4 Al + 3 O2 -> 2 Al2O3 How Much Aluminum Would Be Needed To Completely React With 45 Grams Of Oz?

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Understanding the quantitative relationship between reactants in chemical reactions is fundamental in chemistry, especially when it comes to calculating the amount of a substance needed to fully react with a specific quantity of another. In this case, we are asked to determine how much aluminum (Al) is required to completely react with 45 grams of oxygen (O_2) based on the balanced chemical equation:

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

This reaction involves aluminum reacting with oxygen to form aluminum oxide (Al_2O_3). To solve this problem, we need to understand the stoichiometry of the reaction, convert the given mass of oxygen to moles, and then determine the corresponding mass of aluminum needed for complete reaction.

Understanding the Chemical Reaction and Its Stoichiometry

The Balanced Equation

The balanced chemical equation provides the molar ratios of reactants and products:

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

This tells us that:

- 4 moles of aluminum react with 3 moles of oxygen.
- The molar ratio of Al to O_2 is 4:3.

The Relationship Between Reactants

From the molar ratio:

- For every 4 moles of Al, 3 moles of O_2 are consumed.

- To find out how much Al is needed for a given amount of O_2, we can set up a proportion based on moles.

Calculating the Moles of Oxygen (O_2)

The Molar Mass of Oxygen (O_2)

To convert grams to moles, we need the molar mass of O_2.

- Atomic mass of oxygen (O) ≈ 16.00 g/mol
- Molar mass of O_2 = 2 × 16.00 g/mol = 32.00 g/mol

The Moles of O_2 in 45 Grams

Using the molar mass:

$$
\text{Moles of O}_2 = \frac{\text{Mass of O}_2}{\text{Molar mass of O}_2} = \frac{45 \text{ g}}{32.00 \text{ g/mol}} \approx 1.40625 \text{ mol}
$$

Determining the Required Moles of Aluminum

The Molar Ratio from the Balanced Equation

From the equation:

$$
4 \text{ mol Al} : 3 \text{ mol O}_2
$$

We can set up a ratio:

$$
\text{Moles of Al} = \frac{4}{3} \times \text{Moles of O}_2
$$

Substituting the calculated moles of O_2:

$$
\text{Moles of Al} = \frac{4}{3} \times 1.40625 \approx 1.875 \text{ mol}
$$

This means approximately 1.875 moles of aluminum are needed to react completely with 45 grams of oxygen.

Calculating the Mass of Aluminum Needed

The Molar Mass of Aluminum (Al)

- Atomic mass of aluminum ≈ 26.98 g/mol

The Mass of Aluminum Corresponding to 1.875 Moles

$$
\text{Mass of Al} = \text{Moles of Al} \times \text{Molar mass of Al}
$$

$$
= 1.875 \text{ mol} \times 26.98 \text{ g/mol} \approx 50.66 \text{ g}
$$

Therefore, approximately 50.66 grams of aluminum are needed to react completely with 45 grams of oxygen.

Summary and Final Considerations

Key Points

- The balanced chemical equation indicates a molar ratio of 4:3 for Al to O_2.
- Converting grams to moles is essential for stoichiometric calculations.

- Approximately 50.66 grams of aluminum are required for complete reaction with 45 grams of oxygen.

Practical Implications

- In real-world chemical processes, factors such as purity of reactants, reaction conditions, and efficiency may influence the actual amount of aluminum needed.
- This calculation assumes ideal conditions with complete reaction and no side reactions.

Additional Insights

Understanding Limiting Reactants

Knowing how much of each reactant is present allows chemists to identify the limiting reactant— the substance that is completely consumed first, thus limiting the amount of product formed. In this scenario, if you start with exactly 45 grams of O_2, aluminum in the calculated amount (about 50.66 grams) will be the limiting reactant, assuming excess aluminum.

Scaling and Practical Applications

- This calculation can be scaled up or down depending on the quantities involved.
- Industries utilizing aluminum oxidation, such as in manufacturing aluminum oxide for abrasives or ceramics, rely heavily on such stoichiometric calculations for process efficiency.

