Moles of gases:

- **Many reactions involve gases. The quantity of gas used or produced in a reaction are measured in volumes.**
- There is relationship between the volume of gas and the number of atoms or molecules present. There are two laws help in understanding the relationship.
- **Avogadro's law:**
- It states that equal volumes of gases at same temperature and pressure are found to contain the same number of molecules. This applies to all gases
- **Standard temperature and pressure(S.T.):**
- **One mole of any gas at s.t.p occupies a volume of 22.4dm^3 this refers to as molar gas volume**
- **Temperature 273k= OC^o**
- **Pressure = 1atm= 760mmHg =100kpa**

- **Room temperature and pressure (RTP):**
- **One mole of any gas occupies at rtp 24dm^3**
- **Temperature = 25C^o =298k**
- **Pressure = 1atm=760mmHg=100kpa**
- **Remember 1 liter = 1dm^3 = 1000cm^3**
- **It is therefore easy to convert the volume of any gas into moles and vice versa**
- **Number of moles = Volume/molar volume**
- **Volume = number of moles x molar volume**

Substance	Molar mass (g/mol)	Molar volume (dm^3/mol)	Number of particles
Hydrogen (H_2)	2	24	6.02×10^{23} hydrogen molecules
Oxygen (O_2)	32	24	6.02×10^{23} oxygen molecules
Carbon dioxide (CO_2)	44	24	6.02×10^{23} carbon dioxide molecules
Ethane (C_2H_6)	30	24	6.02×10^{23} ethane molecules

Gay-Lussac’s law”:

- It states that the volume of reacting gases and the volume of any gaseous product are in a simple whole number ratio provided that volume is measured at the same temperature and pressure
- $H_2(g) + Cl_2(g)$ ---------- $2HCl(g)$
- 1volume 1 volume 2 volume

Calculations involving gases:

- **1) What volume (measured at r.t.p) is occupied by**
- (a) 0.5 mol of oxygen gas?
- (b) 2 mol of carbon dioxide gas?
- 2) How many moles are there in
- (a) 48 dm^3 of hydrogen gas measured at room temperature and pressure?
- (b) 12000 cm^3 of a gas measured at room temperature and pressure?

Solution

1. (a) volume = moles x molar volume
= 0.5 mol **x** 24 dm3/mol
= 12 dm3

(b) Volume = moles x molar volume
= 0.5 mol **x** 24 dm3/mol
= 12 dm3

2. **(a)** Moles = $\frac{\text{volume}}{\text{molar volume}}$
= $\frac{48\ \text{dm3}}{24\ \text{dm3/mol}}$
= 2 mol

(b) Moles = $\frac{\text{volume}}{\text{molar volume}}$
= $\frac{12\ \text{dm3}}{24\ \text{dm3/mol}}$
= 0.5 mol

Rules to follow calculations involving gases using an equation:

- Write balanced equation for reaction
- Obtain the mole ratio
- Change mole into masses or volume
- Relate the masses or volumes to those in the equation
- Example:
- What volume of hydrogen gas is obtained when 0.24g of magnesium reacts with excess dilute hydrochloric acid?

Solution:

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

1mol 2mol 1mol 1mol

Mole ratio mg:H_2 1:1

No of moles magnesium = 0.24g/24 =0.01moles

Therefore 0.01moles of hydrogen gas was produced

Volume of hydrogen gas =24000x0.01=240cm^3

Atomicity of gases:

- Is the number of atoms present in the molecule?
- Mono-atomic
- Diatomic
- Polyatomic
- For example, the atomicity of chlorine, cl_2 is 2 and the atomicity of ozone O3 is 3

Atomicity = relative molecular mass/relative atomic mass

The concentration of solutions

- When a chemical substance (the **solute**) is dissolved in a volume of a **solvent**, we can measure the quantity of solute in two ways. We can measure either its mass (in moles). The final volume of the solution is normally measured in cubic decimeters, dm^3 ($1dm^3$ = 1 litre or 1000 cm^3). When we measure the mass of the solute in grams, it is the mass **concentration** that we obtain, in grams per cubic decimeter of solution (g/dm^3). But it is more useful to measure to the amount in moles, in which case we get the **concentration** in moles per cubic decimeter of solution (mol/dm^3):
- Concentration is the amount of solute in moles or grams that is dissolve in 1dm3 of solution

Molarity

- Concentration expressed mole of solute per liter of solution.
- It is abbreviated M(mol/L)
- Contration = amount of solute /volume of solution(dm^3)
- The **mass concentration** of a solution is measured in grams per cubic decimeter (g/dm^3).
- The **concentration** of solution is measured in moles per cubic decimeter (mol/dm^3).
- When 1 mole of a substance is dissolved in water and the solution is made up to 1 dm^3 (1000 cm^3), a solution with a concentration of **1 mol/dm^3** is produced.

