Session-1

CHEMICAL BONDING

1.1 INTRODUCTION;

- Atoms of most elements (except noble gases) are not able to exist independently.
- A group of two or more atoms known as **molecules** have independent existence.
- Atoms of same element or of different elements can join together to form a molecule.
- **Example**: A molecule of oxygen is formed by joining two atoms of oxygen (O_2)
- **Example** A molecule of water is formed by joining two atoms of hydrogen with one atom of oxygen (H_2O).
- The attraction between atoms or ions to form a molecule is called **chemical bond**.
- These molecules or ions aggregate in large numbers to form the **matter**.

What is a chemical bond?
The attractive force which holds constituents (atoms, ions, molecules, etc.)together in different chemical species is called as chemical bond.

What is a molecule?
The smallest particle of an element or a compound made up of group of two or more atoms that is capable of independent existence and shows all the properties of that substance is called as molecule.

1.2 Reasons for bond formation;

➢ Tendency to acquire electronic configuration of nearest noble gas.

a) Noble gases or inert gases like Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn) are the **most stable** elements because atoms of these elements possess an **octet structure** i.e. eight electrons in the outer most orbit (**valence shell**).

Nobe gas	**Atomic number**	**Electronic configuration**	**Valence shell**	**No of electrons in the valence shell**
He	2	$1s^2$	$1s^2$	2
Ne	10	$1s^2 2s^2 2p^6$	$2s^2 2p^6$	8
Ar	18	$1s^2 2s^2 2p^6 3s^2 3p^6$	$3s^2 3p^6$	8
Kr	36	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$	$4s^2 4p^6$	8
Xe	54	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6$	$5s^2 5p^6$	8
Rn	86	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 4f^{14} 5d^{10} 6s^2 6p^6$	$6s^2 6p^6$	8

b)The atoms of noble gases exist **independently** (mono atomic) and **do not combine** with the atoms of other elements.

c)The atoms of other elements have **no octet structure** and hence try to attain **eight electrons in their valence shell** by combining with other atoms.

eiement	**Atomic Number** (number of Electrons orprotons)	Electronic configuration	**No of electrons in the valence shell**
Hydrogen(H)	1	$1s^1$	1
Lithium (Le)	3	$1s^2\mathbf{2s^1}$ **(2 ,1)**	1
Sodium (Na)	11	$1s^2 2s^2 2p^6\mathbf{3s^1}$ **(2 ,8 ,1)**	1
Chlorine(Cl)	17	$1s^2 2s^2 2p^6\mathbf{3s^2 3p^5}$ **(2 ,8 ,7)**	7
Carbon (C)	6	$1s^2\mathbf{2s^2 2p^2}$ **(2 ,4)**	4
Nitrogen(N)	7	$1s^2\mathbf{2s^2 2p^3}$ **(2 ,5)**	5
Magnesium (Mg)	12	$1s^2 2s^2 2p^6\mathbf{3s^2}$ **(2 ,8 ,2)**	2

b) When two or more atoms combine to form a molecule the electrons in their outermost orbits are rearranged in such a way as to achieve **octet or duplet** structure of the **nearest noble gas.**

Example: Sodium (Na) has 11 electrons, 2 in the first orbit, 8 in the second and 1 in the third orbit. If Na loses one electron, it would attain the same electronic configuration of its nearest gas Neon (Ne).

attain octet structure of

Ne by losing one electron

$$Na \longrightarrow Na^{+} + e^{-}$$

	(2, 8, 1)	(2, 8)
Calculation	+11p	+11p
of charge:	-11e	-10e
	0	+1

Neon has the electronic configuration (2, 8)]

To attain minimum energy and maximum stability

(a) When two or more atoms combine to form a molecule, the **energy** of bonded system decreases.(b)Bonded system has less energy (more stable) than the unbonded system (unstable).(c)Therefore atoms combine to form molecules to attain minimum energy and maximum stability.

Points to remember

- The atoms of most elements combine to form molecules due to two reasons
  - **a) To attain the octet structure of the nearest noble gas.**
  - **b) To form more stable molecules by losing energy.**

Concept of valence electrons

a) The electrons present in the outermost shell of an atom are called **valence electrons** because the combining capacity of the element (i.e. valency) depends upon the number of these electrons.

b) All the electrons present in the inner orbitals (core of the atom) excluding valence electrons are called **core electrons** which do not participate in chemical reaction.

