Mole Concept Theory

Elements, Compounds, Mixtures and Substances

Matter is that which has mass and occupies space. A substance is a particular kind of matter, such as air, iron, honey or wood. Water, ice and steam are not different substances, but different physical forms of one substance.

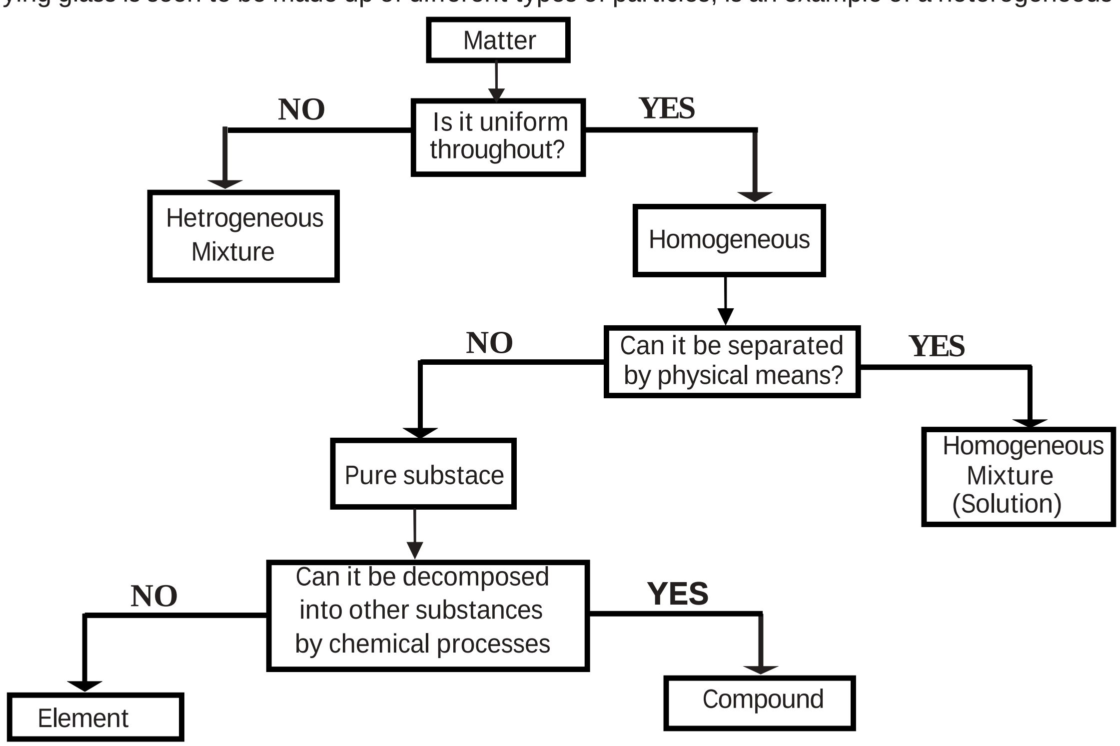
Matter may divided into **pure substances** and **mixture**. A mixture consists of one or more substance, which can normally be separated using physical means. Air is a mixture because it can be separated into a number of pure substances, namely nitrogen, oxygen, carbon dioxide, and other gases.

A pure substance may be an **element**, or a **compound**, and always has the same composition.

Elements cannot be separated into simpler substances by chemical changes, such as are brought about by heat, electric current, or other means.

Compounds are pure substances made up of two or more elements in certain fixed proportions. The simplest unit of a compound is the **molecule**. Water is made up of molecules consisting of two atoms of the element hydrogen, and atom of oxygen (H_2O). There is a compound whose molecules are made up of two atoms of hydrogen and two atoms of oxygen (H_2O_2), which is not water, but hydrogen peroxide, a totally different substance.

Mixtures may be **homogeneous**, where the properties are uniform throughout any sample of the mixture, or **heterogeneous**, in which case the properties can vary from one sample to another. A solution such as salt and water, or a mixture of gases such as air, are examples of homogeneous mixtures. Sea sand, which under the magnifying glass is seen to be made up of different types of particles, is an example of a heterogeneous mixture.



Dalton's Atomic Theory

1. Each element is made up of tiny particles called atoms.
2. The atoms of a given element are identical; the atoms of different elements are different in some fundamental way or ways.
3. Chemical compounds are formed when atoms combine with each other. A given compound always has the same relative numbers and types of atoms.
4. Chemical reactions involve reorganization of the atoms–changes in the way they are bound together. The atoms themselves are not changed in a chemical reaction.
5. Atoms can not be created, destroyed or transformed into atoms of other elements.

Modified View of Dalton's Theory

1. The atom is no longer supposed to be indivisible. The atom is not a simple particle but a complex one.
2. Atoms of the element may not necessarily possess the same mass but possess the same atomic number and show similar chemical properties **(Discovery of isotopes)**.
3. Atoms of the different elements may possess the sane mass but they always have different atomic numbers and differ in chemical properties **(Discovery of isotopes)**.
4. Atoms of one element can be transmutation into atoms of other element. **(Discovery of artificial transmutation)**

Chemical Equations

A chemical changes involves a reorganization of the atoms in one or more substances. For Example, when the methane (CH_4) in natural gas combines with oxygen (O_2) in the air and burns, carbon dioxide (CO_2) and Water (H_2O) Are formed. This process is represented by a **chemical equation** with **reactants** (here methane and oxygen) on the left side of and the **products** (carbon dioxide and water) on the right side :

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

Reactants   Products

Notice that the atoms have been reorganized. Bonds have been broken, and new ones formed it is important to recognize that in a chemical reaction atoms are neither created nor destroyed. All atoms present in the reactants must be accounted for among the products. In other words, there must be the same number of each type of atom on the product side and on the reactant side of the arrow. Making sure that this rule is obeyed is called **balancing a chemical equation** for a reaction.