Finding the concentration in $moldm^{-3}$

- **Example**
- **Calculate the concentration of a solution of sodium hydroxide, NaOH that contains 10g of NaOH in a final volume of 250 cm^3?**
- **Solution**
-

- **The number of moles in a given volume of solution**
- **The following equation is useful when working out the number of moles of a substance present in a particular solution of known concentration:**

No of moles = concetration X volume(dm3)

- **Example**
- How many moles of are present in 500cm^3 of a 3 mol/dm^3 sugar solution?
- **Solution**
- Moles = concentration **x** volume of solution (in dm^3)
- = 3 mol/dm^3 **x** 0.5 dm^3
- = 1.5 mol

Calculating the mass of solute in a solution

- **Example**
- **Calculate the mass of sodium hydroxide in 500 cm^3 of 0.2 sodium hydroxide solution.**
- **Solution**
-

Balancing Chemical Equations

- **A chemical equation provides two type of equation**
- **Nature of the reactant and the relative number of each type of atoms**
- **An equation must also indicate the physical states of the substances: (s) for solid, (!) for liquid,(g) for gas and (aq) for aqueous solution.**
- **In chemical reactions atoms are not created or destroyed, and this is indicated in the balanced equation. Balancing equation is done by introducing the smallest integer *coefficients* to one or more of the reactants and/or products involved in the reaction *without changing their formula*. Thus, the formula of each substance in an equation must be written correctly first before any attempt to balance the equation is made.**

The following steps may be helpful in balancing an equation.

- 1. Begin with the compound that contains the most atoms or types of atoms.
- 2. Balance elements that appear only once on each side of the arrow.
- 3. Next balance elements that appear more than once on either side.
- 4. Balance free elements last.
- 5. Finally, check that smallest whole number coefficients are used.

For example, the combustion of ethanol (C_2H_5OH) to form carbon dioxide and water vapour is represented by the following equation (not balanced):

$$C_2H_5OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

- A correct balanced equation should not contain fractions as coefficients. If a fraction appears after all atoms have been balanced, the entire equation is multiplied by a simplest factor that will eliminate the fraction. For example, when the following equation is balanced, a fraction of 2 appears in the coefficient of O_2:

$$C_8H_{18}(l) + {}^{25}/_{2}\, O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g);$$

(8C, 18H, 25 O) (8C, 18H, 25 O)

To remove this fraction, we multiply the entire equation by 2, which yield the proper equation:

$$2C_8H_{18}(l) + 25\, O_2(g) \rightarrow 16\, CO_2(g) + 18\, H_2O(g);$$

Stoichiometric calculations

- Stoichiometry implies the quantitative relationships between substances in a chemical reaction.
- The coefficients in chemical equations represent numbers of molecules or moles of substances, not the mass of a substance. Yet, in actual reactions, the amounts of reactants and products are measured in units for mass. The number of moles of each substance must be calculated from its MASS.

Mole/mole relationship in stoichiometric

- Example 1:

For example, if we want to know how many moles of H_2 are needed to react with 5 moles of N_2 and how many moles of NH_3 will be formed, we can perform the calculation as follows:

$$\text{Mol of } H_2 = 5 \text{ mol } N_2 \times \frac{3 \text{ mol } H_2}{1 \text{ mol } N_2} = 15 \text{ mol } H_2$$

$$\text{Mol of } NH_3 = 5 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_2}{1 \text{ mol } N_2} = 10 \text{ mol } NH_3$$

Example

1. According to the equation:

$2C_8H_{18}(l) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O(g)$,

(a) How many moles of CO_2 are produced when 5.5 moles of octane (C_8H_{18}) are completely burned in air?

(b) How many moles of water are also formed?

(c) How many moles of oxygen react with 5.5 moles of octane?

