Reading assignment: Chang, Chemistry 10th edition, pp. 18-19.

Goals

The purpose of this experiment is to become familiar with the concept of density. We will determine the density of water and of an unknown metal. We will also learn to use the triple-beam balance.

Equipment and Materials

10 mL graduated cylinder, 100 mL graduated cylinder, 100 mL beaker, distilled or deionized water, metal bar, triple-beam balance.

Discussion

A commonly measured physical property of materials is density. The density of a material depends on the atomic or molecular structure of the material and is defined as mass divided by volume:

$$d = \frac{mass}{volume} = \frac{m}{V}$$

Triple-beam balance

graduated cylinders

Mass can be measured using any one of several devices, such as the digital analytical balance or a mechanical triple-beam balance. In this experiment we will measure mass using a triple-beam balance.

To measure the volume of a material we must consider its physical state.

For liquids, volume can be measured using volumetric flasks, graduated cylinders, volumetric pipettes, or burets. In this experiment we will use graduated cylinders to measure the volume of water.

Density is an example of an intensive property, meaning that it doesn't depend on the amount of the material. The density of a small piece of copper is the same as the density of a large piece of copper. The mass of an object, on the other hand, does depend on how large the object is and is an example of an extensive property.

The density of liquid water is about 1 g·mL^{-1} at room temperature. Among metals, densities range from 0.6 g·mL^{-1} for lithium to 22.3 g·mL^{-1} for osmium. Exotic solids known as aerogels possess very low densities, as low as 0.004 g·mL^{-1}. A general trend in the periodic table is that density increases with atomic number. An explanation for this trend is that as the atomic number increases the nucleus possesses an increasing number of protons and neutrons, resulting in an increased mass of the atomic nucleus. The volume of the nucleus increases more slowly with the addition of protons and neutrons, resulting in increasing density.

Table 1 shows density values for several elements from the periodic table. All of the elements listed are solids at room temperature, with the exception of mercury. The density of liquid water is included for the purpose of comparison.

**Table 1. Density values for selected materials at 20°C**

Element	Symbol	Density ($g \cdot mL^{-1}$)	Atomic number
aluminum*	Al	2.698	13
cadmium*	Cd	8.65	48
copper*	Cu	8.960	29
lead*	Pb	11.350	82
magnesium*	Mg	1.738	12
tin (white)*	Sn	7.28	50
zinc*	Zn	7.133	30
water (l)	H_2O	0.9982	N/A

*These are the metals we will use in this experiment.

Water Immersion Method for Density Determination

The volume of a solid object can be measured by using the water displacement method. In this method the object is placed in a liquid that is less dense than the object. The addition of the object to the liquid raises the level of the liquid because the two volumes are additive. This experiment assumes that the solid doesn't react with or dissolve in the liquid.

V_1 is the volume of the liquid. V_2 is the sum of the volume of the liquid and the solid object. Notice that V_2 is greater than V_1. This is because the volume of the liquid and the volume of the solid object are additive. The volume of the solid object is:
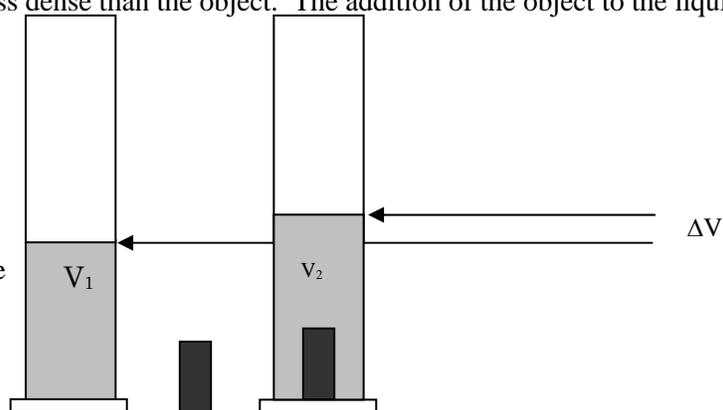
$$V_{solid} = \Delta V = V_2 - V_1.$$

Significant Figures

When the mass of an object is measured using the triple-beam balance the result should be reported to 0.002 g. The number of significant figures in the volume measurement depends on the type of graduated cylinder used. For the 10 mL graduated cylinder the water level should be estimated to 0.05 mL. For the 100 mL graduated cylinder the volume should be estimated to 0.5 mL.