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

Reactant	Product
1 C	1 C
4 H	4 H
2 O	2 O

Meaning of Chemical Equation

The chemical for a reaction gives two important types of informations.

1. Nature of the reactants and products
2. Stoichiometry coefficient of reaction

Notation of Physical State Reactants and Products

State	Symbol
Solid	(s)
Liquid	(l)
Gas	(g)
Dissolved in Water (in aqueous solution)	(aq)

Information Produced by Balanced Equation

Reactants		Products
CH_4 (g) + $2O_2$ (g)	⟶	CO_2 (g) + $2H_2O$ (g)
1 molecule CH_4 + 2 molecules O_2	⟶	1 molecule CO_2 + 2 molecules H_2O
1 mole CH_4 molecules + 2 mole O_2 molecules	⟶	1 mole CO_2 molecules + 2 mole H_2O molecules
6.022×10^{23} CH_4 molecules+ $2(6.022\times10^{23})$ O_2 molecules	⟶	6.022×10^{23} CO_2 molecules $+2(6.022 \times 10^{23})H_2O$ molecules
16 g CH_4 + 2(32 g) O_2	⟶	44 g CO_2 + 2(18 g) H_2O
80 g reactants	⟶	80 g product

MOL CONCEPT

- A mol (Symbol mol) is defined as the quantity of given substance that contains as many molecules or formula units as the no of atoms in exactly 12 gm of C–12.

  The number of atoms in a 12 gm sample of C–12 is called Avogadro's number (N_A). Recent measurement of this number gives the value 6.0221367×10^{23}, which to three significant figures is 6.02×10^{23}.

- A mol Avogadro's no (6.02×10^{23}) of molecules or formula units.

- A mol of a substance contains Avogadro's no (6.02×10^{23}) of molecules (or formula units). The term mol, like a Dozen. A Dozen equals 12 eggs , a gross of Pencil equal 144 Pencil. Mol is also known as chemist dozen.

- In using the term mol for ionic substance, we mean the number of formula units of the substances. For example, a mol of sodium carbonate Na_2CO_3 is a quantity containing 6.02×10^{23} Na_2CO_3 units. But each formula unit of Na_2CO_3 contains two Na^+ ions and one CO_3^{-2} ions.

The SI unit for an amount of matter is called the **mole**. In the same way that the amount of certain objects (such as apples or eggs) is often expressed in terms of multiples or fractions of a unit we call **dozen**, the amounts of the building blocks of matter (such as protons, electrons, atoms or molecules) are expressed in terms of multiples or fractions of a unit we call **mole**, or just **mol** for short.

Thus, if you are familiar with expressions such as "two dozen eggs" or "half a dozen apples", you will easily see the similarity with expressions such as "3 mol sulphuric acid", "half a mol of copper atoms" and "0.001 mol photons".

Of course, everyone knows that the unit we call "dozen" is associated with the number 12. But mole is defined as the amount of matter which contains the same number of elementary particles of the matter in question as there are atoms in 0.012 kg of the carbon isotope 12 C.

Atomic Mass Unit

Atomic mass unit is defined as a mass exactly equal to one-twelfth the mass of one carbon -12 atom. One atomic mass unit also called one **Dalton**.

Mass of one mole C-12 = 12 g = mass of 6.023×10^{23} C-12 atom

Mass of one C-12 atom = $12/6.023 \times 10^{23}$ g = $12 \times 1.66 \times 10^{-24}$ = 12 amu **(1 amu or 1 dalton = 1.66×10^{-24} g)**

Molar mass

If the relative atomic mass of an atom (or the relative molar mass of a molecule, or the relative formula mass of a salt, as the case may be) is expressed in grams, this gives rise to a quantity known as the molar mass of the substance in question.

Equal numbers of moles of different substances always contain the same number of elementary particles. Just as half a dozen eggs is always 6 eggs and half a dozen onions is always 6 onions, half a mole of hydrogen gas is always equal to 3.012×10^{23} molecules of H_2. Similarly, we know that half a mole of gold is always equal to 3.012×10^{23} atoms of Au.

To convert a given number of moles of a substance to the corresponding mass in grams, multiply the relative molar mass (or relative atomic mass for an monatomic element) by the number of moles, and express the result in grams.

The molar volume

The volume occupied by one mole of a substance is called the **molar volume** for that substance. It may be easily calculated from the density of the substance:

Density = Mass / Volume

If one works in moles, this becomes

Density = Molar mass / Molar volume

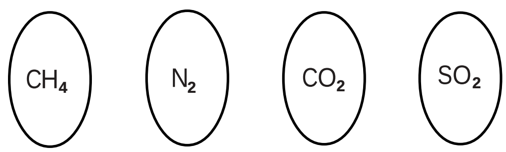
The molar volume is of particular interest when dealing with gases. Since the density of a gas is greatly dependent on the temperature and pressure, the density should be measured at the standard temperature and pressure (STP), which is a temperature of 273.14 K (0ºC) and pressure of 1.0 atm or 760 mm of Hg or 760 torr or 76 cm of Hg.

It turns out that the molar volume (measured at STP) is nearly the same for all gases, and has the value of 22.4 dm^3. To put it in another way, one mole of any gas at STP will occupy a volume of 22.4 dm^3.

Avogadro's law

The constancy of the molar volume of gases is explained in terms of Avogadro's Law, formulated in by 1811 by Amedeo Avogadro.

"Equal volumes of all gases, measured at the same temperature and pressure, will contain the same number of molecules."



These balloons hold 1.0 litre of gas at 25°C and 1.0 atm each balloons contains .041 mole of gas or 2.5×10^{22} molecules.

Molecular Weight

Weight of one mole molecule in gram is known as Molecular Weight of molecule or weight of one molecule in amu. is known as molecular weight of molecule.

For Example:- Molecular weight of CO_2 is 44. It means weight of one molecule CO_2 is 44 amu or weight of one mole molecule CO_2 is 44 g.

$\because$ Weight of one mole molecule CO_2 is 44 gm.
or,
Weight of N_A molecule CO_2 is 44 gm.
$\therefore$ Weight of one molecule of CO_2 is 44 / N_A gm. or 44 amu. ($1/N_A$ = 1 amu. = 1 dalton = 1.66×10^{-24} gm)

Atomic Weight

Weight of one mole atom in gram is known as atomic Weight of atom or weight of one atom in amu. is known as atomic weight of atom.

For Example:- atomic weight of He is 4. It means weight of one atom He is 4 amu or weight of one mole atom He is 4 g.

$\because$ Weight of one mole atom He is 4 gm.
or,
Weight of N_A atom He is 4 gm.
$\therefore$ Weight of one atom of He is 4 / N_A gm. or 4 amu. ($1/N_A$ = 1 amu. = 1 dalton = 1.66×10^{-24} gm)

Density and Specific Gravity

The density of a sample of matter is defined as the mass per unit volume:

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad D = \frac{m}{v}$$

Densities may be used to distinguish between two substance or to assist in identifying a particular substance. They are usually expressed as g/cm^3 or g/mL for liquids and solids and as g/L for gases. These units can be expressed as $g\ cm^{-3}$, $g\ mL^{-1}$, $g\ L^{-1}$, respectively. Densities of several substances are listed in following table.

Density of Common Substances

Substance	Density, g/cm^3	Substance	Density, g/cm^3
Hydrogen (gas)	0.000089	Sand	2.32
Carbon dioxide (gas)	0.0019	aluminum	2.70
Cork	0.21	iron	7.86
oak wood	0.71	copper	8.92
ethyl alcohol	0.789	lead	11.34
water	1.00	mercury	13.59
magnasium	1.74	gold	19.3
table salt	2.16		

Specific Gravity (Sp. Gr.) of a substance is the ratio of its density to the density of water, both at the same temperature. Specific gravities are dimensionless numbers.

$$\text{Sp. Gr.} = \frac{D_{\text{substance}}}{D_{\text{water}}}$$

The density of water is 1.000 g/mL at 3.98°C, the temperature at which the density of water is greater However, variations in the density of water with changes in temperature are small enough that we may use 1.00 g/mL up to 25°C.

Vapour Density

It is defined as mass of one mole vapour with respect to mass of one mole H_2.

$$\text{Vapour Density} = \frac{\text{mass of one mole vapour}}{\text{mass of one mole } H_2} = \frac{\text{molecular weight}}{2}$$

Molecular weight = 2 × Vapour Density

Relative Density

It is defined as density of one substance respect to density of other substance.

Q. Calculate relative density of Cl_2 with respect to air. (Molecular weight of air is 29 g/mole)

Ans. Relative density of Cl_2 wrt air $= \frac{\text{Vapour Density of } Cl_2}{\text{Vapour Density of air}}$

$$= \frac{\text{Vapour Density of } Cl_2 \times 2}{\text{Vapour Density of air} \times 2} = \frac{\text{Molecular weight of } Cl_2}{\text{Molecular weight of air}} = \frac{71}{29} = 2.45$$

Q. 105 mL of pure water at 4°C saturated with NH_3 gas yeilded a solution of density 0.9 g mL^{-1} and containing 30% NH_3 by mass. Find out the volume of NH_3 solution resulting and the volume of NH_3 gas at 4°C and 775 mm of Hg which was used to saturate water.

[Ans: 166.67 mL solution, 59.03 litre pure NH_3]

❖ When using the term mol, it is important to specify the formula of the unit to avoid any misunderstanding.

❖ 1 mol oxygen (Confusing)

1 mol oxygen may be

(a) 1 mol oxygen molecule

(b) 1 mol oxygen atom.

The molar mass of a substance is the mass of one mol substance. C–12 has molar mass of exactly 12 gm/mol, by definition.

Mole can be defined in three terms :

1. Mole in terms of number
2. Mole in terms of mass
3. Mole in terms of volume.

1. MOLE IN TERMS OF NUMBER:

Mole of an unit of chemists to count atoms, molecules, ions, electrons, protons, neutrons, Chemical bond etc. and one mole of any thing is equal to 6.022×10^{23} pieces or particle of that thing.

e.g., One mole of Na = 6.022×10^{23} atom of Na

One mole of H_2O = 6.022×10^{23} molecule of H_2O

One mole of CO^{2-}_3 = 6.022×10^{23} ions of CO^{2-}_3.

$$\text{No. of mole} = \frac{\text{No. of particle} \times \text{Mol}}{N_A \text{ Particle}}$$

☞ No of particle may be atom, molecule, ion, electron, proton, neutron, photon etc.

For atom

$$\text{No of mole} = \frac{\text{No. of atom} \times \text{Mol}}{N_A \text{ atom}}$$

For ion

$$\text{No of mole} = \frac{\text{No. of ion} \times \text{Mol}}{N_A \text{ ion}}$$

For molecule

$$\text{No of mole} = \frac{\text{No. of molecule} \times \text{Mol}}{N_A \text{ molecule}}$$

For electron

$$\text{No of mole} = \frac{\text{No. of electron} \times \text{Mol}}{N_A \text{ electron}}$$

☞ One mole He = 1 mol He atom = $1 \times 6.022 \times 10^{23}$ He atom

One dozen egg = 1×12 Egg (Mol is a unit like dozen)

2 mol oxygen = 2 mol oxygen atom = $2 \times 6.022 \times 10^{23}$ oxygen atom

☞ 1 mol $C_6H_{12}O_6$ = 1 mol $C_6H_{12}O_6$ molecule = $1 \times 6.022 \times 10^{23}$ $C_6H_{12}O_6$ molecule

2 mol CO_2 = 2 mol CO_2 molecule = $2 \times 6.022 \times 10^{23}$ CO_2 molcule

☞ 1 mol SO_4^{-2} = 1 mol SO_4^{-2} ion = $1 \times 6.022 \times 10^{23}$ SO_4^{-2} ion

2 mol Na^+ = 2 mol Na^+ ion = $2 \times 6.022 \times 10^{23}$ Na^+ ion

2. MOLE IN TERMS OF MASS :

One gram atom of an element or one gram molecule of a substance or one gram ion of an ion is known as one mole of that element or substance or ion respectively. e.g.,

(i) One gram atom Na = One mole Na

= 23 g Na

= 6.022×10^{23} atoms of Na.

