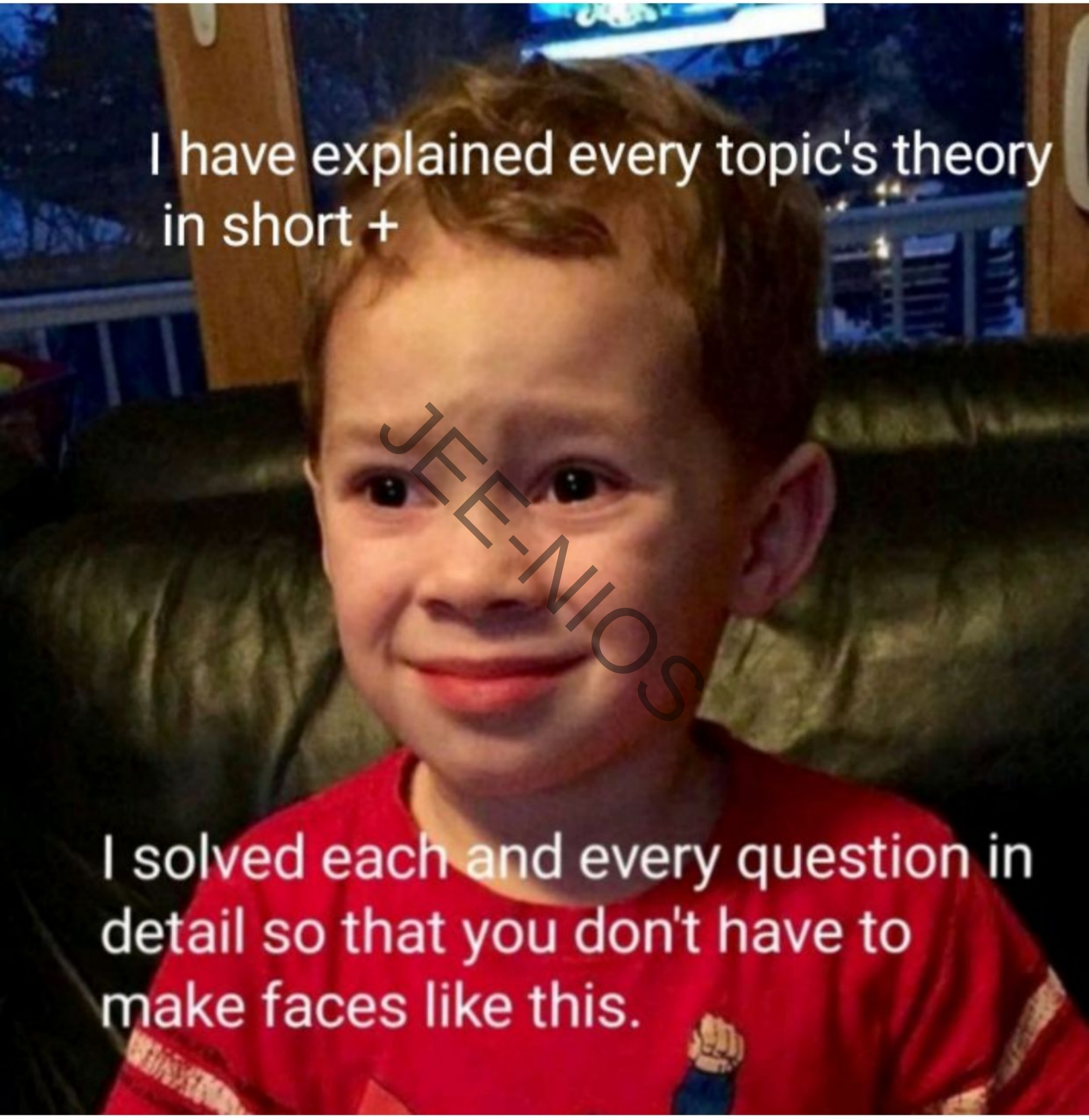
JEE-NIOS

MODULE 1- SOME BASIC CONCEPTS OF CHEMISTRY

CH- ATOMS, MOLECULES & CHEMICAL ARITHMETICS


I have explained every topic's theory in short +
JEE-NIOS
I solved each and every question in detail so that you don't have to make faces like this.

