I Avogadro's Law 27/4/2020. Chemistry

Equal volume of all gases, at the same temperature and pressure, have the same numbers of molecules.

i.e. $V \propto n$ or $\frac{V}{n} = K$

V = Volume of the gas.

n = amount of the gas. & K = Constant = $\frac{RT}{P}$

1 mole of carbon atoms → 6.022×10^{23} numbers of C-atoms.

1 mole of carbon atoms → 12 g of C-atoms.

1 mole of molecules → 6.022×10^{23} numbers of molecules

1 mole of molecules → Molecular mass in grams.

1 mole of any particle like atoms, molecules, ions → 6.022×10^{23} number of that particle

1 mole of any particle like atoms, molecules, ions → Relative molecular mass of that particle in gram.

1 mole = ? g.m. mass occupies 22.4 lit/ 22400 cc. contains 6.023×10^{23} molecules/ atoms/ ions!

6.023×10^{23} = Avog. No. i.e. N_A

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* Cal. the mass of 50 cc of CO at STP [C-12 & O=16]

Ans ∵ 1 mole = ? gmm occupies 22.4 lit/22400 cc at S.T.P & it contain 6.023×10^{23} molecules/atom/ion

mass. vol.

Mol. Mass of CO = 12 + 16
= 28 g.

∵ vol of CO is given

So, we can say,

22400 cc of CO at S.T.P have mass 28 gm.

So, 1 " " " " " $\frac{28}{22400}$

50 cc " " " " " $\frac{28 \times 50}{22400}$ gm = 0.0625 gm.

So at STP. 50 cc of CO will have mass of 0.0625 gm.

* Cal. the vol at STP of 7.1 gm of Chlorine [Cl = 35.5]

Ans ∵ Cl_2 will have mass of 35.5×2 = 71 gm & have 1 mole

Now. 71 gm of Cl_2 at S.T.P occupies 22.4 lit.

1 - - - - - - - - - - $\frac{22.4}{71}$ lit

7.1 gm - - - - - $\frac{22.4}{71} \times 7.1$ = 2.24 lit.

So, 7.1 gm of Cl_2 will occupy a vol of 2.24 lit at S.T.P

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Vapour Density of a gas = $\frac{\text{Wt. of a certain vol of a gas at S.T.P.}}{\text{Wt of an equal vol of } H_2 \text{ at S.T.P.}}$

& Mol wt = 2 x Vap. density.

$V.D = \frac{\text{Mass of 1 molecule of a gas or vapour}}{\text{Mass of 1 molecule of Hydrogen}}$

$= \frac{\text{Mass of 1 molecule of substance (gas)}}{\text{Mass of 2 atoms of hydrogen}}$

eg Cal. the vapour density of ammonia.

Ans Mol. Mass of NH_3 = 14 + 1 x 3 = 17

Vap. Density = $\frac{\text{R. Mol. Mass}}{2} = \frac{17}{2} = 8.5$

Percentage composition

% of an element = $\frac{\text{Mass of that element}}{\text{Total mass of the compound}} \times 100$

example :- Cal the % of water of Crystallisation in Washing soda $Na_2CO_3 \cdot 10H_2O$.
[Na = 23, C = 12, O = 16, H = 1]

Sol: → Mol. mass of $Na_2CO_3 \cdot 10H_2O$ ⇒ 23 x 2 + 12 + 16 x 3 + 10(18)
= 286

% of H_2O in $Na_2CO_3 \cdot 10H_2O$ = $\frac{180}{286} \times 100 = 62.94\%$

X Chemistry. 27/4/2020.

* Cal. the number of moles of nitrogen in 7 gr of Nitrogen [N: 14]

Ans: To find mole. in g molecular mass of N.

∵ 1 mole = __ gmm at STP occupies 22.4 lit & have 6.023×10^{23} molecules

∵ To find mole.

∴ from the above expression.

N_2 = 1 mole of Nitrogen i.e. 14×2 = 28 gr.

So. 28 gr of N_2 = 1 mole

1 ---- $\frac{1}{28}$ mole

7 ---- $\frac{1}{28} \times 7 = 0.25$ mole

* Cal. the mass of 0.2 moles of water

Ans ∵ H_2O

So 1 mole of H_2O = 1×2 + 16×1 = 18 gr.

Now 18 gr of H_2O = 1 mole of H_2O

1 — — $\frac{1}{18}$

0.2 - - - $\frac{1}{18} \times 0.2 = 3.6$ gr.