(ii) One gram molecule H_2O = One mole H_2O

= 18 g H_2O

= 6.022×10^{23} molecule of H_2O.

(iii) One gram ion of CO_3^{2-} = One mole CO_3^{2-}

= 60 g CO_3^{2-}

= 6.022×10^{23} ions of CO_3^{2-}.

3. MOLE IN TERMS OF VOLUME OR STANDARD MOLAR VOLUME OR MOLAR VOLUME :

One mole of any gas contains 22.4 liters at N.T.P or S.T.P. (0°C & 760 m.m of Hg), the volume is called molar volume of standard molar volume of oftenly called **gram molecular volume. e.g.,**

(i) One mole NH_3 = 22.4 litres NH_3 at N.T.P. (Molar volume or **gram molecular volume**)

= One gram molecule NH_3

= 17 g NH_3

= 6.022×10^{23} molecules of NH_3.

(ii) One mole of He = 22.4 litre He at N.T.P. (Molar volume or **gram atomic volume**)

= One gram atom He

= 4 g He

= 6.022×10^{23} atoms of He.

(iii) One mole of Hydrogen = 22.4 litres hydrogen at N.T.P.

(Molar volume or **gram molecular volume**)

= 2 g hydrogen

= 6.022×10^{23} molecules of hydrogen

= $2 \times 6.022 \times 10^{23}$ atoms of hydrogen.

Problem For Practice

1. Convert 0.5 M $KMnO_4$ in gm/liter ....
   (Mol. wt of $KMnO_4$ = 158)
2. Calculate no. of DOZEN in 60 mango.
3. Calculate no. of mol of Na^+ in 6.023×10^{25} ion Na^+.
4. Calculate no. of H^+ per ml in 10^{-5} M H_2SO_4.
5. Calculate no. of H^+ per ml in 10^{-5} M HCl.
6. Calculate molarity of H^+ in resulting solution when 100 ml of 1×10^{-2} M H_2SO_4, 100 ml of 1×10^{-2} M HCl and 100 ml of 1×10^{-2} M HNO_3 mixed.
7. In the above problem (Q. N = 6) calculate no. of H^+ and no. of mol of H^+ in resulting solution.
8. Calculate no. of molecule of CO_2 in 440 amu CO_2.
9. Calculate wt. of one molecule of CO_2, $C_6H_{12}O_6$ and CO in gm.
10. 18 gm $C_6H_{12}O_6$ dissolved in water and make 250 ml solution. 25 ml of this solution diluted ten times. Calculate no. of C atom in final solution.

❖ **Concept 1 :**

Mol is a unit like Dozen.

1 Dozen = 12 unit.

1 mol = N_A = 6.022 × 10^{23} unit

↓

Avogadro number

Ex. 1. Calculate number of Dozen in 24 particle of any substance.

Solution : $\text{No of DOZEN} = \dfrac{\text{No of particles}}{\dfrac{12\ \text{particle}}{\text{Dozen}}} = \dfrac{24\ \text{particle} \times \text{Dozen}}{12\ \text{particle}} = 2\ \text{DOZEN}$. **[Ans : 2]**

Ex.2. Calculate number of mol of 6.022 × 10^{24} particle of any substance.

Solution : $\text{No of mol} = \dfrac{\text{No of particles}}{6.022 \times 10^{23} (N_A)\ \text{particle /mol}} = \dfrac{6.022 \times 10^{24}\ \text{particle} \times \text{mol}}{6.022 \times 10^{24}\ \text{particle}} = 10$

[Ans : 10]

Note : (i) Consider 1 mol molecule $C_6H_{12}O_6$ (consist of 6 mol of C atom, 12 mol of atom & 6 mol of O atom)

Total mol of atom = 24.

(ii) Consider x mol of molecule $C_6H_{12}O_6$ = x mol $C_6H_{12}O_6$ = (Generally written)

↓

(consist of 6x mol of C atom, 12x mol of H atom & 6x mol of O atom)

Total mol of atom = 24x

Ex.3. : Calculate number of oxygen atom present in 9.8 gm H_2SO_4.

Solution : No of mol of $H_2SO_4 = \dfrac{\text{weight}}{\text{molecular weight}}$ = 9.8/9.8 = 0.1

0.1 mol of H_2SO_4 i.e., 0.1 × 4 mol oxygen atom.

No. of atom = 0.4 × N_A oxygen atom.

❖ **Concept 2:**

(a) Consider 1 molecule $C_6H_{12}O_6$. (Consist of 6 atom of C, 12 atom of H and 6 atom of O)

∴ **Total number of atom = 24**

(b) x molecule $C_6H_{12}O_6$ (Consist of 6x atom of C, 12x atom of H and 6x atom of O)

∴ **Total number of atom = 6x + 12x + 6x = 24x**

❖ **Concept 3 :**

Consider 1 mol of $C_6H_{12}O_6$

1 Mol of $C_6H_{12}O_6$ is confusing word.

It should be written as $\rightarrow$ 1 mol molecule $C_6H_{12}O_6$.

Ex. : **No of molecule in 1 mol molecule $C_6H_{12}O_6$.**

Solution : No of molecule = $1 \times N_A$ molecule $C_6H_{12}O_6$.

Analogous example : 2 DOZEN egg = 2 × 12 eggs.

❖ Concept 4 :

Molecular weight of $C_6H_{12}O_6$ is 180. It means weight of one mol molecule $C_6H_{12}O_6$ is 180 gm.

