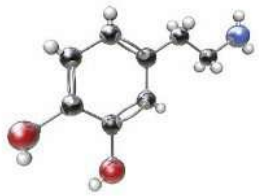
3 CHAPTER

CHEMICAL BONDING



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After studying this chapter, students will be able to:

- Describe that noble gas electronic configuration, octet and duplet rules chemical properties of main group elements
- Compare between the formation of cations and anions
- Account for the electropositive and electronegative nature of metals and non-metals. Define ionic, covalent, coordinate covalent and metallic bonds
- Differentiate between ionic compounds and 'covalent compounds. (The following points need to be included in the respective definitions:
  a. Ionic Bond as strong electrostatic attraction between oppositely charged ions
  b. b: Covalent bond as strong electrostatic attraction between shared electrons and two nuclei.
  c. Metallic bond as strong electrostatic attraction between cloud/sea of delocalized electrons and positively charged cations)
- Explain the properties of compounds in terms of bonding and structure Compare uses and properties of- materials such 'as strength and conductivity as determined by the type of chemical bond present between their atoms.
- Interpret the strength of forces of attraction and their impact on melting and boiling points of ionic and covalent compounds.
- Justify the availability of free charged particles (electrons or ions) for conduction of electricity in. ionic compounds (solid and molten) covalent compounds and metallic bonds.
- Recognize that some substances can ionize when 'dissolved in water: (e.g. acids dissolve in Water and conduct electricity).
- Júsfifý [the suitability of. usage of graphite, 4iarhond and metals-for industrial purposes (Some examples may include:
  a. graphite as lubricant or an electrode
  b. diamond in cutting tools
  c. metals for wires, and sheets)
- Draw the structure of ionic and covalent compounds along with their formation. {some examples can include: a. ionic bonds in binary compounds, such as NaBr,-NaF, $CaCl_2$ using dot-and- cross diagrams and Lewis dot structures; simple molecules including H_2, Cl_2, O_2, N_2, H_2O, CH_4, NH_3, HCl, CH_3OH, C_2H_4, CO_2, HCN, and similar molecules using dot and-cross diagrams and Lewis-dot structures).

3.1 WHY DO ATOMS FORM CHEMICAL BOND?

LONG QUESTIONS

Q.1 What is a chemical bond and why do atoms form chemical bonds? (U.B+K.B)

Ans:

CHEMICAL BOND

"A chemical bond is defined ***as force of attraction between atoms that holds them together in a substance****".*

Example:

A bond formed between H and Cl atoms in a molecule of HCl.

WHY DO ATOMS FORM CHEMICAL BONDS?

Atoms form bonds to get stability

Achievement of Stability:

Atoms achieve stability by **attaining electronic configuration of inert gases (He, Ne or Ar etc)** i.e. **ns^2 np^6 having 2 or 8 electrons in the valence shell** is sign of stability.

Explanation

Atoms have a tendency to decrease their energy. They can do this by combining with other atoms. It is a natural phenomenon because it increases the stability of atoms. .

How do atoms succeed in lowering their energy?

The atoms succeed in lowering their energy by gaining the valence shell configuration of noble gases (completing 2 or 8 electrons in the last shell). They gain the valence shell configuration of noble gases by losing, gaining or sharing electrons.

Explanation

The early chemists had started thinking about this a long time ago. They finally succeeded to get an answer only when the noble gases He, Ne, Ar, Kr, Xe were discovered.

Helium has two electrons in its outer shell while all other noble gases have eight electrons in their outermost shells.

Un-reactivity of Noble Gases

We also know about these gases that neither their atoms combine with themselves nor with other atoms. The probable reason for this lack of reactivity was their stability. It was suggested that these gases were stable due to the presence of two electrons in helium and eight electrons in the outermost shells of the rest of gases. This gave rise to a principle that having two electrons (for hydrogen and helium which have only the first shell) or eight electrons in the outermost shell meant stability and hence un-reactivity as well. This principle was named as Duplet or Octet Rule.

Rules to Complete Valence Shell:

Following are two rules by which atoms complete their valence shells:

(i) Duplet rule:

Attaining ***two electrons*** *in the valence shell is called duplet rule. For example, helium (He).*

(ii) Octet Rule:

Attaining ***eight electrons*** *in the valence shell is called octet rule. For example, Neon (Ne).*

Significance of duplet or octet rule

The discovery of duplet or octet rule was followed by another similar suggestion that atoms form bonds because they would like to lower their energy by completing their duplet or octet.

Example

- **Sodium Atom**

  For sodium atom it is easy to lose one electron and stabilize itself than to gain seven electrons while completing its octet. Sodium atom, therefore, adopts the energetically easier path and loses its electron to form a bond.

- **Hydrogen Atom**

  In the same way, it is energetically favourable for hydrogen atom to lose one electron to become proton (H^+) or gain one electron to become hydride ion (H^-). In the latter case, it completes its duplet.

  Alkali and alkaline earth metals are therefore expected to be electropositive metals which will form bonds with electronegative elements of 6th and 7th groups.

Demerit of Octet Rule

Although, in the beginning, octet rule played a significant role in understanding the nature of a chemical bond, yet further investigations found it to be less important.

SHORT QUESTIONS

Q.1 What is a chemical bond? (RWP 2017)(K.B)

Ans:

CHEMICAL BOND

"A chemical bond is defined as ***force of attraction between atoms that holds them together in a substance****".*

Example:

A bond formed between H and Cl atoms in a molecule of HCl.

Q.2 Why do atoms form chemical bonds? (U.B)

Ans: Answer given on page # 60

Q.3 Why noble gases are non-reactive? (U.B)

Ans: Answer given on page # 60

Q.4 Importance of the noble gas electronic configuration. (U.B)

Ans: Answer given on page # 60

Q.5 Define duplet rule. (K.B)

Ans: Answer given on page # 60

Q.6 What is octet rule? (K.B)

Ans: Answer given on page # 60

Q.7 Define chemical bond. (RWP 2017 G-II)(K.B)

Ans: Answer given on page # 60

Q.8 What is the rule by which atom complete their valence shell? (U.B)

Ans:

RULES TO COMPLETE VALENCE SHELLS

Following are the rules by which atoms complete their valence shells:

Duplet Rule:

"Attaining of two electrons in the outermost shell either by sharing, gaining or losing of electrons is called duplet rule".

Octet Rule:

"The attaining of 8 electrons configuration in the valence shell, either by sharing, by losing or by gaining electrons is called octet rule".

MULTIPLE CHOICE QUESTIONS

1. Atoms react with each other because: (GRW 2016)(U.B)

(A) They are attracted to each other (B) They are short of electrons
(C) They want to attain stability (D) They want to disperse

2. Atoms achieve stability by attaining electronic configuration of: (U.B)

(A) Halogens (B) Transition metals (C) Noble gases (D) Non-metals

3. Electronic configuration of Ne is: (K.B)

(A) 2, 8 (B) 2, 6 (C) 2, 8, 2 (D) 2, 8, 1

4. Noble gases have _____ or _____ electrons in their valence shell. (K.B)

(A) 2 or 8 (B) 2 or 10 (C) 1 or 7 (D) 3 or 5

5. Noble gases are: (K.B)

(A) Reactive (B) Very reactive (C) Unstable (D) Non-reactive

6. An atom can accommodate eight electrons in its valence shell by _____ electrons. (U.B)

(A) Gaining (B) Sharing (C) Giving (D) All of these

3.2 CHEMICAL BOND

LONG QUESTIONS

Q.1 (A) What is meant by chemical bond?

(B) Name the types of chemical bonds? Also define bonding electrons. (K.B)

(C) What is ionic bond? Discuss the formation of ionic bond between sodium and chlorine atoms.(DGK 2016, RWP

Ans:

(A) CHEMICAL BOND

Definition

A chemical bond is a force of attraction between atoms which holds them together in the form of a molecule or a compound.

When atoms of different substances approach each other, there are two possibilities. They may attract or repel each other. If the forces of attraction between them dominate the forces of repulsion, the energy of the system gets lowered and as a result the two atoms will react to form a new molecule. Conversely, the two atoms simply move away from each other.

(B) TYPES OF BOND

There are **four** types of chemical bonds depending upon the way how valence electrons are involved in bonding.

(1) Ionic bond
(2) Covalent bond
(3) Coordinate covalent bond
(4) Metallic Bond

We shall consider here three types of bonds.

Bonding Electrons:

*"The **valence electrons**, which are **involved in chemical bonding**, are termed as bonding electrons".*

(B) IONIC BOND

Definition:

*"The type of chemical bond which is **formed due to complete transfer of electron from one atom to another atom** is called ionic bond".*

Examples:

- Bond between Na and Cl in NaCl
- Bond between K and Cl in KCl

Elements Forming Ionic Bond

Ionic bond is formed between metals of **Group-1** and **Group-2 (more electropositive metals) and non-metals of Group-15 to Group-17 (more electronegative non-metals)**.

If the **difference of electronegativity** between two elements **is more than 1.7** then the bond between them will be predominantly **ionic bond**.

Formation of Ionic Bond

A chemical bond is formed as a result of the tendency of atoms to lose or gain electron or electrons to acquire the electronic configuration of the nearest noble gas because this is a more stable electronic structure.

An ionic bond is therefore a bond which is formed by the complete transference of electron or electrons from one atom to another atom.

Examples

1. Formation of Ionic Bond in NaCl

Let us take the example of the formation of a simple and important compound, sodium chloride. This compound is formed when the elements sodium and chlorine react chemically.

Electronic configurations

The electronic configurations of these elements are shown in Fig (3.1).

	1st shell	2nd shell	3rd shell
$_{11}Na$	2	8	1
$_{17}Cl$	2	8	7

Fig (3.1): Electronic Configurations of Sodium and Chlorine

Steps Involved

Following are the steps involved for the formation of ionic bond in sodium chloride (NaCl):

(i) Formation of Na^+ and Cl^- Ion:

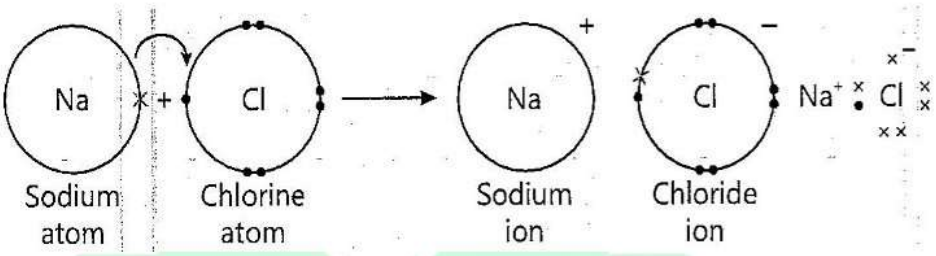
An electron from the outermost shell of sodium atom is transferred to the outermost shell of chlorine atom and in doing so, both these atoms acquire the electronic configurations of their nearest noble gases.

(ii) Establishment of Ionic Bond:

Na^+ and Cl^- ions stabilize themselves by combining with each other due to **electrostatic force of attraction** between them.

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

$$Na \longrightarrow Na^+ + e^-$$
$$e^- + Cl \longrightarrow Cl^-$$
$$Na + Cl \longrightarrow Na^+Cl^-$$



Explanation

Sodium chloride, formed as a result of the chemical reaction contains the positively charged sodium ions (Na+) and the negatively charged chloride ions (Cl-). These oppositely charged ions are then held together by the electrostatic force of attraction. The chemical bond, thus formed, is called an **Ionic or an Electrovalent Bond**.

Electrons Involved in a chemical reaction

It should be noted here that an electron or electrons, which take part in a chemical reaction, come only from the outermost shells of the atoms.

2. **Formation of Ionic Bond in NaF**

Sodium reacts with fluorine to give sodium fluoride, forming ionic bond.

3. **Formation of Ionic Bond in NaBr**

Similarly, sodium also reacts with bromine to give sodium bromide, forming ionic bond.

