

## The Mole in Unit 1

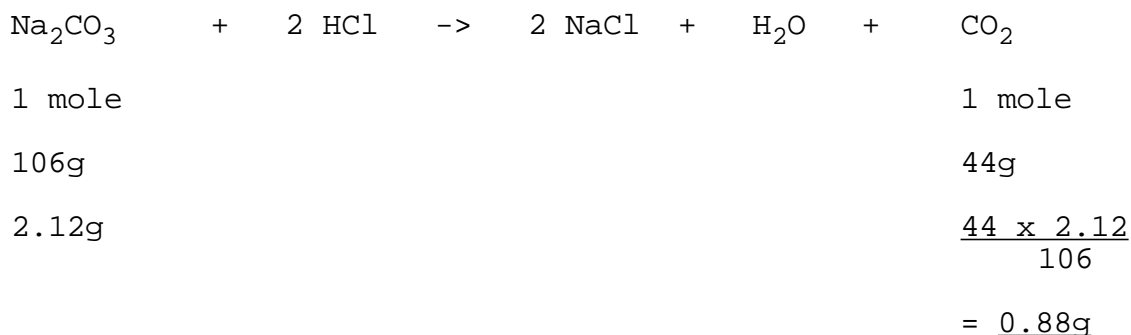
One mole ( $6.023 \times 10^{23}$ ) is the number of atomic mass units in one gram, also known as the Avogadro constant.

e.g. The mass of a  $\text{CO}_2$  molecule is 44 amu ; the mass of 1 mole of  $\text{CO}_2$  is therefore 44g. 1 mole of  $\text{CO}_2$  contains  $6.023 \times 10^{23}$   $\text{CO}_2$  molecules.

### Example

- (a) Calculate the mass of  $\text{CO}_2$  obtained by reaction of 2.12g of Sodium carbonate with excess Hydrochloric acid given the equation.

**Answer :**



- (b) Calculate the mass of  $\text{CO}_2$  obtained by reaction of 2.12g of Sodium carbonate with 10 cm<sup>3</sup> 2M Hydrochloric acid.

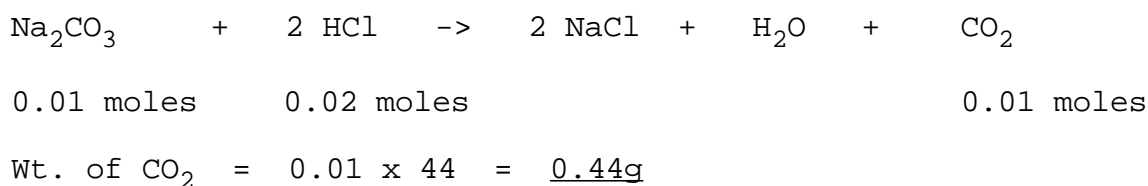
**Answer :**

$$\text{No. of moles of Na}_2\text{CO}_3 = \frac{2.12}{106} = 0.02 \text{ moles}$$

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

0.02 moles of HCl will react with only 0.01 moles of  $\text{Na}_2\text{CO}_3$  !

The  $\text{Na}_2\text{CO}_3$  is in excess ; only 0.01 moles of  $\text{Na}_2\text{CO}_3$  actually react i.e.



**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**

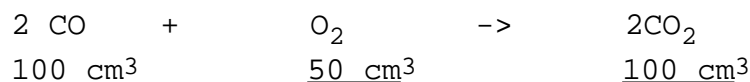
Calculate the volume of Oxygen required to burn 100 cm<sup>3</sup> Carbon monoxide and the volume of Carbon dioxide formed, given the equation.

**Answer**

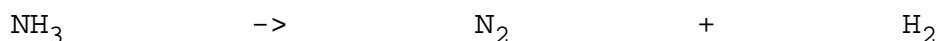
From the above equation, the number of CO<sub>2</sub> molecules is the same as the number of CO molecules ; the CO<sub>2</sub> will therefore occupy the same volume as the CO (100 cm<sup>3</sup>).

The number of O<sub>2</sub> molecules is half the number of CO molecules ; the O<sub>2</sub> will therefore occupy half the volume of the CO (50 cm<sup>3</sup>).

In your answer you need only write the following :

**Example**

50 cm<sup>3</sup> Ammonia is decomposed, by sparking, into Nitrogen and Hydrogen :



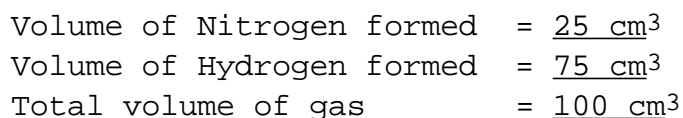
Calculate the total volume and composition of the gas formed.

