Calorimetry Lab

Accompanying all chemical and physical changes is a transfer of heat (energy); heat may be either evolved (exothermic) or absorbed (endothermic). A calorimeter is the laboratory apparatus that is used to measure the quantity and direction of heat flow accompanying a chemical or physical change. The heat flow for chemical reactions is quantitatively expressed as the enthalpy (or heat) of reaction, ΔH, at constant pressure. ΔH values are negative for exothermic reactions and positive for endothermic reactions. This experiment will focus on the heat flow when a metal is placed in water and allowed to come to thermal equilibrium.

Finding the Specific Heat of an Unknown Metal

Specific Heat - the energy (heat, expressed in J) required to change the temperature of one gram of a substance by 1°C. The equation is: $q = mC\Delta T$ where the unit of q is J, the unit of mass is grams, the unit of specific heat is J/g(°C), and the unit of the temperature change is °C.

The following questions, based on the Law of Conservation of Energy, show the calculations for determining the specific heat of a metal. Considering the direction of energy flow by conventional sign notation of energy loss being "negative" and energy gain being "positive", the

-energy (J) lost by metal = energy (J) gained by the water

We can use an equation that is derived from the two equations above:

$$-m_{metal}C_{metal}\Delta T_{metal} = m_{water}C_{water}\Delta T_{water}$$

The data found in this lab can be placed in the above equation to solve for the specific heat of the metal (C_{metal}). Then, the following equation can be used to estimate the molar mass of a metal from its specific heat:

$$C_{metal} \times MM_{metal} = 25$$

Beginning Question: What do you have to investigate or figure out about this concept? What will be the main questions that will guide your learning (complete with your group members)

Hypothesis: "How does one variable depend on the other?"

Materials

Calorimeter cups, 25 mL graduated cylinder, test tube, beaker, unknown metal, 1 regular thermometer, one digital thermometer, and hot plate.

Procedure

1. Obtain a sample of an unknown metal from Mr. Stein. Note its number on your data table.
2. Your water bath is already heating up. Be careful. Turn the heat to a setting of 9.
3. Measure the metal's mass using an electronic balance.
4. Place the regular thermometer in the water bath that is already heating up.
5. Place the metal sample into the beaker of water, allowing the string to hang outside of the beaker

6. Heat the water to boiling and maintain this temperature for at least 5 minutes so that the metal reaches thermal equilibrium with the boiling water. Record the temperature of the boiling water (using a regular thermometer, not the LabQuest probe). Complete steps 7-12 while this process is occurring. It can stay in the hot water bath for more than 5 minutes if needed.
7. Clean the Calorimeter cup with several rinses of distilled water and dry them thoroughly. Record their mass of the cups and the lid.
8. Using a graduated cylinder, add 20.0 mL of distilled water to the calorimeter and put the lid on the cups.
9. Determine the combined mass of the Calorimeter cup, the lid, and the water.
10. Assemble the calorimeter as noted in the diagram. The probe thermometer should be placed in the water of the calorimeter so it can come to equilibrium prior to starting the measurements. Don't record the initial temperature yet.
11. Get the LabQuest unit ready…
    a. Your LabQuest should be on already. You should be able to see the temperature on the screen.
    b. You will be recording the temperature every 20 seconds. Assign duties to your lab group (time keeper, recorder, temperature reader, swirler)
    c. When your metal is ready to transfer (see step 6), you will need to take <u>at</u> <u>least</u> <u>3</u> <u>measurements</u> **prior to transferring the metal**. This temperature will be your initial temperature of the calorimeter water.
    d. Then QUICKLY transfer the metal and get the lid on as quickly as possible. Make sure to swirl the cup continuously as the change happens fast.
12. Once 300 seconds of intervals have been recorded, you can stop. At this point the water has reached thermal equilibrium with the metal. <u>**Do**</u> <u>**not**</u> record the temperature in the calorimeter as the final temperature of the water though! We are going to use our graph to extrapolate the final temperature! SEE DIRECTIONS ON THE WEBSITE TO DO THIS.
13. Refill your water in the beaker on the hot plate and turn the hot plate to a setting of 1 (this will keep it warm for next hour).

<u>Data Table</u> **LAB STATION # (to help identify unknown metal): __________**

Mass of Metal (g)	
Temperature of metal (boiling water) (^oC)	
Mass of Calorimeter and water (g)	
Mass of Calorimeter (g)	
Mass of water (g)	
Temperature of water in calorimeter (^oC)	
Maximum temperature of metal and water (<u>**from**</u> <u>**graph**</u>) (^oC)	

<u>Calculations</u>: <u>(to be included within your Data/Observation)</u> Remember to show your work.

1. Temperature change of water in calorimeter(^oC)
2. Heat gained by water in calorimeter(J)

4. Specific Heat of metal (J/g^{o}C)
5. Estimated molar mass of metal (g/mol)

Follow up Questions (to be completed prior to your Claims/Evidence)

1. Based on the estimated molar mass of your metal, what metal do you think you had? Please restate which unknown number you were given.
2. Explain what law or theory allows us to assume that the heat lost by the metal is then gained by the water.
3. A thermometer is labeled as being miscalibrated at the factory – the freezing point of water reads 1.2^{o}C and the boiling point of water reads 101.2^{o}C at standard pressure. But, because you are in a hurry and the thermometer is the last one available, you decide to go ahead and use it in the experiment, recording the temperatures as they appear on the thermometer. How will the use of this thermometer affect the determination of the specific heat of the metal?

4a. If the measured peak temperature, rather than the extrapolated temperature from the graph, is used to determine the final temperature for an exothermic process, will the change in temperature be too high or too low? Explain.

4b. How will this mistaken interpretation of the data affect the recorded specific heat of the metal? Explain.

DON'T FORGET YOUR Claims/Evidence and Reading/Reflection!!

EXTRAPOLATED TEMPERATURE DIRECTIONS

To draw Line 1: draw a line of best fit though the top horizontal section of your graph and extend it across the whole page.

To draw Line 2: draw a vertical line straight up from 60 seconds (this is the point where you added your metal).

How to get your extrapolated temperature: Find the temperature at which the two lines intersect (this should be higher than your highest recorded temperature on your temperature data table).

EXAMPLE GRAPH ON BACK OF PAGE!

Example Graph: