24 May

Chapter 1

Some basic concepts of Chemistry

Notes

1) Scientific notation : Scientific notation in which any number can be represented in the form of $N \times 10^n$, where

N is equal to number between 1 to 10
n is an exponent having positive or negative.

For example, 232.508 can be written as 2.32508×10^2

0.00016 can be written as 1.6×10^{-4}

2) Precision and Accuracy

Precision refers to the closeness of various measurement for the same quantity.

Accuracy refers to a agreement of a particular value to the true value.

Examples for both Precision and Accuracy: If the true value is 2g.

Student A got 1.95g and 1.93g. Both are precise but not accurate.
Student B got 1.83 and 2.1. They are not precise and not accurate.

Student C got 1.99g and 2.01g. Both are precise and accurate.

3) Law of conservation of mass : In a chemical reaction, the total mass of reactants is equal to the total mass of products.
Chemical equations are balanced according to this law.

For example,
(reactants) (Products)
$2H_2 + O_2 \longrightarrow 2H_2O$
$4g + 32g \rightarrow 36g$

Total mass of reactants $= 4 + 32 = 36g$
Total mass of Products $= 36g$

Total mass of reactants = Total mass of products.

4) Law of definite proportions (Law of constant compositio

It states that a compound always contains exactly the same propotions of the elements by weight.
or
The same compound always contains the same elemen combined in a fixed ratio by mass.

For example, CO_2 can be formed in the atmosphere by various meathods like respiration, buring of fuels etc. All these samples of CO_2 are only two elements. Carbon and O_2 combined in a mass ratio 3:8.

5) Law of Multiple proportions - John Dalton

If two elements can combine to form more than one ~~combined~~ compound, the diffirent masses of one of elements that combine with fixed mass of the other elements, are in small whole number ratio.

For example, $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$

2g + 16g

$H_2 + O_2 \rightarrow H_2O_2$

2g 32g

Ratio of oxygen element - 16 : 32

- 1 : 2

6) Gay Lussac's Law of Gaseous volumns

It states that when gases combine to form gaseous products, their volumn are in whole number ratio, given the temperature and pressure are constant.

For example :- $2H_2 + O_2 \longrightarrow 2H_2O$

100ml 50ml

~~100ml~~ Volumn of H_2 : Volumn of O_2

Ratio :- 100 : 50

÷ 2 : 1

7) Avagadro's Law

It states that equal volumns of all gases at the same temperature and pressure should contain equal number of moles or molecules.

For example : 10 liters of NH_3 , CO_2 and N_2.

8) <u>Dalton's Atomic Theory</u>

Postulates of this theory are:-

a) Matter is made up of minute and indivisible particles called atoms.

b) Atoms can ~~not~~ neither be created nor destroyed

c) Atoms of same element are identical in their properties and mass.

d) Atoms combined to form compound atoms called molecules.

e) When atoms combine, they combine in fixed ratio by mass.

9) <u>Relative atomic mass table</u>

Atomic no.	Element	Symbol	Relative atom mass
1	Hydrogen	H	1u
2	Helium	He	4u
6	Carbon	C	12u
7	Nitrogen	N	14u
8	Oxygen	O	16u
11	Sodium	Na	23u
12	Magnesium	Mg	24u

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13	Aluminium	Al	27u
14	Silicon	Si	28u
15	Phospurus	P	31u
16	Sulphur	S	32u
19	Potassium	K	39u
20	Calcium	Ca	40u
26	Iron	Fe	56u

c) Average Atomic Mass

Almost all elements have isotopes, so we can calculate average atomic mass of an element by considering the atomic mass of the isotopes and their relative abundance.

For example, chlorine has 2 isotopes

Cl^{35}_{17} and Cl^{37}_{17}

Relative abundance = 3:1

$$\text{Avg atomic mass} = \frac{3 \times 35 + 1 \times 37}{4} \quad (3:1,\ 3+1=4)$$

$$= 35.5u$$

d) Molecular mass : It is the sum of atomic masses of the element present in a molecule.

