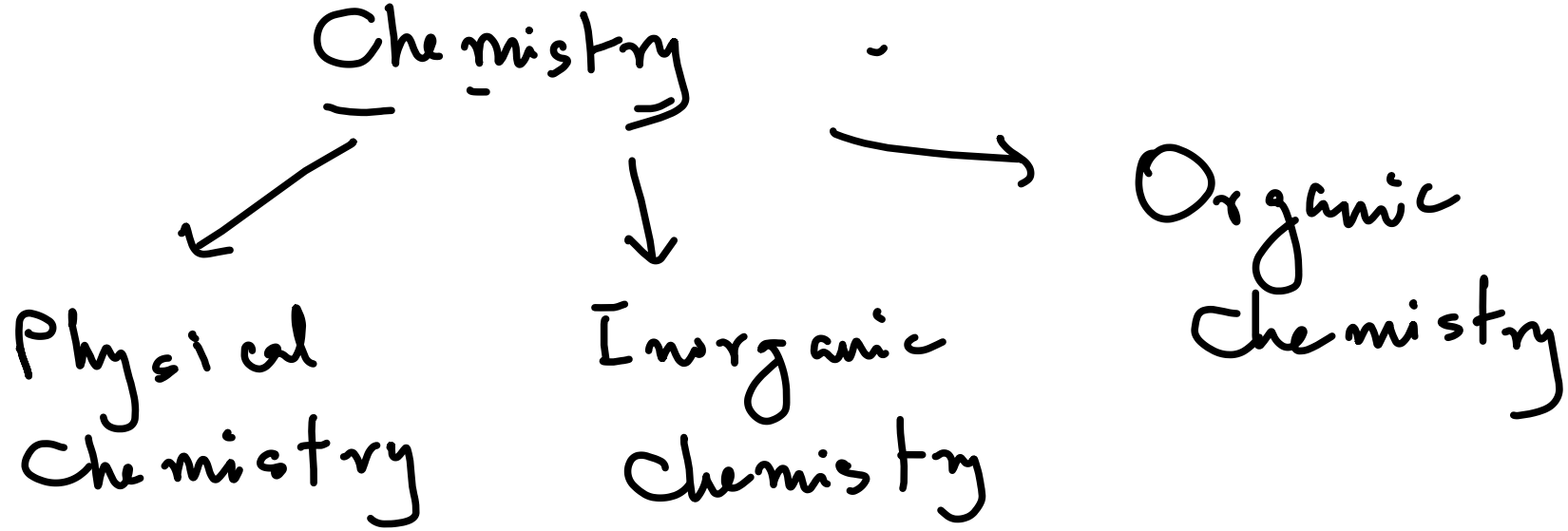


Chemistry ≡ Branch of science that deals with the composition, structure, & properties of matter. Chemistry is the science of atoms & molecules.

Branches of Chemistry

1. Organic chemistry – Chemistry of carbon compounds, especially hydrocarbons & their derivatives.

2. Inorganic chemistry: It deals with study of compounds of all elements except carbon.

Study of materials found on Earth's crust.

Inorganic compounds of carbon: CO_2 (carbon dioxide)
CO : carbon monoxide)

Physical Chemistry -

Explanation of fundamental principles governing various chemical phenomena is the primary concern of this branch of chemistry.

It is concerned with laws & theory of different branches of Chemistry -

Industrial Chemistry - - Chemistry involved in industrial process -

Analytical Chemistry: Qualitative and quantitative analysis of various substances.

Biochemistry: Deals with the chemical changes going on in the bodies of living organisms.

Nuclear Chemistry: Nuclear reaction, such as nuclear fission, fusion, transmutation etc - are studied under this branch.

Some Basic Concepts of Chemistry

Properties of matter

Physical properties

Color, odor, Melting Point, Boiling point, Density

These properties can be measured or observed w.o. changing the identity or composition of the substance

Chemical properties.

Acidity, Basicity
Combustibility

The measurement or observation of these properties require chemical changes

Metric System

The International System of Units (S.I.)

