Heat of Fusion of Ice

Introduction

The concepts of phase changes and heat of fusion will be reinforced in this student lab activity. Students will measure the temperature change when ice melts in water and then calculate the molar heat of fusion of ice.

Concepts

- Heat vs. temperature
- Phase change
- Heat of fusion

Background

Which takes more energy—heating 100 g of water from –1 °C to 5 °C, or from 1 °C to 50 °C? The latter involves a much greater temperature change, but the former has the added energy cost of changing the phase of the water from solid (ice) to liquid. An additional 15,000 Joules of energy are required to melt the ice and then increase its temperature 5 °C. For some perspective on how much energy is needed to melt ice, consider that it takes less energy to lift 3,000 pounds one meter high, and this is at least 10 times the weight a very strong person would consider challenging! Solid water molecules are arranged in a vibrating crystal lattice, held together by hydrogen bonds. When enough energy is added, molecules "break loose" from their fixed positions in the crystal lattice, causing a change in state from a solid to a liquid. The amount of heat that must be absorbed by a quantity of a solid to melt it is called the *heat of fusion*.

In this lab, ice will be added to cool heated water from 50 °C to about 2–4 °C. The temperature difference is used to calculate the amount of energy lost as the water cooled (Equation 1).

$$q_{water} = m \times c \times \Delta T \qquad \textit{Equation 1}$$

Where q_p is the energy, m is the mass of the substance being measured, c is the specific heat (in the case of liquid water, 4.18 J/g·°C), and ΔT is the temperature change.

The law of conservation of energy states that energy can never be created or destroyed. Therefore, all the energy lost by the water being cooled must be going somewhere. Assuming no heat is lost to the cup or the air, and also that the temperature of the ice does not change, all the energy from the water must be transferred to melting the ice, as shown in Equation 2:

$$q_{ice} = -q_{water} \qquad \textit{Equation 2}$$

By measuring how much ice has melted given the amount of energy added to it, the following equation can be used to calculate the molar heat of fusion of ice in kJ/mole:

$$\text{Molar Heat of Fusion of Ice} = q_{ice}/\text{moles of melted ice} \qquad \textit{Equation 3}$$

Materials

Ice cubes
Water, tap, hot
Beakers, 400-mL, 2
Graduated cylinders, borosilicate, 100-mL and 250-mL
Hot plate (optional)
Insulated foam cup (Styrofoam®)
Stirring rods
Thermometer, digital
Tongs

Safety Precautions

Exercise caution when using hot plates and handling hot glassware—remember that "hot" glassware looks exactly the same as "cold" glassware. Wear safety glasses and heat-resistant gloves. Please follow all normal laboratory safety guidelines.

Procedure

1. Measure about 350 mL of hot tap water into a 400-mL beaker.
2. Heat the water to 50 °C using a hot plate. *Note:* If the tap water is sufficiently hot, this step is not necessary.
3. Use a graduated cylinder to obtain 100 mL of hot water from the beaker. Measure and record the precise volume of the water to the nearest 0.2 mL in the Heat of Fusion Worksheet.
4. Place a foam cup into the dry 400-mL beaker for stability, and pour the hot water from the graduated cylinder into the foam cup. Measure the temperature of the water to the nearest 0.1 °C, and record the temperature in the Heat of Fusion Worksheet.
5. Using tongs, immediately and carefully add three ice cubes (approx. 50 g) to the foam cup containing hot water. *Note:* Use solid ice—don't add liquid water!
6. Stir the ice and water. Add more ice, if necessary, to cool the water to between 0 and 4 °C.
7. Record the final temperature of the water (to the nearest 0.1 °C) in the Heat of Fusion Worksheet. Remove any remaining pieces of ice using the tongs.
8. Use a 250-mL graduated cylinder to measure the final amount of water contained in the foam cup. Record the final volume to the nearest 0.2 mL in the Heat of Fusion Worksheet.
9. Repeats steps 1–8 two more times.
10. Complete the calculations on the worksheet to determine the heat of fusion of ice.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Water may be disposed of down the drain according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Evolution and equilibrium
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, conservation of energy and increase in disorder, interactions of energy and matter

Tips

- This lab may be reasonably completed in a 50-minute period.
- If there are not enough hot plates available for each lab group, the water may be heated and dispensed by the instructor prior to the lab.
- Note that the calculations take into account the energy cost of raising the temperature of the melted ice to its final value. Equation 2 is expressed $q_{ice\ (melting)} + q_{ice(\Delta T)} = q_{water}$
- The foam cup is placed in the 400-mL beaker strictly for stability. If the exact size beaker is not available another size may be substituted, as long as it is larger than the foam cup.
- This activity may be expanded to help students understand the difference between heat and temperature. Place ice in a beaker on a hot plate at a medium setting, and measure and record the temperature every minute. Graphing the data will allow students to see how heat continues to transfer into the ice and water system, but the temperature does not rise while the ice is melting.

