2.6 LIMITING REACTANT AND EXCESS REACTANT

Learning outcomes

After the completion of the chapter, the students should be able to:

- Identify the **limiting reactant** and **excess reactant** in a given chemical reaction.
- Calculate the maximum amount of products formed based on stoichiometric principles.
- Solve numerical problems related to leftover reactants, gas volumes at NTP, and sequential neutralisation reactions.

Introduction

In a perfect laboratory setup, reactants would always be mixed in exact theoretical(stoichiometric) ratios. In real-world experiments, however, reactants are rarely mixed in perfect stoichiometric amounts.

Usually, one reactant is present in a smaller proportion than required, while the other is present in a larger amount.

- **Limiting Reactant (or Limiting Reagent):** The reactant that is completely consumed first in a chemical reaction. Because it finishes first, it limits the amount of product that can be formed and halts the reaction.
- **Excess Reactant:** The reactant that is left over after the reaction has completely stopped.

Why is the Limiting Reactant Essential in Stoichiometry?

The limiting reactant is the single most important factor in stoichiometric calculations because **it determines the theoretical yield of the product**. Once it is exhausted, the remaining excess reactant cannot magically transform into products on its own. Therefore, all product calculations must be based strictly on the limiting reactant.

How to Identify the Limiting Reactant?

There are two common approaches used in NEB-level numericals:

- *Comparison method: Calculate how much of the second reactant is actually required by the given mass of the first reactant, then compare it with the amount actually available.*
- *Mole-ratio method: Convert both reactants to moles and divide each by its coefficient in the balanced equation — the smaller value identifies the limiting reactant.*

Worked Example 1

1 g of H_2 is mixed with 71 g of Cl_2. Identify the limiting reactant.

Solution:

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H₂   +  Cl₂  →  2 HCl
1 mol     1 mol
2 g         71 g
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From the equation, 2 g of H_2 reacts exactly with 71 g of Cl_2.

∴ 1 g of H_2 reacts with 71/2 = 35.5 g of Cl_2.

Cl_2 left unreacted = 71 − 35.5 = 35.5 g.

Since Cl_2 remains left over, H_2 is the limiting reactant.

Worked Example 2

1. Given, $CaCO_3(s) + 2HCl\ (aq.) \rightarrow CaCl_2(aq.) + H_2O(l) + CO_2(g)$

If 10 grams of pure $CaCO_3$ are added to a solution containing 7.665 grams of HCl,

i) Find the limiting reactant. ($CaCO_3$)

ii) Calculate the moles of excess reactant left over. (0.01)

iii) Calculate the volume of CO_2 gas produced at NTP. (2.24 litres)

iv) Calculate the number of grams of NaOH required for absorbing the whole of the CO_2 gas as Na_2CO_3. (8) **5**

<u>Solution</u>:

First, write down the balanced chemical equation and calculate molecular weights

$CaCO_3(s) + 2\ HCl\ (aq.) \rightarrow CaCl_2(aq.) + H_2O(l) + CO_2(g)$

1 mol 2 mol 1 mol 1 mol 1 mol

100g 2 x 36.5 g 22.4 l of CO_2 at NTP

[$CaCO_3$ = 40 +12 + 16 x 3= 100 amu HCl = 1 +35.5 = 36.5 amu]

i) For limiting reactant,

100 g of $CaCO_3$ reacts completely with 73 g of HCl.

10 g '' 73/100 x 10 = 7.3 g HCl.

Comparison: We are given 7.665 g of HCl. Since the required amount of 7.3 g is **less** than the given amount 7.665 g, HCl is in excess.

Result: <u>$CaCO_3$ is the limiting reactant</u>

ii) For Excess reactant,

7.665-7.3g = 0.365g

36.5 g HCl = 1 mol HCl

0.365 g HCl = 1/36.5 x 0.365= 0.01 moles.

iii) **For Volume of CO_2**

100 g CaCO3 gives 22.4 l CO_2 at NTP.

10 g '''''''''''''''''''''''''''' 22.4/100 x 10= <u>2.24 l of CO_2 at NTP</u>.

iii) For mass of NaOH

$2\ NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

2 mol 1 mol

2 x40g 22.4 l CO_2 at NTP

NaOH= 23 +16 +1= 40 amu

22.4 l CO_2 at NTP requires 80 g NaOH.

