Concentration of solution

1. **Mass percent or percent by mass :** It is defined as the mass of solute in grams per 100 g of the solution. For example, a 5% solution of sodium chloride means that 5 g of NaCl are present in 100 g of the solution. Mathematically, mass percent of a solute in solution can be expressed as,

$$\text{Mass \% of the solute} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

Both, the mass of solute and that of the solution must be expressed in the same mass units, viz., both in grams or both in kilograms etc.

If w = mass of solute dissolved in grams, and

W = mass of solvent in grams

Then mass of the solution = w + W

and, mass percent of solute is $\left(\frac{w}{w+W}\right) \times 100$

2. **Volume percent or percent by volume :** The number of units of volume of the solute per 100 units of volume of the solution is known as volume percent (% *v/v*). For example, a 5% (*v/v*) solution of ethyl alcohol contains 5 cm^3 of alcohol in 100 cm^3 of the solution. Mathematically, volume percent is expressed as

$$\text{Volume percent of solute} = \frac{\text{Volume of solute}}{\text{Volume of the solution}} \times 100$$

Both, the volume of solute and that of solution must be expressed in the same units, viz., both should either be in cm^3 or in litre (or dm^3). Litre is denoted by the symbol L.

Example: Calculate the amount of NaCl present in 200 gms of its 5% (w/w) aqueous solution.

Solution: 100 gms solution contains 5 gms NaCl.

$$\text{200 gms solution contains } \frac{200 \times 5}{100} = \text{10 gms NaCl}$$

Colloidal Solution

Colloidal solution is a heterogenous mixture but due to the relatively small size of particles as compared to that of suspension the mixture appears to be homogenous. Because of the small size of the particle it can't be observed by naked eyes.

Types of Colloidal solution : Depending upon the phase of the Dispersed phase (solute) and Dispersion medium (solvent), they are catagorised as :

beam of light is passed through a colloidal dispersion, it becomes visible as a bright streak. This phenomenon is known as the Tyndall effect and the illuminated path (streak of light) is known as Tyndall cone. This phenomenon is due to the scattering of light from the surface of colloidal particles. In a true solution, there are no particles of sufficiently large diameter to scatter light and hence the beam is invisible.

e.g. The visibility of dust particles in a semi-darkened room when a sun beam enters or when a light is thrown from a light projector.

The intensity of the scattered light depends on the difference between the refractive indices of the dispersed phase and the dispersion medium.

7. **The Brownian Movement :** It was found that particles of sols were also in a state of ceaseless erratic and random motion similar to pollen grains. This kinetic activity of particles suspended in a liquid is called Brownian movement. The Brownian movement is due to the bombardment on colloidal particles by molecules of dispersion medium which are in constant motion e.g. molecules in a gas.

Purification of Colloidal Solutions

i) Dialysis ii) Ultrafiltration iii) Ultracentrifugation

1. **Dialysis :** It is a process of separating a crystalloid from a colloid by diffusion or filtration through a selectively permeable membrane.
2. **Ultrafiltration :** It is a process of separating colloidal particles from true solution with the help of a ultrafilter.
3. **Ultracentrifugation :** It is a process of separating colloidal solution with the help of centrifugal machine as colloidal particles settle down on centrifugation.

Separating the Components of a Mixture

i) The natural substances are not chemically pure.

ii) Two three components together which is known as heterogenous mixture can be separated by simple physical methods like filtration, evaporation, crystallisation etc.

Separating funnel

Evaporation : The separation of volatile solvent can be done from non-volatile solute. As volatile solvent will easily evaporate leaving behind the non-volatile solute.

Filtration : Solid component can be separated from liquid component by filtration by using filter paper, provided solid particles should not be very small.

Centrifugation : If the solid particles are very small then preferred separation process is centrifugation where the denser particles settle down at the bottom and lighter particles stay at the top

Separating funnel : A mixture of two immiscible liquids can be separated by using separating funnel. For example kerosene oil and water can be separated by separating funnel.

Sublimation : The mixture of sublimable volatile component from non-sublimable impurity can be separated by sublimation.

