

## Experiment 5: Specific Heat Determination

### Skills/Concepts

- Specific Heat
- Calorimetry (measuring heat)
- Closed & Open Systems
- Conservation of Energy

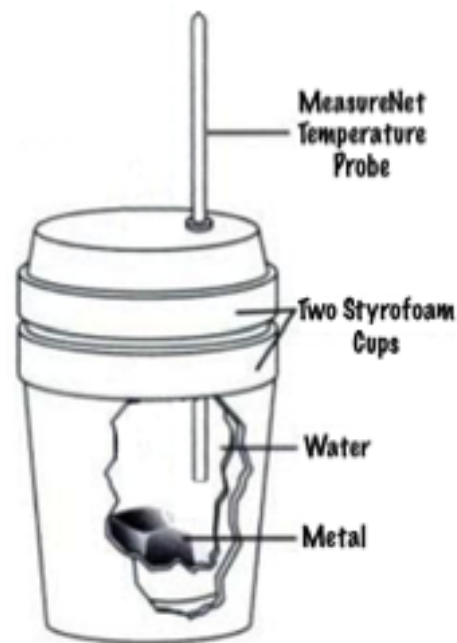
### Relevant Reading

Hein & Arena 4.6-4.8

### Introduction/Background

Substances respond differently to heating and cooling. One calorie of heat (4.18 J of energy) will change the temperature of 1.0 gram of water by 1.0 °C. But that same energy will raise the temperature of 1.0 gram of lead by 32.4 °C.

The physical property of matter that relates temperature change to the amount of heat transferred in or out of a substance is called specific heat. **Specific heat** is defined as the quantity of energy required to raise the temperature of 1.0 grams of a substance by 1.0 °C.



$$\text{Specific Heat} = \frac{\text{Heat}}{\text{Mass} \times \text{change in Temperature}} \quad (\text{eqn \#1})$$

In this experiment you are going to be asked to identify unknown metals by determining the specific heat of your sample and matching it to a list of possible metals with known specific heats. The goal of your experiment will be to identify what metals you are given.

To get the specific heat (C) of the metal, you would need to know the mass (m) of that metal, the change in temperature ( $\Delta T$ ) of the metal and how much heat was gained or lost by the metal (q) during the temperature change. Determining mass is easy—we use a scale to measure it. Determining change in temperature is easy—we use a thermometer or temperature probe to measure the temperature before and after, then subtract them. But there is no tool for determining energy in a substance. **We have no easy way of determining how much heat is going into or out of a substance.**

So we won't measure the heat. Instead, we'll let the heat flow from one substance into another (in this case from metal into water). If we know the specific heat of the substance receiving the heat, we can measure its mass and change in temperature and calculate how much heat it received. If all the heat that came out of the metal went into a sample of water, we can calculate how much heat the water received and know how much heat the metal lost.

$$-q_{\text{lost from metal}} = q_{\text{gained by water}} \quad (\text{eqn \#2})$$

We can rewrite equation #1 to show that the heat gained or lost by any substance ( $q$ ) can be described as the mass ( $m$ ) times the specific heat ( $C$ ) times the change in temperature ( $\Delta T$ ).

$$q = m \cdot C \cdot \Delta T \quad (\text{eqn \#3})$$

$$\Delta T = T_{\text{final}} - T_{\text{initial}} \quad (\text{eqn \#4})$$

We will define a change in temperature as the final temperature of the sample less the initial temperature. By defining change in temperature this way  $q$  will always be positive for systems that gain heat (the water in this case) and negative for systems that lose heat (the metal in this case).

### Overview

You will be issued two of the following unknowns. For each unknown, you will place a sample of the metal in test tube and heat it with a hot water bath. Be sure to record the weight of the sample before heating.

Magnesium	1.05 J/g °C
Aluminum	0.89
Carbon (graphite)	0.71
Steel	0.50
Zinc	0.39
Tin	0.23
Lead	0.13

Table 1: Possible Unknowns

Once the sample is heated, you will add it to about 50 ml of water in a container that prevents heat from entering or leaving the experiment. You'll record the temperature and weight of the water before adding the metal. Using the MeasureNet system, you will monitor the temperature change and record the final temperature. Print out a graph of the temperature change over time to include with your lab report.

Use this data in your post lab report to calculate the specific heat of each unknown and identify which of the unknowns in table 1 you were issued.

