

HEATING CURVE AND HEAT TRANSFER

PART I. PREPARATION OF A HEATING CURVE

OBJECTIVE

To prepare a heating curve

INTRODUCTION

Solids and liquids are sometimes referred to as the **condensed states**. The particles are held together by intermolecular forces, such as ionic bonds, hydrogen bonds, and dispersion forces. When solids melt, the forces holding the particles together are partly overcome and the particles move more freely in the liquid state. As more heat is added, the liquid particles obtain more energy, until the forces are completely overcome and they vaporize or boil. Particles in the vapor state ideally are not influenced by interparticle attractions. Since different substances experience different intermolecular forces, they will have different melting points and boiling points.

In Part I of this experiment, changes in the state of matter will be examined by preparing a heating curve. When a solid is heated, the temperature of the solid increases, indicating an increase in the kinetic energy of the particles. The temperature will continue to rise until the **melting point** is reached. At the melting point, the added heat increases the potential energy of the solid, and the particles move further apart. The solid changes to a liquid, but the temperature does not increase. When all particles have been changed to the liquid state, the further addition of heat will again increase the temperature until the **boiling point** is reached, where the liquid is converted to the gaseous state. The temperature remains at the boiling point until all the liquid is vaporized. Then, further addition of heat will increase the temperature of the vapor. You should look carefully at the heating curve in your textbook, page 190, Chapter 6, to identify these stages.

Part I. Preparation of a heating curve

Obtain enough ice from the laboratory instructor to fill a 250 mL Erlenmeyer flask about half-way. Add a small amount of water. Attach the stopper provided, making sure the thermometer is suspended in the water but does not touch the bottom of the flask. Set the stoppered flask on a wire screen, suspended over a burner. Record the temperature of the melting ice at one-minute intervals for approximately 5 minutes before lighting the burner! Then, keeping the burner on a low flame, continue to record the temperature at regular intervals until the water has boiled for approximately 5 minutes.

After accumulating the data, you will prepare a heating curve on the graph paper provided. The following rules for graphs should be observed:

1. Give the graph a title.
2. Label both the x and y axes, including units.
3. Have "ticks" with reasonable divisions.

4. Use as much of the graph paper as is reasonable.

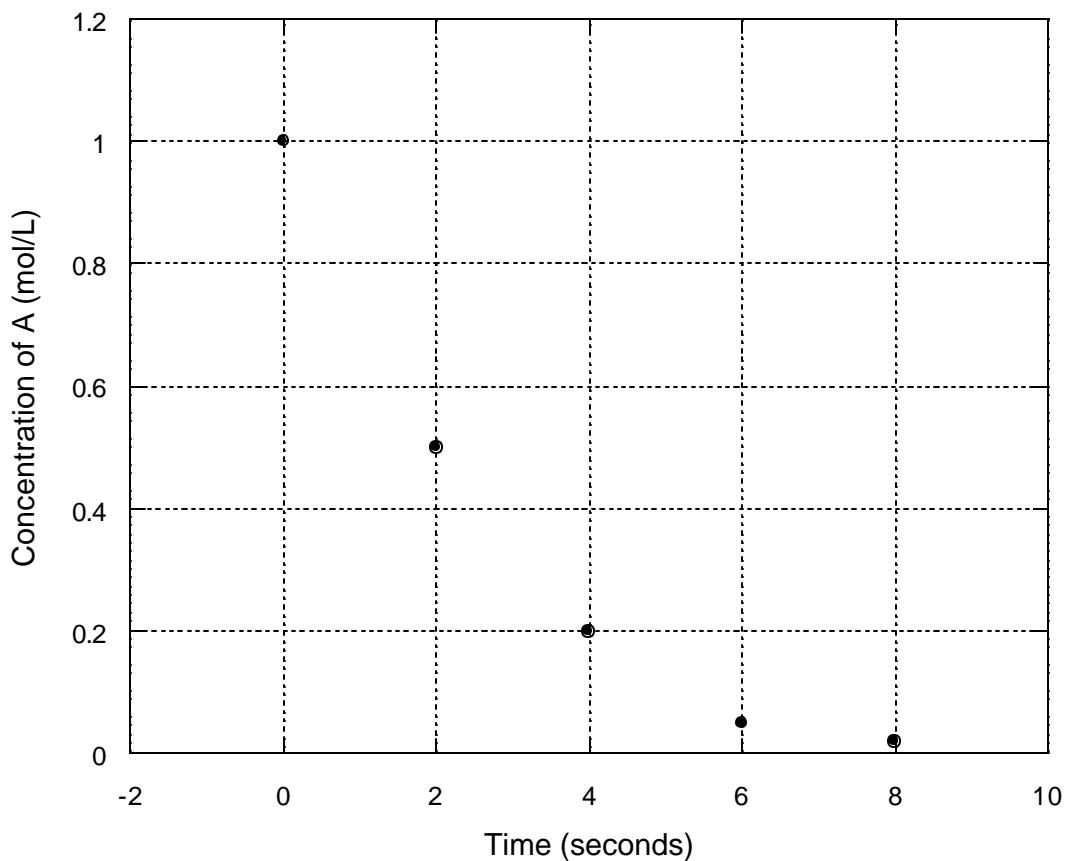
5. Use smooth curves or lines to show the relationship between points. Dot-to-dot curves are not appropriate! (Your heating curve should have three of the five stages described above, and should consist of three straight-line segments.)

