EUDIOMETRY OR GAS ANALYSIS

Gaseous reactions are carried out in a special type of tube known as eudiometer tube. The tube is graduated in millimeter for volume measurement. The reacting gases taken in eudiometer tube are exploded by sparks, produced by passing electricity through the platinum terminal provided in the tube. The volumes of the products of a gaseous explosion are determined by absorbing them in suitable reagents. e.g SO_2, & CO_2 absorbed in KOH solution, O_2 is absorbed in a solution of alkaline pyrogallol, & CO is absorbed in a solution of ammonical cupurous chloride. Since H_2O vapour produced during the reaction changes to liquid on cooling, the volume of water is neglected, but while applying POAC, moles of H_2O produced cannot be neglected.

Eudiometery is mainly based on Avogadro's Law, which states that equal volumes of all gases under similar condition of temperature & pressure contain equal number of molecules also have equal number of moles. The mole concept may be applied in solving the problem.

$$A(g) + B(g) \longrightarrow C(g) + D(g)$$

a volumes b volumes c volumes d volumes

a moles b moles c moles d moles

Example: What volume of oxygen will be required for the complete combustion of 18.2 litre of propane at NTP?

Solution: $C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$.

Applying POAC for Carbon Atom, We have;

Mole of C in C_3H_8 = Moles of C in CO_2.

$3 \times$ moles of C_3H_8 = $1 \times$ moles of CO_2. —(1)

Applying POAC for H & O atoms,

$8 \times$ moles of C_3H_8 = $2 \times$ moles of H_2O —(2)

$2 \times$ moles of O_2 = $2 \times$ moles of CO_2 + $1 \times$ moles of H_2O —(3)

From eq (1) & (2) & (3)

$2 \times$ moles of O_2 = $2 \times 3 \times$ moles of C_3H_8 + $1 \times 4 \times$ moles of C_3H_8

Moles of O_2 = $5 \times$ moles of C_3H_8.

$$\frac{\text{Vol. of } O_2 \text{ at NTP}}{22.4} = 5 \times \frac{\text{Volume of } C_3H_8 \text{ NTP}}{22.4}$$

Vol. of O_2 at NTP = 5×18.2 = 91 litres.

Example: 10 mL of a gaseous hydrocarbon was burnt completely in 80 mL of O_2 at NTP. The remaining gas occupied 70 mL at NTP. The volume became 50 mL on treatment with KOH solution. What is the formula of the hydrocarbon?

Solution: Let the hydrocarbon be C_xH_y.

$C_xH_y + O_2 \longrightarrow CO_2 + H_2O$. Let the volume occupied by water is neglected.

Volume of CO_2 produced + unreacted O_2 = 70 mL

Volume of unreacted O_2 (CO_2 absorbed by KOH) = 50 mL

Volume of O_2 needed with 10 mL of Hydrocarbon

= (80 − 50) mL = 30 mL

and, Volume of CO_2 produced by 10mL of hydrocarbon & 30mL of O_2 = (70 − 50) mL = 20mL.

Applying POAC for Oxygen atoms,

2 × moles of O_2 = 2 × moles of CO_2 + 1 × moles of H_2O

2 × 30 = 2 × 20 + moles of H_2O.

moles of H_2O = 20.

Applying POAC for C atoms,

x × moles of C_xH_y = 1 × moles of CO_2.

x × 10 = 1 × 20 ∴ x = 2.

Applying POAC for H atoms,

y × moles of C_xH_y = 2 × moles of H_2O.

y × 10 = 2 × 20 ∴ y = 4.

The formula of hydrocarbon is C_2H_4.

Example: 10mL of a gaseous organic compound containing C, H and O only was mixed with 100 mL of oxygen and exploded under conditions which allow the water formed to condense. The volume of the gas after explosion was 90 mL. On treatment with potash solution, a further contraction of 20 mL in volume was observed. Given that the vapour density of the compound is 23, deduce the molecular formula.

Solution: Volume of unreacted O_2 + Vol. of CO_2 = 90mL.

Volume of CO_2 (absorbed by KOH) = 20mL.

Volume of unreacted O_2 = (90 − 20) = 70mL.

Volume of O_2 reacted with 10mL of compound = (100 − 70) mL = 30mL.

Thus, $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$.

10mL 30mL 20mL

Applying POAC for C atom,

$x \times$ moles of $C_xH_yO_z$ = $1 \times$ moles of CO_2.

$x \times 10 = 1 \times 20$; $x = 2$.

Applying POAC for H & O atoms, we get respectively;

$y \times$ moles of $C_xH_yO_z$ = $2 \times$ moles of H_2O.

$10y = 2 \times$ moles of H_2O —— (1.)

