EXPERIMENT 0

Energy and Matter

A. Goal

The goal of this laboratory experiment is to experimentally obtain heating curves of substances for boiling and freezing and to measure the heat of fusion of ice.

B. Materials

- ☐ 100mL, 250mL beaker (or a 400mL)
- ☐ hot plate
- ☐ thermometer
- ☐ clam
- ☐ stand
- ☐ 150mL cylinder
- ☐ boling chips
- ☐ jumbo testube with sasol
- ☐ double styrofoam cup
- ☐ crushed ice

C. Background

Temperature

Temperature indicates how hot or cold a substance is compared to another substance. Heat always flows from a substance with a higher temperature to a substance with a lower temperature until the temperatures of both are the same. When you drink hot coffee or touch a hot pan, heat flows to your mouth or hand, which is at a lower temperature. When you touch an ice cube, it feels cold because heat flows from your hand to the colder ice cube. Three units of temperature often employed are celsius (°C, T_C), Fahrenheit (°F, T_F) or Kelvin (K, T_K). If you need to convert temperature units from Fahrenheit to celsius or from celsius to Fahrenheit you need to use the formulas below:

$$\boxed{T_F = 1.8T_C + 32} \quad \boxed{T_F = 1.8T_K - 459.4} \quad \boxed{T_K = T_C + 273} \tag{1}$$

Sample Problem 1

Convert 25 °C to °F.

SOLUTION

1 **Step one:** list of the given variables.

Analyze the Problem	Given	Asking
	$T_c = 25°C$	T_F

2 **Step two:** use the formula $T_F = 1.8T_C + 32$ to convert from °C to °F.

3 **Step three:** solve for $T_F = 1.8 \times 25 + 32 = 77°F$.

STUDY CHECK

Convert 200°C to K.

Answer: 473K.

From energy to temperature

Heat transforms in a temperature change. Some substances like metals can increase their temperature very quickly with a small amount of heat received, whereas others need a larger amount of heat to rise their temperature. Think about why you use oil to deep fry food. Why not use water? First of all, oil can raise its temperature very quickly and on top of that it does not boil easily.

Heat capacity

The heat capacity c of a material is defined as:

$$c = \frac{\text{heat adsorbed}}{\text{temperature increase}} \tag{2}$$

This is a characteristic property of each material that indicates the energy required to rise its temperature and can be expressed in $\mathrm{cal/°C}$ or $\mathrm{J/°C}$ units. As this property depends on the amount of matter, oftentimes the heat capacity is expressed per mass as the specific heat capacity also known as *specific heat* (c_e) or mole unit as the *molar heat capacity* c_m. For example, the specific heat of water is $1\mathrm{cal/g°C}$ that is the same as $4.184\mathrm{J/g°C}$. That means that we need to give 1 calorie to warm up one gram of water $1°C$. Similarly, the specific heat of aluminum, a metal, is $0.2\mathrm{cal/g°C}$ or $0.89\mathrm{J/g°C}$; that means the energy needed to raise the temperature of an aluminum gram is 0.2 calories of 0.89 J. Mind the difference between these two values: we need to give 1 cal to increase the temperature of a gram of water in $1°C$, whereas we need to give 0.2 cal to increase the temperature of a gram of aluminum in $1°C$. Why are these two numbers so different? The answer is that water and aluminum are different materials. Normally metals warp up very easily, that is, they need less heat to increase their temperature, whereas liquids need more heat to increase their temperature. That is why pans and cooking pots tend to be metallic. Table 1 lists specific heats of common substances. Mind the specific heat if water is a well know value that you need to be familiar with:

$$\boxed{c_e^{\mathrm{H_2O}} = 4.184\mathrm{J/g°C} \qquad \textit{or} \qquad c_e^{\mathrm{H_2O}} = 1\mathrm{cal/g°C}} \tag{3}$$

Heat

When a material receives heat, that heat normally becomes temperature as the temperature of the material increases. For example, if you warm milk in a microwave, the milk's temperature increases from room temperature (25°C) to a higher temperature. How to estimate the temperature increase given the heat received? Or how to estimate the heat needed to increase the temperature of an object? We can use the following formula:

$$\boxed{Q = m \cdot c_e \cdot (T_f - T_i)} \tag{4}$$

where:

Q is the amount of heat received, either in cal or J.

m is the mass of material in grams

c_e is the specific heat of the material (in cal/g°C or J/g°C)

$T_f - T_i = \Delta T$, is the temperature change from the initial to the final temperature

A system can receive or give away heat and this is indicated by the sign of Q. The sign convention for heat is:

$Q > 0$ the system receives heat *and* $Q < 0$ the system gives away heat

Sample Problem 2

How many calories are absorbed by a 45.2g piece of aluminum ($c_e = 0.214\frac{cal}{g°C}$) if its temperature rises from 25°C to 50°C.

SOLUTION

1 **Step one:** list of the given variables.

Analyze the Problem	Given	Asking
	$c_e = 0.214\frac{cal}{g°C}$ $m = 45.2g$ $T_{initial} = 25°C$ $T_{final} = 50°C$	Q

2 **Step two:** use the formula $Q = m \cdot c_e \cdot (T_{final} - T_{initial})$ to transform the temperature increase into heat absorbed. Mind this formula depends on the mass involved and the specific heat of the material, in this case, aluminum.

3 **Step three:** solve $Q = 45.2 \cdot 0.214 \cdot (50 - 25) = 241.82cal$.

STUDY CHECK

How many calories are absorbed by 100g of Gold ($c_e = 0.0308\frac{cal}{g°C}$) if its temperature rises from 25°C to 100°C.

Answer: $Q = 231cal$.