Ex. CO_2 → 1 mole of CO_2 or, 44 gr of CO_2 means 1 mole

H_2O → 1 mole of H_2O 18 gr of H_2O means 1 mole

$5N_2$ → 5 mole of N_2 140 gr of N_2 = 5 mole of N_2

X Chemistry. 27/4/2020

Empirical & Molecular formula.

Compound	Molecular formula	Simplest ratio	Empirical formula
Glucose	$C_6H_{12}O_6$	1:2:1 [$C_6H_{12}O_6$]	CH_2O 1:2:1
Benzene	C_6H_6	1:1	CH

To find EMPIRICAL FORMULA: make a table as shown

Element	% Composition ①	At.Wt ②	Relative no. of atoms = ①/②	Simplest Ratio.

from the question Element, % & At wt will be given & for R.N of atom div %cmp/At.wt

Eg. Cal. Emperical formula of a compound of sodium, sulphur and oxygen having the percentage composition Na = 29·11%, S = 40·51%; O = 30·38%.
[Na = 23; S = 32, O = 16]

Sol.

Element	% Comp.	At Wt	R. No of atoms	Emp. Ratio
Na	29·11	23	$\frac{29.11}{23}$ = 1·26	$\frac{1.26}{1.26}$ = 1×2 = 2
S	40·51	32	$\frac{40.51}{32}$ = 1·26	$\frac{1.26}{1.26}$ = 1×2 = 2
O	30·38	13	$\frac{30.38}{16}$ = 1·80	$\frac{1.80}{1.26}$ = 1·5 = 3

∵ 1·26 is lowest among the three. So it has to be devide by all to get S. Ratio.

∴ E M. For = $Na_2S_2O_3$

Determination of molecular formula of a compound from its empirical formula

Example : To determine the molecular formula of a compound having the percentage composition C=26.59%, H=2.22%, O=71.19%. Vapour density of the compound = 45. [C=12, H=1, O=16]

The empirical formula of the compound is determined as explained already.

Step I : **Calculate the empirical formula weight from the empirical formula.**

Empirical formula of above compound was calculated to be CHO_2.

$\therefore$ empirical formula weight = 12 + 1 + 16 x 2 = 45
[C] [H] [2 (O)]

Step II : **Record the molecular weight [or calculate it from the V.D. of the compound]**

Molecular weight from vapour density.

V. D. is given = 45 $\therefore$ molecular weight = 2 x V. D. = 2 x 45 = 90

Step III : **Determine the value of n an integer** by applying the formula.

Molecular weight = n x Empirical formula weight

$$\text{or , } n = \frac{\text{Molecular weight}}{\text{Empirical formula weight}}$$

$$\therefore n = \frac{90}{45} = 2$$

Step IV : **Calculate the molecular formula** by applying the formula

Molecular formula = $[\text{Empirical formula}]_n$

ie. $[CHO_2]_2$

Hence molecular formula = $C_2H_2O_4$

PROBLEMS BASED ON EMPIRICAL & MOLECULAR FORMULA [Type 5]

1. A compound has the following percentage composition :
Carbon=26.6%, Hydrogen = 2.2%, Oxygen=71.2%. Calculate the empirical formula of the compound. If its molecular weight is 90, find its molecular formula. [C=12, H=1, O=16]

Solution :

Element	% Composition	At. Wt.	Relative No. of Atoms [At Ratio]	Simplest Ratio of whole numbers
Carbon	26.6%	12	$\frac{26.6}{12} = 2.21$	$\frac{2.21}{2.20} = 1$
Hydrogen	2.20%	1	$\frac{2.20}{1} = 2.20$	$\frac{2.20}{2.20} = 1$
Oxygen	71.2%	16	$\frac{71.2}{16} = 4.45$	$\frac{4.45}{2.20} = 2$

Empirical formula of the compound = CHO_2 – Ans.

∴ Empirical formula weight = 12 + 1 + [2 x 16] = 45

Molecular weight = 90 [given]

∴ $n = \frac{\text{Molecular Weight}}{\text{Empirical Formula Weight}} = \frac{90}{45} = 2$

> Molecular formula = Empirical formula x n [n is an integer]
>
> $n = \frac{\text{Molecular Weight [or 2 x V.D.]}}{\text{Empirical Formula Weight}}$

∴ Molecular formula = Empirical formula x n [n is an integer]

= $CHO_2 \times 2$

= $C_2H_2O_4$

∴ Molecular formula of the compound = $C_2H_2O_4$ – Ans.

