How Many Liters Of Chlorine Gas At 25.0c And 0.950 Atm Can Be Produced By The Reaction Of 23.3 G Of Mno2?

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Understanding the relationship between chemical reactions and the gases they produce is fundamental in chemistry. In this article, we will explore how to determine the volume of chlorine gas generated from a specified mass of manganese dioxide (MnO_2) under certain temperature and pressure conditions. This involves applying stoichiometry principles, ideal gas law calculations, and understanding reaction mechanisms. By the end of this discussion, you will be able to confidently calculate the volume of chlorine gas produced in similar reactions.

Overview of the Reaction Involving MnO_2 and Chlorine Gas

To determine the volume of chlorine gas produced, we first need to understand the chemical reaction involved. Manganese dioxide (MnO_2) can act as an oxidizing agent, and one common reaction is its interaction with hydrochloric acid (HCl) to produce chlorine gas (Cl_2). The typical reaction is:

$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$

This reaction indicates that one mole of MnO_2 reacts with four moles of HCl to produce one mole of Cl_2 gas. For our calculations, we focus on the molar ratio between MnO_2 and Cl_2, which is 1:1.

Step 1: Calculating Moles of MnO_2

The first step involves converting the given mass of MnO_2 into moles.

Molar Mass of MnO_2

Let's compute the molar mass:

- Manganese (Mn): approximately 54.94 g/mol
- Oxygen (O): approximately 16.00 g/mol

So,

Molar mass of MnO_2 = 54.94 + 2 × 16.00 = 54.94 + 32.00 = 86.94 g/mol

Calculating Moles of MnO_2

Given mass: 23.3 g

Number of moles (n) = mass / molar mass = 23.3 g / 86.94 g/mol ≈ 0.268 mol

Result:

$n(MnO_2) \approx 0.268$ mol

Step 2: Determining Moles of Chlorine Gas Produced

From the reaction, the molar ratio between MnO_2 and Cl_2 is 1:1, so:

Moles of Cl_2 = Moles of MnO_2 = 0.268 mol

This means that 0.268 mol of MnO_2 will produce approximately 0.268 mol of Cl_2 gas under ideal conditions.

Step 3: Applying the Ideal Gas Law to Find Volume

The ideal gas law relates pressure, volume, temperature, and moles:

$PV = nRT$

Where:
- P = pressure (atm)
- V = volume (liters)
- n = number of moles
- R = universal gas constant (0.08206 L·atm/mol·K)
- T = temperature in Kelvin (K)

Converting Temperature to Kelvin

Given temperature: 25.0°C

T(K) = 25.0 + 273.15 = 298.15 K

Calculating Volume of Chlorine Gas

Using the ideal gas law:

$V = (nRT) / P$

Plugging in the values:

$V = (0.268 \text{ mol} \times 0.08206 \text{ L·atm/mol·K} \times 298.15 \text{ K}) / 0.950 \text{ atm}$

Calculating numerator:

$0.268 \times 0.08206 \times 298.15 \approx 6.55 \text{ L·atm}$

Dividing by pressure:

$V \approx 6.55 / 0.950 \approx 6.89$ liters

Therefore, approximately 6.89 liters of chlorine gas can be produced.

Summary of the Calculation Steps

Here's a quick overview of the process:

1. Convert the mass of MnO_2 to moles using its molar mass.
2. Use the molar ratio from the balanced chemical equation to find moles of Cl_2 produced.
3. Apply the ideal gas law at the given temperature and pressure to find the volume of Cl_2 gas.

Additional Considerations and Assumptions

While the calculation above provides an accurate estimate under ideal conditions, several factors can influence the actual volume of chlorine gas produced:

- **Non-ideal gas behavior:** At high pressures or low temperatures, gases deviate from ideal behavior.
- **Reaction completeness:** The calculation assumes complete reaction with no side reactions.

