Grade (12 LS & GS)

Chapter: Zero

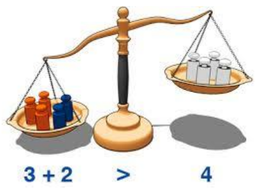
Chemical Reactions

Be Smart ACADEMY

Chapter Zero

Chemical Reactions

Recalling



1) Chemical Reaction:

A chemical reaction is a change during which substances are consumed (reactants) and others are formed (products).

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2) Evidences of a Chemical Reaction:

- Change of color
- Change in temperature
- Formation of water
- Release of bubbles (gas)
- Formation of precipitate

3) Chemical Equation:

A chemical reaction is represented by an equation:

E.g: $aA + bB \longrightarrow cC + dD$

A, B: reactants C, D: products

a, b, c, d: coefficients $\longrightarrow$: gives or yield

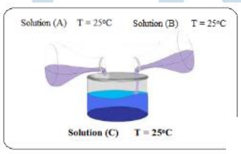
A- Symbols of state: (*l*): Liquid (s): Solid

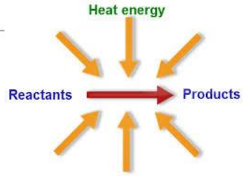
(g): Gas: (aq): Aqueous

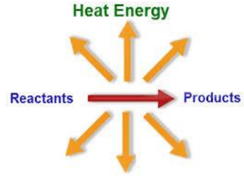
4) Thermal Effect:

From the thermal site, chemical reactions may be athermic or thermic.

Reactions
- Athermic
- Thermic
  - Endothermic
  - Exothermic







- A rise in temperature of the surrounding indicates that the reaction has occurred with a release of heat; this is an exothermic reaction.

$$A + B \longrightarrow C + D + heat$$

E.g: Combustion reaction

- A decrease in temperature of the surrounding indicates that the reaction has occurred with heat consumption (needs heat); this is an endothermic reaction.

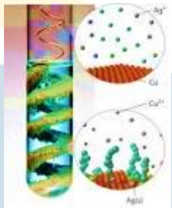
$$A + B + heat \longrightarrow C + D$$

E.g: Reaction of ammonium nitrate and water.

5) A- <u>Slow Reactions and Fast Reactions</u>:

Reactions

Slow reactions



Fast reactions

- A reaction is fast when its evolution is not observable.

  E.g: Titration (acid-base reaction).

- A reaction is slow when its evolution is observable.

  E.g: Rusting of iron.

B- <u>Complete and Incomplete Reactions</u>:

- **<u>Complete Reaction</u>:**

  Some reactions occur in one direction and are characterized by complete consumption of one or all reactants. These are called complete reactions.

  E.g: $C + O_2 \longrightarrow CO_2$

- **<u>Incomplete Reaction:</u>**

  It occurs in both directions and characterized by partial consumption of reactants.

  E.g: $C_2H_5OH + C_2H_6O \rightleftharpoons C_4H_8O_2 + H_2O$

6) <u>Reactants in Stoichiometric Mixture:</u>

A reactant mixture is termed stoichiometric when the quantities (in mol) of the reactants are proportional to their stoichiometric coefficients in the equation of the reaction. There is a total consumption of the reactants, and the final mixture contains only the product(s).

E.g: $aA + bB \longrightarrow cC + dD$

According to s.t ratio: $\frac{n(A)}{a} = \frac{n(B)}{b} = \frac{n(C)}{c} = \frac{n(D)}{d}$

Mixtures

- Stoichiometric mixture
  Both reactants are consumed totally
- Non-stoichiometric mixture
  One of the reactants is a limiting reactant, and the other is in excess.

A- <u>Study of a Stoichiometric Mixture</u>:

Given the balanced equation:

$aA + bB \longrightarrow cC + dD$

$R_{(A)} = \frac{n(A)}{a} = ...$

$R_{(B)} = \frac{n(B)}{b} = ...$

$R_{(A)} = R_{(B)}$

Stoichiometric mixture

(Both reactants consumed totally)

B- <u>Study of a Non Stoichiometric Mixture</u>:

Given the balanced equation:

$aA + bB \longrightarrow cC + dD$

$R_{(A)} = \frac{n(A)}{a} = ...$

$R_{(B)} = \frac{n(B)}{b} = ...$

$R_{(A)} \neq R_{(B)}$

Non-stoichiometric mixture

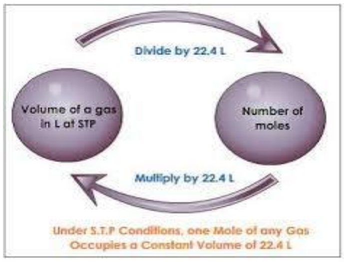
If: $R_{(A)} > R_{(B)} \Rightarrow$ (B) is the limiting reactant and (A) is in excess