Name: \_\_\_\_\_

**Pre-Lab**

(answer these questions before coming to lab)

1. If you mixed a sample of metal at 105.0 °C and a sample of water at 20.2 °C then found the temperature of the mixture to be 24.5 °C what would be the change in temperature of the metal? What would be the change in temperature of the water?

$$\Delta T_{\text{metal}} =$$

$$\Delta T_{\text{water}} =$$

2. In the above example, if you had 35.0 grams of water, how much heat was transferred into the water? How much heat was lost from the metal?

$$q_{\text{gained by water}} =$$

$$q_{\text{lost from metal}} =$$

Hint: Gained heat is positive, lost heat is negative.

3. In the above example, if your metal sample weighed 20.5 grams—would it be more likely the sample was copper or gold? Copper has a specific heat of 0.385 J/g °C; gold has a specific heat of 0.131 J/g °C.

## Preparation

1. Show your pre-lab to your instructor at this time your instructor will issue you two unknown codes. Write down the code for each unknown on the included data pages. If your instructor is helping other students, continue your preparation and come back to this step.

2. Collect the equipment you will need.

Equipment:

- |                             |                   |
|-----------------------------|-------------------|
| - Thermometer (1)           | - Coffee Cups (2) |
| - Large Test Tube (2)       | - Coffee Cup Lid  |
| - 1000 or 500 mL Beaker (2) | - Lab stand (1)   |
| - 500 or 250 mL Beaker (2)  | - Clamp (2)       |
| - Hot Plate (1)             | - Hot mitt (1)    |

3. We will be using the MeasureNet system to measure our temperature data. Confirm your lab bench has the following components to setup your data collection system:

- MeasureNet Terminal (1)
- MeasureNet Temperature Probe (1)
- AC Adapter for MeasureNet Terminal
- Data Cable for MeasureNet Terminal

4. Connect the AC Adapter, data cable and temperature probe to the MeasureNet terminal. Plug in the AC Adapter to an electrical socket and plug in the data cable to the **black** data socket (not the orange one) in your lab bench.

5. Press the power key on the MeasureNet terminal. Wait for the MeasureNet terminal to report online status, then initialize MeasureNet by doing the following:

### MeasureNet Task: Setup for Temperature Measurements

Your Actions:	MeasureNet Response:
Press: <b>MAIN MENU</b>	<b>LCD:</b> Shows Function Choices
Press: <b>F2</b> – Temperature	<b>LCD:</b> Shows More Temperature Choices
Press: <b>F1</b> – Temp v Time	<b>LCD:</b> Shows SELECT OPTION screen
Press: <b>DISPLAY</b>	<b>LCD:</b> Shows the Temp Measurement Screen

You are now ready to begin your experiment.

**Procedure**

Record your data on the included data summary pages. You will need to complete this experiment for two unknowns. This may require two lab periods.

**IMPORTANT SAFETY REMINDERS:**

- Use caution with the hot plate and with hot glassware. Reminder: hot glass looks the same as cold glass.
- You must wear safety glasses at all times in this lab! Whether you are conducting an experiment or not, someone else is—if you do not have safety glasses on, you cannot be in the lab room.

**PREPARE WATER BATH:**

1. Plug in the hot plate at least 2 feet from your MeasureNet terminal (heat from the hot plate could throw off your MeasureNet temperature readings).
2. Fill a 500 ml or 1,000 ml beaker about 3/4 full with water and set it on the plate.
3. Turn on the hot plate and let the water start heating while you prepare the rest of the experiment. You want to heat the water to where steam is rising from it, but the water is not boiling (60-80 °C).
4. Set a lab stand behind the hot plate and install one lab clamp on the stand.

**SYNCHRONIZE MEASURENET & YOUR THERMOMETER**

5. Half fill a 250 ml or 500 ml beaker with ice water.
6. Place both the thermometer and the MeasureNet temperature probe in the ice water and wait until both instruments reach a final temperature.
7. Record the temperature from the thermometer.
8. Record the temperature from MeasureNet—there will likely be a 1-5 degree difference.
9. Subtract the thermometer temperature from the MeasureNet temperature; this difference will be your thermometer correction factor. Record it.
10. Remove both the temperature probe and the thermometer from the ice water, dry them and place them in a clean dry 500 mL beaker next to MeasureNet while you prepare the rest of the experiment. (Be sure this is at least 2 feet from the hot plate or ice water.)