4. **Formation of Ionic Bond in $CaCl_2$**

Calcium, an alkaline earth metal, loses two electrons to form calcium chloride ($CaC1_2$). Fig (3.3)

$$Ca \longrightarrow Ca^{2+} + 2\bar{e}$$
$$2Cl + 2\bar{e} \longrightarrow 2Cl^-$$

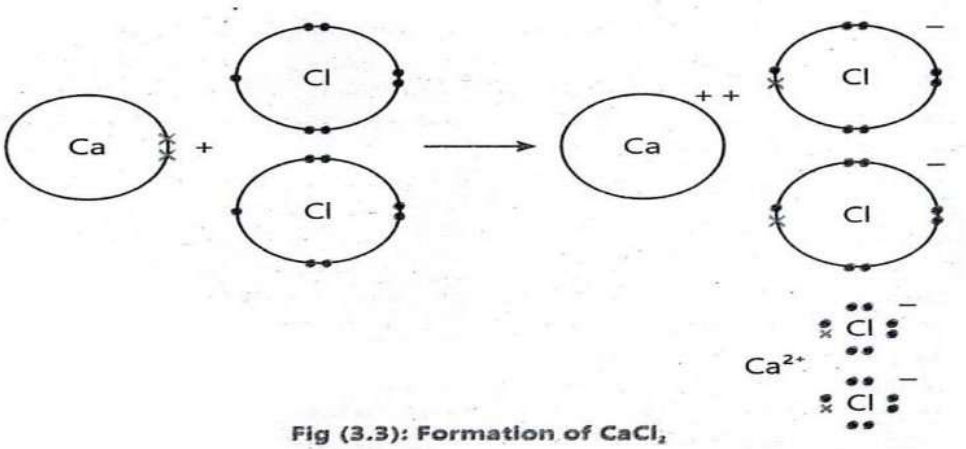
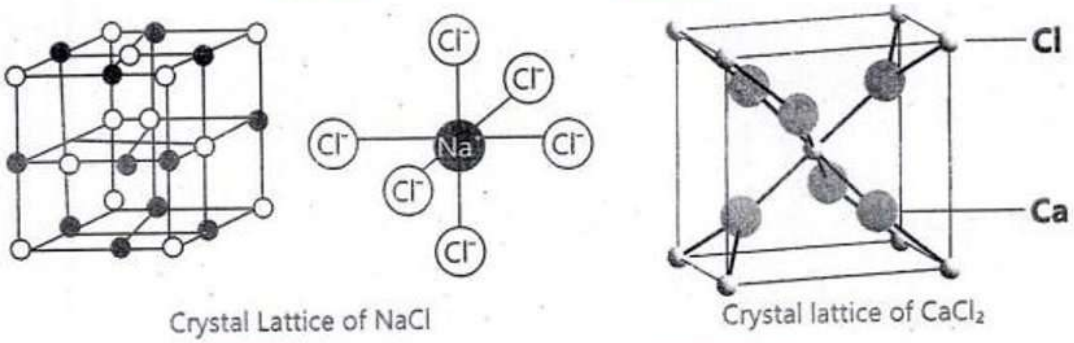


Fig (3.3): Formation of $CaCl_2$

There ions then surround each other three dimensionally to form a crystal lattice.

Figures of crystal lattices of NaCl, NaBr, NaF and $CaC1_2$. (fig 3.4)



Crystal Lattice of NaCl

Crystal lattice of $CaCl_2$

An ionic bond is therefore a bond which is formed by the complete transference of electron or electrons from one atom to another atom.

Ionic Compounds

Definition

The compounds having ionic bond in them are called ionic compounds or electrovalent compounds.

Examples

KCI, MgF, NaF, KBr, CaF_2

INTERESTING INFORMATION
ELECTRONIC CONFIGURATION The arrangement of electrons around the nucleus of an atom in shells and sub-shells is called electronic configuration

EXERCISE
1. What types of elements form ionic bonds? **Ans: ELECTRONS FORMING IONIC BOND** The elements of **Group-1** and **Group-2 being metals** have the tendency to **lose their valence electrons forming positively charged ions** whereas **non-metals of Group-15 to Group-17** have tendency to **gain or accept electrons**. They are electronegative

elements with high electron affinities. If atoms belonging to these **two different groups, metals and non-metals, are allowed to react, chemical bond is formed**.
If the **difference of electronegativity** between two elements **is more than 1.7** then the bond between them will be predominantly **ionic bond**.

2. What are the conditions for an ionic bond to form?

Ans:

CONDITIONS FOR AN IONIC BOND

- Ionic bond is formed involving valence electron only.
- It is formed between more electropositive metals and more electronegative non-metals.
- More electropositive metals lose electron to form positive ion
- More electronegative non-metals gain electron to form negative ion

Q.2 Define covalent bond. Explain the types of covalent bond.

(MTN 2016, BWP 2016, FSD 2017, GRW 2016 G-I)(U.B+K.B)

OR

Explain the types of covalent bond with at least one example of each.

Ans:

COVALENT BOND

Definition:

*"The type of bond, which is **formed due to mutual sharing of electrons**, is called covalent bond."*

Examples:

Bonds formed between atoms in hydrogen, chlorine, nitrogen and oxygen are covalent in nature.

Elements Forming Covalent Bond:

The **elements of Group-13 to Group-17** when allowed to react with each other, they form a chemical bond by mutual sharing of their valence shell electrons.
When bonding atoms have **comparable values of electronegativity** they share their electrons and form covalent bonds.

Formation of Covalent Bond

During the formation of an ionic bond, the atoms lower their energy by the transference of an electron and thus acquire the electronic configuration of the nearest noble gas. However, it is not the only way by which atoms can lower their energy. Some atoms decrease their energy by mutually sharing their electrons. This can be explained as follows.

Mechanism of Covalent Bond Formation

When two atoms approach each other in order to form a bond, they undergo important changes in their energy.

i. Decrease in energy (Attractive Force)

The electrons belonging to one atom will come under the attractive influence of the nucleus of the other atom. This is the new force of attraction and will be responsible for lowering the energy.

ii. Increase in Energy (Repulsive Force)

The electrons and the nucleus of one atom will also repel the electrons and the nucleus of the other atom. This is the force of repulsion and will obviously increase the energy.

iii. Dominance of Attractive Force

The two atoms will bring themselves at such a distance so that the attractive forces dominate the repulsive forces.

iv. Total Energy of the System

The total energy at this distance will be **minimum** and thus a stable molecule is formed. A covalent bond is therefore a bond formed by the mutual sharing of an electron pair provided by the bonded atoms. This is called a single covalent bond.

Bond Pair:

*The covalent bond is formed by mutual sharing of electrons between two atoms. The **electrons that pair up to form a chemical bond** are called 'bond pair' electrons.*

TYPES OF COVALENT BONDS

Depending upon the number of bond pairs, covalent bond is classified into following three types:

- Single Covalent bond

- Double Covalent bond
- Triple Covalent bond

(i) Single Covalent Bond:

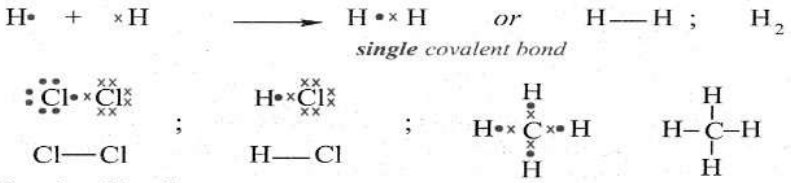
*"When **one electron is contributed by each bonded atom, one bond pair is formed** and it forms a single covalent bond".*

Representation:

A single covalent bond is represented by a single line **(–),** between two bonded atoms.

Examples

Hydrogen (H_2), chlorine (Cl_2), hydrochloric acid (HCl) and methane (CH_4).



(ii) Double Covalent Bond:

*"When **two electrons are contributed by each bonded atom, two bond pairs are formed** and it forms a double covalent bond".*

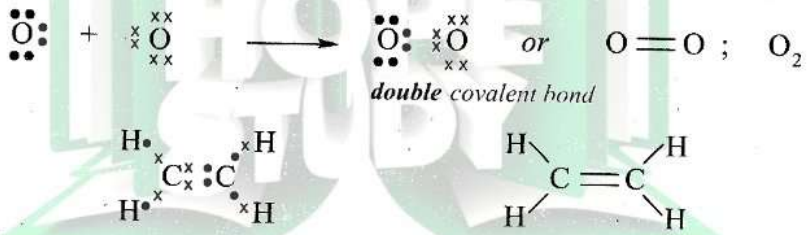
In some compounds, the atoms share two electrons each to form a double covalent bond. Double and triple covalent bonds have two and three electron pairs respectively which are mutually shared between the two atoms.

Representation:

A double covalent bond is represented by two lines **(=),** between two bonded atoms.

Examples:

Oxygen (O_2) gas, ethene (C_2H_4).



(iii) Triple Covalent Bond:

*"When **three electrons are contributed by each bonded atom, three bond pairs are formed** and it forms a triple covalent bond".*

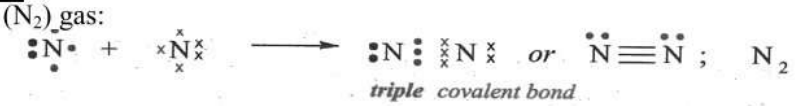
In the same way atoms can share three electrons each to form a triple covalent bond.

Representation:

A triple covalent bond is represented by **three lines (≡),** between two bonded atoms.

Examples:

Nitrogen (N_2) gas:



Ethyne (C_2H_2) gas:

The mutually shared electrons may be shown by a dot or a cross. The formation of single, double and triple covalent bonds in different molecules is explained in the examples.

NOTE:

By this **mutual sharing of valence shell electrons,** each of the **contributing atom attains the 'octet'** or **nearest noble gas electronic configuration**.

EXERCISE

1. What type of elements form covalent bond?

Ans: **ELEMENTS FORMING COVALENT BOND**

The **elements of Group-13 to Group-17** when allowed to react with each other, they form a chemical bond by mutual sharing of their valence shell electrons.

When bonding atoms have **comparable values of electronegativity** they share their electrons and form covalent bonds.

2. How covalent bond is different from an ionic bond?

Ans: **DIFFERENTIATION**

The differences between covalent bond and ionic bond is as follows:

Covalent Bond	Ionic Bond
Definition	
It is a bond formed between two atoms by mutual sharing of electrons.	It is a bond formed between two atoms by complete transfer of electros from one atom to other atom.
Strength of Bond	
It is a weak bond.	It is a strong bond.
Examples	
• HCl, HBr, HF, H_2O, H_2, Cl_2, N_2, O_2 are examples of covalent bond.	• NaCl, KCl, $NaNO_3$ are examples of ionic bond.

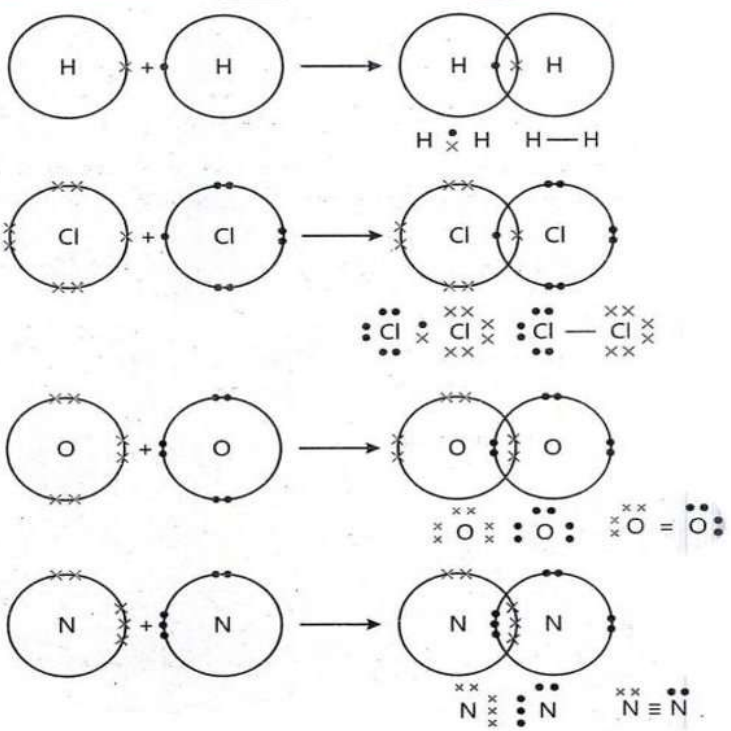


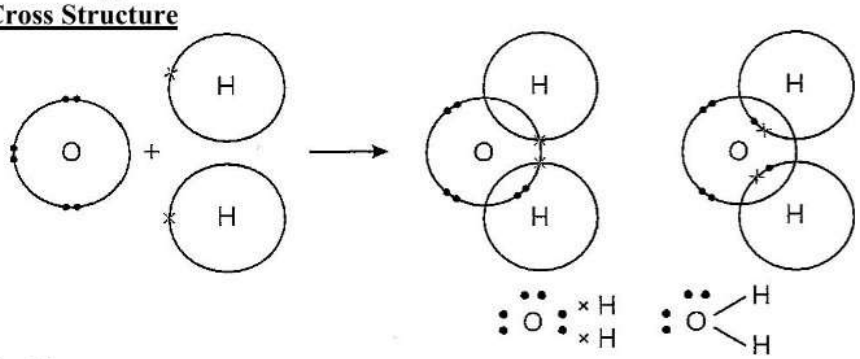
Fig (3.5): Formation of Single, Double and Triple Covalent Bonds

FORMATION OF COVALENT COMPOUNDS

1. **Water**

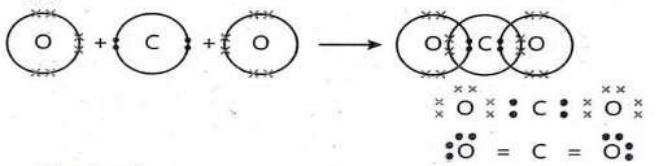
A water molecule is formed when two hydrogen atoms share their electrons separately with the electrons of one oxygen atom.

