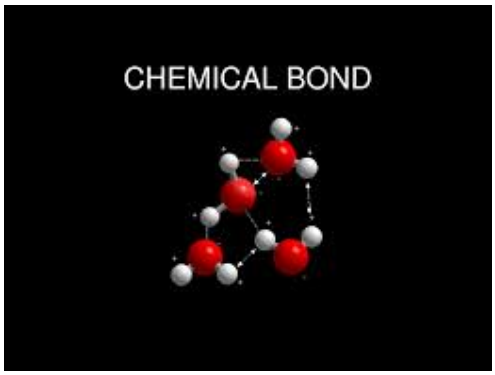
Chemical Bonding

Synopsis



Atoms of elements which have the atoms are electrical neutral. All atoms have a tendency to attain the 8 electrons in their valency orbit as in noble gases.

For this, they form bonds with another atom.

There are two kinds of bonds -

i) Ionic bond

ii) Covalent bond

Ionic bond is formed between atoms of two dissimilar elements due to transfer of electrons from the atom of one element to the other. The covalent bond is formed by the sharing of electrons between atoms.

Electronic theory of valency, valence – shell – electron – pair repulsion- theory (VSEPRT) are two theories which explains the formation on these bounds.

These theories are also explain the bond angles and bond nature of between atoms.

2 Mark Questions

1. List the factors that determine the type of bond that will be formed between 2 atoms?

A. There are several factors that determine the type of bond will be formed between the two atoms. They are-

a) The force of attraction or repulsion between the electrons and protons

b) Number of valence electrons present in the valence shell of the atom

c) Electro negativity (Electronegative) difference between the atoms ($\Delta EN \approx$ electronegative difference)

i) If $\Delta EN > 1.9$, ionic bond is formed.

ii) If ΔEN α 1.9, covalent bond is formed.

d) Atomic size

e) Ionization potential

f) Electron affinity.

2. Explain the difference between the valence electrons and the covalencey of an element.

A.

Valence Electrons	Covalence of an Element
1. Number of electrons present in the valence shell is known as valence electrons.	1. The capacity of atoms to neither gain, nor loose or share electrons is known as covalence.
2. Number of valence electrons is equal to the group number of the atom.	2. Covalence is equal to the number of electrons participate in the bonding

3. Valence electrons number is always a positive integer	3. Covalence may be positive or negative

3. Predict the reasons for low melting point for covalent compounds when compared with ionic compound.

A. In general, melting points depend on the force of attraction among the molecules & the atoms.

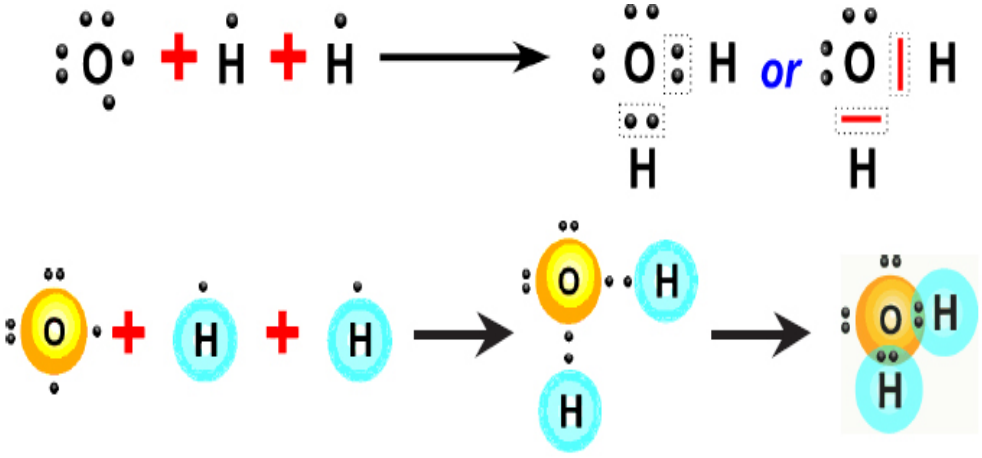
1) In case of covalent compounds, there exists a weak van der Walls force between the molecules. So, these covalent compounds posses low melting points.

2) While in case of ionic compounds, there exists on strong electrostatic attractions, between the Molecules. So, these requires high amount of energy to break the bond between the molecules, so, these posses high melting points.

But, in case of some covalent compounds like Diamond and graphite, Melting points & Boiling points are quite high, due to its giant structure.