Lewis symbols for the elements of second period

Element	Atomic No	E.C	Group Noin the periodic table	Valance Electrons	Lewis symbol	valency
Li	3	$1s^2\mathbf{2s^1}$	1	1	**Li.**	1
Be	4	$1s^2\mathbf{2s^2}$	2	2	**Be:**	2
B	5	$1s^2\mathbf{2s^2 2p^1}$	13	3	**.B:**	3
C	6	$1s^2\mathbf{2s^2 2p^2}$	14	4	**. .C. .**	4
N	7	$1s^2 2\mathbf{s^2 2p^3}$	15	5	**. :N. .**	8-5=3
O	8	$1s^2\mathbf{2s^2 2p^4}$	16	6	**.. :O. .**	8-6=2
F	9	$1s^2 2\mathbf{s^2 2p^5}$	17	7	**.. :F. ..**	8-7=1
Ne	10	$1s^2\mathbf{2s^2 2p^6}$	18	8	**.. :Ne: ..**	8-8=0

Significance of Lewis symbols

- The number of valence electrons (number of dots) helps to calculate the valency of the element.
- The valency is generally either equal to the number of dots in Lewis symbols or 8 minus the number of dots or valence electrons.

Octet rule (Kossel and Lewis)

Atoms can combine either by **transfer of valence electrons** from one atom to another or by **sharing of valence electrons** in order to have an **octet electron structure** in their valence shells. This is known as **octet rule**. This theory of chemical combination is known as **electronic theory of chemical bonding.**

Remember
Elements with lower atomic number try to attain two electrons ie **duplet** (instead of octet). It is called **duplet rule.**

Types of Bonds

The type of bond formed between the atoms depends upon the way in which the combining atoms attain octet structure in their valence shell.

(a) **Ionic or electrovalent bond (b) Covalent bond (c)Coordinate covalent bond(d)Metallic bond(e)Hydrogen bond(f)Van der Waal's force of attraction**

Remember	
Metal (electropositive element) **+** Nonmetal (electronegative element) E.g.: NaCl, MgO etc.	**Ionic bond**.
Nonmetal (electronegative element) **+** Nonmetal (electronegative element) E.g.: H_2, HCl etc.	**Covalent or coordinate bond**
Metal (electropositive element) **+** Metal (electro positive element) E.g.: gold, silver, sodium etc.	**Metallic bond**

For your knowledge
➢ **Electronegativity is the ability of an atom to attract bonded pair of electrons towards itself.** ➢ **Among all the elements F has highest electronegativity and Cs has lowest electronegativity** ➢ **The electronegativity of nonmetals is greater than metals**

Session-2 IONIC BOND OR ELECTROVALENT BOND

<u>Ionic Bond or Electrovalent bond</u> (bonding by transfer of electrons)

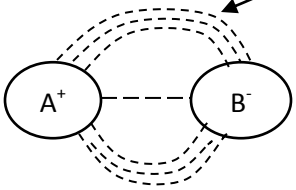
- Ionic bond is formed by the transfer of one or more valence shell electrons from a metal atom to the valence shell of a nonmetal atom.
- The metal atom which has lost electron(s) is converted into a positive ion (**cation)**and the nonmetal atom which gains electron(s) is converted into a negative ion (**anion).**
- The cations and anions thus formed attain **stable noble gas electronic configuration**.
- The negative and positive ions are held by electrostatic force of attraction.

An ionic bond is defined as the <u>electrostatic force of attraction</u> between the cations and anions resulting in the formation of ionic crystal.