The SI system has 7 base units.

Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Amfere	A
Luminous intensity	Candela	cd.

Prefixes in SI system.

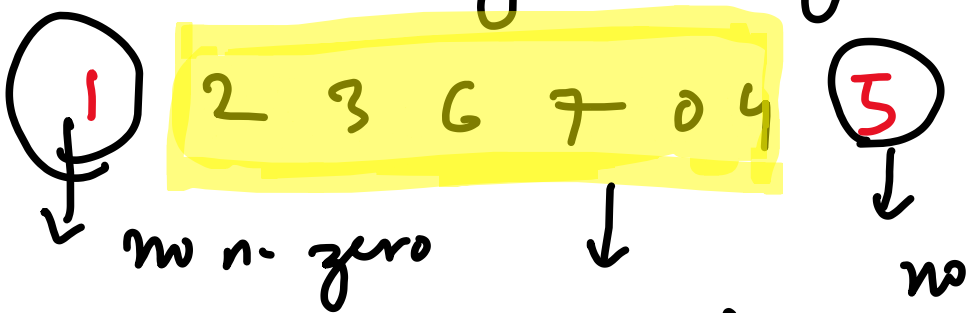
Multiple	Prefix	Symbol
10^{-12}	→ pico	p
10^{-9}	→ nano	n
10^{-6}	→ micro	μ
10^{-3}	→ milli	m
10^{-2}	→ centi	c
10^{-1}	→ deci	d
10^{1}	→ deca	da
10^{2}	→ hecto	h
10^{3}	→ kilo	k
10^{6}	→ mega	M
10^{9}	→ giga	G
10^{12}	→ tera	T

Basic Concepts of Chemistry

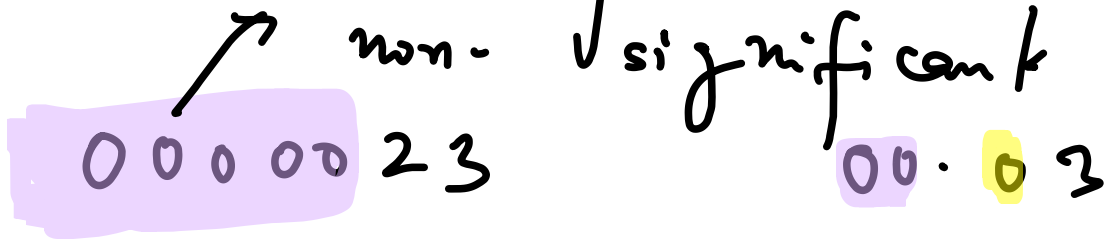
Significant figures.

0.00003

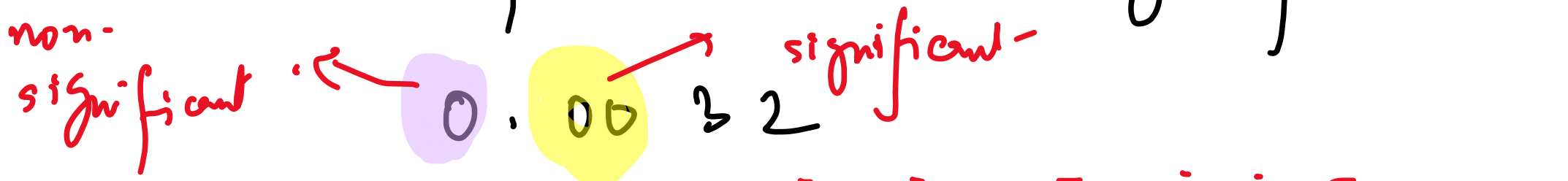
1. All non-zero digits and zero present in between two non zero digits are significant.



(2) Zero present at the left is not significant.



③ Zeroes at the right of a decimal point are significant. However, zeroes at the left of the decimal point is not significant.



The Law of Chemical Combination.

