Heat and Temperature

Goals

Operate a Bunsen burner properly.
Measure temperature using the Celsius temperature scale.
Convert a Celsius temperature reading to its Fahrenheit and Kelvin temperatures.
Graph a heating or cooling curve to show the change in temperature with time.
Identify change(s) of state on a heating or a cooling curve.

Lab Questions

1. Is a body temperature of 39.4°C normal or a fever?
2. What is meant by absolute zero on the Kelvin temperature scale?
3. What change of state occurs at boiling? freezing?
4. Why is temperature constant when water is freezing or boiling?

Concepts to Review

Celsius temperature scale
Kelvin temperature scale
Temperature conversion equations
Graphing
Changes of state
Heating and cooling curves
Measuring heat energy
Calories

Discussion

Temperature is a measure of the intensity of heat in a substance. A substance with little heat feels cold. Where the heat intensity is great, a substance feels hot. The temperature of our bodies is an indication of the heat produced. An infection may cause body temperature to deviate from normal. On the Celsius scale, water freezes at 0°C; on the Fahrenheit scale, water freezes at 32°F. When converting a Celsius temperature to its corresponding Fahrenheit temperature, the difference in freezing point value is indicated by adding 32 to temperature using the following equation:

$$T_F = 1.8\,(T_C) + 32$$

When the Fahrenheit temperature is known, the Celsius temperature is determined by rearranging the equation. Be sure you subtract 32 from the T_F, then divide by 1.8.

$$T_C = \frac{(T_F - 32)}{1.8}$$

A Celsius temperature can be converted to a Kelvin temperature by using the equation:

$$T_K = T_C + 273$$

Heating Curve

The temperature of a substance indicates the kinetic energy (energy of motion) of its molecules. The particles of a liquid are in constant motion. As they gain heat, they move faster. Some of the molecules gain enough energy to overcome the attractions between them and separate from the other liquid molecule. A gas forms as the liquid changes its state. During this change of state, bubbles of gas form within the liquid: the liquid is *boiling*. A change of state becomes obvious when a graph is drawn of the temperature change as the substance is heated until it boils as seen in Figure 7.1. When a liquid is at its *boiling point*, the temperature is constant; a horizontal line *(plateau)* appears on the graph.

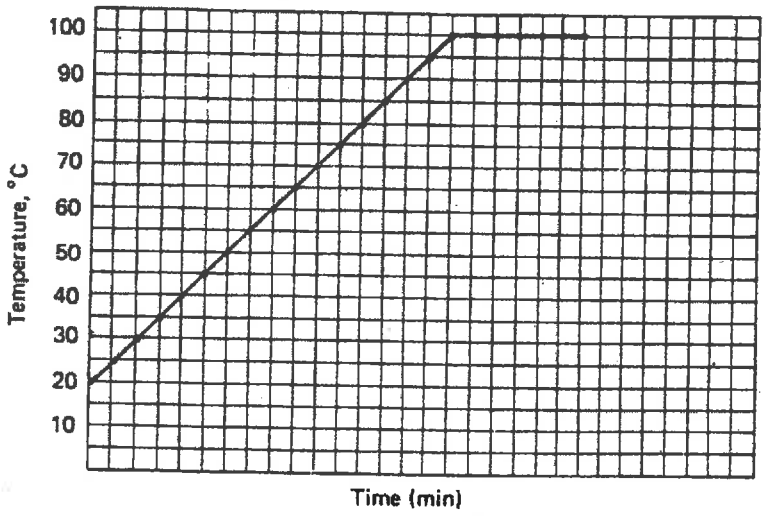

Figure 7.1 Example of a graph for plotting a heating curve.

Laboratory Activities

A. The Laboratory Burner

Materials needed: Bunsen burner, striker or matches

BE SURE YOU HAVE YOUR SAFETY GOGGLES ON BEFORE YOU LIGHT THE BURNER AND BEGIN THIS EXPERIMENT!

In the laboratory, substances are heated with a Bunsen burner as seen in Figure 7.3. The burner consists of a metal tube on a base, which is connected to a gas source. The flow of gas is adjusted by opening or closing the gas lever at the bench or by turning the wheel at the base of the burner. The amount of air that enters the burner is adjusted by twisting the tube to open or close the air vents. The gas and air mixture is ignited at the top of the tube using a match or a striker. Make sure the gas valves are tightly closed when you leave the laboratory after using the Bunsen burner.

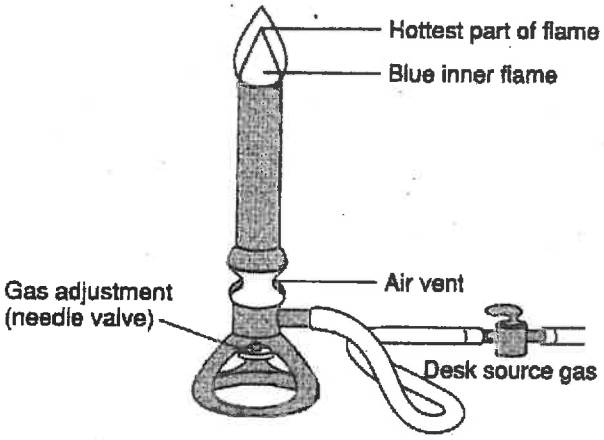

Figure 7.3 A typical laboratory burner.

