SPECIFIC HEAT OF A METAL

0103CP1

Chemists identify substances on the basis of their chemical and physical properties. One physical property of a substance is the amount of energy it will absorb per unit of mass. This property can be measured quite accurately and is called **specific heat** (C_p). Specific heat is the amount of energy, measured in joules, needed to raise the temperature of one gram of the substance one Celsius degree. Often applied to metallic elements, specific heat can be used as a basis for comparing energy absorption and transfer.

To measure specific heat in the laboratory, a **calorimeter** of some kind must be used. A calorimeter is a well-insulated container used in measuring energy changes. The calorimeter is insulated to reduce the loss or gain of energy to or from the surroundings. Energy always flows from an object at a higher temperature to an object at a lower temperature. The heat gained by the cooler substance equals the heat lost by the warmer substance, if we assume no loss of heat to the surrounding environment.

heat lost = heat gained

In this experiment, you will determine the specific heat of a metal sample. The metal sample will be heated to a high temperature then placed into a calorimeter containing a known quantity of water at a lower temperature. Having measured the mass of the water in the calorimeter, the temperature change of the water (ΔT), and knowing the specific heat of water (4.184 J/g˚C), the heat gained by the water (lost by the metal) can be calculated as follows:

$$\text{Heat gained by the water (J)} = \text{Mass of water (g)} \times \text{Change in temperature } (\Delta T) \times \text{Specific heat of the water (4.184 J/g°C)}$$

The specific heat of the metal can now be calculated:

$$\text{Specific heat of metal } (C_p) = \frac{\text{heat gained by the water (J)}}{\text{mass of metal (g)} \times \Delta T \text{ of metal (°C)}}$$

Objectives

In this experiment, you will

- measure the mass and temperature of water in a calorimeter,
- heat a metal sample of known mass to a specific temperature,
- calculate the change in water temperature caused by adding the hot metal sample, and
- calculate the specific heat of the metal using your mass and temperature data.

EQUIPMENT

hot plate	temperature probe	beaker (250 cm^3)
balance	plastic foam cup	

PROCEDURE

1. Fill a 250-mL beaker *about* half full of water. Place the beaker of water on a hot plate or a ring stand with wire gauze. Begin heating the water to the boiling point. Continue with the procedure while the water is heating.
2. Measure the mass of a metal cylinder. Record the mass and the kind of metal.
3. Place the metal cylinder into the beaker of water and continue heating. Leave the metal cylinder in the boiling water bath while you complete Steps 4–6.
4. Obtain a plastic foam cup to be used as a calorimeter and measure the mass carefully. Record.
5. Fill the plastic foam cup with just enough room temperature water to cover the cylinder. **DO NOT FILL TO THE TOP**. Record the mass.
6. Measure the temperature of the water in the cup with a temperature probe. Do not add the hot metal until a steady temperature has been reached (*at least* 30 seconds). (It will be assumed the temperature of the metal is the same as the boiling water.)
7. Remove the metal from the boiling water – it has to be in **BOILING WATER** for at least 2 minutes - and *immediately* put it into the plastic foam cup.
8. Stir the water in the plastic foam cup and continue to watch the temperature and stir the water until the temperature starts to drop. Write down the highest temperature reached.
9. Repeat steps 2 to 8 with 2 different metals. Return all metal samples to the reagent table.

Name ____________________ Partner ____________________ Date ________ Per. ___

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DATA & RESULTS

		metal 1	metal 2	metal 3
1.	mass of cup + water			
2.	mass of empty cup			
3.	mass of water			
4.	initial temp. water, T_{w_i}			
5.	final temp. water, T_{w_f}			
6.	change in temp. of water, ΔT_w			
7.	specific heat of water, C_p, $\frac{\text{J}}{\text{g}\cdot{}^\circ\text{C}}$			
8.*	heat gained by water, q			
9.	symbol of metal			
10.	mass of metal			
11.	initial temp. metal, T_1	100. ˚C	100. ˚C	100. ˚C
12.	final temp. metal, T_2			
13.	change in temperature of metal, ΔT_{m}			
14.*	heat lost by metal, q			
15.*	experimental specific heat of metal, C_p			
16.	theoretical specific heat of metal, C_p			
17.*	error			
18.*	percentage error			

bold = lab measurement * = calculations must be shown in lab report

***N.B.*: three points are deducted for each missing unit from a data table or calculation.**

ANALYSIS

> ***N.B.*: three points are deducted for each missing unit from a data table or calculation.**

1. Prepare another table for your data if yours is messy.
2. Calculate the heat gained by the water (lost by the metal) in the calorimeter using the equation in the Introduction.

metal 1	metal 2	metal 3

3. Calculate the specific heat of the metal using the answers from number 2 and the equation in the Introduction.

metal 1	metal 2	metal 3

4. Calculate the error and % of error for each metal used.

metal 1	metal 2	metal 3

QUESTIONS

1. What physical properties, other than specific heat, could you use to help you identify the sample(s) used in this experiment?

2. Why is water an excellent material to use in a calorimeter?

3. Calculate the specific heat of a metallic element if 314 joules of energy are needed to raise the temperature of a 50.0 g sample from 25.0˚C to 50.0˚C.

4. Propose a method for determining the specific heat, C_p, for a metal, like sodium, that reacts with water.

5. How is the atomic mass of metals related to their specific heats? (use chart below)

metal	atomic mass (g/mol)	specific heat (J/g•˚C)	metal	atomic mass (g/mol)	specific heat (J/g•˚C)	metal	atomic mass (g/mol)	specific heat (J/g•˚C)
aluminum	27.0	0.9025	iron	55.8	0.4494	rhodium	102.9	0.2427
antimony	121.7	0.2072	lanthanum	138.9	0.1952	rubidium	85.5	0.3634
barium	137.3	0.2044	lead	207.2	0.1276	ruthenium	101.1	0.2381
beryllium	9.01	1.824	lithium	6.9	3.569	scandium	45.0	0.5677
bismuth	209.0	0.1221	lutetium	175.0	0.1535	silver	107.9	0.235
cadmium	112.4	0.2311	magnesium	24.3	1.024	sodium	23.0	1.228
calcium	40.1	0.6315	manganese	54.9	0.4791	strontium	87.6	0.301
cesium	132.9	0.2421	mercury	200.6	0.1395	tantalum	180.9	0.1402
chromium	52.0	0.4491	molybdenum	95.9	0.2508	thallium	204.4	0.1288
cobalt	58.9	0.421	nickel	58.7	0.4442	tin	118.7	0.2274
copper	63.5	0.3845	niobium	92.9	0.2648	titanium	47.9	0.5226
gallium	69.7	0.3709	osmium	190.2	0.130	tungsten	183.9	0.132
germanium	72.6	0.3215	palladium	106.4	0.2441	vanadium	50.9	0.4886
gold	197.0	0.129	platinum	195.1	0.1326	yttrium	88.9	0.2984
hafnium	178.5	0.1442	potassium	39.1	0.7566	zinc	65.4	0.3884
indium	114.8	0.2407	rhenium	186.2	0.1368	zirconium	91.2	0.278
iridium	192.2	0.1306						