Measurement of Physical Properties
Introduction

Just as people can be identified by their appearance and their behavior, substances are described and identified by their physical (appearance) and chemical (behavior) properties. Physical properties are those than can be studied without attempting to change the substance into a different substance, while chemical properties can only be studied while trying to change the substance into another substance. In today's lab, you will measure 2 physical properties of an unknown substance and use your data to try to identify the substance.

In Part A you will determine the density of a solid substance. The density of a material may be defined as mass per unit volume. The units generally used are g / mL. The values of some solids, liquids and gases at room temperature are listed below:

Substance	***Density in g/mL at 20°C***
air	**0.00129**
ethyl alcohol	**0.7893**
acetone	**0.7899**
water	**1.0000 (4°C)**
mercury	**13.5939**
gold	**19.3**
methanol	**0.7928**
iron	**7.86**

The densities of solids and liquids change slightly with temperature, in general, decreasing with increasing temperature. This can be explained by the change in volume with temperature, since the mass of a material does not depend on temperature. The density of gases varies greatly with temperature, since the volume of gases may vary considerably with temperature.

The mass of the material may be found in the laboratory by the use of a balance. These operate by comparing the mass of the unknown sample to the mass of a known set of standard weights. Because of common convention, however, the mass determined on the balance will be called weight not mass. (It should be noted that weight is obtained when a spring scale is used).

The volume of a solid may be determined by direct measurement if the solid has a regular geometrical shape. The volume of irregularly shaped solids may be determined by measuring the amount of liquid which is displaced when the solid is placed in a liquid. This assumes, of course, that the liquid does not react with the solid or that the solid does not dissolve or float in the liquid. This concept was discovered by an ancient Greek philosopher scientist named Archimedes, and is therefore called Archimedes' Principle. We will be using this method in today's experiment.

In Part B of today's experiment you will be measuring the specific heat of this same substance. Heat is a form of energy. Temperature is used to describe the **intensity** of heat. The two are **NOT** the same. A flame of a match and the burner of a stove may be at the same temperature but the stove burner possesses a great deal more heat. The amount of heat required to raise the temperature of a quantity of matter is directly related to the amount of matter - i.e. its mass. The amount of heat is also directly related to the size of the temperature change.

Q (heat in calories or joules) α mass (in g) x (temp. change in °C)

The symbol α means "is proportional to". In order to make this an equality it is necessary to multiply the right side by a "proportionality constant" k, so that

$$Q = km(\Delta t)$$

Solving for k we get:

$$k = \frac{Q}{m(\Delta t)}$$

Δ t means change in temperature and is always calculated as $\mathbf{t_{final} - t_{initial}}$
"k" is known as **specific heat** and it is a characteristic property of the kind of matter being studied. "k" has the units of calories/gram-°C or joules/gram-°C. We will be using joules as our heat unit in this experiment

. Temperature is a rough measure of molecular motion. The same quantity of heat will produce a different temperature change in equal masses of different substances. This is not at all odd. Engines of the same horsepower will move a Lincoln and an Escort at rather different speeds. It takes less heat to raise the temperature of a cup of milk a given number of degrees than it does a cup of water. In other words, different and characteristic amounts of heat are required to heat the same mass of different substances through the same temperature range. Be sure not to confuse temperature and quantity of heat. Which should melt more ice, a thimbleful of boiling water or a bucket of water at 90°C? Vote for the bucket!

Some fundamental definitions would seem to be in order now.

Heat: Heat lost is **negative** and heat gained is **positive**, because of the way in which heat is defined scientifically.

Calorie (cal): quantity of heat liberated or absorbed when 1.00 g of water is cooled or heated 1.00°C (To be exact, this is true only between 14.5° and 15.5°C. However, the amount of heat associated with 1°C temperature change is usually so close to 1 cal that this figure is used unless very precise work is in progress.)
Calorie is the unit most often used in the older Metric System.

Joule (J): Unit of heat most commonly used in the SI system. **1.00 cal = 4.184 J**

Specific Heat: The quantity of heat liberated or absorbed when the temperature of 1.00 grams of a substance falls or rises 1.00°C. Specific heat is temperature (and phase) dependent. Thus one must know not only the substance but also the temperature range and whether a solid, liquid or gas is involved.

Substance	*Specific Heat (J/g- ℃)*
water(gas)	1.874
water(liquid)	4.184
water(solid)	2.113
ammonia(liquid)	4.39
ammonia(solid)	2.09
ethanol(liquid)	2.43

In this activity the specific heat of a metal will be determined using the concept of the **zero'th law** which states that in any process where heat is transferred,

Heat loss = **-** Heat gain

A sample of hot metal (of known mass and temperature) will be mixed with water (also of known mass and temperature). The metal will lose heat and water will gain heat. The temperature after mixing will be uniform - that is, the water and metal will be at the same temperature.