Distillation : The two miscible liquid components in a given mixture with great difference in boiling point are separated by distillation. The one with lesser boiling point will vapourise first and can be separated in other vessel.

molecule of hydrogen is 3.32×10^{-24} g and that of one molecule of sucrose is 5.68×10^{-22} g. Such negligible quantities cannot be used in chemical calculations. To overcome these difficulties comparative values for the weights of molecules are used instead of their actual weights. Hence is the necessity of expressing molecular weights (mass) as their relative weights with reference to a standard atom. Consequently the molecular weights are only numbers and have no unit. Thus,

i) **Hydrogen scale :** The molecular weight of an element or a compound is a number which represents how many times a molecule of the element or compound is heavier than one atom of hydrogen.

$$\text{Molecular weight} = \frac{\text{weight of one molecule of the substance}}{\text{weight of one atom of hydrogen}}$$

ii) **Oxygen scale :** The molecular weight of a substance (element or compound) is a number which represents how many times a molecule of the substance is heavier than $^{1}/_{16}$th part of the weight of an oxygen atom.

$$\text{Molecular weight} = \frac{\text{weight of 1 molecule of the substance}}{^{1}/_{16}\text{th part of the weight of an atom of oxygen}}$$

iii) **Carbon scale :** The molecular weight of a substance (element or compound) is defined as the ratio of the weight of one molecule of the substance to $^{1}/_{12}$th part of the weight of one atom of C-12 isotope.

$$\text{Molecular weight} = \frac{\text{weight of 1 molecule of the substance}}{^{1}/_{12}\text{th part of the weight of an atom of C-12 isotope}}$$

Atomicity

The number of atoms in a molecule of an element is called its atomicity.

i) Thus the atomicity of inert gases (He, Ne, Ar, Kr etc.) and metals like Li, Na, K, Cu etc. is 1.

ii) The molecules of some elements contain 2 atoms e.g., (H_2, O_2, N_2, Cl_2 etc.)

These are diatomic.

iii) The ozone molecule contains 3 atoms and so its atomicity is 3.

iv) Phosphorus molecules (P_4) is tetra atomic.

In general, the molecular weight is always the sum of the atomic weights of the atoms in the molecule. Consequently by knowing the composition of the molecule, the molecular weight can easily be calculated.

Element or compound	Molecular formula	Molecular weight
Hydrogen	H_2 – two atoms of hydrogen	$2 \times 1 = 2$
Oxygen	O_2 – two atoms of oxygen	$2 \times 16 = 32$
Carbon di-oxide	CO_2 – 1 atom of carbon and 2 atoms of oxygen	$12 \times 1 + 2 \times 16 = 44$
Nitric acid	HNO_3 – 1 atom of hydrogen, 1 atom of nitrogen and 3 atoms of oxygen	$1 \times 1 + 14 \times 1 + 3 \times 16 = 63$
Sulphuric acid	H_2SO_4 – 2 atoms of hydrogen, 1 atom of sulphur and 4 atoms of oxygen	$2 \times 1 + 1 \times 32 + 4 \times 16 = 98$
Glucose	$C_6H_{12}O_6$ – 6 atoms of carbon, 12 atoms of hydrogen and 6 atoms of oxygen	$6 \times 12 + 1 \times 12 + 6 \times 16 = 180$

The number of particles present in one mole of a substance (element or compound) is known as **Avogadro's number**. It is equal to 6.023×10^{23}. Avogadro number is represented as 'N'. Thus, in one gram molecule of any substance (element or compound) the total number of molecules is 6.023×10^{23} and in one gram of any element the number of atoms present is 6.023×10^{23}.

Since one gram molecule or one gram mole of any gas occupies 22.4 litre at N.T.P. Avogadro's number may also be defined as the total number of molecules present in 22.4 litre of any gas at N.T.P.