Conclusion

By understanding the stoichiometry of the reaction between aluminum and oxygen, we can accurately determine the amount of aluminum necessary to completely react with a given mass of oxygen. For 45 grams of oxygen, approximately 50.66 grams of aluminum are required. This calculation underscores the importance of molar ratios and fundamental chemistry principles in practical applications, from laboratory experiments to industrial processes. Properly applying these concepts ensures the efficient and safe use of chemical reactants, optimizing resource management and minimizing waste.

Frequently Asked Questions

How do you determine the amount of aluminum needed to react completely with 45 grams of oxygen in the reaction $4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$?

First, convert 45 grams of O_2 to moles by dividing by its molar mass (32 g/mol). Then, use the mole ratio from the balanced equation (4 Al : 3 O_2) to find the moles of Al needed. Finally, convert moles of Al to grams by multiplying by its molar mass (26.98 g/mol).

What is the molar mass of oxygen and aluminum used in the calculation?

The molar mass of oxygen (O_2) is 32 g/mol, and the molar mass of aluminum (Al) is approximately 26.98 g/mol.

How many moles of oxygen are in 45 grams?

Number of moles of O_2 = 45 g / 32 g/mol ≈ 1.406 moles.

What is the mole ratio between aluminum and oxygen in the balanced reaction?

The balanced equation shows that 4 moles of Al react with 3 moles of O_2, so the ratio is 4:3.

How many moles of aluminum are needed to react with 1.406 moles of oxygen?

Using the ratio 4 Al : 3 O_2, moles of Al needed = (4/3) × 1.406 ≈ 1.875 moles.

What is the mass of aluminum required to completely react with 45 grams of oxygen?

Mass of Al = 1.875 moles × 26.98 g/mol ≈ 50.62 grams.

Can the calculation be used to find the aluminum needed for any amount of oxygen?

Yes, by converting the amount of oxygen to moles and using the molar ratio, you can determine the aluminum required for any amount.

What assumptions are made in this calculation?

The calculation assumes complete reaction with no excess reactants, and that the reaction proceeds to completion under ideal conditions.

How would the calculation change if the oxygen amount was given in moles instead of grams?

If given in moles directly, you would skip converting grams to moles and directly apply the mole ratio to find the moles of aluminum needed.

What practical applications does this calculation have?

This calculation helps in industrial processes involving aluminum and oxygen, such as manufacturing aluminum oxide, ensuring precise reactant quantities for efficiency and safety.

Additional Resources

How Much Aluminum Would Be Needed To Completely React With 45 Grams Of Ozone?

Understanding the quantitative aspects of chemical reactions is fundamental in chemistry, especially when it comes to calculating the amount of reactants needed to produce a desired product or to completely consume a particular reactant. In this detailed guide, we will explore the problem: "How much aluminum would be needed to completely react with 45 grams of ozone?" Using the balanced chemical equation:

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

we will break down the problem step-by-step, elucidate the calculations involved, and demonstrate how to handle similar stoichiometric problems with confidence.

Understanding the Chemical Equation

Before diving into calculations, it’s essential to interpret the balanced chemical equation properly:

Equation:

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

Key points:

- Reactants: Aluminum (Al) and oxygen gas (O_2)
- Products: Aluminum oxide (Al_2O_3)
- Stoichiometry: 4 moles of Al react with 3 moles of O_2

The question centers on how much aluminum is needed to react with a given amount of ozone (O_3). This introduces a significant point: the chemical equation involves oxygen gas (O_2), but the problem states ozone (O_3). Since ozone is a different allotrope of oxygen, we need to consider how ozone reacts in similar reactions.

Step 1: Clarify the Reactants — Ozone vs. Oxygen Gas

The balanced equation involves O_2, but the problem provides ozone (O_3).

Important distinction:

- Oxygen gas (O_2) is diatomic oxygen.
- Ozone (O_3) is triatomic oxygen.

Key point:

- The reaction with aluminum typically involves oxygen molecules (O_2), but ozone can also oxidize metals, often acting as an oxidizing agent providing oxygen atoms.

However, for the purpose of this problem, we should clarify whether the equation applies directly to ozone or if it needs to be adjusted.

Assumption:

- The reaction is similar, but with ozone (O_3), which contains more oxygen atoms per molecule.