4. Represent the molecule H_2O using Lewis notation.

A. One atom of Oxygen to from a water molecule i.e.-



2 hydrogen atoms One Oxygen atom water molecule (H_2O)

5. Represent each of the following atoms using Lewis notation:

a) Beryllium

b) Calcium

c) Lithium

A. a) Beryllium: $(_4Be^9) \rightarrow 1s^2\ 2s^2$

Its inner shell electrons are 2 & outer shell electrons are 2 we can represent its Lewis notation as $[\dot{B}\dot{e}]$

b) Calcium: $\mathbf{(_{20}Ca^{40})} \rightarrow 1s^2\ 2s^2\ 2p^6 3s^2 3p^6 4s^2$

(2, 8, 8, 2)

It has $2e^-$ in I shell, Be^- in 2^{nd} shell, $8e^-$ in 3^{rd} shell & it has $2e^-$ in 4^{th} shell i.e., in valence shell.

So, its Lewis structure is $[\dot{C}\dot{a}]$

c) Lithium $(_3Li^6) \rightarrow 1s^2\ 2s^2$

It has $2e^-$s in I shell & $1e^-$ in II shell ie in valence shell

So, its Lewis structure is $[\dot{L}\dot{i}]$

6. Represent each of the following molecules using Lewis notation:

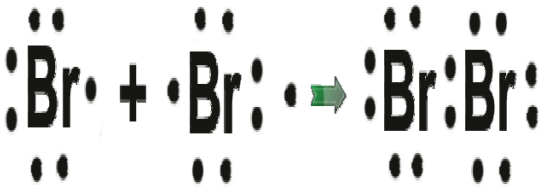
(a) Bromine gas (Br_2)

(b) Calcium chloride ($CaCl_2$)

(c) Carbon dioxide (CO_2)

(d) Which of the three molecules listed above contains a double bond?

A. a) Bromine gas (Br_2):



b) Calcium chloride ($CaCl_2$):

c) Carbon dioxide (CO_2)

d) In the above, Carbon dioxide (CO_2) contains double bond

$$CO_2 \approx (O = C = O)$$

7. How Lewis dot structure helps in understanding bond formation between atoms?

A. The valence electrons with the atom of an element are represented in a short form by Lewis symbol is electron dot structure. We represent the nucleus and inner shell electrons of the atom by the symbol of the element and electrons in the outer shell by dots or cross mark.

Basing, on the Lewis structure we can understand the valence of an element. Basing on the valence we can predict that it may form ionic bond or covalent bond.

1 Mark Question

1. What is Octet rule?

A. "Generally atoms of elements undergo chemical reaction, that to form stable electronic configuration either by loss or gain of electrons to forms atoms with eight outer shell electrons.

This phenomenon is defined as the octet law.

2. What is hybridization?

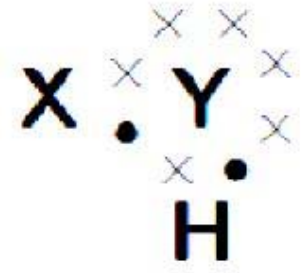
A. It is a phenomenon of inter mixing of orbitals of almost equal energies which are present in the outer shells of the atom and their resulting (or) redistributing (or) reshuffling into the same number of orbitals but with equal properties like energy and shape.

3. Define Co-ordination Number?

A. Number of ions of opposite charge that surrounds a given ion in a crystal is known as co-ordination number.

4 Mark Questions

1. A chemical compound has the following Lewis notation:



a) How many valence electrons does element Y have?

b) What is the valency of element Y?

c) What is the valency of element X?

d) How many covalent bonds are there in the molecule?

e) Suggest a name for the elements X and Y.

A. a) Six (6)

b) Two (2)

c) One (1)

d) Two (2)

e) Element X – hydrogen ($_1H^1$)

Element Y – Oxygen ($_8O^{16}$)

The formed molecule may be H_2O.

2. Why do only valence electrons involve in bond formation? Why not electron of inner shells? Explain.

A. 1. The electrons present in the outermost orbital of an atom are known as valence electrons.

2. They are very active.

3. They are weakly attracted to the nucleus. So that involves a chemical bond formation

4. Electrons present in the inner shells cannot participate in bond formation because.

i) The electrons present in the inner shells are stable.

ii) Inner electrons are strongly attracted by the nucleus.

3. Explain the formation of sodium chloride and calcium oxide on the basis of the concept of electron transfer from one atom to another atom.