CAUTION: ***A BUNSEN BURNER IS A POTENTIAL HAZARD!***
Be sure that long hair is tied back.
Keep the work area clear of books, papers, backpacks, and other flammable items.
Always place the burner at the back of the desk top.
***Never* stack books up to set the burner at a higher level.**
Remember what you heated: Hot metal and glass items do not *look* hot!

A.1 Before you light the burner, practice the following:
(a) opening and closing the *gas lever at the lab bench*
(b) opening and closing the *gas needle valve at the base of the burner*
(c) opening and closing the *air vents*

Close the holes of the air vents. Prepare to ignite the burner by having a striker or match ready. Your instructor may demonstrate the use of the striker. Turn on the gas and hold the flame or spark at the top of the burner. If the gas needle valve is closed, open it until gas flows through. If you are using a striker, be sure you strike the flint hard enough to get sparks. Practice lighting the burner a few times.

A.2 When the air vents are closed, the gas mixture does not have an adequate supply of oxygen. The orange, sooty flame indicates incomplete combustion of the gas. As you open the air vents to increase the amount of air, the color of the flame will change to blue. However, opening the air vents too far may blow out the flame. Adjust the gas flow and open the air vents until you have a flame that is 3-5 cm high with two distinct parts, an inner cone and an outer flame.

A.3 The hottest part of a flame is at the tip of the inner blue flame. For efficient heating, the tip of the inner flame is placed just under the substance you heat.

B. Measuring Temperature

Materials needed: Thermometer, 150- or 250 mL beaker, ice, rock salt and a stirring rod (A set of beakers containing the substances to be measured may be available in the lab.)

The laboratory thermometer is larger than the thermometer you use at home or in the hospital. The liquid in a laboratory thermometer responds quickly to the surroundings. When you are measuring the temperature of a solution or substance, always read the thermometer while it is **immersed** in that solution or substance.

CAUTION: NEVER SHAKE DOWN A LABORATORY THERMOMETER! There is no need to shake a laboratory thermometer because it contains no constrictions as does an oral thermometer. Shaking a laboratory thermometer can cause breakage and serious accidents. Always set a thermometer down in a safe place at your lab station.

B.1 Observe the markings on a thermometer. Answer the questions on your laboratory report.

B.2 To measure the temperature of a liquid, place the bulb of the thermometer in the center of the solution. When the temperature becomes constant, record the temperature (°C). *A set of beakers with the following contents may be available in the lab.* Determine the temperature of each of the following:

a. Room temperature: Place the thermometer on the lab bench.
b. Tap water: Fill a 250-mL beaker about 1/3 full of water.
c. Ice-water mixture: Add enough ice to the water in *part b* to double (approx.) the volume. Allow 5 minutes for the temperature to change.
d. A salted ice mixture: adding rock salt to the ice-water mixture in *part c*. Allow 5 minutes for the temperature to change.

Complete the table by converting the Celsius temperatures to their corresponding temperatures on the Fahrenheit and Kelvin scales.

C. Preparing A Heating Curve

Materials needed: Beaker (250- or 400-mL), hot plate (or Bunsen burner, ring stand, iron ring, wire gauze), Buret clamp, thermometer, timer, ice

As shown in Figure 7.4 (a), water can be heated in a 250 mL or 400 mL beaker placed on a hot plate. To use the Bunsen burner as shown in Figure 7.4 (b), place the beaker on a wire screen placed on an iron ring. The height of the iron ring should be about 3-5 cm above the burner. Tie a string to the loop in the top of the thermometer or place the thermometer securely in a clamp. Carefully adjust the height of the thermometer so that the bulb is in the center portion of the ice or liquid. (Do not let the thermometer rest on the side or bottom of the beaker.)