Table 1 Values of specific heat for different materials

Material	Specific heat (J/g°C)	Material	Specific heat (J/g°C)
$H_2O_{(l)}$	4.184	$Fe_{(s)}$	0.444
ethyl alcohol$_{(l)}$	2.460	$Au_{(s)}$	0.129
vegetable oil$_{(l)}$	1.790	$Cu_{(s)}$	0.385
$NH_{3(l)}$	4.700	$H_2O_{(s)}$	2.010
Dry Air$_{(g)}$	1.0035	$CO_{2(g)}$	0.839

D. Procedure

1. Heating curve for water While heating a liquid its temperature raises up until the moment the liquid boils.

Step 1: – Place a 250mL beaker (or a 400mL) on top of a hot plate. Place a thermometer in the beaker so that it does not touch the walls of the beaker and secure it with a clam.

Step 2: – Use a cylinder and place 150mL cool of water into the beaker.

Step 3: – Using the thermometer record and write down the initial temperature of water.

Step 4: – Start heating the liquid at medium heat.

Step 5: – Record the temperature in the table below every minute (you might need to add extra space in the table to accommodate all numbers). Use a stopwatch to measure time.

Step 6: – When large bubbles continuously appear (not small bubbles), the liquid will be boiling. After that point record the temperature for only 10 minutes. In some cases, water may seem like that does not boil after 20 minutes. In those cases, consult with your instructor.

Step 7: – Turn off the hop plate when the experiment is done.

Step 8: – Using a pencil, plot the heating curve of water by graphing temperature (Vertical axis) vs. time (Horizontal axis). Make sure the time occupies the whole space in the plot. Show this plot to your instructor.

2. Cooling curve of salol Phenyl salicylate, or salol, is a chemical once used in sunscreens, phenyl salicylate and now used in the manufacture of some polymers, lacquers, adhesives, waxes, and polishes. This chemical is solid at room temperature. The goal of this mini experiment is to draw the cooling curve of melted salol.

Step 1: – Half-fill a 400mL beaker with water. Add boiling chips and start boiling the liquid with a hot plate. This is a water bath meant to melt salol.

Step 2: – Place the salol container in the water bath. Add a thermometer inside the salol tube to control its temperature. Melt the solid completely. Never warm up salol beyond 80°C.

Step 3: – When salol is all melted stop the hot plate and start recording temperature every minute. Write down the results in the table below.

Step 4: – After the solid forms, continue measuring temperature for five more minutes.

Step 5: – Stop recording when salol is fully solidified.

Step 6: – Write down the measurement in the table below.

Step 7: – Plot the heating curve of water by graphing temperature (Vertical axis) vs. time (Horizontal axis).

3. Heat of fusion of ice The goal of this mini experiment is to calculate an estimate of the heat of fusion of ice. You will do this by using a calorimeter (a double styrofoam cup) and a thermometer.

Step 1: – Weight a empty double styrofoam cup and record its mass.

Step 2: – Add 100mL of water to the cup and weight again. Record the new mass.

Step 3: – Record the initial temperature of water with a thermometer.

Step 4: – Add crushed ice to the cup with water. The amount of ice should fill half of a 100mL beaker.

Step 5: – Close the calorimeter until all the ice is melted. Record the final temperature.

Step 6: – Weight the cup with water and the melted ice and record the final mass.

Calculate the fusion heat of ice by using the following formula, in which $C_{e,water}$ is the specific heat of water (1cal/g/°C):

$$-m_{ice} \times Q_{fusion} + m_{water} \times C_{e,water} \times \Delta T = 0$$

STUDENT INFO

Name: ____________________ Date: ______

Pre-lab Questions

Energy and Matter

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1. When ice melts is heat lost or gained? Explain.

2. Calculate the mass of 100mL of water. Density is 1g/mL.

3. What happens to the temperature of water while its boiling?

4. How many calories are needed to boil 100g of water? ($heat_{vaporization}$=540 cal/g)

5. How many calories are needed to melt 100g of ice? ($heat_{fusion}$=80 cal/g)

6. How many calories are needed to warm up 100g of water from 10 to 50°C? (C_e=1 cal/g/°C)

7. The following formula is used to calculate the heat of fusion of ice using a calorimeter, where $C_{e,water}$ is the specific heat of water (1cal/g/°C), the mass of ice is 5g, the mass of water in the calorimeter is 100g and the temperature decrease is -4°C

$$-m_{ice} \times Q_{fusion} + m_{water} \times C_{e,water} \times \Delta T = 0$$

Calculate the heat of fusion of ice.

STUDENT INFO

Name: ____________________ Date: ______

Results

EXPERIMENT

Energy and Matter

1. Heating curve for water

Time (min)	Temperature (°C)				

2. Cooling curve of salol

Time (min)	Temperature (°C)				

3. Heat of fusion of ice

1	Mass of the calorimeter (g)	________
2	Mass of the calorimeter+ water (g)	________
2 – 1	Mass of the water,m_{water} (g)	________
3	Initial temperature of water (°C)	________
4	Final temperature of water (when ice is melted) (°C)	________
4 – 3	Temperature change, ΔT (°C)	________
5	Mass of the calorimeter+ water + melted ice (g)	________
5 – 2	Ice mass, m_{ice} (g)	________

$Q_{fusion} =$________

STUDENT INFO

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Post-lab Questions

Energy and Matter

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1. Label the different areas of the heating and cooling curves you plotted with the labels ((s), (l), (g), (s+l), or (l+g)) representing solid, liquid or gas.

2. According to your plot, what is the boiling or freezing temperature of the liquid.

3. Explain the meaning of heat of fusion.

4. Explain why during a phase transition temperature is constant.