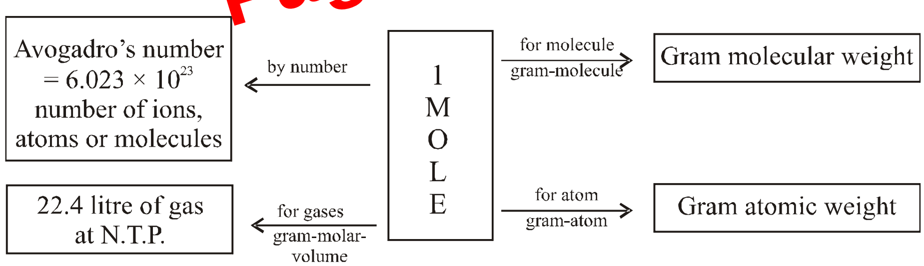
Avogadro's hypothesis : *Under the same conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules.*

According to this hypothesis under the similar conditions of temperature and pressure the number of molecules present in 1 ml of any gas will be the same, whatever be the nature of the gas – whether oxygen or chlorine or CO_2. Thus if *n* number of oxygen molecules are present in 1 litre of the gas under the given conditions of temperature and pressure, then according to Avogadro's hypothesis 1 litre of Cl_2 or 1 litre of CO_2 or 1 litre of NH_3 will contain *n* number of molecules of the respective gases under the identical conditions of temperature and pressure.

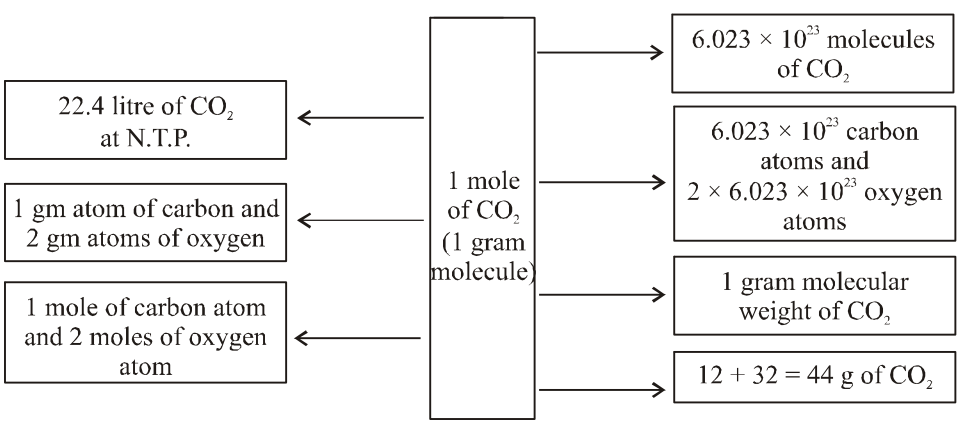
Mole Concept

1 gram mole or gram molecule represents the molecular weight of the substance expressed in grams. Thus 1 gram molecule of water is 18 g of water. It is evident from Avogadro's hypothesis that one mole or 1 gram mole of any gas or vapour contains the same number of molecules. The importance of using the quantity known as mole is that it contains the same number of molecules irrespective of the gas or vapour. This number is called Avogadro's number which is 6.023×10^{23}. Again the gram molecular volume of all gases or vapour at N.T.P. is 22.4 litre. Therefore it can be fairly argued that the number of molecules present in 22.4 litre of any gas or vapour at N.T.P. is 6.023×10^{23}.

Mole is a unit of counting the number of atoms or molecules present per gram atom or gram molecules of the substance. It also represents the weight of the substance (element or compound) expresses in gram which contains Avogadro number or 6.023×10^{23} particles (atoms or molecules) of that substance.



For example : 1 mole of CO_2 are represented as follows.



iii) Charge of a proton : Experimental studies show that the charge on a proton is the same as that of an electron but of opposite nature. Hence, the charge on a proton is 4.8×10^{-10} e.s.u. or 1.602×10^{-19} coulomb. The charge carried by a proton has been accepted as the unit of positive electricity as no positively charged particle is known which has charge less than that of a proton.