Ex. **Calculate weight of 1 molecule in the term of (a) gm (b) amu (Atomic Mass Unit)**

Solution: $\because$ weight of 6.023×10^{23} molecule $C_6H_{12}O_6$ is 180 gm.

$\therefore$ weight of 1 molecules $C_6H_{12}O_6$ is $\dfrac{180}{6.022 \times 10^{23}}$

$$\frac{180}{6.022 \times 10^{23}} = 1 \text{ amu} = 1.66 \times 10^{-24} \text{ gm}$$

(a) weight of 1 molecule $C_6H_{12}O_6$ is $180 \times 1.66 \times 10^{-24}$ gm.

(b) weight of 1 molecule $C_6H_{12}O_6$ is 180 amu.

[**Ans : (a)** $180 \times 1.66 \times 10^{-24}$ gm **(b)** 180 amu]

Note : (i) Atomic weight of He is 4. It means weight of 1 mol He atom is 4 gm. Hence weight of atom He can be calculate in the term of gm and amu.

Weight of one atom He = $1.66 \times 10^{-23} \times 4$ gm

Weight of one atom He = 4 amu

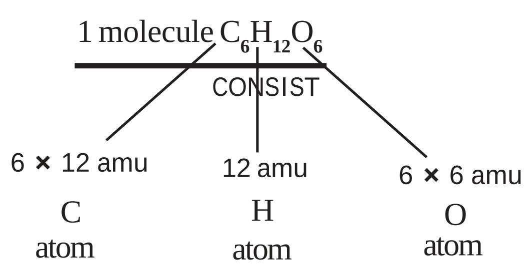
(ii) Weight of 1 molecule CO_2 is 44 amu.

Weight of 1 molecule H_2SO_4 is 98 amu.

Weight if 10 molecule $C_6H_{12}O_6$ is 180 amu.

❖ Concept 5 :

EX.1 : **Calculate percentage of Carbon atom in $C_6H_{12}O_6$.**



Total wt of one molecule is 180 amu

wt of carbon atom in 1 molecule $C_6H_{12}O_6$ is 72 amu

$$\% \text{ of C} = \frac{72 \text{ amu} \times 100}{180 \text{ amu}} = \frac{6 \times 12 \text{ amu} \times 100}{180 \text{ amu}}$$

$$\% \text{ of C} = \frac{\text{No of C atom} \times 12 \times 100}{\text{Mol} - \text{wt of } C_6H_{12}O_6}$$

Conclusion :

% of particular atom α No. of particular atom in molecule

Molecular weight of substance α No. of particular atom in substance.

Note : Minimum molecular wt of substance means molecule consist contain 1 atom s atom. (Which is described in problem)

EX.2 : **Calculate minimum mot-wt of insulin. If it contains 3.4% s atom.**

Solution : Minimum molecular weight of insulin means insulin contain ! Atom s atom. (Infact insulin molecule consist 6 atoms)

$$\% \text{ of } S = \frac{1 \times 32}{\text{Minimum molecular weight}} \times 100$$

Minimum molecular weight $= \dfrac{3200}{3.4}$. [**Ans :** $\dfrac{3200}{3.4}$]

Problem Related with Minimum molecular weight

1) A sample of polystyrene prepared by heating styrene with tribromobenzoyl peroxide in the absence of air has the formula $Br_3\ C_6H_3\ (C_8H_8)_n$. The number n varies with conditions of preparation. One sample of polystyrene prepared in this manner was found to contain 10.46% bromine. What is the value of n ?
   Ans : 19
2) One of the earliest method for determining the molecular weight of protein was based on chemical analysis. A haemoglobin preparation was found to contain 0.335% iron.
   (a) If the haemoglobin molecule contain one atom of iron. What is its molecular weight ?
   (b) If the haemoglobin molecule contains four atom of iron. What is its molecular weight ?
   Ans : (a) 16700
   (b) 66800
3) A polymeric substance, tetrafluroethylene, can be represented by the formula $(C_2F_4)_x$, where x is a large number. The material was prepared by polymerizing C_2H_4 in the presence of sulphur bearing catalyst that served as a nucleus upon which polymer grew. The final product was found to contain 0.012% S. What is the value of x if each polymer molecule contains
   (a) 1 Sulphur atom
   (b) 2 Sulphur atom
   In either case assume that the catalyst contributes a negligible amount to the total mass of the polymer.
   Ans : (a) 2.7×10^3
   (b) 5.3×10^3
4) A peroxidase enzyme isolated from human red blood cell was found to contain 0.29% selenium. What is the minimum mol.wt of the enzyme.
   Ans : 2.7×10^4
5) A purified pepsin isolated from a bovine preparation was subjected to an amino acid analysis. The amino acid present in smallest amount was lysine, $C_6H_{14}N_2O_2$ and the amount of lysine was found to be 0.43 gm per 100 gm protein. What is the minimum mol. wt of protein?
   Ans : 34000
6) Vitamin B_{12}, cyanocobalamin, is essential for human nutrition. It is concentrated in animal tissue but not in higher plants. Although nutritional requirements for the vitamin are quite low, people who abstain completely from animal products may develop a deficiency anemia. Cyanocobalamin is the form used in vitamin supplements. It contains 4.34% cobalt by mass. Calculate the molecular weight (molar mass) of cyanocobalamin assuming there is one atom of cobalt in every molecule of cyanocobalamin.
   Ans : 1360 g/mol
7) Hemoglobin is the protein that transports oxygen in mammals. Hemoglobin is 0.342% Fe by mass, and each hemoglobin molecules contains four iron atoms. Calculate the molecular weight (molar mass) of hemoglobin.
   Ans : 65497 g/mol

Molarity (Molar Concentration)

Molarity(M), or molar concentration, is a common unit for expressing the concentrations of solutions. Molarity is defined as the number of moles of solute per litre of solution:

$$\text{Molarity} = \frac{\text{number of moles of solute}}{\text{number of litres of solution}}$$

To prepare one litre of a one molar solution, one mole of solute is placed in a one litre volumetric flask, enough solvent is added to dissolve the solute, and solvent is then added until the volume of the solution is exactly one litre. Students sometimes make the mistake of assuming that a one molar solution contains one mole of solute in a liter of solvent. This is not the case; one litre of solvent plus one mole of solute usually has a total volume of more than one litre. A 0.100 M solution containing 0.100 mole of solute per litre and a 0.0100 M solution contains 0.0100 mole of solute per litre.

