

When 0.107 G Of Zn(s) Is Combined With Enough Hcl To Make 53.2 Ml Of Solution In A Coffee-cup Calorimeter,

When 0.107 G Of Zn(s) Is Combined With Enough Hcl To Make 53.2 Ml Of Solution In A Coffee-cup Calorimeter, it provides a fascinating example of a classic chemistry experiment involving acid-metal reactions and calorimetry. This scenario is often used in educational settings to explore concepts such as enthalpy changes, reaction energetics, and the principles of calorimetry. Understanding this process requires a grasp of the chemical reaction involved, the principles behind calorimetry, and how to interpret the data obtained from such experiments.

In this article, we will delve into the detailed chemistry of zinc reacting with hydrochloric acid, the setup and functioning of a coffee-cup calorimeter, and the calculations involved in determining the heat released or absorbed during the reaction. We will also explore the significance of such experiments in scientific research and practical applications.

Understanding the Chemical Reaction: Zinc and Hydrochloric Acid

The Reaction Equation

The reaction between zinc metal and hydrochloric acid is a classic example of an acid-metal reaction:



This reaction involves zinc metal reacting with hydrochloric acid to produce zinc chloride in aqueous form and hydrogen gas. It is an example of a single displacement reaction where zinc displaces hydrogen from hydrochloric acid.

Stoichiometry of the Reaction

To understand the amount of heat involved, we need to analyze the stoichiometry:

- 1 mol of zinc reacts with 2 mol of HCl.
- The molar mass of zinc (Zn) = 65.38 g/mol.
- The molar mass of HCl = 36.46 g/mol.

Given the mass of zinc is 0.107 g, the number of moles of zinc reacting is:

$$\text{moles of Zn} = \frac{0.107 \text{ g}}{65.38 \text{ g/mol}} \approx 0.001637 \text{ mol}$$

Correspondingly, the amount of HCl needed is:

$$\text{moles of HCl} = 2 \times 0.001637 \text{ mol} \approx 0.003274 \text{ mol}$$

The Role of a Coffee-cup Calorimeter in Measuring Enthalpy Changes

What Is a Coffee-cup Calorimeter?

A coffee-cup calorimeter is a simple, inexpensive device used to measure the heat exchanged during a chemical reaction occurring in aqueous solution. It typically consists of a Styrofoam cup (which acts as an insulator), a lid, a thermometer, and sometimes a stirrer.

Principles of Operation

- The calorimeter measures temperature change (ΔT) resulting from the reaction.
- It assumes that the heat exchanged with the surroundings is negligible.
- The heat released or absorbed by the reaction can be calculated using the specific heat capacity of the solution and the temperature change observed.

Assumptions in Coffee-cup Calorimetry

- The calorimeter is assumed to be perfectly insulated.
- The specific heat capacity of the solution is similar to that of water (approximately 4.18 J/g°C).
- The total mass of the solution can be estimated based on volume, assuming the density of water (~1 g/mL).

Calculating the Heat Involved in the Reaction

Step 1: Determine the Total Volume and Mass of the Solution

Given:

- Volume of solution = 53.2 mL
- Assuming the solution density is similar to water:

$$\text{Mass of solution} \approx 53.2 \text{ g}$$

Step 2: Measure Temperature Change (ΔT)

In a typical experiment, the temperature of the solution is recorded before and after the reaction:

- Pre-reaction temperature: T_{initial}
- Post-reaction temperature: T_{final}

The temperature change:

$$\Delta T = T_{\text{final}} - T_{\text{initial}}$$

This value is crucial for calculating the heat exchanged.

Step 3: Use the Specific Heat Capacity to Calculate Heat (q)

The heat absorbed or released by the solution:

$$q = m \times c \times \Delta T$$

Where:

- m = mass of the solution (~53.2 g)
- c = specific heat capacity (~4.18 J/g°C)
- ΔT = temperature change in °C

For example, if the temperature increases by 5°C:

$$q = 53.2 \text{ g} \times 4.18 \text{ J/g}^\circ\text{C} \times 5^\circ\text{C} \approx 1113 \text{ J}$$

This value indicates the amount of heat released or absorbed during the reaction.

Calculating the Enthalpy Change Per Mole of Zinc

To compare the energy change to standard enthalpy values, it is useful to express the heat per mole of zinc reacted.

$$\Delta H_{\text{reaction}} = \frac{q}{\text{moles of Zn}}$$

Using the earlier calculated moles of zinc (~0.001637 mol), and the example heat:

$$\Delta H_{\text{reaction}} \approx \frac{1113 \text{ J}}{0.001637 \text{ mol}} \approx 679,526 \text{ J/mol}$$

or approximately 679.5 kJ/mol.

This value indicates the molar enthalpy change associated with the zinc reacting with hydrochloric acid under the experimental conditions.

Relevance and Applications of Such Experiments

Educational Significance

- Demonstrates the principles of thermochemistry.
- Helps students understand how to measure and interpret temperature changes related to chemical reactions.
- Reinforces concepts of stoichiometry and enthalpy.

