# ENGINEERING CHEMISTRY

## DIPLOMA COURSE IN ENGINEERING
## FIRST AND SECOND SEMESTER

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Untouchability is a sin
Untouchability is a crime
Untouchability is a inhuman

DIRECTORATE OF TECHNICAL EDUCATION
GOVERNMENT OF TAMILNADU

# ENGINEERINGCHEMISTRY-I

# FIRST SEMESTER

## UNIT-I

## ATOMIC STRUCTURES, MOLECULAR MASS, ACIDS AND BASES

### 1.1 ATOMIC STRUCTURE

### INTRODUCTION

**Chemistry is a branch of science that deals with the study of the nature of matter, its composition, occurrence, isolation, methods of preparation, properties and uses.**

An **atom** is the smallest form of a chemical particle that retains the properties of the particle. The word 'atom' comes from the Greek word 'atomos', meaning 'unable to be cut'. The original meaning of atom was the smallest, indivisible form of a chemical particle. Now we know how to divide atoms into sub-atomic particles, the definition of an atom includes the concept that the particle must retain its chemical properties.

### ATOM

An Atom is the smallest invisible particle of element, having all the characteristics of the parent element, which can neither be created nor destroyed by any chemical change. It cannot exist freely. It is the ultimate particle of an element, which may or may not have independent existence.

The atoms of certain elements such as hydrogen, oxygen, nitrogen, etc.do not have independent existence where as atoms of helium, neon, argon, etc. do have independent existence. All elements are composed of atoms.

**Fundamental particles of an atom**

Almost the atoms of all elements are made up of three main particles known as fundamental particles. They are electrons, protons and neutrons. Hydrogen is the only element that do not have neutron.

### PROTON

1.The proton is a positively charged particle.
2.It has unit positive charge and unit mass. The mass of proton is approximately equal to the mass of one hydrogen atom. It is equal to 1.00732 amu.
3.The proton is present in atoms of all the elements.
4. he protons are present inside the nucleus of an atom.

## ELECTRON

1. The electron is a negatively charged particle.
2. It has unit negative charge and negligible mass.
3. The mass of and electron is about 1/1837 of mass of a hydrogen atom.
4. Electrons are present in all the atoms.
5. Electrons are revolving around the nucleus in various circular orbits (shell).

## NEUTRON

1. The neutron is a neutral particle. Hence, it has no charge.
2. It has unit mass. The neutron is present in atoms of all elements except hydrogen. The mass of a neutron is slightly greater than the mass of a proton. It is equal to 1.00871 amu.
3. Neutron is present inside the nucleus of an atom.

## ATOMIC NUMBER (Z)

**The atomic number is the number protons present in the nucleus of an atom or number of electrons revolving around the nucleus in an atom**. Based on the carbon standard the atomic mass of an element may be defined as the ratio between the mass of one atom of the element and $1/12^{th}$ of mass of an atom of carbon

Atomic number= No of protons=No of electrons

## MASS NUMBER (A)

The mass number of an element is given by the total number of protons and neutrons present in the nucleus of an atom. A= (P+N)
Therefore the number of neutrons is = A-Z.

## ISOTOPES

The isotopes are atoms of the same elements having the same atomic number but different mass number.
e.g. Isotope of oxygen: $_8O^{16}$, $_8O^{17}$, $_8O^{18}$.

## ISOBAR

Isobars are the atoms of different elements having the same mass number but different atomic number.
e.g. $_{92}U^{234}$, $_{91}Pa^{234}$.

## STRUCTURE OF ATOM

The atom consists of two parts. They are 1.The central nucleus 2.The outer extra nuclear part.

