At Conditions Of Standard Temperature And Pressure, Determine How Many Liters Of Hydrogen Gas Are Produced

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Understanding how to determine the volume of hydrogen gas produced under standard conditions is fundamental in chemistry, especially in stoichiometry and gas law applications. Standard Temperature and Pressure (STP) serve as a reference point that allows chemists to compare gas quantities in a consistent manner. This article explores the principles involved in calculating the volume of hydrogen gas generated during chemical reactions, the relevant gas laws, and step-by-step methods to perform such calculations.

What Are Standard Temperature And Pressure (STP)?

Definition of STP

Standard Temperature and Pressure is a set of conditions widely used in chemistry to provide a standard reference for gas measurements. These conditions are typically defined as:

- Temperature: 0 degrees Celsius (273.15 K)
- Pressure: 1 atmosphere (atm)

Some contexts may use other standards such as 1 bar pressure, but 1 atm remains common in many educational and practical settings.

Significance of STP

Using STP allows chemists to:

- Compare gas volumes directly without needing to account for varying conditions
- Use molar volume directly to convert between moles and liters
- Apply gas laws straightforwardly, knowing the fixed temperature and pressure

At STP, one mole of an ideal gas occupies exactly 22.4 liters. This molar volume is a key concept for calculations involving gases.

Understanding the Chemical Reaction Producing Hydrogen Gas

Common Reactions Producing Hydrogen

Hydrogen gas (H_2) can be produced via several chemical reactions, generally involving metals, acids, or electrolysis. Some typical reactions include:

1. **Reaction of acids with metals:**
   Metal + Acid → Salt + Hydrogen
   Example: $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
2. **Reaction of water with metals:**
   Some metals react with steam to produce hydrogen
3. **Electrolysis of water:**
   $H_2O \rightarrow H_2 + O_2$ (via electrical current)

For simplicity, this article focuses on the reaction between zinc and hydrochloric acid, a common laboratory example.

General Stoichiometry of Hydrogen-Producing Reactions

The key to calculating the volume of hydrogen gas is understanding the molar ratio between reactants and products. In the example of zinc reacting with hydrochloric acid:

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

The molar ratio of zinc to hydrogen gas is 1:1, meaning one mole of zinc produces one mole of hydrogen gas.

Calculating the Volume of Hydrogen Gas at STP

Step 1: Determine the Moles of Reactant

Begin by identifying the amount of reactant that reacts, typically given in grams or moles.

- If given in grams, convert to moles using the molar mass.

Example:
If 5 grams of zinc are used:
Molar mass of Zn = 65.38 g/mol
Moles of Zn = 5 g / 65.38 g/mol ≈ 0.0765 mol

Step 2: Use the Stoichiometric Relationship to Find Moles of Hydrogen

- From the balanced chemical equation, relate the moles of zinc to moles of hydrogen gas.

In the example:
1 mol Zn → 1 mol H_2
Therefore, 0.0765 mol Zn → 0.0765 mol H_2

Step 3: Convert Moles of Hydrogen to Volume at STP

- At STP, 1 mol of gas occupies 22.4 liters.

Calculation:
Volume of H_2 = moles of H_2 × 22.4 L/mol
= 0.0765 mol × 22.4 L/mol ≈ 1.7136 liters

Result:
Approximately 1.71 liters of hydrogen gas are produced from 5 grams of zinc reacting with excess hydrochloric acid at STP.

Factors Affecting the Calculation and Real-World Considerations

While the above calculations assume ideal behavior, real-world factors can influence results:

1. Gas Non-Ideal Behavior

- Under high pressure or low temperature, gases deviate from ideal behavior, affecting volume calculations.

2. Reaction Completion

- Reactions may not go to completion or may be limited by reactant availability, influencing the amount of hydrogen produced.

3. Purity of Reactants

- Impurities may reduce the effective amount of reactant reacting, thus decreasing hydrogen yield.