3. **Discovery of Neutrons**

J. Chadwick was successful in discovering a new fundamental particle by bombarding beryllium with fast moving alpha particles. In 1932 he concluded that the radiation consisted of particles of mass nearly equal to that of the proton and with no net charge. This particle was identified as neutron, the existence of which was predicted earlier by *Rutherford*. Rutherford after his α-particle scattering experiment concluded that mass of an atom is more than the sum of protons and electrons which proves the existence of a third particle in the atom. The bombardment of the nuclei of light metals (Be, B etc.) with alpha particles may be expressed as follows :

$$_4Be^9 + \underset{\alpha\text{ particle}}{_2He^4} \rightarrow {_6C^{12}} + {_0n^1}, \quad {_5B^{10}} + {_2He^4} \rightarrow {_7N^{13}} + {_0n^1}$$

Properties of Neutron :

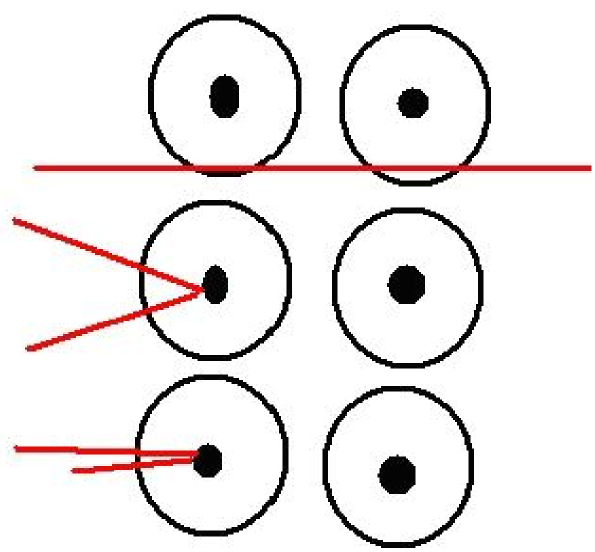
i) Since the neutron carries no electrical charge, its penetrating power is more than that of electron and proton.

ii) Except hydrogen atom, all atoms contain neutron, hence neutron is also a fundamental particle of matter.

iii) The mass of neutron is 1.00893 a.m.u. (on the physical atomic weight scale) or 1.675×10^{-24} g.

Structure of Atom

i) **Rutherford's experiment – Scattering of alpha particles by thin metal foil :**



The first idea of atomic model was proposed by *E. Rutherford* (1911) which was based upon his experiment of scattering of alpha particles by thin metal foil.

An alpha-emitter was placed in a lead box. A narrow beam of alpha particles escaped through a small hole in the lead box and hit a thin metal foil of gold which was placed in the beam of the alpha particles. A fluorescent screen was set around the metal foil. A flash of light was observed when the alpha particles hit the screen after penetrating through the thin foil. It was observed that most of the alpha particles passed straight through the foil without any deflection and hit the fluorescent screen. Very few α-particles suffered minor deflection. Only one in 20,000 α-particles changed its linear path and was deflected through 90º or more. Some α-particles have their path reversed showing that they were deflected through 180º. Radium was used as a source of α-particle.

b) Rutherford's model could not explain the existence of line spectra of atom which according to the quantum theory should correspond to definite amount of energy.

ii) Bohr's atomic model

In order to overcome the difficulties encountered in Rutherford's atomic model Bohr made the following revolutionary postulates :

a) Stationary state : The electrons always move in certain selected orbits having particular energies. So long as electron does so, there is no absorption or emission of energy and electron continues to move around the nucleus along the same path. These orbits or paths are called as stationary states.

b) Quantisation of angular momentum : The electrons can occupy only that orbit or energy level in which the angular momentum of electron is an integral multiple of $h/2\pi$ where h is the Planck's constant.

$$mvr = nh/2\pi, \text{ where } n = 1, 2, 3 \text{ ....etc.}$$

c) The third postulate of Bohr is that if energy is available an electron will absorb energy in quanta and move to the higher energy level. The quantum of energy absorbed by the electron is equal to the difference in the energies of the two levels.