We often express the volume of a solution in milliliters rather than in litres. Likewise, we may express the amount of solute in millimoles (mmol) rather than in moles. Because one milliliter is 1/1000 of a litre and one millimole is 1/1000 of a mole, molarity also may be expressed as the number of millimoles of solute per millilitre of solution:

$$\text{Molarity} = \frac{\text{number of millimoles of solute}}{\text{number of millilitres of solution}}$$

Water is the solvent in most of the solutions, until other solvent not indicated.

The solutions of acid and bases that are sold commercially are too concentrated for most laboratory uses. We often dilute these solutions before we use them. We must know the molar concentration of a stock solution before it is diluted.

$$\textbf{Molarity} = \frac{\text{no. of mole}}{\text{volume (in L)}}$$

$$\textbf{Molarity} = \frac{\text{weight} \times 1000}{\text{molecular weight} \times \text{Volume (in mL)}}$$

$$\textbf{Molarity} = \frac{\text{no. of milli mole}}{\text{volume (in mL)}} \quad \text{[Hint: No of milli mole} = \frac{\text{weight} \times 1000}{\text{molecular weight}}$$

No. of millimol = Molarity × volume (in mL)

Problem for Practice

1. What is the molarity of NaOH in a solution which contains 24.0 gram NaOH dissolved in 300 ml of solution ?
   Ans : 2.00 M
2. Calculate the volume of 2.5 M sugar solution which contains 0.400 mol sugar.
   Ans : 0.160 L
3. How many ml of water must be added to 200 ml of 0.65 M HCl to dilute the solution to 0.20 M.
   Ans : 450 ml
4. How much 1.0 M HCl should be mixed with what volume of 0.250 M HCl in order to prepare 1.0 L of 0.500 M HCl.
   Ans : 667 ml of 0.25 M HCl and 333 ml of 1.0 M HCl
5. What volume of 0.30 M Na_2SO_4 solution is required to prepare 2.0 L of a solution 0.40M in Na^+.
   Ans : 1.3 L
6. Which two of the following solutions contains approximately equal hydrogen ion concentration ?
   (a) 50 ml of 0.10 M HCl + 25 ml H_2O
   (b) 50 ml of 0.10 M H_2SO_4 + 25 ml H_2O
   (c) 50 ml of 0.10 M HCl + 50 ml H_2O
   (d) 25 ml of 0.10 M H_2SO_4 + 50 ml H_2O
   Ans : a and d

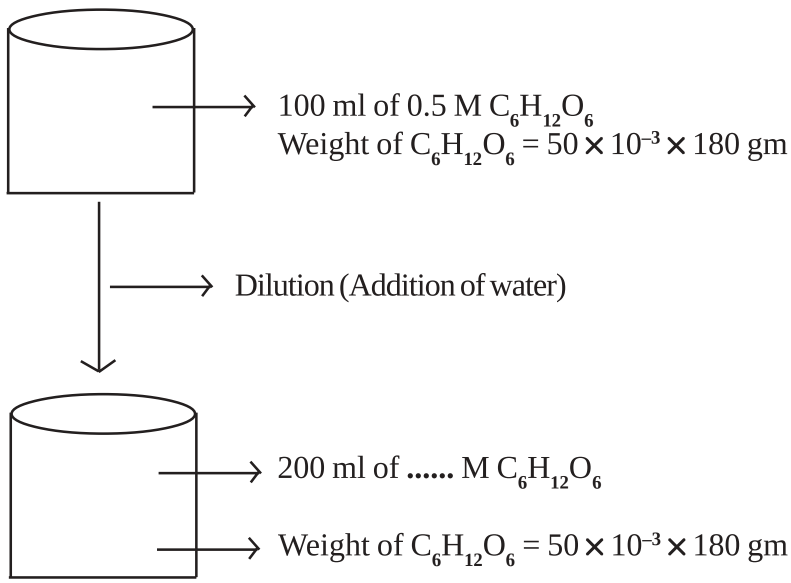
DILUTION

To save time and space in the laboratory routinely used solutions are often purchased or prepared in concentrated form called stock solution. water is then added to achieve the molarity desired for particular solution this process is called dilution.

For example :-

the common acids are purchased as concentrated solutions and diluted as needed.

Dilution Calculation



During dilution

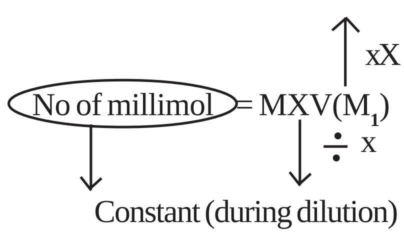
weight of solute	⟶	Remains constant
Mol. weight of solute	⟶	,, ,,
No of mol of solute	⟶	,, ,,
No of milli mol of solute	⟶	,, ,,

We can say

No of millimol before dilution = No of millimol after dilution

$$M_1V_1 = M_2V_2$$

In another words if we dilution x times then for keep millimol of solute constant we must divide molarity of solution by a factor x.

- 

- $M \times 1/V$

- No of M eq. before dilution = No of M eq. after dilution.

$$N_1V_1 = N_2V_2$$

- No of Meq. = N XV(M1)

  (N ↑ ×X ; V ↓ ÷ x ; No of Meq. ↓ Constant (during dilution))

Conclusion :- During Dilution, weight of solute, no of solute, no of millimole of solute, no of equivalent of solute or no of meq of solute remains constant

[Q] what volume of 16 M sulphuric acid must be used to prepare 1.5 liter of a 0.10 M H_2SO_4?