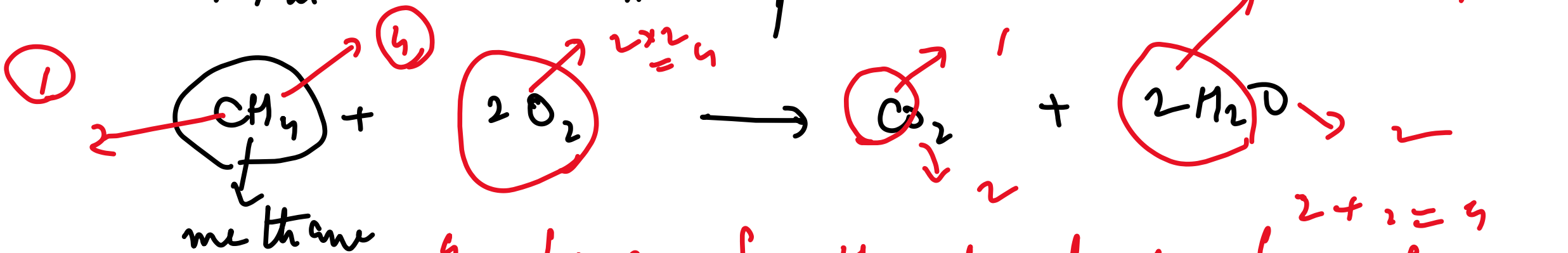
1. Law of conservation of mass.
2. Law of definite proportion
3. Law of multiple proportion.
4. Law of reciprocal proportion
5. Gay-Lussac's Law.

Law of Conservation of Mass

Matter can neither be created nor destroyed.

For a chemical reaction,

Total mass of the reactant
= Total " " product.



4 atoms of H, 4 atoms of O & 1 atom of C are present in the reactants as well as products.

So, mass of the reactants
= " " " products.

Law of conservation of mass & energy:

$E = mc^2$ → Einstein eqn :-

where E = energy

m = mass of an object

c = velocity of light.

Mass & energy are interconvertible.

Law of definite proportion

A given compound always contains the same proportion of elements by weight.

H_2O : 2 atoms of H + 1 atom of oxygen.

Atomic weight of H = 1

" " " O = 16

H_2O : 2 × 1 gm H combines with 16 gm oxygen

H : O

= 2 : 16

= 1 : 8

2 gm H ⟶ 16 gm oxygen - oxygen

H_2O : H : O = 1 : 8 ; H : $\frac{1}{1+8} \times 100 = \frac{100}{9} = \sim 11\%$

O : $\frac{8}{1+8} \times 100 = \frac{8}{9} \times 100 = \sim 89\%$.

CO_2 : Atomic weight of C : 12

" " " O : 16

1 C + 2 O

= 12 g C + 2 × 16 g O = 12 g C + 32 g O

combines to form CO_2

CO_2 : C : O = 12 : 32

= 3 : 8

Despite the no. of moles of water or carbon dioxide participating in a reaction the mass ratio of H : O will always remain the same.

The Law of Multiple Proportion

H_2O vs H_2O_2 — H : O

Water

1. H_2O : 2 g H + 16 g O ; 2 : 16 = 1 : 8

2 H_2O_2 : 2 g H + 16 × 2 g O ; 2 : 32 = 1 : 16

Hydrogen Peroxide

= 2 g H + 32 g O ;

(O) H_2O : O (H_2O_2) = 8 : 16 = 1 : 2

If two elements combine together to form several compounds, the weight of one of these elements that combines with a fixed weight of the other element are in simple integral ratios.

$2C + O_2 \longrightarrow 2CO$

$C + O_2 \longrightarrow CO_2$

CO vs CO_2

C : O

12 ← CO → 16

CO : 12g C + 16g O : 12 : 16 = 3 : 4

atomic wt.