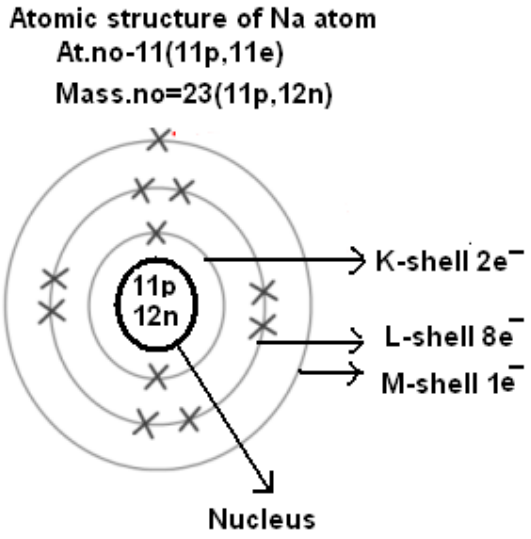
**1. The central Nucleus**:

The nucleus is the central part of an atom consists of protons and neutrons. Since the protons are positively charged particle and neutrons are neutral, the nucleus is always positive part of an atom. The entire weight of an atom is present only in the nucleus.

**2. The outer extra nuclear part.**

1. It is the part around the nucleus. It contains all electrons of an atom. It is the negative part of the atom. The electrons are revolving around the nucleus in a regular path called shell or orbit or energy levels.
2. The shells or orbits are numbered, as 1,2,3,4 etc from the nucleus. They are also known as K, L, M, N Shell or orbit.
3. Each shell can accommodate only certain number of electron, which is given by the formula $2n^2$ where the 'n' is the number of the shell. Therefore, the numbers of electrons that are accommodated in the 1st, 2nd, 3rd shell respectively are 2,8,18.
4. The electrons present in the outer most orbit is called as **valence electron**.
5. The atom as whole is a neutral one. Since the number of protons (positively charges) is equal to the number of electrons (negative charges).

**The atomic structure of Sodium atom is given below.**

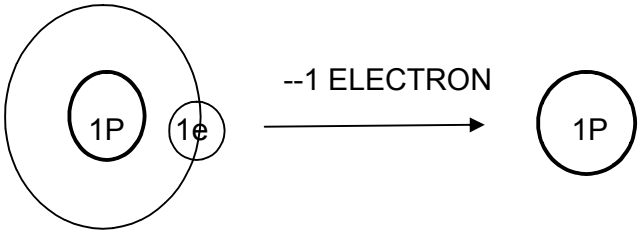



**FORMATION OF CATION AND ANION**

**Example.1**

**1. Hydrogen atom**

Number of proton = 1 (number of positive charge is +1)
Number of electron = 1 (number of negative charge is -1)
Number of neutron = 0




Hydrogen atom  Hydrogen ion ($H^+$) or proton

So, Z=1 , A=1

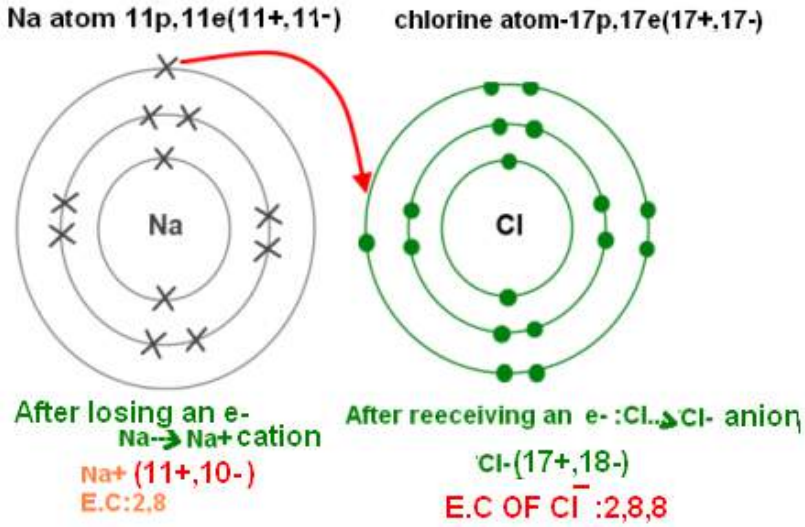
When hydrogen atom losses its outer most electron, it has only one proton. The H becomes $H^+$ ion due to the loss of one electron. Hence, the $H^+$ ion is called as proton.

$$H \longrightarrow H^+(\text{proton}) + 1e^-$$

A-Z=1-1=0(No neutron)

## FORMATION OF CATION AND ANION

**A**tom as whole is a neutral one, since the number of proton and electrons are equal. An atom becomes an ion only when there is a gain or loss of an electron. Anion (-ve ion) is formed by the gain of electron. Similarly, cation (positive) is formed by the loss of electron.