Electrostatic force of attraction

$A + B \longrightarrow A^+ \quad B^-$ or

Cation Anion



Example: **<u>Formation of NaCl</u>**

Na(2,8,1) transfers it's excess electron to Cl atom (2,8,7) and thus Na atom acquires the configuration of Ne(2,8) and Cl acquires the configuration of Ar(2,8,8)

$$\mathbf{Na} \longrightarrow \mathbf{Na^+} + \mathbf{e}$$

[Ne] $3s^1$ [Ne]

$$\mathbf{Cl} \longrightarrow \mathbf{Cl^-}$$

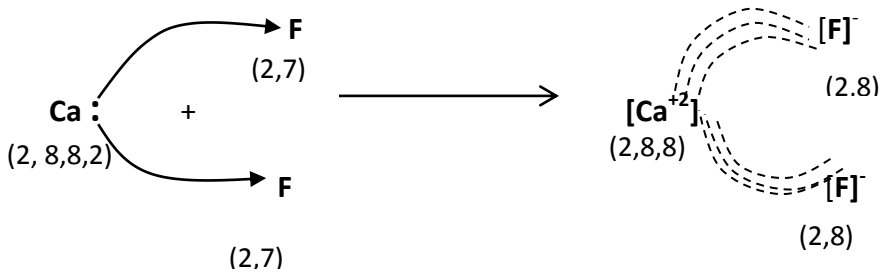
[Ne] $3s^2 3p^5$ [Ne] $3s^2 3p^6$ or [Ar]

The positive sodium ion and negative chloride in are held by electrostatic force of attraction to form ionic crystal.

$$\mathbf{Na} + \mathbf{Cl} \longrightarrow \mathbf{Na^+\,[Cl]^-}$$

(2, 8,1) (2,8,7) (2,8) (2,8,8)

Similarly the formation of CaF_2 may be shown as:



One calcium has two valence electrons in the outermost orbit. These electrons are transferred to two fluorine atoms which have seven electrons in their outermost. Calcium forms calcium ions (cation) and fluorine forms fluoride ions (anions). The calcium ion and two fluoride ions combine to attain the electronic configuration nearest noble gas .

Writing Chemical Formulae

- The symbolic representation of a molecule is called a **formula.**
- To write chemical formulae of different compounds, we need to learn the **Symbols** and combining capacity (**valency**) of elements.
- **Valency** can be used to find out how the atoms of an element recombine with the atoms of the another element to form a chemical compound.
- Compounds composed of metals and nonmetals contain charged species(cations and anions). Such compounds are called **ionic compounds**. The charged species are known as **ions.**

What is an ion or radical?
Radical or an ion is an atom or group of atoms possessing electric charge E.g: Na^+,Cl^- , SO_4^{2-}

Names and symbols of some ions

Valency	Name of ion	Symbol	Nonmetallic ion	Symbol	Polyatomic ions	Symbol
1.	Sodium Potassium Silver Copper (I)*	Na^{+} K^{+} Ag^{+} Cu^{+}	Hydrogen Hydride Chloride Bromide Iodide	H^{+} H^{-} Cl^{-} Br^{-} I^{-}	Ammonium Hydroxide Nitrate Hydrogen carbonate	NH_4^{+} OH^{-} NO_3^{-} HCO_3^{-}
2.	Magnesium Calcium Zinc Iron (II)* Copper (II)*	Mg^{2+} Ca^{2+} Zn^{2+} Fe^{2+} Cu^{2+}	Oxide Sulphide	O^{2-} S^{2-}	Carbonate Sulphite Sulphate	CO_3^{2-} SO_3^{2-} SO_4^{2-}
3.	Aluminium Iron (III)*	Al^{3+} Fe^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}

** Some elements show more than one valency. A Roman numeral shows their valency in a bracket.*

The rules for writing chemical formula of an ionic compound

- Write the symbols of both positive ion and negative ion side by side with their respective valencies or charges below their symbols.
- The positive ion (metal ion) is written to the left and negative ion (nonmetal ion) to the right .
- The valencies or charges on the ion must balance. To achieve this cross the valencies after removing the common factor. The numbers are to be placed at the right hand bottom corner of each symbol.
- When the number is **more than one** the polyatomic ion must be placed **within the bracket** and the number has to be placed outside the bracket .
- If the number placed at the right hand corner of the symbol is **one** then **it should not be written in the final formula.**

FORMULAE OF SIMPLE COMPOUNDS

- While writing the chemical formulae for compounds, we write the constituent symbols and their valencies as shown below.
- Then we must cross over the valencies of the combining atoms after removing common factors.