The specific heat of water is 4.184 joules per gram per degree. Thus, the heat gained by the water can be calculated. From the **zero'th law** the amount of heat must be equal to the heat lost by the metal sample. From this, the specific heat of the metal is calculated.

EXPERIMENTAL PROCEDURE:

Part A: Density of a Solid:

1. Clean and dry a 10 mL graduated cylinder. Add approximately 5 mL of distilled water to the graduated cylinder and record the liquid level as accurately as possible. Proper significant figures for a 10 mL graduated cylinder will give you 2 decimal places. Record the mass of the cylinder plus water as precisely as your balance allows.

2. Add about one third of your unknown solid sample to the graduated cylinder. Record the new level of the liquid in the cylinder and the new mass.

3. Calculate the mass and volume of your solid sample by difference. Determine its density.

Part B: Specific Heat of a Metal:

1. Weigh out about half of your remaining solid sample into a large test tube and the other half into another large test tube.

2. Gently insert a thermometer into the metal sample in one of the test tubes. Place the test tube in a 600 mL beaker containing about 400 mL of water.

3. Heat to boiling and allow to boil for about ten minutes. Meanwhile weigh an empty plastic foam cup. Using a graduated cylinder, place 100 mL of distilled water into the cup. Reweigh to

obtain the mass of the water. Place a second thermometer through the cover of the cup. Support the thermometer by a paper clip and clamp arrangement, so that the bulb of the thermometer will be in the center of the water. Read the temperature of the water in the cup as accurately as possible, and record the temperature when it becomes steady. This is the initial temperature of the water.

4. After 10 minutes of heating, read and record the temperature of the metal in the hot water bath. This is the initial temperature of the metal.

5. Remove the hot tube of metal from the water bath. Pour the metal quickly into the water in the cup. Quickly replace the cover, swirl, and watch the temperature of the water/metal mixture. Record the highest temperature reached by this mixture. This is the final temperature for the metal and for the water.

6. Repeat this procedure with the sample of metal in the other test tube, using either a clean, dry foam cup or reusing the same one after drying it out.

7. From your data calculate the specific heat of your unknown metal in each trial and average the results.

Lab #1

NAME ______________________________________ SECTION # __________

DATA SHEET:

Unknown Solid # ___________

Part A: Density of a Solid:

Mass of graduated cylinder + water	_________________
Mass of graduated cylinder + water + metal	_________________
Mass of metal	_________________
Volume reading of water	_________________
Volume reading of water + metal	_________________
Volume of metal	_________________
Density of metal	_________________

Part B: Specific Heat of a Metal:

	TRIAL 1	TRIAL 2
Metal Unknown #	________	
Mass of test tube plus metal	________	________
Mass of test tube	________	________
Mass of metal	________	________
Initial temperature of metal (hot)	________	________
Mass of empty cup	________	________
Mass of cup plus water	________	________
Mass of water in cup	________	________
Initial Temperature of water	________	________
Temperature of water/metal mixture	________	________
Change in temperature of water (Δt_w)	________	________
Change in temperature of metal (Δt_m)	________	________

CALCULATIONS:

	TRIAL 1	**TRIAL 2**
1. Heat gained by water. Show set-up and calculations.	________	________
2. Heat lost by the metal. Remember: **$Q_{lost} = -Q_{gained}$**	________	________

Specific Heat of metal. (Show set-up)	___________	___________

Average __________

4. Using your values of density and specific heat, and any appropriate reference source, identify your metal.

Lab #1

PRESDTUDY

NAME ____ SECTION # _____________

1.(2.5 points) A graduated cylinder is filled with water to the 7.25 mL mark. After placing an unknown solid into the graduated cylinder, the volume reading is 14.30 mL. The mass of the cylinder and water before the metal was added was 35.46 g and after adding the solid, it was 85.79 g. Calculate the density of the metal.

_____________ g / mL

2.(2.5 points) How many joules are necessary to raise the temperature of 53.5 g of water from 16.5°C to 70.1°C ?

______joules

3.(2.5 points) What is the specific heat of a metal, if 50.3 g of the metal requires 152.0 joules for a 20.0°C temperature change?

______J/ °-g

4.(2.5 points) 33.5 g of an unknown metal, at a temperature of 99.0°C is mixed with 100.0 g of water at a temperature 22.0°C. The resulting mixture reached a maximum temperature of 26.5°C. What is the specific heat of the metal?

______J/ °-g