If A 20.0-g Sample Of Caco3 Is Put Into A 10.0-l Container And Heated To 800.8c, What Percentage By Mass

If A 20.0-g Sample Of Caco3 Is Put Into A 10.0-l Container And Heated To 800.8°C, What Percentage By Mass is a question that combines principles of chemistry, thermodynamics, and stoichiometry. To understand the outcome of such a scenario, it is essential to analyze the behavior of calcium carbonate ($CaCO_3$) when subjected to high temperatures, the resulting chemical reactions, and how to determine the mass changes involved. This article will explore these elements in detail, providing a comprehensive understanding of the process and calculations involved.

Understanding Calcium Carbonate and Its Thermal Decomposition

Properties of $CaCO_3$

Calcium carbonate ($CaCO_3$) is a common mineral found in rocks such as limestone, marble, and chalk. It is widely used in various industries, including construction, agriculture, and manufacturing. Structurally, it is a crystalline compound composed of calcium, carbon, and oxygen atoms.

Thermal Decomposition of $CaCO_3$

When calcium carbonate is heated to high temperatures, it undergoes thermal decomposition:

$$
\mathrm{CaCO_3 (s)} \xrightarrow{\Delta} \mathrm{CaO (s)} + \mathrm{CO_2 (g)}
$$

This reaction occurs at elevated temperatures, typically around 840°C, but can begin to take place at lower temperatures depending on conditions. At 800.8°C, the decomposition is significant, but not necessarily complete, depending on the duration of heating and other factors.

Calculating Moles and Masses Involved

Initial Mass and Moles of $CaCO_3$

The starting point is a 20.0 g sample of calcium carbonate. To analyze what happens during heating, we calculate the number of moles:

$$
\text{Molar mass of CaCO}_3 = 40.08 + 12.01 + (3 \times 16.00) = 100.09\, \mathrm{g/mol}
$$

Number of moles initially:

$$
n_{initial} = \frac{20.0\, \mathrm{g}}{100.09\, \mathrm{g/mol}} \approx 0.1998\, \mathrm{mol}
$$

\]

Mass of CO_2 Produced

According to the reaction, each mole of $CaCO_3$ produces one mole of CO_2:

$$
\text{Mass of CO}_2 = n_{initial} \times \text{molar mass of CO}_2
$$

$$
\text{Molar mass of CO}_2 = 12.01 + (2 \times 16.00) = 44.01\, \mathrm{g/mol}
$$

$$
\text{Mass of CO}_2 = 0.1998\, \mathrm{mol} \times 44.01\, \mathrm{g/mol} \approx 8.80\, \mathrm{g}
$$

Behavior of the System at 800.8°C

Extent of Decomposition

While the exact degree of decomposition at 800.8°C depends on the heating duration and other conditions, we assume that the majority of $CaCO_3$ decomposes in this scenario, especially at such a high temperature close to the decomposition point.

If complete decomposition occurs:
- All 20.0 g of $CaCO_3$ converts into CaO and CO_2.
- The calcium oxide (CaO) formed will have a mass:

$$
n_{initial} \times \text{molar mass of CaO} = 0.1998\, \mathrm{mol} \times 56.08\, \mathrm{g/mol} \approx 11.21\, \mathrm{g}
$$

- The CO_2 released will be approximately 8.80 g, as calculated above.

Since the total initial mass was 20.0 g, and the CO_2 escapes as a gas, the remaining solid mass (CaO) is what stays in the container.

Calculating the Percentage By Mass

Mass of Residual Solid in the Container

Assuming complete decomposition:

$$
\text{Mass of CaO remaining} \approx 11.21\, \mathrm{g}
$$

The total mass of solids remaining in the container after heating is approximately 11.21 g.

Mass of Gaseous CO_2 Escaped

Since CO_2 is a gas at high temperature and escapes from the container:

$$
\text{Mass of CO}_2 \text{ lost} \approx 8.80\, \mathrm{g}
$$

Calculating the Percentage by Mass of the Residual CaO

The percentage by mass of CaO in the original sample (assuming complete decomposition) is:

$$
\frac{\text{Mass of CaO}}{\text{Initial mass of CaCO}_3} \times 100 = \frac{11.21\, \mathrm{g}}{20.0\, \mathrm{g}} \times 100 \approx 56.05\%
$$

Alternatively, if you are asked for the percentage by mass of the remaining solid in the container after heating, it would be approximately 56.05%.

Impact of Temperature and Reaction Conditions

Is Complete Decomposition Always Achieved?

While high temperatures favor decomposition, complete conversion depends on:
- Heating duration
- Presence of catalysts or inhibitors
- Containment and pressure conditions

If the decomposition is incomplete, the residual $CaCO_3$ would be higher, and the calculations would need adjustment based on the extent of decomposition.

Gas Behavior in the Container

Since CO_2 is a gas at 800.8°C, it will likely escape unless the container is sealed and capable of withstanding high pressure. If it remains trapped, the pressure inside will increase significantly, potentially affecting the reaction equilibrium.