2.24 l '''''''''''''''''''''''''''''''' 80/22.4 x 2.24= <u>8 g NaOH</u>

Worked Example 3

2 g of magnesium is burnt in a closed vessel containing 1.2 g of oxygen, producing magnesium oxide.

i) Find the limiting reagent.

ii) Calculate the number of molecules of unreacted reagent left over. ($5.019 x 10^{21}$)

iii) What mass of MgO is produced? (3g)

iv) How many grams of pure HCl are required to neutralise the whole MgO produced? (5.475)

<u>Solution</u>:

$2\ Mg + O_2 \rightarrow 2\ MgO$

2 mol. 1 mol 2 mol

2 x 24 g 16g 2 x 40 g

i. *48 g of Mg reacts with 32 g of oxygen*

2 g of Mg reacts with $\frac{32x\ 2}{48}$ g of oxygen

= 1.34 g of oxygen

Since the amount of oxygen required by calculation is higher than the given, **the limiting reagent is oxygen**.

ii. 32 g of oxygen reacts with 48 g of Mg

1.2 g of oxygen reacts with $\frac{48\ x\ 1.2}{32}$ g Mg = 1.8 g of Mg

∴ The leftover magnesium = (32−1.8) g = 0.2 g

Now,

No of moles of leftover magnesium = $\frac{0.2}{24}$ moles

= $\frac{0.2}{24}$ x 6.023×10^{23}

= $\underline{5.01 \times 10^{21}\ \text{Mg atoms}}$

iii. 32 g of oxygen produces 80 g of MgO

1.2 g of oxygen produces $\frac{80\ x\ 1.2}{32}$ g of MgO

= <u>3 g of MgO</u>

iv. The reaction between HCl and MgO is as follows:

$2\ HCl + MgO \rightarrow MgCl_2 + H_2O$

2×36.5g 40 g

40 g of MgO is completely neutralised by 2 × 36.5 g of HCl

3 g of MgO is completely neutralised by $\frac{2\ x\ 36.5}{40}$ g of HCl

= <u>5.475g of HCl</u>

Worked Example 4

2g of Magnesium is burnt in a closed vessel containing 3g of oxygen.
i) Which one is the limiting reagent?
ii) Calculate the moles of reactant left over. (0.052)
iii) How many grams of MgO are produced? (3.33)
iv) What is the mass of H_2SO_4 required to neutralise MgO formed in the reaction? (8.16g) 5

Solution:

$2Mg + O_2 \rightarrow 2MgO$

2x24 g 32 g 2x40 g

i. From the balanced chemical equation,

48 g of Mg reacts with 32 g of oxygen

2 g of Mg reacts with 32*2/48 g of oxygen

= 1.34 g of oxygen

Since the amount of oxygen required by calculation is smaller than the amount given, Mg is the limiting reagent.

ii. Mass of the reactant left over = (3-1.34) g = 1.66 g

No. of moles = 1.66/32 = 0.051 moles

iii. Since magnesium is the limiting reagent,

48 g of Mg produces 80 g of MgO

2 g of Mg produces 80*2/48 g of MgO = 3.33 g of MgO

iv. Now, the MgO produced is reacted with H_2SO_4

$MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$

40 g 98 g

40 g of MgO reacts with 98 g of H_2SO_4

3.33 g of MgO reacts with 98*3.33/40 g of H_2SO_4

= 8.15 g of H_2SO_4

Exam Tips (NEB Style)

- Always start by writing the balanced chemical equation with mole ratios and gram masses written below each substance — this earns method marks even if the final answer is wrong.
- State clearly which reactant is limiting and which is in excess before proceeding — examiners specifically look for this line.
- Keep units consistent (g, mol, L) throughout, and box or underline your final numerical answer with correct units.

Key Points to Remember
The limiting reactant is completely consumed first and decides the theoretical yield of product.
The excess reactant is left over, partially unreacted, once the reaction stops.
Product calculations are always based on the limiting reactant — never the excess one.
Two methods to find it: the comparison method (mass required vs mass available) and the mole-ratio method.

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