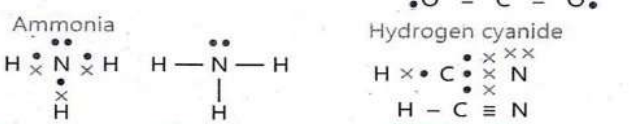
Dot and Cross Structure



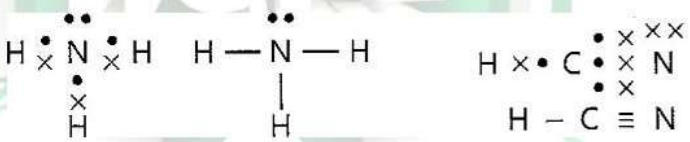
2. Carbon dioxide

A carbon dioxide molecule is formed when an atom of carbon shares its four electrons with two oxygen atoms. Each oxygen atom also shares two electrons.

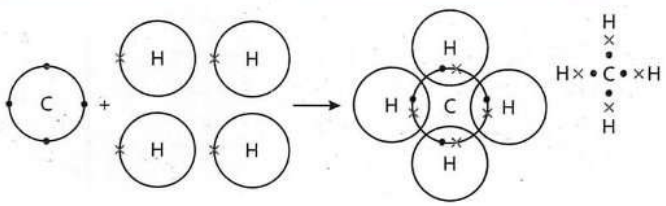




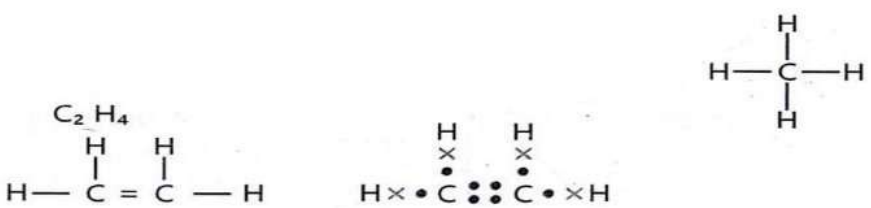
3. Hydrogen Cyanide



4. Methane



5. Ethene



6. Methanol

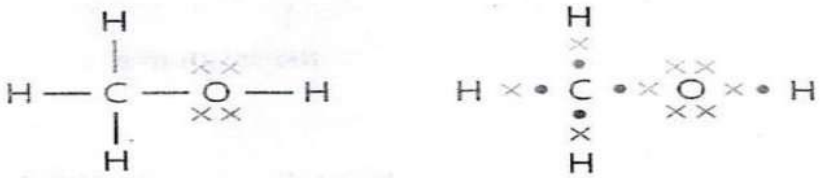


Fig (3.6): Formation of Covalent Compounds

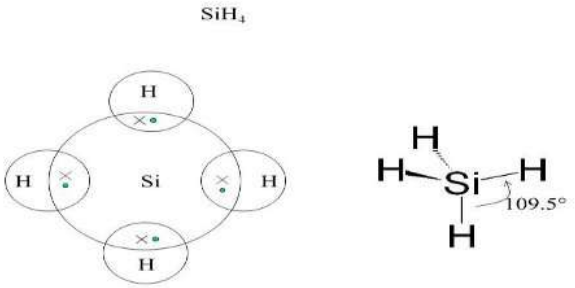
EXERCISE

ELECTRON DOT AND CROSS STRUCTURE

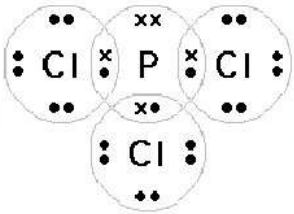
1. Draw electron dot and cross structure of the following compounds. SiH_4, PCl_3, SO_2, SO_3.

Ans: **ELECTRON DOT AND CROSS STRUCTURES**

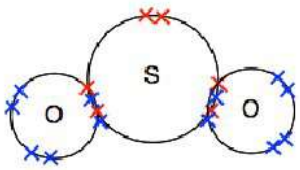
SiH_4



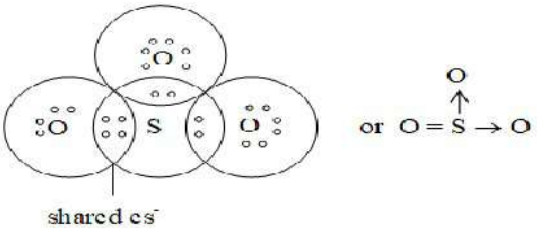
PCl_3



SO_2



SO_3



Conclusion

It is quite clear from the examples shown above that after mutually sharing their electrons, the bonded atoms acquire the electronic configuration of the nearest noble gas.

Q.3 Define the coordinate covalent bond. Explain coordinate covalent bond with the help of example. (U.B+K.B+A.B)

(SWL 17, FSD 2016, RWP 2016,17, SGD 2017, DGK 2017, BWP 2017, GRW 2017 G-I, LHR 2016 G-I)

OR

How a coordinate covalent bond is formed? Explain with examples. (SGD 2017)

Ans:

COORDINATE COVALENT BOND

Definition:

"Coordinate covalent or dative covalent bonding is a ***type of, covalent bonding*** *in which the* ***bond pair of electrons is donated by one bonded atom only.****"*

OR

Coordinate covalent bond is a type of covalent bond in which the shared electron pair is donated by one atom only.

Examples:

- Bond between NH_3 and BF_3 in NH_3BF_3
- Bond between NH_3 and H^+ in NH_4^+

Formation of Coordinate Covlent Bond

This bond is formed when a molecule has an electron pair to donate to another molecule.

Donor:

"The molecule which donates the electron pair, is called a donor".

Acceptor:

"The molecule which accepts the electron pair, is called an accepter".

Representation:

An arrow head (—) pointing towards the acceptor represents this type of bond.

Examples

Following examples will help to explain this bond.

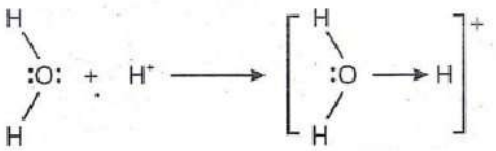
1. **Hydronium Ion (H_3O^+)**

Acids provide protons (H^+) when dissolved in water. This proton has an empty outer shell and can accept a pair of electrons present on the oxygen atom in water molecule. As a result of this, a hydronium ion (H_30+) is formed. (Fig 3.7)

The positive charge covers whole of the hydronium ion.

Difference between coordinate covalent bond and covalent bond

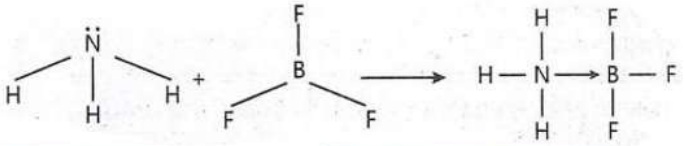
(After the formation of coordinate covalent bond)



After the formation of hydronium ion, there does not remain any difference between a coordinate covalent bond and a covalent bond. All the three bonds of oxygen behave exactly alike.

2. **Formation of Ammonia boron trifluoride (Reaction Between NH_3 and BF_3)**

A reaction between ammonia (NH_3) and boron trifluoride (BF_3) is another example of the formation of a coordinate covalent bond. During the reaction, an electron pair from nitrogen of ammonia fills the partially empty outer shell of boron present in boron trifluoride Fig (3.8).



Other example

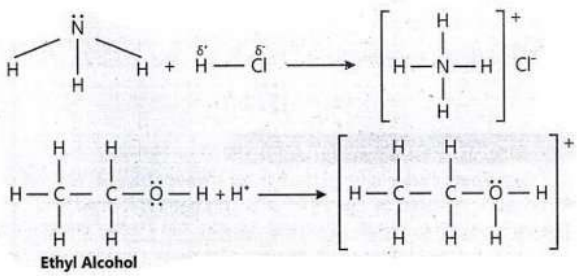


Fig (3.8): Formation of Boron trifluoride ammonia, ammonium chloride and protonated ethyl alcohol

3. **Formation of Ammonium chloride (Reaction Between NH_3 and HCl)**

In the above example, a coordinate covalent bond in ammonium chloride links nitrogen of ammonia and the proton. The positive charge is spread all over ammonium ion. All the four bonds between nitrogen and hydrogen in ammonium ion behave exactly alike. This proves the

point that the difference between a covalent bond and a coordinate covalent bond lies in the way they are formed. Once such bonds are formed, there does not remain any difference.

4. **Formation of protonated ethyl alcohol (Reaction Between C_2H_5OH and H^+)**

EXERCISE

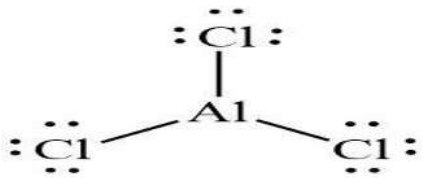
Q. Draw the pictures of coordinate covalent bond formed between:

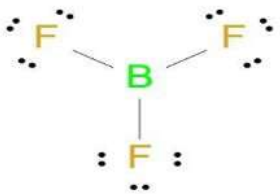
(a) BF_3 and $AlCl_3$

(b) CH_3OCH_3 and H^+

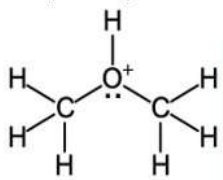
Ans:

(a) BF_3 and $AlCl_3$





(b) CH_3OCH_3 and H^+



EXERCISE

Q. Which compound is not able to form a coordinate covalent bond?

Ans: **COMPOUND NOT ABLE TO FORM COORDINATE COVALENT BOND**

A compound that is not able to form a coordinate covalent bond is HCl (hydrogen chloride) because both hydrogen and chlorine atoms contribute one electron each to form a covalent bond rather than coordinate covalent bond. No one can donate an electron pair to form coordinate covalent bond.

SHORT QUESTIONS

Q.1 Which electrons are involved in chemical bonding? **(U.B+K.B)**

Ans: Valence shell electron are involved in chemical bonding.

Q.2 What are bonding electrons? **(K.B)**

Ans: Answer given on page # 62

Q.3 What is ionic bond? **(K.B)**

Ans: Answer given on page # 62

Q.4 Why does sodium form a chemical bond with chlorine? **(U.B)**

Ans: **BOND FORMATION BETWEEN SODIUM AND CHLORINE**

Sodium forms chemical bond with chlorine because:

- Sodium has only one electron in its valence shell and has tendency to lose one electron while chlorine has seven electrons in its valence shell and has tendency to gain one electron, this favours the transfer of electron from sodium to chlorine and forms chemical bonds.
- Sodium is electropositive in nature, and is at high energy state while chlorine is electronegative and is at low energy state. This energy difference favours the formation of chemical bond between them.

Q.5 Why does sodium lose an electron and attains +1 charge? **(U.B)**

Ans: **ATTAINING OF +1 CHARGE**

Sodium is electropositive in nature, it easily loses its valence electron to attain noble gas

electronic configuration like $_{10}Ne$.

$$Na_{11} \xrightarrow{\text{loss one electron}} Na^{+} + le^{-}$$
$$(2,8,1) \qquad (2,8)$$

Q.6 How do atoms follow octet rule? (U.B)

Ans:

OCTET RULE

Atoms follow octet rule to achieve stability by attaining noble gases electronic configuration. Atoms follow octet rule in three ways:

- By giving valence electrons (If less than 3) to other atoms.
- By gaining electrons from other atoms (if the valence shell has 5 or more electrons in it).
- By sharing electron with other atoms.