- **Purity of reactants:** Impurities or excess reactants can alter the amount of gas produced.
- **Experimental conditions:** Variations in temperature or pressure during the reaction can affect the volume.

In practical scenarios, these factors should be considered for more precise measurements.

Conclusion

By understanding the stoichiometry of the reaction between MnO_2 and hydrochloric acid, and applying the ideal gas law, we have determined that approximately 6.89 liters of chlorine gas can be produced at 25.0°C and 0.950 atm from 23.3 grams of MnO_2. This calculation exemplifies how fundamental chemistry principles can be combined to predict real-world outcomes, essential for laboratory planning, industrial processes, and safety considerations involving reactive gases.

Key Takeaways:
- Moles of MnO_2 can be calculated from mass and molar mass.
- Molar ratios from the balanced equation determine moles of chlorine gas produced.
- The ideal gas law allows conversion from moles to volume under specified conditions.
- Always consider real-world deviations from ideal behavior for precise applications.

Understanding these principles empowers chemists and students alike to analyze reactions involving gases effectively and accurately.

Frequently Asked Questions

What is the balanced chemical equation for the reaction of MnO_2 to produce chlorine gas?

The reaction typically involves MnO_2 reacting with a suitable reagent like hydrochloric acid to produce chlorine gas, such as: $MnO_2 + 4\ HCl \rightarrow MnCl_2 + Cl_2 + 2\ H_2O$.

How do you calculate the moles of MnO_2 used in the reaction?

Calculate moles of MnO_2 by dividing the given mass by its molar mass: Molar mass of MnO_2 is approximately 86.94 g/mol, so moles = 23.3 g / 86.94 g/mol ≈

0.268 mol.

What is the molar ratio between MnO_2 and Cl_2 in the reaction?

From the balanced equation, 1 mol of MnO_2 produces 1 mol of Cl_2, so the molar ratio is 1:1.

How do you calculate the volume of chlorine gas produced at 25°C and 0.950 atm?

Use the ideal gas law: $PV = nRT$. Rearranged: $V = (nRT) / P$. Plug in n (moles of Cl_2), R = 0.08206 L·atm/(mol·K), T = 298 K, and P = 0.950 atm to find the volume.

What is the final volume of chlorine gas produced in liters under the given conditions?

Using n = 0.268 mol, T = 298 K, P = 0.950 atm: $V = (0.268 \text{ mol} \times 0.08206 \text{ L·atm/(mol·K)} \times 298 \text{ K}) / 0.950 \text{ atm} \approx 6.54$ liters.

Why is it important to consider temperature and pressure when calculating gas volume?

Because gases are compressible and their volume depends on temperature and pressure, applying the ideal gas law ensures accurate volume calculations under specific conditions.

Additional Resources

How Many Liters Of Chlorine Gas At 25.0°C And 0.950 Atm Can Be Produced By The Reaction Of 23.3 G Of MnO_2?

In the realm of chemical reactions, understanding how quantities of reactants translate into gaseous products is fundamental — especially when it involves environmentally relevant gases like chlorine. Imagine a scenario in a laboratory or industrial setting where a chemist needs to determine the volume of chlorine gas produced from a specific amount of manganese dioxide (MnO_2). This question becomes particularly pertinent when considering safety, efficiency, and environmental impact. Today, we delve into the detailed calculation process to find out: How many liters of chlorine gas at 25.0°C and 0.950 atm can be generated from 23.3 grams of MnO_2?

Understanding the Reaction: Manganese Dioxide and Chlorine Gas Production

Before jumping into calculations, it’s essential to grasp the chemical reaction involved. Manganese dioxide (MnO_2) can react with concentrated hydrochloric acid (HCl) or other reagents to produce chlorine gas (Cl_2). The most common laboratory or industrial reaction involves the reaction of MnO_2 with hydrochloric acid:

Reaction:

$$ \text{MnO}_2 + 4 \text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2 \text{H}_2O $$

This balanced chemical equation indicates that:

- 1 mole of MnO_2 produces 1 mole of Cl_2 gas.