**PREPARE METAL SAMPLE:**

11. Place a 250 ml or 500 ml beaker on the scale and tare it.
12. Take a clean dry large test tube and set in the beaker, record the weight of the test tube.
13. Put your unknown metal in the test tube. The sample should fill about 2 inches of the bottom of the test tube.

14. Put the test tube back on the scale and record the weight of the metal and the test tube.
15. Determine the weight of your metal by difference.

#### HEAT METAL SAMPLE:

16. You need to insert the clean dry thermometer into the metal sample, but you must take special care not to force it! Trying to force the glass thermometer into the metal sample could break it and create a hazard—proceed slowly and carefully.
17. Tip the test tube to one side to create a cavity in the metal granules. Insert the glass thermometer into this empty space, it should be about 1 inch from the bottom of the test tube.
18. Turn the test tube with thermometer right side up and allow the metal to settle around the thermometer. The thermometer should not be against any wall of the tube—it should be directly in the center and be embedded about 1 inch into the metal granules. It may be necessary to **lightly** tap the test tube with a pencil to cause the granules to settle around the thermometer.
19. Set the test tube with thermometer into the hot water bath, carefully clamp the test tube using the lab stand so the test tube is suspended in the water and does not touch the bottom of the container.
20. Allow the sample to heat until it reaches a stable temperature. Your temperature goal is between 60-80°C.

#### PREPARE CALORIMETER:

21. Nest one Styrofoam cup in a second and be sure the inside cup is clean and dry.
22. Weigh and record the weight of the clean dry Styrofoam double cup.
23. Collect about 50 mL of de-ionized water using a clean 50ml or 100ml graduated cylinder.
24. Add the water to the Styrofoam double cup and record the new total weight.
25. Determine the mass of the water by difference and record this weight to at least .001 grams precision.
26. Place the cap on the Styrofoam double cup.
27. Remove the MeasureNet temperature probe from the clean dry 500 mL beaker and set the double Styrofoam cup inside this beaker.
28. Insert the MeasureNet temperature probe as shown on the first page of this lab. The temperature probe should be suspended about half way into the water, touching neither the side nor the bottom of the cups.

**DO NOT PROCEED UNTIL THE MEASURENET TEMPERATURE STABILIZES.**

#### MIX THE METAL AND WATER:

29. When the MeasureNet temperature stabilizes, record that temperature. Press START/STOP on MeasureNet to begin capturing data.

30. **WARNING:** The test tube will be very hot! The water bath is very hot!
31. Using a thermal mitt, carefully remove the hot test tube with your metal sample from the water bath. Record the thermometer temperature of the test tube and then remove the thermometer.
32. Open the lid of the double Styrofoam cup (without removing the temperature probe from the water) and quickly pour the entire contents of the test tube into the cup. Replace the lid on the Styrofoam cup and be sure the temperature probe is not touching the bottom or walls of the cup or any of the hot metal you added).
33. Slowly swirl the cup and watch the temperature on the MeasureNet terminal.
34. When the temperature stabilizes, record the final temperature of the experiment (the final temperature should also be the highest temperature displayed during the experiment).
35. Press START/STOP on MeasureNet to end capturing data. Save your data and printout one copy of the data for each member of your lab group.

**MeasureNet Task:** How to Save the Data File

<b>Your Actions:</b>	<b>MeasureNet Response:</b>
Press: <b>FILE OPTIONS</b>	<b>LCD:</b> Shows Function Choices
Press: <b>F3</b> – SAVE	<b>LCD:</b> Asks Enter File Number
Respond “051” on Keypad & Press <b>ENTER</b> (Lab 05 File 1)	<b>LCD:</b> Shows saving data & Asks SELECT a FUNCTION (Choose what to do next)

**MeasureNet Task:** How to Create Printouts

<b>Your Actions:</b>	<b>MeasureNet Response:</b>
Press: <b>FILE OPTIONS</b>	<b>LCD:</b> Shows Function Choices
Press: <b>F1</b> – Print Standard	<b>LCD:</b> Asks for Number of Copies
Respond “3” (or one printout per group member) on Keypad & Press <b>ENTER</b>	Printouts are available at Lab Printer

36. Confirm that each member of your lab group has their own printout and all the data requested in the Data Summary section.
37. Complete the Post-Lab analysis at home, the lab report is due at the start of the next lab period.