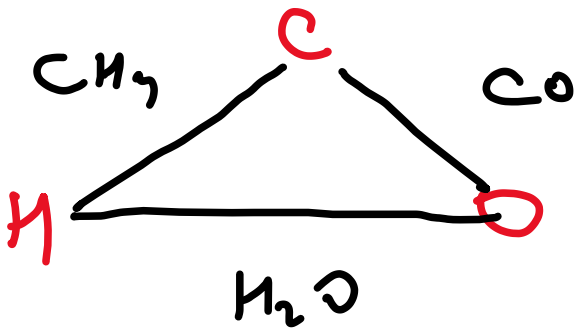
CO_2 : 12g C + 32g O : 12 : 32 = 3 : 8

$(O)_{CO} : (O)_{CO_2} = 4 : 8 = 1 : 2$

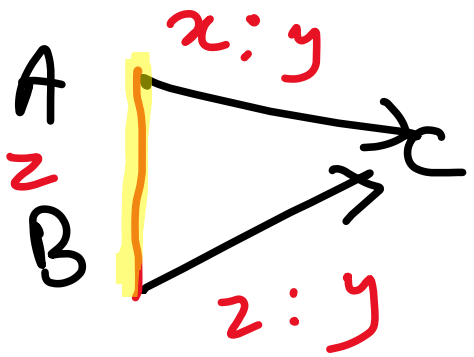
simple integral ratio

The Law of Reciprocal Proportion

If two different elements combine separately with the same weight of a third element, the ratio of the masses in which they do so are either the same or a simple multiple of the mass ratios in which they combine -



	Compound	Combining Elements		Combining weights	
1.	CH_4	C	H	12	4
2.	CO_2	C	O	12	32
3.	H_2O	H	O	4 : 32 → fixed.	



1 : 8

Gay-Lussac's Law.

Gases when combine or form in a chemical reaction they do so by simple volume ratios provided all gases are at constant and temperature. This law is only applicable for gases & is not applicable for solid & liquids.

Dalton's Theory of Atoms

1. Matter consists of indivisible atoms → something that can be divided
2. All the atoms of an element have

identical properties and identical mass - Atoms of different element differs in mass.

3- Compound formation takes place when atoms of different elements combine in a fixed ratio.

4- A chemical reaction involves reorganization of atoms. They are neither created nor destroyed in a chemical reaction.

Limitations 1. Existence of sub atomic particles i.e. protons, neutrons & electrons

contradicts the postulate that atoms are indivisible.

2. This law is unable to explain the Gay Lussac's law of gaseous volumes.

3 - Why similar or different atoms combine to form a molecule - cannot be explained by Dalton's atomic theory.

4. Nature of binding force between atom or molecules

Atomic mass unit: Atomic mass unit can be defined as $\frac{1}{12}$ of the mass of ^{12}C atom. The absolute mass of ^{12}C atom is obtained by dividing the value of 12 with Avogadro's no.

Avogadro's no: 6.023×10^{23}

N_A

Mass of 1 C atom: $\frac{12}{6.023 \times 10^{23}}$

Average atomic mass:

Isotopes : Atoms of same element with same atomic no. but different mass no.

	^{35}Cl	^{37}Cl
natural abundance	75%	25%

Average atomic mass :

$$= \frac{\sum (\text{mass of isotope} \times \text{natural abundance})}{100}$$

$\sum$: summation

$$= \frac{35 \times 75 + 37 \times 25}{100} = \frac{3535}{100}$$

Chlorine : atomic mass $= 35.5$

$= 35.5\%$

Basic Concepts of Chemistry

Molecular mass:

HNO_3 : $1 + 14 + 16 \times 3 = 63$

H_2SO_4 : $2 + 32 + 64 = 98$

$CaCO_3$: $40 + 12 + 16 \times 3 = 100$

HCl : $1 + 35.5 = 36.5$

↓ atomic mass/wt. of Cl = 35.5.

a.m.u = atomic mass unit

Molar mass. 63 g HNO_3 contains 6.022×10^{23} molecules of HNO_3

Mole: The mole is defined as the amount of substance that contains as many elementary

entities as there are atoms in exactly 12 g of carbon-12.

