The Mole in Unit 1

One mole (6.023×10^{23}) is the number of atomic mass units in one gram, also known as the Avogadro constant.

e.g. The mass of a CO_2 molecule is 44 amu ; the mass of 1 mole of CO_2 is therefore 44g. 1 mole of CO_2 contains 6.023×10^{23} CO_2 molecules.

Example

(a) Calculate the mass of CO_2 obtained by reaction of 2.12g of Sodium carbonate with excess Hydrochloric acid given the equation.

Answer :

Na_2CO_3 + 2 HCl -> 2 NaCl + H_2O + CO_2

1 mole	1 mole
106g	44g
2.12g	$\frac{44 \times 2.12}{106}$
	= <u>0.88g</u>

(b) Calculate the mass of CO_2 obtained by reaction of 2.12g of Sodium carbonate with 10 cm^3 2M Hydrochloric acid.

Answer :

No. of moles of Na_2CO_3 = $\frac{2.12}{106}$ = 0.02 moles

No. of moles of HCl = $\frac{MV}{1000}$ = $\frac{2 \times 10}{1000}$ = 0.02 moles

0.02 moles of HCl will react with only 0.01 moles of Na_2CO_3 !

The Na_2CO_3 is in excess ; only 0.01 moles of Na_2CO_3 actually react i.e.

Na_2CO_3 + 2 HCl -> 2 NaCl + H_2O + CO_2

0.01 moles	0.02 moles	0.01 moles

Wt. of CO_2 = 0.01 x 44 = <u>0.44g</u>

Avogadro's Law

Equal volumes of all gases, at the same temperature and pressure, contain the same number of molecules.

It therefore follows that a given number of molecules of any gas, at a given temperature and pressure, will always occupy the same volume no matter what the gas is.

Example

Calculate the volume of Oxygen required to burn 100 cm^3 Carbon monoxide and the volume of Carbon dioxide formed, given the equation.

Answer

$2\,CO \quad + \quad O_2 \quad -> \quad 2CO_2$

From the above equation, the number of CO_2 molecules is the same as the number of CO molecules ; the CO_2 will therefore occupy the same volume as the CO (100 cm^3).

The number of O_2 molecules is half the number of CO molecules ; the O_2 will therefore occupy half the volume of the CO (50 cm^3).

In your answer you need only write the following :

2 CO	+	O_2	->	$2CO_2$
100 cm^3		<u>50 cm^3</u>		<u>100 cm^3</u>

Example

50 cm^3 Ammonia is decomposed, by sparking, into Nitrogen and Hydrogen :

$NH_3 \quad -> \quad N_2 \quad + \quad H_2$

Calculate the total volume and composition of the gas formed.

Answer

First balance the equation :

$2\,NH_3 \quad -> \quad N_2 \quad + \quad 3\,H_2$

By Avogadro's Law, the volume of N_2 is half the volume of Ammonia ; the volume of H_2 is 1.5 times the volume of Ammonia.

Volume of Nitrogen formed = 25 cm^3
Volume of Hydrogen formed = 75 cm^3
Total volume of gas = 100 cm^3

Example

100 cm^3 hydrocarbon gas were mixed with 350 cm^3 Oxygen and the mixture ignited. The volume of gas after the reaction was 250 cm^3. After removing the Carbon dioxide, 50 cm^3 Oxygen remained. Calculate the formula of the hydrocarbon gas.

Answer

Let the formula of the hydrocarbon be C_xH_y. The reaction is, therefore,

$$C_xH_y \quad + \quad O_2 \quad -> \quad CO_2 \quad + \quad H_2O$$

Of the 250 cm^3 gas present after reaction, 50 cm^3 is unused Oxygen so the actual volume of Oxygen used was only 300 cm^3. The rest of the 250 cm^3 must be 200 cm^3 Carbon dioxide (Water would condense to a negligible volume of liquid). Hence the actual volumes of gases involved in this reaction are :

C_xH_y	+	O_2	->	CO_2	+	H_2O
100 cm^3		300 cm^3		200 cm^3		

By Avogadro's Law, 200 cm^3 CO_2 will contain twice as many molecules as 100 cm^3 C_xH_y and 300 cm^3 O_2 will contain three times as many molecules as 100 cm^3 C_xH_y. We can therefore partially balance the equation (since we do not know the volume of Water vapour we let the number of H_2O molecules be z) :

$$C_xH_y \quad + \quad 3O_2 \quad -> \quad 2CO_2 \quad + \quad zH_2O$$

Now equate the atoms on both sides of the equation :

Carbon $x = 2$

Hydrogen $y = 2z$

Oxygen $6 = 4 + z$ => $z = 2$
=> $y = 4$
=> Formula is C_2H_4

Molar Volume

The number of molecules in a mole of any gas is always 6.023×10^{23} - the Avogadro constant (N). It therefore follows that 1 mole of any gas at the same temperature and pressure will occupy the same volume. At 273K and 1 Atm. pressure (Standard Temperature and Pressure) this volume is **22.4 litres mol^{-1}**.

Example

2.03g of Krypton gas occupies 541.4 cm^3 at standard temperature and pressure. Calculate the volume occupied by 1 mole of Krypton gas.

Answer

2.03g Kr occupies 541.4 cm^3

=>84g Kr occupies $\frac{541.4 \times 84}{2.03}$ = 22402.8 cm^3

Example

Calculate the volume of Hydrogen given off when 7.2g Magnesium is added to excess Hydrochloric acid given the equation.

Answer

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

7.2g ? vol

No.of moles of Mg = $\frac{7.2}{24}$ = 0.3 mol

=>No.of moles of H_2 = 0.3 mol

=>Volume of H_2 = 22400 x 0.3

= 6720 cm^3

Example

Calculate the weight of Methanol produced, and the volume of Hydrogen required, when 2240 cm^3 Carbon monoxide reacts as follows :

$CO + 2H_2 \rightarrow CH_3OH$

Answer

$CO + 2H_2 \rightarrow CH_3OH$

2240 cm^3 ? vol ? wt

No.of moles CO = $\frac{2240}{22400}$ = 0.1 mol

=>No.of moles CH_3OH = 0.1 mol

=>Wt.of CH_3OH = 0.1 x 32 = 3.2g

Since the no.of molecules of H_2 is twice the number of molecules of CO the H_2 will occupy twice the volume of the CO i.e. 4480 cm^3