Additional Considerations for Accurate Calculations

- Ensure the temperature is sufficient for significant decomposition.
- Account for the reaction kinetics and duration of heating.
- Consider whether the container is open or sealed.
- Understand that real-world reactions may not go to completion, leading to partial

decomposition.

Conclusion

Heating a 20.0-g sample of calcium carbonate to 800.8°C in a 10.0-liter container results in the thermal decomposition of $CaCO_3$ into calcium oxide (CaO) and carbon dioxide (CO_2). Assuming complete decomposition, approximately 56.05% of the original mass remains as solid CaO, while the rest is released as gaseous CO_2. The percentage by mass of the residual solid (CaO) provides a useful metric to understand the outcome of the reaction under these conditions.

Understanding these principles allows chemists and students to predict reaction outcomes, perform accurate calculations, and appreciate the importance of reaction conditions in chemical processes. Whether for industrial applications like lime production or academic experiments, mastering these concepts is essential for interpreting thermal decomposition reactions and their implications in real-world scenarios.

Frequently Asked Questions

What is the chemical reaction involved when $CaCO_3$ is heated to 800.8°C?

When calcium carbonate ($CaCO_3$) is heated to high temperatures like 800.8°C, it decomposes into calcium oxide (CaO) and carbon dioxide (CO_2) gas: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$.

How do you calculate the percentage by mass of a component after heating $CaCO_3$?

The percentage by mass is calculated by dividing the mass of the component (e.g., CO_2 gas) produced or remaining by the initial mass and multiplying by 100%. In decomposition, it often involves calculating the mass of gaseous products relative to the original sample.

What is the significance of the 10.0 L container in this problem?

The 10.0 L container provides the volume in which the CO_2 gas produced is contained, allowing for calculations involving the gas's moles and the ideal gas law if needed.

How can the ideal gas law be applied to find the amount of CO_2 produced at 800.8°C?

Using $PV = nRT$, where P is pressure, V is volume, R is the gas constant, and T is temperature in Kelvin, you can find the moles of CO_2 produced. From moles, you can determine the mass of CO_2 generated.

What is the initial mass of $CaCO_3$ used in the problem?

The initial mass of $CaCO_3$ is 20.0 grams, as specified in the problem statement.

Why is the temperature specified as 800.8°C important in this problem?

The temperature is critical because it affects the decomposition of $CaCO_3$ and the behavior of gases produced, especially when applying the ideal gas law and calculating the amount of CO_2 generated.

What assumptions are typically made when solving this type of problem?

Assumptions include that the gas behaves ideally, the container is rigid and insulated, and complete decomposition of $CaCO_3$ occurs at the given temperature.

How do you determine the percentage by mass of CO_2 in the original sample after heating?

Calculate the mass of CO_2 generated from the decomposition, then divide by the original sample mass (20.0 g), and multiply by 100% to get the percentage by mass of CO_2 in the initial sample.

Additional Resources

If a 20.0-g sample of $CaCO_3$ is put into a 10.0-L container and heated to 800.8°C, what percentage by mass? This question encompasses several fundamental principles of chemistry, including stoichiometry, thermodynamics, and the behavior of gases at high temperatures. Understanding how calcium carbonate ($CaCO_3$) decomposes upon heating and how to calculate the resulting composition requires a detailed step-by-step approach. Whether you're a student preparing for an exam or a professional analyzing chemical reactions, this guide aims to clarify the process involved in determining the percentage by mass of products formed when $CaCO_3$ is heated to such an extreme temperature.

Understanding the Context: The Behavior of $CaCO_3$ at High Temperatures

Before delving into calculations, it’s essential to understand what happens when calcium carbonate is heated to approximately 800.8°C.

Calcium carbonate decomposition:

$CaCO_3$ (s) → CaO (s) + CO_2 (g)

This reaction occurs at elevated temperatures and results in:

- The formation of calcium oxide (quicklime)
- The release of carbon dioxide gas

The decomposition temperature of $CaCO_3$ is typically around 825°C, but it can begin to decompose at slightly lower temperatures, especially under specific conditions like the presence of catalysts or reduced pressure. For this problem, we're assuming complete decomposition at 800.8°C, which is close enough for the reaction to proceed significantly.

Step 1: Establish the Initial Conditions and Known Data

Let's list out the data provided and what we need to find:

- Mass of $CaCO_3$ initially: 20.0 g
- Volume of the container: 10.0 L
- Temperature: 800.8°C (which is 1074.0 K, since T(K) = T(°C) + 273.15)
- Question: What is the percentage by mass of the remaining substances after heating?

Note: The question as phrased is incomplete, but based on typical chemistry problems, it likely asks for the percentage of CaO remaining, the percentage of CO_2 released, or the composition after heating. For this guide, we will assume it seeks the percentage of CaO by mass after the process.