## CATION FORMATION

$$Na\ (Atom) \xrightarrow{-1e^-} Na^+\ (cation).$$

When an atom losses an electron it becomes cation. When electron is transferred from sodium atom to chlorine atom the sodium atom becomes cation.

## ANION FORMATION

When an atom gains an electron, it becomes anion. From the above example, chlorine atom gains an electron from sodium it becomes an anion.

$$Cl\ (Atom) \xrightarrow{+1e^-} Cl^-\ (Anion)$$

## ELECTRONIC CONCEPT OF OXIDATION AND REDUCTION

The electronic concept of oxidation and reduction can be explained as below.

## OXIDATION

Oxidation is a process that involves removal (loss) of electrons.

**Example:**

$$Na \xrightarrow{-1e^-} Na^+$$

$K \xrightarrow{-1e^-} K^+$

$H \xrightarrow{-1e^-} H^+$

Here Na, K and H are oxidised into $Na^+$, $K^+$ and $H^+$ respectively.

**REDUCTION**

Reduction is a process that involves addition (gain) of electrons.

**Example:**

$Cl \xrightarrow{+1e^-} Cl^-$

$F \xrightarrow{+1e^-} F^-$

$Br \xrightarrow{+1e^-} Br^-$

Here Cl, F and Br are reduced into $Cl^-$, $F^-$ and $Br^-$ respectively.

**What is chemical bonding?**

When two atoms in a molecule strongly tend to remain together, they are said to be in chemical bonding with each other. In other words, it is said that a chemical bond has been established between the two atoms. Thus,

**"A chemical bond may be defined as an attraction between the two atoms in a molecule"**

**Why do atoms combine?**

There is a deep relationship between the properties and the electrons lying in their outermost orbits. The elements having same number of valency electrons have similar properties. The elements in the zero groups have two or eight electrons are inactive chemically.

**OCTET RULE**

The inert gases have the stable configuration of eight electrons (octet structure) in their outer most orbits except helium which 2 have only electrons. Due to their stable octet structure, these gases are inert in nature. They do not chemically react with other elements. "According to Lewis "**octet theory, all the elements with an unstable or incomplete electronic configuration have a tendency to attain the stable electronic configuration of the nearest inert gas configuration either by complete transfer of valence electron from one atom to another or by mutual sharing of valence electron between the atoms".** This tendency to attain the stable electronic configuration is responsible for the formation of **chemical bonding**.

**INERT GASES OR NOBLE GASES**

| Element | Atomic number | Electronic configuration |
|---|---|---|
| Helium | 2 | **2 (H-1 unstable-for stable-2)** |
| Neon | 10 | 2,**8** |
| Argon | 18 | 2,8,**8** |
| Krypton | 36 | 2,8,18,**8** |
| Xenon | 54 | 2,8,18,18,**8** |
| Radon | 86 | 2,8,18,32,18,**8** |

## TYPES OF BONDING

The process by which unstable atoms acquire a stable configuration has been found to take place in two different ways.

1. The complete transfer of valency electrons from one atom to another. This is called Ionic bond (or) Electrovalent bonding.

2. The mutual sharing of (pair of) valency electrons between the atoms. The shared pair of electrons is given by both atoms. This is called as Covalent bonding.

### Ionic (or) Electrovalent Bond

This type of bond is formed as a result of the complete transfer of one or more electrons from one atom to other.

This bond is generally present in inorganic compounds

**Example : Formation of Sodium Chloride**

**Explanation :**

The atomic number of sodium is 11(11P/11e=11+/11- )

The electronic configuration is $1s^2$, $2s^2$, $2p^6$, $3s^1$(2, 8, 1).

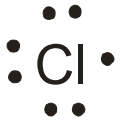
The electron dot formula is Na.