Examples:

1. Formula of hydrogen chloride

Symbol **H** **Cl**

Valency 1 1

Formula of the compound would be HCl

2. Formula of hydrogen sulphide

Symbol **H** **S**

Valency 1 2

Formula: **H_2S**

3. Formula of magnesium chloride

Symbol **Mg** **Cl**

valency 2+ 1-

Formula: **$MgCl_2$**

4. Formula of calcium oxide

Symbol **Ca** **O**

valency 2+ 2+

Remove

common factor 1 1

Formula: **CaO**

5. Formula of sodium nitrate

Symbol **Na** **NO_3**

valency 1+ 1-

Formula: **$NaNO_3$**

6. Formula of calcium hydroxide

Symbol **Ca** **OH**

valency 2+ 1-

Formula: **$Ca(OH)_2$**

7. Formula of ammonium sulphate

Symbol **NH_4** **SO_4**

valency 1+ 2-

Formula: **$(NH_4)_2SO_4$**

8. Formula of sodium carbonate

Symbol **Na** **CO_3**

valency 1+ 2-

Formula: **Na_2CO_3**

9. Formula ofaluminium sulphate

Symbol **Al** **SO_4**

valency 3+ 2-

Formula: **$Al_2(SO_4)_3$**

10 Formula of calcium carbonate

Symbol Ca **CO_3**

valency 2+ 2-

Remove common factor 1 1

Formula: **$CaCO_3$**

Properties of ionic compounds

- **Physical state**: Ionic compounds consists of three dimensional solid aggregates of cations and anions which are arranged in a **well defined geometrical pattern**. Thus ionic compounds are solids at room temperature
- **Electrical conductivity**:
  a. Ionic compounds do not conduct electricity when they are in the solid state because the cations and anions are held tightly by electrostatic force of attraction.
  b. The ionic solids conduct electricity when they are dissolved in water or in the molten state because ions are free to move in water solution or molten state.
- They are quite hard and have high melting points.
- Ionic compounds **exist as ions** in the solid as well as in the liquid state.
- They are **soluble** in polar solvents like water but insoluble in nonpolar solvents like ether, alcohol, benzene etc.
- The reactions between ionic compounds takes place between ions .
- They do not exhibit isomerism because the ionic bonds are non-directional.

SESSION-3

COVALENT BOND

Introduction

What is covalent bond?
A covalent bond is a force which binds atoms of same or different elements by mutual sharing of electrons.

- **G.N.Lewis** suggested that when two atoms having similar or almost similar electro negativities can achieve a stable valence shell configuration (2 or 8 electrons in the outer shell) **by sharing one or more valence electrons** between them.
- A bond formed by mutual sharing of electrons is called a **covalent bond**.
- During the formation of covalent bond the two combining atoms contribute equal number of electrons for sharing.
- The shared electrons contribute equally two both the atoms and both the atoms attain **octet number of electrons** in the valence shell.
- The shared electrons is represented by a dash (-) and is responsible for holding the two atoms together.
- The shared pair constitutes what is known as covalent bond.
- The molecule formed is called **covalent molecule (**or covalent compound).

Points to remember
• The number of electrons contributed by an atom for sharing to form a covalent bond is called **covalency.** • The valence electrons which are not involved in sharing are known as **non-bonding** or **lone pairs.**

Multiple covalent bonds

- When the atoms share one electron pair, the bond formed is called **single covalent bond.**
- If two electrons pairs are shared by the atoms, the bond formed is called **double covalent bond.**
- When the atoms share three electrons pairs, the bond is called **triple covalent bond.**
- The double and triple covalent bonds are called **multiple covalent bonds.**

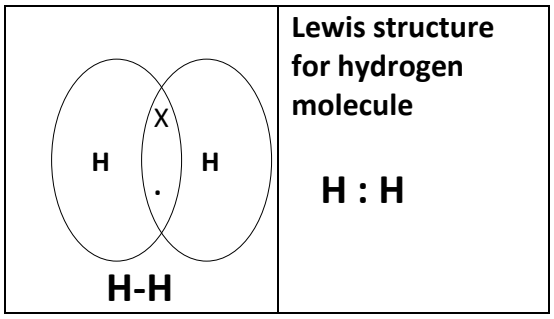
Illustration of the formation of covalent bonds

a. Formation of hydrogen (H_2) molecule.

i. Electronic configuration of H atom is $1s^1$.

ii. Each hydrogen atom share one electron pair between them to attain the helium gas configuration ($1s^2$)

iii. The two hydrogen atoms are thus joined by a single covalent bond.