A. Formation of sodium chloride (NaCl):

1. Sodium chloride is formed from the elements sodium (Na) and chlorine (C*l*).

2. When sodium (Na) atom loses one electron to get octet electron configuration, it forms action (Na^+)

3. Now Na^+ gets electron configuration that of Neon (Ne) atom.

$$N^a \rightarrow Na^+ e^-$$

4. Chlorine, has storage of one electron to get octet in its valence shell.

5. So, it gains the electron that was lost by Na to form anion and gets electron configuration of Argon(Ar)

$$Cl + e^- \rightarrow Cl^-$$

6. Transfer of electrons between Na and C*l* atoms, results in the formation of Na^+ and Cl^- ions.

7. These oppositely charged ions get attracted towards each other due to electrostatic forces and forms the compound sodium chloride (Nac*l*)

$Na^+ + Cl^- \rightarrow NaCl$

Formation of Calcium Oxide (CaO):

1. Calcium (Ca) reacts with Oxygen (O) to from an ionic compound calcium Oxide(CaO).
2. Calcium atomic number is 20. Its electronic configuration is 3. 8, 8, 2.
3. $Ca \rightarrow Ca^{+2} + 2e^-$

   i.e., calcium losses $2e^-$ and becomes Ca^{+2}.
4. Oxygen atomic number is 8. Its electronic configuration is 2, 6.
5. $O \xrightarrow[2e^-]{} O^{-2}$ i.e., Oxygen $2e^-$ and becomes O^{-2}.
6. These oppositely charged ions gets attracted towards each other due to electrostatic forces and form the compound calcium Oxide (CaO)

   $Ca^{+2} + O^{-2} \rightarrow CaO$

4. A, B, and C are three elements with atomic number 6, 11 and 17 respectively.

i. Which of these cannot form ionic bond? Why?

ii. Which of these cannot form covalent bond? Why?

iii. Which of these can form ionic as well as covalent bonds?

A. Here given elements are

A – Carbon ($_6C^{12}$)

B – Sodium ($_1Na^{23}$)

C – Chlorine ($_{17}Cl^{34}$)

i) A – Carbon ($_6C^{12}$) forms covalent bonds and cannot form ionic bond. Its valence electrons are 4. It is difficult to lose or gain $4e^-$ to get octet configuration. So, it forms bond by sharing of electron, i.e., it forms covalent bond.

ii) B – Sodium ($_1Na^{23}$) forms ionic bond and cannot form covalent bonds. It valence electrons are only 1. So, it is so easy to donate that one electron for other atom, rather than sharing it and then it becomes an ion. So, it can form ionic bond.

iii) Element C – Chlorine ($_{17}Cl^{34}$) forms both ionic & covalent bonds. As its atomic number is 17. It is able to in Hc*l* molecule to form covalent bond.

5. How bond energies and bond lengths of molecule help us in predicting their chemical properties? Explain with examples.

A. Bond length: It is defined as the distance between the 2 nuclei of the atoms which involved in bonding.

Bond Energy: It is defined as the energy required to break the bond between 2 atoms of a diatomic covalent compound in its gaseous state.

Generally, bond energies and bond lengths of molecule help us in predicting their chemical properties. If a molecule is having low bond energy and high bond length values, it is a very active one. They are having polar nature. They actively participate in chemical reactions.

For example:

In Iodine molecule, as the bond length between the atoms is high due to its large sized atoms. So, amount of energy required for bond breakage is low. So, it is highly reactive in reactions.

$$i.e\left(Bond\ energy\ \alpha \frac{1}{Bond\ length} \right)$$

So, higher the bond energy, more stable and less reactive in case of chemical reactions.

Similarly, Melting and Boiling points of a substance can also be determined by this bond energies and bond lengths.

6. Collect the information about properties and uses of covalent compounds and prepare a report.

A. Properties of covalent compounds:

1) These are usually liquids or gases in nature, but some of them are solids.
2) These are having low melting and boiling points.
3) These are freely soluble in non polar solvents like benzene, carbon tetrachloride, but soluble in polar solvents like water.
4) These are bad conductors of electricity.
5) Covalent bond is a directional bond. So, covalent compounds exhibit the phenomenon of isomerism.

