Calculate The Mass Of Chlorine Gas Contained In A 5.00dm^3 Flask At 25C And 98KPa Pressure

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Understanding how to determine the mass of a gas under specific conditions is a fundamental concept in chemistry, especially when dealing with gases like chlorine. Whether you're a student preparing for exams, a chemist conducting laboratory experiments, or an enthusiast interested in chemical calculations, mastering how to calculate the mass of a gas using the ideal gas law is essential. This article provides a detailed, step-by-step guide to calculating the mass of chlorine gas in a given container at a specified temperature and pressure, with an emphasis on clarity and SEO optimization for those seeking in-depth explanations.

Introduction and Context

Chlorine gas (Cl2) is a diatomic molecule widely used in various industrial processes, including water purification, disinfectants, and the production of plastics. Knowing how to determine the amount of chlorine gas present in a container under specific conditions is crucial for safety, efficiency, and compliance with regulatory standards.

In this scenario, we are tasked with calculating the mass of chlorine gas contained in a 5.00 dm3 flask at a temperature of 25°C and a pressure of 98 kPa. This involves applying the ideal gas law, understanding the relationships between pressure, volume, temperature, and moles, and converting moles to mass.

Understanding the Ideal Gas Law

The ideal gas law is a fundamental equation in chemistry that describes the behavior of ideal gases:

The Ideal Gas Equation

\[PV = nRT \]

Where:

- P = Pressure (in pascals, Pa)
- V = Volume (in cubic meters, m3)
- n = Number of moles of gas
- R = Universal gas constant (8.314 J/(mol·K))

- T = Temperature (in kelvins, K)

This law allows us to calculate the number of moles of gas in a container when the pressure, volume, and temperature are known.

Converting Units for the Ideal Gas Law

Before applying the ideal gas law, ensure all units are compatible:

- Pressure: Convert from kilopascals (kPa) to pascals (Pa)

$$ 98\, \text{kPa} = 98,000\, \text{Pa} $$

- Volume: Convert from cubic decimeters (dm3) to cubic meters (m3)

$$ 1\, \text{dm}^3 = 1 \times 10^{-3}\, \text{m}^3 $$

$$ 5.00\, \text{dm}^3 = 5.00 \times 10^{-3}\, \text{m}^3 $$

- Temperature: Convert from Celsius to Kelvin

$$ T(K) = T(°C) + 273.15 $$

$$ 25°C = 25 + 273.15 = 298.15\, \text{K} $$

Step-by-Step Calculation of the Moles of Chlorine Gas

Now, with all units converted, proceed to calculate the moles of chlorine gas using the ideal gas law.

1. Write Down the Known Values

- Pressure (P): 98,000 Pa
- Volume (V): 5.00 × 10-3 m3
- Temperature (T): 298.15 K
- Gas constant (R): 8.314 J/(mol·K)

2. Rearrange the Ideal Gas Law to Solve for n

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

3. Plug in the Known Values

$$ n = \frac{98,000\, \text{Pa} \times 5.00 \times 10^{-3}\, \text{m}^3}{8.314\, \text{J/(mol·K)} \times 298.15\, \text{K}} $$

4. Perform the Calculation

$$ n = \frac{490\, \text{Pa·m}^3}{2477.76\, \text{J/mol}} $$

Note: 1 Pa·m3 = 1 Joule (J), so:

$$ n = \frac{490\, \text{J}}{2477.76\, \text{J/mol}} $$

$$ n \approx 0.1975\, \text{mol} $$

So, approximately 0.198 mol of chlorine gas is contained in the flask.

Calculating the Mass of Chlorine Gas

Once the number of moles is known, converting this to mass involves using the molar mass of chlorine gas.

The Molar Mass of Chlorine Gas

Chlorine gas (Cl_2) has a molar mass calculated as:

- Atomic mass of chlorine (Cl): approximately 35.45 g/mol

$$ \text{Molar mass of Cl}_2 = 2 \times 35.45\, \text{g/mol} = 70.90\, \text{g/mol} $$

Calculating the Mass

$$ \text{Mass} = n \times \text{molar mass} $$

$$ \text{Mass} = 0.198\, \text{mol} \times 70.90\, \text{g/mol} $$

$$ \text{Mass} \approx 14.07\, \text{g} $$

Therefore, the mass of chlorine gas contained in the flask is approximately 14.07 grams.