Solution :- Millimol before dilution = Millimole after dilution

$$16\ V(L) = 1.5 \times 0.10$$

$$V(L) = 0.15/16 = 9.4 \times 10^{-3} L$$

or

9.4 ml solution.

Thus to make 1.5 L of 0.10 M H_2SO_4 using 16 M H_2SO_4, we must take 9.4 ml of the concentrated acid and dilution with water to 1.5 L. The correct way to do this is to add the 9.4 ml of acid to about 1.0 L of water and then dilute to 1.5 L by adding more water.

PRACTICE PROBLEM

[Q] 1. 15.8 gm $Na_2S_2O_3$ dissolved in water and make 250 mL solution, 25 mL the solution is diluted 10 times. Calculate molarity of final solution.

Ans:- 0.04 M

[Q] 2. Calculate pH of 10^{-2} M HCl when it is diluted

(a) 10 times (b) 10^2 times (c) 10^3 times (d) 10^4 times

Ans :- (a) 3 (b) 4 (c) 5 (d) 6

[Q] 3. Calculate change in pH when 5×10^{-3} M H_2SO_4 is diluted

(a) 10 times (b) 10^2 times (c) 10^3 times (d) 10^4 times

Ans :- (a) 3 (b) 4 (c) 5 (d) 6

[Q] 4. 18 g glucose dissolved in water and make 250 mL solution, 25 mL the solution is diluted 10 times. 25 mL of this diluted solution add into 500 mL volumetric flask and filled water to the mark, 50 mL of this solution added into 250 mL volumetric flask and filled water to the mark. Calculate

(a) Molarity of final solution
(b) weight of $C_6H_{12}O_6$ in final solution
(c) Mole of $C_6H_{12}O_6$ in final solution
(d) molecule of $C_6H_{12}O_6$ in final solution
(e) weight of C, H, and O in final solution
(f) number of C, H, and O in final solution

Ans :- Solved in class room

[Q] 5. 15.8 g $KMnO_4$ dissolved in water and make 250 mL solution, 25 mL the solution is diluted 10 times.25 mL of this diluted solution add into 500 mL volumetric flask and filled water to the mark, 50 mL of this solution added into 250 mL volumetric flask and filled water to the mark. Calculate

(a) Molarity of final solution
(b) weight of $KMnO_4$ in final solution
(c) Mole of $KMnO_4$ in final solution
(d) molecule of $KMnO_4$ in final solution
(e) weight of K, Mn, and O in final solution
(f) number of K, Mn, and O in final solution

Ans :- Solved in class room

[Q] 6 Calculate pOH when 5×10^{-3} M $Ca(OH)_2$ is diluted

(a) 10 times (b) 10^2 times (c) 10^3 times (d) 10^4 times

Ans :- (a) 3 (b) 4 (c) 5 (d) 6

Simple Rules For Solubility Of Salts In Water

(1) Most nitrate (NO_3^-) salts are soluble.
(2) Most salt of Na^+, K^+ and NH_4^+ are soluble.
(3) Most chloride salt are soluble notable exceptions are AgCl, $PbCl_2$ and Hg_2Cl_2.
(4) Most sulphate salts are soluble . Notable exception are $BaSO_4$, $PbSO_4$, and $CaSO_4$.
(5) Most hydroxide salts are only slightly soluble. The important soluble hydroxides are NaOH, KOH and $Ca(OH)_2$.
(6) Most sulphide (S^{-2}), Carbon ate (CO_3^{-2}) and phosphate (PO_4^{-3}) salts are only slightly soluble.

(Q) Using solubility rule, predict what will happen when the following pairs of solution are mixed.
(a) KNO_3(aq) and $BaCl_2$(aq)
(b) Na_2SO_4(aq) and $Pb(NO_3)_2$(aq)
(c) KOH(aq) and $Fe(NO_3)_3$(aq).

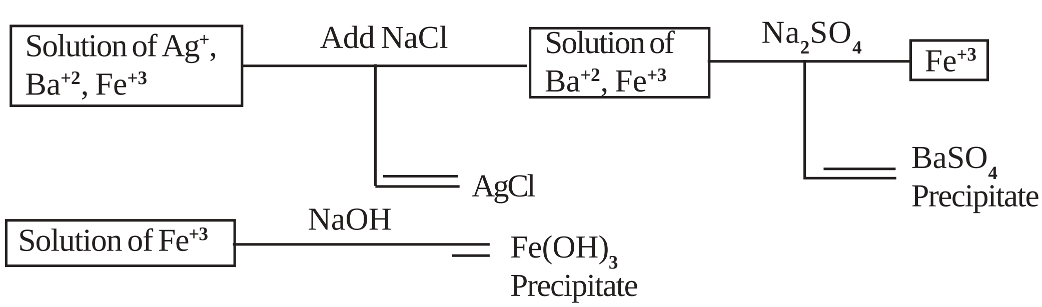
Solution :- (a) No precipitation reaction occur
(b) Precipitation of $PbSO_4$ takes place
(c) Precipitation of $Fe(OH)_3$ takes place.

Selective Precipitation

Separation of cations by precipitating them by an anion one at a time, called selective precipitation. Suppose we have an aqueous solution containing the cations Ag^+, Ba^{+2} and Fe^{+3}. Reactivity of there cations tested with Cl^{-1}, SO_4^{-2} and OH^-.

ANION

Cation	Cl^-	SO_4^{-2}	OH^-
Ag^+	AgCl White PPT	No Reaction	AgOH White PPT $\longrightarrow$ Ag_2O Brown
Ba^{+2}	No Reaction	$BaSO_4$ White PPT	No Reaction
Fe^{+3}	Yellow Colour but no solid	No Reaction	Reddish Brown PPT [$Fe(OH)_3$]



The process where by mixtures of ion are separated and identify is called qualitative analysis.