Q.7 Which electrons are involved in chemical bonding? (U.B+K.B)

Ans:

ELECTRONS INVOLVED IN BONDING

Only valence shell electrons are involved in chemical bonding which are called bonding electrons. The inner shell electrons do not take part in chemical bonding.

Q.8 Why does group 1elements prefer to combine with group 17 elements? (U.B)

Ans:

COMBINATION OF GROUP 1 AND 17 ELEMENTS

Group I elements are highly electropositive with low ionization energies. Thus they have tendency to lose electrons easily and become positive ions. On the other hand group 17 elements are highly electronegative with high ionization energies. Thus they have tendency to gain electron easily and become negative ion. Therefore group I elements prefer to combine with group 17 elements to form ions and develop ionic bond due to electrostatic force of attraction.

Q.9 Why chlorine can accept only 1 electron? (U.B)

Ans:

ACCEPTANCE OF 1 ELECTRON BY Cl

Chlorine has seven electrons in its outermost shell. It requires only one electron to complete its valence shell to gain electronic configuration of noble gas (Argon ($_{18}Ar$). That's why it accepts only one electron.

Q.10 Define single covalent bond. Give examples. (K.B)

Ans: Answer given on page # 65

Q.11 Define double covalent bond? Give examples. (SGD 2016, GRW 2016 G-I)(K.B)

Ans: Answer given on page # 65

Q.12 What is meant by lone pair of electrons? (RWP 2016, SGD 2017)(K.B)

Ans:

LONE PAIR OF ELECTRONS

The non-bonded electron pair available on an atom in a molecule is called lone pair of electrons.

Example:

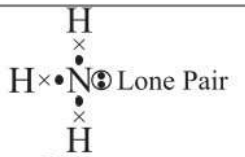
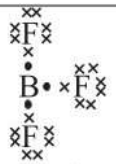
The electron pair available on nitrogen atom in ammonia (NH_3) molecule is called lone pair of electrons.

Q.13 What is the difference between donor and acceptor? (FSD 2017 G-I)(U.B)

Ans:

DIFFERENTIATION

The differences between donor and acceptor are as follows:_**Donor**	**Acceptor**
Definition	
• An atom which donate the electron pair is called donor.	• An atom which accept the electron pair is called acceptor.
Example	

 Donor	 (Acceptor)
Donor always contain at least one lone pair of electrons.	Acceptor must be deficient of two electrons in valence shell.

MULTIPLE CHOICE QUESTIONS

1. The types of chemical bond are: (GRW 2014)(K.B)
(A) 1 (B) 2 (C) 3 (D) 4

2. Chlorine has _____ electrons in its outer most shell: (GRW 2014)(K.B)
(A) 3 (B) 4 (C) 7 (D) 8

3. After gaining one electron, chlorine atom attains the electronic configuration of which noble gas? (LHR 2015)(U.B)
(A) Helium (B) Neon (C) Argon (D) Krypton

4. The formation of ionic bond between the ions is due to: (K.B)
(A) Hydrogen bonding (B) Electrostatic forces (C) Metallic forces (D) All of these

5. How many valence shell electrons are there in Na^+ ion? (U.B)
(A) 8 (B) 9 (C) 10 (D) 11

6. Electronic configuration of sodium is: (U.B)
(A) 2, 8, 1 (B) 2, 8, 5 (C) 2, 8, 4 (D) 2, 8, 2

7. A bond formed between two non-metals is expected to be: (K.B)
(A) Covalent (B) Ionic (C) Coordinate (D) Metallic

8. The example of single covalent bond is: (U.B+A.B)
(A) N_2 (B) Cl_2 (C) O_2 (D) C_2H_4

9. H_2C_2 is an example of: (U.B+A.B)
(A) Single bond (B) Double bond (C) Triple bond (D) None of these

10. The bond which is formed due to mutual sharing of electrons is called: (K.B)
(A) Ionic bond (B) Covalent bond (C) Dative bond (D) Hydrogen bond

11. C_2H_6 is an example of: (U.B+A.B)
(A) Single covalent bond (B) Double covalent bond
(C) Triple covalent bond (D) Coordinate covalent bond

12. The number of electrons participating in double covalent bond is: (GRW 2017 G-I)(U.B)
(A) 2 (B) 4 (C) 6 (D) 8

13. Which molecule has triple covalent bond? (LHR 2017 G-II)(U.B+A.B)
(A) H_2 (B) O_2 (C) N_2 (D) C_2H_4

14. How many electrons are involved in the formation of single covalent bond? (RWP 2017 G-II)(U.B)
(A) Two (B) Four (C) Six (D) Eight

15. Which one of the following is an electron deficient molecule? (LHR 2016 G-I)(U.B)
(A) NH_3 (B) BF_3 (C) N_2 (D) O_2

16. **A dative bond is formed between ammonia and boron trifluoride the donor atom is:** **(U.B)**
(A) Fluorine (B) Boron (C) Hydrogen (D) Nitrogen

17. **NH_4Cl is an example of:** **(U.B)**
(A) Covalent bond (B) Ionic bond (C) Dative covalent bond (D) All of these

18. **Coordinate covalent bond is also known as:** **(K.B)**
(A) Dative covalent bond (B) Double covalent bond
(C) Ionic bond (D) Triple covalent bond

19. **BF_3 is deficient of electrons:** **(U.B)**
(A) Three (B) Four (C) Two (D) Five

3.3 METALLIC BOND

LONG QUESTIONS

Q.1 What is metallic bond? Explain metallic bonding with the help of diagram. (SGD 2016, FSD 2016, 17) (U.B+K.B)

Ans:

METALLIC BOND

Definition

"The metallic bond is defined as a ***bond formed between metal atoms (positively charged ions) due to mobile or free electrons****".*

OR

A metallic bond, is therefore a type of chemical bond which has positively charged ions bound together by the mobile electrons.

Example:

The bond found between atoms in sodium, calcium and magnesium metals.

Different Type of Metallic Bond:

The characteristics shown by metals are very different from those of ionic and covalent compounds. This suggests the presence of different types of binding forces among the metallic atoms.

Properties of Metals

(i) Metals usually show metallic luster.
(ii) Metals usually have high melting and boiling points.
(iii) Metals are good conductors of heat and electricity.
(iv) Metals are usually hard and heavy.
(v) Metals can be made into different shapes by applying pressure.

These characteristics of metals can be explained if we know the nature of binding forces present between their atoms.

FORMATION OF METALLIC BOND

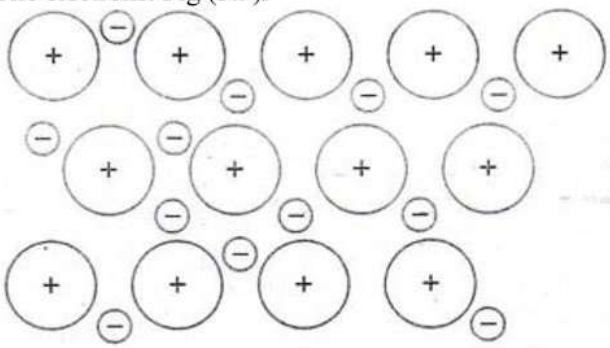
Weak Hold of Nucleus over Outermost Electrons/ Low Ionization Energy:

Usually metals have low values of ionization energy. Their atoms can therefore, lose their outer electron or electrons easily. In other words, the nuclei of metallic atoms cannot hold their outer electrons firmly.

Example

In sodium metal, each sodium atom is surrounded by eight other sodium atoms. The outer electrons of these atoms move freely between the vacant spaces present between atoms because of the loose linkage they have with their nuclei. No electron remains attached with any particular nucleus. Instead all the electrons at the same time, get attached with all the nuclei. When the atoms attract all the electrons collectively, obviously they will be bound together. A metal will appear to have a sea of electrons in which all the nuclei of atoms are submerged.

A metallic bond, is therefore a type of chemical bond which has positively charged ions bound together by the mobile electrons. Fig (3.9)



Strength of Metallic Bond

The strength of a metallic bond depends upon two factors:

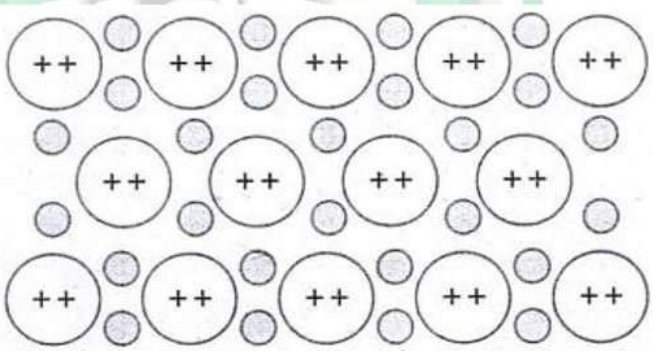
(i) the number of positive charges present on the positive ions

(ii) the number of mobile electrons set free by each atom.

Examples

In sodium metal, for example, each sodium atom sets free **only one electron**. The metallic bond in sodium metal is, therefore, **not very strong**.

In magnesium metal, each magnesium atom releases **two electrons** to acquire two positive charges. The metallic bond in magnesium metal will evidently be **stronger than that in sodium metal.** This explains why the magnesium metal melts at a higher temperature than sodium metal. Fig (3.10)



PROPERTIES OF METALS

i. Good conductors of heat and electricity

The presence of freely moving electrons in metals makes them good conductor of heat and electricity.

ii. Hard and Heavy

Moreover, in metals, the atoms are strongly held and arranged in the form of rows one above the other. This arrangement makes them hard and heavy.

iii. Malleable and Ductile

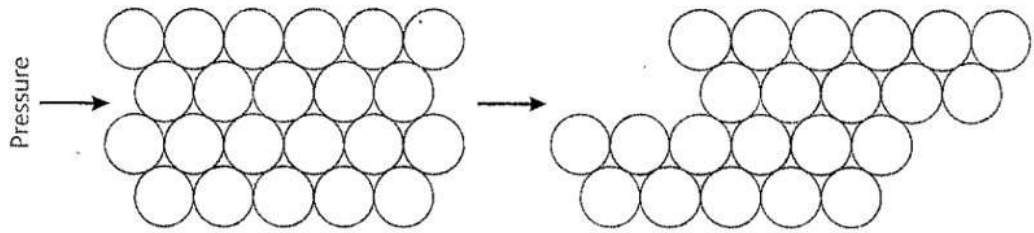
When pressure is applied on the metals, the upper rows of atoms slip pass the lower rows. As a result, their shapes are changed. Metals can, therefore, be easily drawn into wires and sheets.

iv. Density

Metals have high density.

v. Melting and Boiling Points

Metals have high melting and boiling points due to strong metallic bond.



INTERESTING INFORMATION

USES OF METALS

Metals are intrusively used in many industries. They are used in:

- Machinery
- Automobile
- Railways
- air craft
- rockets
- construction industry
- electronics industry

SHORT QUESTIONS

Q.1 What is metallic bond? (GRW 2017 G-I, GRW 2016 G-II)(K.B)

Ans: Answer given on page # 74

Q.2 What types of elements form metallic bond? (U.B+K.B)

Ans:

ELEMENTS FORMING METALS

Metals form metallic bond because they have low ionization energies and high shielding effect due to these properties metal atom lose electrons easily and form a sea of mobile electrons with positive ions.

Examples:

- Sodium
- Calcium

Q.3 What type of elements form metallic bonds? (K.B)

Ans:

METALLIC BOND

Metals form metallic bond because they have low ionization energies and high shielding effect. Due to these properties metal atoms lose electrons easily and form a sea of mobile electrons with positive ions.

Examples:

Sodium
Calcium

Q.4 Why is the hold of nucleus over the outermost electrons in metals weak? (U.B)

Ans:

WEAK HOLD OF NUCLEUS

The hold of nucleus over the outermost electrons in metals is weak because of:

- Large sized atoms
- Greater number of shells in between nucleus and valence electrons
- Low ionization energy

Q.5 Why the electrons move freely in metals? (U.B)

Ans:

FREE MOVEMENT OF ELECTRONS

Electrons move freely in metals because of large sized atoms, increased shielding effect and low

ionization energy. Due to these properties the metals have the tendency to lose their outer electrons easily. Resultantly loose or free electrons of all metal atoms move freely in the spaces between atoms of a metal. None of these electrons is attached to any particular atoms.

Q.6 Which types of electrons are responsible for holdings the atoms together in metals? (K.B)

Ans: **ELECTRON HOLDING THE ATOM**

Mobile electrons present within the metals are responsible for holding the atoms of metals together forming a metallic bond.

