Mole Concept

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Types of Formulae for Compounds

Empirical Formula → It represents the simplest relative whole number ratio of atoms of each element present in the molecule of compound

Example: for $C_6H_{12}0_6$, empirical formula is CH_20

Molecular Formula → Represents actual number of atoms of each element present in the compound

$$= \boldsymbol{n \times Empirical\ formula}$$

$$n = \frac{molecular\ formula\ mass}{emperical\ formula\ mass}$$

Example: $n = 6$ for $C_6H_{12}0_6$

Related to Emperical formula

Q5) A hydrocarbon contains 85% carbon by mass VD = 28 molecular formula is

Approach Molmass = 56

wt of C = $56 \times \frac{85}{100} = 47.6 \simeq \frac{48}{12} = 4$

$H = 56 - 48 = \frac{8}{1} =$

formula is C_4H_8

Q6) A hydrocarbon has 10.5 g of carbon per g of H. One litre vapours of hydrocarbon at 127°C and 1 atm pressure weighs 2.8 g. Molecular formula?

Approach $PV = nRT$, $PV = \frac{\omega}{M'} RT$

$M' = 92$.

11.5 g —— 1 g H

92 g —— $\frac{8 g H}{1} = 8$

wt of C $= \frac{84}{12} = 7$

Molecular formula = C_7H_8

Concept of Limiting Reagent

In the reactions, where more than one reactant is involved, the reactant which is completely consumed is **called limiting reagent**

Example: $A \quad + \quad 2B \longrightarrow 4C$

At time$= 0$ $\quad 5\, moles \quad 12\, moles$

A gives 20 moles of C (if A is limiting reagent)

B gives 24 moles of C (if B is limiting reagent)

NOTE: Limiting reagent decides that what quantity of products will be formed

Reactant producing least number of moles of the product is the limiting reactant ($\therefore A$ in above example)

Q) 5.4 g of Allumunium reacts with 3.2 g of O_2 to form Al_2O_3. find out.

1) LR 2) wt of left Reactant

3) no of moles of Al_2O_3 formed

Solution : $2Al + \frac{3}{2}O_2 \longrightarrow Al_2O_3$

t=0 5.4 g 3.2 g

$\frac{5.4}{27}$ $\frac{3.2}{32}$

0.2 0.1 for $3/2\ O_2$

2 Al

$\left(\frac{1}{10}\right)$ $\frac{0.2}{2}$ $\frac{0.1}{1.5}$ $\left(\frac{1}{15}\right) \rightarrow$ LR.

$\frac{1}{10} - \frac{1}{15} = \frac{1}{30}$ 0 $\frac{1}{15}$ moles

$\frac{1}{30} \longrightarrow 1\ Al$

$\frac{1}{15} \longrightarrow 2\ Al$

$\frac{1}{15} = \frac{w}{27}$

$w = 1.8\ g$

Vapor density

$$Absolute\ density = \frac{mass}{volume}$$

$$Relative\ density = \frac{absolute\ density}{density\ of\ pure\ water\ at\ 4℃}$$

$$\boldsymbol{vapor\ density} = \frac{mass\ of\ vapor\ of\ substance\ per\ mLat\ NTP}{mass\ of\ hydrogen\ per\ mL\ \ at\ NTP}$$

Since both, vapor of substance and hydrogen occupy equal volume at NTP

Or

$$\boldsymbol{vapor\ density = \frac{molecular\ mass\ of\ vapor}{molecular\ mass\ of\ hydrogen}}$$

$\frac{molecular\ mass}{2}$ (since, molecular mass of $H_2 = 2$)

From vapor density calculation, molecular mass of a compound can be found out

Law of Chemical Equivalence in a Chemical Reaction

$$aA + bB \rightarrow mM + nN$$

The equivalent weight (in grams) of a compound taking part in a reaction	=	weight of compound which combines with 1 equivalent of another compound

$$eq.of\ A = eq.of\ B = eq.of\ M = eq.of\ N$$

$$\boldsymbol{\frac{wt.of\ A}{E_A} = \frac{wt.of\ B}{E_B} = \frac{wt.of\ M}{E_M} = \frac{wt.of\ N}{E_N}}$$

Where E stands for equivalent weight

Q) Metal $\xrightarrow{HNO_3}$ $M(NO_3)_n$ $\xrightarrow{\Delta}$ M_2O_n 12)

1.6 g 2g 32

Q) Eq wt of Metal ?