Ch no. - ATOMS, MOLECULES & CHEM ARITHMATICS

What is Chemistry?

Chemistry is the study of matter and the changes it undergoes

Importance and Scope of Chemistry?

Chemistry plays a vital role in many areas of science & technology eg. in health, medicine, energy and environment, food etc.

Dalton's Atomic Theory

In 1803, Dalton published a new system of chemical philosophy in which the following statements comprise the atomic theory of matter:
1. Matter consists of individual atoms.
2. All the atoms of a given chemical element are identical in mass and in all other properties.

Atoms

Smallest particle of an element that retains its (elements) chemical properties. An atom of one element is diff in size & mass from the atoms of the other elements.

Molecules

A molecule is an aggregate of at least two atoms in a definite arrangement held together by chemical forces (also called chemical bonds). It is smallest particle of matter, an element or a compound, which can exist independently.

A B ⟶ AB

Elements (118)

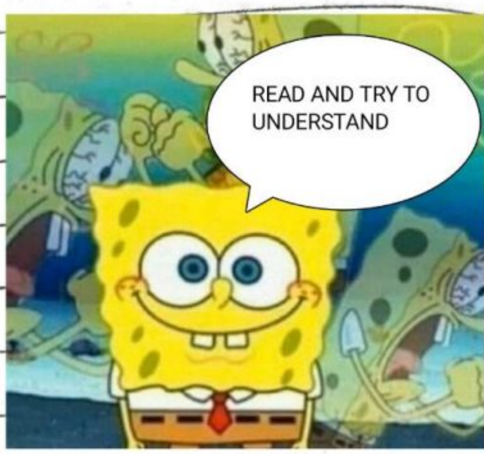
An element is a substance that cannot be separated into simpler substances by chemical means.

Eg- Aluminium = Al, Gold = Au, Silicon = Si etc.

SI Units

SI units is the abbreviation of international system of units. There are seven base SI units.

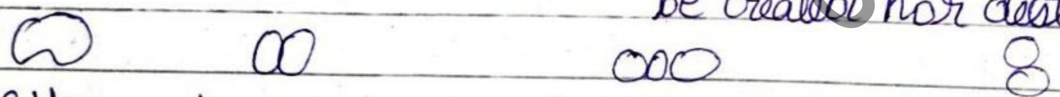
Physical Quantity	Name of SI unit	Symbol for SI unit
Length	Meter	m
Mass	Kilogram	kg
Time	Second	S
Electric current	~~Kelvin~~ Ampere	A
Temperature	Kelvin	K
Amt. of substance	Mole	mol
~~Electric~~ Luminous intensity	Candela	cd



Law of Chemical Combinations

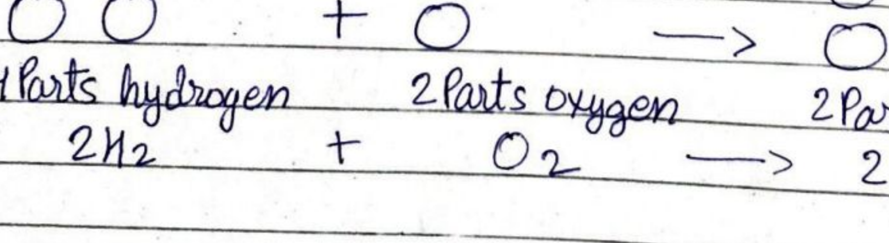
The combination of elements to form compounds is governed by the following five basic laws.
① Law of Conservation, ② Law of Definite Proportion,
③ Law of Multiple Proportion, ④ Gay Lussac's law of Gaseous vol^m,
⑤ Avogadro's law.

① **Law of Conservation of Mass** - It states that matter can neither be created nor destroyed.



CH_4 + O_2 ⟶ CO_2 + water
(Methane) (oxygen) (Carbondioxide) ($2H_2O$)

② **Law of Definite Proportion** - A given compound always contains exactly the same proportion of elements by weight.



4 Parts hydrogen + 2 Parts oxygen $\xrightarrow{\Delta}$ 2 Parts gaseous water

$2H_2 + O_2 \longrightarrow 2H_2O$

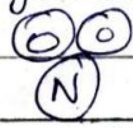
③ **Law of Multiple Proportions** - If two elements can combine to form more than one compound, the masses of one element that combine with a fixed mass of the other element, are in the ratio of small whole no.