4. Measurement and Experimental Errors

- Loss of gas during collection, leakage, or measurement inaccuracies can impact the volume obtained.

Alternative Methods to Calculate Hydrogen Gas Volume

Aside from direct stoichiometry, other approaches exist:

Using Gas Laws

- Combining ideal gas law PV = nRT to determine volume when pressure, temperature, or moles are known, especially under varying conditions.

Application of the Ideal Gas Law

- Rearranged to:
$V = (nRT)/P$

- Where:
$R = 0.0821$ L·atm/(mol·K)
T = temperature in Kelvin
P = pressure in atm

- At STP, this simplifies to $V = n \times 22.4$ L.

Practical Example: Calculating Hydrogen from Aluminum and Hydrochloric Acid

Suppose 10 grams of aluminum are reacted:

$Al + 3HCl \rightarrow AlCl_3 + 3H_2$

- Molar mass of Al = 26.98 g/mol
- Moles of Al = 10 g / 26.98 g/mol ≈ 0.3707 mol

- Moles of H_2 produced:
1 mol Al → 3 mol H_2
0.3707 mol Al → 0.3707 × 3 ≈ 1.112 mol H_2

- Volume at STP:
1.112 mol × 22.4 L/mol ≈ 24.9 liters

Thus, approximately 24.9 liters of hydrogen would be produced under ideal conditions.

Summary and Final Remarks

Calculating the volume of hydrogen gas produced at standard temperature and pressure involves understanding the chemical reaction's stoichiometry, converting reactant quantities to moles, and applying the molar volume of gases at STP. The key steps include:

- Identifying the balanced chemical equation and molar ratios
- Converting reactant mass to moles
- Using the molar ratio to find moles of hydrogen gas

- Multiplying by the molar volume (22.4 L/mol at STP) to obtain volume in liters

This systematic approach allows chemists and students alike to estimate hydrogen gas production accurately under standard conditions, facilitating laboratory planning, industrial processes, and theoretical calculations.

Remember: Real-world factors such as reaction efficiency, purity, and gas collection methods can influence actual yields, so calculations often serve as ideal estimates.

Frequently Asked Questions

How do you calculate the volume of hydrogen gas produced at standard temperature and pressure (STP)?

To calculate the volume of hydrogen gas at STP, first write the balanced chemical equation, determine the moles of reactant involved, then use the molar volume of gas at STP (22.4 L per mole) to find the volume of hydrogen produced.

What is the molar volume of a gas at standard temperature and pressure (STP)?

The molar volume of an ideal gas at STP is 22.4 liters per mole.

Given a reaction, how do you determine the liters of hydrogen gas produced at STP?

Identify the mole ratio from the balanced equation, calculate the moles of the limiting reactant, then multiply by 22.4 L/mole to find the volume of hydrogen gas at STP.

If 2 grams of zinc react with acid, how many liters of hydrogen gas are produced at STP?

First, calculate moles of zinc (using molar mass), then use the balanced equation to find moles of hydrogen generated, and multiply by 22.4 L/mole to get the volume at STP.

Why is the molar volume of gas at STP important in

calculating gas volumes?

Because it provides a standard volume per mole for gases at STP, allowing easy conversion between moles and liters regardless of the specific gas involved.

How does temperature and pressure affect the calculation of hydrogen gas volume at STP?

At STP, temperature and pressure are standardized; deviations from these conditions require using gas laws (PV=nRT) to adjust the volume calculations accordingly.

Can you determine the volume of hydrogen gas produced from a reaction if the reactant is in excess?

Yes, by calculating the moles of the limiting reactant, then using the molar ratio and molar volume at STP to find the hydrogen volume produced.

What are the common reactions that produce hydrogen gas at standard conditions?

Reactions such as the reaction of metals like zinc, magnesium, or aluminum with acids like hydrochloric acid, produce hydrogen gas at standard conditions.

How do you convert moles of hydrogen gas to liters at STP?