In many oxidation reactions involving ozone, ozone provides oxygen atoms equivalent to about 1.5 times that of O_2 for the same number of molecules, because:

$$
1\, \text{O}_3 \text{ contains 3 oxygen atoms}
$$

$$
\text{O}_2 \text{ contains 2 oxygen atoms}
$$

Thus, to convert ozone to an equivalent amount of oxygen molecules, we consider that:

$$
1\, \text{O}_3 \equiv \frac{3}{2} \text{O}_2
$$

This ratio will allow us to relate ozone to O_2, enabling us to use the balanced equation directly.

Step 2: Convert 45 grams of Ozone (O_3) to Moles

Calculating moles of ozone:

- Molar mass of ozone (O_3):

$$
\text{O}_3: 3 \times 16.00\, \text{g/mol} = 48.00\, \text{g/mol}
$$

- Moles of ozone in 45 grams:

$$
\text{moles of } \text{O}_3 = \frac{\text{mass}}{\text{molar mass}} = \frac{45\, \text{g}}{48.00\, \text{g/mol}} \approx 0.9375\, \text{mol}
$$

Step 3: Convert Ozone Moles to Equivalent O_2 Moles

Using the ratio $1\, \text{O}_3 \equiv \frac{3}{2} \text{O}_2$:

$$
\text{moles of } \text{O}_2 = \text{moles of } \text{O}_3 \times \frac{3}{2} = 0.9375 \times 1.5 = 1.40625\, \text{mol}
$$

This means that the 0.9375 mol of ozone provides an equivalent of approximately 1.40625 mol of O_2.

Step 4: Use the Balanced Equation to Find Aluminum Needed

From the reaction:

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

- Stoichiometric ratio:

$$
4\, \text{mol Al} \leftrightarrow 3\, \text{mol } \text{O}_2
$$

- Calculate the molar amount of aluminum needed:

$$
\text{mol Al} = \text{mol } \text{O}_2 \times \frac{4}{3}
$$

Plugging in the O_2 moles:

$$
\text{mol Al} = 1.40625 \times \frac{4}{3} \approx 1.875\, \text{mol}
$$

Step 5: Convert Moles of Aluminum to Mass

- Molar mass of aluminum:

$$
\text{Al}: 26.98\, \text{g/mol}
$$

- Total mass of aluminum:

$$
\text{Mass} = 1.875\, \text{mol} \times 26.98\, \text{g/mol} \approx 50.63\, \text{g}
$$

Final Answer:

Approximately 50.63 grams of aluminum are needed to completely react with 45 grams of ozone.

Additional Considerations and Summary

Summary of the Calculation Steps:

1. Convert 45 g of ozone to moles:

$$
45\, \text{g} \div 48.00\, \text{g/mol} \approx 0.9375\, \text{mol}
$$

2. Translate ozone to equivalent O_2 moles:

$$
0.9375\, \text{mol} \times \frac{3}{2} = 1.40625\, \text{mol}
$$

3. Use the stoichiometry of aluminum and oxygen:

$$
4\, \text{mol Al} \leftrightarrow 3\, \text{mol } \text{O}_2
$$

\]

\[
\text{mol Al} = 1.40625 \times \frac{4}{3} \approx 1.875\, \text{mol}
\]

4. Convert aluminum moles to grams:

\[
1.875\, \text{mol} \times 26.98\, \text{g/mol} \approx 50.63\, \text{g}
\]

Practical Implications:

- Safety note: Handling ozone is hazardous due to its strong oxidizing properties, and reactions involving metals and ozone should be conducted under controlled laboratory conditions.
- Real-world application: This calculation can help chemists determine the amount of aluminum required in industrial processes involving ozone or similar oxidants.

Final Remarks

Calculating the amount of aluminum needed to react with a certain amount of ozone involves understanding the chemistry of both substances, appropriately converting between different forms of oxygen, and applying stoichiometry carefully. By following a systematic approach—clarifying reactants, converting units, applying molar ratios, and performing conversions—you can confidently solve similar problems involving different chemical species and complex reactions.

Remember: Always double-check your assumptions, especially when dealing with different allotropes or reactive species, to ensure your calculations are physically meaningful and accurate.

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