HEAT OF FUSION OF ICE

OBJECTIVES

- Introduce you to timed data collection using the LabQuest.
- Remind you how to measure heat flow using a simple calorimeter.
- Review potential versus kinetic energy.

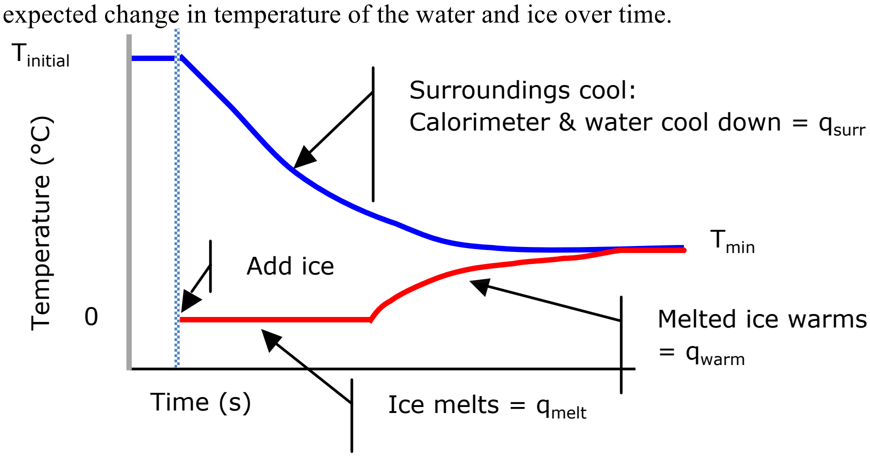
PRE-LABORATORY READING

Constant Pressure Calorimetry- Chapter 5.5.

BACKGROUND

Melting and freezing behavior are among the characteristic properties that give a pure substance its unique identity. As energy is added, pure solid water (ice) at 0°C changes to liquid water at 0°C. In this experiment, you will determine the energy (in joules) required to melt one gram of ice, this is called the **heat of fusion** of ice. Ice will be added to warm water at a known temperature (≈ 25 °C) in a Styrofoam calorimeter. The warm water will be cooled down to a lower temperature as the ice melts. The mass of ice, mass of water and the temperature change of the water will be recorded.

It is helpful to picture the expected change in temperature of the water and ice over time.



We can write equations for heat flow for each step in the above graph, q_{surr}, q_{melt}, and q_{warm}. First, lets start with the surroundings, the heat we actually measure in the lab and then we will do the system.

THE SURROUNDINGS:

The heat lost by the calorimeter and the water inside the calorimeter combined are the q_{surr}. **THIS IS A KINETIC ENERGY CHANGE.** The total heat lost is the sum of the heat lost from the calorimeter ($q_{calorimeter}$) and the water ($q_{contents}$):

$$q_{surr} = q_{calorimeter} + q_{contents} = C_{cal}\bullet\Delta T_{cal} + C_p\bullet m\bullet\Delta T_{cal} = (C_{cal} + C_p\bullet m)\bullet\Delta T_{cal} \quad (1)$$

Where q stands for heat (J), C_{cal} is the heat capacity of the calorimeter. **We will use a value of 20 J/°C (2 sig figs) as the heat capacity of the calorimeter, C_{cal}.** This means the calorimeter itself loses (or gains) 20 J of heat as it cools (warmes) by 1 °C. ΔT_{cal} is the change in temperature of the water and calorimeter defined as $T_{min} - T_{initial}$. C_p is specific heat capacity of water, m is the mass in grams of the water. For water, C_p is 4.184 J/g °C.

THE SYSTEM:

The heat gained by the system is equal to all the heat lost by the surroundings ("Conservation of Energy Principle"):

$$q_{sys} = -q_{surr} \quad (2)$$

This heat flow into the system occurs in two steps ("Hess Law Principle").
First the ice must be melted at a constant temperature of 0°C. The heat required to do this is q_{melt} **THIS IS A POTENTIAL ENRGY CHANGE.** There is no change in temperature! This occurs at exactly 0°C.

$$q_{melt} = \Delta H_{fus} \cdot m_{ice} \quad (3)$$

Where ΔH_{fus} is the heat of fusion of ice (to be determined in this experiment) and **m is the mass of ice**.

Secondly the melted ice must be warmed to the final temperature of the water in the cup since they reach thermal equilibrium, this is q_{warm} **THIS IS A KINETIC ENERGY CHANGE.**

$$q_{warm} = C_p \cdot m_{ice} \cdot \Delta T_{warm} \quad (4)$$

Where C_p is the heat capacity of water (the ice has melted), **m is the mass of ice** and ΔT_{warm} is the change in temperature of the melted ice as it warms. This ΔT_{warm} is T_{min} – 0°C.