For example, H_2O

Molecular mass $= 2 \times 1 + 16 = 18u$

Molecular mass = Atomic mass × no. of atoms

12) Calculate molecular mass of following compound

a) Glucose ($C_6H_{12}O_6$)

Molecular mass = $6 \times 12 + 12 \times 1 + 6 \times 16$
= 180u

b) Sulpuric acid (H_2SO_4)

$4 \times (15) \times 32$

Molecular mass = $2 \times 1 + 4 \times \cancel{(324}(15) \times 32$
$\cancel{= 2 + 4 \times (47)}$ = $2 + 60 \times 32$
$\cancel{= 2 + 188}$ = $2 + 1920$
$\cancel{= 190u.}$ = 1922u

c) Sucrose ($C_{12}H_{22}O_{11}$)

Molecular mass = $12 \times 12 + 22 \times 1 + 16 \times 11$
= $144 + 22 + 176$ = 340u

12) Formula mass

It is used for compounds that exist as ions.
For examples, Sodium ($NaCl$)
$Na^+ Cl^-$
Formula mass = $23 + 35.5 = 58.5$u

13) Define one mole of a substance.

One mole is the amount of substance that contains as many particles as there are in exactly C^{12} isotope
1 mole = 6.022×10^{24} (Avagrado number)

14) Molar mass : Mass of one mole is called molar mass. It's expressed in g/mol.

For example :- $C_{12}H_{22}O_{11} \Rightarrow 12\times12 + 22\times1 + 11\times16$
$= 342g/mol$

$G_6H_6 \Rightarrow 6\times12 + 6\times1 = 28\ g/mol$

15) Equation to find (a) the number of moles from given mass.

i) No. of moles = $\frac{\text{given mass}}{\text{Molar mass}}$

$n = \frac{m}{M}$

n = no. of moles
m = given mass
M = Molar mass.

$m = n \times M$

$M = \frac{m}{n}$

(b) number of moles from given no. of particles

no of moles = $\frac{\text{Given no. of particles}}{\text{Avagadro no.}}$

$n = \frac{N}{N_A}$

n = no. of moles
N = Given no. of partick
N_A = Avagrado no. $= 6.02\times10^{23}$

$N = n \times N_A$

16) In 3 moles of ethene, find

i) no. of moles of carbon atom
ii) no. of moles of Hydrogen
iii) no. of molecules of ethene.

Sol. C_nH_{2n} ~~ne~~
$n=2$
$= C_2H_4 \rightarrow$ ethene

According to question, 3 moles of $C_2H_4 = 3C_2H_4$

i) no. of C atom $= 3 \times C_2 = 3 \times 2 = 6$
ii) no. of moles of H atom $= 3 \times 4 = 12$
iii) no. of molecules of C_2H_4

$$N = n \times N_A$$
$$= 3 \times 6.022 \times 10^{23}$$
$$= 18.066 \times 10^{23}$$

17) Calculate the number of moles in 120g of Sodium Hydroxide (NaOH)

Sol. Given mass $= 120g$
molar mass $= 23 + 16 + 1 = 40\ g/mol$

$$\text{No. of moles} = \frac{\text{Given mass}}{\text{Molar mass}} = \frac{120}{40} = 3 \text{ moles}$$

18) Calculate the number of molecules in 22g of CO_2

Sol. given mass = 22g

molar mass of $CO_2 = 12 + 2 \times 16 = 44 g/mol$

No. of moles = $\frac{\text{Given mass}}{\text{molar mass}} = \frac{22}{44} = \frac{1}{2}$ moles

No. of molecules => $N = n \times N_A$

$= \frac{1}{2} \times 6.022 \times 10^{23}$

$= 3.011 \times 10^{23}$

19) Percentage composition : Mass % of the element = $\frac{\text{Mass of the element}}{\text{Molar mass of the compound}} \times 100$

20) What is the mass percent of carbon, hydrogen and oxygen in ethanol.