Industrial and Practical Applications

- Designing processes involving metal-acid reactions.
- Estimating the energy released during corrosion or metal processing.
- Developing energy-efficient methods for metal extraction or waste management.

Research and Development

- Calorimetric measurements contribute to developing new materials with specific energy properties.

- Understanding reaction energetics aids in catalysis and reaction engineering.

Factors Affecting the Accuracy of the Experiment

- Insulation quality: Poor insulation leads to heat loss to surroundings, underestimating the heat released.
- Precise temperature measurement: Using sensitive thermometers ensures accurate ΔT readings.
- Solution purity: Impurities can affect reaction kinetics and heat transfer.
- Reaction completeness: Ensuring the zinc fully reacts with the acid is crucial for accurate calculations.
- Volume measurements: Accurate measurement of solution volume impacts mass and subsequent calculations.

Conclusion

The scenario of combining 0.107 g of zinc with enough hydrochloric acid to produce 53.2 mL of solution in a coffee-cup calorimeter presents an insightful method of understanding thermochemical principles. By analyzing the reaction stoichiometry, measuring temperature changes, and applying calorimetry calculations, students and researchers can determine the enthalpy change associated with the zinc and hydrochloric acid reaction. Such experiments are fundamental in both educational contexts and real-world applications involving energy calculations, reaction engineering, and materials science.

Through careful experimental design and precise measurements, calorimetric studies like this deepen our understanding of chemical energetics and help advance technological innovations in various industries.

Frequently Asked Questions

What is the main chemical reaction when zinc reacts with hydrochloric acid in a coffee-cup calorimeter?

The main reaction is $\text{Zn(s)} + 2 \text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$, where zinc reacts with hydrochloric acid to produce zinc chloride and hydrogen gas.

How can I calculate the amount of heat released or

absorbed during the zinc and HCl reaction in this setup?

You can determine the heat using the temperature change of the solution and its specific heat capacity, applying the formula $q = mc\Delta T$, where m is the mass of the solution, c is the specific heat capacity, and ΔT is the temperature change.

What is the significance of using 0.107 g of zinc in this experiment?

Using 0.107 g of zinc allows for precise calculation of the molar amount of zinc reacting, which is essential for determining the enthalpy change per mole of zinc in the reaction.

How do I determine the concentration of HCl used in the reaction if only the volume is known?

To find the concentration, you need the molarity or the number of moles of HCl added. If not provided, you may need additional data about the amount of HCl used or assume a specific concentration if specified.

Why is a coffee-cup calorimeter suitable for this type of reaction?

A coffee-cup calorimeter is ideal because it provides a simple, insulated environment to measure temperature changes during the reaction, making it suitable for studying solution reactions and heats of reaction.

How do you convert the volume of solution (53.2 mL) into mass for heat calculations?

Assuming the solution is mostly water, you can convert volume to mass using the density of water (approximately 1 g/mL), so 53.2 mL corresponds to about 53.2 g of solution.

What assumptions are typically made when calculating the enthalpy change in this calorimetry experiment?

Common assumptions include that the solution's specific heat capacity is similar to water (4.18 J/g·°C), no heat loss to the surroundings, and that the reaction occurs instantaneously within the calorimeter.

How can I determine the enthalpy change per mole of zinc from this experiment?

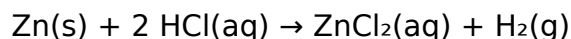
Calculate the total heat absorbed or released (q), then divide that value by the number of moles of zinc reacted (moles = mass / molar mass), to find the enthalpy change per mole (ΔH).

Additional Resources

When 0.107 G Of Zn(s) Is Combined With Enough HCl To Make 53.2 MI Of Solution In A Coffee-cup Calorimeter, a fascinating intersection of chemistry and thermodynamics unfolds. This seemingly simple reaction offers a window into the principles of energy transfer, reaction stoichiometry, and calorimetric measurement techniques. Understanding this process not only illuminates fundamental chemical concepts but also highlights the practical applications in fields ranging from industrial manufacturing to environmental science. In this article, we will explore the detailed chemistry behind this experiment, the methodology of calorimetry, and the significance of the thermal data obtained.

Understanding the Reaction: Zinc and Hydrochloric Acid

At the core of this experiment lies a straightforward chemical reaction:



This reaction involves zinc metal reacting with hydrochloric acid to produce zinc chloride in solution and hydrogen gas. It is classified as an acid-metal reaction, a common type of single-displacement reaction characterized by the transfer of electrons and the formation of new compounds.

Key points about this reaction:

- Stoichiometry: One mole of zinc reacts with two moles of HCl.
- Energy Changes: The reaction releases heat, making it an exothermic process.
- Reaction Rate: The rate depends on factors like temperature, surface area of zinc, and concentration of HCl.

Knowing the amount of zinc and the volume of solution helps determine the extent of the reaction and the energy involved.

Quantitative Aspects: Calculating Moles of Zinc

The initial step involves converting the given mass of zinc into moles, as mole quantities are fundamental to stoichiometric calculations.

