Calculate The Mass Of Magnesium Needed To Produce 72mL Of Hydrogen Gas At A Pressure Of 755mmHg And A

Calculate The Mass Of Magnesium Needed To Produce 72mL Of Hydrogen Gas At A Pressure Of 755mmHg And A crucial computational task often encountered in chemistry laboratories and educational settings. This problem involves understanding gas laws, stoichiometry, and chemical reactions to determine the amount of magnesium required to generate a specified volume of hydrogen gas under given conditions. Accurate calculations are essential for laboratory planning, safety considerations, and theoretical understanding of chemical reactions.

Understanding the Problem: Key Concepts and Data

Before delving into calculations, it is important to familiarize ourselves with the key concepts and data provided:

- Volume of hydrogen gas (V): 72 mL
- Pressure (P): 755 mmHg
- Temperature (T): Not explicitly given; assume standard laboratory conditions unless specified
- Chemical reaction: Magnesium reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas

The overall reaction is:

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

To find the mass of magnesium, we need to relate the volume of hydrogen gas produced to the amount of magnesium used, considering the gas laws and stoichiometry.

Converting Gas Volume to Moles: Applying the Ideal Gas Law

The ideal gas law is fundamental for converting gas volume to moles:

$PV = nRT$

Where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant
- T = temperature in Kelvin

Step 1: Standardize the units

- Convert pressure from mmHg to atmospheres:

$P_{atm} = 755 \text{ mmHg} \times (1 \text{ atm} / 760 \text{ mmHg}) \approx 0.9934 \text{ atm}$

- Convert volume from milliliters to liters:

$V_L = 72 \text{ mL} \times (1 \text{ L} / 1000 \text{ mL}) = 0.072 \text{ L}$

- Assume room temperature (T): typically 25°C or 298 K

Step 2: Use the ideal gas law to find moles of hydrogen

The gas constant R (in L·atm/(mol·K)):

R = 0.082057 L·atm/(mol·K)

Calculating:

$n = (P \times V) / (R \times T)$

$n = (0.9934 \text{ atm} \times 0.072 \text{ L}) / (0.082057 \text{ L·atm/(mol·K)} \times 298 \text{ K})$

$n \approx (0.0716448) / (24.447) \approx 0.00293 \text{ mol}$

Result: Approximately 0.00293 moles of H_2 gas are produced.

Relating Hydrogen Gas to Magnesium: Stoichiometry of the Reaction

The balanced chemical equation indicates that:

1 mol of Mg produces 1 mol of H_2 gas.

Therefore:

- Moles of magnesium needed = moles of hydrogen gas produced

Given:

$n_{H2} \approx 0.00293$ mol

- Mass of magnesium required:

Mass = moles × molar mass

Molar mass of Mg ≈ 24.305 g/mol

Mass of Mg = 0.00293 mol × 24.305 g/mol ≈ 0.0712 g

Conclusion: Approximately 0.0712 grams of magnesium are needed to produce 72 mL of hydrogen gas under the specified conditions.

Factors Affecting the Calculation and Practical Considerations

While the above calculation provides a theoretical value, real-world factors can influence the actual amount of magnesium required:

1. Gas Collection Conditions

- Gas may not be collected at ideal conditions; leaks or incomplete reactions can alter the actual volume of hydrogen produced.
- Measurement inaccuracies can also affect results.

2. Temperature Variations

- If the temperature differs from standard conditions, the ideal gas law calculation must be adjusted accordingly.

3. Reaction Efficiency

- Not all magnesium may react completely; side reactions or passivation layers can reduce efficiency.

4. Purity of Reactants

- Impurities in magnesium or hydrochloric acid can influence the reaction's extent.

Summary and Final Thoughts

Calculating the mass of magnesium needed to produce a specific volume of hydrogen gas involves integrating gas laws with chemical stoichiometry. In this scenario:

- Convert the volume of hydrogen gas to moles using the ideal gas law at the given pressure, volume, and temperature.
- Use the molar ratio from the balanced chemical equation to relate hydrogen gas to magnesium.
- Calculate the mass of magnesium based on its molar mass.

Final answer: Approximately 0.071 grams of magnesium are required to produce 72 mL of hydrogen gas at a pressure of 755 mmHg under standard laboratory temperature conditions.

This calculation exemplifies the importance of understanding gas laws, chemical reactions, and unit conversions in chemistry. Whether for academic purposes, laboratory experiments, or industrial applications, mastering these principles ensures accurate and safe handling of chemical processes.

Additional Resources for Further Learning

- Ideal Gas Law and Its Applications: Understanding how to manipulate PV=nRT in different scenarios.
- Chemical Stoichiometry: Techniques for relating reactants and products in balanced equations.
- Laboratory Safety: Proper handling of reactive metals like magnesium and gases like hydrogen.
- Environmental Considerations: Managing gases and chemical wastes responsibly.

By mastering these concepts, students and professionals can confidently perform calculations involving gases and chemical reactions, ensuring precision and safety in their work.

Keywords: magnesium calculation, hydrogen gas volume, ideal gas law, stoichiometry, chemical reaction, gas laws, laboratory chemistry

Frequently Asked Questions

How do I calculate the mass of magnesium needed to produce a specific volume of hydrogen gas under given conditions?

Use the ideal gas law (PV = nRT) to find moles of hydrogen, then relate it to the mass of magnesium via the reaction $Mg + 2HCl \rightarrow MgCl_2 + H_2$, considering molar ratios.

What is the first step in calculating the magnesium mass from the volume of hydrogen gas produced?

Convert the given volume of hydrogen gas to moles using the ideal gas law, adjusting for pressure, temperature, and volume.

How do I convert pressure from mmHg to atmospheres for the calculation?

Divide the pressure in mmHg by 760 to convert it to atmospheres (atm).

What temperature should I assume if it is not provided in the problem?

Typically, standard temperature (25°C or 298 K) is assumed unless specified otherwise.

How do I determine the number of moles of hydrogen gas produced from the given volume?

Use the ideal gas law: $n = PV / RT$, where P is pressure in atm, V is volume in liters, R is 0.0821 L·atm/(mol·K), and T is temperature in Kelvin.

What is the molar ratio between magnesium and hydrogen gas in the reaction?

From the balanced chemical equation, 1 mol of Mg produces 1 mol of H_2 gas.

How do I calculate the mass of magnesium needed once I know the moles of hydrogen gas?

Multiply the moles of hydrogen by the molar mass of magnesium (24.305 g/mol) to find the required mass of magnesium.

How does pressure affect the amount of magnesium required to produce a fixed volume of hydrogen?

Higher pressure increases the number of moles of gas produced per volume, thus requiring less magnesium; lower pressure requires more magnesium.

Can I use the ideal gas law directly if the gas is produced at non-standard conditions?

Yes, but you must use the actual pressure and temperature values provided in the problem for accurate calculation.

What is the final formula to calculate magnesium mass from the volume of hydrogen gas at given pressure and temperature?

First, convert volume to moles: n = (PV) / (RT). Then, calculate magnesium mass: mass = n × molar mass of Mg. Remember to convert pressure to atm and volume to liters.

Additional Resources

Calculate The Mass Of Magnesium Needed To Produce 72mL Of Hydrogen Gas At A Pressure Of 755mmHg And A

In the realm of chemistry, understanding the quantitative relationships between reactants and products is fundamental. Whether you're a student preparing for exams or a professional conducting laboratory experiments, accurately calculating the required amount of a reactant is crucial for safety, efficiency, and success. Today, we delve into a practical example: determining the mass of magnesium needed to produce a specific volume of hydrogen gas under certain conditions. This problem combines principles from stoichiometry, gas laws, and unit conversions, illustrating the interconnectedness of chemical concepts in real-world applications.

Understanding the Chemical Reaction

Before performing any calculations, it is essential to understand the underlying chemical reaction involved. Magnesium reacts with acids, such as hydrochloric acid, to produce hydrogen gas. The balanced chemical equation for this reaction is:

Mg (s) + 2 HCl (aq) → $MgCl_2$ (aq) + H_2 (g)

This tells us that one mole of magnesium produces one mole of hydrogen gas. Recognizing this 1:1 molar relationship is key to translating between the amount of magnesium and the volume of hydrogen gas produced.

Key Concepts and Principles

Several core concepts underpin the calculation:

- Ideal Gas Law: PV = nRT, where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant
- T = temperature (in Kelvin)

- Molar Mass of Magnesium: Approximately 24.305 g/mol.