Solubility Rule

Rule	Applies t0	Statement	Exceptions
1	Li^+, Na^+, K^+, NH_4^+	Group IA and ammonium compounds are soluble.	–
2	$C_2H_3O_2^-$, NO_3^-	Acetates and nitrates are soluble.	–
3	Cl^-, Br^-, L^-	Most chlorides, bromides, and iodides are soluble.	AgcI, Hg_2Cl_2, $PbCl_2$, $AgBr_2$, $HgBr_2$, Hg_2Br_2, $PbBr_2$, AgI, HgI_2, Hg_2I_2, PbI_2
4	SO_4^{2-}	Most sulfates are soluble.	$CaSO_4$, $SrSO_4$, $BaSO_4$, Ag_2SO_4, Hg_2SO_4, $PbSO_4$
5	CO_3^{2-}	Most carbonates are insoluble.	Group IA carbonates, $(NH_4)_2CO_3$
6	PO_4^{3-}	Most phosphates are insoluble.	Group IA phosphates, $(NH_4)_3PO_4$
7	S^{2-}	Most sulfides are insoluble.	Group IA sulfides, $(NH_4)_2S$
8	OH^-	Most hydroxides are insoluble	Group IA hydroxides, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$

Acid Base Reaction

An acid can be defind as a substance that produces hydrogen ion. H^+ in aqueous solutions.

Strong acid – Strong acid ionize (separate in to ions) completely in dilute aqueous solutions. The seven common strong acids and their ions are listed in the table given the below :

Common Strong Acids		Anions of These Strong Acids	
Formula	**Name**	**Formula**	**Name**
HCl	hydrochloric acid	Cl^-	chloride ion
HBr	hydrobromic acid	Br^-	bromide ion
HI	hydroiodic acid	I^-	iodide ion
HNO_3	nitric acid	NO_3^-	nitrate ion
$HClO_4$	perchloric acid	ClO_4^-	perchlorate ion
$HClO_3$	chloric acid	ClO_3^-	chlorate ion
H_2SO_4	sulfuric acid	HSO_4^-	hydrogen sulfate ion
		SO_4^{2-}	sulfate ion

Consider the ionization of hydrochloric acid. Pure hydrogen chloride, HCl is a gas at room temperature and atmospheric pressure. When it dissolved in water,it reacts nearly 100% to produce a solution that contains hydrogen ions and chloride ions :

$$HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl^-(aq) \quad \text{(to completion)}$$

Similar equations can be written for all strong acids.

Weak acid – Ionize slightly (usually less than 5%) in dilute aqueous solutions many common weak acids are listed below :

Common Weak Acids		Anions of These Weak Acids	
Formula	**Name**	**Formula**	**Name**
HF	hydrofluoric acid	F^-	fluoride ion
CH_3COOH	acetic acid	CH_3COO^-	acetate ion
HCN	hydrocyanic acid	CN^-	cyanide ion
HNO_2	nitrous acid	NO_2^-	nitrite ion
H_2CO_3	carbonic acid	HCO_3^- CO_3^{2-}	hydrogen carbonate ion carbonate ion
H_2SO_3	sulfurous acid	HSO_3^- SO_3^{2-}	hydrogen sulfite ion sulfite ion
H_3PO_4	phosphoric acid	$H_2PO_4^-$ HPO_4^{2-} PO_4^{3-}	dihydrogen phosphate ion hydrogen phosphate ion phosphate ion
$(COOH)_2$	oxalic acid	$H(COO)_2^-$ $(COO)_2^{2-}$	hydrogen oxalate ion oxalate ion

Acid-Base Titration

Titration → Titration is a chemical process in which the unknown strength of solution is measured by known strength of another solution.

or

A procedure in which one solution is added to another solution until the chemical reaction between the two solute is complete usually the concentration of one solution is known and the other is unknown.

End Point → The stage during titration at which completion of reaction indicated by an indicator known as end point. Indicator indicate completion of reaction by change of color. It gives rough result.

Equivalent Point → The stage during titration at which completion of reaction indicated by Ph meter. It gives completely accurate result. At this point meq of acid is equal to meq base.

Standard solution → A solution of known strength is called standard solution. Standardization is a process by which one determines the concentration of solution by measuring accurately the volume of solution repaired to react with exactly known amount of primary standard. The standardized solution is then know as secondary standard.

The Properties Of An Ideal Primary Standard Includes The Following:

(1) It must not react with or absorb the components of the atmosphere. Such as water, vapor, oxygen and carbon dioxide.

(2) It must react according to one invariable reaction.

(3) It must have high percentages purity.

(4) It should have high formula weight to minimize the effect of error in weighting.

(5) It must be soluble in the solvent of interest.

(6) It should be nontoxic.

☞ Primary standard are often costly and difficult to prepare, secondary standard are used in day-to-day work.

Examples of primary standard

(a) Na_2CO_3 for acid

(b) KHP (Potassium hydrogen Phthalate) for acid

Acid-base titration are an example of volumetric analyses, a technique in which one solution is used to analyze another. The solution used to carry out the analysis is called the titrant and is delivered from a device called a buret, which measures the volume accurately. The point in the titration at which enough titrant has been added to react exactly with the substance being determined is called the equivalence point of the stoichiometric point.

The following requirements must be met for a titration to be successful:

(1) The concentration of the titrant must be known. Such a titrant is called a standard solution.

(2) The exact reaction between titration and substance being analyzed must be known.

(3) The stoichiometric (equivalent) point must be known. An indicator that changes color at, of very near, the stoichiometric point is often used.

(4) The point at which the indicator changes color is called the endpoint. The goal is to choose and indicator whose end point coincides with the stoichiometric point. An indicator very commonly used for acid-base titrations is phenolphthalein, which is colorless in acid and turns pink at the end point when an acid is titrated with a base

(5) The volume of titrant required to reach the stoichiometric point must be known as accurately as possible.