What Number Of Moles Of H2 Will Be Produced When 4.0 Mol Na Is Added To 1.2 Mol H2o?

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Understanding the chemical reaction between sodium (Na) and water (H_2O) is fundamental in chemistry, particularly in studying chemical reactions, stoichiometry, and the principles of conservation of mass. When sodium metal reacts with water, it produces sodium hydroxide (NaOH) and hydrogen gas (H_2). This article aims to explore the detailed process of calculating the amount of hydrogen gas produced when 4.0 mol of sodium is added to 1.2 mol of water, providing a comprehensive understanding for students, educators, and chemistry enthusiasts alike.

Overview of the Reaction Between Sodium and Water

The reaction between sodium and water is a classic example of a single displacement reaction, characterized by the following chemical equation:

$2\ Na\ (s) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_2\ (g)$

This equation indicates that two moles of sodium react with two moles of water to produce two moles of sodium hydroxide and one mole of hydrogen gas. This reaction is highly exothermic and vigorous, often accompanied by the release of heat and hydrogen gas.

Key Concepts in Stoichiometry

Before calculating the amount of hydrogen gas produced, it is essential to understand some fundamental concepts:

1. Mole Ratio

The mole ratio is derived from the coefficients of the balanced chemical equation. For this reaction:

- 2 mol Na reacts with 2 mol H_2O

- 1 mol H_2 is produced per 2 mol Na

This ratio allows us to determine how many moles of hydrogen gas will be produced based on the amounts of reactants involved.

2. Limiting Reactant

The limiting reactant is the reactant that is completely consumed in the reaction, limiting the amount of product formed. To determine the actual amount of hydrogen gas produced, we need to identify the limiting reactant between sodium and water.

Step-by-Step Calculation Process

Let's walk through the detailed steps to find out how many moles of H_2 are produced when 4.0 mol Na is added to 1.2 mol H_2O.

Step 1: Write the Balanced Equation

As provided, the balanced equation is:

$$2\ Na\ (s) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_2\ (g)$$

Step 2: Determine the Mole Ratios

From the balanced equation:

- 2 mol Na produces 1 mol H_2
- 2 mol H_2O produces 1 mol H_2

This simplifies to:

- 1 mol Na produces 0.5 mol H_2
- 1 mol H_2O produces 0.5 mol H_2

Step 3: Calculate the Theoretical Hydrogen Gas from Each Reactant

From Sodium (Na):

- 4.0 mol Na × (0.5 mol H_2 / 1 mol Na) = 2.0 mol H_2

From Water (H_2O):

- 1.2 mol H_2O × (0.5 mol H_2 / 1 mol H_2O) = 0.6 mol H_2

Step 4: Identify the Limiting Reactant

Since sodium can produce up to 2.0 mol H_2, and water can produce only 0.6 mol H_2, water limits the amount of hydrogen gas produced because it produces fewer moles of H_2. Therefore, water is the limiting reactant in this scenario.

Step 5: Final Calculation of Hydrogen Gas Produced

Because water is limiting, the maximum amount of H_2 produced is based on the available water:

- Hydrogen gas produced = 0.6 mol

This means that, under the given conditions, 0.6 mol of hydrogen gas will be produced when 4.0 mol of sodium reacts with 1.2 mol of water.

Additional Considerations

While the above calculations assume ideal conditions and complete reaction, real-world scenarios may involve factors such as:

- Reaction kinetics and rate
- Presence of impurities
- Temperature and pressure effects

However, for stoichiometric calculations, the assumption of complete reaction is standard.

Implications and Applications

Understanding this calculation has practical significance:

- Hydrogen Production: Sodium-water reactions are a source of hydrogen gas, which can be used as a clean fuel.
- Safety Precautions: Sodium’s vigorous reaction with water necessitates handling under controlled conditions.
- Industrial Processes: Knowledge of limiting reactants is crucial in manufacturing and chemical engineering.

Summary of Key Points

- The balanced chemical reaction between sodium and water is 2 Na + 2 H_2O → 2 NaOH + H_2.
- The mole ratio indicates that 2 mol Na produces 1 mol H_2.
- When adding 4.0 mol Na and 1.2 mol H_2O, water is the limiting reactant.
- The maximum hydrogen gas produced is 0.6 mol based on the limiting reactant.
- Understanding stoichiometry helps predict product quantities in chemical reactions.

