CALORIMETER DOUBLE WALL

Experiment Guide

GENERAL BACK GROUND:

Specific Heat Capacity- The amount of heat it takes to raise the temperature of one gram of a substance one degree Celcius.

Heat Capacity- The amount of heat it takes to raise the temperature of a substance one degree Celcius.

Specific Heat Capacity = Amount of heat lost or gained / (Mass * Change in Temperature)

Heat energy is transferred from an object of higher temperature to an object of lower temperature until both objects reach the same temperature.

The change in temperature that a substance experiences when heat is transferred to or from the object depends on the mass of the substance and the identity of that substance. It can be summed up in the following formula:

$$Q = mc(T_f - T_i)$$

Where "Q" is the amount of heat transferred and is positive if heat is added and negative if heat is removed. "m" is the mass of the object, usually measured in grams. "c" is the specific heat of the object usually measured in $J/g{*}^0C$. "T_f-T_i" is the change in temperature of the object. Change in temperature is the same in degrees Celsius as well as Kelvin.

Therefore, if we have a certain mass of water and we add a hot piece of metal, the amount of heat lost by the metal once the system reaches equilibrium (a constant temperature) will equal the amount of energy gained by the water. However, some heat is lost to the air in the calorimeter as well as to the calorimeter itself. In order to obtain a more accurate value for some experiments we must know what the heat capacity of the calorimeter itself is.

Heat always flows naturally from hot to cold. If two objects with different temperatures come in contact with one another, the temperature will reach thermal equilibrium when the temperatures of both objects are the same.

We can use the equation above to calculate the specific heat of a given metal. This is shown in activity 4.

The specific heat of water is 1 $cal/g{*}^\circ C$, or 4.186 $J/g{*}^0C$.

Density and Specific Heat Values for some Common Metals Including this Set:

Material	*Density (g/cm^3)*	*Specific Heat ($J/g{}^\circ C$)*
Brass	8.44-8.75*	0.385*
Lead	11.3	0.13
Iron	7.87	0.45
Copper	8.96	0.39
Aluminum	2.70*	0.91
Zinc	7.14	0.39
Tin	7.26	0.21
Silver	10.5	0.23
Steel	7.85	0.12
Gold	19.3	0.13
Water	1.000 g/cm^3 (at 4^0C)	4.186
	*These values can change based on how the metal is made	

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Outside Cup	1
Orange Rubber Stopper with Temperature Probe hole	1
Plastic lid with resistor and leads	1
Inside aluminum cup	1
Insulating Styrofoam ring	1
Stirring ring	1
Plastic ring to hold inside cup in place	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Distilled water	200 mL
Thermometer or temperature probe	1
Balance (digital or triple beam)	1
Glycerol	1

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Assorted metal samples	several
Tongs for transferring metals	1
Beaker	1
Hot plate	1
Voltmeter	1
Ammeter	1
Power supply DC	1
Connecting leads	5
Stop watch	1

SAFE HANDLING OF APPARATUS:

SAFETY EQUIPMENT REQUIRED:

Safety goggles and lab coat are required while using chemicals or handing boiling water. Gloves may be necessary for handing hot metal or chemicals. Follow all standard laboratory safety procedures while conducting your experiments.

Warning:

Some chemicals are dangerous to put into your calorimeter. For example HNO3 will react with the copper to produce NO, which is toxic. Make sure when doing heat of reaction experiments that neither products nor reactants will react with the copper in your calorimeter.

The resistor gets very HOT. Do not connect resistor to the circuit while it is outside of the water. Make sure resistor is cooled before handling.

MAINTENANCE REQUIRED:

Wash and dry all equipment after use. Store calorimeter in a dry place so the aluminium does not oxidize.

Before performing experiments that do not use the electric resistor, remove the spring by unscrewing the two nuts at the end of the heating unit and gently pulling the spring out. This will prevent the spring from being damaged while other materials besides liquids are introduced to the calorimeter.

