometimes called Castile soap or Marseille soap, and is reputed for being extra mild. The term “Castile” is also sometimes applied to soaps from a mixture of oils, but a high percentage of olive oil.

Soap is an emulsification agent. Oil and grease are not soluble in water (they don’t dissolve in water), which is why, for instance, oil and water will separate when combined. This is because oils are non-polar molecules, but water is a polar molecule, and non-polar things do not mix well with polar things. In order to remove oil from clothes or from your dishes with water, the oils must be made soluble by the process of emulsification.

The non-polar end adsorbs the oil or other hydrophobic dirt. The ionic end is highly soluble in water. This allows for an emulsion to be formed. The alkali metal (sodium or potassium ion) does not play a role in the action of the soap.

Soap use is not a chemical reaction, but a physical one. Under normal conditions, the soap does not react with the dirt chemically. If "hard water" minerals are present (magnesium or calcium) these can chemically react with the soap and lessen its effectiveness by removing the soap from solution.

The structure of the emulsion is such that the oil or oily dirt is surrounded by soap molecules with the ionic part of the molecules toward the outside where water will react with the ionic end (by hydrogen bonding) and keep the oil in "solution." Hot water helps in the formation and suspension of the emulsion.

Other additives are sometimes added to soap for antibacterial or antifungal effects, but these are not the main ingredients — they just enhance the primary function of emulsifying oils in water.

Miscellaneous Topics

Zeolites

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents. Zeolites are widely used in industry *for water purification, as catalysts, for the preparation of advanced materials and in nuclear reprocessing*. They are used to extract nitrogen from air to increase oxygen content for both industrial and medical purposes. Their biggest use is in the production of laundry detergents. They are also used in medicine and in agriculture.

Zeolites and Permanent Hardness of water

Hardness in water is due to the presence of carbonates and biocarbonates of Calcium or Magnesium (when it is temporary hardness) or sulphates and chlorides of Calcium and Magnesium (when it is permanent hardness). Temporary hardness of water can be removed easily by boiling water or by adding washing soda (Sodium Carbonate-hydrated). Permanent hardness cannot be removed by merely boiling or adding washing soda. A complex salt called sodium aluminium silicate (zeolite) is used to remove permanent hardness in water.

Permotit or zeolite is packed into a column and the hard water is allowed to flow through it. Double decomposition occurs and calcium aluminium silicate is formed. Eventually the permotit is completely converted into its calcium salt. It can be made fit for use again by pouring a strong solution of common salt through the column.

Sodium Aluminium Silicate (zeolite)+ Calcium Sulphate (salt causing hardness of water)→ Calcium Aluminium Silicate+ Sodium Sulphate (zeolite)

After adding salt water:-

Calcium Aluminium Silicate + Sodium Chloride (common salt) →Sodium Aluminium silicate (zeolite) + Calcium Chloride

In the above reaction the tower is revived and reset for use again, thus the zeolite is not wasted. The principle of the permutit process has been greatly extended to modern synthetic ion-exchange resins.

These can be used to remove all metallic and acidic ions from water and provide a cheap and convenient way of making high purity water purer even than the best distilled water. Another application is in the preparation of drinking water from sea water

Use of Barium and Iodine based materials as contrast media in X-Ray

The production of X-ray images depends on the differences between the X-ray absorbing powers of various tissues. This difference in absorbing power is called contrast and is directly dependent on tissue density. To artificially enhance the ability of a soft tissue to absorb X-rays, the density of that tissue must be increased. The absorption by targeted soft tissue of aqueous solutions of barium sulfate and iodized organic compounds provides this added density through the heavy metal barium and the heavy nonmetal iodine.

Brinjal and Apples become dark when they are kept open

This is mainly because of so called *Climacteric Rise*. In many fruits, especially the fleshy types, there are marked changes in their `respiration rate' after they mature. In certain fruits, there is a considerable increase in the respiration rate at the time of `ripening', which is known as *climacteric rise*. Even after the fruits are harvested, they continue to respire, which leads to consumption of food, water and other cellular fluids. This results in the breakdown of tissues eventually and causes the perishability of fruits. The onset of fruit ripening happens due to the release of ethylene (C2H2).