30g Nitric oxide - NO

$14gN + 16gO$

$1 : 1$

46g Nitrogen dioxide - NO_2



$14gN + 32gO$

$1 : 2$

④ **Gay Lussac's Law of Gaseous Vol^m** - When gases combine or are produced in a chemical reaction they do so in a simple ratio by vol^m provided all gases are at same temperature and pressure.

$2H_2 + O_2 \Rightarrow H_2O$

HYDROGEN	+	OXYGEN	->	WATER VAPOUR
HYDROGEN				WATER VAPOUR

$2x : 1x : 2x$

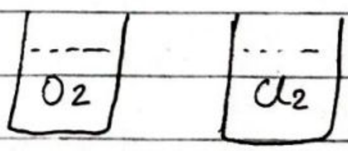
$2 : 1 : 2$

2 vol^m of Hydrogen + 1 vol^m of oxygen = 2 vol^m of water

⑤ **Avogadro Law** - Equal vol^m of gases at the same temperature and pressure should contain equal no. of molecules

Avogadro's law's formula

$$V \propto n \quad \text{or} \quad \frac{V}{n} = k$$



1 ltr 1 ltr

At same temp & pressure.

where,

V = vol^m of gas

n = no. of moles of the gas

k = constant

It can be written as

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Atomic Mass

One atomic mass unit is defined as a mass exactly equal to one twelfth the mass of one carbon = 12 atom.

And $1\ amu = 1.66056 \times 10^{-24} g$

Mass of an atom of hydrogen $= 1.6736 \times 10^{-24} g$

Thus, in terms of amu, the mass of hydrogen atom

$$= \frac{1.6736g \times 10^{-24}}{1.66056g \times 10^{-24}}$$

$$= 1.0078\ amu$$

$$= 1.0080\ amu$$

'amu' can be written as 'u'.

Atomic Mass of Element

$^{A}_{Z}X$

Mass no. (#Protons+ neutrons) → 12

C ← Symbol of element

6 → Atomic no. (#Protons)

Avg Atomic Mass

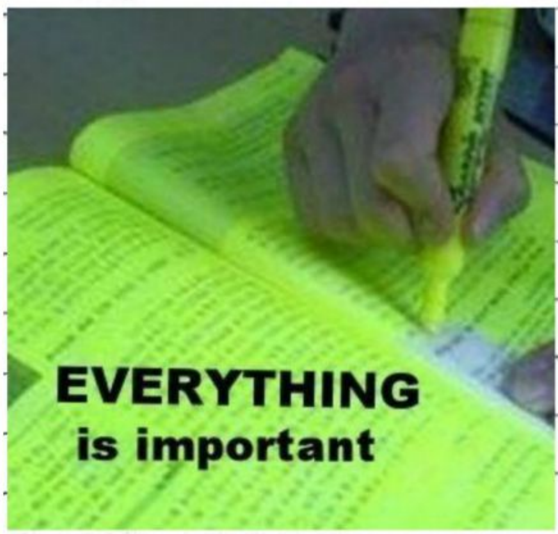
As carbon has three isotopes.

C-12	C-13	C-14
98%	0.011%	Rare coz Radioactive

From the above data, the avg atomic mass of carbon will come out to be:

$$\text{Avg. atomic mass}(C) = (0.98892)(12u) + (0.01108)(13.00335u) + (2 \times 10^{-12})(14.00317u) = 12.011u$$

$$\approx 12u.$$



Isotopes - Same no. of PROTONS (atomic no.) but have

Isobars - Both Protons + Neutrons (mass no.) is same but have diff atomic no.

Q1. Calculate Avg. atomic mass of Chlorine.

$^{35}_{17}Cl$ $\quad$ $^{37}_{17}Cl$

$\underbrace{3 : 1}_{\text{Two isotopes of Cl}}$

Avg. atomic mass

$$= \frac{(\text{abundance} \times \text{Mass})_1 + (\text{abundance} \times \text{mass})_2}{\text{Total \% abundance}}$$

$$= \frac{3 \times 35 + 1 \times 37}{4}$$

$$= \frac{105 + 37}{4}$$

$$= \frac{\cancel{142}\,71}{\cancel{4}\,2}$$

$$= 35.5\%$$

Molecular Mass

Molecular mass is the sum of atomic masses of the elements present in a molecule. It is obtained by multiplying the atomic mass of each element by the no. of its atoms and adding them together.