2. A compounds of carbon, hydrogen and oxygen is found to contain 40% of carbon, 6.7% of hydrogen and 53.3% of oxygen. Calculate its empirical formula. If its vapours density is 30, calculate the molecular formula. [C=12, H=1, O=16]

Element	% Composition	At. Wt.	Relative No. of Atoms [At Ratio]	Simplest Ratio of whole numbers
Carbon	40%	12	$\frac{40}{12} = 3.33$	$\frac{3.33}{3.33} = 1$
Hydrogen	6.70%	1	$\frac{6.70}{1} = 6.70$	$\frac{6.70}{3.33} = 2$
Oxygen	53.3%	16	$\frac{53.3}{16} = 3.33$	$\frac{3.33}{3.33} = 1$

Problems based on a] Weight-Weight relationship, b] Weight-Volume relationship.

1. **Calculate the weight of potassium nitrite formed by thermal decomposition of 15.15 g of potassium nitrate. [K=39, N=14, O=16].**

Solution :

The chemical equation for the reaction is

$$2KNO_3 \xrightarrow{\Delta} 2KNO_2 + O_2\,(g)$$

$2[39 + 14 + 3 \times 16]$ $2[39 + 14 + 2 \times 16]$

2×101 $2[85]$

	$2KNO_3 \xrightarrow{\Delta}$	$2KNO_2 + O_2$
a]	$\frac{2 \times 101\ g.}{[mol.\ wt.]}$	$\frac{2 \times 85\ g.}{[mol.\ wt.]}$
b]	$\frac{15.15\ g.}{[wt.]}$	$\frac{?\ g.}{[wt.]}$

$\therefore$ 2×101 gms of KNO_3 yield 2×85 gms of KNO_2.

$\therefore$ 15.15 gms. of KNO_3 yields $\frac{15.15 \times 85 \times 2}{101 \times 2}$ = **12.75 g of KNO_2.**

$\therefore$ **Weight of potassium nitrite formed is 12.75 g. – Ans.**

2. **Copper on reacting with conc. H_2SO_4 produces copper sulphate. If 1.28 gm of copper is to be converted to copper sulphate. Find the weight of the copper sulphate formed and the weight of the acid required. [Cu=64, S=32, O=16].**

Solution :

The chemical equation for the reaction is

a] $Cu + 2H_2SO_4 \longrightarrow CuSO_4 + 2H_2O + SO_2$

64 g $[64 + 32 + 4 \times 16 = 160\ g]$

	Cu +	$2H_2SO_4 \longrightarrow$	$CuSO_4 + 2H_2O + SO_2$
a]	$\frac{64\ g.}{[wt.]}$	$\frac{2\,[98] = 196\ g.}{[mol.\ wt.]}$	$\frac{160\ g.}{[mol.\ wt.]}$
b]	$\frac{1.28\ g.}{[wt.]}$	$\frac{?\ g.}{[wt.]}$	$\frac{?\ g.}{[wt.]}$

64 g of Cu yields 160 g of $CuSO_4$

$\therefore$ 1.28 g of Cu will yield $\frac{160 \times 1.28}{64}$

Wt. of $CuSO_4$ formed = 3.2 g of $CuSO_4$ – Ans.

b] $Cu + 2H_2SO_4 \longrightarrow CuSO_4 + 2H_2O + SO_2$

64 g $2[2x1 + 1x32 + 4x16]$

$2[98] = 196$

$\therefore$ 196 g of H_2SO_4 are required to react with 64 g of Cu

Hence ? g of H_2SO_4 are required to react with 1.28 g of Cu

$\chi = \frac{1.28 \times 196}{64} = 3.92$ g

$\therefore$ **The weight of acid required = 3.92 g. of H_2SO_4 – Ans.**

(iv) 6.02×10^{23} atoms of carbon

$$=\frac{\text{Mass}}{12}\times 6.02\times 10^{23}$$

Mass of carbon = 12 g

So, weight of carbon is least. *[2]*

48. Calculate the mass of calcium that will contain the same number of atoms as present in 3.2 g of sulphur. (Atomic masses : S = 32, Ca = 40) *[2015]*

Sol. Number of atoms in 3.2 g of sulphur

$$N_A = \frac{3.2}{32}\times 6.02\times 10^{23} = 6.02\times 10^{22}$$

= Number of atoms in Ca

Molecular mass of Ca = 40

Let the mass of calcium = x

$$6.02\times 10^{22} = \frac{x}{40}\times 6.02\times 10^{23}$$

$$x = 4\text{ g}$$ *[2]*

49. O_2 is evolved by heating $KClO_3$ using MnO_2 as a catalyst

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$$

(i) Calculate the mass of $KClO_3$ required to produce 6.72 L of O_2 at STP. (Atomic masses of K = 39, Cl = 35.5, O = 16)

(ii) Calculate the number of moles of oxygen present in the above volume and also the number of molecules.