MULTIPLE CHOICE QUESTIONS

1. Metals have _____ or free electrons. (K.B)

(A) Mobile (B) Tightly bonded (C) Free (D) None of these

2. Metals are good conductor of heat and: (K.B)

(A) Electricity (B) Energy (C) None of these (D) All of these

3. Metals have tendency to lose electrons due to: (U.B)

(A) High ionization energy (B) Low ionization energy

(C) High electron affinity (D) Less umberof free electrons

3.4 ELECTROPOSITIVE CHARACTER OF METALS

LONG QUESTIONS

Q.1 Write a comprehensive note on the electropositive character of metals. (FSD 2016) (U.B)

Ans: **ELECTROPOSITIVE CHARACTER / METALLIC CHARACTER**

Definition:

*"Metals have the tendency to **lose** their **valance electrons**. This property of a metal is termed as **electropositivity** or **metallic character** or **electropositive character**".*

OR

Metals generally have a tendency to lose electrons to form positive ions called cations. This property is called the electropositive character of metals.

Relation between Electropositive character and Reactivity

This property is also related to the reactivity of the metals. Metals which lose electron or electrons easily are considered more reactive.

Electropositivity $\propto$ Reactivity

Examples

(a) **Alkali metals (Na, K)** are highly electropositive elements and thus they undergo reactions very easily.

- Sodium and potassium react vigorously **with water** and halogens to give their respective hydroxides and halides.
- They also react **with acids** to give salts and water.

(b) **Alkaline earth metals (Mg, Ca),** on the other hand, lose their outer electrons less easily and thus they are less electropositive than alkali metals.
Their reactions towards water and halogens are also less vigorous.

(c) **Aluminum** is also highly electropositive metal. It reacts readily with mineral acids to form salts and water.

SHORT QUESTIONS

Q.1 What is a relationship between electropositivity and ionization energy? (U.B)

Ans: **ELECTROPOSITIVITY AND IONIZATION ENERGY**

Electropositivity depends upon the ionization energy which in turn depends upon size and nuclear charge of the atom. Small sized atoms with high nuclear charge have high ionization energy value. Atoms having high ionization energy are less electropositive or metallic.

$$\text{Electropositivity} \propto \frac{\text{I}}{\text{Ionization energy}}$$

Q.2 What is the atomic size and ionization energy of sodium? (K.B)

Ans: **ATOMIC SIZE AND IONIZATON ENERGY**

Atomic size of sodium is 186pm and ionization energy of sodium is 496kJmol^{-1}.

Q.3 What is second ionization energy of magnesium? (K.B)

Ans: **IONIZATION ENERGY OF MAGNESIUM**

Second ionization energy of magnesium is 1450kJmol^{-1}

Q.4 What is the trend of electropositivity in groups? (MTN 2017)(U.B)

Ans: It increases from top to bottom in a group.

Q.5 What is the trend of electropositivity in periods? (DGK 2017)(U.B)

Ans: It decreses from left to right in a period.

Q.6 What type of elements are metals? (FSD 2017)(K.B)

Ans: **METAL ELEMENTS**

Definition:

"The elements which are **electropositive** and form **cations** by losing electrons are metals".

They **form basic oxides** with oxygen, are good conductor of heat and electricity and are usually hard.

Examples:

(i) Sodium
(ii) Potassium
(iii) Calcium
(iv) Magnesium
(v) Aluminum

Q.7 What is the nature of a metal oxide? (U.B+K.B)

Ans: **NATURE OF METAL OXIDE**

Metal oxides are basic in nature because they change red litmus paper to blue.

Examples:

Na_2O, CaO, K_2O, MgO

Q.8 Which group of metal is highly reactive? (K.B)

Ans: **HIGHLY REACTIVE METAL**

Alkali metals of group I **(Li, Na, K, Rb, Cs, Fr)** of the periodic table are **highly reactive** because they are **highly electropositive** in nature.

Q.9 Why Sodium metal is more reactive than magnesium metal? (U.B)

Ans: **REACTIVITY OF SODIUM AND MAGNESIUM**

Sodium metal is more reactive than magnesium metal because **sodium has larger size,** low ionization energy than magnesium and thus can **lose electrons more easily** than magnesium.

Q.10 Name a metal which can be cut with knife? (K.B)

Ans: **METAL CAN CUT WITH KNIFE**

Sodium metal can be cut with knife, because it is soft due to **weak metallic bonding**.

Q.11 Name the best ductile and malleable metal? (RWP 2017)(K.B)

Ans: **DUCTILE AND MALLEABLE METAL**

The best ductile and malleable metal is **gold**.

Q.12 Name the metal which is the poorest conductor of heat? (K.B)

Ans: **POOREST CONDUCTOR METAL**

The poorest conductor of heat is lead **(Pb)**.

Q.13 What do you mean by malleable and ductile? (K.B)

Ans: **MALLEABLE AND DUCTILE**

Malleable:

*"Malleability is the property of metals due to which they can be **beaten/hammered into sheets**".*

Ductile:

*"Ductility is the property of the metals due to which they can be **drawn into***

wires".

Q.14 Why alkali metals are more reactive than alkaline earth metals? (U.B)

Ans: **REACTIVITY OF ALKALI AND ALKALINE EARTH METALS**

Alkali metals are more reactive than alkaline earth metals because **alkali metals have the largest size** and the lowest ionization energy in their respective periods therefore alkali metals have highest metallic character, so these are more reactive than alkaline earth metals.

Q.15 What do you mean by metallic character? (SGD 2017) (U.B+K.B)

OR

Define electropositivity. (SWL 2016, BWP 2016) (U.B+K.B)

Ans: **ELECTROPOSITIVE CHARACTER / METALLIC CHARACTER**

*"Metals have the tendency to **lose** their **valance electrons**. This property of a metal is termed as **electropositivity** or **metallic character***

Q.16 Why metallic character decreases along a period and increases in a group? (U.B)

Ans: **METALLIC CHARACTER**

Metallic character decreases in a period because size of atom decreases in periodand increases in a group because size of atom increases.

MULTIPLE CHOICE QUESTIONS

1. Atomic number of Cs is: (K.B)
(A) 55 (B) 35 (C) 25 (D) 503

2. Metals lose their electron easily because: (Ex-7)(U.B)
(A) They are electronegative (B) They have electron affinity
(C) They are electropositive (D) Good conductor of heat

3. Metals have generally: (LHR 2015)(U.B)
(A) High ionization energy values (B) Low ionization energy values
(C) High electron affinity values (D) High electronegativity values

4. Metals can form ions carrying charges: (GRW 2016)(U.B)
(A) Uni-positive (B) Dipositive (C) Tri-positive (D) All of these

5. Ionization energy of sodium is less than: (U.B)
(A) Al (B) Mg (C) Cu (D) All of these

6. Electropositivity is also known as: (K.B)
(A) Metalloid character (B) Metallic character
(C) Non-metallic character (D) Both B and C

7. The more easily a metal _____ its electrons the more electropositive it is. (U.B)
(A) Loses (B) Gains (C) Shares (D) Transfers

8. Electropositive character _____ across period due to _____ of nuclear charge. (U.B)
(A) Increases, decrease (B) Increases, increase
(C) Decreases, increase (D) Decreases, decrease

9. Electropositive character increases down the group because size of atoms: (U.B)
(A) Increases (B) Decreases
(C) Remains constant (D) Both A and B

3.5 ELECTRONEGATIVE CHARACTER OF NON-METALS

LONG QUESTIONS

Q.1 What are non-metals? Explain electronegative characteristics of non-metals. (SWL 2017)(U.B+K.B)

Ans: **NON-METALS**

Definition:

*"The elements which are **electronegative** and form **negative ions (anions)** by **gaining electrons** are called non-metals".*

Examples:

- Oxygen
- Sulphur
- Phosphorus
- Nitrogen

ELECTRONEGATIVE CHARACTER

"The **tendency** of an element **to gain electrons** and from **negative ions** is called **non-metallic character** or **electronegative character** or **electronegativity**.

Properties of Non-metals

i. Non-metals have an affinity towards electrons.
ii. They tend to gain electrons and become negatively charged ions called anions.
iii. They are therefore, named as electronegative elements.
iv. Fluorine is the most electronegative element in the periodic table followed by oxygen, nitrogen and chlorine.
v. Nonmetals readily react with metals forming ionic bonds.
vi. Non-metals also combine with other non-metals to form a wide variety of molecular substances.

SHORT QUESTIONS

Q.1 What is the trend of electronegativity of non-metals? (FSD 2016)(U.B)

Ans:

TREND OF ELECTRONEGATIVITY

Electro negativity of first member of group 14, 15, 16 and 17 are higher than that of other members of the group decreasing their electronegativity. The **decreasing order** of electronegativity is as under.

F > O > Cl > N > Br > S > C > I > P

Q.2 What is non-metallic character? (RWP 2016)(U.B)

Ans:

NON-METALLIC CHARACTER

***"**The tendency of an element to gain electrons and form negative ions is called non-metallic character or electronegative character".*

Trends in Periodic Table:

Non-metallic character decreases in a group and increases in a period

Q.3 Which factors affect the nonmetallic character? (RWP 2017 G-I)(U.B)

Ans:

FACTORS AFFECTING NONMETALLIC CHARACTER

The non-metallic character depends upon the electron affinity and electronegativity of the atom. Small sized elements having high nuclear charge are electronegative in nature. They have high electron affinity. Therefore, they possess non-metallic nature.

Non-metallic character × Electronegativity

MULTIPLE CHOICE QUESTIONS

1. Which one of the following halogens has lowest electronegativity? (LHR 2015)(K.B)
(A) Chlorine (B) Iodine (C) Bromine (D) Fluorine

2. Which one of the following non-metals is lustrous? (GRW 2017 G-I)(K.B)
(A) Sulphur (B) Phosphorus (C) Iodine (D) Carbon

3. Non-metals are generally soft but which one of the following is extremely hard? (K.B)
(A) Graphite (B) Phosphorous (C) Iodine (D) Diamond

4. In the group non-metallic character: (U.B)
(A) Increases (B) Decreases (C) Remains same (D) None of these

5. Non-metals do not react with: (K.B)
(A) Dilute acids (B) Concentrated acids (C) Water (D) Both A and C

6. Small sized atoms have: (U.B)
(A) High nuclear charge (B) Low nuclear charge

(C) Low ionization energy (D) All of these

3.6 COMPARE THE PROPERTIES OF IONIC AND COVALENT COMPOUNDS

LONG QUESTIONS

Q.1 What is difference between polar and non-polar covalent bonds, explain with one example of each? (GRW 2017 G-I, LHR 2016 G-II)(U.B+A.B)

Ans: **COMPARISON OF PROPERTIES**

The differences between polar and non-polar covalent bond is as follows:

Ionic Compounds	Covalent Compounds
Definition	
The compounds having ionic bond in them are called ionic compounds.	*The compounds having covalent bond in them are called covalent compounds.*
Composition and Extent of Attraction	
In ionic compounds oppositely charged ions are properly arranged to give a _ crystalline structure. As a whole the compound is neutral. There exists a strong electrostatic force between their ions.	Covalent compounds mostly exist as discrete neutral molecules. There exists a strong electrostatic Attraction between the two nuclei and the shared electrons.
Melting And Boiling Points	
• Ionic compounds are usually solids having high melting and boiling points. The melting point of sodium chloride is 800 ^{0}C because it is difficult to break the strong electrostatic forces of attraction between the oppositely charged ions.	• Covalent Compounds are made of two or more non-metals. Lower compounds are gases or low boiling liquids. High molecular solids. Generally, they have lower melting add boiling points.
Solubility	
• Ionic compounds are generally soluble in polar solvent like water	They are usually insoluble in water
Electrical Conductivity	
• They are usually good conductor of electricity in molten state or in solution form. Their conductance is due to the presence of free ions.	• They are üsually bad conductor of electricity but soluble In non-polar solvents like ether; benzene and acetone.
Examples	
• NaCl, $CaCl_2$, KNO_3, MgO are examples of ionic compounds.	• HCl, HBr, HF, H_2O are examples of covalent compounds.

SHORT QUESTIONS

Q.1 Write properties of covalent compounds. (K.B)

Ans: Answer given on page # 80

Q.2 What is the composition of ionic compounds? (MTN 2016)(K.B)

Ans: **COMPOSITION OF IONIC COMPOUNDS**

Ionic compounds are made up of positively and negatively charged ions. Thus they consist of ions and not the molecules.

Q.3 Write any two properties of ionic compounds. (RWP 2017 G-I, II)(K.B)

Ans: **PROPERTIES OF IONIC COMPOUNDS**

The two properties of ionic compounds are as follows:

Crystalline Solids:

Ionic compounds are mostly crystalline solids.