For example, if the reaction $A \rightarrow B$ were carried out and the concentration of the reactant A measured at various time intervals, the data collected might be:

Concentration of A (mol/L)	Time (seconds)
1.0	0
0.50	2
0.20	4
0.050	6
0.020	8

Concentration of A vs. Time for the Reaction $A \rightarrow B$

From this data, the graph would look like:



QUESTIONS

1. Prepare a heating curve from your data in part I. Graph paper will be provided.
2. From your heating curve, report the melting point and boiling point of water.

PART II. HEAT TRANSFER AND CALORIMETRY

OBJECTIVES

1. To calculate the specific heat of a metal
2. To see the relationship between temperature and energy

INTRODUCTION

The first law of thermodynamics states that energy is neither created nor destroyed. In other words, energy is never lost, just transferred. Therefore it is possible to determine the energy given off by one substance by measuring how much energy was transferred to another substance. Experiments of this type are called “calorimetry”.

One form of energy is heat. It is not possible to measure the amount of heat energy directly. However, the amount of heat energy can be measured indirectly by measuring temperature.

Although they are often confused, temperature is not the same thing as energy. Applying the same amount of energy to two different substances can raise them to different temperatures. However, temperature is easy to measure (unlike energy) and temperature changes can be related to energy changes. This is done by taking into account heat transferring properties of the different materials and different amounts of materials. These properties can be illustrated by considering the rate at which water boils.

When you heat water on a stove, you are adding energy at a constant rate, provided you don't change the settings. Consequently, the longer something spends on the burner, the more energy you have added.

“Specific heat” is the property of a material which expresses the relationship between temperature and energy. It is characteristic of the material. Metal has a lower specific heat than water. Therefore, a pan will get very hot quickly, but more energy must be applied to heat the water inside.

You may have also noticed that it takes longer to increase the temperature of a lot of water than it does for a smaller amount of water.

The amount of energy gained or lost or gained is calculated from the following equation

$$\text{energy} = (\text{specific heat})(\text{mass})(\text{change in temperature}) \quad (1)$$

It has been well established that the specific heat of water is $4.18 \text{ J/g}\cdot^\circ\text{C}$. This means that it takes 4.18 J of energy to raise 1 gram of water one degree Celsius. (An older unit of energy, a calorie, is the amount of energy required to raise 1 gram of water one degree Celsius.) So the temperature change of a known mass of water can be used to determine how much energy was transferred to the water. For example, if the temperature of 100 g of water changed from 15°C to 20°C then

$$\text{energy} = (4.18 \text{ J/g}\cdot^\circ\text{C})(100 \text{ g})(5^\circ\text{C}) = 2090 \text{ J} \quad (2)$$

so 2090 J of energy was transferred to the water.

Since energy is neither gained nor lost, then the same amount of energy must have been lost from something else. If the temperature increase was due to dropping a piece of hot metal into the water, then the metal must have lost 2090 J of energy.

If 75 g of this unknown metal started out at a temperature of 90°C , it must have ended up at the same temperature as the water, so

$$\text{Change in temperature} = 90^{\circ}\text{C} - 20^{\circ}\text{C} = 70^{\circ}\text{C} \quad (3)$$

The specific heat can be calculated using equation 1

$$2090 \text{ J} = (\text{specific heat})(75 \text{ g})(70^{\circ}\text{C}) \quad (4)$$

$$0.40 \text{ J/g}\cdot^{\circ}\text{C} = \text{specific heat} \quad (5)$$

Since specific heat is characteristic of the substance, you can refer to a table (Like Table 6.8 in Introductory Chemistry for Today by Seager and Slabaugh) to match it with a substance. For example, the specific heat of copper is $0.39 \text{ J/g}\cdot^{\circ}\text{C}$ and very close to our value. Therefore it is likely that this unknown metal is copper.

PROCEDURE

Weigh 2 nested, empty Styrofoam cups. Add 50 mL of water, using a graduated cylinder to the cup. Measure the temperature of the water in the cup and weigh the cups and water together.

In the hood, there will be boiling water containing washers attached to strings. Measure the temperature of the water. Quickly remove a washer (using the string) and add to the water in your Styrofoam cup.

Measure the temperature of the water containing the hot washer at 15 second intervals until the temperature of the water decreases at least 3 times in a row.

Remove the washer with the string and dry it. Weigh both the washer and string.

HEAT TRANSFER
LABORATORY REPORT

NAME: _____

DATE: _____

Data:

Initial weight of Styrofoam cups _____

Final weight of Styrofoam cup + water _____

Mass of water _____

Initial temperature of water _____

Temperature of hot water containing washers _____

Temperatures of water + washer in Styrofoam cup at 15 s intervals

Mass of washer and string _____

Results: SHOW YOUR WORK

maximum temperature for washer/water mixture _____

Change in temperature of washer _____

Change in temperature of water _____

Heat gained by water _____

Heat lost by washer _____

Specific heat of washer _____

QUESTIONS

1. Why do you use the highest temperature of washer/water to determine temperature changes?
2. If two washers were used instead of one, how would the final temperature change? How would the specific heat change? Predict approximate values.
3. If 100 mL of water instead of 50 mL of water was used, how would the final temperature change? How would the specific heat change? Predict approximate values.
4. Why are Styrofoam cups used instead of glass beakers? (Consider why *you* use Styrofoam cups.)
5. What requires more energy: increasing the temperature of the washer 5°C or increasing the temperature of the water 5°C. Explain why.