Procedure

SAFETY PRECAUTIONS
Safety glasses are not required for this experiment.
Students work individually on this experiment.

Part 1: The Density of Water

1. Measure the mass of an empty dry 10 milliliter (mL) graduated cylinder using the triple-beam balance. Record the mass using the data sheet provided.

2. Pour some distilled or deionized water into the graduated cylinder and wipe away any water on the outside of the cylinder. Carefully measure the volume of the water in the cylinder.

3. Re-measure the mass of the graduated cylinder.

4. From the measured mass and volume of the water, calculate the density of the water. The density of water at 20 °C is 0.998 g·mL^{-1}. If you find the density of the water to be less than 0.96 g·mL^{-1} or greater than 1.04 g·mL^{-1} check your measurements and calculation. After finding the source of error, complete the calculation and go to Part 2 of the experiment.

Part 2: **Determination of the Density of a Metal**
1. Obtain a dry metal bar from the instructor. Record the unknown number for the metal in the data sheet.

2. Measure the mass of the metal using the triple-beam balance.

3. Measure the volume of the metal bar by the displacement of water. This is done by placing 40 to 70 mL of tap water into a 100 mL graduated cylinder. The amount of water you place in the cylinder depends on the length of the metal. For the experiment to work, the metal has to be completely immersed in water. Carefully measure and record the volume of the water.

4. Tilt the graduated cylinder and place the metal bar into the graduated cylinder. Allow the metal bar to slowly slide down the cylinder until it reaches the bottom. Do not allow the bar to slide fast. It might break the glass cylinder or splash water out of the cylinder. Carefully measure and record the new volume.

5. Repeat the volume measurements in steps 3 and 4 so that you have two sets of volume measurements for the metal. Calculate the average volume of the metal from these two sets of measurements.

Calculations

Show all calculations on a separate sheet of paper.

Part 1
1. The density of the water is its mass divided by its volume:

$$d_{H_2O} = \frac{m_{H_2O}}{V_{H_2O}}$$

Part 2
2. Calculate the volume of the metal using the measured masses of the water and the water with the metal:

$$V_{metal} = V_{metal+water} - V_{water}$$

3. The average volume of the metal can be determined from the two measurements of the metal's volume:

$$V_{average} = \frac{volume\,1 + volume\,2}{2}$$

4. Calculate the density of the metal using the average volume of the two measurements. Be sure to report your density value to the correct number of significant figures.

$$d_{metal} = \frac{m_{metal}}{V_{metal(average)}}$$

5. We will assume that the metal you used is one of the metals listed in the Table 1. Select the metal that has the closest value of density to the density you calculated.

6. To determine how close you were to the accepted value for the density of the metal, calculate the percentage error. Percentage error is a measure of how close your experimental value is to the accepted value. Use the following equation:

$$\%\ error = \frac{|known - measured|}{known}\ x\ 100$$

where the known value is the accepted value for density and is found in Table 1. The measured value is the density you measured and calculated in this experiment. The difference between the known value and the measured value should be positive. Using the absolute value of the difference ensures this.

Observations and Notes
Density

Date

Name_____   Section_____   Date_____

Part 1: The Density of Water

Mass of 10 mL graduated cylinder   _____ g

Mass of cylinder + water   _____ g

Mass of distilled or deionized water   _____ g

Volume of distilled or deionized water   _____ mL

Density of distilled or deionized water   _____ $g \cdot mL^{-1}$

Part 2: The Density of an Unknown Metal

Unknown metal number   _____

Mass of metal   _____ g

Volume of water   _____ mL   _____ mL

Volume of water and metal   _____ mL   _____ mL

Volume of metal   _____ mL   _____ mL

Average volume of the metal   _____ mL

Density of metal (mass/volume)   _____ $g \cdot mL^{-1}$

Name of metal   _____

% error   _____

Name_____   Section_____   Date_____

Show all calculations on this sheet