Electrical Conductivity:

Ionic compounds in solid state have negligible electrical conductance but they are good conductors in solution and in the molten form. It is due to presence of free ions in them.

Q.4 Why the ionic compounds have high melting and boiling points? (U.B)

Ans: **IONIC COMPOUND**

As ionic compounds are made up of positive and negative ions, there exist strong electrostatic forces of attraction between oppositely charged ions. So, a great amount of energy is required to break these forces, therefore ionic compounds have high melting and boiling points.

Q.5 What do you mean by malleability? (SGD 2017 G-II)(K.B)

Ans: **MALLEABILITY**

Malleability is a special property of metal, by virtue of metal can be rolled into sheets.

Examples:

Metals such as gold, silver, copper, are malleable.

Q.6 Why are ionic compounds easily soluble in water? (U.B)

Ans: **IONIC COMPOUNDS**

Ionic compounds are easily soluble in water, because water is a polar solvent and has high dielectric constant that weakens the attraction between ions of ionic compounds like dissolved like similar solvents dissolve similar solutes. Ionic compounds are polar that's why they are soluble in polar solvent like water.

Examples:

Sodium chloride can easily be soluble in water.

Q.7 What type of bond exists in sodium chloride? (U.B)

Ans: **BOND EXIST IN SODIUM CHLORIDE**

Sodium chloride is an ionic compound therefore ionic bond is present in sodium chloride.

MULTIPLE CHOICE QUESTIONS

1 Ionic compounds mostly exist in: (K.B)
(A) Solid (B) Crystalline solid (C) Amorphous (D) Liquid

2. Ionic compounds do not conduct electricity in: (K.B+U.B)
(A) Solid state (B) Liquid state (C) Molten state (D) Both A and C

3. Ionic compounds dissolve easily in: (K.B)
(A) Ether (B) Benzene (C) Petrol (D) Water

4. Non-polar covalent compound usually dissolve in: (K.B)
(A) Water (B) Alcohol (C) Acid (D) Ether

5. Covalent compounds have melting and boiling points: (K.B)
(A) Low (B) High (C) Moderate (D) Very high

6. Non polar covalent compound usually _____ conduct electricity. (K.B)
(A) Do (B) Do not (C) Both (D) None of these

7. Benzene is: (K.B)
(A) Polar compound (B) Non-polar compound
(C) Homoatomic compound (D) Monoatomic compound

3.7 INTERMOLECULAR FORCES OF ATTRACTION

LONG QUESTIONS

Q.1 What are intermolecular forces? Compare this forces with chemical bond forces with reference to HCl molecule. (SWL 2016, MTN 2016, RWP 2016, FSD 2016,17) (U.B+K.B)

Ans:

INTERMOLECULAR FORCES

Definition:

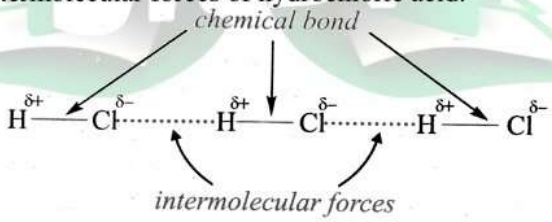
The forces of attraction which are present between the molecules of elements and compounds are named as intermolecular forces of attraction.

OR

"The **forces of attraction present between molecules of a substance** are called intermolecular forces".

Example:

The bonding and intermolecular forces of hydrochloric acid.



Strength of Intermolecular and Intramolecular Forces

There attractive forces are generally very weak as compared to the bonding forces present between the atoms within one molecule (intramolecular forces) of substances.

Properties and Significance of Intermolecular forces

(i) Determination of physical states of matter:

Among the three states of matter, these forces are the weakest among the molecules of the gases and the strongest among the molecules of solids.

(ii) Types

The intermolecular forces of attraction are of many type: some are weak and other are relatively strong.

(iii) Effect on Physical Properties

They affect the physical properties of the substances. The melting and boiling points of substances depend on the strength of these forces.

- The stronger the forces among the molecules of a liquid the higher is its boiling point and vice versa.
- Similarly, stronger the intermolecular forces the higher will be the melting point of a solid.

Q.2 Write a note on dipole-dipole interaction.

(FSD 2016, SWL 2016, SGD 2016, BWP 2016, MTN 2017)(U.B+K.B)

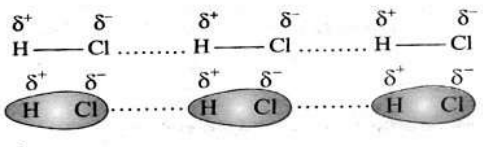
Ans:

DIPOLE–DIPOLE INTERACTION

Definition:

"The **force of attraction present between partial positive end of one polar molecule and partial negative end of other polar molecule** is called dipole - dipole force".

Example:



Occurrence:

These attractive forces are present between the molecules of a polar compound like HCI.

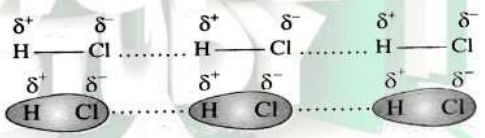
Development of Dipole-Dipole Forces:

These forces of attraction arise due to difference of electronegativity between bonded atoms.

Example

Hydrogen and chlorine attract the shared pair of electron between them with different force. This force of attraction of an atom is called its electronegativity. Since the electronegativity of chlorine is greater than that of hydrogen it attracts the shared pair of electron with greater force. As a result, the bond between hydrogen and chlorine becomes polar as shown in the following.

Due to these partial charges the molecules of HCI start attracting each other. These forces of attraction are called dipole-dipole forces. (Fig 3.12)



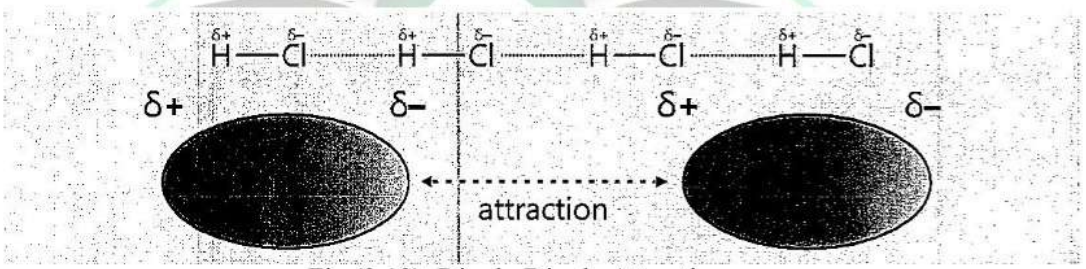


Fig (3.12): Dipole-Dipple Attraction

The compounds which have this type of attractive forces will show relatively higher melting and boiling points.

Dependence:

These forces depend upon:

- **Electronegativity difference** between bonded atoms
- **Distance** between molecules

Q.3 Explain hydrogen bonding in detail. (LHR 2016, FSD 2016, SGD 2016, MTN 2016, DGK 2016, SWL 2016, BWP 2017)(U.B+K.B)

OR

Define hydrogen bonding. Explain that how these forces affect the physical properties of

compounds. **(U.B+K.B)**

Ans:

HYDROGEN BONDING

Definition:

*"The **forces of attraction present between partially positively charge hydrogen atom of one molecule and partially negatively charged atom (N, O or F) of another molecule** is called hydrogen bonding".*

Explanation:

Occurrence:

Hydrogen bonding is a special case of dipole-dipole attractive forces.

It is present in the **permanently polar molecules**.

Development of Hydrogen Bonding:

When hydrogen is covalent bonded to highly electronegative elements **like F, O or N** then the large difference of electronegativity values will make the covalent bond highly polar. As a result, strong dipole-dipole attractions are observed among the molecules. This is called hydrogen bonding.

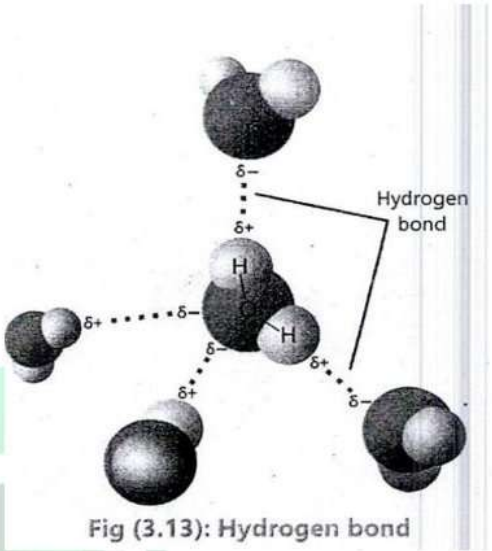


Fig (3.13): Hydrogen bond

Example

In H_2O, the O—H bonds are highly polar. Due to this strong attractive forces are developed between water molecules.

This attractive force present between the molecules of water is called Hydrogen Bonding.

Effect of Hydrogen Bonding on Physical Properties:

(i) Melting and Boiling Points:

The strength of the hydrogen bonds causes water to have relatively higher melting and boiling points as compared to compounds like H2S and NH3.

(ii) Density of Water:

The density of ice is less than liquid water due to hydrogen bonding and thus ice **floats over water** because of **hydrogen bonding.**

SHORT QUESTIONS

Q.1 What are intermolecular forces? **(FSD 2017 G-II)(K.B)**

Ans: Answer given on page # 82

Q.2 Define hydrogen bonding. **(GRW 2016 G-II, LHR 2016 G-I)(K.B)**

Ans: Answer given on page # 83,84

Q.3 What are dipole-dipole interactions?

Ans: Answer given on page # 83

Q.4 Why a dipole develops in a molecule? **(U.B)**

Ans:

DEVELOPMENT OF DIPOLE

A dipole develops in a molecule due to electronegativity difference between the two bonded atoms. The unequal sharing of electrons between two different types of atoms makes one end of the molecule slightly positive and other end slightly negatively charged. Hence a dipole develops in a molecule.

Example:

$$H^{\delta+}— Cl^{\delta-} \text{------} H^{\delta+}— Cl^{\delta-} \text{------} H^{\delta+}— Cl^{\delta-}$$

Q.5 What do you mean by induced dipole? **(U.B)**

Ans:

INDUCED DIPOLE

"A temporary dipole which is produced in a non-polar molecule due to the influence of a polar molecule is called an induced dipole".

The positive end of polar molecule attracts the mobile electrons of the nearby non polar molecule and induce the polarity in non-polar molecule.

Q.7 Why are dipole forces of attraction not found in halogen molecules? (U.B)

Ans: **NO DIPOLE FORMATION IN HALOGENS**

Dipole forces of attraction are not found in halogen molecules because halogens are homo atomic molecules. Due to no difference of electronegativity between atoms halogen molecules have no dipoles and thus are non-polar.

Example:

Cl_2, I_2, Br_2 and F_2

Q.6 What types of attractive forces exist between HCl molecules? (U.B)

Ans: **ATTRACTIVE FORCES BETWEEN HCl MOLECULES**

HCl forms a polar covalent bond between atoms due to difference of electronegativity between bonded atoms. There exists a dipole in the molecule. The positive end of one molecule attracts the negative end of other molecule. Hence dipole forces (intermolecular forces) exist between HCl molecules.

Example:

$$H^{\delta+} — Cl^{\delta-} \text{------} H^{\delta+} — Cl^{\delta-}$$

Q.7 Define intermolecular forces; show these forces among HCl molecule.

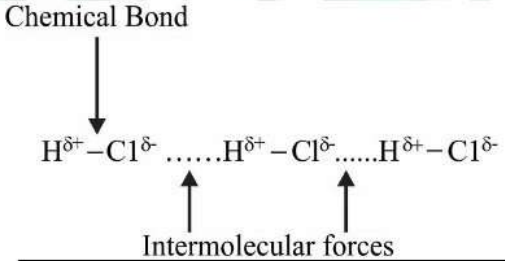
(BWP 2017, FSD 2017 G-II)(U.B+K.B)

Ans: **INTERMOLECULAR FORCES**

"The forces that hold atoms in a compound are chemical bonds. In addition to these strong bonding forces, relatively weak forces also exist in between the molecules, which are called intermolecular forces".