$z \times$ moles of $C_xH_yO_z$ + $2 \times$ moles of O_2 = $2 \times$ moles of CO_2 + $1 \times$ moles of H_2O.

$10z + 2 \times 30 = 2 \times 20 +$ moles of H_2O —— (2.)

From eq (1) & (2.)

$y - 2z = 4$ —— (3.)

Molecular wt. of the compound $= 2 \times 23 = 46$.

For the compound, $C_xH_yO_z$

$2 \times 12 + y \times 1 + z \times 16 = 46$

$y + 16z = 22$ —— (4)

From eq (3) & (4), we get; $y = 6$ & $z = 1$.

Formula of the compound is C_2H_6O.

<u>Example:</u> 9 volumes of gaseous mixture consisting of a gaseous organic compound A and just sufficient amount of oxygen required for complete combustion, yielded on burning, 4 volume of CO_2, 6 volume of water vapour & 2 volume of N_2, all volume measured at the same temperature & pressure. If the compound A contained only C, H and N (i) How many volumes of oxygen are required for complete combustion (ii) What is the molecular formula of the compound A)

<u>Solution;</u> The compound A is $C_xH_yN_z$.

(i) $C_xH_yN_z + O_2 \longrightarrow CO_2 + H_2O + N_2$.

(9−v) vol. v vol. 4 vol. 6 vol. 2 vol.

Applying POAC for Oxygen Atoms,

2 × moles of O_2 = 2 × moles of CO_2 + 1 × moles of H_2O

$2v = 2 \times 4 + 1 \times 6 = 14$; v = 7 volumes.

(ii) $C_xH_yN_z + O_2 \longrightarrow CO_2 + H_2O$ (vapour) $+ N_2$.

2 vol. 7 vol. 4 vol. 6 vol. 2 vol.

or 2 moles 7 moles 4 moles 6 moles 2 moles.

Applying POAC for C, H & N, we get respectively.

x × moles of $C_xH_yN_z$ = 1 × moles of CO_2.

$x \times 2 = 1 \times 4$; $x = 2$.

y × moles of $C_xH_yN_z$ = 2 × moles of H_2O (vapour)

$y \times 2 = 2 \times 6$; $y = 6$.

z × moles of $C_xH_yN_z$ = 2 × moles of N_2.

$z \times 2 = 2 \times 2$; $z = 2$.

Hence, the compound is $C_2H_6N_2$.

Example: 50 mL of mixture of CO & CH_4 was exploded with 85 mL of O_2. The volume of CO_2 produced was 50 mL. calculate the percentage composition of the gaseous mixture if all volumes are measured under the same conditions, and the given vol. of O_2 is just sufficient for the combustion of 50 mL of the mixture CO & CH_4.

Solution: $CO + CH_4 + O_2 \longrightarrow CO_2 + H_2O$.

(50−x) mL x mL 85 mL 50 mL.

(50−x) mole x mole 85 mole 50 moles.

Applying POAC for H and O atoms,

4 × moles of CH_4 = 2 × moles of H_2O. —— (1)

and 1 moles of CO + 2x moles of O_2 = 2x moles of CO_2 + 1x moles of H_2O. —(2.)

From eq (1) & (2.)

moles of CO + 2x moles of O_2 = 2x moles of CO_2 + 2x moles of CH_4.

$(50-x) + 2\times 85 = 2\times 50 + 2\times x$

$x = 40.$

Hence, volume of CH_4 = 40 mL.

volume of CO = (50−40) = 10 mL.

% of CH_4 in the mixture $= \frac{40}{50}\times 100 = 80\%$.

Percentage of CO = 20%.

Example: A sample of coal gas contained H_2, CH_4 & CO. 20 mL of this mixture was exploded with 80 mL of oxygen. On cooling, the volume of gases was 68 mL. There was contraction of 10 mL when treated with KOH. Find the composition of the original mixture.

Solution: Volume of total O_2 = 80 mL.

Volume of CO_2 + unreacted O_2 = 68 mL.

Volume of CO_2 = 10 mL (absorbed in KOH)

∴ Volume of unreacted O_2 = (68−10) mL = 58 mL.

Volume of O_2 used in explosion = (80−58) = 22 mL.

Let the volume of H_2 & CO in the mixture be x mL and y mL respectively.