If: $R_{(A)} < R_{(B)} \Rightarrow$ (A) is the limiting reactant and (B) is in excess

$$n(B)_{left} = n(B)_{initial} - n(B)_{reacted}$$

7) <u>Molar Volume</u>:

The molar volume V_m of a gas is the volume occupied by one mole of this gas. This volume depends on the temperature and pressure of the gas. (at S.T.P) standard conditions of temperature and pressure



At T = 0°C and P = 1.013bar $\Rightarrow V_m = 22.4\ L.mol^{-1}$

$n = \frac{V}{V_m} \Rightarrow V = n \times V_m$ where n: number of mole (in mol)

V: volume of gas in (L)

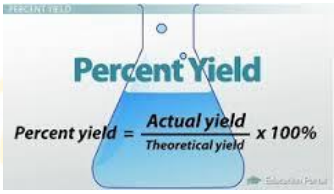
V_m: molar volume (L/mol)

8) <u>Yield of a Reaction</u>:

During a chemical reaction, the obtained quantity of the product usually less than the calculated one using stoichiometric ratios.

This difference is due to many factors:

- The formation of side products other than those represented by the equation of the reaction.
- The loss of a portion of the reactants.
- Impurities in the reactants.



Quantity given to you

$$\%yield = \frac{\text{Actual quantity of product}}{\text{theortical quantity of product}} \times 100$$

Found by s.t ratio

where quantity may be moles, mass or volume.

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Exercises and Problems

Exercise: 1

0.2mol of iron (Fe) reacts with oxygen to give ferric oxide according to the following equation:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

1- Determine the number of moles of ferric oxide formed.

2- Calculate the number of moles of oxygen reacted with iron.

Solution

1- Using s.t ratio:

$$\frac{n(Fe)}{4} = \frac{n(Fe_2O_3)}{2}$$

$$\frac{0.2}{4} = \frac{n(Fe_2O_3)}{2} \Rightarrow n(Fe_2O_3) = \frac{2\times 0.2}{4} = 0.1\,mol$$

2- Using s.t ratio:

$$\frac{n(Fe)}{4} = \frac{n(O_2)}{3}$$

$$\frac{0.2}{4} = \frac{n(O_2)}{3} \Rightarrow n(O_2) = \frac{0.2\times 3}{4} = 0.15mol$$

Exercise: 2

0.4mol of iron reacts with hydrochloric acid (HCl) to give ferrous chloride and hydrogen gas. The reaction is represented by the chemical equation:

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

1- Give the evidence of the occurrence of reaction.

2- Determine the mass of ferrous chloride obtained.

3- Determine the volume of the gas released. Explain how can we identify it?

Given: Fe = 56 Cl = 35.5 g/mol V_m = 22.4 L/mol

Solution

1- Evidence of the reaction: release of gas

2- Using s.t ratio:

$$\frac{n(Fe)}{1} = \frac{n(FeCl_2)}{1}$$

$n(FeCl_2)$ = 0.4mol $M(FeCl_2)$ = 56 + (2 × 35.5) = 127g/mol

$$n = \frac{m}{M} \Rightarrow m(FeCl_2) = n \times M = 0.4 \times 127 = 50.8g$$

3- Using s.t ratio:

$$\frac{n(Fe)}{1} = \frac{n(H_2)}{1} \Rightarrow n(H_2) = 0.4mol$$

$$n(H_2) = \frac{V}{V_m} \Rightarrow V = n \times V_m \Rightarrow V(H_2) = 0.4 \times 22.4 = 8.96L$$

Hydrogen gas burns with a pop sound.

Exercise: 3

0.4 moles of Aluminium react with 0.3moles of sulfur to give aluminium sulfide. The reaction is represented by the chemical equation:

$$2Al + 3S \rightarrow Al_2S_3$$

1- Explain if the above mixture is stoichiometric? If not identify the limiting reactant.

2- Determine the number of moles of the reactant left.

3- Calculate the mass of aluminium sulfide formed.