Uses of covalent compounds:

1) 99% of our body, was made up of covalent compounds
2) Water is a covalent compound. We know its many uses.
3) Sugars, tea, coffee as many food materials are all a form of covalent compounds.
4) Covalent bonding can change ability of ice to melt itself, because when the CO_2 interact with the hydrogen atoms, the atoms of water splits into lower. Molecules with molecular compounds.
5) Almost everything on earth other than most simple inorganic salts are covalent.

7. Draw simple diagrams to show how electrons are arranged in the following covalent molecules:

a) Calcium oxide (CaO)

b) Water (H_2O)

c) Chlorine (Cl_2)

A. a) Calcium oxide (CaO):

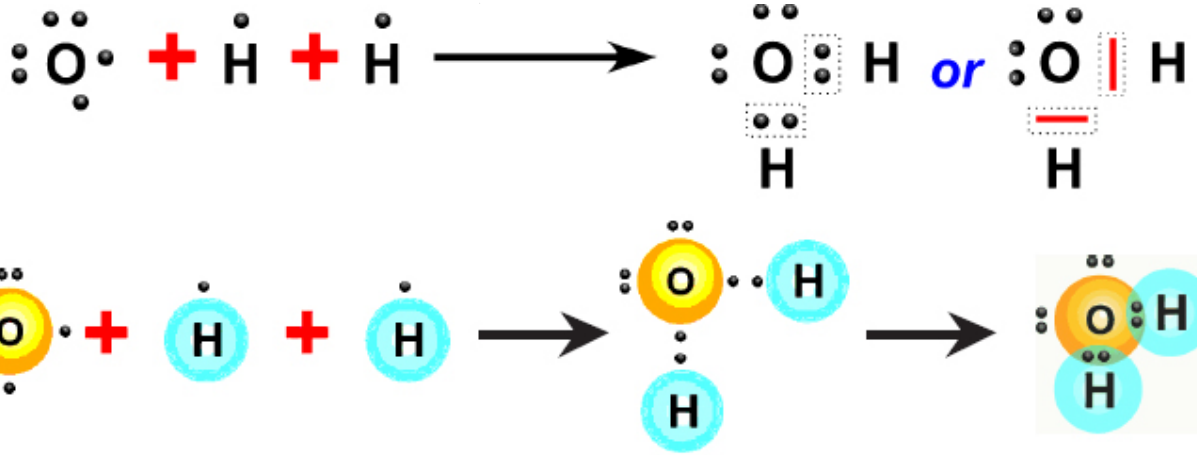
$$CaO \rightleftharpoons Ca^{+2} : O^{-2}$$

$$Ca^{+2} + O^{-2} \longrightarrow CaO$$

Calcium atom	Oxygen	Calcium ion	Oxygen ion
2, 8, 8, 2	atom 2, 6	2, 8, 8	2, 8

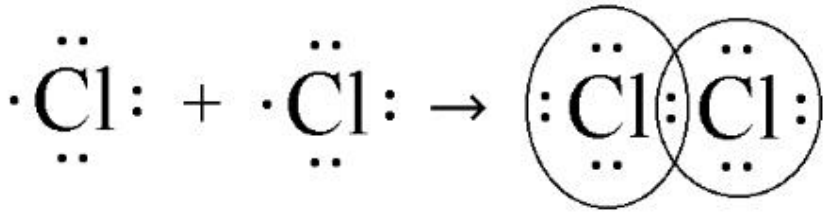
b) Water (H_2O):

The formation of water molecule of 2-hydrogen atoms, one oxygen atom can be shown like this also:



c) Chlorine (Cl_2):

Shared pair of electrons



Cl atom 2, 8, 7 Cl atom 2, 8, 7 Chlorine molecule (2, 8, 8) ; (2, 8,8)

8. Two chemical reactions are described below.

i) Nitrogen and hydrogen react to form ammonia (NH_3)

ii) Carbon and hydrogen bond to form a molecule of methane (CH_4).

For each reaction, give:

a) The valency of each of the atoms involved in the reaction.

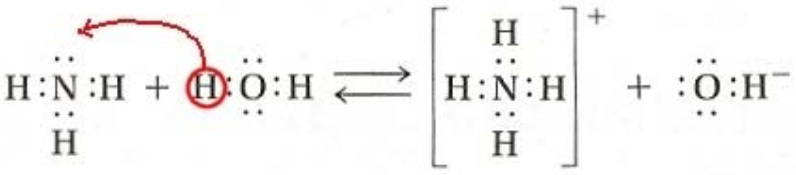
b) The Lewis structure of the product that is formed.