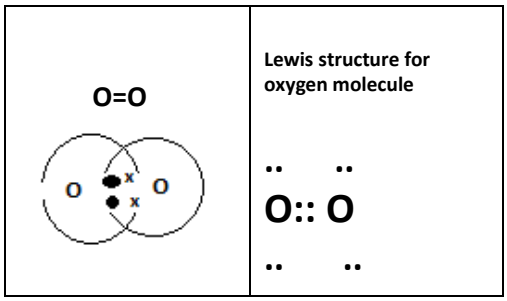
b. Formation of oxygen (O_2) molecule.

i. Electronic configuration each oxygen atom is $1s^2$**$2s^2 2p^4$**.

ii. The number of valence electrons in each oxygen atom is 6. (Total valence electrons of both oxygen atoms - 6+6=12).

iii. Each atom **shares two electron pairs** between them to attain the octet number of electrons.

iv. The two oxygen atoms are thus joined by two covalent bonds (double bond).



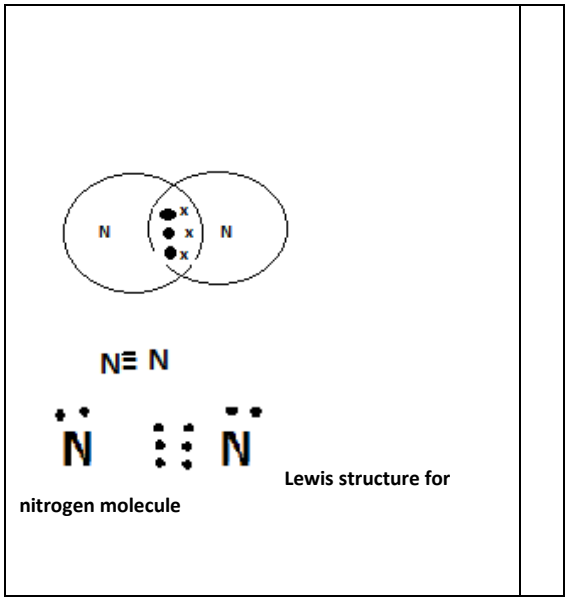
c. Formation nitrogen (N_2) molecule.

i. Electronic configuration of each nitrogen atom is $1s^2$**$2s^2 2p^3$.**

ii. The number of valence electrons in each nitrogen atom is 5. (Total valence electrons of both nitrogen atoms - 5+5=10).

iii. Each atom **shares three electron pairs** between them to attain the octet number of electrons.

iv. The two nitrogen atoms are thus joined by three covalent bonds (triple bond).



Properties of covalent compounds

- Covalent compounds exist as **molecules** and not as ions.
- Covalent compounds are generally gases, liquids or solids with **low melting points**.
- They are generally **insoluble** in polar solvents like water but soluble in non-polar solvents like benzene and ether.
- They do not conduct electricity because they contain neutral molecules (no ions).
- The covalent bonds are directional and covalent molecules have definite geometrical shape. Hence they may show **isomerism.**

POLAR AND NON POLAR MOLECULES

- **Non polar bond:** if a covalent bond is formed between same atoms, the shared pair of electron remain at the centre of two atoms. Such a covalent bond is called non polar covalent bond.