(iii) Calculate the volume occupied by 0.01 mole of CO_2 at STP. *[2013]*

Sol.
$$\underset{\substack{2\times(39+35.5+3\times 16)\\ 2\times 122.5=245.0}}{2KClO_3} \xrightarrow{MnO_2} \underset{\substack{2\times(39+35.5)\\ 2\times 74.5=149\text{ g}}}{2KCl} + \underset{\substack{3\times 22.4\\ =67.2}}{3O_2}$$

(i) 67.2 L of O_2 produced by $KClO_3$ = 245 g of $KClO_3$

$$1\text{ L of }O_2\text{ produced by }KClO_3 = \frac{245}{67.2}$$

$$6.72\text{ L of }O_2\text{ produced by }KClO_3 = \frac{245\times 6.72}{67.2}$$

$$= 24.5\text{ g}$$ *[1]*

(ii) 245 g of $KClO_3$ contain = 3 moles of oxygen

$$24.5\text{ of }KClO_3\text{ contain} = \frac{3\times 24.5}{245}$$

= 0.3 mol of oxygen

Since, 1 mole of oxygen contain = 6.022×10^{23} molecule

$\therefore$ 0.3 mole of oxygen contain = $6.022\times 10^{23}\times 0.3$

$= 1.8066\times 10^{23}$ molecules *[1]*

(iii) Since, 1 mole of CO_2 occupied = 22.4 L,

$\therefore$ 0.01 mole of CO_2 occupied = $22.4\times 0.01 = 0.224$ L. *[1]*

50. A gas cylinder contains 12×10^{24} molecules of oxygen gas. If Avogadro's number is 6×10^{23}. Calculate

(i) the mass of oxygen present in the cylinder.

(ii) the volume of oxygen at STP present in the cylinder. (O = 16) *[2016]*

Sol. Number of molecules of oxygen gas = 12×10^{24}

Avogadro's number = 6×10^{23}

(i) $$\frac{\text{Mass of oxygen present}}{(\text{Molecular mass of }O_2\text{ gas} = 32\text{ g})} = \frac{\text{Number of molecules of }O_2\text{ gas}}{\text{Avogadro's number}}$$

$$\text{Mass of oxygen} = \frac{12\times 10^{24}\times 32}{6\times 10^{23}} = 640\text{ g}$$ *[1]*

(ii) $$\text{Number of moles} = \frac{\text{Given weight}}{\text{Molecular weight}} = \frac{640}{32} = 20$$

Volume occupied by 1 mole = 22.4 L

Volume occupied by 20 moles = 448 L *[1]*

51. How many molecules are present in the following?

(i) 2.2 g of CO_2 (ii) 16 g of SO_2

(iii) 2 g of oxygen

Sol. (i) 44 g of CO_2 contains 6×10^{23} molecules at STP.

$$2.2\text{ g of }CO_2 = \frac{6\times 10^{23}}{44}\times 2.2$$

$= 3\times 10^{22}$ molecules. *[1]*

(ii) 64 g of SO_2 contains 6×10^{23} molecules at STP

$$16\text{ g of }SO_2 = \frac{6\times 10^{23}}{64}\times 16 = 1.5\times 10^{23}\text{ molecules.}$$ *[1]*

(iii) 32 g of O_2 contains 6×10^{23} molecules at STP.

$$2\text{ g of }O_2 = \frac{6\times 10^{23}}{32}\times 2 = 3.75\times 10^{22}\text{ molecules.}$$ *[1]*

52. A cylinder contains 68 g of ammonia gas at STP.

(i) What is the volume occupied by this gas?

(ii) How many moles of ammonia are present in the cylinder?