Given data:

- Mass of zinc, $m = 0.107 \text{ g}$
- Molar mass of zinc, $M_n = 65.38 \text{ g/mol}$

Calculation:

$$\text{Number of moles of Zn, } n = m / M_n = 0.107 \text{ g} / 65.38 \text{ g/mol} \approx 0.001636 \text{ mol}$$

This amount indicates that approximately 0.001636 moles of zinc are involved in the reaction.

Determining the Volume and Concentration of HCl

The experiment specifies that the final solution volume is 53.2 mL (or 0.0532 L). Since the solution contains both the excess HCl and the zinc chloride produced, the initial concentration of HCl is a critical parameter.

Assuming excess HCl:

- The amount of HCl added is sufficient to react completely with the zinc.
- The exact volume or concentration of HCl used might be unknown; however, for calorimetric calculations, knowing the moles of HCl reacting or the total heat released is essential.

If the concentration of HCl is known, the number of moles can be calculated:

$$n_{\text{HCl}} = C_{\text{HCl}} \times V$$

Where:

- C_{HCl} = concentration of HCl (mol/L)
- V = volume of HCl added (L)

In the absence of explicit concentration data, the focus shifts to measuring the heat change associated with the reaction, which can then be related back to the amount of zinc reacted.

Calorimetry in Action: Coffee-Cup Calorimeter Setup

A coffee-cup calorimeter is a simple, effective device used to measure the heat of chemical reactions occurring at constant pressure. It typically consists of a styrofoam cup insulator, a lid, a thermometer, and a stirrer.

Procedure overview:

1. Preparation: Add the measured acid solution into the calorimeter.
2. Reaction Initiation: Introduce the zinc metal, often in powdered form or as a small strip.
3. Measurement: Record the temperature change (ΔT) as the reaction proceeds.
4. Data Analysis: Use the temperature change and calorimeter's heat capacity to determine the heat evolved or absorbed.

Because the calorimeter is insulated, the heat measured corresponds primarily to the reaction's enthalpy change (ΔH), assuming negligible heat loss.

Calculating the Heat of Reaction:

The fundamental relation:

$$Q = C_{\text{calorimeter}} \times \Delta T$$

Where:

- Q is the heat exchanged (Joules)
- $C_{\text{calorimeter}}$ is the heat capacity of the calorimeter (J/°C)
- ΔT is the temperature change (°C)

Critical considerations:

- Calibration: The heat capacity of the calorimeter must be known or determined experimentally.
- Temperature Recording: Multiple readings ensure accuracy.
- Sign Convention: A negative Q indicates an exothermic process (heat released), while positive indicates endothermic.

Once Q is known, the molar enthalpy change (ΔH) can be calculated:

$$\Delta H = Q / n$$

where n is the number of moles of zinc reacted.

Thermodynamic Significance:

The measurement of ΔH for this reaction provides insights into:

- Reaction energetics: How much energy is released per mole of zinc.
- Reaction spontaneity: Exothermic reactions tend to be spontaneous under standard conditions.
- Application in thermochemistry: Validates theoretical predictions with experimental data.

For example, literature values indicate the standard enthalpy of zinc's reaction with hydrochloric acid is approximately -153 kJ/mol. Comparing experimental results with these values helps assess the accuracy and precision of calorimetric techniques.

Factors Influencing the Experiment:

Several variables can affect the heat measurement:

- Incomplete Reaction: If zinc does not fully react, heat measurements underestimate the true value.
- Heat Loss: Despite insulation, some heat may escape, leading to inaccuracies.
- Reaction Rate: Too slow or too fast can impact temperature readings.
- Purity of Zinc: Impurities affect reaction completeness and heat evolved.
- Solution Volume: Precise measurement of the solution volume ensures accurate calculations.

Understanding and controlling these factors are essential for reliable calorimetric

measurements.

Real-World Applications and Implications

The principles demonstrated in this experiment extend far beyond academic curiosity. Accurate measurements of enthalpy changes underpin fields like:

- Industrial Chemistry: Designing energy-efficient processes.
- Environmental Science: Assessing reaction energetics in natural systems.
- Materials Science: Developing corrosion-resistant metals and coatings.
- Education: Teaching fundamental thermodynamic concepts through tangible experiments.

In applied settings, calorimetry helps optimize reactions for maximum energy efficiency and minimal environmental impact.

Conclusion: The Broader Significance

When 0.107 g of zinc reacts with hydrochloric acid in a coffee-cup calorimeter to produce 53.2 mL of solution, it encapsulates a fundamental chemical process—converting chemical energy into measurable heat. This experiment exemplifies how careful measurement and understanding of thermodynamic principles allow scientists to quantify energy changes, predict reaction behavior, and apply this knowledge across various scientific and industrial contexts.

By meticulously analyzing the amount of zinc, the volume of solution, and the temperature change, researchers can derive the enthalpy change of the reaction—a key parameter in thermochemistry. Such experiments deepen our understanding of energy transfer in chemical reactions, fostering innovations that impact energy management, material development, and environmental sustainability.

This seemingly simple laboratory setup thus serves as a gateway to the broader universe of chemical thermodynamics, illustrating the profound connection between microscopic reactions and macroscopic energy phenomena.

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