A. i) Nitrogen and hydrogen reacts to form Ammonia (NH_3).

$$N_2 + 3H_2 \rightarrow 2NH_3$$

a) Valency of Nitrogen is 3 & hydrogen is 1.

b) The chemical formula of the product is NH_3

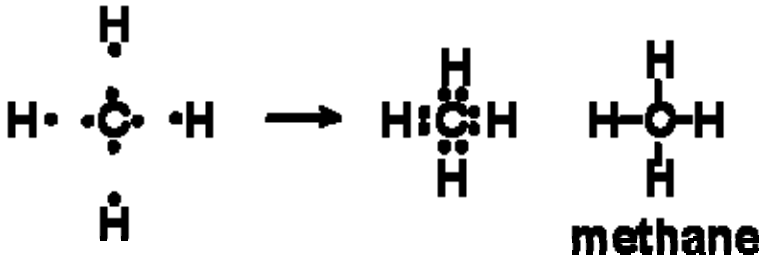


ii) Carbon and hydrogen reacts to form methane (CH_4).

$$C + cH_2 \rightarrow CH_4$$

a) Valency of carbon is 4 & hydrogen is 1.

b) Chemical formula of formed product is CH_4.



9. What is octet rule? How do you appreciate role of the octet rule in explaining the chemical properties of elements?

A. Octet rule:

It states that the atoms of elements tend to undergo chemical changes that help to leave their atoms with eight outer shell electrons.

It was found that the elements which participate in chemical reaction get Octet (or) $ns^2\ np^6$ configuration similar to that of nobel gas elements.

Chemically active elements do not have an octet of electrons in the valence shell of their atoms. Their reactivity arises from their tendency to achieve the octet, by forming bonds either with atoms of their own type or with atoms of other elements.

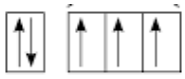
10. Explain the formation of the following molecules using valence bond theory.

a) N_2 molecule

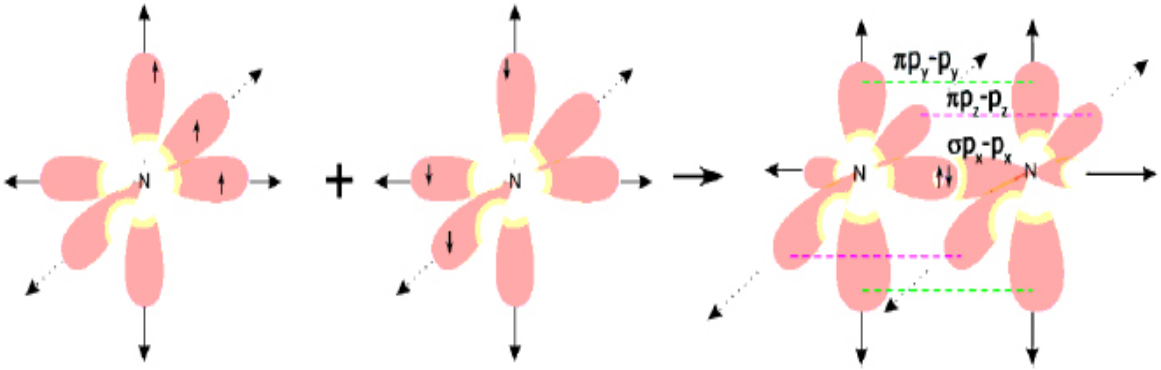
b) O_2 molecule.

A. a) formation of N_2 molecule:

Nitrogen ($_7N^{14}$) has electronic configuration $1s^2\ 2s^2sp^3$ i.e., in its valence shell $2s^2\ 2p^3\ (2p^1_x\ 2p^1_y\ 2p^1_z)$



If the Px one of the Orbital of 'N' atom overlaps with px orbital of another 'N' atom giving ($\sigma p_x - p_x$) bound, along the internuclear axis. Similarly p_y and p_z orbitals of one N atom, overlap with p_y and p_z orbital of other N atom N atom laterally. Respectively perpendicular to internuclear axis given ($\pi\ p_y - p_y$) ($\pi p_z - p_z$) bonds. So, N_2 molecule has a triple bond between 2 Nitrogen atoms.