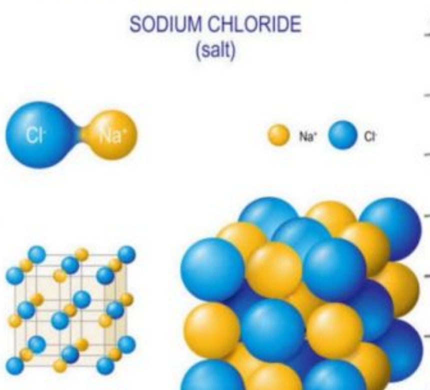
Molecular mass of methane
$(CH_4) = (12.011u) + 4(1.008u) = 16.043u$

Similarly, molecular mass of water
$(H_2O) = 2$ atomic mass of hydrogen $+$
1 atomic mass of oxygen
$\Rightarrow 2(1.008u) + 16.00u = 18.02u$

H_2O $\quad$ $2 \times H = 1.008\,g/mol$
$+ \quad O = 16.00\,g/mol$
$\boxed{H_2O = 18.02\,g/mol}$
$2 + 16 = \underline{18u}$

Formula Mass

~~Some~~ Formula mass - Some substances such as sodium chloride do not discrete as their constituent units. In such compounds, +ve (sodium) and -ve (chloride) entities are arranged in a three-dimensional structure.



It may be noted that in sodium chloride, one Na^+ is surrounded by six Cl^- and vice versa. The formula such as NaCl is used to calculate the formula mass instead of molecular mass as in the solid state sodium chloride does not exist as a single entity.

Thus, formula mass of sodium chloride
= atomic mass of sodium + atomic mass of chloride
= 23.0u + 35.5u
= 58.5u

$Na_2CO_3.10H_2O$

(K2SO4)

Q1. Calculate the molecular mass of ① Potassium Sulphate ② Washing soda

① atomic mass of Potassium sulphate + atomic mass of sulphur + at" " oxygen

39(2) + 32 + 16(4)
= 78 + 32 + 64
= 174 g/mol

② atomic mass of sodium + atomic mass of carbon + atomic mass of oxygen + atomic mass of hydrogen

23 (2) + 12 + 16(3) + 1(2) + 16(1) (10)
= 46 + 12 + 48 + 2 + 16 × 10
= 268 g/mol.

One Mole - 1 mol of hydrogen atoms = 6.022×10^{23} atoms.
1 mol of water molecules = 6.022×10^{23} water molecules.

eg.	2 shoes	1 Pair
	12 eggs	1 dozen
	48 doughnuts	4 dozen
	500 sheets of paper	1 ream

Mole Concept

A mole is the amt. of a substance that contains as many elementary entities (atoms, molecules or other particles) as there are atoms in exactly 0.012 kg or 12 g of the carbon-12 isotope.

Avogadro Constant (NA)

Avogadro's no. (NA), no. of units in one mole of any substance (defined as its molecular weight in grams), equal to $6.02214076 \times 10^{23}$ (or 6.022×10^{23}). The units may be electrons, atoms, ions or molecules, depending on the nature of the substance and the character of the reaction.

$$\boxed{1 \text{ mol} = N_A = 6.022 \times 10^{23}}$$

Molar Mass

Molar mass is the mass of 1 mol of the substance.
Also, 1 mol of any substance is the collection of its 6.022×10^{23} elementary ~~units~~ entities.

Molar mass = Mass of 6.022×10^{23} elementary entities.

$$\boxed{MM = N_A \times \text{molecular mass}}$$

The mass of one mole of a substance in grams is called its molar mass.