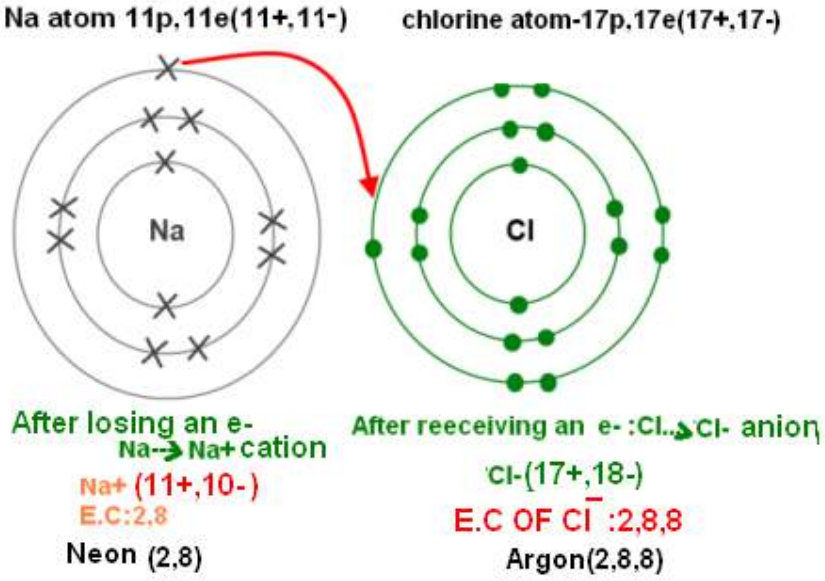
Sodium has only one electron in its outermost orbital.

The atomic number of chlorine is 17(17p/17e=17+/17- )

The electronic configuration is $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^5$ (2, 8, 7)

The electron dot formula is



Sodium has one electron in excess of the stable neon configuration (2, 8). and chlorine is one electron short of the stable argon configuration (2, 8, 8).

When these atoms are in contact, sodium has a tendency to lose its single valence electron and chlorine has a tendency to accept a single electron to reach the stable electronic configuration of the nearest inert gas. By transferring one electron from sodium to chlorine, sodium acquires a unit positive charge while by gaining the electron; the chlorine atom acquires a unit negative charge.

Now sodium has attained the stable electronic configuration of neon (2,8).Similarly chlorine has attained the stable electronic configuration of neon(2,8,8).

These charged ions are held together by electrostatic attraction and form a neutral molecule of sodium chloride.

Compounds formed in this way are called electrovalent or ionic compounds and the bond is called Ionic bond or electrovalent bond.

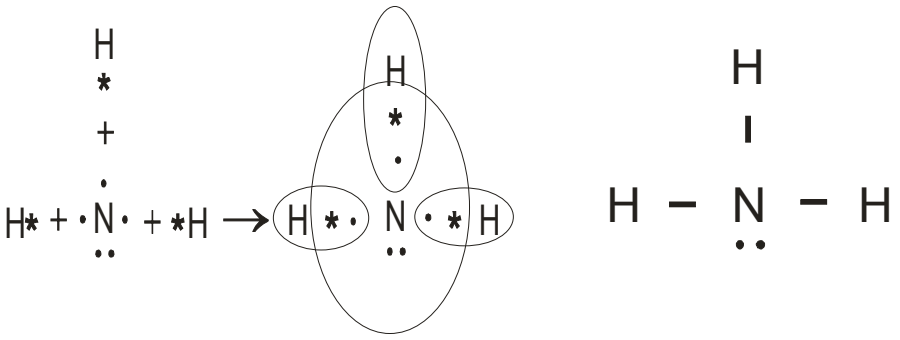
**Covalent bond**

**<u>Formation of a covalent compound($NH_3$)</u>**

**This type of bond is formed by the mutual sharing of pair of electrons between two atoms each atom supplying equal number of electrons for sharing. The covalent bond is indicated by (-).**

**Example : Formation of Ammonia ($NH_3$ ).**

**Explanation :**



The atomic no of Nitrogen is 7. (E.C:2, 5 unstable)

The electronic configuration $1s^2,2s^2,2p^3$.

The electron dot formula of N is 

The electron dot formula is **H·**

The atomic number of Hydrogen is 1.