Given: Al = 27 S = 32 g/mol

Solution

1- $R(Al) = \frac{0.4}{2} = 0.2$, $R(S) = \frac{0.3}{3} = 0.1$

R (Al) > R (S)
The mixture isn't stoichiometric
Al is in excess
S is the limiting reactant

2- n(Al) left = ni – nr

$$\frac{n(Al)\text{reacted}}{2} = \frac{n\,S}{3}$$

$$\frac{n(Al)\text{reacted}}{2} = \frac{0.3}{3} \Rightarrow n(Al)\text{reacted} = \frac{2 \times 0.3}{3} = 0.2\text{mol}$$

n(Al) left = 0.4 – 0.2 = 0.2mol

3- Using s.t ratio:

$$\frac{n(S)}{3} = \frac{n(Al_2S_3)}{1}$$

$$\frac{0.3}{3} = \frac{n(Al_2S_3)}{1} \Rightarrow n(Al_2S_3) = 0.1\text{mol}$$ but $M(Al_2S_3) = (2 \times 27) + (3 \times 32) = 150\text{g/mol}$

$$n(Al_2S_3) = \frac{m}{M} \Rightarrow m = n \times M = 0.1 \times 150 = 15\text{g}$$

Exercise: 4

8.8g of propane undergoes combustion with 12L of oxygen gas.

The reaction is represented by the chemical equation:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

1- Specify if the above mixture is stoichiometric. If not identify the limiting reagent.

2- Determine the mass of water vapor formed.

3- Calculate the volume of carbon dioxide gas.

Given: C = 12 H = 1 O = 16g/mol V_m = 24 L/mol

Solution

1- $n(C_3H_8) = \frac{m}{M} = \frac{8.8}{44} = 0.2mol$

$$n(O_2) = \frac{V}{V_m} = \frac{12}{24} = 0.5mol$$

$$R(C_3H_8) = \frac{0.2}{1} = 0.2$$

$$R(O_2) = \frac{0.5}{5} = 0.1$$

$R(C_3H_8) > R(O_2)$

The mixture isn't stoichiometric

O_2 is the limiting reactant

2- Using s.t ratio:

$$\frac{n(O_2)}{5} = \frac{n(H_2O)}{4}$$

$$\frac{0.5}{5} = \frac{n(H_2O)}{4} \Rightarrow n(H_2O) = \frac{0.5 \times 4}{5} = 0.4mol$$

$$n(H_2O) = \frac{m}{M} \Rightarrow m = n \times M$$

but $M(H_2O) = 2 + 16 = 18g/mol$

$m = 0.4 \times 18 = 7.2g$

3- Using s.t ratio:

$$\frac{n(O_2)}{5} = \frac{n(CO_2)}{3}$$

$$\frac{0.5}{5} = \frac{n(CO_2)}{3} \Rightarrow n(CO_2) = \frac{0.5 \times 3}{5} = 0.3mol$$

$$n(CO_2) = \frac{V}{V_m} \Rightarrow V = n \times V_m = 0.3 \times 24 = 7.2L$$

Exercise: 5

4g of calcium reacts with oxygen to give 5g of calcium oxide. The reaction is represented by the chemical equation: $2Ca + O_2 \rightarrow 2CaO$

Show that the % yield of the above reaction is 89.28%

Given: Ca = 40 O = 16g/mol

Solution

$$n(Ca) = \frac{m}{M} = \frac{4}{40} = 0.1mol$$

Using s.t ratio:

$$\frac{n(Ca)}{2} = \frac{n(CaO)}{2}$$

$$\frac{0.1}{2} = \frac{n(CaO)}{2} \Rightarrow n(CaO) = 0.1mol$$

M(CaO) = 40 + 16 = 56g/mol

$$n(CaO) = \frac{m}{M} \Rightarrow m = n \times M = 0.1 \times 56 = 5.6g$$

$$\% \text{ yield} = \frac{\text{actual mass}}{\textit{theortical}\text{ mass}} \times 100$$

$$\% \text{ yield} = \frac{5}{5.6} \times 100 = 89.28\%$$

Exercise: 6

m (g) of barium chloride reacts with sulfuric acid to give a white precipitate (Barium sulfate) of mass 18.64g and hydrogen chloride. The % yield of the reaction is 80%. The reaction is represented by the chemical equation: $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$

1- Give the evidence of the occurrence of the reaction.
2- Show that m = 20.8g.