Molar mass of water = 18.02 g mol^{-1}
" " sodium chloride = 58.5 g mol^{-1}

* Also, keep in mind that g mol^{-1} means Molar mass & u means molecular mass

Molar Vol^m

Molar vol^m is the vol^m of one mole of a substance.
It depends upon temperature and pressure.
It is related to the density, by the relation.

$$\boxed{\text{Molar vol}^m = \frac{\text{Molar Mass}}{\text{Density}}}$$

In case of gases, we use their vol^m at standard temperature & pressure (STP).
Standard Temperature = $0^\circ C$ or $273.15 K$
" Pressure = 100 kPa

Molar vol^m = 22.7 L mol^{-1}

Relation b/w Mole, Mass and Molar mass

$$\text{No. of moles (amt.) of a substance} = \frac{\text{mass of the substance}}{\text{molar mass of the substance}}$$

$$n = \frac{\text{given wt}}{\text{Molar mass}} \qquad n = \frac{m}{M}$$

or, $m = n \times M$

Q1. How many moles of sulphur atoms & oxygen atoms are present in one mole each of H_2SO_4, H_2SO_3 & SO_2?

H_2SO_4
- 1 mole S atom
- 4 mole O atom
- 2 mole H atom

H_2SO_3
- 1 mole S atom
- 3 mole O atom
- 2 mole H atom

SO_2
- 1 mole S atom
- 2 mole O atom
- ~~2 mo~~

Q2. How many moles of NaOH are present in 120g of it?

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

$M.M = Na + O + H$
$= 23 + 16 + 1 = 40 g\ mol^{-1}$

$$n = \frac{\overset{3}{\cancel{120}} g}{\underset{1}{\cancel{40}} g/mol} = \cancel{3 \text{ moles}}$$

$n = 3$ mole

Emperical formula

It is the simplest +ve integer ratio of atoms present in a compound. They provide the lowest whole-no.-ratio btw the elements in a compound. Unlike molecular ~~mo~~ formulas, they do not provide info about the absolute no. of atoms in a single molecule of a compound. The molecular formula for a compound is equal to, or a whole-no. multiple of, its emperical formula.

It is also possible for diff types of compound to have equal empirical formula.

Molecular Formula

It shows the no. of each type of atom in a molecule. The structural formula shows the arrangement of the molecule.

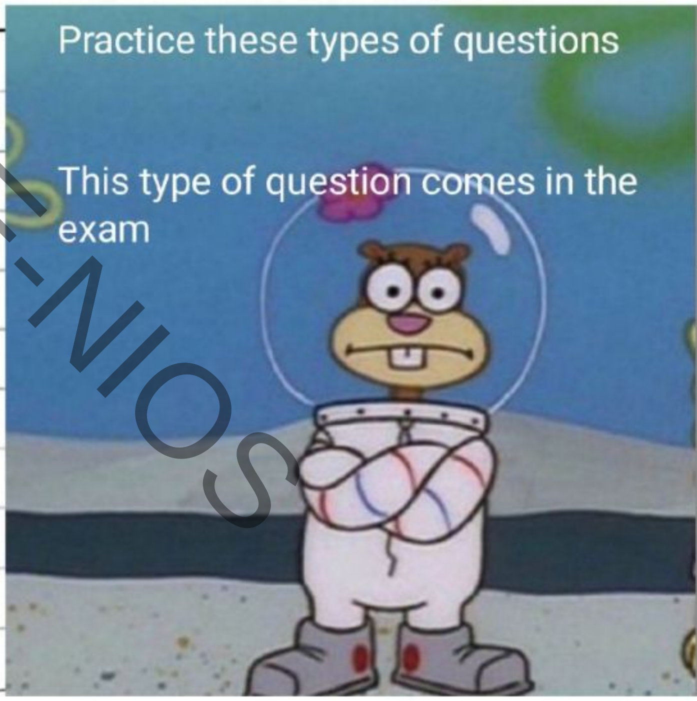
eg-

Compound	Molecular Formula
Glucose	$C_6H_{12}O_6$
Butane	C_4H_{10}
Octane	C_8H_{18}

Q1. Find the emperical formula of the following:

H_2O_2, C_6H_{12}, Li_2CO_3, $C_2H_4O_2$, S_8, H_2O, B_2H_6, O_3, S_3O_9, N_2O_3

Substance		Emperical formula
H_2O_2	$\xrightarrow{\overset{H\ \ O}{2:2}}$	HO
C_6H_{12}	$\xrightarrow{\overset{C\ \ H}{6:12}}$	CH_2
Li_2CO_3	$\xrightarrow{\overset{Li\ C\ O}{2:1:3}}$	Li_2CO_3
$C_2H_4O_2$	$\xrightarrow{\overset{C\ H\ O}{2:4:2}}$	CH_2O_1
S_8	$\longrightarrow$	S
H_2O	$\longrightarrow$	H_2O
B_2H_6	$\xrightarrow{\overset{B\ \ H}{2:6}}$	BH_3
O_3	$\longrightarrow$	O
S_3O_9	$\xrightarrow{\overset{S\ \ O}{3:9}}$	SO_3
N_2O_3	$\longrightarrow$	NO_3



Percentage Composition

The percentage composition of an element in a compound is the mass % of the element present in the compound.

It tells the mass %age of each element present in a compound

Percentage mass of an element in a compound

$$= \frac{\text{mass of element in one molecular formula or in one emperical form}}{\text{molecular mass or emperical formula mass of compound}} \times 100$$

$$= \frac{\text{Mass of element in 1 mol of compound}}{\text{Molar mass of compound}} \times 100$$

Q1. Butanoic acid $H_3C-H_2C-H_2C-COOH$

Molar mass of butanoic acid $= 4\times12+8\times1+2\times16 = 88\,g\,mol^{-1}$

Percentage of Carbon (C) by mass $= \frac{48}{88}\times100 = 54.5\%$

" " Hydrogen (H) " $= \frac{8}{88}\times100 = 9.1\%$

" " Oxygen (O) $= \frac{32}{88}\times100 = 36.4\%$

~~The %age of O in butanoic acid can also be cal~~

Q2. Find the %age mass of water in washing soda crystals? $Na_2CO_3.10H_2O$

Molar mass of $Na_2CO_3.10H_2O$

$2[Na]+1[C]+3[O]+10[18]$

$= 2\times23+12+3\times16+180$

$= 286g$

286g of washing soda contains 180g of water of crystall-isation

$= \frac{180\times100}{286} = \frac{9000}{143} = 6.29$ of H_2O

Q3. An organic compound contains $H=4.07\%$, $Cl=71.65\%$ chlorine and remaining carbon. Its molar mass $=98.96$. Find,

(a) Empirical formula, and

Sol-: (a) Emperical formula $= CH_2Cl$

sol-: (b) emperical formula mass $= 49.5$

Since, molecular Mass $= 98.96$

So, molecular formula $= (CH_2Cl)_2 = C_2H_4Cl_2$

(b) Molecular formula

Element	% Composition	Atomic Mass	Atomic Ratio	Simplest Ratio
H	4.07	1	$4.07/1 = 4.07$	2
Cl	71.65	35.5	$71.65/35.5 = 2.01$	1
C	24.28	12	$24.28/12 = 2.02$	1

Stoichiometry

Stoichiometry is the calculation of products and reactants in a chemical rxn. It is basically concerned with no.

Stoichiometry is an imp concept in chem that helps us use balanced chemical eq. to calculate amt of reactants and products. Here, we make use of ratio from the balanced eq. In general, all the ce rxn that take place are dependent on one main factor, how much substance is present.

$$\underset{\text{Reactant}}{2A + 3B} \longrightarrow \underset{\text{Product}}{C}$$

Eg:
$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Stoichiometric Coefficient

The no. of molecules that participate in the reaction.
It can be fractional as well as whole no. In essence, the coefficient helps us to establish the mole ratio btw reactants & products.

Eg- $4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$

LHS = RHS

Reaction Stoichiometry
- Qualitative Info.
- Quantitative Info.
  - Microscopic Quantities
    - Atoms
    - Molecules
    - Formula unit
  - Macroscopic Quantities
    - Moles
    - Masses
    - Vol^m

* Haber's Process ⟹ Ammonia gas (~~used~~ produced in industrial level).