Mole is defined as exactly 6.022×10^{23} particles, which may be atoms, molecules, ions, or electrons.

← Avogadro's no.

How many oxygen atoms are there in 18 g of water?

Molar mass of water = 18 g/mol - H_2O : 2 + 16 = 18

molar mass

18 g of water contains 6.022×10^{23} H_2O molecules.

↓ molar mass.

1 H_2O molecule = 2 H atoms + 1 O atom.

6.022×10^{23} H_2O molecules will contain =

$2 \times 6.022 \times 10^{23} = 12.044 \times 10^{23}$ H atoms

6.022×10^{23} H_2O molecules will contain $1 \times 6.022 \times 10^{23} = 6.022 \times 10^{23}$ O atoms.

At S.T.P., 1 gm. mole of any gas occupies ~ 22.4 l.

1 mol of H_2, 1 mol of O_2, 1 mol. of N_2 — regardless of their atomic mass will occupy 22.4 l at S.T.P.

H_2 : $1 \times 2 = 2$ g.

O : $16 \times 2 = 32$ g

N_2 : $14 \times 2 = 28$ g

At S.T.P, 2 g of H_2, 32 g of O_2 & 28 g of N_2 — each will occupy 22.4 litre

Since 22.4 litre corresponds to molar

volume, 22.4 l of any gas at S.T.P will contain 6.022×10^{23} molecules.

S.T.P: Standard temperature and Pressure is defined as 0°C (273 K) & 1 atm. of pressure.

N.T.P: Normal temperature & pressure: 273.15 K & 0.987 ~ 1 atm.

Stoichiometry: The study of chemical reactions and related calculations is called stoichiometry

N.B: Points to note –

1 mol $CaCO_3$ reacts with 2 mole of HCl

$CaCO_3$: HCl = 1 : 2

$CaCO_3(s) + 2HCl \rightarrow$ aq. (aqueous soln.) $= CaCl_2 + H_2O + CO_2$

s = solid

$N_2(g) + 3H_2(g) = 2NH_3(g)$ g = gaseous

3 → stoichiometric coefficient.

The stoichiometric coefficient is the ratio of moles of atoms that reacts.

1 mol. of N_2 reacts with 3 mol of H_2 to produce 2 mol. of NH_3 gas.

Only when all reactants are present in a stoichiometric ratio, the ratio can be used to predict the number of moles of product formed.

Actual quantity of product formed is always less than the quantity predicted by the theoretical calculation.

Limiting Reagent and Excess reagent

Reactant ≡ Reagent ≡ equivalent

Limiting reagents are defined as the substances which are entirely consumed in the completion of a chemical reaction.

According to the stoichiometry of chemical reaction, fixed amounts of reactants are necessary to complete a reaction.

Excess reagent: Substances that are not entirely consumed in a chemical reaction.

Basic concepts of Chemistry

NCERT Question

1. Calculate the molecular mass of : atomic mass unit.

a) H_2O b) CO_2 c) CH_4 a.m.u.

2. Calculate the mass percent of different elements present in sodium sulfate (Na_2SO_4)

% Na = ? % S = ?

% O = ?

Molecular mass :

1. a) H_2O : $(2 \times 1.008 + 16.00)$ a.m.u

$\simeq$ 18.016 a.m.u

b) CO_2 : $(12.01 + 2 \times 16.00)$ a.m.u.

$\simeq$ 44.01 a.m.u.

c) CH_4 : $(12.01 + 4 \times 1.008) \simeq 16.042$ a.m.u.

2. Mass % of an element

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

Na_2SO_4 : $2 \times 23 + 32.0 + 16.0 \times 4$

$= 96 + 32 + 64 = 192\ g\ mol^{-1}$

Mass % of Na $= \frac{96}{192} \times 100 = 32.39\%$

" " S $= \frac{32}{192} \times 100 = 22.57\%$

" " O $= \frac{64}{192} \times 100 = 45.07\%$

(3) Determine the empirical formula of an oxide of iron which has 69.9% iron & 30.1% dioxygen by mass.