Dry Cleaning Materials

Dry cleaning uses non-water solvents such as highly vaporising organic solvents. Many dirt, soil or stains producing substances on the fabric are organic in nature (sticky oily compounds). In dry cleaning, cleansing is achieved by the action of a solvent, which dissolves out the sticky matter due to its like nature. Dry cleaning fluids serve as a vehicle to carry away the soil. *Camphene, naphtha, benzene, benzol, petrol, carbon tetrachloride, trichloroethylene and tetrachloroethylene* are some of the frequently used dry cleaning fluids.

Teer Gas

Tear gas, formally known as a lachrymatory agent or lachrymator stimulates the corneal nerves in the eyes to cause tears, pain, and even blindness. Common lachrymators include OC, CS, CR, CN (phenacyl chloride), nonivamide, bromoacetone, xylyl bromide and syn-propanethial-S-oxide (from onions).

Tear gas is a noxious gas. It is also called as war gas since it is used to disperse soldiers in a battle and an attacking mob. It is one kind of Lachrymator.

Deodorants and Antiperspirants

Deodorants mask the smell of body odour, which is actually caused by bacteria, where as anti-perspirants block the pores of the skin to stop us from perspiring.

There are two types of glands in our underarms, apocrine and eccrine. The eccrine glands are by far the most numerous sweat glands and are responsible for producing most of the sweat in our underarms, as well as in our entire body.

Most antiperspirants contain *aluminium chlorohydrate/ aluminium chloride or aluminium zirconium,* which are highly soluble and readily absorbed into the skin. Once in the body, the aluminium passes freely across cell membranes and is readily absorbed. The aluminium ions are taken into the cells that line the eccrine-gland ducts at the opening of the epidermis, the top layer of the skin. When the aluminium ions are drawn into the cells, water passes in with them. As more water flows in, the cells begin to swell, squeezing the ducts closed so that sweat can't get out.

Knocking of Engine

An Internal combustion engine under load develops `pinging' or `knocking', where the fuel mixture starts exploding due to compression before the right time, causing rough running, stalling going up hills, and so on.

Tetra Ethyl Lead (TEL) is one such component that is added to petrol to reduce its tendency to `ping' under compression. TEL breaks down to lead at upper cylinder temperatures. Lead atoms spread around and combining with the free radicals and slowing down the reaction.

However, `Leaded' petrol was a grave danger to the environment, as lead is a poison when it is absorbed into the body.

But reason for going completely unleaded is different. The reason is to reduce other pollutants, the unburned hydrocarbons and nitrogen oxides. To achieve this, catalytic exhausts have been adopted, and they cannot stand even the residual lead, which will affect the platinum catalyst. It was discovered that passing the exhaust gases through a filter of platinum caused a catalytic conversion of the oxides to other products, which could then be prevented from escaping into the greenhouses, used for food production.

Lead Alternates

There are three main groups of substances oil companies use instead of lead to improve octane number.

- **Aromatics:** organic compounds based on the benzene ring, a 6-carbon ring with 3 delocalised double bonds e.g., benzene, toluene, xylene,
- **Olefines:** organic compounds, which have, double bonds. After combustion, one critical by-product is 1,3-butadiene.
- **Oxygenates:** organic compounds containing oxygen molecules such as methane, ethane or MTBE (methyl-tertiary-butyl ether).

As benzene and 1,3-butadiene are the top toxic air pollutants. They are both highly carcinogenic substances, MTBE is the most popular additive in unleaded petrol. The third group of alternative octane-raising substances mentioned above are the oxygenates. A major by-product of their combustion is acid aldehyde — the first substance the body produces in the alcohol-detoxifying process. So the oxygenates are less toxic than benzene and 1, 3-butadiene. Another advantage of oxygenates is that, because they contain oxygen molecules, they cause the fuel to burn more efficiently-and thus lowering the levels of all pollutants from car emissions.

