Determination of Unknown Metal by Heat Capacity Lab
Advanced Chemistry
NIVA International School 2010-2011

Thoroughly read the entire procedure before starting the lab.

Note: This lab will be submitted as a formal lab report. All observations must be properly recorded, in pen, on your data sheet (use the back if needed) and submitted with your formal lab report.

Introduction:

As you saw in the last laboratory investigation, every chemical change is accompanied by a change in energy, usually in the form of heat. The energy change of a reaction that occurs at constant pressure is termed the heat of reaction or the enthalpy change.

Each substance has a unique and specific heat capacity, given in units of J / g °C. Generally, substances that are strong conductors of heat have a high value for heat capacity. The reverse is true for substances that are poor conductors of heat. It is therefore possible to identify an unknown metal sample based on its heat capacity.

This quantity of heat is measured experimentally by allowing the reaction to take place in a thermally insulated Styrofoam cup calorimeter. The heat transferred to the solution by the strip of heated metal will cause an increase in the temperature of the solution and of the calorimeter. The heat lost by the metal will equal the heat gained by the water and calorimeter. Because we are concerned with the heat of the reaction and because some heat is absorbed by the calorimeter itself, the heat capacity of the calorimeter calculated in the previous lab investigation will be used as a correction. Once the heat capacity of the calorimeter is known, we will then determine the heat capacity of the unknown metal sample as instructed in the procedure.

Materials:
- 2 Styrofoam cups
- 1 insulated cover (cardboard or Styrofoam)
- 1 thermometer (or Vernier LabQuest with Temperature Probe)
- 1-400 mL beaker
- 1-100 mL graduated cylinder

Chemicals:
- Tap Water
- 1 sample of unknown metal

Note: For this lab, one group will use the digital temperature probe attached to the Vernier LabQuest, while the other group will use a standard liquid thermometer.

Procedure:

Part A: Determining the Heat Capacity of a Metal

1. Obtain a metal sample from your teacher.

2. Record the mass of your metal.

3. Using forceps, carefully place your metal in the water that is gently boiling on the hot plate. Allow the metal to heat up for 5-10 minutes. Continue to the next steps while you wait.

4. Setup a makeshift calorimeter by placing two nested Styrofoam cups in a 400-mL beaker.

5. Measure 75-100 mL of cool tap water in a graduated cylinder and pour this water into your calorimeter. Record the exact amount (nearest 0.5 mL) as the mass of your water (since the density of water = 1.0 g/mL, the volume = mass. Thus, 50 mL = 50 grams of water).

6. Measure the temperature (to the nearest 0.5ºC) of the water in the calorimeter. Record this as the initial temperature of the water in your data table.

7. Check the thermometer of the hot water bath and record this temperature (to the nearest 0.1ºC) as the initial temperature of the metal.

8. Using tongs, remove the metal from the hot water and immediately place it in the calorimeter.

9. Monitor the temperature of the water in the calorimeter. Carefully use the thermometer to gently stir the water. Record the highest temperature (to the nearest 0.1ºC) as the final temperature of the metal and as the final temperature of the water in your data table.

10. Remove the metal from the cup, dry the metal, and proceed to the next procedure.

Part B: Determining the Volume of the Sample

1. The volume of your metal will be determined by using the water displacement method. Fill a 100 mL graduated cylinder with tap water. Record the volume on your data sheet.

2. Using tongs, gently insert your sample into the graduated cylinder. Record the new volume on your data sheet. The difference between this volume and the original volume represents the water that was displaced by the sample, or the volume of the sample. (1 mL = 1 cm^3)

3. Pour out the water in your calorimeter, wiping up any spills. Clean your designated lab area. Wash all glassware and the Styrofoam cups and set to dry.

These questions must be answered and attached to your lab report on a separate piece of paper. They can be typed or hand-written, but must be completed neatly and legibly. They will be marked in addition to your formal lab report.

To be clear: You are required to write a formal lab report, and attach your responses to these questions to your report when you submit it.

Analysis Questions

1. Calculate the heat gained by the water. Use $Q=mC\Delta T$, solving for Q (heat) and inserting m (mass of water), C (specific heat of water = 4.184 J/g ºC), and ΔT (change in temperature for water). **[3 marks]**

2. Since the heat gained by the water is equal to the heat lost by the metal, we can use this value to determine the specific heat of the unknown metal. **[4 marks]**
    a. Starting with $Q=mC\Delta T$, solve for C, the specific heat.
    b. Next, use Q (answer from 1), m (mass of your metal), and ΔT (change in temperature for the metal) to solve for C (specific heat of the unknown metal).

3. Determine the density of your metal using the mass and volume of your metal. **[2 marks]**

4. Use the included table of specific heats and densities to determine the identity of your unknown metal. **[2 marks]**

Metal	Specific Heat (J/g ºC)	Density (g/cm^3)
Aluminum	0.91	2.712
Copper	0.39	8.930
Iron	0.46	7.850
Magnesium	1.05	1.738
Nickel	0.54	8.800
Tin	0.21	7.280
Tungsten	0.13	19.600
Zinc	0.39	7.135

5. Pierre Dulong and Alexix Petit, two French scientists, suggested in 1819 that molar mass is proportional to heat capacity. They proposed the following relationship: **[4 marks]**

$$\text{molar mass} \approx \frac{25\ \text{J / mol ºC}}{\text{heat capacity}}$$

Does your experimental data support this relationship? Why or why not? Explain.

6. Calculate the percent error for this experiment. Use your value as the experimental and the value in the table as the accepted. **[2 marks]**

$$\%\ \text{error} = \frac{\text{(accepted value - experimental)}}{\text{accepted}} \times 100\%$$

Formal Lab Report: 40 marks (see attached rubric)
Analysis Questions: 17 marks
TOTAL: 57 marks