Ethanol => C_2H_6O

Molar mass $= 2 \times 12 + 6 \times 1 + 1 \times 16 = 46 g/mol$

Mass % of C $= \frac{2 \times 12}{46} \times 100 = 52.17\%$

Mass % of H $= \frac{6}{46} \times 100 = 13.04\%$

Mass % of O $= \frac{16}{46} \times 100 = 34.78\%$

21) Calculate the mass percentage of different element in Na_2SO_4 (Sodium Sulphate).

Sol. Molar mass of $Na_2SO_4 = 2\times23 + 32 + 4\times16$
$= 142$ g/mol

Mass % of Na $= \frac{2\times23}{142} \times 100$
$= 32.39\%$

Mass % of S $= \frac{32}{142} \times 100 = 22.5\%$

Mass % of O $= \frac{4\times16}{142} \times 100 = 45\%$

22) Empirical formula : An empirical formula represents a simpilest whole number ratio of various atoms present in a compound.

23) Molecular formula : It shows the exact number of different types of atom present in a moleacules of a compound.

Molecular formula = n x empirical formula

24) A compound contains 4.07% hydrogen, 24.27% carbon, 71.65% chlorine. It's molar mass is 98.96 g/mol What are it's empirical formula and molecular formula?

Element	Mass %	Atomic mass	mass % / atomic mass	Simplest atomic ratio
C	24.27	24.27/12	2.0225	2.022/2.0183 ≃ 1
H	4.07	4.07/1	4.07	4.07/2.018 ≃ 2
Cl	71.65	71.65/35.5	2.0183	2.0183/2.183 = 1

Empirical formula = CH_2Cl

$$n = \frac{\text{Molar mass \%}}{\text{Empirical formula mass}}$$

$$n = \frac{98.96}{49.5} \approx 2$$

Molecular formula = n × Empirical formula
= $C_2H_4Cl_2$

25) Determine the empirical formula of an oxide of iron which has 69.9% iron and 30.1% dioxygen by mass (Fe = 55.85u).

Elements	Mass%	Atomic mass	mass% / atomic mass	simplest atom ratio	Simplest whole no.
Fe	69.9	55.8	69.9/55.8	1.25	1.25/1.25 = 1×2=
O	30.1	16	30.1/16	1.88	1.88/1.25 ≃ ~~2.0~~ 1.5 ×2=

Empirical formula = Fe_2O_3

26) A compound containing carbon, hydrogen and oxygen are 40%, 6.67% respectively. Calculate the molecular formula of the compound if its molar mass is 180 g/mol.

Sol. Percentage of Oxygen $= 100 - (40 + 6.67)$
$= 100 - 46.37$
$= 53.33\%$

Element	Mass %	Atomic Mass	Mass %/Atomic mass	Relative no. of atoms	Simple atomic ratio
C	40	12	40/12	3.33	$3.33/3.33 = 1$
H	6.67	1	6.67/1	6.67	$6.67/3.33 \approx 2$
O	53.33	16	53.33/16	3.33	$3.33/3.33 = 1$

Empirical formula $= CH_2O$
Empirical formula mass $= 12 + 2 + 16 = 30\,g/mol$

$$n = \frac{\text{Molar mass}}{\text{Empirical formula mass}} = \frac{180}{30} = 6$$

Molecular formula $= n \times$ Empiral formula
$= C_6H_{12}O_6$

27) Can two compound with different molecular formula have same empirical formula?

Ans) Yes, for example

Example	Ethyne	Benzene
Molecular formu	C_2H_2	C_6H_6
Empirical formula	CH	CH

28) Can the empirical Formula and molecular formula be same?

Ans) Yes, for example, Sulphuric acid
Empirical Formula = H_2SO_4
Molecular formula = H_2SO_4

29) Some molecular formula and empirical formula:

Molecular formula	Empirical formula
$C_6H_{12}O_6$	CH_2O
C_6H_6	CH
H_2O_2	HO
$C_2H_4Cl_2$	CH_2Cl
$C_{12}H_{22}O_{11}$	$C_{12}H_{22}O_{11}$
Na_2O_2	NaO
H_2SO_4	H_2SO_4

30) Hydrogen and oxygen react to produce water. Find the number of mole of water produced is ~~when~~ 10 moles of water.