Name: \_\_\_\_\_

Lab Partner: \_\_\_\_\_

**First Unknown – Data Summary**

Unknown metal ID: \_\_\_\_\_

Description	Data
<u>Thermometer Synchronization</u>	
Thermometer Reading <i>(temperature of ice water from thermometer)</i>	_____ (a)
MeasureNet Corrected <i>(temperature of ice water from MeasureNet)</i>	_____ (b)
Thermometer Correction Factor <i>(subtract a from b)</i>	_____ (c)
<u>Metal</u>	
Clean/Dry Empty Test Tube <i>(weight before metal)</i>	_____ (d)
Test Tube w/ Metal <i>(weight after adding metal)</i>	_____ (e)
Mass of Metal <i>(subtract d from e)</i>	_____ (f)
Thermometer Reading of Hot Metal	_____ (g)
Heat of Metal After Correction <i>(c added to g)</i>	_____ (h)
<u>Water</u>	
Clean/Dry Styrofoam Double Cup <i>(weight before water)</i>	_____ (i)
Styrofoam Double Cup w/ ~50 ml of Water <i>(weight after adding water)</i>	_____ (j)
Mass of Water <i>(subtract i from j)</i>	_____ (k)
MeasureNet Temperature of Water <i>(before mixing)</i>	_____ (l)
MeasureNet Temperature After Mixing	_____ (m)

Name: \_\_\_\_\_

Lab Partner: \_\_\_\_\_

**Second Unknown – Data Summary**

Unknown metal ID: \_\_\_\_\_

Description	Data
<u>Thermometer Synchronization</u>	
Thermometer Reading <i>(temperature of ice water from thermometer)</i>	_____ (a)
MeasureNet Corrected <i>(temperature of ice water from MeasureNet)</i>	_____ (b)
Thermometer Correction Factor <i>(subtract a from b)</i>	_____ (c)
<u>Metal</u>	
Clean/Dry Empty Test Tube <i>(weight before metal)</i>	_____ (d)
Test Tube w/ Metal <i>(weight after adding metal)</i>	_____ (e)
Mass of Metal <i>(subtract d from e)</i>	_____ (f)
Thermometer Reading of Hot Metal	_____ (g)
Heat of Metal After Correction <i>(c added to g)</i>	_____ (h)
<u>Water</u>	
Clean/Dry Styrofoam Double Cup <i>(weight before water)</i>	_____ (i)
Styrofoam Double Cup w/ ~50 ml of Water <i>(weight after adding water)</i>	_____ (j)
Mass of Water <i>(subtract i from j)</i>	_____ (k)
MeasureNet Temperature of Water <i>(before mixing)</i>	_____ (l)
MeasureNet Temperature After Mixing	_____ (m)

Name: \_\_\_\_\_

Lab Partner: \_\_\_\_\_

**First Unknown — Post-Lab Analysis**

Unknown metal ID: \_\_\_\_\_

1. Using the data you collected, calculate the change in temperature for the metal and water in your unknown. Write them below.

$$\Delta T_{\text{metal}} =$$

$$\Delta T_{\text{water}} =$$

2. Calculate the heat gained by the water and the heat lost by your metal. Show your calculation.

$$q_{\text{gained by water}} =$$

$$q_{\text{lost from metal}} =$$

3. Calculate the specific heat of this unknown. Show your calculation.

4. What metal from table 1, is most likely your unknown?

Name: \_\_\_\_\_

Lab Partner: \_\_\_\_\_

**Second Unknown — Post-Lab Analysis**

Unknown metal ID: \_\_\_\_\_

5. Using the data you collected, calculate the change in temperature for the metal and water in your unknown. Write them below.

$$\Delta T_{\text{metal}} =$$

$$\Delta T_{\text{water}} =$$

6. Calculate the heat gained by the water and the heat lost by your metal. Show your calculation.

$$q_{\text{gained by water}} =$$

$$q_{\text{lost from metal}} =$$

7. Calculate the specific heat of this unknown. Show your calculation.

8. What metal from table 1, is most likely your unknown?

Name: \_\_\_\_\_

Lab Partner: \_\_\_\_\_

**Post-Lab Questions**

1. Did your calculated specific heat match the known specific heat of any of the possible metals exactly?
2. One of the assumptions you made was that all of the heat escaping the metal went into the water. It is possible some heat wasn't captured by the water. Where else could the heat have gone?
3. If some heat was not captured by the water, would you have over estimated or under estimated the  $q_{\text{lost from metal}}$ ? Explain your reasoning.
4. If the water did not capture some heat, would you have over estimated or underestimated the specific heat of your unknown? Explain your reasoning.