(iii) How many molecules of ammonia are present in the cylinder? (N-14, H-1) *[2014]*

Sol. (i) Molecular mass of NH_3 gas = 14 + 3 = 17

If 17 g of NH_3 contains 22.4 L at STP

Then, 68 g of NH_3 contains $= \frac{22.4}{17} \times 68 = 89.60$ L. *[1]*

(ii) Number of moles $= \frac{\text{Mass in gram}}{\text{Gram molecular mass}} = \frac{68}{17}$

= 4 mol *[1]*

(iii) Here, we apply the Avogadro's law,

One mole of NH_3 contains $= 6.022 \times 10^{23}$ molecules

$\therefore$ 4 moles of NH_3 contains $= 4 \times 6.022 \times 10^{23}$

$= 2.4088 \times 10^{24}$ molecules *[1]*

53. (a) The percentage composition of a gas is nitrogen – 82.35%, hydrogen – 17.64%. Find the empirical formula of the gas. [N = 14, H = 1] *[2]*

(b) Aluminum carbide reacts with water according to the following equation.

$Al_4C_3 + 12H_2O \longrightarrow 4Al(OH)_3 + 3CH_4$

(i) What mass of aluminum hydroxide is formed from 12 g of aluminum carbide?

(ii) What volume of methane at STP is obtained from 12 g of aluminum carbide? (Relative molecular weight of $Al_4C_3 = 144$, $Al(OH)_3 = 78$) *[4]*

(c) (i) If 150 cc of gas, *A* contains *X* molecules, how many molecules of gas *B* will be present in 75 cc of *B* ? The gases *A* and *B* are under the same temperature and pressure.

(ii) Name the law on which the above problem is based ? *[2]*

Sol. (a) Calculation of empirical formula

Element	% by mass	Atomic mass	No. of atoms	Simplest ratio
N	82.35	14	$\frac{82.35}{14} = 5.88$	$\frac{5.88}{5.88} = 1$
H	17.64	1	$\frac{17.64}{1} = 17.64$	$\frac{17.64}{5.88} = 3$

$\therefore$ Empirical formula of the gas $= NH_3$

(b) $\underset{\substack{1\text{ mol}\\144\text{ g}}}{Al_4C_3} + \underset{12\text{ mol}}{12H_2O} \longrightarrow \underset{\substack{4\text{ mol}\\4\times 78\text{ g}}}{4Al(OH)_3} + \underset{3\text{ mol}}{3CH_4}$

144 g of Al_4C_3 produced $= 4 \times 78$ g of $Al(OH)_3$

$\therefore$ 12 g of Al_4C_3 produced $= \frac{4 \times 78}{144} \times 12$ of $Al(OH)_3 = 26$ g of $Al(OH)_3$

(ii) $\underset{\substack{1\text{ mol}\\144\text{ g}}}{Al_4C_3} + \underset{12\text{ mol}}{12H_2O} \longrightarrow \underset{4\text{ mol}}{4Al(OH)_3} + \underset{\substack{3\text{ mol}\\3\times 22.4\text{ L at STP}}}{3CH_4}$

144 g of Al_4C_3 will produce $= 3 \times 22.4$L of CH_4

$\therefore$ 12 g of Al_4C_3 will produce $= \frac{22.4 \times 3 \times 12}{144} = 5.6$L

(c) (i) Given, 150 cm^3 of gas *A* contains *X* molecules.

Let 75 cm^3 of gas *B* contains *Y* molecules.

According to Avogadro's law,

$V \propto n$, (at constant T and p)

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

where, V_1 and V_2 are the volumes of gas *A* and *B* respectively and n_1 and n_2 are the number of moles of gas *A* and *B*, respectively.

$\because$ 1 mol $= 6.023 \times 10^{23}$ molecules

$= N_A$ molecules

$\therefore \quad \frac{150}{75} = \frac{N_A \times X}{N_A \times Y} \Rightarrow \quad Y = \frac{X}{2}$

Thus, number of molecules of *B* will be the half of the number of molecules of *A*.

(ii) The law on which the above problem is based known as Avogadro's law which states that "under the same conditions of temperature and pressure equal volumes of all gases contain equal number of molecules, irrespective of the nature of the gas".

54. Ethane burns in oxygen to form CO_2 and H_2O according to the equation,

$$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$$

If 1250 cc of oxygen is burnt with 300 cc of ethane.

Calculate

(i) the volume of CO_2 formed.

(ii) the volume of unused O_2.