Sol. $2H_2 + O_2 \longrightarrow 2H_2O$

2 mol → 2 mol
10 mol → x

$2 : 2 = 10 : x$

$2x = 10 \times 2$

$x = \frac{10 \times 2}{2}$

$x = 10$ moles

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31) Nitrogen reats with halogen to produce ammonia. Calculate the moles of ammonia produced when 5 moles of nitrogen react.

Sol. $N_2 + 3H_2 \longrightarrow 2NH_3$

1 mol — 2 mol

5 mol — x

$x = 5 \times 2 = 10$ moles of NH_3

32) In the commercial manufacturing of nitric acid, how many moles of NO_2 produce 7.33 moles of HNO_3?

Sol. $NO_2 + H_2O \longrightarrow HNO_3 + NO$

$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$

3 mol — 2 mol

x — 7.33

$7.33 \times 3 = 2x$

$x = \frac{21.99}{2} = 10.99$ mols

33) Solutions: Solutions are homogenous mixtures of two or three components.

Solute + Solvent $\longrightarrow$ Solution

examples: Salt solution

Alcohol in water

~~Solution~~ Metal alloys.

Meathod to determine concentration of solutions

a) Mass by mass percentage
b) Mole fraction
c) Molarity
d) Molality

34) Mass by mass percentage.

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

a) Find the mass% of the solution prepared by dissolving 20g of $NaOH$ in 180g water.

Sol. $\text{Mass \% of solute} = \frac{20}{20+180} \times 100 = \frac{20}{200} \times 100$

$= 10\%$

35) Mole fraction

Mole fraction is the ratio of no. of moles of the component to total number of moles.

$$\text{Mole fraction} = \frac{\text{no. of moles of component}}{\text{Total no. of moles}}$$

Solute B no. of moles $= n_B$
Solute A no. of moles $= n_A$

Mole fraction of A, $X_A = \frac{n_A}{n_A + n_B}$

Mole fraction of B, $X_B = \frac{n_B}{n_A + n_B}$

$$X_A + X_B = 1$$

a) Find the mole fraction of each component when 1.8 gram of glucose is mixed with 36 gram of water.

Sol. Glucose

$$n_g = \frac{\text{Given mass}}{\text{Molar mass}} = \frac{1.8g}{(6\times12+12\times1+6\times16)}$$

$$= \frac{1.8g}{180} = 0.01 \text{ mol}$$

Water

$$n_{H_2O} = \frac{\text{Given mass}}{\text{molar mass}} = \frac{36}{2+16} = \frac{36}{18} = 2 \text{ mol}$$

$$X_{H_2O} = \frac{n_{H_2O}}{n_{H_2O} + n_{glu}} = \frac{2}{2+0.01} = \frac{2}{2.01} = 0.995$$

$$X \text{ glucose} = 1 - X_{H_2O} = 1 - 0.995 = 0.005$$

36) Molarity

$$\text{Molarity} = \frac{\text{no. of moles of solute}}{\text{V of solution in L}}$$

1 molar solution => 1 mole in 1L solution
2 molar solution => 2 moles solution + 1L solution

a) 2 moles of solute present in 10L solution molarity.

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{V in L}}$$

$$= \frac{2\,mol}{10\,L} = 0.2\ mol/L$$

b) Find the molarity of the solution prepared by disolving in 4g of NaOH in water to give 500 ml solution.