Shared pair at the centre

Ex: Cl —— : —— Cl

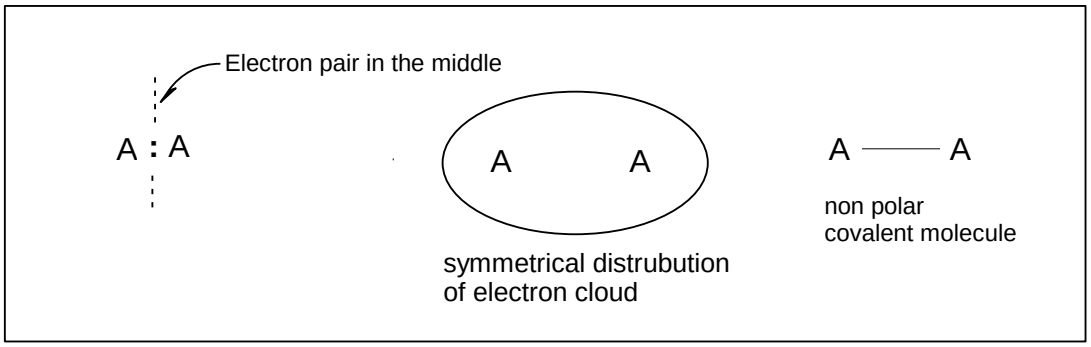
Non polar covalent bond in Cl_2

Polar bond: If a covalent bond is formed between two different atoms (such as HCl or H_2O etc), the shared pair of electrons is slightly shifted towards more electronegative atom causing a slight charge separation in the bond. Such a covalent bond is called polar covalent bond

Ex: $H^{+\delta}$ —— : → $Cl^{-\delta}$

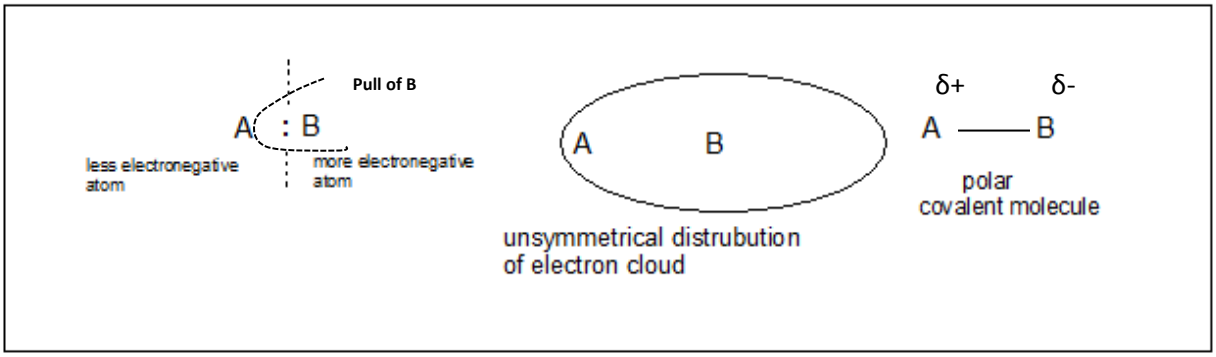
(Polar covalent bond in HCl)

non Polar molecules.(illustration)



- Some examples of molecules containing non polar covalent bonds are **H_2,Cl_2,O_2** etc.

Polar molecules(illustration)



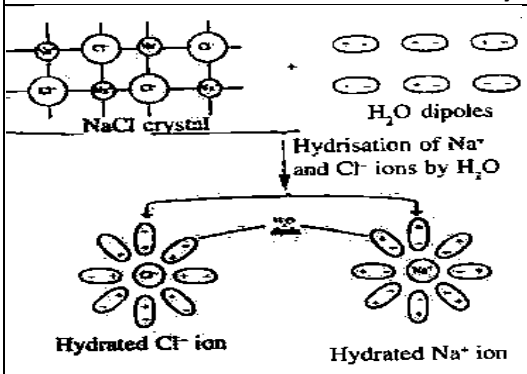
The examples of molecules containing polar covalent bonds are HCl, H_2O,NH_3 etc.

Water as a polar solvent.

A polar solvent like water, ammonia etc. are having ability to cut the lines of force binding the ions and thus separates them. This effect of a solvent is measured by its **dielectric constant**.

What is dielectric constant?
The dielectric constant of a solvent is its capacity to weaken the force of attraction between the ions of a ionic compound immersed in that solvent.

Point to remember
The dielectric constant of water (80) is highest and hence its capacity to dissolve the ionic compounds is maximum. Therefore water is called as **universal solvent**.