Apply law of equivalence

eq of M = eq of M_2O_n { eq of M = eq of O_2

$\frac{1.6}{E} = \frac{2}{E+8}$ $\frac{1.6}{E} = \frac{0.4}{8}$

Q) Acid + Base

w = 0.366 g 15 ml $\frac{N}{5}$

M' = 122 g

nf = ?

meq of B = meq of A

$3 = \frac{0.366}{122/n} \times 1000$

n = 1

Q) $BaCl_2$ + Na_3PO_4 (4) —— $Ba_3(PO_4)_2$ + NaCl

0.5 mole 0.2 mole 0.6 eq

1 eq 0.6 eq 0.6 eq

as eq = moles × nf

0.6 6

n $Ba_3(PO_4)_2$ = 0.1

n NaCl = 0.6

Q) LR

Q) n $Ba_3(PO_4)_2$ & NaCl

Equivalent Weight for Acids and Bases

For Acids,

$$\boldsymbol{E = \frac{Molecular\ weight\ of\ acids(i.e.weight\ of\ 1\ mole)}{basicity\ of\ Acid}}$$

i.e. mole of H^+ furnished

For Bases,

$$\boldsymbol{E = \frac{Molecular\ weight\ of\ base}{acidity\ of\ Base}}$$

i.e. moles of OH^- furnished or moles of H^+ accepted

Equivalent Weight for Salts

$$E = \frac{molecular\ weight\ of\ salt}{moles\ of\ H\ equivalent\ to\ total\ number\ of\ cations\ or\ anions}$$

or

$$E = \frac{molecular\ weight\ of\ salt}{moles\ of\ metal\ atoms\ \times valency\ of\ metal}$$

Example 1: For $CaSO_4$, $E = \frac{M}{2}$

$$for\ oxides: E = \frac{molecular\ weight\ of\ oxide}{moles\ of\ element\ atoms\ \times valency\ of\ element}$$

Example 2: For Al_2O_3, $E = \frac{M}{6}$

NOTE: Equivalent weight of a compound taking part in a reaction should be determined from chemical equation, as it depends on stoichiometry of the reaction

Equivalent Weight in Redox Reactions

In redox reactions, equivalent weight $(E) = \dfrac{Mol.wt\ of\ oxidising\ or\ reducing\ agent}{change\ in\ oxidation\ no.per\ mole\ of\ Redox\ agent}$

Example: when ${MnO_4}^-$ is reduced to Mn^{2+} → oxidation number changes from $+7\ to + 2$

$$\boldsymbol{E = \frac{M_{MnO_4^-}}{5}}$$

NOTE: Oxidation number of ions taking part in the precipitation reaction does not change. For them $\boldsymbol{E = \dfrac{weight\ of\ 1\ mole\ of\ ions}{mole(s) of\ charge\ on\ ion}}$

Example: $E_{Fe^{2+}} = \frac{56}{2} = 28$ AND $E_{Fe^{3+}} = \frac{56}{3} = 18.67$

Molecular weight of a Compound

It is defined as the weight of a molecule of the compound relative to a carbon atom

NOTE: Molecular weight in grams is the weight of 1 mole of molecule

$$molecular\ weight = \frac{weight\ of\ molecules\ in\ grams}{number\ of\ moles\ of\ molecules}$$

It is measured in $\boldsymbol{atomic\ mass\ unit}\ (\boldsymbol{amu})$

REDOX REACTION

1) INTERMOLECULAR:

Spectator

$$\overset{0}{Zn} + \overset{+2}{Cu}\overset{-2}{SO_4} \longrightarrow \overset{+2}{Zn}\overset{-2}{SO_4} + \overset{0}{Cu}$$

Ox   Red

2) INTRAMOLECULAR:

6 (Ox)

$$\overset{+1}{K}\overset{+5}{Cl}\overset{-6}{O_3} \longrightarrow \overset{+1}{K}\overset{-1}{Cl} + \frac{3}{2}\overset{0}{O_2}$$

6 (Red)

3) DISPROPORTIONATION:

$$\overset{0}{Cl_2} \longrightarrow \overset{-1}{Cl^-} + \overset{+5}{ClO_3^-}$$

Red   Ox

4) Comproportionation:

$$\underset{-1}{Cl^-} + \underset{+5}{ClO_3^-} \longrightarrow \underset{0}{Cl_2}$$

Red   Ox

5) SELECTING, OA, RA

OA,	H_2SO_4, (+6)	HNO_3 (+5),	$KMnO_4$ (+7)
RA	H_2S (−2)	NH_3 (−3)	MnO (+2)

Selecting OA and RA both acting one Species

SO_2 (+4) → H_2SO_4 (+6), → H_2S (−2) | HNO_2 (+3) → HNO_3 (+5), → NH_3 (−3) | MnO_2 (+4) → Mn_2O_7 (+7), → MnO (+2)

Q6) Ox. State of A = +2, B = +5, C = −2. Formula of compound is

a) $A_3(BC_4)_2$ b) $A_3(B_4C)_2$ c) A_2BC_3 d) A_3BC_2

$+6 \; +10 \; -16$

Q7) 2.5 moles of N_2H_4 looses 25 mole of e^- to form a new Compound Y Assuming all Nitrogen appears in new Compound. OS of Y?

2.5 —— 25

1 —— 10

$N_2H_4 \longrightarrow 10e^- + Y$

$\overset{-4}{N_2} \longrightarrow 10e^- + (2N)^a$

$-4 = -10 + 2a$

$\boxed{a = +3}$

⟹ Normality and Molarity are Temp dependent

Molality: $\dfrac{\text{no of moles of solute}}{\text{kg of solvent}} = \dfrac{w}{M'} \times \dfrac{10^3}{W(g)}$

↓, temp Independent.

Molarity: $\dfrac{\text{no of moles of solute}}{\text{Litre of solution}} = \dfrac{w}{M'} \times \dfrac{10^3}{V(ml)}$

Relation between Density(solution), Molarity, Molality and molar mass

$$D = M\left(\frac{1}{m} + \frac{m'}{1000}\right)$$

Normality = $\dfrac{\text{no of eq of solute}}{\text{Litre of solution}} = \dfrac{w}{Eq\,wt} \times \dfrac{10^3}{V(ml)}$

$N = M \times nf$

Molefraction: $X_{solute} + X_{solvent} = 1$ (1)

(2) $\dfrac{X_{solute}}{X_{solvent}} = \dfrac{n_{solute}}{n_{solvent}}$

$m = \dfrac{X_{solute}}{X_{solvent}} \times \dfrac{10^3}{W_{solvent}}$

$m = \dfrac{n_{solute}}{n_{solvent}} \times \dfrac{10^3}{\text{Molmass solvent}}$

Q) 20 ml / 0.1M $BaCl_2$ reacts with 30 ml / 0.2M H_2SO_4 calculate the moles of $BaSO_4$ formed

→ $BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + HCl$

	$BaCl_2$	H_2SO_4	$BaSO_4$	HCl
nf	2	2		
t = 0	2 mm	6 mm	0	0
t = t'	0		2 mm	

moles of $BaSO_4$ = 2×10^{-3} moles

Q) 20 ml / 0.1M $BaCl_2$ reacts with 30 ml / 0.2M $Al_2(SO_4)_3$ Calculate the weight of $BaSO_4$ and $AlCl_3$ formed

→ $BaCl_2 + Al_2(SO_4)_3 \longrightarrow BaSO_4 + AlCl_3$

	$BaCl_2$	$Al_2(SO_4)_3$	$BaSO_4$	$AlCl_3$
nf	2	6		
t = 0	2 mm	6 mm	0	0
t = 0	4 meq	36 meq	0	0
t = t'	0 meq	32 meq	4 meq	4 meq

$4 = \frac{w}{233/2} \times 10^3$ $\quad\quad$ $4 = \frac{w}{44.5} \times 10^3$