Sol. $\underset{\substack{2\text{ mol}\\2\times 22400\\cm^3}}{2C_2H_6} + \underset{\substack{7\text{ mol}\\7\times 22400\\cm^3}}{7O_2} \longrightarrow \underset{\substack{4\text{ mol}\\4\times 22400\\cm^3}}{4CO_2} + 6H_2O$

2×22400 cm^3 of C_2H_6 reacts with 7×22400 cm^3 of O_2

$\therefore$ 1 cm^3 of C_2H_6 will reacts with $\frac{7 \times 22400}{2 \times 22400}$

$= 3.5$ cm^3 of O_2

$\therefore$ 300 cm^3 of C_2H_6 will rect with

$3.5 \times 300 = 1050$ cm^3 of O_2

Hence, C_2H_6 is the limiting reagent and O_2 is in excess.

(i) $2 \times 22400\,cm^3$ of C_2H_6 will produce $4 \times 22400\,cm^3$ of CO_2

Thus, $300\,cm^3$ of C_2H_6 will produce CO_2

$$= \frac{4 \times 22400}{2 \times 22400} \times 300 = 600\,cm^3$$

(ii) Volume of unused $O_2 = (1250 - 1050)\,cm^3$

$$= 200\,cm^3$$

55. The vapour density of a gas is 8. What would be the volume occupied by 24.0 g of the gas at STP?

Sol. Vapour density of gas = 8

Molecular weight of gas = 2 × vapour density (VD)

$$= 2 \times 8 = 16\,g$$

Volume of 16 g of gas = 22.4 L

Volume of 24 g of gas $= \frac{22.4}{16} \times 24 = 33.6\,L$ [2]

56. (i) Calculate the number of moles and the number of molecules present in 1.4 g of ethylene gas. What is the volume occupied by the same amount of ethylene?

(ii) What is the vapour density of ethylene? (Avogadro's number $= 6 \times 10^{23}$; atomic weight of C = 12, H = 1; molar volume = 22.4 L at STP).

Sol. (i) Molecular weight of ethylene ($CH_2 = CH_2$)

$$= 12 + 2 + 12 + 2 = 28\,g$$

$$\text{Number of moles} = \frac{\text{Given weight}}{\text{Molecular weight}}$$

$$= \frac{1.4}{28} = 0.05 \text{ mol}$$

Number of molecules in 1 mole $= 6 \times 10^{23}$

∴ Number of molecules in 0.05 mole

$$= 6 \times 10^{23} \times 0.05 = 0.3 \times 10^{23}$$

$$= 3 \times 10^{22} \text{ molecules}$$

Volume occupied by 1 mole = 22.4 L

∴ Volume occupied by 0.05 mole $= 22.4 \times 0.05$

$$= 1.12\,L$$ [1/2]

(ii) Vapour density can be calculated using the following formula,

$$\text{Vapour density (VD)} = \frac{\text{Molecular weight}}{2} = \frac{28}{2} = 14$$ [1/2]

57. Find the total percentage of magnesium in magnesium nitrate crystals, $Mg(NO_3)_2 \cdot 6H_2O$. (Mg = 24, N = 14, O = 16 and H = 1)

Sol. Molecular mass of $Mg(NO_3)_2 \cdot 6H_2O$

$$= 24 + 2(14 + 48) + 6 \times 18 = 256\,g$$

Percentage of Mg $= \frac{24}{256} \times 100 = 9.375\%$ [1]

58. If the empirical formula of a compound is CH and it has a vapour density of 13, find the molecular formula of the compound. [2015]

Sol. Empirical formula of a compound = CH

Empirical formula mass = 12 + 1 = 13 g

Molecular formula mass = 2 × Vapour density

$$= 2 \times 13 = 26\,g$$

$$n = \frac{26}{13} = 2$$

Molecular formula = $(\text{Empirical formula})_n$

∴ Molecular formula $= (CH)_2 = C_2H_2$ [2]

59. A gaseous hydrocarbon contain 82.76% of carbon. Given that its vapour density is 29, find its molecular formula. (C = 12, H = 1)

Sol.