Example:

Chemical Bond



MULTIPLE CHOICE QUESTIONS

1. The density of ice at 0°C is: (K.B)

(A) $0.917 g/cm^3$ (B) $0.719 g/cm^3$ (C) $0.197 g/cm^3$ (D) $0.0917 g/cm^3$

2. Which properties are affected by hydrogen bonding? (U.B)

(A) Physical (B) Chemical (C) Ionic (D) Metallic

3. Ice floats on water because: (U.B)

(A) Ice is denser than water (B) Water is denser than ice

(C) Ice is crystalline in nature (D) Water molecule move randomly

4. Which type of force is present in hydrogen bonding? (LHR 2015)(U.B)

(A) Intermolecular forces (B) Ionic forces (C) Covalent forces (D) Metallic force

5. Hydrogen bonding is present in: (U.B+K.B)

(A) Non polar molecule (B) Temporary polar molecule

(C) Permanently polar molecule (D) Homoatomic molecule

6. Weakest force among the molecules is: (U.B+K.B)

(A) Ionic force (B) Metallic force

(C) Covalent force (D) Intermolecular force

3.8 NATURE OF BONDING AND PROPERTIES

LONG QUESTIONS

Q.1 Define crystal lattice. What are properties of Ionic solids? (U.B)

Ans: **CRYSTAL LATTICE**

Definition

The **symmetrical three-dimensional structural arrangements of atoms, ions or molecules** *(constituent particle) inside a crystalline solid is called crystal lattice.*

Explanation

In ionic compounds, the oppositely charged ions are held together by the strong electrostatic force of attraction in the form of a crystal lattice. Since the ions are rigid in ionic compounds, such compounds therefore exist in the form of very stable solids with significantly high melting points. Since ions are spherical and oppositely charged they can surround each other from all the sides, ionic bonds are non-directional. This arrangement of ions is called crystal lattice.

Application of Force on Crystal Lattice

If an external force is applied on the crystal lattice, it breaks easily.

Properties of Ionic Solids

(i) Brittleness

It shows that ionic solids are **highly brittle**.

(ii) Electrical Conductivity

In the **solid form,** ionic compounds **do not conduct electricity** because ions are tightly held and cannot move. However, **in the molten state**, the **ions get free and start conducting electricity**.

(iii) Solubility in water

Ionic solids are also generally soluble in water. Water not only breaks the electrostatic force of attraction but also hydrates the resulting free ions.

(iv) Electrical conductivity in Aqueous Solution

Ionic compounds in an aqueous solution also conduct electricity because the free ions can now move towards their respective electrodes.

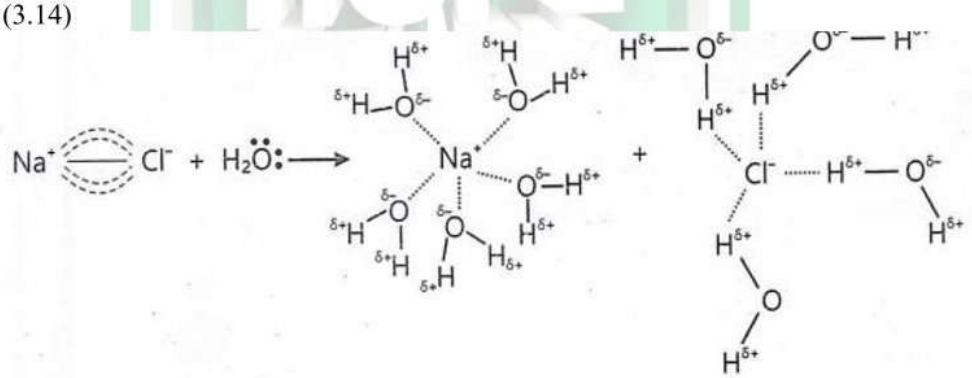
(v) Melting and Boiling Points

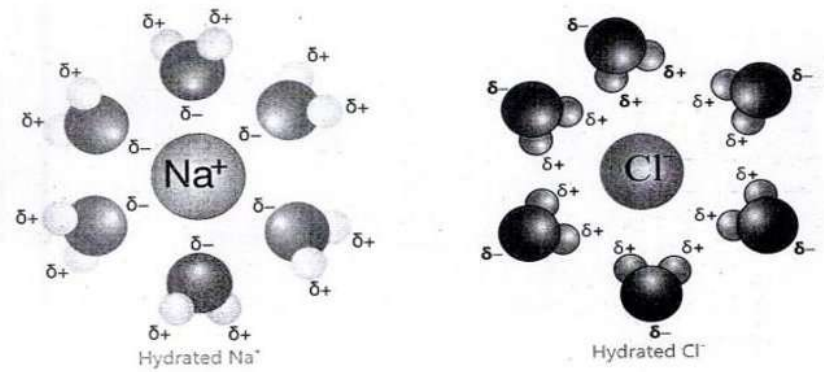
They have high melting and boiling point due to **strong Metallic bond**.

(vi) Crystalline Solids

They are crystalline solids.

Fig (3.14)





Reactivity of Ionic compounds

Ionic compounds generally react in an aqueous solution. When we mix two solutions of ionic compounds, the positive ions of one compound may react with the negative ions of the other to form a new compound.

Example

When aqueous solutions of sodium chloride and silver nitrate are mixed together, the following reaction takes place.

$$NaCl_{(3)} + AgNO_{3\,(s)} \xrightarrow{H_2O} Na^{+}_{(aq)} + Cl^{-}_{(aq)} + Ag^{+}_{(aq)} + NO^{-}_{3(aq)}$$

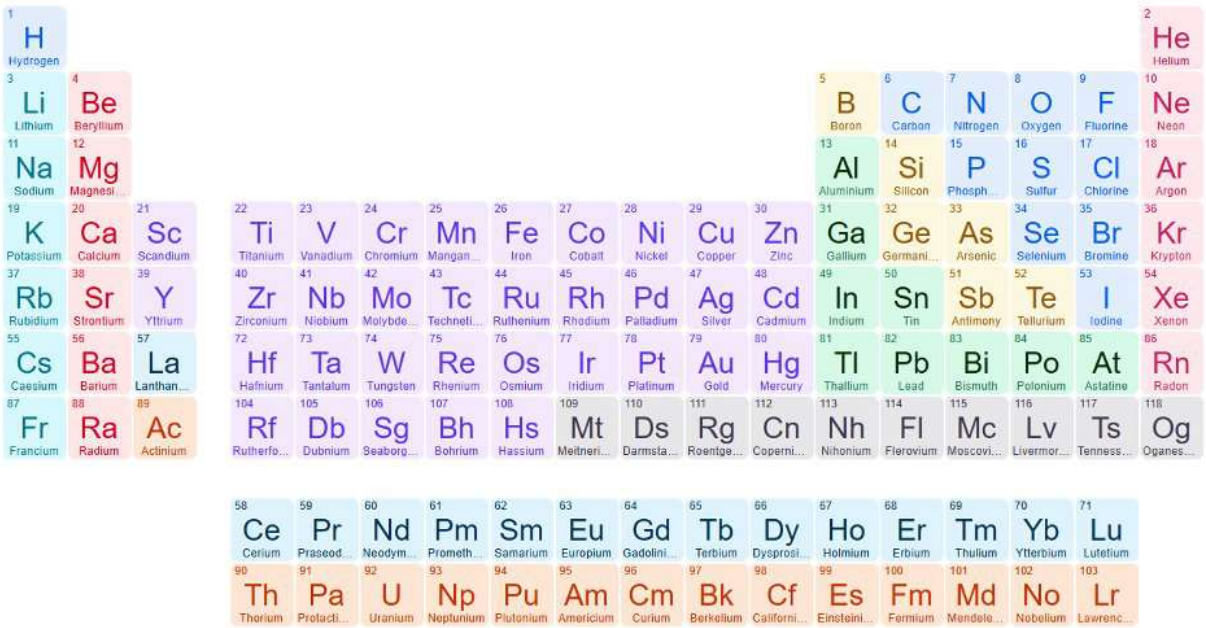
$$\downarrow$$

$$AgCl_{(s)} + Na^{+}_{(aq)} + NO^{-}_{3(aq)}$$

White precipitate of silver chloride comes out of the aqueous solution.

INTERESTING INFORMATION
APPLICATIONS OF CONDUCTION IN IONIC COMPOUNDS
Conduction of ionic compounds in molten state and in form of an aqueous solution has been utilized to prepare many important elements and compounds. **Example**
• Electrolysis of molten sodium chloride gives us sodium metal and chlorine gas. • Similarly, electrolysis of aqueous sodium chloride gives sodium hydroxide and chlorine gas.
APPLICATIONS OF DIAMOND AND GRAPHITE
(a) Diamond
• Diamonds, due to their exceptional hardness, are highly valued in industries. • Diamond tipped glass cutters are used to make clean cuts in glass. • Diamond-tipped drill bits are used to drill through hard rocks in mining operation.
(b) Graphite
• Graphite is used in pencils, in polishes and to make crucibles. • Graphite electrodes are used in battery cells and in electric arc furnaces-to produce

steel.



Q.2 Define crystal lattice. What are properties of Ionic solids? (U.B)

Ans:

PROPERTIES OF COVALENT SUBSTANCES

(Elements and Compounds)

Comparison with the Ionic Compounds

Covalent elements and compounds behave very differently from ionic compounds.

i. Diatomic Molecules

Elements present at the right side of the periodic table exist as covalently bonded diatomic molecules.

Example

Nitrogen(N_2), oxygen(O_2), fluorine(F_2) and chlorine($C1_2$).

ii. Densities and Boiling Points

Due to very weak forces of attraction between their molecules, their densities and boiling points are very low. Bromine (Br_2) exists as volatile fuming liquid while elements like carbon, phosphorous and sulphur exist as covalent solids

iii. Amorphous and Crystalline Forms

All these solid elements exist both in amorphous and crystalline forms

Example

Coal is the amorphous form of carbon whereas diamond and graphite are its crystalline forms.

(a) Coal: Coal is used as a fuel in electricity generating plants.

(b) Diamond: In diamond, each carbon atom is surrounded by four other carbon atoms linked together by strong covalent bonds. Due to this rigid structure, diamond is the hardest thing on this planet. It is used as a cutting, polishing and drilling tool.

(c) Graphite: Graphite consists of a layered structure, made of hexagonal rings of carbon. Since layers are not bonded strongly, they can slip past each other. Graphite is thus used as a lubricant in industry. Further, these layers in graphite have mobile electrons in between them. Graphite is a good conducter of electricity and it is also used as an electrode.

iv. Binary covalent compounds

Binary covalent compounds generally exist as low temperature boiling gases except

water.

Examples

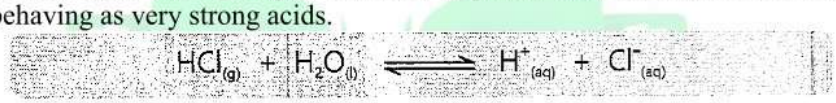
- Methane (CH_4)
- ammonia (NH_3)
- hydrogen sulphide (H_2S)
- hydrogen chloride (HCl)
- nitrogen dioxide (NO_2)
- carbon dioxide (CO_2)
- sulphur dioxie (SO_2)

These are all covalent compounds which are gases at room temperature.

- Water and hydrogen fluoride on the other hand, are liquids at room temperature.
- Liquid water has a high boiling point because strong intermolecular forces are present between its molecules

v. .Ionization in water

Covalent molecules like hydrogen chloride, sulphuric acid and nitric acid ionize completely in water (H_2O), behaving as very strong acids.



SHORT QUESTIONS

Q.1 Write properties of ionic compounds. (K.B)

Ans: Answer given on page # 80

Q.2 What is the composition of ionic compounds? (MTN 2016) (K.B)

Ans:

COMPOSITION OF IONIC COMPOUNDS

Ionic compounds are made up of positively and negatively charged ions. Thus they consist of ions and not the molecules.

Q.3 Write any two properties of ionic compounds. (RWP 2017 G-I, II) (K.B)

Ans:

PROPERTIES OF IONIC COMPOUNDS

The two properties of ionic compounds are as follows:

Crystalline Solids

Ionic compounds are mostly crystalline solids.

Electrical Conductivity

Ionic compounds in solid state have negligible electrical conductance but they are good conductors in solution and in the molten form. It is due to presence of free ions in them.