Summary of the Calculation Process

To summarize:

1. Convert all units to SI units:
- Pressure: kPa to Pa
- Volume: dm3 to m3
- Temperature: °C to K
2. Apply the ideal gas law to find the number of moles:

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

3. Multiply the moles by the molar mass of chlorine to find the mass:

$$\text{Mass} = n \times 70.90\, \text{g/mol}$$

This systematic approach ensures accurate calculations and a clear understanding of the process.

Additional Considerations and Real-World Applications

While the ideal gas law provides a good approximation, real gases may deviate slightly from ideal behavior, especially at high pressures or low temperatures. For most practical purposes and typical laboratory conditions, the ideal gas law yields sufficiently accurate results.

Applications include:

- Chemical manufacturing: determining quantities of gases needed or produced.
- Safety protocols: calculating gas quantities to prevent over-pressurization.
- Environmental monitoring: assessing gas concentrations in various scenarios.

Safety tip: Always handle chlorine gas with appropriate safety measures due to its toxic and corrosive nature.

Conclusion

Calculating the mass of chlorine gas in a given container under specific conditions involves understanding and applying the ideal gas law, unit conversions, and molar mass calculations. By following a structured approach, you can accurately determine the amount of chlorine gas contained in a flask at 25°C and 98 kPa pressure. This process is fundamental in chemistry, enabling practitioners to perform precise measurements crucial for laboratory safety, industrial applications, and environmental assessments.

Key points to remember:

- Convert units to SI units before calculations.
- Use the ideal gas law to find moles.

- Multiply moles by molar mass for mass.
- Always consider safety when working with hazardous gases like chlorine.

By mastering these calculations, you enhance your analytical skills and deepen your understanding of gas behavior in real-world contexts.

Meta Description: Learn how to accurately calculate the mass of chlorine gas in a 5.00 dm3 flask at 25°C and 98 kPa pressure using the ideal gas law. Step-by-step guide with unit conversions and practical insights.

Frequently Asked Questions

What is the first step to calculate the mass of chlorine gas in the flask?

Convert the given pressure, volume, and temperature into the ideal gas law equation PV = nRT to find the number of moles of chlorine gas.

Which gas law is used to determine the number of moles of chlorine in this problem?

The ideal gas law (PV = nRT) is used to relate pressure, volume, temperature, and moles of the gas.

What units must be used for pressure, volume, and temperature in the ideal gas law calculations?

Pressure should be in pascals (Pa), volume in cubic meters (m^3), and temperature in kelvin (K).

How do you convert the given volume from dm^3 to m^3?

Since 1 dm^3 = 1 x 10^-3 m^3, multiply 5.00 dm^3 by 1 x 10^-3 to get 5.00 x 10^-3 m^3.

What is the molar mass of chlorine gas (Cl2) used in this calculation?

The molar mass of Cl2 is approximately 70.90 g/mol.

How do you calculate the mass of chlorine gas after finding the number of moles?

Multiply the number of moles by the molar mass (70.90 g/mol) to obtain the mass in grams.

What is the final formula to calculate the mass of chlorine gas in this problem?

Mass = (PV / RT) × molar mass of Cl2, where P is pressure in Pa, V in m^3, R = 8.314 J/(mol·K), and T in K.

Additional Resources

Chlorine Gas Mass Calculation: An Expert Breakdown of Conditions and Computation

When it comes to understanding the fundamental principles of gases in chemistry, calculating the mass of a specific gas under given conditions is a vital skill. Today, we focus on determining the mass of chlorine gas contained within a 5.00 dm^3 flask at a temperature of 25°C and a pressure of 98 kPa. This task exemplifies the practical application of the ideal gas law, a cornerstone concept in chemical physics. Let's explore this calculation in depth, unraveling each step with clarity and precision.

Understanding the Context: The Significance of Gas Calculations

Before delving into the calculation, it's essential to appreciate why such computations are fundamental. Gases are ubiquitous in chemical processes, industrial applications, and environmental systems. Accurately determining the mass of a gas under specific conditions enables scientists and engineers to:

- Design safe and efficient chemical reactors
- Calculate reactant and product quantities in stoichiometric reactions
- Monitor environmental pollutants
- Develop gas storage and transportation protocols

In our scenario, knowing the mass of chlorine gas (Cl_2) in a flask at given conditions allows for precise control during laboratory experiments or industrial processes involving chlorine, which is widely used for disinfection, manufacturing plastics, and other chemical syntheses.