DIAGRAM LABELING ALL PARTS:

ACTIVITY 1 : HOW TO CALCULATE THE HEAT CAPACITY OF YOUR CALORIMETER:

NOTE: Remove the spring before performing this experiment.

1. Get water that is about 5-10 degrees cooler than room temperature .
2. Weigh and record mass of a metal cube or cylinder. Also record the name of the element to determine the specific heat capacity with a trusted reference source later.
3. Carefully insert thermometer or temperature probe into the rubber stopper at the top of the calorimeter. Make sure that the probe or thermometer is not touching the bottom of the calorimeter. Many thermometers have a line marking how far the probe needs to be submerged in order to give the most accurate result. Adjust your thermometer or temperature probe accordingly.

   NOTE: the thermometer should never be used for stirring. Use the stirrer (aluminum ring) attached to the top of the calorimeter.
4. Place a beaker filled 1" from the top with water and place on burner plate.
5. Add metal cube or cylinder carefully to the beaker.
6. Turn on beaker and bring water with metal in it to a boil.
7. While you are waiting for the water to boil, weigh the inside cup of the calorimeter without the top and the stirring rod without the handle.
8. Take the room temperature and record this value as well.
9. Add about 200 mL of water that is about five degrees cooler than the surrounding air to the inside cup of the calorimeter until the water level is about 1.5 cm from the top. Make sure that adding the metal will not make the water spill over the side.
10. Weigh and record the mass of the inside cup of the calorimeter filled with water.
11. Carefully place the smaller cup filled with water inside the larger cup. Then place the lid on the calorimeter so the stirrer is also in the water. Very gently move the stirrer up and down and back and forth. Do not hit the thermometer.
12. When the temperature has stopped changing, record this value as the initial temperature of the water.
13. Remove the top of the calorimeter when the water/metal on the hot plate has come to a boil.
14. Very carefully and quickly add the metal from the hotplate to the water inside the calorimeter and place lid back onto to the calorimeter.
15. Use the stirrer to gently stir the water until the temperature of the water is no longer changing. Record the final temperature of the water.

SAMPLE DATA TABLE :

Type of Metal	Specific Heat of Metal (J/(g*°C))	Mass of Metal (g)	Temperature Initial of Metal (°C)	Temperature Initial of Water (°C)	Temperature Final of Water (°C)	Specific Heat Capacity of water (J/(g*°C))	Mass of Calorimeter inside cup (g)	Mass of Calorimeter + Water (g)
Al Bar	0.901	12.1	100	20.2	23.3	4.18	46.4	97.9
Copper Bar	0.385	41.2	100	20.2	23.0	4.18	46.4	144.8
Al Cube	0.901	85.4	100	20.0	32.3	4.18	46.4	136.8
Al Cube	0.901	85.4	100	21.7	34.1	4.18	46.4	129.7

*this number changes depending on atmospheric pressure. Use a reference table to get more accurate data for this column.

______________ room temperature during this experiment

CALCULATIONS:

Energy Lost by Metal = Energy gained by water + Energy gained by Calorimeter

Energy Lost by Metal:

Mass of Metal * Specific Heat of Metal * Change in Temperature of Metal

Energy gained by water:

Mass of water * 4.18 J/(g*°C)*Change in Temperature of Water

Energy gained by Calorimeter:

Mass of smaller cup plus stirrer*0.901 J/(g*°C)*Change in Temperature of Water

It is important to prevent heat transfer through the container from affecting the experimental results. A standard way to do this is to start with the water below room temperature and end with it about the same amount above room temperature. A temperature change of about 10 degrees or more is desirable for good experimental results. This ensures that the heat gain from the environment in the early stages of the experiment is balanced by a nearly equal heat loss in the later stages. To achieve this will require some knowledge of the expected temperature change, so the initial water temperature is chosen correctly. A preliminary "trial run" can give this information.

To double check your calculations, the energy gained by the calorimeter should be equal to the mass of the small aluminium cup and the lid and stirrer multiplied by the specific heat capacity of aluminium.