Given: Ba = 137 Cl = 35.5 S = 32 O = 16 g/mol

Solution

1- Formation of white precipitate

2- $\% \text{ yield} = \dfrac{\text{m (actual)}}{m\,(theortical)} \times 100$

$$80 = \frac{18.64}{\text{m}\,(theortical)} \times 100$$

$$m\,(theortical) = \frac{18.64 \times 100}{80} = 23.3\text{g}$$

$M(BaSO_4) = 137 + 32 + 16(4) = 233$g/mol

$$n(BaSO_4) = \frac{m}{M} = \frac{23.3}{233} = 0.1\text{mol}$$

Using s.t ratio:

$$\frac{n(BaCl_2)}{1} = \frac{n(BaSO_4)}{1} \Rightarrow n(BaCl_2) = 0.1\text{mol}$$

$M(BaCl_2) = 137 + 2(35.5) = 208$g/mol

$$n = \frac{m}{M} \Rightarrow m = n \times M = 0.1 \times 208 \Rightarrow m(BaCl_2) = 20.8\text{g}$$

Exercise: 7

Magnesium burns with a brilliant flame giving a white powder. 2.4g of magnesium reacts with oxygen gas to give 3g of magnesium oxide. The reaction is represented by the chemical equation: $2Mg + O_2 \longrightarrow 2MgO$

Show that the % yield of the above reaction is 75%.

Given: Mg = 24 O = 16 g/mol

Solution

$2Mg + O_2 \longrightarrow 2MgO$

$$n(Mg) = \frac{m}{M} = \frac{2.4}{24} = 0.1mol$$

Using s.t ratio:

$$\frac{n(Mg)}{2} = \frac{n(MgO)}{2}$$

$n(MgO) = 0.1mol$ $M_{(MgO)} = 24 + 16 = 40g/mol$

$$n(MgO) = \frac{m}{M} \Rightarrow m = n \times M = 0.1 \times 40 = 4g$$

$$\%yield = \frac{\text{actual mass}}{\text{theortical mass}} \times 100 = \frac{3}{4} \times 100 = 75\% \text{ (verified)}$$

Exercise: 8

(m) grams of iron react with excess hydrochloric acid solution to give 20.16g of ferrous chloride and hydrogen gas. The % yield of the reaction is 80%.

The reaction is represented by the chemical equation:

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$

1- Calculate the value of (m).

2- Determine the volume of hydrogen gas evolved at S.T.P.

Given: Fe = 56 Cl = 35.5 g/mol V_m = 22.4L/mol

Solution

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$

(m) m = 20.16g

%yield = 80%

1- $\% \, yield = \frac{\text{actual mass}}{\textit{theoretical}\text{ mass}} \times 100$

$$80 = \frac{20.16}{\text{theoretical mass}} \times 100$$

$$\Rightarrow \text{theoretical mass of } FeCl_2 = \frac{20.16 \times 100}{80} = 25.2g$$

$$n(FeCl_2) = \frac{m}{M} = \frac{25.2}{127} \qquad M(FeCl_2) = 56 + 2(35.5) = 127 g/mol$$

$n(FeCl_2)$ = 0.198mol

Using s.t ratio:

$$\frac{n(Fe)}{1} = \frac{n(FeCl_2)}{1} = 0.198mol$$

$$n(Fe) = \frac{m}{M} \Rightarrow m = n \times M = 0.198 \times 56 = 11.088g$$

2- Using s.t ratio:

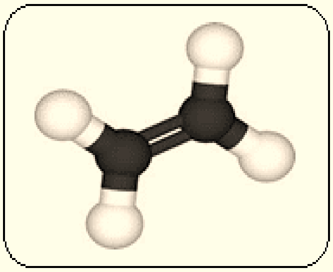
$$\frac{n(FeCl_2)}{1} = \frac{n(H_2)}{1} \Rightarrow n(H_2) = 0.198mol$$

$$n(H_2) = \frac{V}{V_m}$$

$$V(H_2) = n \times V_m = 0.198 \times 22.4 = 4.435L$$

Exercise: 9

15g of ethane (C_2H_6) is burned with 15.68L of oxygen gas to produce carbon dioxide and water vapor. The reaction is represented by the chemical equation:



$$C_2H_6 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$$

1- Specify if the given mixture is a stoichiometric mixture? Indicate the limiting reagent.
2- Calculate the mass of the excess reactant.
3- Calculate the mass of carbon dioxide evolved.
4- If only 15g of carbon dioxide were produced, show that % yield of the reaction is 85.22%.

Given: C = 12 H = 1 O = 16 g/mol V_m = 22.4L/mol

Solution

1- $C_2H_6 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$

15g 15.68L

$n(C_2H_6) = \frac{m}{M} = \frac{15}{30} = 0.5\text{mol}$ $M_{(C_2H_6)} = (12 \times 2) + (6 \times 1) = 30\text{g/mol}$