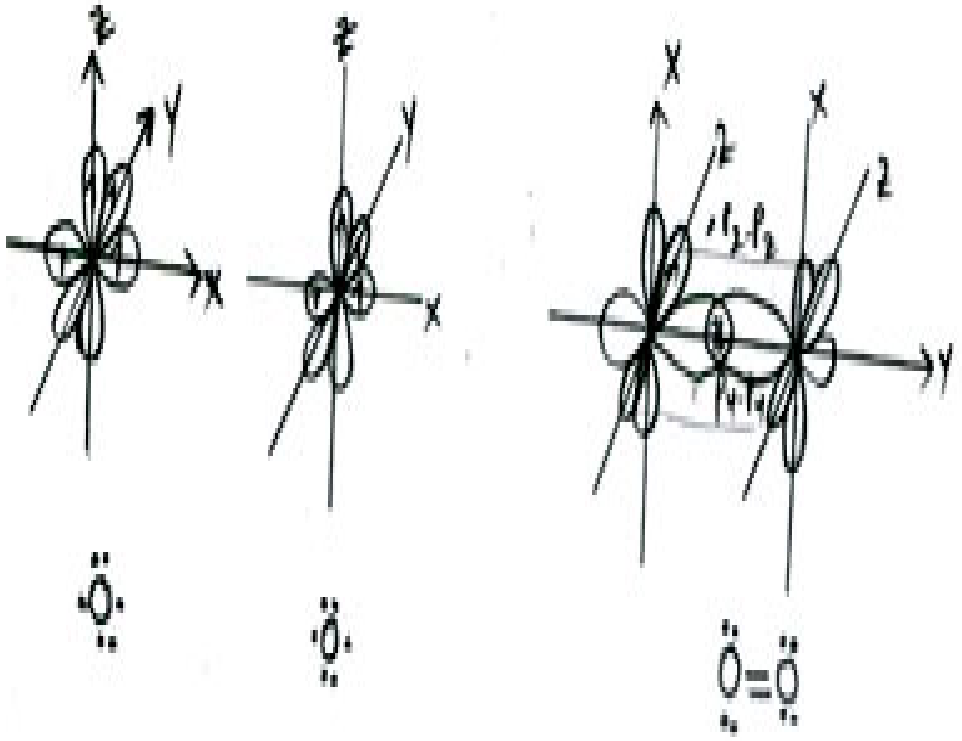
b) Formation of O_2 molecule:

Oxygen ($_8O^{16}$) – has electronic configuration $1s^2 2s^2 2p^4$ i.e., in its valence shell $2s^2\ 2p^4$ ($p^2_x p^1_y p^1_z$)

If the py orbital of one Oxygen atom overlaps with p_y orbital of another Oxygen atom along the intern clear axis, a sigma $p_y - p_y$ bond (σp_y - p_y) is formed.

Similarly p_z orbital of 'O' atom overlaps with p_z orbital opf other 'O' atom laterally, perpendicular to the internuclear axis giving a $\pi p_z - p_z$ bond.

O_2 molecule has a double bond between 2 Oxygen atom.



11. What is hybridization? Explain the formation of the following molecules using hybridization.

a) Be Cl_2 b) BF_3

A. Hybridization:

The phenomenon of intermixing of orbitals of the same atom which have near same atom and near same energy to form equal number of new orbitals of equivalent energy is known as hybridization

a) Formation of $BeCl_2$:

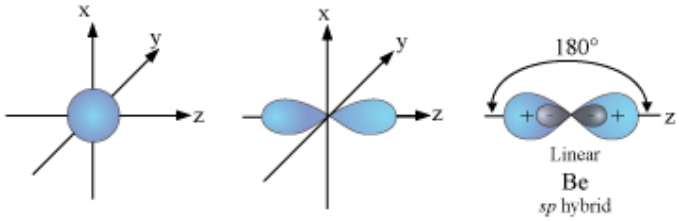
$BeCl_2$- Beryllium chloride

The atomic number of Beryllium = 4

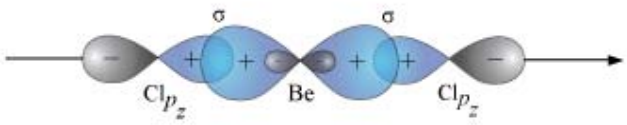
The electronic configuration of Beryllium atom in its ground state is $1s^2 2s^2$

The electronic configuration of beryllium atom in its excited state us $1s^2\ 2s^1\ 2p^1$

In the excited state beryllium atom '2s' and '2p' orbital's intermix to give 2 equivalents of be is $1s^2 2s^1 2p^1$.



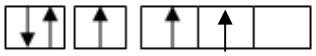
It has one half filled p-orbital. The half filled 3px orbitals of 2 chlorine atoms overlap with 'sp' hybrid orbitals of beryllium atom in their axes to form σsp –p bonds.