This molar ratio (1:1) simplifies calculations significantly.

Step 1: Calculating the Moles of MnO_2 Reacted

The initial step in determining the volume of Cl_2 gas produced is to convert the given mass of MnO_2 into moles.

Given Data:

- Mass of MnO_2 = 23.3 grams
- Molar mass of MnO_2:

- Manganese (Mn): approximately 54.94 g/mol
- Oxygen (O): approximately 16.00 g/mol

Calculating:

$$ \text{Molar mass of MnO}_2 = 54.94 + 2 \times 16.00 = 54.94 + 32.00 = 86.94\, \text{g/mol} $$

Calculating moles:

$$ \text{Moles of MnO}_2 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{23.3\, \text{g}}{86.94\, \text{g/mol}} \approx 0.268\, \text{mol} $$

Step 2: Determining Moles of Chlorine Gas Produced

From the balanced reaction, 1 mol of MnO_2 produces 1 mol of Cl_2.

Therefore,

$$ \text{Moles of Cl}_2 = \text{Moles of MnO}_2 = 0.268\, \text{mol} $$

Step 3: Applying the Ideal Gas Law to Find the Volume of Cl_2

The ideal gas law relates pressure, volume, temperature, and moles of gas:

$$ PV = nRT $$

Where:

- P = pressure (atm)
- V = volume (liters)
- n = number of moles
- R = ideal gas constant = 0.08206 L·atm/(mol·K)
- T = temperature in Kelvin (K)

Given Data:

- $P = 0.950\, \text{atm}$
- $T = 25.0^\circ C = 25.0 + 273.15 = 298.15\, \text{K}$
- $n = 0.268\, \text{mol}$

Calculating the volume:

$$ V = \frac{nRT}{P} $$

$$ V = \frac{0.268 \times 0.08206 \times 298.15}{0.950} $$

Calculating numerator:

$$ 0.268 \times 0.08206 \times 298.15 \approx 6.54 $$

Dividing by pressure:

$$ V = \frac{6.54}{0.950} \approx 6.88\, \text{liters} $$

Final Answer:

Approximately 6.88 liters of chlorine gas at 25.0°C and 0.950 atm can be produced from 23.3 grams of MnO_2.

Deeper Insights and Practical Considerations

While the calculation appears straightforward, several factors influence the actual yield and measurement in real-world settings.

1. Reaction Efficiency

Chemical reactions often do not proceed to 100% completion due to side reactions or incomplete conversion. The calculation assumes perfect efficiency. In practice, yields might be slightly less.

2. Gas Purity and Measurement Conditions

The volume calculated assumes ideal gas behavior and no impurities. Variations in temperature, pressure, or gas collection methods can affect observed volume.

3. Safety Measures

Chlorine gas is toxic and corrosive. Proper ventilation, gas detection systems, and protective equipment are essential when handling or producing chlorine.

Summary

To encapsulate, the process involves:

- Converting the mass of MnO_2 to moles.
- Using the molar ratio from the balanced chemical equation to find the moles of Cl_2.
- Applying the ideal gas law to determine the volume at specific conditions.

This calculation exemplifies the interconnectedness of stoichiometry, gas laws, and practical chemistry. Whether for industrial production or laboratory experiments, such calculations enable chemists to predict yields, plan safety measures, and optimize processes.

Conclusion

Understanding how to translate a given mass of reactant into the volume of gaseous product under specified conditions is a cornerstone of chemical engineering and laboratory science. In this case, from 23.3 grams of MnO_2, roughly 6.88 liters of chlorine gas can be generated at 25.0°C and 0.950 atm, assuming ideal behavior and complete reaction. Mastery of these calculations aids in designing safe, efficient, and environmentally conscious chemical processes—an essential competency in the modern chemical industry.

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