		$\overset{2atom}{N_2(g)}$ +	$\overset{6atom}{3H_2(g)}$ ⟶	$2NH_3(g)$
Eg:	Microscopic relationship			
	Microscopic relationship	1 Molecule	3 Molecule	2 Molecule
	(i) Moles	1 mol	3 mol	2 mol
	(ii) Mass	28g	$(3\times2.0)=6.0g$	$(2\times17.0)=34g$
	(iii) Vol[m]	$1\times22.7L$ $=22.7L$	(3×22.7) $=68.1L$	(2×22.7) $=45.4L$
	or	1 Vol	3 Vol	2 vol

Q. ~~Butane~~ Eg: Butane + O_2 ⟶ CO_2 + water

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

$2C_4H_{10}(g)$	$13O_2(g)$	$8CO_2(g)$	$10H_2O(g)$
2 molecules	13 molecules	8 molecules	10 molecules
2 mol	13 mol	8 mol	10 mol
$2\times(4\times12+10\times1)g$	$(13\times32)g$	$8\times(12+2\times16)g$	$10\times(2\times1+16)g$
116g	416g	352g	180g
$2\times22.7=45.4L$	$13\times22.7=295.1L$	$8\times22.7=181.6L$	$10\times22.7=227L$
2 vol	13 vol	8 vol	10 vol

Limiting Reagent

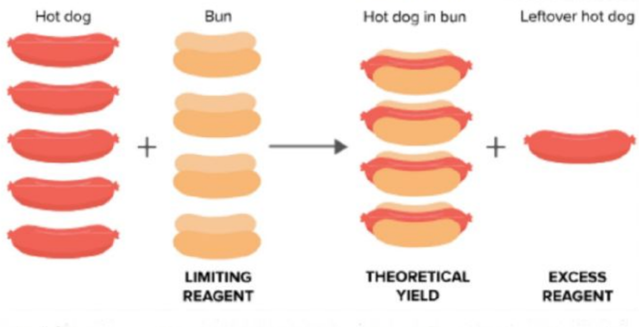
The limiting reagent (or limiting reactant or limiting agent) in a chemical rxns is a reactant that is totally consumed when the chemical rxn is completed. The amt. of product formed is limited by this reagent, since the rxn cannot continue without it.

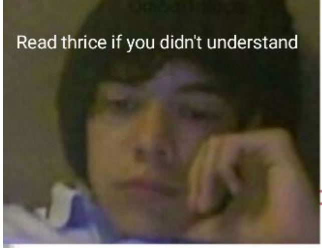
Suppose, A + B ⟶ C + D

A: excess reagent; B: consumed

B ⟹ limiting reagent

If one or more other reagents are present in excess of the quantities required to react with the limiting reagent, they are described as excess reagents or excess reactants.





$$\underset{1\,mol}{N_2} + \underset{3\,mol}{3H_2} \longrightarrow \underset{2\,mol}{2NH_3}$$

Eg: In the rxn given above, 3 moles of Hydrogen gas are required to react with 1 mole of nitrogen gas to form 2 moles of ammonia. But what if, during the rxn, only 2 moles of hydrogen gas are available along with 1 mole of nitrogen.

In that case, the entire quantity of nitrogen cannot be used (because the entirely of nitrogen requires 3 moles of hydrogen gas to react). Hence, the hydrogen gas is limiting the rxn and is therefore called the limiting reagent for this rxn.

Q1. Calculate the total no. of electrons in 1.6 g of methane. (CH_4)

Molecular mass CH_4

$12+4 = 16\,g\,mol^{-1}$

1 mole = 16g = 6.022×10^{23} molecules

no. of moles (n) = $\dfrac{\text{Molecular mass}}{\text{Given mass}}$

$= \dfrac{1.6}{16 \times 10}$

$= \dfrac{1}{10}\,mol = 0.1\,mol$

$0.1\,mole = 0.1 \times 6.022 \times 10^{23}$ molecules

$= 6.022 \times 10^{22}$ molecules

1 molecule no. of e^- = $C + H \times 4 = 6e^- + 4e^- = 10e^-$

No. of e^- in 6.022×10^{23}

$= 10 \times 6.022 \times 10^{22}$

$= 6.022 \times 10^{23}\,e^-$

Q2. What is the mass of one atom of Hydrogen in gram?

Molar mass is mass of 1 mole of that substance.