Chlorination and Ozonation of Water

Chlorine, Iodine and Bromine can be used for disinfecting water but not fluorine because it is too reactive. Chlorine is often chosen simply because it is cheap, readily available and relatively easy to handle. Disinfection relies on disrupting a harmful organism's metabolism or structure. That can be achieved by oxidation and non-oxidising chemicals which have similar effects, as well as by non-chemical processes such as ultraviolet (including sunlight), X-rays, ultrasound, heat (as in pasteurisation), variations in pH and even storage to allow organisms to die naturally. Chlorine gas consists of molecules of two chlorine atoms but no oxygen. When added to water, one of the atoms forms a chloride ion. The other reacts with water to form hypochlorous acid, an oxidising agent. Disinfection comes from the hypochlorous acid reacting with another molecule, most probably in the bacterial cell wall, in an oxidation-reduction reaction. If this happens enough times, the organism's repair mechanisms are overwhelmed and it dies. So concentration of disinfectant and the length of time pathogens are exposed to it are important factors. Disinfection needs to be carried out under closely controlled pH conditions, ideally between 7 and 7.6. If the pH is too low — less than 6.8 — there is a tendency for nitrogen compounds, especially urea (a common pool contaminant) to degrade via another route to chloramines. The worst of these is nitrogen trichloride, which irritates the eyes and creates the so-called chlorine smell associated with poorly run or overused swimming pools.

Best time of Chlorination of Swimming Pool is Night Hours.

Chlorine, or more commonly a substance containing hypochlorite ion, is added to pools as a disinfectant. However, sunlight rapidly destroys hypochlorite, drastically reducing the effectiveness of the sanitizer. Hence, the effectiveness of the disinfectant is maximized when added in the evening hours.

Ozonation Versus Chlorination

Ozonation of water has strong virucidal effect. It inactivates viruses in a matter of seconds. Many countries around the world are using ozone for water treatment. Ozone has no residual germicidal effect, but in the case of chlorination there is residual effect over the germs. Combined treatment of water with ozone and chlorine effectively sterilise the water. 0.2 to 1.5 mg of ozone is necessary to sterilise one litre of water. As ozone destroys all micro organisms and it removes disagreeable odours, the resultant water is absolutely safe, pure, fresh and healthy. Ozonised water is colourless and odourless.

Sodium Vapour Lamp and Mercury Vapour Lamp

Difference	Sodium Vapour Lamp	Mercury Lamp
Light Source	Works by electric discharge (passage of electricity through sodium vapours at high/low pressure)	Works through the combined effect of electric discharge through mercury vapours and fluorescence from phosphors (luminescent materials).
Process of Lightning	Filaments of the lamp sputter fast moving electrons, which hit the sodium atoms (vapour) causing the valence electrons of the sodium atoms to excite to higher energy levels and the electrons thus excited relax by emitting the characteristic monochromatic bright yellow light (589nm).	The mechanism in mercury vapour lamp is more involved and sequential. The sputtered electrons from the filaments, after having been accelerated by high voltage, hit the mercury atoms. Here also, the excited electrons of mercury atoms relax by emitting characteristic but ultraviolet (254nm, invisible) light.
		The photons of this ultraviolet light fall on the fluorescent layer on the inner walls of the tube and excite the molecular bonds of the fluorescent material to various electronic and vibrational energy states. Hence, the light from the mercury vapour lamp is white.
Applications	Although sodium vapour lamps produce much higher light output (about 90 lumens/watt) they cannot be used in lighting applications where colour-rendering property is very crucial. This is because most of the light emitted from a sodium vapour lamp is concentrated in the yellow part of the visible spectrum (around 580-590 nm).	Mercury vapour lamp is quite suitable for lighting applications. This is because, the mercury vapour lamp can feed almost the entire visible region (380-780 nm) of the human visual system

Colors in Fireworks

Pyrotechnics is the art of making fireworks, which produce different colours when lit. The art involves the intimate mixing of a fuel (burnable material) that is in a fine state of subdivision and an oxidising agent using a binder. This burning coincides with the fuel oxidizer interaction. The binder also burns in air and that adds to flame formation. The effects, so produced owe their selective light emission to the presence of the various elements and compounds. These are summarized below:

- Aluminium is used to produce silver and white flames and sparks. It is a common component of sparklers.