- Conversion of Units: Ensuring all measurements are in compatible units, especially pressure, volume, and temperature.

- Standard Conditions: Understanding the implications of the given pressure and volume, and adjusting calculations accordingly.

Step 1: Convert Volume of Hydrogen Gas to Liters

The volume provided is 72 mL. Since the ideal gas law uses liters, convert this volume:

$$ \text{Volume in liters} = \frac{72\, \text{mL}}{1000} = 0.072\, \text{L} $$

This conversion is straightforward but essential for consistency in calculations.

Step 2: Adjust Pressure to Absolute Units

Given pressure is 755 mmHg. The ideal gas law requires pressure in atmospheres (atm):

$$ 1\, \text{atm} = 760\, \text{mmHg} $$

Thus,

$$ P = \frac{755\, \text{mmHg}}{760\, \text{mmHg/atm}} \approx 0.9934\, \text{atm} $$

This near-1 atm pressure simplifies calculations but still warrants precise conversion for accuracy.

Step 3: Determine the Temperature in Kelvin

The problem statement mentions "and A," which appears to be incomplete. Typically, temperature is a critical parameter. Assuming standard laboratory conditions, we can proceed with a common temperature:

$$ T = 25^\circ\text{C} = 25 + 273.15 = 298.15\, \text{K} $$

If a different temperature is specified in the original problem, substitute accordingly.

Step 4: Use the Ideal Gas Law to Find Moles of Hydrogen

The ideal gas constant R in units compatible with atm, liters, mol, and Kelvin is:

$$ R = 0.08206\, \text{L·atm/(mol·K)} $$

Applying the ideal gas law:

$$ n = \frac{PV}{RT} $$

Plugging in the known values:

$$ n = \frac{0.9934\, \text{atm} \times 0.072\, \text{L}}{0.08206\, \text{L·atm/(mol·K)} \times 298.15\, \text{K}} $$

Calculating numerator:

$$ 0.9934 \times 0.072 \approx 0.07165 $$

Calculating denominator:

$$ 0.08206 \times 298.15 \approx 24.45 $$

Thus,

$$ n \approx \frac{0.07165}{24.45} \approx 0.00293\, \text{mol} $$

This is the number of moles of hydrogen gas produced.

Step 5: Relate Moles of Hydrogen to Magnesium

From the balanced reaction, 1 mol of magnesium produces 1 mol of hydrogen gas. Therefore:

$$ \text{Moles of Mg} = \text{Moles of } H_2 = 0.00293\, \text{mol} $$

Now, calculate the mass of magnesium needed:

$$ \text{Mass of Mg} = \text{moles} \times \text{molar mass} $$

$$ \text{Mass of Mg} = 0.00293\, \text{mol} \times 24.305\, \text{g/mol} \approx 0.0712\, \text{g} $$

Result: Approximately 0.071 grams of magnesium are needed to produce 72 mL of hydrogen gas under the specified conditions.

Additional Considerations and Real-World Factors

While this calculation provides a theoretical value based on ideal conditions, practical scenarios may introduce variations:

- Non-ideal Gas Behavior: At high pressures or low temperatures, gases deviate from ideal behavior, affecting volume and moles calculations.
- Reaction Efficiency: Not all magnesium may react completely; side reactions or incomplete reactions can alter the actual amount needed.
- Temperature Variability: Laboratory temperature might differ from standard conditions, requiring adjustments.
- Measurement Precision: Small errors in measuring volume, pressure, or temperature can impact the final calculation.

In laboratory settings, scientists often include safety margins or perform multiple trials to ensure accuracy.

Conclusion: Bridging Theory and Practice

Calculating the mass of magnesium required to produce a specific volume of hydrogen gas involves a harmonious application of chemical equations, gas laws, and unit conversions. The process underscores the importance of understanding fundamental principles to predict reaction outcomes accurately. Whether designing a chemical synthesis, assessing safety protocols, or exploring energy applications like hydrogen fuel, mastering such calculations is invaluable. As science advances, these foundational skills continue to enable innovations and deepen our understanding of chemical processes, illustrating the elegant interconnectedness of theory and experimentation.

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