Element	% Composition	Atomic Mass	No. of Atoms	Simplest Ratio
C	82.76	12	$\frac{82.76}{12} = 6.89$	$\frac{6.89}{6.89} = 1$
H	100 − 82.76 = 17.24	1	$\frac{17.24}{1} = 17.24$	$\frac{17.24}{6.89} = 2$

Empirical formula of the compound = CH_2

Empirical formula weight = 12 + 2 × 1 = 14

Vapour density = 29 (given)

Molecular weight = 2 × vapour density

$$= 2 \times 29 = 58$$

$$n = \frac{\text{Molecular weight}}{\text{Empirical formula weight}}$$

$$= \frac{58}{14} = 4$$

Molecular formula $= (CH_2)_4 = C_4H_8$ [3]

60. An organic compound with vapour density 94 contains C = 12.67%, H = 2.13 %, and Br = 85.11%. Find the molecular formula. (Atomic mass of C = 12, H = 1 and Br = 80)

Sol. Calculation of empirical formula

Element	% Composition	Atomic mass	Simplest ratio
C	12.67	12	$\frac{12.67}{12}=1$
H	2.13	1	$\frac{2.13}{1}=2$
Br	85.11	80	$\frac{85.11}{80}=1$

Empirical formula of compound $= CH_2Br$

Empirical formula weight $=12+2\times1+80=94$

Vapour density $=94$ (given)

Molecular mass $=2\times$ Vapour density $=2\times94=188$

$$n=\frac{\text{Molecular weight}}{\text{Empirical formula weight}}=\frac{188}{94}=2$$

Molecular formula $=(CH_2Br)_2=C_2H_4Br_2$ *[3]*

61. (i) A compound has the following percentage composition by mass, carbon 14.4%, hydrogen 1.2% and chlorine 84.5%. Determine the empirical formula of this compound. ($H=1$, $C=12$ and $Cl=35.5$)

(ii) The relative molecular mass of this compound is 168, so, what is its relative molecular formula?

Sol. (i) It can be solved using the same concept as discussed in the previous problem.

Element	% by mass	Atomic mass	Number of atoms	Simplest ratio
H	1.2	1 g	1.2	$\frac{1.2}{1.2}=1$
C	14.4	12 g	1.2	$\frac{1.2}{1.2}=1$
Cl	84.5	35.5 g	2.38	$\frac{2.38}{1.2}=1.98\simeq2$

$\therefore$ Empirical formula of compound $= CHCl_2$

Empirical formula weight $=12+1+2(35.5)=84.0$

Molecular weight $=168$

$$n=\frac{\text{Molecular weight}}{\text{Empirical formula weight}}$$

$$=\frac{168}{84}=2$$

Molecular formula = (Empirical formula)$_n$

$=(CHCl_2)_2$

$=C_2H_2Cl_4$ *[2]*

(ii) Formula mass of both molecular formula and relative molecular formula is same hence both will be similar *i.e.,* $C_2H_2Cl_4$. *[1]*

62. (i) Calculate the number of gram atom in 4.6g of sodium ($Na=23$).

(ii) Calculate the percentage of water of crystallisation in $CuSO_4\cdot5H_2O$ ($H=1, O=16, S=32, Cu=64$).

(iii) A compound of X and Y has the empirical formula XY_2. Its vapour density is equal to its empirical formula weight. Determine its molecular formula. *[2017]*

Sol. (i) 1 g atom of sodium $=23$g of sodium *[1]*

$\therefore$ 4.6g atom of sodium $=23\times4.6\text{g}=105.8$ g of Na.

(ii) Percentage of an element in a compound

$$=\frac{\text{Total weight of the element in one molecule}}{\text{Gram molecular weight of the compound}}\times100$$

Molecular mass of $CuSO_4\cdot5H_2O$

$=64+32+(4\times16)+5(2\times1+16)$

$=64+32+64+90+=250$

$\therefore$ Percent of water of crystallisation

$$=\frac{5\times18}{250}\times100=0.3\%\text{ of }H_2O$$ *[1]*

(iii) $$n=\frac{2\times\text{Vapour density (VD)}}{\text{Empirical formula weight}}$$

$n=2$ ($\because$ vapour density = empirical formula weight)

Empirical formula $=XY_2$

Molecular formula $=n\times$ Empirical formula

$\therefore$ Molecular formula $=2\times$ Empirical formula

$=2\times XY_2=X_2Y_4$ *[1]*

63. The equation,

$$4NH_3+5O_2\longrightarrow4NO+6H_2O$$

represents the catalytic oxidation of ammonia. If 100 cm^3 of ammonia is used, calculate the volume of oxygen required to oxidise the ammonia completely.

Sol. (c) The given equation is

$$\underset{\text{4 volume}}{4NH_3}+\underset{\text{5 volume}}{5O_2}\longrightarrow4NO+6H_2O$$

4 volumes of NH_3 is completely oxidised by 5 volumes of O_2, 1 volume of NH_3 is completely oxidised by 5/4 volumes of O_2.