- Barium is used to create green colors in fireworks.
- Carbon is one of the main components of black powder, which is used as a propellant in fireworks. Carbon provides the fuel for a firework.
- Calcium is used to deepen firework colors. Calcium salts produce orange fireworks.
- Chlorine is an important component of many oxidizers in fireworks. Several of the metal salts that produce colors contain chlorine.
- Cesium compounds help to oxidize firework mixtures. Cesium compounds produce an indigo color in fireworks.
- Copper produces blue-green colors in fireworks and halides of copper are used to make shades of blue.
- Iron is used to produce sparks. The heat of the metal determines the color of the sparks.
- Potassium nitrate, potassium chlorate, and potassium perchlorate are all important oxidizers. The potassium content can impart a violet-pink color to the sparks.
- Lithium is a metal that is used to impart a red color to fireworks.
- Magnesium burns a very bright white, so it is used to add white sparks or improve the overall brilliance of a firework.

- Phosphorus burns spontaneously in air and is also responsible for some glow in the dark effects.
- Sulfur is a component of black powder, and as such, it is found in a firework's propellant/fuel.
- Strontium salts impart a red color to fireworks.
- Zinc is a bluish white metal that is used to create smoke effects for fireworks.

Silver Tarnish

Silver tarnish is the discoloration that occurs on silver. Silver is not appreciably affected by dry or moist air that is free from ozone, halogens, ammonia, and sulphur compounds. The presence of hydrogen sulphide in any material that silver comes into contact with is one of the prime reasons for silver tarnish. The hydrogen sulphide reacts with the silver to form silver sulphide.

$2Ag + H2S \rightarrow Ag2S + H2$

Silver sulphide is black. When a thin coating of silver sulphide forms on the surface of silver, it darkens the silver. Rubber contains sulphur, which will cause silver to tarnish. Certain foods like eggs, mayonnaise, mustard, table salt, olives, salad dressing, vinegar, fruit juices and onions also hasten the silver tarnish process. The sulphur in these foods will corrode silver. Flowers and fruits can etch the silver containers due to the acid produced as they decay.

Ice Cubes are Cloudy on the Inside

Water contains both dissolved gases (e.g., oxygen) from the atmosphere and dissolved minerals (e.g., calcium and magnesium salts). The presence of these substances affects the temperature at which water freezes. Pure water freezes at 0~ water with dissolved gases and mineral salts freezes at a lower temperature. The higher the concentration of dissolved gases and minerals, the lower the freezing point of water. As water cools, the first layer of ice that forms is at the interface with air. As ice forms, pure water solidifies, leaving the dissolved gases and salts in solution. Thus, the freezing process concentrates the dissolved species in smaller and smaller volumes of liquid solution, effectively increasing their concentration. With a higher concentration of dissolved material, the temperature at which additional ice will form is lowered. The cloudiness in the center of an ice cube thus is the consequence of the concentration of dissolved gases and minerals that refract light and create an opaque appearance.

Free Flowing Salts and Desiccants

Calcium silicate ($CaSiO3$), a commonly used anti-caking agent, added to e.g. table salt, absorbs both water and oil. This white powder has the incredible ability to absorb liquids and still remain a flee-flowing powder. In general, calcium silicate absorbs 1 to 2.5 times its weight of liquids. For water, its total absorption power is estimated as 600%, that is, absorbing 600 times its weight of water.

Desiccants – Silica Gel

A desiccant is a hygroscopic substance that induces or sustains a state of dryness (desiccation) in its local vicinity in a moderately well-sealed container. Some commonly used desiccants are: silica gel, activated charcoal, calcium sulfate, calcium chloride, montmorillonite clay, and molecular sieves such as Zeolites. These desiccants remove water by a variety of physical and chemical methods: adsorption, a process whereby a layer or layers of water molecules adhere to the surface of the desiccant; capillary condensation, a procedure whereby the small pores of the desiccant become filled with water; and chemical action, a procedure whereby the desiccant undergoes a chemical reaction with water.

Montmorillonite clay is a naturally occurring adsorbent that swells to several times its original volume when water adsorption occurs.