The electronic configuration $1s^1$(E.C:1 unstable)

To get stable electronic configuration Nitrogen shares its three electrons with electrons of three Hydrogen atoms.

Ammonia is formed by the covalent bonding between one atom of hydrogen and three atoms of hydrogen. Nitrogen has five valence electrons. The electronic configurationis2,5(unstable). Therefore, it needs three electrons to attain stable inert gas configuration. Hydrogen has one electron. So it needs one electron to attain the stable inert gas configuration of Helium. The nitrogen atom shares three of its valence electron with three hydrogen atom forming the covalent bonds.

All the four atoms attain the stable configuration. Thus, the covalent bond is formed.

**QUESTIONS**

**PART-A**

1. What is the charge of a nucleus of an atom?
2. Define isotopes
3. Define isobars
4. What is the charge of an anion?
5. What is the charge of a cation?
6. Define oxidation
7. Define reduction

**PART-B**

1. We can call $H^+$ ion as a proton. How?
2. Atomic number and mass number of an element is 9 & 19 respectively. What is the number of neutrons present in the atom of the element?
3. Explain the formation of a cation with example?
4. Explain the formation of an anion with example**?**

**PART-C**

1. Why do atoms of elements combine?
2. Which is more stable Na or $Na^+$ Why?
3. Explain the formation of NaCl?
4. Explain the formation of NH3?
5. While atoms of most of the elements are unstable but atoms of noble gases are stable. Explain?
6. Which is more stable Cl or $Cl^-$ Why?

## 1.2. MOLECULAR MASS

**Introduction**

Chemistry is chiefly concerned with atoms and molecules and their interactions and transformations, for example, the properties of the chemical bonds formed between atoms to create chemical compounds or molecule. As such, chemistry studies the involvement of electrons and various forms of energy in chemical reactions.

**Molecule:**

A Molecule is the smallest particle of matter(element or a compound) that can exit freely. The molecule is made up of two or more atoms of the same element or different elements. It can be further divided into atoms.

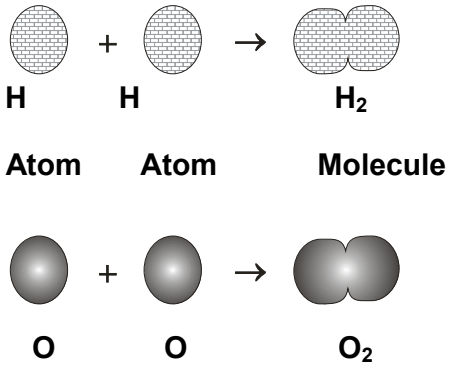
Types of molecules:

Molecules are of two types

1. Homoatomic molecules
2. Heteroatomic molecules

**1. Homoatomic molecule**

The molecule is made up of two or more atoms of the same elements**.** Molecules of Chlorine($Cl_2$), Oxygen($O_2$), and Hydrogen($H_2$) contain only two atoms of same kind. So they are called as Homoatomic molecules.

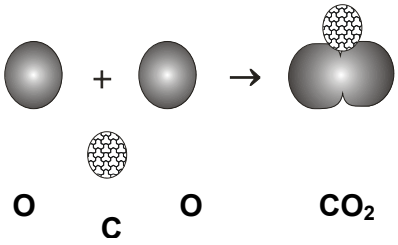



Most of the elementary gases consist of homoatomic molecules. For example hydrogen gas consists of two atoms of hydrogen ($H_2$).Similarly oxygen gas consists of two atoms of oxygen ($O_2$).

In accordance with the number of atoms present in these molecules they are classified as mono atomic, di-atomic, tri-atomic and polyatomic molecules showing that they contain one, two, three, or more than three atoms respectively.

**2. Heteroatomic molecules**

The molecule is made up of more than two of more atoms of different elements. Thus in the molecule of carbon dioxide one atom of carbon & two atoms of oxygen have united. Hence, it is called as Heteroatomic molecules.




**MOLECULAR FORMULA**

Molecular formula is the short form of representation (symbolical) of one molecule of an element or a compound.

