2.7 Theoretical yield, experimental yield, and % yield

🎯 **Learning outcomes**

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

- Calculate the theoretical yield and percentage yield from the given actual yield (experimental yield)

Introduction to Yields

When performing a chemical synthesis, we use a balanced chemical equation to compute exactly how much product *should* theoretically form from our starting materials.

- **Theoretical Yield (Stoichiometric Yield):** The maximum amount of a particular product that could be formed from the given amount of reactants, calculated strictly based on the stoichiometry of the balanced chemical reaction. This calculation must always be based on the **limiting reagent** (the reactant that is completely consumed first).
- **Experimental Yield (Actual Yield):** The actual, physical amount of a product obtained when the reaction is carried out in a laboratory setting. Due to various known and unknown factors—such as side reactions, incomplete conversions, or loss of material during filtration and purification—the experimental yield is almost always lower than the theoretical yield.

Percent Yield

To measure the efficiency of a synthetic procedure, chemists calculate the **per cent yield**. It is the ratio of the experimental yield to the theoretical yield, expressed as a percentage.

$$\text{Percent yield} = \frac{\text{Exerimental yield}}{\text{Theoretical yield}} \text{ x } 100\ \%$$

Percent yield is very important in the calculation of products in chemical synthesis.

Worked Examples (Yield Calculations)

Example 1

Question: 1.274 g of CuSO4 reacts with an excess of zinc metal. If 0.392 g of Cu metal is obtained experimentally, calculate the percentage yield.

Equation: CuSO4(aq) + Zn(s) → Cu(s) + ZnSO4(aq)

(Atomic Masses: Cu = 63.5, S = 32, O = 16, Zn = 65.4)

Solution:

1. Find the molar mass of CuSO4:

Molar Mass = 63.5 + 32 + (16 × 4) = 159.5 g/mol

2. Calculate the Theoretical Yield of Cu:

From the balanced equation, 1 mole of CuSO4 (159.5 g) produces 1 mole of Cu (63.5 g).

Theoretical Yield of Cu = (63.5 g / 159.5 g) × 1.274 g ≈ 0.507 g

3. Calculate Percent Yield:

Given Experimental Yield = 0.392 g

Percent Yield = (0.392 g / 0.507 g) × 100% ≈ **77.3%**

Example 2

Question: 6.55 g of pure zinc is reacted with an excess of dilute hydrochloric acid. If the percentage yield of the reaction is 75%, calculate the actual mass of hydrogen gas produced.

Equation: Zn + 2HCl → ZnCl2 + H2

Solution:

1. Calculate the Theoretical Yield of H2:

1 mole of Zn (65.4 g) produces 1 mole of H2 (2.016 g ≈ 2 g).

Theoretical Yield of H2 = (2 g / 65.4 g) × 6.55 g = 0.20 g

2. Calculate the Experimental Yield using Percent Yield:

Percent Yield = (Experimental Yield / Theoretical Yield) × 100%

75% = (Experimental Yield / 0.20 g) × 100%

Experimental Yield = (75 × 0.20) / 100 = **0.15 g**

1. *1.274 g of $CuSO_4$ reacts with an excess of zinc metal, 0.392 g of Cu metal was obtained according to the equation*

   $CuSO_4(aq.) + Zn \rightarrow Cu + ZnSO_4(aq.)$

   Calculate the percentage yield.

2. *6.55 g of pure zinc is reacted with an excess of dilute hydrochloric acid. If the percentage yield of the reaction is 75%, calculate the amount of hydrogen gas produced.* (*ans = 0.15 g*)

3. *4.6 g of pure sodium was reacted with an excess of chlorine to produce sodium chloride. If the amount of sodium chloride obtained was 10g, what is the percentage yield of this reaction?* (*ans = 85.47%*)

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