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84-1207

Determining the Molar Enthalpy of Fusion for Water

TEACHER'S GUIDE

Introduction

This activity introduces the use of probeware in the chemistry laboratory and demonstrates the benefits of probeware over conventional methods of data acquisition. Although this activity can be done using conventional apparatus, probeware offers superior precision and accuracy, while saving time. Because data is recorded electronically, students can quickly tabulate or graph their data electronically and spend their time analyzing data, not managing it.

The benefits of probeware extend beyond improved data and efficiency. Probeware's rapid data sampling rate and extreme sensitivity allow students to study fast or subtle changes inaccessible with typical lab equipment.

Note: The following procedure is written specifically for the Palm™ m100 and an ImagiProbe™ data collection system; however, the procedures apply to any Palm "m" series computer. With minimal modification, the procedures may also be used with other data collection systems.

Materials

For 30 students working in pairs

Carolina Biological Supply Company item numbers are in parentheses.

15 Palm m100s (RN-41-8255)

15 ImagiProbe "m" series (RN-41-8245A)

15 telephone plug-in adapters with DIN plugs (come with ImagiProbes)

15 temperature probes with DIN connector (RN-41-8214)

15 graduated cylinders, 100 mL (RN-72-1746)

30 styrene cups with tops

15 400-mL beakers (RN-72-1210A)

1.5 L of warm water

30 large ice cubes

paper towels

blackline master for Student Guide (printed in this manual)

Sample Problem Solution

A student adds two ice cubes to 100.0 mL of water at 46.9°C. When the ice has melted, the temperature of the water is 24.2°C. The final volume of the water is 122.0 mL. Calculate the molar enthalpy of fusion for water. The density of water is 1.0 g/mL.

Answer:

1. Mass of warm water: 100.0 g
2. Initial temperature of warm water: 46.9°C
3. Temperature of melting ice: 0.0°C
4. Final temperature of mixture: 24.2°C
5. Final volume of mixture: 122.0 mL

$$(m_1)(H_{fus}) + (m_2)(Cp)(\Delta T_1) = -[(m_3)(Cp)(\Delta T_2)]$$

The mass of the ice equals the difference between the starting volume of the water and the final volume converted to grams.

m_1 = 122.0 mL – 100.0 mL = 22.0 mL = 22.0 g

m_2 = 22.0 g

m_3 = 100.0 g

$Cp = 4.18 \times 10^{-3}$ kJ•g^{-1}•°C^{-1}

ΔT_1 = 24.2°C – 0.0°C = 24.2°C

ΔT_2 = 24.2°C – 46.9°C = –22.7°C

$$(m_1)(H_{fus}) + (m_2)(Cp)(\Delta T_1) = -[(m_3)(Cp)(\Delta T_2]$$

22.0 g H_{fus} + 22.0 g 4.18 10^{-3} kJ•g^{-1}•°C^{-1} 24.2°C = –(100.0 g 4.18 10^{-3} kJ•g^{-1}•°C^{-1} –22.7°C)

$$H_{fus} = 0.330 \text{ kJ/g}$$

To convert enthalpy of fusion to molar enthalpy, multiply by the number of grams per mole of water, 18.0 g/mol.

$$H_{fus} = 0.330 \text{ kJ/g} \quad 18.0 \text{ g/mol} = 5.94 \text{ kJ/mol}$$

Sample Data

1. Mass of warm water: *100.0* g
2. Initial temperature of warm water: *43.5* °C
3. Temperature of melting ice: *0.0* °C
4. Final temperature of mixture: *26.9* °C
5. Final volume of mixture: *116.0* mL

Sample Calculations

1. Calculate the molar enthalpy of fusion of water.

$$(m_1)(H_{fus}) + (m_2)(Cp)(\Delta T_1) = -[(m_3)(Cp)(\Delta T_2)]$$

m_1 = 16.0 g

m_2 = 16.0 g

m_3 = 100.0 g

Cp = 4.18 10^{-3} kJ•g^{-1}•°C^{-1}

ΔT_1 = 26.9°C

ΔT_2 = –16.6°C

16.0 g H_{fus} + 16.0 g 4.18 10^{-3} kJ•g^{-1}•°C^{-1} 26.9°C = –(100.0 g 4.18 10^{-3} kJ•g^{-1}•°C^{-1} –16.6°C)

$$H_{fus} = 0.321 \text{ kJ/g}$$

To convert enthalpy of fusion to molar enthalpy, multiply by the number of grams per mole of water, 18.0 g/mol.

$$H_{fus} = 0.321 \text{ kJ/g} \quad 18.0 \text{ g/mol} = 5.78 \text{ kJ/mol}$$

2. Calculate the percentage error of your experimental value of molar enthalpy of fusion for water. The accepted value is 6.02 kJ/mol.