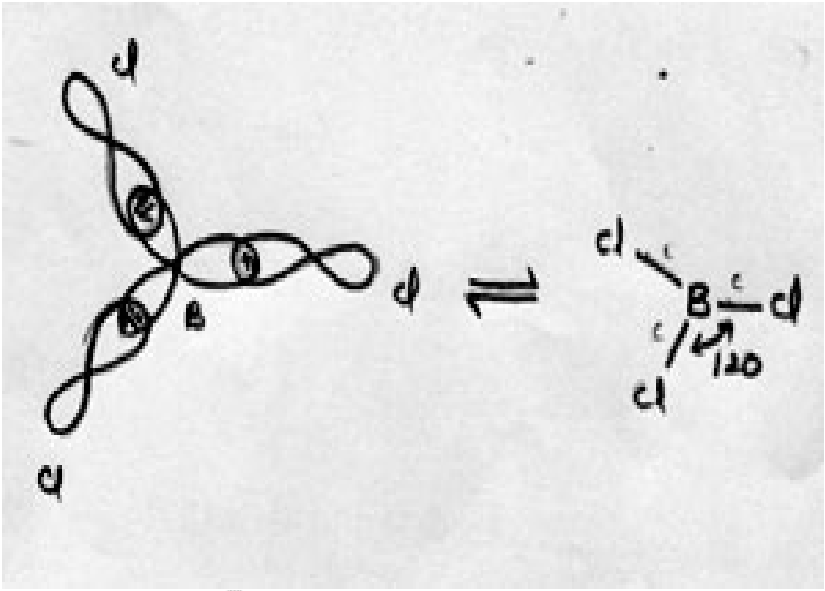
$BeCl_2$ Molecule so found has liner shape. The bond angle in $BeCl_2$ is 180^0.

b) Formation of Boron Trichloride (BCl_3):

The central atom in BCl_3 is boron. The electronic configuration of boron atom in its excited state is $1s^2\ 2s^1 2p^2$.

B (7 = 5) is 

In the excited boron atom ‘2s’ orbital and 2 ‘2p’ orbital intermix to give three equivalent sp2 hybrid orbitals. In the formation of BCl_3 Molecule, 3 $8p^2$ hybrid orbitals of boron overlap with half filled $3p_z$ orbital’s of boron overlap with half filled 3px orbital of 3 chlorine atoms in their axes to give three σsp^2 –p bonds. BCl_3 molecule so formed has trigonal planar structure. The bond angle in BCl_3 is 120^0.



Fill in the Blanks

1. Electrons in _____ shell are called valence electrons.
2. Except _____ gas all other noble gases have octet in their valence shell.
3. Covalency of elements explains about member of _____ formed by the atom.
4. Valence bond theory was proposed by _____.
5. In _____bonding, the valence electrons are shared among all the atoms of the metallic elements.
6. Expand USEPRT _____.
7. Water molecule having _____ shape.

Key:

1) Valency / Outermost; 2) Helium (He); 3) Bonds;
4) Linus Pauling; 5) Covalent;
6) Valence shell Electron pair repulsion theory;
7) Angular/v;

Multiple Choice Questions

1) Which of the following elements is electronegative? [ ]

a) Sodium (Na) b) Oxygen (O)
c) Magnesium(Mg) d) Calcium (Ca)

2) An element $_{11}X^{23}$ forms an ionic compound with another element 'Y'. Then the charge on the ion formed by X is [ ]

a) +1 b) +2 c) -1 d) -2

3) An element 'A' forms a chloride ACl4. The number electrons in the valence shell of 'A' is? [ ]

a) 1 b) 2 c) 3 d) 4

4. General electronic configuration (valence shell) of inert gas is- [ ]

a) $ns^2\ np^4$ b) $ns^2\ np^3$ c) $ns^2\ np^5$ d) $ns^2\ np^6$

5. Ionic bond is formed between atoms of elements with EN (electronegativity differences) is _____. [ ]

a) > 1.7 b) < 1.7 c) > 1.9 d) < 1.9

Key:

1) b; 2) a; 3) d; 4) c; 5) c.