Element	Symbol	% by mass	Atomic mass	Moles of the element (relative no. of moles)	Simplest molar ratio	Simplest whole no. molar ratio
Iron	Fe	69.9	55.85	$\frac{69.9}{55.85} = 1.25$	$\frac{1.25}{1.25} = 1$	$1 \times 2 = 2$
Oxygen	O	30.1	16.00	$\frac{30.1}{16.0} = 1.88$	$\frac{1.88}{1.25} = 1.5$	$1.5 \times 2 = 3$

∴ Empirical formula = Fe_2O_3

55.85 grams Fe = 1 mole

1 " Fe = $\frac{1}{55.85}$ mole.

69.9 " " = $\frac{1}{55.85} \times 69.9$ mole.

(4) Calculate the amount of carbon dioxide that could be produced when

i) 1 mole of C is burnt in air

ii) 1 " " C " " in 16g. of oxygen.

iii) 2 moles of carbon are burnt in 16g. of oxygen.

Soln

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

1 mole 1 mole 1 mole

12 g 16 g 12 + 16×2 = 44 g.

i) In air, combustion is complete.

∴ CO_2 produced from the combustion of 1 mole C = 44 g

ii) As only 16 g of dioxygen is available, it can combine only with 0.5 mole of C i.e. dioxygen is the

Limiting reactant.

$$C(s) + O_2(g) \longrightarrow CO_2(g)$$

$32\ g$ — $44\ g$

$1\ g$ — $\frac{44}{32}\ g$

$16\ g$ — $\frac{22}{32} \times 16 = 22\ g$

Limiting reagent
or
Limiting reactant → A reactant that is totally consumed when the chemical reaction is completed.

Limiting reagent / reactant is the reactant that gets consumed first in a chemical reaction and therefore limits how much product can be formed.

iii) Here, again dioxygen (O_2) is the limiting reagent. 16 g of dioxygen can combine only with 0.5 mole of carbon. CO_2 produced again is equal to 22 g.

(5) Calculate the mass of sodium acetate (CH_3COONa) required to make 500 ml of 0.375 molar aqueous soln.

Molar mass of sodium acetate is $82.0245\ g\ mol^{-1}$.

1000 ml] — 82 g. — — 1 (M)

1000 ml - 0.375 (M) ∴ Mass of sodium acetate required =

500 " - $\frac{0.375}{2}$ (M) $\frac{0.375}{2} \times 82.0245 =$

15.38 g.

⑤ Calculate the concentration of nitric acid in moles per litre in a sample which has a density $1.41\ g\ ml^{-1}$ & the mass % of HNO_3 in it is 69%.

Sol^n :- 100 g of HNO_3 soln. contains 69 g of nitric acid by mass.

$\therefore$ Moles in 69 g HNO_3 = $\frac{69}{63\ g\ mol^{-1}}$

Volume of 100 g HNO_3 : $V = \frac{M}{D} = \frac{100\ g}{1.41\ g\ ml^{-1}} = 70.92\ ml.$

$= 1.095\ mol$

$70.92\ \text{ml} = \frac{70.92}{1000} = 0.07092\ \text{L}$

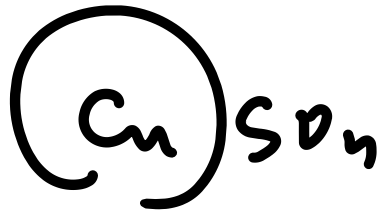
$0.07092\ \text{L} - 1.095\ \text{mol}$

$1\ \text{L} - \frac{1.095}{0.07092}\ \text{L}$

$= 15.44\ \text{M}$

(7) How much copper can be obtained from 100 g of $CuSO_4$? (atomic mass of Cu = 63.5 a.m.u)

Soln 1 mole $CuSO_4$ contains → 1 mole Cu



Molar mass of $CuSO_4$ =

$63.5 + 32 + 4 \times 16 = 159.5\ g\ mol^{-1}$

159.5 g of $CuSO_4$ will produce → 63.5 g Cu

1 " " " " " $\frac{63.5}{159.5}$ g Cu.