The most commonly used desiccant is silica gel ($SiO2.\ H20$), an amorphous form of silica manufactured from sodium silicate and sulphuric acid. The porous nature of silica gel forms a vast surface area that attracts and holds water by both adsorption and capillary condensation, allowing silica gel to adsorb about 40% of its weight in water. Zeolites or “molecular sieves” are rigid, hydrated crystalline aluminosilicate minerals that contain alkali and alkaline earth metals. Zeolites possess a three-dimensional crystal lattice structure that forms surface pores of uniform diameter and contain numerous regular internal cavities and channels. Water molecules are readily incorporated within the pores and cavities.

Copper & Brass cleaning by Vinegar

Copper is a metallic element; brass is an alloy or mixture of the metallic elements copper and zinc. The surfaces of copper and brass items tamish with prolonged exposure to air, particularly in moist environments with high carbon dioxide (CO2) or sulfur dioxide (SO2) concentrations. The compounds that form on the surface, ranging in color from black to blue to dark green, dissolve readily in acidic solutions. Vinegar contains acetic acid, ketchup contains tomatoes rich in ascorbic acid (Vitamin C), and onions contain malic acid and citric acid. All of these foods provide variable amounts of acid to dissolve the tamish on copper surfaces.

List of Chemical Compounds with Common Names

Common Name	Chemical Name
Alum	Ammonium aluminium sulphate
Aspirin	Acetyl salicyclic acid
Battery acid or oil of vitriol	Sulphuric acid
Blue vitriol	Copper sulphate
Baking soda	Sodium bicarbonate
Bleaching powder	Calcium chlorohypochlorite
Borax	Sodium tetraborate
Butter of tin	Stanic chloride
Caustic soda	Sodium hydroxide
Caustic potash	Potassium hydroxide
Carbolic acid	Phenol
Chile saltpeter	Sodium nitrate
Carborundum	Silicon carbide
Corrosive sublimate	Mercuric chloride
Colomel	Mercuric chloride
Dry ice	Carbon dioxide (solid)

Common Name	Chemical Name
Formalin	Formaldehyde (40% solution)
Grain alcohol (spirit)	Ethyl alcohol
Green vitriol	Ferrous sulphate
Gypsum	Calcium sulphate
Gammexane (bhc)	Benzene hexachloride
Corrosive sublimate	Mercuric chloride
Colomel	Mercurous chloride
Dry ice	Carbon dioxide (dolid)
Foremalin	Formaldehyde (40% solution)
Grain alcohol (spirit)	Ethyl alcohol
Green vitriol	Ferrous sulphate
Gypsum	Calciumm sulphate
Gammexane	Benzene hexachloride
Butter of tin	Stanic chloride
Caustic soda	Sodium hydroxide
Caustic potash	Potsssium hydroxide
Carbolic acid	Phenol
Chile saltpetre	Sodium nitrate
Carbrundum	Silicon carbide
Corrosive sublimate	Mercuric chloride
Hydrolith	Calcium hydride
Hypo (antichlor)	Sodium thio sulphate

Common Name	Chemical Name
Indian nitre	Potassium nitrate
Lime stone	Calcium carbonate
Lunar caustic	Silver nitrate
Laughing gas	Nitrous oxide
Litharge	Lead monoxide
Muratic	Hydrochloric acid
Mohr's salt	Ferrous ammonium sulphate
Milk of magnesia	Magnesium hydroxide
Microcosmic salt	Sodium ammonium hydrogen posphate
Marsh gas (damp-fire)	Methane
Oleum	Sulphuric acid(fuming)
Oxone	Sodium peroxide
Plaster of paris	Calcium sulphate hemihydrate
Philospher's wool	Zinc oxide
Phosgene	Carboxyl chloride
Pearl ash	Potassium carbonate
Pyrene	Carbon tetrachloride
Picric acid	2, 4, 6, trinitrophenol
Quick lime	Calcium oxide
Red lead (minium)	Lead tetroxide
Sugar	Sucrose
Salked lime(milk of lime)	Calcium hydroxide

Common Name	Chemical Name
Sal ammoniac	Ammonium chloride
Sugar of lead	Lead acetate
Sand	Silicon dioxide
Table salt (common salt)	Sodium chloride
Tel	Tetra-ethyl lead
Tear gas	Chloropicrin
Washing soda	Sodium carbonate
Water glass	Sodium silicate
White vitriol	Zinc sulphate