Match the following

I.	**Group-I**		**Group-II**
	Compound		**Shape**
1.	$BeCl_2$	**[ ]**	A) Angular or Bent
2.	BCl_3	**[ ]**	B) Pyramidal
3.	CH_4	**[ ]**	C) Linear
4.	NH_3	**[ ]**	D) Tetrahedral
5.	H2O	**[ ]**	E) Trigonal planar

Key:

1. C; 2. E; 3. D; 4. B; 5. A.

II. **Group-I** **Group-II**

1.	Ionic Bonding	[ ]	A) Attraction of electronic clouds
2.	Covalent Bond	[ ]	B) Negative ion
3.	Cation	[ ]	C) Formed by electrostatic forces
4.	Anion	[ ]	D) Formed by sharing of electors
5.	Metallic bond	[ ]	E) Positive ion

Key:

1. C; 2. D; 3. E; 4. B; 5. A.

III. **Group-I** **Group-II**

	Compound		**Bond angle**
1.	$BeCl_2$	[ ]	A) 104^028^1
2.	BCl_3	[ ]	B) 109^028^1
3.	CH_4	[ ]	C) 107^0
4.	NH_4	[ ]	D) 120^0
5.	H_2O	[ ]	E) 180^0

Key:

1. E; 2. D; 3. B; 4. C; 5. A.

5 Mark Questions

1. Formation Of different elements

1. H_2O 2) $BeCl_2$ 3) BF_3 4) CH_4 5) NH_3

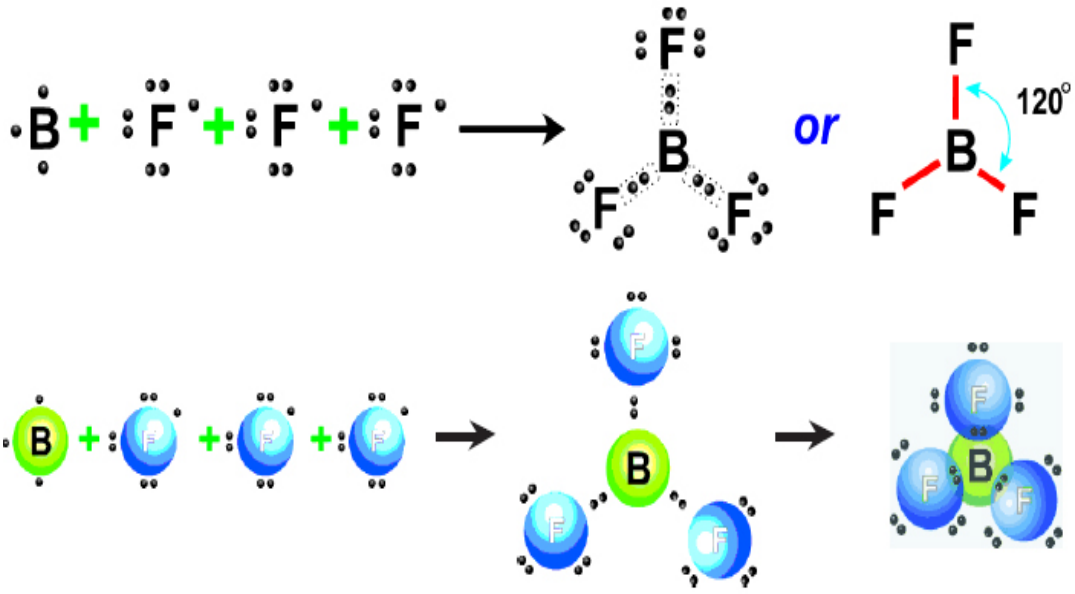
A.

1. H_2O

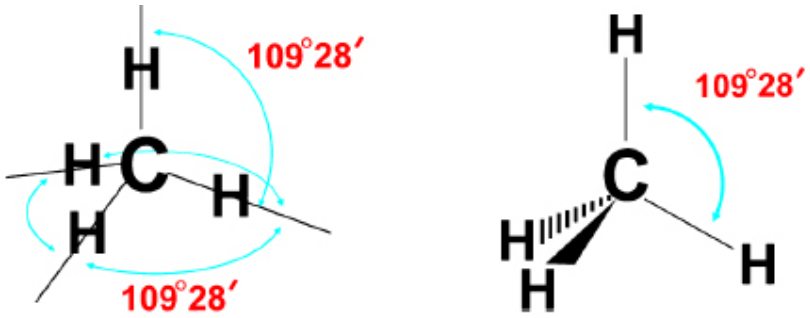
2) $BeCl_2$

Cl — Be — Cl

3) BF_3



4) CH_4



5) NH_3