Conclusion

In conclusion, when 4.0 mol of sodium reacts with 1.2 mol of water, the reaction produces approximately 0.6 mol of hydrogen gas. This calculation underscores the importance of limiting reactants in chemical reactions and demonstrates the practical application of stoichiometry principles. Whether in laboratory settings or industrial applications, mastering these calculations is essential for predicting reaction outcomes, optimizing processes, and ensuring safety.

Keywords: sodium water reaction, hydrogen gas production, stoichiometry, limiting reactant, chemical reaction calculation, molar ratios, chemical equations, H_2 gas, sodium hydroxide, chemical safety

Frequently Asked Questions

What is the balanced chemical equation for the reaction between sodium (Na) and water (H2O)?

The balanced chemical equation is 2Na + 2H2O → 2NaOH + H2.

How many moles of H2 are produced when 4.0 mol of Na reacts with water?

According to the balanced equation, 2 mol of Na produce 1 mol of H2. Therefore, 4.0 mol of Na will produce 2.0 mol of H2.

Does the initial amount of water (1.2 mol H2O) limit

the amount of H2 produced?

Yes. Since 2 mol of Na react with 2 mol of H2O, 4 mol of Na would need 4 mol of H2O to react completely. With only 1.2 mol H2O available, water is the limiting reagent, so H2 production is limited by water availability.

How much H2 will be produced when 4.0 mol Na reacts with only 1.2 mol H2O?

Since 2 mol of Na react with 2 mol of H2O, 1.2 mol of H2O will produce (1.2 mol H2O) × (1 mol H2 / 2 mol H2O) = 0.6 mol of H2.

What is the limiting reagent in this reaction?

Water (H2O) is the limiting reagent because only 1.2 mol is available, which limits the amount of H2 produced regardless of how much Na is present.

If excess sodium were present, how many moles of H2 could theoretically be produced from 1.2 mol H2O?

If Na is in excess, 1.2 mol of H2O would produce 0.6 mol of H2, based on the reaction ratio.

What is the significance of the molar ratio in predicting H2 production?

The molar ratio from the balanced equation (2Na : 1H2) helps determine how much H2 is produced from a given amount of sodium, considering limiting reagents.

How do you calculate the actual moles of H2 produced in this reaction scenario?

Identify the limiting reagent (water in this case), then use its amount and the molar ratio from the balanced equation to calculate H2, resulting in 0.6 mol of H2 produced.

Additional Resources

Number of Moles of H_2 Produced When 4.0 Mol Na Is Added to 1.2 Mol H_2O

Understanding the chemical reaction between sodium (Na) and water (H_2O) is fundamental in chemistry, especially in the context of stoichiometry—the calculation of reactants and products in chemical reactions. When sodium metal reacts with water, it produces sodium hydroxide (NaOH) and hydrogen gas (H_2). This reaction is not only classic in chemistry textbooks but also has practical implications in various industrial processes and safety considerations.

In this detailed review, we will explore the reaction mechanism, stoichiometric calculations, and the factors influencing the amount of hydrogen gas produced when 4.0 mol of sodium reacts with 1.2 mol of water.

Understanding the Reaction: Sodium and Water

The Chemical Equation

The reaction between sodium and water can be represented by the balanced chemical equation:

$$ 2 \, \text{Na} (s) + 2 \, \text{H}_2O (l) \rightarrow 2 \, \text{NaOH} (aq) + \text{H}_2 (g) $$

This equation indicates that:

- 2 moles of sodium react with 2 moles of water.
- The products are 2 moles of sodium hydroxide and 1 mole of hydrogen gas.

From the stoichiometry, the molar ratio of Na to H_2O to H_2 is:

- Na : H_2O : H_2 = 2 : 2 : 1

This ratio simplifies to:

- Na : H_2O = 1 : 1
- Na : H_2 = 2 : 1

Key Point: For every 2 moles of sodium, 1 mole of hydrogen gas is produced.

Reaction Conditions and Safety Considerations

Sodium reacts vigorously with water, often explosively, releasing hydrogen gas, which is flammable and potentially explosive in the presence of air. Therefore, in laboratory or industrial settings, careful control of reaction conditions is necessary to prevent accidents. The reaction is highly exothermic, releasing significant heat during the process.

Stoichiometric Calculations: Step-by-Step Approach

Understanding the amount of hydrogen gas produced requires a clear grasp of the molar relationships in the reaction. Here's how to approach the problem systematically:

Step 1: Identify the Given Data

- Moles of sodium (Na): 4.0 mol
- Moles of water (H_2O): 1.2 mol

Step 2: Determine the Limiting Reactant

Since both reactants are present, we need to determine which is the limiting reactant—the one that will be completely consumed first and thus limits the amount of hydrogen produced.