Multiply the number of moles by 22.4 liters per mole (the molar volume at STP) to convert to liters.

What assumptions are made when calculating hydrogen gas volume at STP?

Assumptions include that the gas behaves ideally, temperature is 0°C (273.15 K), pressure is 1 atm, and the gas law applies without deviations.

Additional Resources

At Conditions Of Standard Temperature And Pressure, Determine How Many Liters Of Hydrogen Gas Are Produced

Understanding the relationship between chemical reactions and the volumes of gases involved is fundamental in chemistry, especially in the realm of gases

and their behaviors under specific conditions. When dealing with gases such as hydrogen, standard temperature and pressure (STP) serve as a benchmark for measuring and comparing gas volumes. This comprehensive guide explores how to determine the volume of hydrogen gas produced at STP, delving into the principles of stoichiometry, gas laws, and practical applications.

Introduction to Standard Temperature and Pressure (STP)

Before calculating the volume of hydrogen gas produced, it is essential to understand what STP entails and why it acts as a reference point.

Definition of STP

- Standard Temperature: 0°C (273.15 K)
- Standard Pressure: 1 atm (101.325 kPa)
- Standard Molar Volume: At STP, one mole of any ideal gas occupies 22.4 liters.

This standardized condition allows chemists to compare gas volumes directly and simplifies calculations involving gases.

Why Use STP?

- Provides a common basis for measurements.
- Facilitates calculations involving gases, especially in chemical reactions.
- Helps in converting between moles and volume for gases.

Fundamental Concepts in Gas Volume Calculations

To determine how many liters of hydrogen are produced, several core principles and laws are employed:

Avogadro's Law

- States that equal volumes of gases at the same temperature and pressure contain an equal number of molecules.
- Implies that volume is directly proportional to the number of moles at STP.

Ideal Gas Law

- $PV = nRT$
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant (8.314 J/(mol·K))
- T = temperature in Kelvin
- Used when conditions deviate from STP, but at STP, simplified calculations are often used.

Stoichiometry

- The quantitative relationship between reactants and products in a chemical reaction.
- Determines how many moles of hydrogen gas are produced from a given amount of reactant.

Common Reactions Producing Hydrogen Gas

Hydrogen gas (H_2) is produced via various chemical reactions, notably:

1. Metal Acid Reactions

$$
\text{Metal} + \text{Acid} \rightarrow \text{Salt} + \text{Hydrogen gas}
$$

- Example: Zinc reacting with hydrochloric acid

$$
Zn + 2HCl \rightarrow ZnCl_2 + H_2
$$

- Reaction yields 1 mole of H_2 per mole of zinc.

2. Water Splitting (Electrolysis)

- Using electrical energy to split water into hydrogen and oxygen:

$$
2H_2O \xrightarrow{\text{electricity}} 2H_2 + O_2
$$

- Produces hydrogen gas directly from water, often used in industrial hydrogen production.

3. Decomposition of Hydrocarbons

- High-temperature reactions like methane reforming:
$$
CH_4 + H_2O \rightarrow CO + 3H_2
$$
- Produces hydrogen along with other gases.

Calculating Hydrogen Gas Volume: Step-by-Step Approach

To determine the volume of hydrogen gas produced at STP, follow these steps:

Step 1: Write and Balance the Chemical Equation

- Ensure the reaction is properly balanced to identify the molar ratios.
- Example: Reaction of zinc with hydrochloric acid:
$$
Zn + 2HCl \rightarrow ZnCl_2 + H_2
$$
- Molar ratio: 1 mol Zn produces 1 mol H_2.

Step 2: Determine Moles of Reactant Used

- Given the amount of reactant (mass, volume, or moles), calculate the moles of hydrogen expected.
- If starting with a mass:
$$
n = \frac{\text{mass}}{\text{molar mass}}
$$
- Example: 65.38 g of zinc:
$$
n_{Zn} = \frac{65.38 \text{ g}}{65.38 \text{ g/mol}} = 1 \text{ mol}
$$

Step 3: Use Stoichiometry to Find Moles of Hydrogen Gas

- Based on the balanced equation, relate the moles of reactant to moles of hydrogen.
- Example: 1 mol Zn produces 1 mol H_2.