**Answer**

First balance the equation :



By Avogadro's Law, the volume of N<sub>2</sub> is half the volume of Ammonia ; the volume of H<sub>2</sub> is 1.5 times the volume of Ammonia.

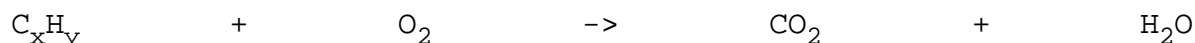


**Example**

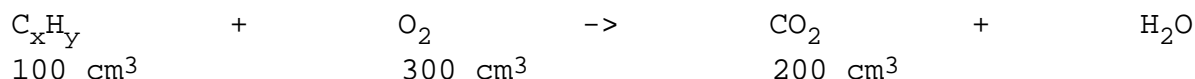
100 cm<sup>3</sup> hydrocarbon gas were mixed with 350 cm<sup>3</sup> Oxygen and the mixture ignited. The volume of gas after the reaction was 250 cm<sup>3</sup>. After removing the Carbon dioxide, 50 cm<sup>3</sup> Oxygen remained. Calculate the formula of the hydrocarbon gas.

**Answer**

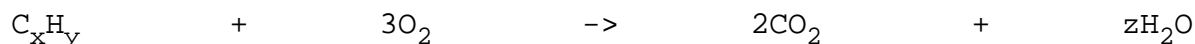
Let the formula of the hydrocarbon be C<sub>x</sub>H<sub>y</sub>. The reaction is, therefore,



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



By Avogadro's Law, 200 cm<sup>3</sup> CO<sub>2</sub> will contain twice as many molecules as 100 cm<sup>3</sup> C<sub>x</sub>H<sub>y</sub> and 300 cm<sup>3</sup> O<sub>2</sub> will contain three times as many molecules as 100 cm<sup>3</sup> C<sub>x</sub>H<sub>y</sub>. We can therefore partially balance the equation (since we do not know the volume of Water vapour we let the number of H<sub>2</sub>O molecules be z) :



Now equate the atoms on both sides of the equation :

$$\text{Carbon} \quad x = 2$$

$$\text{Hydrogen} \quad y = 2z$$

$$\text{Oxygen} \quad 6 = 4 + z \quad \Rightarrow \quad z = 2$$

$$\Rightarrow \quad y = 4$$

$$\Rightarrow \quad \text{Formula is C}_2\text{H}_4$$

**Molar Volume**

The number of molecules in a mole of any gas is always  $6.023 \times 10^{23}$  - 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<sup>-1</sup>**.

**Example**

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

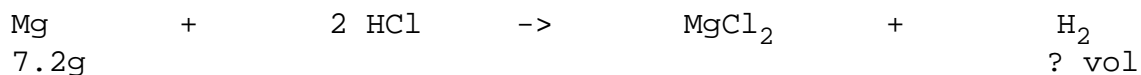
**Answer**

$$2.03\text{g Kr occupies } 541.4 \text{ cm}^3$$

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

**Example**

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

**Answer**

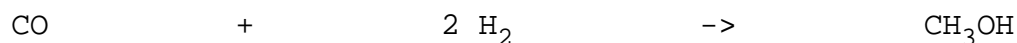
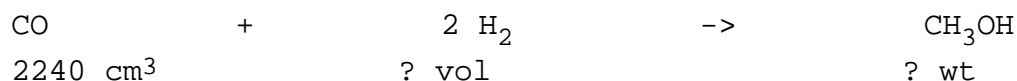
$$\text{No. of moles of Mg} = \frac{7.2}{24} = 0.3 \text{ mol}$$

$$\Rightarrow \text{No. of moles of H}_2 = 0.3 \text{ mol}$$

$$\begin{aligned} \Rightarrow \text{Volume of H}_2 &= 22400 \times 0.3 \\ &= \underline{6720 \text{ cm}^3} \end{aligned}$$

**Example**

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

**Answer**

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

$$\Rightarrow \text{No. of moles CH}_3\text{OH} = 0.1 \text{ mol}$$

$$\Rightarrow \text{Wt. of CH}_3\text{OH} = 0.1 \times 32 = \underline{3.2\text{g}}$$

Since the no. of molecules of H<sub>2</sub> is twice the number of molecules of CO the H<sub>2</sub> will occupy twice the volume of the CO i.e. 4480 cm<sup>3</sup>