100 g " " " $\frac{63.5}{159.5} \times 100\ g = 39.81\ g$.

Basic Principles in Chemistry

Practice Questions.

1. Suppose the elements x & y combine to form two compounds XY_2 and X_3Y_2. When 0.1 mole of XY_2 weighs 10g and 0.05 mole of X_3Y_2 weighs 9g the atomic weight of x & y are

a) 40, 30 b) 60, 40 c) 20, 30 d) 30, 20

NEET – 2016

Soln Let atomic masses of x & y be x & y respectively

For XY_2, $n_{XY_2} = 0.1 = \frac{10}{x+2y}$

If X_3Y_2, $n_{X_3Y_2} = 0.05 = \frac{9}{3x+2y}$

40 g mol^{-1}
30 g mol^{-1}

$\Rightarrow 3x + 2y = 180$
$x + 2y = 100$

$2y = 180 - 3x$

$\Rightarrow y = \frac{180-3x}{2} = \frac{180-3\times 40}{2} = 30$

$2x = 80 \quad x = 80/2 = 40$ g

(2) If Avogadro's no. N_A, is changed from $6.022 \times 10^{23}\ mol^{-1}$ to $6.022 \times 10^{20}\ mol^{-1}$ this would change

i) the definition of mass in unit

ii) the mass of one mole of carbon

iii) the ratio of chemical species to each other in a balanced eqn.

iv) the ratio of elements to each other in a compound.

(ii) → Correct.

AIPMT → 2015.

(3) 20.0 g of $MgCO_3$ sample decomposes on heating to give CO_2 and 8.0 g of MgO. What will be the % purity of $MgCO_3$ in the sample?

[Mg = 24 atomic mass]

a) 75 b) 96 c) 60 d) 84

$$MgCO_3 \longrightarrow MgO + CO_2$$

$24 + 12 + 48 = 84$ $\quad$ $24 + 16 = 40$

$84\,g \longrightarrow 40$

40 g of MgO is formed from 84 g $MgCO_3$

8 " " " 1? " " —

$\frac{84}{40} \times 8 = \frac{84}{5}$ gm

% purity $= \frac{84}{5} \times \frac{100}{20} = 84\%$

Correct answer $= 84$

(4) What is the mass of precipitate formed when 50 ml of 16.9 % solution of $AgNO_3$ is mixed with 50 ml of 5.8 % NaCl solution?

[Ag = 107.8, N = 14, O = 16, Na = 23, Cl = 35.5]

a) 28 g b) 3.5 g c) 7 g ✓ d) 14 g

Correct answer: c AIPMT : 2015

5. The number of water molecules is maximum in

a) 18 molecules water
b) 1.8 g of water
c) 18 g of water
d) 18 moles of water

Correct option: 'd'

Key concept: Mole is the biggest unit

(6) When 22.4 L of $H_2(g)$ is mixed with 11.2 L of $Cl_2(g)$, each at S.T.P. the moles of HCl formed is equal to

a) 1 mole of $HCl(g)$

b) 2 moles of $HCl(g)$

c) 0.5 moles of $HCl(g)$

d) 1.5 moles of $HCl(g)$

Correct option: a

Stoichiometry : Limiting yield

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

22.4 L 11.2 l 2 mol -

22.4 L volume at S.T.P. is occupied by - Cl_2 = 1 mole

11.2 L = 0.5 mole

1 mol H_2 is reacting 0.5 mole Cl_2.

Since Cl_2 possesses minimum no. of moles, it is the limiting reagent.