$\therefore 6.022 \times 10^{23} \times$ H atoms = 1g

$\therefore$ 1 H atoms = xg

By unitary method (cross multiflication) $\Rightarrow 1 \times 1 = x \times 6.022 \times 10^{23}$

$\Rightarrow x = \dfrac{1}{6.022 \times 10^{23}}$

$\Rightarrow x = 0.166 \times 10^{-23}$

$\Rightarrow x = 1.66 \times 10^{-24}\,g$

Q3. Calculate the vol^m occupied by 3.2g of O_2 at STP.

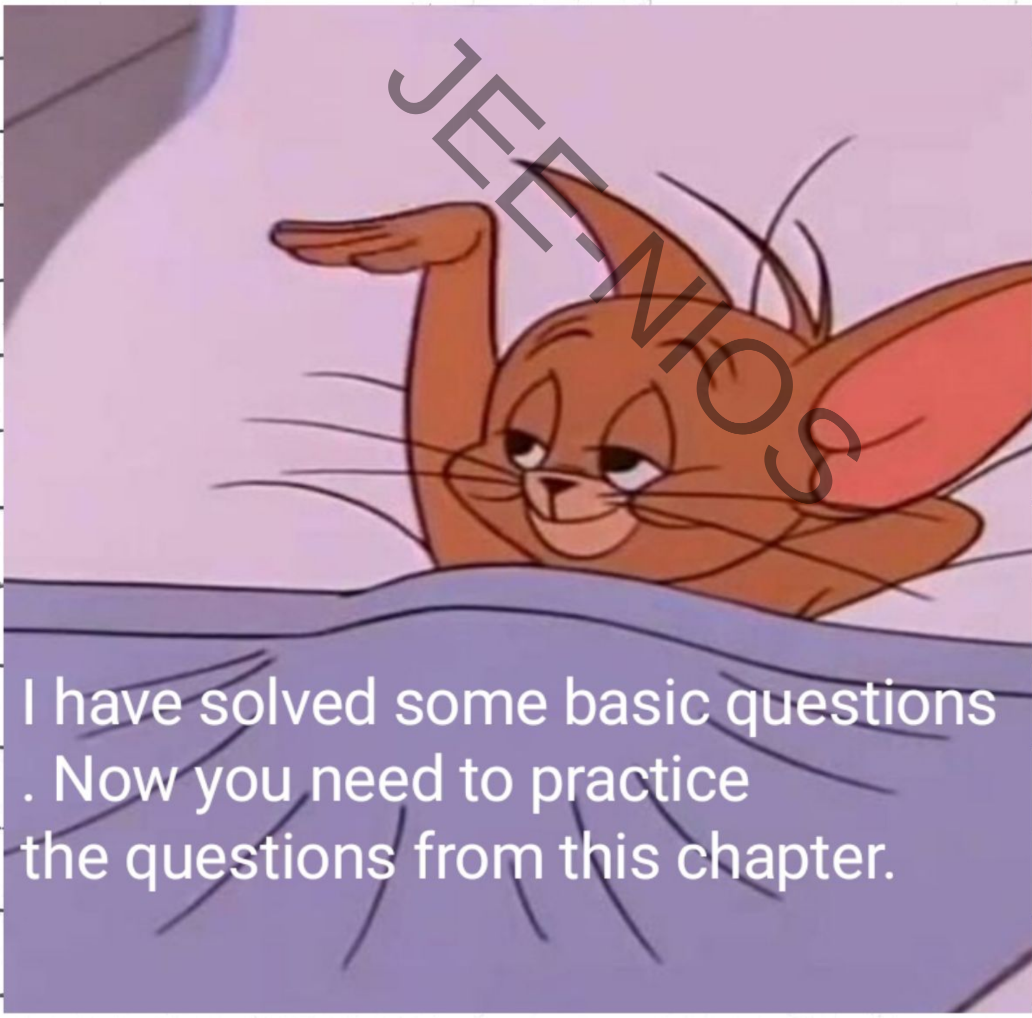
No. of moles = $\frac{\text{vol}^m \text{ of gas}}{22.4 \text{ litres}}$

Vol^m of gas = no. of moles $\times$ 22.4

no. of moles = $\frac{\text{given mass}}{\text{molar mass}} = \frac{3.2}{32} = 0.1$ moles

Vol^m of gas = 0.1×22.4

= 2.24 litres.

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