**Example:** Molecular formula of Oxygen is $O_2$ (element.).

Molecular formula of water is $H_2O$ (compound)

**Significance of molecular formula**

1. It shows the elements present in one molecule.
2. It gives the exact number of atoms present in one molecule.
3. It is used to calculate the molecular mass of a molecule.

**MOLECULAR MASS:**

Molecular mass of an element or a compound is the ratio between the mass of one molecule of the element or the compound and the mass of 1/12 part of a carbon Atom.

$$\text{Molecular Mass of an Element / Compound} = \frac{\text{Mass of one molecule of an element or compound}}{\text{1/12 part by mass of carbon}}$$

**Calculation of Molecular Mass:**

Molecular mass can be calculated as the sum of total atomic mass of each element present in one molecule of an element or a compound.

**Example:**

Molecular mass of $O_2$ = Atomic mass x No of atoms

(Oxygen=16)

= 16 x 2 = 32

Molecular mass of $NH_3$ = (14 x 1) + (1 x 3) = 17

(Atomic mass of Nitrogen = 14,Hydrogen=1)

**MOLE:**

If the molecular mass is expressed in grams, then it is called gram molecular mass or one mole. The **mole** is a unit of measurement used in chemistry to express amounts of a chemical substance. One mole of any substance contains Avagadro number of particles i.e.,$6.023X10^{23}$ particles.(Atom, ion or molecules).

$$\text{Number of Moles} = \frac{\text{Mass in grams}}{\text{Molecular Mass}}$$

**Example:**

Molecular mass of $O_2$ = 32

Gram molecular mass of $O_2$ = 32gms

32 gms of $O_2$ = 1 mole of $O_2$

2 mole of $O_2$=64 g.

**Problem: 1**

How many moles are represented by 4.4 Gms. of $CO_2$ ?

At. Mass of Carbon = 12

At. Mass of Oxygen = 16

Molecular mass of $CO_2$ = (12 x 1) + (16 x 2)

= 12 + 32

= 44

$$\text{No of moles} = \frac{\text{Mass in gm}}{\text{Molecular mass}}$$

$$\text{Thus no of moles of } CO_2 = \frac{4.4}{44} = \mathbf{0.1\ mole}$$

**Problem: 2**

How many moles are present in 8.5gms of Ammonia?

At. Mass of Nitrogen = 14

At. Mass of Hydrogen = 1

Molecular mass of Ammonia ($NH_3$) = (14 x 1) = (1 x 3 )

= 17

$$\text{No of moles} = \frac{\text{Mass}}{\text{Molecular mass}}$$

$$= \frac{8.5}{17} = 0.5$$

NO of moles present in 8.5of Ammonia= **0.5**

**Problem: 3**

How many grams of $SO_2$ are present in 0.4 moles of $SO_2$ ?

| | | |
|---|---|---|
| Atomic Mass of Sulphur | = | 32 |
| Atomic Mass of Oxygen | = | 16 |
| Molecular mass of $SO_2$ | = | (32 x 1 ) + (2 x 16 ) |
| | = | 64 |
| Gram molecular mass of $SO_2$ | = | 64g |
| 1 mole | = | 64g |
| ∴0.4 Moles | = | 64 x 0.4 |
| | = | **25.6g** |

**Problem: 4**

How many moles of Carbon atoms are present in three moles of $C_3 H_8$?

1 mole of $C_3 H_8$ has 3 moles of carbon

∴3 moles of $C_3H_8$ will have 9 moles of carbon atoms.

## AVOGADRO'S HYPOTHESIS

Avogadro's Hypothesis states that, **"Equal volumes of all gases contain the same number of molecules at the same temperature and pressure".**

### Relationship between Molecular Mass & Vapour Density

**Vapour Density :-**

Vapour Density of a gas is the ratio between the mass of certain volume of the gas & the mass of the same volume of hydrogen at the same temperature and pressure.

$$\text{Vapour Density} = \frac{\text{Mass of certain volume of a gas}}{\text{Mass of same volume of hydrogen at S.T.P}}$$

Let there be 'n' molecules in certain volume of a gas

$$\text{Vapour Density} = \frac{\text{Mass of 'n' molecules of a gas}}{\text{Mass of 'n' molecules of hydrogen}}$$

Let n =1