$\therefore$ 100 cm^3 volume of NH_3 is completely oxidised by $\frac{5}{4}\times100cm^3$ of $O_2=125\ cm^3$. *[2]*

QUESTIONS FROM TEXT BOOK

Solution 1.

(a) Gay-Lussac's law states that when gases react, they do so in volumes which bear a simple ratio to one another, and to the volume of the gaseous product, provided that all the volumes are measured at the same temperature and pressure.

(b) Avogadro's law states that equal volumes of all gases under similar conditions of temperature and pressure contain the same number of molecules.

Solution 2.

a) The number of atoms in a molecule of an element is called its atomicity. Atomicity of Hydrogen is 2, phosphorus is 4 and sulphur is

. of hydrogen has 2 atoms of hydrogen and I molecule of helium has 1 atom of helium

Therefore 2H=He

Therefore atoms in hydrogen is double the atoms of helium.

(b) For a given volume of gas under given temperature and pressure, a change in any one of the variable i.e., pressure or temperature changes the volume.

(c) Inflating a balloon seems violating Boyles law as volume is increasing with increase in pressure. Since the mass of gas is also increasing.

Solution 4.

$2H_2 + O_2 \rightarrow 2H_2O$

$2H_2 + O_2 \rightarrow 2H_2O$

2 V 1V 2V

From the equation, 2V of hydrogen reacts with 1V of oxygen

so $200cm^3$ of Hydrogen reacts with = 200/2= 100 cm^3

Hence, the unreacted oxygen is 150 − 100 = $50cm^3$ of oxygen.

Solution 5.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

1V 2V 1V

From equation,1V of CH_4 reacts with = 2 V of O_2

so, 80 cm^3 CH_4 reacts with = 80 × 2 = $160cm^3$ O_2

Remaining O_2 is 200-160 = $40cm^3$

From equation, 1V of methane gives 1 V of CO_2

So, 80 cm^3 gives $80cm^3$ CO_2 and H_2O is negligible.

ion 6.

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O\ (l)$

2 V 5 V 4 V

From equation, 2 V of C_2H_2 requires = 5 V of O_2

So, for 400ml C_2H_2, O_2 required = 400 × 5/2 = 1000 ml

Similarly, 2 V of C_2H_2 gives = 4 V of CO_2

So, 400ml of C_2H_2 gives CO_2 = 400 × 4/2 = 800ml

Solution 7.

Balanced chemical equation:

$H_2S_{(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)} + S_{(s)}$

1mole 1mole 2moles 1mol

112cm^3 120cm^3

(i)At STP, 1 mole gas occupies 22.4 L.

As 1 mole H_2S gas produces 2 moles HCl gas,

22.4 L H_2S gas produces 22.4 × 2 = 44.8 L HCl gas.

Hence, 112 cm^3 H_2S gas will produce 112 × 2 = 224 cm^3 HCl gas.

(ii) 1 mole H_2S gas consumes 1 mole Cl_2 gas.

This means 22.4 L H_2S gas consumes 22.4 L Cl_2 gas at STP.

Hence, 112 cm^3 H_2S gas consumes 112 cm^3 Cl_2 gas.

120 cm^3 - 112 cm^3 = 8 cm^3 Cl_2 gas remains unreacted.

Thus, the composition of the resulting mixture is 224 cm^3 HCl gas + 8 cm^3 Cl_2 gas.

Solution 8.

$+7O_2 \rightarrow 4CO_2 + 6H_2O$

2V 7V 4V

Now from equation, 2V of ethane reacts with = 7 V of oxygen

So, 600cc of ethane reacts with= 600 $\times$ 7/2 = 2100cc

Hence, unused O_2 is = 2500 - 2100 = 400 cc

From 2V of ethane = 4 V of CO_2 is produced

So, 600cc of ethane will produce = 4 $\times$ 600/2 =1200cc CO_2

Solution 9.

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

1V 3V

11litre 33 litre

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{380 \times 33 \times 273}{549 \times 760} = 8.25 \text{ litres}$$

Solution 10.

$CH_4 + 2Cl_2 \rightarrow CH_2Cl_2 + 2HCl$

1 V 2 V 1 V 2 V

From equation, 1V of CH_4 gives = 2 V HCl

so, 40 ml of methane gives = 80 ml HCl

For 1V of methane = 2V of Cl_2 required