From Bohr's atomic model we can calculate the energy, radius, velocity of electron moving in an orbital around the nuclei.

A Brief Introduction to Quantum numbers

The concept of quantum number was first introduced by Bohr, where it was postulated that while an electron moves in a circular orbit its angular momentum becomes an integral multiple of $h/2\pi$ i.e., angular momentum $mVr = n \times h/2\pi$ where n = principle quantum number which indicates the energy state of an electron.

Normally the term quantum number is used to indicate the various energy levels or orbits of an atom. They also denote the region of space or orbitals where the electron is likely to be found. Each electron in an atom is confined to its own orbital.

Bohr's model predicts only one quantum number (n), but the quantum mechanical model of atom introduces three more quantum numbers.

1. **The principal quantum number (n) :** This indicates the size of the electron orbit and the distance of the electronic orbit from the nucleus and also the energy of the electrons.

2. **Azimuthal quantum number (l) :** This gives the shape of the orbit of the electron.

3. **Magnetic quantum number (m) :** Indicates the orientation of the electronic orbit in space under the influence of magnetic field.

4. **Spin quantum number (s) :** This indicates the spin of the electron while moving about its axis either clockwise or anticlockwise.

Types of Subshells and Orbitals

In a given shell the electrons are present in subshells s, p, d, f. The s-subshell is with one orbital, the p-subshell is with three orbitals p_x, p_y and p_z. Similarly, d-subshell is with five orbitals d_{xy}, d_{yz}, d_{xz}, $d_{x^2-y^2}$, d_{z^2}. For example, the sub-shells and orbitals for M shell i.e., third shell (n = 3) is given below.

Similarly , the three isotopes of carbon are represented as ${}^{12}_{6}C$, ${}^{13}_{6}C$ and ${}^{14}_{6}C$

It may be mentioned here that atoms of different elements may have same mass number. *The atoms of different elements which have same mass number are called isobars. For example,* ${}^{14}_{6}C$ and ${}^{14}_{7}N$ are isobars.

Sometimes atoms of different elements contain same number of neutrons. Such atoms are known as *isotone*. Thus, *isotones may be defined as the atoms of different elements containing same number of neutrons*. For example, ${}^{13}_{6}C$ and ${}^{14}_{7}N$. For isotones, the difference of mass number and atomic number is same.

Isotopes are the atoms of same element whereas isobars and isotones are atoms of different elements.

Calculation of Number of Electrons, Protons and Neutrons

From the knowledge of atomic number and mass number of an element it is possible to calculate number of electrons, protons and neutrons in an atom of the element. For example, atomic number and mass number of aluminium are 13 and 27 respectively. Number of electrons, protons and neutrons in an atom of it can be calculated as under :

Number of protons = Atomic number = 13

Number of electrons = Atomic number = 13

Number of neutrons = Mass number – Atomic number

= 27 – 13 = 14..

ASSIGNMENTS

Multiple Choice Questions

1. Rutherford's scattering experiment is related to
   (a) neutrons (b) atom (c) electron (d) nucleus

2. Size of the nucleus is of the order
   (a) 10^{-12} m (b) 10^{-8} m (c) 10^{-15} m (d) 10^{-10} m

3. Name of scientist associated with the discovery of Neutron is
   (a) J.J. Thomson (b) James Chadwick (c) Rutherford (d) Yukawa

4. In a given atom no two electrons can have the same values for all the four quantum numbers. This is called
   (a) Hund's rule (b) Aufbau principle
   (c) Uncertainty principle (d) Pauli's exclusion principle

5. When an alpha (α)-particle are sent through a thin metal foil, most of them go straight through the foil because
   (a) α-particles are much heavier than electrons (b) α-particles are positively charged
   (c) most part of the atom is empty space (d) α-particles move with high velocity

6. Cathode rays have
   (a) mass only (b) charge only
   (c) no mass, no charge (d) mass and charge both

7. Electron was discovered by
   (a) Rutherford (b) J.J. Thomson (c) Chadwick (d) Moseley