H_2	+ CO	+ CH_4	+ O_2	⟶	CO_2	+ H_2O
x mL	y mL	(20−x−y) mL	22 mL		10 mL.	
x mole	y mole	(20−x−y) mole	22 mole		10 moles	

Applying POAC for H, O & C atoms,

2 × moles of H_2 + 4 × moles of CH_4 = 2 × moles of H_2O.

$$2x + 4(20-x-y) = 2 \times \text{moles of } H_2O \quad \text{——— (1)}$$

1 × moles of CO + 1 × moles of CH_4 = 1 × moles of CO_2.

$$y + (20-x-y) = 10 \quad \text{——— (2)}$$

1 × moles of CO + 2 × moles of O_2 = 2 × moles of CO_2 + 1 × moles of H_2O.

$$y + 2 \times 22 = 2 \times 10 + \text{moles of } H_2O \quad \text{——— (3)}$$

From eq (1) & (3): $x = 10\,mL$.

Eliminating moles of H_2O, we get:

$$y + 44 = 20 + x + 2(20-x-y)$$

$$3y = 6.$$

$$y = 2\,mL.$$

Volume of CH_4 = 20 − (10 + 2) = 8 mL.

% of H_2 in the mixture = $\frac{10}{20} \times 100 = 50\%$.

% volume of CO in the mixture = $\frac{2}{20} \times 100 = 10\%$

% volume of CH_4 in the mixture = $\frac{8}{20} \times 100 = 40\%$.

Example: 10 mL of mixture of CO, CH_4 & N_2, exploded with excess of oxygen gave a contraction of 6.5 mL. There was a further contraction of 7 mL when the residual gas was treated with KOH. What is the composition of the mixture?

Solution: In the explosion, N_2 does not take part in the reaction, while CO & CH_4 changes to CO_2 & H_2O, volume of H_2O (water) being zero.

Let the Volume of CO = x mL, CH_4 = y mL, N_2 = (10−x−y) mL.

The reaction is

$$CO + CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

x mL y mL 7 mL

or x moles y moles 7 moles.

Applying POAC for C, O, & H atoms, we get respectively:

moles of CO + moles of CH_4 = moles of CO_2.

$$x + y = 7 \quad \text{——— (1)}$$

moles of CO + 2 × moles of O_2 = 2 × moles of CO_2 + moles of H_2O

$$x + 2 \times \text{moles of } O_2 = 14 + \text{moles of } H_2O \quad \text{——— (2)}$$

$$4 \times \text{moles of } CH_4 = 2 \times \text{moles of } H_2O \quad \text{——— (3)}$$

$$4y = 2 \times \text{moles of } H_2O$$

From eq (2) & (3),

$$\text{moles of } O_2 = \left(7 + y - \frac{x}{2}\right)$$

$$CO + CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

x mole y mole $\left(7 + y - \frac{x}{2}\right)$ mole 7 moles

x mL y mL $\left(7 + y - \frac{x}{2}\right)$ mL 7 mL

Volume of reactants − volume of products = 6.5 mL.

Volume of $(CO + CH_4 + O_2)$ − Vol. of CO_2 = 6.5 mL.

$$x + y + \left(7 + y - \frac{x}{2}\right) - 7 = 6.5$$

$$x + 4y = 13 \quad \text{——— (4)}$$

From eq (1) & (4), x = 5, y = 2.

Vol. of CO = 5 mL

Vol. of CH_4 = 2 mL

Vol. of N_2 = (10 − 5 − 2) = 3 mL.

: Exercise :

1.) 10mL of a mixture of CH_4, C_2H_4 and CO_2 was exploded with excess of air. After explosion there was contraction of 17mL and after treatment with KOH, there was a further reduction of 14mL. What was composition of the mixture? [Ans: vol. of NO = 44mL; vol. of N_2O = 16mL]

(2.) A mixture of formic acid and oxalic acid is heated
with concentrated H_2SO_4. The gas is produced is colle-
with concentrated H_2SO_4. The gas is produced is colle-
-cted and on its treatment with KOH solution the
volume of the gas decreased by $1/6^{th}$. Calculate
the molar ratio of the two acids in the original
mixture?

Ans: [4:1]

(3) 40mL of a mixture of H_2, CH_4 and N_2 was exploded
with 10mL of oxygen. On cooling, the gases occupied
36.5mL. After treatment with KOH, the volume reduced
by 3mL and again on treatment with alkaline pyrog-
-allol, the volume further decreased by 1.5mL. Dete-
-ermine the composition of the mixture?

Ans: [H_2 = 12.5%, CH_4; 7.5% N_2 = 80%]

(4) 20mL of a mixture of C_2H_2 and CO was exploded with 30mL of oxygen. The gases after the reaction had a volume of 34mL. On treatment with KOH, 8mL of oxygen remained. Calculate the composition of the mixture?

[Ans: C_2H_2 : 6mL, CO : 14mL]

(5) One volume of a compound of carbon, Hydrogen and oxygen was exploded with 2.5 volume of oxygen. The resultant mixture contained 2 volumes of water vapour & 1 volumes of CO_2. Determine the formula of compound.

Ans: [C_2H_4O].