Step 4: Convert Moles of Hydrogen to Volume at STP

- Use the molar volume at STP:
$$
V_{H_2} = n_{H_2} \times 22.4 \text{ L}
$$
- For 1 mol H_2:
$$
V_{H_2} = 1 \times 22.4 \text{ L} = 22.4 \text{ L}
$$

Practical Examples and Applications

Let's consider some real-world scenarios to solidify understanding.

Example 1: Calculating Hydrogen Produced from Zinc and Hydrochloric Acid

Suppose 13.0 grams of zinc are reacted with excess hydrochloric acid.

Solution:
1. Calculate moles of zinc:
$$
n_{Zn} = \frac{13.0 \text{ g}}{65.38 \text{ g/mol}} \approx 0.199 \text{ mol}
$$
2. Determine moles of H_2 produced:
$$
n_{H_2} = n_{Zn} = 0.199 \text{ mol}
$$
3. Calculate volume at STP:
$$
V_{H_2} = 0.199 \text{ mol} \times 22.4 \text{ L/mol} \approx 4.46 \text{ L}
$$

Result: Approximately 4.46 liters of hydrogen gas are produced under STP conditions.

Example 2: Electrolysis of Water to Produce Hydrogen

- Suppose 18 grams of water are electrolyzed.

Solution:
1. Calculate moles of water:
$$
n_{H_2O} = \frac{18 \text{ g}}{18.015 \text{ g/mol}} \approx 1 \text{ mol}
$$
2. Determine moles of hydrogen:
- From the reaction:
$$
2H_2O \rightarrow 2H_2 + O_2
$$
- 2 mol water produce 2 mol H_2, so 1 mol water produces 1 mol H_2.
3. Calculate volume:
$$
V_{H_2} = 1 \text{ mol} \times 22.4 \text{ L} = 22.4 \text{ L}
$$

Result: 22.4 liters of hydrogen gas can be obtained from 18 grams of water via electrolysis at STP.

Adjustments for Non-STP Conditions

While calculations at STP are straightforward, real-world conditions often deviate from standard parameters. To account for this:

Use of Ideal Gas Law

- For temperatures and pressures other than STP, apply the ideal gas law:
$$
V = \frac{nRT}{P}
$$
- Convert temperature to Kelvin and pressure to atmospheres.

Example: Hydrogen Volume at 25°C and 2 atm

- Using 1 mol H_2:
$$
V = \frac{1 \times 0.0821 \times (25 + 273.15)}{2} \approx \frac{1 \times 0.0821 \times 298.15}{2} \approx 12.23 \text{ L}
$$
- This shows that under these conditions, 1 mol of H_2 occupies approximately 12.23 liters.

Factors Affecting Gas Volume Calculations

Several factors can influence the accuracy of gas volume determinations:

- Purity of reactants: Impurities can affect the amount of hydrogen produced.
- Reaction completeness: Incomplete reactions lead to less hydrogen than theoretically calculated.
- Gas collection efficiency: Losses during collection (leakage, absorption) can reduce measured volumes.
- Temperature and pressure variations: Deviations from STP require adjustments via the gas law.
- Gas behavior: Real gases deviate slightly from ideal behavior at high pressures or low temperatures.

Real-World Applications and Significance

Calculating hydrogen gas volume at STP isn't just an academic exercise—it has profound industrial and environmental implications:

- Hydrogen Fuel Cells: Precise volume calculations are vital for designing fuel cell systems for vehicles and power generation.
- Industrial Hydrogen Production: Quantifying hydrogen output from reactions guides scaling processes.
- Environmental Impact Assessments: Accurate estimates of hydrogen emissions are

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