MULTIPLE CHOICE QUESTIONS

1. Ionic compounds do not exist in: (K.B)

(A) Solid (B) Gas (C) Amorphous (D) Liquid

2. Ionic compounds conduct electricity in: (K.B+U.B)

(A) Solid state (B) Aqueous form (C) Molten state (D) Both B and C

3. Ionic compounds dissolve easily in: (K.B)

(A) Ether (B) Benzene (C) Petrol (D) All of these

4. Non-polar covalent compound usually do not dissolve in: (K.B)

(A) Water (B) Alcohol (C) Benzene (D) Ether

5. Ionic compounds have melting and boiling points: (K.B)

(A) Low (B) High (C) Moderate (D) Very low

6. **Polar covalent compound usually _____ conduct electricity.** **(K.B)**

(A) Do (B) Do not (C) Both (D) None of these

ANSWER KEY
MULTIPLE CHOICE QUESTIONS

3.1 WHY DO ATOMS FORM CHEMICAL BONDS

1	C	**2**	C	**3**	A	**4**	A
5	D	**6**	D				

3.2 CHEMICAL BOND

1	D	**2**	C	**3**	C	**4**	B
5	A	**6**	A	**7**	A	**8**	B
9	C	**10**	B	**11**	A	**12**	B
13	C	**14**	A	**15**	B	**16**	D
17	D	**18**	A	**19**	C		

3.3 METALLIC BOND

1	A	**2**	A	**3**	B

3.4 ELECTROPOSITIVE CHARACTER OF METALS

1	A	**2**	C	**3**	B	**4**	D
5	D	**6**	B	**7**	A	**8**	C
9	A						

3.5 ELECTRONEGATIVE CHARACTER OF NON METALS

1	B	**2**	C	**3**	D	**4**	B
5	A	**6**	A				

3.6 COMPARE THE PROPERTIES OF IONIC AND COVALENT COMPOUNDS

1	A	**2**	A	**3**	D	**4**	B
5	A	**6**	B	**7**	B		

3.7 INTERMOLECULAR FORCES OF ATTRACTION

1	A	**2**	A	**3**	B	**4**	A
5	C	**6**	D				

3.8 NATURE OF BONDING AND PROPERTIES

1	B	**2**	D	**3**	D	**4**	A
5	B	**6**	A				

EXERCISE SOLUTION

MULTIPLE CHOICE QUESTIONS

1. Tick (L) the correct answer.

1. When molten copper and molten zinc are mixed together, they give rise to a new substance called brass. Predict what type of bond is formed between copper and zinc.

(A) Coordinate covalent bond (B) Ionic bond
(B) Metallic bond (D) Covalent bond

2. Which element is capable of forming all the three types of bonds; covalent, coordinate covalent or ionic?

(A) Carbon (B) Oxygen
(C) Magnesium (D) Silicon

3. Why is H_2O a liquid while H_2S is a gas?

(A) Because in water, the atomic size of oxygen is smaller than that of sulphur
(B) Because water is a polar compound and there exists strong forces of attraction between its molecules
(C) Because **H_2O** molecule is lighter than H_2S
(D) Because water can easily freeze into ice

4. Which of the following bonds is expected to be the weakest?

(A) C-C (B) Cl-Cl
(C) O-O (D) F-F

5. Which form of carbon is used as a lubricant?

(A) Coal (B) Diamond
(C) Graphite (D) Charcoal

6. Keeping in view the Intermolecular forces of attraction; indicate which compound has the highest boiling point?

(A) H_2O (B) H_2S
(C) HF (D) NH_3

7. Which metal has the lowest melting point?

(A) Li (B) Na
(C) K (B) Rb

8. Which ionic compound has the highest melting point?

(A) NaCl (B) KCI
(C) LiCl (D) RbCl

9. Which compound contains both covalent and ionic bonds?

(A) $MgCl_2$ (B) NH_4Cl
(C) CaO (D) PCl_3

10. Which among of the following has a double covalent bond?

(A) Ethane (B) Methane
(C) Ethylene (D) Acetylene

ANSWER KEY

1	C	**2**	B	**3**	B	**4**	B	5	C
6	A	**7**	D	**8**	C	**9**	B	10	C

LAST
HOPE
STUDY

QUESTIONS FOR SHORT ANSWERS

2 Questions for Short Answers

Q1. What type of elements lose their outer electron easily and what type of elements gain electron easily?

Ans: **LOSS AND GAIN OF ELECTRONS**

Metals lose their outer electron easily to form positive ions.

GAIN OF ELECTRONS

Non-metals gain electron easily to form negative ions.

Q2. Why does lower molecular mass covalent compound exist as gases or low boiling liquids.

Ans: **PHYSICAL STATE AND MASS OF COMPOUNDS**

Lower molecular mass covalent compounds exist as gases or low boiling liquids because of weak intermolecular forces between their molecules.

Q3. Give one example of an element which exists as a crystalline solid and it has covalent bonds in its atoms.

Ans: **COVALENT CRYSTALLINE SOLID**

Carbon has covalent bonds between atoms and exists as diamond and graphite crystals.

Q4. Which property of metals makes them malleable and ductile?

Ans: **MALLEABILITY AND DUCTILITY OF METALS**

In metals atoms are arranged in the form of layers. When pressure is applied, layers slip pass over each other but remain intact due to the metallic bond. Thus metals can be converted into wires and sheets layered structure of metals and metallic bond.

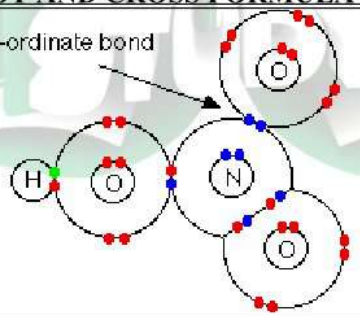
Q5. Is coordinate covalent bond a strong bond?

Ans: **STRENGTH OF COORDINATE COVALENT BOND**

No, a coordinate covalent bond is weaker bond as compared to simple covalent bond.

Q6. Write down dot and cross formula of HNO_3.

Ans: **DOT AND CROSS FORMULA OF HNO_3**



CONSTRUCTED RESPONSE QUESTIONS

3. Constructed response question

Q1. Why HF is a liquid while HCl is a gas?

Ans: **HF AS LIQUID & HCl AS GAS**

HF is a liquid while HCl is a gas because hydrogen fluoride (HF) has strong hydrogen bonding while hydrogen chloride (HCl) has much weaker intermolecular forces (dipole-dipole forces).

Q2. Why covalent compounds are not soluble in water?

Ans: **INSOLUBILITY OF COVALENT COMPOUNDS**

Covalent compounds are generally not soluble in water because water is a polar solvent, while most of the covalent compounds are nonpolar. Thus there is no strong attraction between the water molecules and molecules of the covalent compounds.

Q3. How do metals conduct heat?

Ans: **CONDUCTION OF HEAT BY METALS**

Metals conduct electricity due to presence of mobile electrons throughout the lattice.

Q4. How many oxides does nitrogen form? Write down formulas of oxides.

Ans: **OXIDES OF NITROGEN**

Nitrogen forms five different oxides which are as follows:

- Nitrous oxide (N_2O)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)
- Dinitrogen trioxide (N_2O_3)
- Dinitrogen pentoxide (N_2O_5)

Q5. What will happen if NaBr is treated with $AgNO_3$ in water?

Ans: **REACTION OF NaBr WITH $AgNO_3$**

If NaBr is treated with $AgNO_3$ in water, a white precipitate of AgBr (silver bromide) is formed along with Sodium nitrate ($NaNO_3$).

Q6. Why does iodine exist as a solid while $C1_2$ exist as a gas?

Ans: **IODINE AS SOLID & $C1_2$ AS GAS**

Iodine exist as a solid while $C1_2$ exist as a gas because iodine has larger atomic size more contact surfaces for intermolecular forces as compared to Cl_2.

DESCRIPTIVE QUESTIONS

4. Descriptive Questions

Q1. Explain the formation of an ionic bond and a covalent bond.

Ans: Answer given on page #

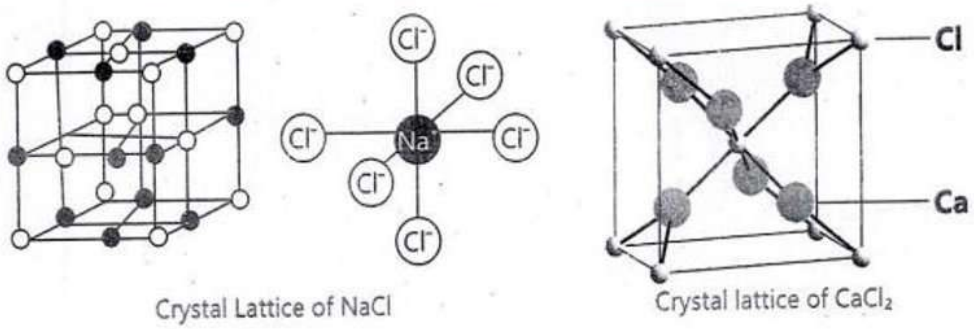
Q2. How do ions arrange themselves to form NaCl crystal?

Ans: **FORMATION OF NaCl CRYSTALS**

Sodium chloride, formed as a result of the chemical reaction contains the positively charged sodium ions (Na+) and the negatively charged chloride ions (Cl-). These oppositely charged ions are then held together by the electrostatic force of attraction. The chemical bond, thus formed, is called an **Ionic or an Electrovalent Bond**.

There ions then surround each other three dimensionally to form a crystal lattice.

Fig. Crystal lattices of NaCl



Crystal Lattice of NaCl Crystal lattice of $CaCl_2$

Q3. Explain the properties of metals keeping in view the nature of metellic bond.

Ans: Answer given on page #

Q4. Compare the properties of ionic and covalent compounds.

Ans: Answer given on page #

Q5. How will you explain the electrical conductivity of graphite crystals?

Ans: **CONDUCTIVITY OF GRAPHITE CRYSTALS**

Graphite crystals are good electrical conductors due to the presence of delocalized electrons or free moving electrons. These electrons can move easily within the layers of carbon atoms that

make up the graphite structure. This movement of electrons particularly parallel to the layers allows electricity to pass through graphite crystals.

Q6. Why are metals usually hard and heavy?

Ans: Answer given on page #

INVESTIGATIVE QUESTIONS

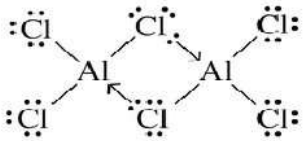
5. Investigative Questions:

Q1. The formula of $AlC1_3$ in vapour phase is $A1_2C1_6$ which means it exists as a dimer. Explain the bonding between its two molecules?

Ans:

DIMER OF ALUMINIUM TRICHLORIDE

In vapour phase AlCl3 exists as $A1_2C1_6$ which means it exists as a dimer. A chlorine atom from each of the **two molecules** forms a coordinate covalent **bond** with one of **its** lone electron pairs to the aluminium centre and make the **molecule** Al_2Cl_6**, which is a dimer**.

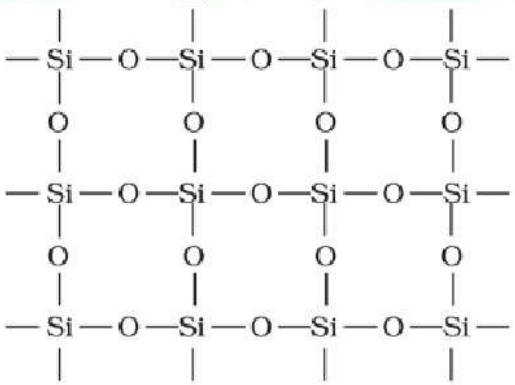


Q2. Explain the structure of sand (SiO_2).

Ans:

STRUCTURE OF SAND (SiO_2)

Sand (SiO_2) is made up of silicon dioxide. Silicon dioxide has a tetrahedral structure in which each silicon atom (Si) is covalently bonded to four oxygen atoms (O), and each oxygen atom is bonded to two silicon atoms. In this way a three-dimensional network solid is obtained.



TERMS TO KNOW

Terms	Definitions
Formation of Bonds	Atoms form bonds with other atoms to stabilize themselves by obeying duplet and octet rules.
Chemical Bond	The force of attraction which keeps the atoms together is called a chemical bond.
Ionic Bond	Bond which is formed by the transference of one or more electrons is called ionic bond.
Types of Covalent Bond	A covalent bond is formed by the mutual sharing of electrons between atoms. A covalent bond may be single, double or triple.
Coordinate covalent bond	When an electron pair is shared by one atom only, it is called a coordinate covalent bond
Ionic Solids	Ionic solids are crystalline compounds with high melting and boiling points. They are generally soluble in an aqueous solution.
Physical State of Covalent	Lower molecular mass covalent compounds are gases or low boiling liquids. Higher molecular mass covalent compounds exist as solids. They are bad

Compounds	conductors of electricity and are soluble in organic solvents.
Properties of ionic and covalent compounds	Properties of ionic and covalent compounds are adequately explained on the basis of type of attractive forces present between them