$n(O_2) = \frac{V}{Vm} = \frac{15.68}{22.4} = 0.7\text{mol}$

$R_{(C_2H_6)} = \frac{0.5}{1} = 0.5$

$R_{(O_2)} = \frac{0.7}{\frac{7}{2}} = 0.2$

$R_{(C_2H_6)} > R_{(O_2)}$

so the reaction is non stoichiometric

C_2H_6 is in excess and O_2 is the limiting reactant

2- Using s.t ratio:

$$\frac{n\,(C_2H_6)\text{reacted}}{1}=\frac{n(O_2)}{3.5}\Rightarrow n\,(C_2H_6)\text{reacted}=\frac{0.7}{3.5}=0.2\text{mol}$$

$n(C_2H_6)$excess = n (initial) – n (reacted) = 0.5 – 0.2 = 0.3mol

$$n(C_2H_6)=\frac{m}{M}\Rightarrow m(\text{excess})=n\times M=0.3\times 30=9\text{g}$$

3- Using s.t ratio:

$$\frac{n(O_2)}{3.5}=\frac{n(CO_2)}{2}\Rightarrow\frac{0.7}{3.5}=\frac{n(CO_2)}{2}\Rightarrow n(CO_2)=0.4\text{mol}$$

$$n(CO_2)=\frac{m}{M}\Rightarrow m=n\times M \qquad M(CO_2)=12+(16\times 2)=44\text{g/mol}$$

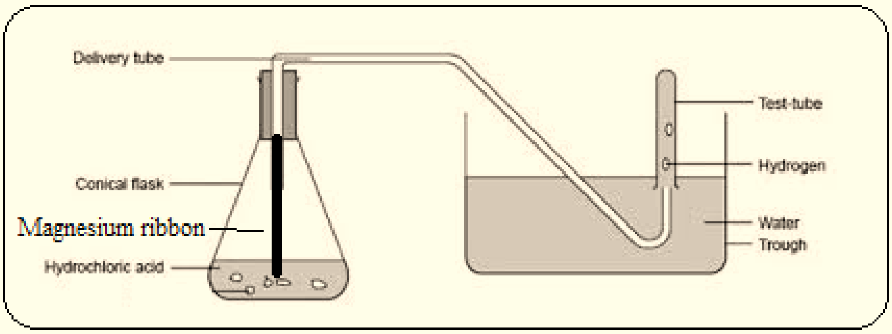
$m = 0.4 \times 44 = 17.6\text{g}$

4- $$\%\ \text{yield}=\frac{m\,(\text{actual})}{m\,(\text{theoretical})}\times 100$$

$$\%\ \text{yield}=\frac{15}{17.6}\times 100\Rightarrow \%\text{yield}=85.22\%$$

Exercise: 10

Document (1) shows the reaction between magnesium ribbon and a hydrochloric acid solution.



The equation of the above reaction is: $Mg + HCl \longrightarrow MgCl_2 + H_2$

1- Balance the above reaction.

2- Calculate the mass of the obtained salt during the reaction of 0.3g of magnesium ribbon with an excess amount of HCl solution.

3- Determine the volume of hydrogen gas released.

4- **The released gas from the above reaction is collected in a graduated cylinder and its volume is measured with time. The obtained results are tabulated below.**

t (min)	0	2	4	8	10	12	14	16
V (ml)	0	25	38	62	78	84	84	84

a. Identify the instant which corresponds to the end of the reaction.

b. Calculate the number of moles of the released gas when the reaction is over.

c. Deduce the % yield of the reaction.

Given: V_m = 24L/mol M(Mg) = 24g/mol

Solution

$Mg + 2HCl \longrightarrow MgCl_2 + H_2$

1- $n(Mg) = \frac{m}{M} = \frac{0.3}{24} = 0.0125 mol$

Using s.t. ratio:

$$\frac{n(Mg)}{1} = \frac{n(MgCl_2)}{1} \Rightarrow n(MgCl_2) = 0.0125 mol$$

$M(MgCl_2) = 24 + 2(35.5) = 95 g/mol$

$$n = \frac{m}{M}$$

$$m_{(MgCl_2)} = n \times M = 0.0125 \times 95 = 1.1875 g$$

2- Using s.t ratio:

$$\frac{n(Mg)}{1} = \frac{n(H_2)}{1} \Rightarrow n(H_2) = 0.0125 mol$$

$$n(H_2) = \frac{V}{V_m} \Rightarrow V = n \times V_m = 0.0125 \times 24 = 0.3 L$$

3- a. The reaction is terminated at t = 12min since the amount of the gas released remains constant.

b. $n(H_2) = \frac{V}{V_m} = \frac{84 \times 10^{-3}}{24} = 3.5 \times 10^{-3}$ mol

c. $\% \text{ yield} = \frac{\text{actual volume}}{\text{theortical volume}} \times 100 = \frac{84 \times 10^{-3}}{0.3} \times 100 = 28\%$

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