Percentage of error: $\dfrac{|6.02 \text{ kJ/mol} - 5.78 \text{ kJ/mol}|}{6.02 \text{ kJ/mol}} \quad 100 =$ *4.0* %

Student Guide

84-1207

Name _____

Date _____

Determining the Molar Enthalpy of Fusion for Water

Objective

To determine the molar enthalpy of fusion of water.

Discussion

The energy required to melt a solid at its melting temperature is the enthalpy of fusion, H_{fus}. This process is described by the following chemical equation

$$X(s) \quad X(l)$$

where X is any substance. In this activity, the molar enthalpy of fusion of water will be calculated.

In the experiment, warm water will be used to melt ice at its melting temperature (0°C) in a styrene cup calorimeter. The ice will remain at 0°C until it is melted. As the ice melts, the hot water will lose heat to the ice and to the cold water it forms. The heat lost by the warm water and ultimately the molar enthalpy of fusion of ice can be calculated by measuring the initial temperature of the warm water and the final temperature of the water. The required equation is derived from the Law of Conservation of Energy (heat lost equals heat gained).

heat gained by the ice + heat gained by cool water = heat lost by the warm water

$$(m_1)(H_{fus}) + (m_2)(Cp)(\Delta T_1) = -[(m_3)(Cp)(\Delta T_2)]$$

where m_1 is the mass of ice, H_{fus} is the enthalpy of fusion of water, m_2 is the mass of the water formed by the melting of the ice (and is the same number as m_1), Cp is the specific heat of water (4.18 10^{-3} kJ•g^{-1}•°C^{-1}), ΔT_1 is the change in temperature of melted ice water originally at 0°C to the final water temperature, m_3 is the mass of the warm water, and ΔT_2 is the change in temperature of the warm water before the addition of ice to the final water temperature.

Sample Problem

A student adds two ice cubes to 100.0 mL of water at 46.9°C. When the ice has melted, the temperature of the water is 24.2°C. The final volume of the water is 122.0 mL. Calculate the molar enthalpy of fusion for water. The density of water is 1.0 g/mL.

Materials

Per pair of students

- Palm m100
- ImagiProbe "m" series
- telephone plug-in adapter with DIN plug
- temperature probe with DIN connector
- graduated cylinder, 100 mL
- 2 styrene cups with tops
- 400-mL beaker
- 100 mL of warm water
- 2 ice cubes
- paper towels

Procedure

1. Measure 100 mL of warm (50–55°C) water with a graduated cylinder and record the volume exactly. Pour the water into a styrene cup nested inside another styrene cup.
2. Attach a lid to the cup with the warm water and place both cups in the 400-mL beaker.
3. Insert a temperature probe in the center of the lid and move it down until it touches the bottom of the cup.
4. Obtain 2 ice cubes and allow them to start melting on a paper towel.
5. Attach the temperature probe to the adapter and plug the adapter into the ImagiProbe connected to the Palm.
6. Turn on the Palm and select the **ImagiProbe** icon on the desktop screen.
7. Select **[New Investigation]** and label it **Enthalpy of Fusion**.
8. Select **[Trial 1]** and select **[Preview]** to monitor temperature.
9. When the temperature of the water cools to around 47–45°C, select **[Collect]** to start recording data.
10. Pat the ice cubes dry with the paper towel, remove the lid-probe assembly, and carefully add them to the warm water in the cup.
11. Replace the lid-probe.
12. Stir gently by swirling the beaker-cup assembly in a small circle on the tabletop.
13. Keep recording data until the temperature remains constant for several minutes.
14. Select **[Stop]** to end data collection.
15. Select **[Save]** on the screen.
16. Choose your last trial on the screen and select **[View Data]**.
17. Choose the *magnifying glass* icon to zoom out. Continue until the entire graph is displayed.
18. Touch graph with stylus to view initial and final temperatures.
19. Record the initial and final temperature of the mixture in the data table below.
20. Measure and record the exact volume of water in the cup by pouring it into the graduated cylinder.

Data

1. Mass of warm water: _____g
2. Initial temperature of warm water: _____°C
3. Temperature of melting ice: _____°C
4. Final temperature of mixture: _____°C
5. Final volume of mixture: _____ mL

Calculations

1. Calculate the molar enthalpy of fusion of water.
2. Calculate the percentage error of your experimental value of molar enthalpy of fusion for water. The accepted value is 6.02 kJ/mol.

$$\text{Percentage of error: } \frac{|\text{Accepted value} - \text{Experimental value}|}{|\text{Accepted value}|} \times 100 = \_\_\_\_\_\%$$

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