Sol. no. of moles of NaOH = $\frac{\text{Given mass}}{\text{Molar mass}}$

$$= \frac{4}{23+16+1} = \frac{4}{40} = 0.1\ mol$$

$$V \text{ in } L = \frac{500}{1000} = 0.5L$$

e) The solution of molarity M_1 and Volumn V_1 is diluted or concentrated to give a new molarity M_2 and new volumn V_2.

$$M_1 \times V_2 = M_2 \times V_2$$

Note: When mass percentage density in gram per ml is given, molarity can be calculated as

$$\text{Molarity} = \frac{\text{Mass\%} \times \text{Density} \times 10}{\text{Molar mass of solute}}$$

c) Find the molarity of the solution prepared by dissolving 10g NaOH in H_2O to get a 2L solution (Atomic mass Na=23, O=16, H=1)

Sol. Solute NaOH (B), Solvent Water (A)
Given mass of solute, $M_B = (23+16+1 \text{ g/mol})$
$= 40 \text{ g/mol}$

No. of moles of solute $= \frac{W_B}{M_B} = \frac{1}{4} = 0.25 \text{ mol}$

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Volumn of solute in L}} = \frac{0.25}{2} = 0.125 \text{ M}$$

d) Concentrated HNO_3 used in lab is 69%. (Given mass / Total mass). Find the molarity of the solution if the solution density is 1.41g/ml.

Sol. Mass % = 69%
density = 1.41g/ml
$M_B = (1+14+48) = 63 g/mol$

$$\text{Molarity} = \frac{\text{Mass\%} \times \text{density} \times 10}{M_B} = \frac{69 \times 1.41 \times 10}{63}$$

$= 15.44$ Mols

e) What is the concentration of sugar ($C_{12}H_{22}O_{11}$) in mole/liter if its 20g are dissolved in enough water to make a final volumn upto 2 L.

Sol. Solute sugar (B), Solvent Water (A)

Given mass of solute, $W_B = 20g$
Molar mass of solute, $M_B = (144+22+176 g/mol)$
$= 342 g/mol$

$$\text{No. of moles of solute} = \frac{W_B}{M_B} = \frac{20}{342} = 0.058$$

$$\text{molarity} = \frac{\text{no. of moles of solute}}{\text{Volumn of solute in L}} = \frac{0.058}{2}$$

$= 0.029$ mols

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f) 5 ml of concentrated H_2SO_4 with mol is diluted to 25 ml, find the molarity of Solution obtained.

Sol. $M_1 = 2$ mols , $V_1 = 5$ ml
$M_2 = ?$, $V_2 = 25$ ml

$$M_1 V_1 = M_2 V_2$$

$$5 \times 2 = M_2 \times 25$$

$$10 = M_2 \times 25$$

$$M_2 = \frac{10}{25} = 0.4 \text{ mols}$$

g) If density of methanol is 0.793 Kg/L. What is it's volumn needed for making 2.5 L of its 0.25 M solution.

Sol. density $= 0.793$ Kg/L
$W_B = 793$ g
$V_1 = 1$ liter
$M_B = 12 + 16 + 3 + 1 = 36$ g/mol
No of moles $= \frac{793}{36} = 24.78$ mol

$$\text{Molarity} = 24.78 \times \frac{1000}{1000} = 24.78 \text{ m}$$

$$m_1 v_1 = m_2 v_2$$

$$v_1 = m_2 v_2$$

$$v_1 = \frac{m_2 v_2}{m_1} = \frac{0.25 \times 2.5}{24.78} = 0.025 \text{ mols}$$

37) Molality

$$\text{Molality} = \frac{\text{no of moles of solute}}{\text{mass of solvent in kg}}$$

$$\frac{W_B}{M_B} = \frac{1000}{W_A \text{ in g}} \quad (W_A \text{ in g})$$

Unit of molarity :- Mol/Kg or m or molal

a) What mass of urea to be dissolved in 2kg of water to be produced a 2m solution [urea = NH_3]

Sol. $$\text{Molality} = \frac{W_B}{M_B} \times \frac{1}{W_A} \quad (\text{in kg})$$

$$2 = \frac{W_B}{60} \times \frac{1}{2}$$

$$W_B = 2 \times 2 \times 60 = 240\,g$$

38) Molarity or Molarity, which is better unit for expressing concentration? Why?

Ans) Molarity is better unit for expressing concentration as it is independent of temperature. ~~as its~~ The calculatetations are based on mass. But molarity varies with temperature as its calculation are volume based.