Finally, add the two heat terms to get the heat of the system:

$$q_{sys} = q_{melt} + q_{warm} \quad (5)$$

EQUIPMENT AND REAGENTS

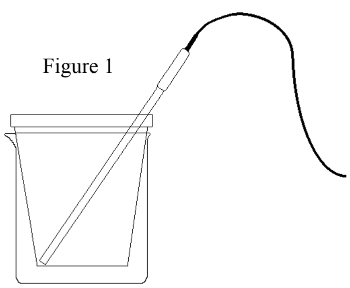
Lab Quest System with Temp-probe	Calorimeter
100-mL graduated cylinder	ice cubes

SAFETY

Wear safety goggles.

PROCEDURE (WORK IN PARTNERS)

Figure 1



1. Prepare the LabQuest for timed temperature data acquisition. Details will be given by your instructor. Typically you will use a 4 second data collection interval and take data for 300 seconds.
2. Obtain a dry calorimeter with lid. **Record the mass of the cups and lid in your notebook.**
3. Use a 100-mL graduated cylinder to obtain ≈100 mL of water at about 25 °C. You may use a hot plate to warm the water.
4. Pour the water into the calorimeter. **Replace the lid and record the mass of the calorimeter plus water.**
5. Lower the temperature probe into the warm water to about 1 cm from the bottom.
6. Obtain 4 or 5 single ice cubes from the cooler label "ICE". Wrap them in a paper towel so the surface of the cubes remains dry. Keep them as dry as possible.
7. Start data collection BEFORE adding the ice. Wait about twenty seconds (5 data points) and then lift up the lid and add the **dry ice cubes** to the calorimeter. Close the lid.
8. **Important:** Use the temperature probe to constantly stir the mixture as the temperature decreases.
9. When data collection stops remove the temperature probe from the calorimeter making sure any drops of water fall back into the calorimeter. **Obtain the final mass of the calorimeter and contents.**
10. Examine the first few data points on the LabQuest to **obtain an average initial temperature for the water, $T_{initial}$ (round to the nearest 0.1°C)**. Next, examine the data points along the cooling curve to find the **minimum temperature, $T_{minimum}$ (round to the nearest 0.1°C).**
11. **Repeat the experiment as many times as you like – experiment with other data collection sample intervals and collection times using the LabQuest.**

Circle Lab Section:: MW or TTh Partner(s): ____________________

REPORT SHEET – SHOW ALL DATA WITH UNITS

Initial calorimeter mass, m_1	
Calorimeter mass + water, m_2	
Calorimeter mass + water + ice, m_3	
Initial water temperature, $T_{initial}$	
Minimum water temperature, $T_{minimum}$	

CALCULATIONS
SHOW ALL YOUR WORK IN THE BOXES WITH UNITS! USE CORRECT SIGNIFICANT FIGURES!

Change in water temperature, $\Delta T_{cool} = T_{min} - T_{initial}$	
Change in melted ice temperature, $\Delta T_{warm} = T_{min} - 0\ °C = T_{min}$	
Mass of water in calorimeter	
Mass of ice added	
Heat change of SURROUNDINGS (water and calorimeter), q_{surr} (eqn 1) ____________	
TOTAL heat change of SYSTEM, q_{sys} (eqn 2) ____________	
Heat change of melted ice being warmed in the system, q_{warm} (eqn 4) ____________	
Heat change of melting ice in the system, q_{melt} $q_{melt} = q_{sys}-q_{warm}$. (eqn 5) ____________	
Calculated heat of fusion of ice, ΔH_{fus} in J/g (Use eqn 3 and previous answer) ____________ J/g Convert this to kJ/mol ____________ kJ/mol	
Literature ΔH_{fus} (Look-up in the CRC or your textbook) ____________ kJ/mol	
Percent error in ΔH_{fus} ____________ %	

QUESTIONS

1. Finish the potential energy level diagram (below) for the fusion process. Label the initial and final chemical states and give the energy difference between them (your measured heat of fusion in kJ/mol). Indicate which state has the higher potential energy. Indicate which state has the greater strength of intermolecular forces.

2. Some students find their experimental heat of fusion is lower than the literature value. Give a reasonable source of experimental error that would lead to a lower than literature experimental heat of fusion. IN OTHER WORDS, EXPLAIN WHAT SOURCE OF ERROR COULD CAUSE THE RESULT TO BE TOO LOW. (Assume that all data was recorded correctly and calculations were done correctly. You are looking for a systematic error that is likely to occur based on the procedure as written.)

3. One way to experimentally measure the heat capacity of a Styrofoam cup calorimeter would be to melt a known mass of ice in warm water and measure the temperature change. Use the data below to determine the experimental heat capacity of a calorimeter. ***Use the literature heat of fusion for ice in your calculations***. Assume the ice added is at 0.0 °C.

mass ice added: 17.69 g
mass water in calorimeter: 98.67 g
$T_{initial}$ of water: 28.7 °C
T_{final} of water after melting ice: 12.9 °C