Dissolution of NaCl crystals in water	
	• When NaCl crystal is added to water both Na^+ and Cl^- ions are surrounded by a number of polar water molecules. This is called **hydration ions.** • When the ions are hydrated an energy known as **hydration energy** is released. • This helps in breaking the ionic molecules present in their crystal structure. Thus sodium chloride dissolves in water due to hydration

Other types of bonds;

*A **hydrogen bond** is the attractive force which binds hydrogen atom of one molecule with electronegative atom (F, O, or N) present in the same molecule or another molecule.*

Example: Hydrogen bonds in HF:

$H^{+\delta} – F^{-\delta}$..... $H^{+\delta} – F^{-\delta}$..... $H^{+\delta} – F^{-\delta}$.....$H^{+\delta} – F^{-\delta}$.....

Hydrogen bonds

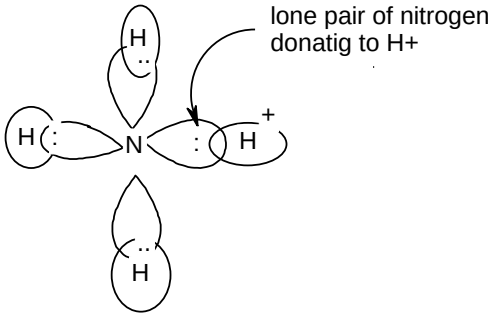
Van der Waal's force of attraction:

A weak inter atomic or intermolecular force of attraction which holds the constituents together is called Van der Waal's force of attraction.

Metallic bond;A metallic bond is a typical bond and is formed in metals.In this bond, a variable number of electrons are shared simultaneously by a variable number of metal ions. This type of bond is altogether different from the three bonds mentioned before.

Co-ordinate covalent bond: *Coordinate covalent bond is formed of sharing of an electron pair between the atoms where the shared pair of electrons is contributed by only one of the atoms.*

Ex: 1) formation of NH^{+}_{4}: ammonium ion is formed by the donation of lone pair of electrons by nitrogen to H^{+} ion



Exercise on chemical bonding

Answer the following questions;

1. What is a chemical bond?

2. The atoms of noble gases do not combine with other elements. Why?

3. Except noble gases, the atoms of other elements combine to form molecules. Why?

4. What are valence electrons?

5. What is octet rule?

6. Write the Lewis dot symbols for the following elements,

i) sodium ii) Aluminum iii) phosphorous iv)Boron

7. What is an ionic bond?

8. How is an ionic bond formed? Explain with an example.

9. What is formula of a compound?

10. What are ionic compounds?

11. What are the characteristics of ionic compounds?

12. What is a radical?

13 Write the symbols of the following radicals i) chloride ii)phosphate iii)oxide iv)iron(III) radical v)magnesium radical vi)aluminum radical vii)nitride radical viii)hydride

14.Write the formula of the following compounds

i)Calcium phosphate ii)Sodium sulphide iii)Magnesium nitride iv)Ammonium carbonate

15.Name the following compounds i)NH_4Cl ii)$Al_2(SO_4)_3$ iii)$Na_2\ SO_4$ iv)FeS

16. Solid sodium chloride does not conduct electricity. Why?

17. Ionic compounds do not show isomerism. Why?

18. Explain the solubility of ionic compounds in polar solvents with an example.

19.What is a covalent bond ?

20.Explain the formation of a covalent compound with an example.

21. What do you mean by lone pair of electrons?

22. Covalent compounds do not conduct electricity. Why?

23.Why are covalent compounds show isomerism?

24. What are non-polar molecules ? Give examples.

25. What are polar molecules ? Give examples.

26.What is dielectric constant?

27.What is hydration energy?

28. What is i)coordinate bond ii)Hydrogen bond iii)Metallic bond

29.Covalent compounds contain ions. True/False.

30.Give the reasons for chemical bond formation.

31.What is the theoretical difference between a sodium atom and a sodium ion? How are the properties of sodium atom different from those of sodium ions?

32.What is wrong with the expression " a molecule of sodium chloride"?

33.Classify the following bonds as ionic or covalent. For those bonds that are covalent ,indicate whether they are polar or nonpolar.

a.KF b. IBr c.MgS d.NO e.CaO f. NaBr g.Br_2 h.F_2 i.HCl