As per eqn. -

1 mol. Cl_2 = 2 moles of HCl

∴ 0.5 " " = 2 × 0.5

= 1 mole of HCl

1.0 mol. of HCl gas is produced by 0.5 mole Cl_2 i.e. 11.2 L -

(7) 1.0 g of magnesium is burnt with 0.56 g of oxygen in a closed vessel. Which reactant is left in excess and how much?

a) Mg, 0.16 g
b) O_2, 0.16 g
c) Mg, 0.44 g
d) O_2, 0.28 g.

Correct option : a

8. How many grams of concentrated nitric acid solution should be used to prepare 250 ml of 2.0 M. HNO_3? The concentrated acid is 70 % HNO_3

a) 45.0 g conc. HNO_3

b) 90.0 g " "

c) 70.0 g " "

d) 54.0 g " "

(a) Correct option

NEET - 2013

$$\text{Molarity} = \frac{\text{Weight of } HNO_3}{\text{Molecular mass of } HNO_3 \times \text{volume of soln.(L)}}$$

9. 6.02×10^{20} molecules of urea are present in 100 ml of its solution. The concentration of solution is

a) 0.02 M b) 0.01 M NEET – 2013

c) 0.001 M d) 0.1 M

Correct option: B.

10. Haemoglobin contains 0.33% of iron by weight. The molecular weight of haemoglobin is approximately 67200 g. The number of iron atoms (At. wt. of Fe is 56) present in one molecule of haemoglobin are —

a) 1 b) 6 c) 4 d) 2

∴ 0.33% of Fe by weight

means 100 g of Hb has 0.33 g Fe

100 g Hb contains = 0.33 g Fe

∴ 6720 g of Hb " iron

$= \frac{0.33 \times 6720}{100}$

No. of Fe atoms $= \frac{221.76}{56}$ = 221.76 g of Fe

$\simeq 3.96 \simeq 4$

11. Ratio of C_p & C_v of a gas X is 1:4. The no. of atoms of the gas X present in 11.2 L of it at N.T.P will be

a) 6.02×10^{23}

b) 1.2×10^{23}

c) 3.01×10^{23}

d) 2.02×10^{23}

Diatomic $\Rightarrow$ ratio of $C_p/C_v = 1.4$

Correct option: 'c'

At N.T.P, volume of 1 mole of a gas

= 22.4 l

1 mole of a gas = 6.023×10^{23} molecules

At N.T.P.

22.4 l contains - 6.023×10^{23}

At N.T.P: 11.2 L 11 - $\frac{6.023 \times 10^{23} \times 11.2}{22.4}$

$= 3.01 \times 10^{23}$ molecule molecules

12. In the final answer of the expression.

Correct answer: (c)

$$\frac{(29.2 - 20.2)\ (1.71 \times 10^{-5})}{1.37}$$

the no. of significant figures is

a) 1 b) 2 c) 3 d) 4

3 significant $\rightarrow 1.17 \times 10^{-4}$

At least precise no. contain 3 significant digits.

$\therefore$ X is diatomic.

no. of atoms of the gas =

$3.01 \times 10^{23} \times 2$ atoms

$= 6.02 \times 10^{23}$ atoms.

(13) 5 moles of AB_2 weighs 125×10^{-3} kg and 10 moles of A_2B_2 weighs 300×10^{-3} kg. The molar mass of A (M_A) and molar mass of B (M_B).

in kg mol^{-1} are :

a) $M_A = 10 \times 10^{-3}$ and $M_B = 5 \times 10^{-3}$

b) $M_A = 50 \times 10^{-3}$ & $M_B = 25 \times 10^{-3}$

c) $M_A = 25 \times 10^{-3}$ & $M_B = 50 \times 10^{-3}$

d) $M_A = 5 \times 10^{-3}$ & $M_B = 10 \times 10^{-3}$

Correct answer : (d)

2019 Main

(14) The percentage composition of carbon by mole in methane is

a) 75% b) 20% c) 25% d) 80%.

% Composition = Composition of a substance in a compound / Total composition of the compound × 100

CH_4 : mole of C = 1
" " H = 4

$\%C = \frac{1}{1+4} \times 100 \times 100 = 20\%$