<u>What are some causes for error in this calculation?</u>

- Some heat is lost due to heating up the stirrer, the thermometer, and the air around the calorimeter.
- Also if the mass is small, the mass will lose a lot of heat to the air as soon as it is taken from the boiling water.

ACTIVITY 2: USING THE ELECTRIC CALORIMETER

PROCEDURE:

1. To measure the voltage and power, an ammeter and voltmeter should be used. Use a direct current voltage of no more than 3.0 Volts. Make sure that the voltmeter is set up in parallel and the ammeter is set up in series as shown in diagram 3.

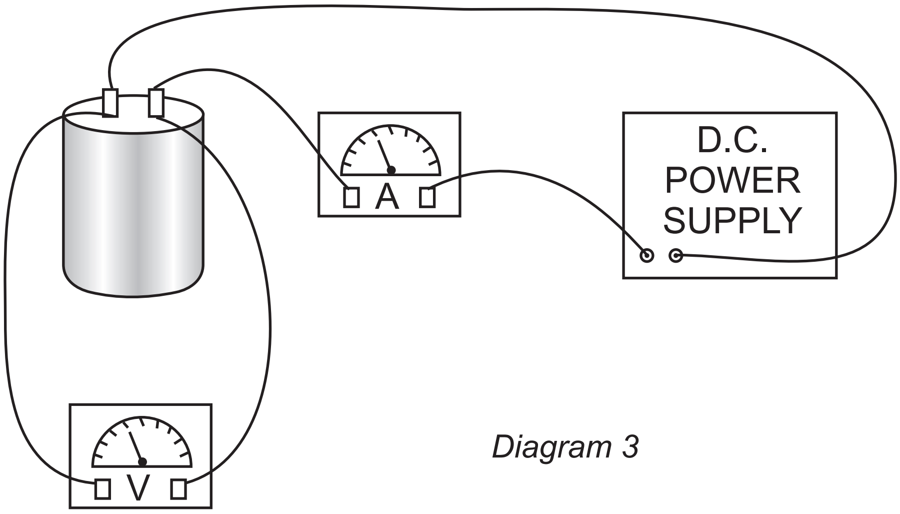

Diagram 3

2. Fill the inner cup with 100-150 mL of distilled water that is about five to ten degrees cooler than room temperature. Assemble the calorimeter, but do not turn the power supply on yet.

3. Use your stirring rod to gently mix the water together so the aluminum cup and resistor are about the same starting temperature as the water. Record the initial temperature of the water.

4. Then simultaneously turn on the power supply to about 3.0-6.0 volts DC current and begin your stop watch.

5. Record the temperature change of your apparatus until it is about five to ten degrees above room temperature and then stop your stopwatch and turn off your power supply. This should take at least 10 minutes, if not longer.

6. Record the time it took to heat your water as well as the final temperature of the water.

WARNING: Let your resistor coil cool before handling it.. Do not take it out of the water while current is running through it.

DATA ANALYSIS:

Power = Voltage * Current = Heat energy/time

$$P = VI = \frac{Q}{t}$$

Therefore:

$$Q = VIt$$

Then calculate the heat absorbed by the water using Q = mc T, where "Q" is the amount of heat added, "m" is the mass of the water (200mL = 200 g), "c" is the specific heat of water and " T" is the change in temperature of the water.

Compare the "Q" added by the resistor, to the "Q" added to the water. The "Q" added to the water should be less than that given off by the resistor. This is because the heat didn't go only into the water, but also into the surrounding air, the stirring rod, the resistor coil itself and the aluminum cup. Students may want to mass the cup and stirring rod calculate the amount of heat given to the cup and stirring and then find the percent error in their calculations.

[Heat energy added by the resistor coil] = [Heat gained by the water] + [Heat gained by the calorimeter]

$Q_r = Q_w + Q_c$

You can find a value for the heat capacity of the calorimeter using this method.

[Heat energy added by the resistor coil] - [Heat gained by the water] = [Heat gained by the calorimeter]

= [Heat Capacity of the calorimeter] [Change in temperature of the water]

Once the heat capacity of the calorimeter is known, the specific heat of different liquids can now be determined by using the method above, and substituting different liquids for water.