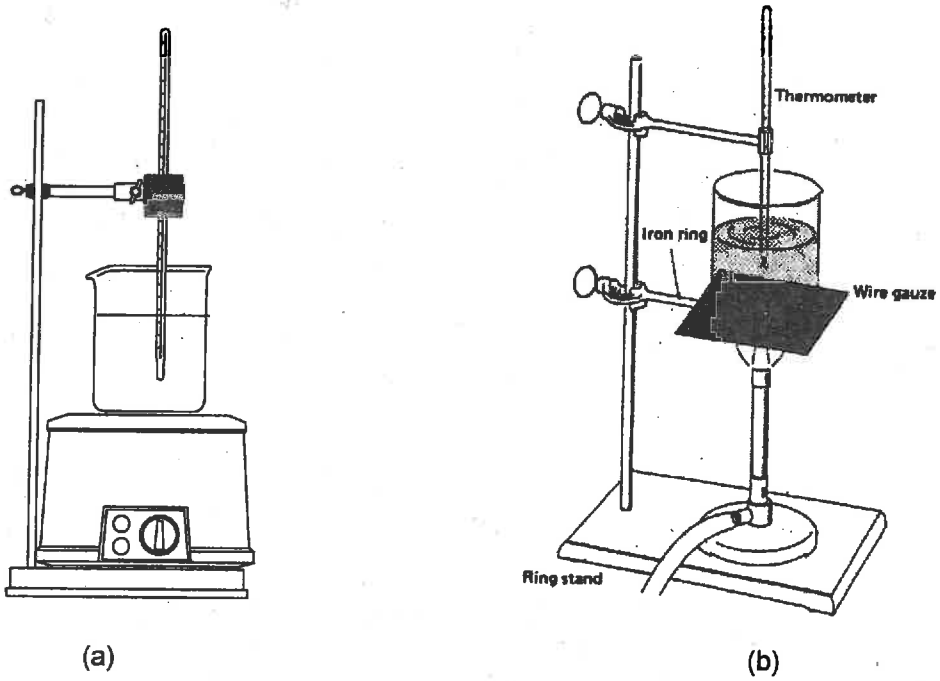

Figure 7.4 Setups of apparatus for heating water: (a) Using a hot plate. or (b) Using a Bunsen burner.

C.1 Fill a 250-mL or 400-mL beaker about one-half full of ice and cover with water. Stir the ice-water mixture until the temperature is constant. Record this measurement at a time of 0 min. Place the beaker of water on the hot plate or the Bunsen burner and begin heating. Use a timer or a watch with a second hand and record the temperature of the water each 1 minute. On most thermometers, you can estimate the tenths of a degree (0.1°C). Note the temperature at which the last piece of ice disappears.

Eventually the water will come to a ***full boil***. (The appearance of small bubbles of escaping gas does not indicate boiling. During boiling, bubbles will be seen beneath the surface of the water). After boiling begins and the temperature has become constant, record five more readings. Add more time to the data table if more temperatures are needed.

NOTE: If you are to proceed to Part D, turn off the burner or hot plate, but do not discard the hot water. While the water is still hot, the material in the freezing-point apparatus for Part D can be melted by placing the test tube apparatus in the hot water. ***Save the water for part C.4.***

C.2 Use the data you collected in C.1 to prepare a heating curve for water. On the graph, label the areas of solid, liquid and boiling on the graph.

C.3 The plateau (flat part of graph) indicates the *boiling point* of the water. Record its value.

C.4 Determine the temperature change for the water from the temperature at which the last piece of ice melts to the temperature of the boiling water (plateau) C.3 - C.1.

C.5 After cooling, pour the water into a graduated cylinder to determine its volume. Assuming a density of 1 g/mL, calculate the mass of the water.

C.6 Calculate the calories absorbed by the water to increase its temperature to the boiling point. Use the mass of the water, the temperature change and the specific heat of water.

$$\text{calories} = \text{mass} \times \Delta T \times 1.00 \text{ cal/g°C}$$

D. Graphing A Cooling Curve

Materials needed: Freezing-point apparatus (a large test tube, 8", containing phenylsalicylate (salol), a two-hole stopper, thermometer and wire stirrer), beaker with hot water (from part C), ring stand and clamp

The substance called phenylsalicylate (salol) is a solid at room temperature. Your instructor will indicate the location of the *already prepared* freezing-point test tubes containing salol and stirring set ups. See Figure 7.5.

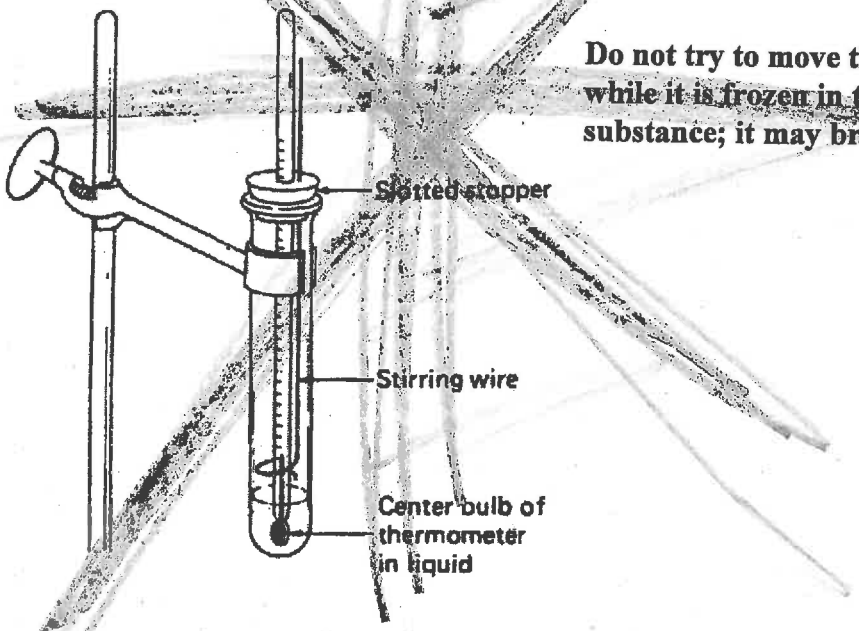

Figure 7.5 Stirring apparatus for freezing point determination