Chemistry

Topic: Stoichiometry and Limiting Reactants

Given:

Mass of Aluminum (Al) = 2.82 g
Mass of Oxygen gas (O_2) = 2.56 g
Molar Mass of Aluminum (Al) = 26.98 g/mol
Molar Mass of Oxygen gas (O_2) = 32.00 g/mol
Molar Mass of Aluminum Oxide (Al_2O_3) = 101.96 g/mol

Step-by-Step Solution:

Step 1: Calculate the number of moles of Aluminum (Al).

Formula:

$$\text{Number of moles of Al} = \frac{\text{Mass of Al}}{\text{Molar Mass of Al}}$$

Calculation:

$$\text{Number of moles of Al} = \frac{2.82 \, \text{g}}{26.98 \, \text{g/mol}}$$

$$\text{Number of moles of Al} \approx 0.1045 \, \text{moles}$$

Explanation: The number of moles is obtained by dividing the given mass by the molar mass.

Supporting statement: Calculating the moles of aluminum prepares for the subsequent stoichiometric analysis.

Step 2: Calculate the number of moles of Oxygen gas (O_2).

Formula:

$$\text{Number of moles of } O_2 = \frac{\text{Mass of } O_2}{\text{Molar Mass of } O_2}$$

Calculation:

$$\text{Number of moles of } O_2 = \frac{2.56 \, \text{g}}{32.00 \, \text{g/mol}}$$

$$\text{Number of moles of } O_2 = 0.08 \, \text{moles}$$

Explanation: The number of moles is obtained by dividing the given mass by the molar mass.

Supporting statement: Calculating the moles of oxygen gas allows determining the limiting reactant.

Step 3: Determine the limiting reactant using the balanced chemical equation.

Balanced chemical equation:

$$4 \text{Al} + 3 \text{O}_2 \rightarrow 2 \text{Al}_2\text{O}_3$$

Check the mole ratio:

4 moles of Al react with 3 moles of O_2.

Calculate the stoichiometric ratio for the given moles:

For Aluminum:

$$\text{Required moles of } O_2 \text{ for given moles of Al} = \frac{3}{4} \times 0.1045 = 0.0784 \, \text{moles of } O_2$$

For Oxygen gas:

$$\text{Required moles of Al for given moles of } O_2 = \frac{4}{3} \times 0.08 = 0.1067 \, \text{moles of Al}$$

Explanation: The stoichiometric ratios are used to determine which reactant will be fully consumed first.

Supporting statement: Determining the stoichiometric ratios reveals the limiting reactant.

Step 4: Identify the limiting reactant.

Given moles of O_2 (0.08 moles) is more than the required moles of O_2 (0.0784 moles) for the available Al.

Given moles of Al (0.1045 moles) is less than the required moles of Al (0.1067 moles) for the available O_2.

Therefore, Aluminum (Al) is the limiting reactant.

Explanation: The substance with fewer available moles than required is the limiting reactant.

Supporting statement: Aluminum is the limiting reactant since it has fewer available moles than required for complete reaction with oxygen gas.

Step 5: Calculate the maximum theoretical moles of the product (Al_2O_3).

Using the limiting reactant (Al):

From 4 moles of Al, 2 moles of Al_2O_3 are produced.

Calculation:

$$\text{Moles of } Al_2O_3 = \frac{2}{4} \times 0.1045 = 0.05225 \, \text{moles of } Al_2O_3$$

Explanation: Use the stoichiometric coefficients from the balanced equation to find the moles of the product formed by the limiting reactant.

Supporting statement: The theoretical yield of the product is based on the amount of limiting reactant available.

Final Solution:

The limiting reactant is **Aluminum (Al)**, and the maximum theoretical moles of the product (Al_2O_3) is **0.0523 moles**.

This concludes that Aluminum is the limiting reactant and it produces 0.0523 moles of Aluminum Oxide (Al_2O_3).