Fundamental Principles: The Ideal Gas Law

At the heart of this calculation lies the ideal gas law, expressed as:

\[PV = nRT \]

where:

- P = pressure (in pascals, Pa)
- V = volume (in cubic meters, m^3)
- n = number of moles of gas
- R = universal gas constant ($8.314\, \mathrm{J\, mol^{-1}\, K^{-1}}$)
- T = temperature (in kelvins, K)

This law provides a relationship between the physical conditions of a gas and its amount in moles. Once n is determined, calculating the mass becomes straightforward by multiplying the number of moles by the molar mass of chlorine.

Converting Units for Consistency

To ensure accuracy, all quantities must be in compatible SI units:

- Volume: Given as 5.00 dm^3

Conversion:
$$
1\, \mathrm{dm^3} = 1\, \mathrm{L} = 1 \times 10^{-3}\, \mathrm{m^3}
$$

Therefore:
$$
V = 5.00\, \mathrm{dm^3} = 5.00 \times 10^{-3}\, \mathrm{m^3}
$$

- Temperature: 25°C

Conversion:
$$
T(K) = 25 + 273.15 = 298.15\, \mathrm{K}
$$

For simplicity, we often round to 298 K in calculations.

- Pressure: 98 kPa

Conversion:
$$
1\, \mathrm{kPa} = 1 \times 10^{3}\, \mathrm{Pa}
$$

So:
$$
P = 98\, \mathrm{kPa} = 98 \times 10^{3}\, \mathrm{Pa} = 98,000\, \mathrm{Pa}
$$

Step-by-Step Calculation of Moles of Chlorine Gas

Step 1: Write Down Known Values

Quantity	Value	Units
P	98,000	Pa
V	5.00×10^{-3}	m^3
T	298	K
R	8.314	$J\ mol^{-1}\ K^{-1}$

Step 2: Rearrange the Ideal Gas Law to Find n

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

Step 3: Plug in the Values

$$
n = \frac{98,000 \times 5.00 \times 10^{-3}}{8.314 \times 298}
$$

Calculating numerator:
$$
98,000 \times 5.00 \times 10^{-3} = 98,000 \times 0.005 = 490
$$

Calculating denominator:
$$
8.314 \times 298 \approx 2478.572
$$

Step 4: Compute n

$$
n = \frac{490}{2478.572} \approx 0.1974\, \text{moles}
$$

Thus, approximately 0.1974 moles of chlorine gas are present in the flask under the specified conditions.

Calculating the Mass of Chlorine Gas

Step 1: Find the Molar Mass of Chlorine (Cl_2)

Chlorine's atomic mass:
- Cl: approximately 35.45 g/mol

For Cl_2:
$$
M_{Cl_2} = 2 \times 35.45 = 70.90\, \mathrm{g/mol}
$$

Step 2: Calculate the Total Mass

$$
\text{Mass} = n \times M_{Cl_2}
$$

$$
\text{Mass} = 0.1974 \times 70.90 \approx 14.00\, \mathrm{g}
$$

Result:

The mass of chlorine gas contained in the flask under the specified conditions is approximately 14.00 grams.

Additional Considerations and Practical Insights

While the calculation above assumes ideal gas behavior, real gases deviate slightly due to intermolecular forces and molecular volume, especially at high pressures or low temperatures. Chlorine gas, being relatively heavy, exhibits minor deviations under standard conditions, but for most practical purposes, the ideal gas law provides an excellent approximation.

Potential sources of error or variation include:

- Temperature fluctuations: Slight changes in temperature can significantly affect molar amounts.
- Pressure inaccuracies: Precise pressure measurement is crucial.
- Purity of gas: Impurities alter the molar mass and overall mass calculation.
- Container volume accuracy: Ensure the flask volume is accurately known and remains unchanged.

Safety note: Chlorine gas is toxic and corrosive. Proper handling, ventilation, and protective equipment are mandatory when working with or calculating quantities involving chlorine.

Summary and Practical Applications

To encapsulate, calculating the mass of chlorine gas in a given volume at specified temperature and pressure involves:

- Converting all measurements to SI units
- Applying the ideal gas law to find the number of moles
- Multiplying the moles by molar mass to find the total mass

This methodology is fundamental in chemical engineering, environmental science, and laboratory research, enabling professionals to tailor processes, ensure safety, and optimize resource utilization.

In essence:

> Given a 5.00 dm^3 flask at 25°C and 98 kPa, approximately 14 grams of chlorine gas are contained within. This precise calculation exemplifies how theoretical principles translate into real-world applications, illustrating the power of chemistry in understanding and manipulating the gaseous state.

In conclusion, mastering such calculations enhances your ability to predict, measure, and control gaseous substances in various scientific and industrial contexts, reinforcing the importance of meticulous unit conversions, a thorough understanding of gas laws, and attention to detail.

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