Using the molar ratio from the balanced equation:

- 2 mol Na reacts with 2 mol H_2O
- Therefore, 1 mol Na reacts with 1 mol H_2O

Calculating the amount of water required for 4.0 mol Na:

$$ \text{Water needed} = 4.0 \, \text{mol Na} \times \frac{2 \, \text{mol H}_2O}{2 \, \text{mol Na}} = 4.0 \, \text{mol H}_2O $$

But only 1.2 mol of water is available, which is less than the 4.0 mol needed. Therefore, water is the limiting reactant.

Step 3: Use the Limiting Reactant to Find Hydrogen Gas Produced

From the balanced equation, the molar ratio of H_2O to H_2 is:

$$ 2 \, \text{H}_2O : 1 \, \text{H}_2 $$

or equivalently,

$$ 1 \, \text{H}_2O : 0.5 \, \text{H}_2 $$

Thus, the moles of hydrogen gas produced are:

$$\text{Moles of H}_2 = \text{Moles of H}_2O \times \frac{1 \, \text{mol H}_2}{2 \, \text{mol H}_2O} = 1.2 \times \frac{1}{2} = 0.6 \, \text{mol}$$

Result: When 1.2 mol of water reacts completely with sodium, it produces 0.6 mol of hydrogen gas.

Additional Considerations and Real-World Implications

Extent of Reaction and Practical Conditions

While stoichiometry provides the theoretical maximum amount of H_2 gas produced, real-world reactions may not always reach this ideal due to:

- Incomplete reactions: Some sodium may remain unreacted if the reaction conditions are not optimized.
- Reaction kinetics: The rate at which sodium reacts with water influences how quickly hydrogen gas is generated.
- Physical factors: Surface area of sodium (e.g., granular vs. lump sodium), temperature, and stirring can affect the reaction's completeness.

In laboratory setups, excess sodium is often used to ensure complete reaction, but in this scenario, with only 4 mol Na and 1.2 mol H_2O, water is limiting.

Safety and Handling of Hydrogen Gas

Hydrogen is highly flammable and explosive when mixed with air in certain proportions (about 4% to 75%). Proper venting, absence of ignition sources, and controlled reaction conditions are essential when generating hydrogen gas in laboratory or industrial contexts.

Summary of Findings

- Limiting Reactant: Water (H_2O) at 1.2 mol.
- Hydrogen Gas Produced: 0.6 mol.
- Sodium Reacted: Since water is limiting, only 2.4 mol of sodium can react with 1.2 mol of water, but given 4 mol Na present, some sodium remains unreacted.

Additional Insights and Extensions

Calculating the Mass of Hydrogen Gas

Knowing the number of moles of H_2 produced allows us to find the mass:

- Molar mass of H_2 = 2.016 g/mol

$$ \text{Mass of H}_2 = 0.6 \, \text{mol} \times 2.016 \, \text{g/mol} \approx 1.21 \, \text{g} $$

Thus, approximately 1.21 grams of hydrogen gas can be generated under these conditions.

Energy Considerations

The reaction's enthalpy change (ΔH) is highly exothermic, with typical values around -285.8 kJ per mole of H_2 produced. This means:

$$ \text{Energy released} = 0.6 \, \text{mol} \times 285.8 \, \text{kJ/mol} \approx 171.5 \, \text{kJ} $$

This energy release is significant and should be managed carefully during practical applications.

Environmental and Safety Protocols

- Hydrogen gas should be collected and stored in proper vessels designed for flammable gases.
- Reactions should be conducted in well-ventilated areas or under a fume hood.
- Protective gear, including gloves and eye protection, is essential.
- Emergency measures should be in place for accidental leaks or ignition.

Conclusion: Final Summary

When 4.0 mol of sodium reacts with 1.2 mol of water:

- The limiting reactant is water.
- The maximum amount of hydrogen gas produced is 0.6 mol.
- This corresponds to about 1.21 grams of hydrogen gas.
- The reaction is highly exothermic and produces hazardous hydrogen gas, emphasizing the importance of safety precautions.

This analysis highlights the importance of stoichiometry in predicting reaction outcomes. It underscores how a seemingly simple reaction involves multiple considerations—limiting reactants, reaction conditions, safety, and practical applications—making it a cornerstone of chemical understanding and laboratory practice.

In summary, understanding the mole ratios and limiting reactants allows chemists to accurately predict the amount of hydrogen gas generated in the reaction between sodium and water. Such calculations are critical not only for academic purposes but also for industrial processes, safety protocols, and energy applications.

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