Discussion

The amount of heat that must be absorbed to melt a specific quantity of ice is called the "heat of fusion." The amount of heat that must be absorbed to evaporate a specific quantity of liquid water is called the "heat of vaporization." Vaporization and fusion are examples of endothermic physical changes. In the case of a solid melting, heat absorbed during the process is used to break up the lattice "bonds." The reverse physical processes, namely a liquid freezing or a vapor condensing, are exothermic, that is, they release heat. As winter approaches, farmers will often spray fruit with water, allowing the water to freeze. This releases heat back to the fruit, thus shielding it from losing more heat.

Sample Data

		Trial 1	Trial 2	Trial 3
1	Initial volume of water (mL)	100.0	98.0	98.7
2	Initial temperature of water (°C)	51.3	51.5	51.2
3	Final temperature of water (°C)	1.4	1.2	2.2
4	Final volume of water (mL)	156.1	153.9	158.0
5	Change in temperature (°C) (line 3 – line 2)	–49.9	–50.3	–49.0
6	Change in volume (mL) (line 4 – line 1)	56.1	54.0	59.3

Sample Calculations and Results

		Trial 1	Trial 2	Trial 3
A	Mass of initial volume of water (g) (density of water at initial temperature × line 1)	98.5 g	96.8 g	97.5 g
B	Amount of heat released by hot water (J), Equation 1	–20545 J	–20358 J	–19973 J
C	Amount of heat absorbed by ice (J), Equation 2	20545 J	20358 J	19973 J
D	Mass of melted ice (g), (line 6 × density of water at final temperature)	58 g	56.1 g	60.5 g
E	Energy used to raise temperature of melted ice (J), Equation 1	339.4 J	281.4 J	556.4 J
F	Energy used to melt ice (J), (line C – line E)	20205.6 J	20076.6 J	19416.0 J
G	Moles of ice (line D/18.0 g/mol)	3.2 mol	3.1 mol	3.4 mol
H	Molar heat of fusion for ice, Equation 3	6.31 kJ/mol	6.48 kJ/mol	5.9 kJ/mol
I	Percent error ([line H – 6.02 kJ/mole]/6.02 kJ/mol)	4.8%	7.6%	–5.1%

Average molar heat of fusion of ice ________________ (kJ/mol)

Average percent error: ________________ %

Reference

This activity was adapted from *Flinn ChemTopic™ Labs*, Vol. 10, *Thermochemistry;* Cesa, I., Ed.; Flinn Scientific: Batavia, IL, (2002). Special thanks to Annis Hapkiewicz for suggested improvements.

Materials for *Molar Heat of Fusion of Ice* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1190	Styrofoam Cups, 8 oz
GP1025	Beaker, 400 mL
GP2056	Graduated Cylinder, Economy Choice, 100 mL
GP2058	Graduated Cylinder, Economy Choice, 250 mL
AP1359	Utility Tongs
GP5075	Glass Stirring Rod
AP6049	Flinn Digital Thermometer, Economy Choice
OB2089	Flinn Scientific Balance, Economy Choice
AP4674	Flinn Hot Plate (4" × 4")

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: ___________________________________

Heat of Fusion Worksheet

Data Table

		Trial 1	Trial 2	Trial 3
1	Initial volume of water (mL)			
2	Initial temperature of water (°C)			
3	Final temperature of water (°C)			
4	Final volume of water (mL)			
5	Change in temperature (°C) (line 3 – line 2)			
6	Change in volume (mL) (line 4 – line 1)			

Density of Water

Temperature (°C)	Density of Water (g/mL)
0	1.00
5	0.999
10	0.999
40	0.992
45	0.990
50	0.988
55	0.985

Calculations

		Trial 1	Trial 2	Trial 3
A	Mass of initial volume of water (g) (density of water at initial temperature × line 1)			
B	Amount of heat released by 50 °C water (J), Equation 1			
C	Amount of heat absorbed by ice (J), Equation 2			
D	Mass of melted ice (g), (line 6 × density of water at final temperature)			
E	Energy used to raise temperature of melted ice (J), Equation 1			
F	Energy used to melt ice (J), (line C – line E)			
G	Moles of ice (line D/18.0153 g/mol)			
H	Molar heat of fusion for ice, Equation 3			
I	Percent error ([line H – 6.02 kJ/mole]/6.02 kJ/mol)			

Average molar heat of fusion of ice _______________ (kJ/mol)

Average percent error: _______________ %