Solution

(a) Mol of $CO_2 = 5.5\ mol\ C_8H_{18} \times \frac{16\ mol\ CO_2}{2\ mol\ C_8H_{18}} = 44\ mol\ CO_2$

(b) Mol of $H_2O = 5.5\ mol\ C_8H_{18} \times \frac{18\ mol\ H_2O}{2\ mol\ C_8H_{18}} = 49.5\ mol\ H_2O$

(c) Mol of $O_2 = 5.5\ mol\ C_8H_{18} \times \frac{25\ mol\ O_2}{2\ mol\ C_8H_{18}} = 68.75\ mol\ O_2$

Mass/mole relation in stoichiometric

Again consider the reaction: $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

Suppose that 454 g N_2 is available and we want to know how many grams of H_2 are needed to react completely with this amount of N_2 and how many grams of NH_3 will be produced.

Acid –base titrations

- **The concentration of an unknown acid solution can be found if it is reacted with a standard solution of an alkali**
- **Standard solution are solutions of known concentration**
- **The reaction is carried out in a carefully controlled way. The volumes are measured accurately using a pipette and a burette. Just sufficient acid is added to the alkali to neutralize the alkali. This end point is found using an indicator. The method is known as titration, and can be adapted to prepare a soluble salt.**

example

solution of hydrochloric acid is titrated against a standard sodium hydroxide solution. It is found that 20 cm^3 of acid neutralize 25 cm^3 of 0.1 mol/dm^3 NaOH solution. What is the concentration of the hydrochloric acid solution?

- **Solution**
- *Method 1*
- Step 1: use information on the standard solution. *How many moles of alkali are in the flask?*
- Number of moles of NaOH = concentration **x** volume(in dm3)

= 0.0025 mol

Step 2: use the chemical equation. *How many moles of acid are used?*

$$\underset{1\text{ mol}}{HCl} + \underset{1\text{ mol}}{NaOH} \rightarrow NaCl + H_2O$$

So 1 mol of NaOH neutralizes 1 mol of HCl and so:

0.0025 mol of NaOH neutralize 0.0025 mol of HCl

Step 3: use the titration value. *What is the concentration of the acid?*

The acid solution contains 0.0025 mol in 20 cm^3:

So:

$$\text{Concentration in mol}dm^{-3} = \frac{\text{No.of moles}}{\text{Volume of solution in } dm^3} = \frac{0.0025\text{ mol}}{0.020\ dm^3} = 0.125 mol/dm^3$$

Method 2

The equation below is used in situations where the stoichiometric moles are in the ratio 1:1.

$$\mathbf{M_a \times V_a = M_b \times V_b}$$

Where Ma= concentration of the acid, M_b= concentration of the alkali, V_a=volume of the acid and V_b=volume of the alkali.

$$M_a \times 0.02\ dm^3 = 0.1\ mol/dm^3 \times 0.025\ dm^3$$

$$M_a = \frac{0.1\ moldm^{-3} \times 0.025\ dm^3}{0.02\ dm^3} = 0.125\ mol/dm^3$$

Example

25 cm^3 of NaOH needed 21.5 cm^3 of 0.1 mol dm^{-3} H_2SO_4 for neutralisation. Calculate the concentration of the NaOH solution. The equation for the reaction is:

$H_2SO_4 + 2NaOH \rightarrow 2NaCl + 2H_2O$

Solution

Method 1

Step 1: use information on the standard solution. *How many moles of acid are in the flask?*

Number of moles of H_2SO_4 = concentration **x** volume(in dm3)

$= 0.1\ mol dm^{-3} \times 0.0215\ dm^3$

$= 0.00215$ mol

Step 2: use the chemical equation. *How many moles of alkali are used?*

$$\underset{1\text{ mol}}{H_2SO_4} + \underset{2\text{ mol}}{2NaOH} \rightarrow Na_2SO_4 + 2H_2O$$

So 1 mol of H_2SO_4 neutralizes 1 mol of NaOH and so:

0.00215 mol of H_2SO_4 neutralize 0.0043 mol of NaOH

Step 3: use the titration value. *What is the concentration of the alkali?*

The alkali solution contains 0.0043 mol in 25 cm^3:

So:

$$\text{Concentration in mol}dm^{-3} = \frac{\text{No.of moles}}{\text{Volume of solution in } dm^3} = \frac{0.0043\text{ mol}}{0.025\ dm^3} = 0.172 \text{mol}/dm^3$$

Method 2

The equation below is used in situations where the stoichiometric moles are not in the same ratio.

$$\frac{M_a V_a}{M_b V_b} = \frac{a}{b}$$

Where Ma= concentration of the acid, M_b= concentration of the alkali, V_a=volume of the acid and V_b=volume of the alkali and a and b are the coefficients of the acid and the alkali in the balanced equation respectively.