Step 2: Convert the initial mass to moles of $CaCO_3$

The molar mass of calcium carbonate ($CaCO_3$):

- Ca: 40.08 g/mol
- C: 12.01 g/mol
- O_3: 3 × 16.00 g/mol = 48.00 g/mol

Total molar mass:

40.08 + 12.01 + 48.00 = 100.09 g/mol

Calculate moles of $CaCO_3$:

$$ \text{moles of CaCO}_3 = \frac{\text{mass}}{\text{molar mass}} = \frac{20.0 \text{ g}}{100.09 \text{ g/mol}} \approx 0.1998 \text{ mol} $$

Step 3: Determine the amount of CaO formed

From the decomposition reaction:

$CaCO_3$ (s) → CaO (s) + CO_2 (g)

- Moles of CaO formed = moles of $CaCO_3$ decomposed = 0.1998 mol

Calculate the mass of CaO produced:

- Molar mass of CaO:

Ca: 40.08 g/mol
O: 16.00 g/mol

Total: 40.08 + 16.00 = 56.08 g/mol

Mass of CaO:

$$ 0.1998 \text{ mol} \times 56.08 \text{ g/mol} \approx 11.22 \text{ g} $$

So, after heating:

- Remaining solid CaO: approximately 11.22 g
- Released CO_2: amount determined via molar mass and gas laws

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Step 4: Calculate the amount of CO_2 gas released

The moles of CO_2:

$$ \text{moles of CO}_2 = 0.1998 \text{ mol} $$

Using the ideal gas law to find the volume of CO_2 at the given temperature and pressure:

$$ PV = nRT $$

Assuming the container is open to atmospheric pressure (standard pressure, $P = 1 \text{ atm}$), and using the ideal gas constant:

- $R = 0.082057 \text{ L·atm/(mol·K)}$
- $T = 1074.0 \text{ K}$

Calculate the volume of CO_2:

$$ V_{CO_2} = \frac{nRT}{P} = \frac{0.1998 \times 0.082057 \times 1074.0}{1} \approx 17.65 \text{ L} $$

Important note: The initial container volume is 10.0 L, which is less than the volume of CO_2 generated (~17.65 L). This indicates gas buildup within the container, leading to increased pressure or the need for the container to be flexible.

Step 5: Addressing the Container and Pressure Conditions

Since the container volume (10.0 L) is less than the volume of CO_2 produced at the given temperature (about 17.65 L), the system cannot contain all the gas at constant volume without increasing pressure.

Implications:

- If the container is rigid (fixed volume), the pressure will rise dramatically, potentially affecting the reaction equilibrium or causing rupture.
- If the container is flexible or allows gas escape, the amount of CO_2 retained depends on the system's conditions.

For this calculation, assume the container is rigid (fixed volume of 10.0 L). The gas produced will increase the pressure significantly, but the amount of CO_2 remains the same in moles, regardless of pressure.

Step 6: Determine the Final Composition by Mass

Since the initial mass was 20.0 g of $CaCO_3$ and 11.22 g of CaO is formed, the remaining solid is:

$$ \text{Remaining CaO mass} = 11.22 \text{ g} $$

The total mass of the system remains constant (mass conservation):

$$ \text{Mass of CaO} + \text{mass of CO}_2 \text{ (gas)} = 20.0 \text{ g} $$

The mass of CO_2 gas is:

$$ 0.1998 \text{ mol} \times 44.01 \text{ g/mol} \approx 8.80 \text{ g} $$

Adding up:

$$ 11.22 \text{ g} + 8.80 \text{ g} = 20.02 \text{ g} $$

The slight discrepancy arises from rounding.

Step 7: Calculate the Percentage by Mass

Final composition:

- CaO (solid): approximately 11.22 g
- CO_2 (gas): approximately 8.80 g

Total initial mass was 20.0 g; after reaction, the mass distribution is:

- CaO: 11.22 g
- CO_2: 8.80 g

Percentage by mass:

- CaO:

$$\frac{11.22 \text{ g}}{20.0 \text{ g}} \times 100 \approx 56.1\%$$

- CO_2:

$$\frac{8.80 \text{ g}}{20.0 \text{ g}} \times 100 \approx 44.0\%$$

Summary and Key Takeaways

- Heating 20.0 g of $CaCO_3$ to about 800.8°C results in decomposition into calcium oxide and carbon dioxide.
- Approximately 11.22 g of CaO remains as a solid, accounting for about 56.1% of the original mass.
- The decomposition releases about 8.80 g of CO_2 gas, representing roughly 44.0% of the initial mass.
- The total mass remains conserved, but the distribution shifts from solid to gas.

Final Remarks and Practical Considerations

This analysis underscores the importance of understanding chemical reactions, molar relationships, and the behavior of gases at high temperatures. In real-world applications, factors like container pressure limits, gas escape, and reaction kinetics influence the actual outcome. Nonetheless, the calculations here provide a solid foundation for predicting the products and their proportions after heating calcium carbonate.

Always remember: When dealing with reactions at high temperatures and gases, consider both the stoichiometry and physical constraints of the system. This comprehensive approach ensures accurate predictions and meaningful insights into chemical processes.

If you want to explore similar problems or need further clarification, don't hesitate to reach out or consult additional resources on thermodynamics and chemical stoichiometry.

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