Q_r = the energy added by the resistor coil
V = voltage
I = current
t = time the resistor coil was turned on
mc_c = the heat capacity of the calorimeter
T_u = the change in temperature of the unknown
c_u = specific heat capacity of the unknown
Q_u = energy gained by the unknown
Q_c = energy gained by the calorimeter
m_u = mass of the unknown

$$Q_r = Q_u + Q_c$$

$$VIt = (m_u)(c_u)(\ T_u) + (mc_c)(\ T_u)$$

Then solve for the specific heat capacity of the unknown.

Name:____ Date:_____________

Partners:_____________________

WHAT HAVE WE GOT HERE?
(Using Specific Heat to Identify a Metal)

PURPOSE:

Using specific heat to identify metals

MATERIALS NEEDED:

- Hot plate
- 250 mL beaker filled with 6 inches of water
- Metal cylinders or metal cylinders with hooks numbered 1-4 so you know which metal is which
- Thermometer or temperature probe
- Hook or tongs (for removing metal from the boiling water)
- 100 mL graduated cylinder
- Calorimeter
- Digital balance or triple beam balance
- 5° - 10° cooler than room temperature water in prefilled pitchers

PROCEDURE:

1. Clear the lab area of all extra materials (books, coats, hats, etc.) and tie back hair. Have students follow all safety precautions when using a hot plate or handling extremely hot materials. Students should have only the materials listed above and a paper and pencil for recording information.
2. Record the number metal you have acquired.
3. Use your balance to mass your metal and record this value below.
4. Place the beaker with the water on top of the hot plate and carefully add the unknown metal to the beaker.
5. Turn on the hot plate and bring the water and metal to a boil.
6. While the water is heating up, use the graduated cylinder to measure 100 mL - 200 mL of water and place the water into the small cup of the calorimeter. Measure and record the initial temperature of the water in the calorimeter using your thermometer or temperature probe.

7. When the water is boiling, measure the temperature of the boiling water and record this value as well.

8. Using your hook or tongs, carefully and quickly remove your metal from the boiling water and place immediately into your calorimeter and add the lid.

9. Carefully watch the temperature change in the calorimeter while very gently stirring the water. When the temperature reaches its highest value, record this value in your data section. You will know you have reached the highest value when the temperature starts to decrease.

DATA:

(Be sure to label each value with units.)

Number of unknown metal ____________________

Mass of the unknown metal ____________________

Initial temperature of the boiling water __________________

Initial temperature of the metal ________________

Initial temperature of the calorimeter water_________________

Volume of calorimeter water ___________________

Final temperature of the water/metal in the calorimeter _____________________

Anything of note that happened during the lab that could affect your results?

DATA ANALYSIS:

1. Use the formula $Q = mc(T_f - T_i)$ to calculate the amount of heat gained by the water in the calorimeter. Show all work below including formula and substitution with units.

2. Assuming that the amount of heat gained by the water in the calorimeter is equal to the amount of heat lost by the metal, solve for the specific heat of the metal. Show all work below including formula and substitution with units.

3. The calorimeter is made of aluminium and also will absorb some of the heat from your metal. Either calculate the amount of heat absorbed by the aluminium cup, or obtain this value from your teacher.

4. Using the formula : heat lost by metal = heat gained by water + heat gained by aluminium cup, calculate specific heat of your metal in the space provided below. Show all work including formula and substitution with units.

5. Using a list of given values for certain metals, which metal do you think you tested and why?

6. Was all the heat from the metal transferred directly into the water? If not, where could some heat have escaped to?

EXTENSIONS:

- Calculate the Heat Capacity of the Calorimeter experimentally and mathematically and compare the two, discuss what possible sources of error could cause a difference in these two numbers.
- Add HCl acid to water and measure the heat of reaction.

WARNING: Some chemicals are dangerous to put into your calorimeter. For example HNO_3 will react with the copper to produce NO, which is toxic. Make sure when doing heat of reaction experiments that neither products nor reactants will react with the copper in your calorimeter.