EXPERIMENT 5

Mass and Density

Goals

Use a laboratory balance correctly.
Identify the gram as a unit of mass.
Determine the conversion factor for mass and weight.
Calculate the density of a substance from measurements of its mass and volume.
Calculate the specific gravity of a liquid from its density.
Determine the specific gravity of a liquid using a hydrometer.
Graph the relationship between the mass and volume of a liquid.

Lab Questions

1. What is the difference between mass and weight?
2. How would you determine the mass of an object?
3. What property of oil makes it float on water?
4. Why would heating the gas in an air balloon make the balloon rise?
5. What is the difference between density and specific gravity?

Concepts to Review

Mass
Metric prefixes
Percent
Conversion factors for mass and weight
Density
Specific gravity

Discussion

In the metric system, the unit of mass is the ***gram*** (g). A larger unit, the *kilogram* (kg), is used in measuring a patient's weight in a hospital, while a smaller unit of mass, the *milligram* (mg) is often used in the laboratory. (See Table 5.1.)

Table 5.1 Some Metric Units used to Measure Mass

Mass	Equality
kilogram (kg)	1 kg = 1000 g
gram (g)	1 g = 1000 mg
milligram (mg)	1 mg = 0.001 g

The *mass* of an object indicated the amount of matter present in that object. The *weight* of an object is a measure of the attraction the Earth has for that object. Because this attraction is proportional to the mass of the object, we will use the terms mass and weight interchangeably.

Percent (%) by Weight

When a mixture contains different items, we can determine their mass and calculate their mass percent (%). A percent (%) is the parts per 100. In a mixture of two different items, the percent is obtained by dividing the mass of one of the items by the mass of the whole mixture and multiplying by 100.

$$\frac{\text{Mass (g) of item 1}}{\text{Mass (g) item 1} + \text{Mass (g) item 2}} \times 100 = \text{Percent by mass (\%) item 1}$$

$$\frac{\text{Mass (g) of item 2}}{\text{Mass (g) item 1} + \text{Mass (g) item 2}} \times 100 = \text{Percent by mass (\%) item 2}$$

Density

The density of a substance represents a relationship between the mass of a substance and its volume. Hospital laboratories determine the density of urine as part of a health checkup. Whether a substance sinks or floats in a liquid is determined by the densities of the two substances.

To determine the density of a substance, you need to measure both its mass and its volume. You have carried out both of these procedures in previous labs. From the mass and volume, the density is calculated. If the mass is measured in grams, and the volume in milliliters, the density will have the units of g/mL.

$$\text{Density of a substance} = \frac{\text{Mass}}{\text{Volume}} = \frac{\text{g substance}}{\text{mL substance}}$$

Specific Gravity

The specific gravity of a liquid is a comparison of the density of that liquid with the density of water which is 1.00 g/mL (4°C).

$$\text{Specific gravity (sp gr)} = \frac{\text{Density of liquid (g/mL)}}{\text{Density of water (g/mL)}}$$

Specific gravity is a number with no units; the units of density (g/mL) have canceled out. This is one of the few measurements in chemistry written without any units.

Laboratory Activities

BE SURE TO PUT ON YOUR SAFETY GOGGLES BEFORE YOU BEGIN ANY EXPERIMENT!

A. The Mass of A Solid

Materials needed: Laboratory balance, objects to weigh (beaker, rubber stopper, evaporating dish, watch glass), and unknown mass

A.1 Your instructor will demonstrate the use of a laboratory balance. Determine the mass of several objects from your lab drawer. Place each object on the balance pan and record its mass. ***Do <u>not</u> round off any measurements of mass.*** If you are using a triple beam balance, be sure that all of your recorded measurements include a figure in the hundredth's, (0.01) place. Be sure to put a 0 in the hundredth's place when it is part of the precision of the measurement. See Example 5.1.

Example 5.1

To what decimal place are each of the following masses measured?
a. beaker 42.18 g b. pencil 11.6 g

Solution:

a. to the hundredth's place b. to the tenth's place

A.2 Now that you have used the balance several times, you are ready to determine the mass of an unknown. Obtain an unknown from your instructor and record its code number. Determine its mass and record. Check your result with the instructor.

B. Percent (%) by Weight

Materials needed: Beaker, rubber stoppers (2), and a laboratory balance

B.1 Obtain a beaker that will hold 2 stoppers. Find the mass of the beaker, and then the mass of the stoppers. Add together the mass of the beaker and the mass of the stoppers to determine the total mass.

B.2 Calculate the percent by mass for the beaker.

$$\frac{\text{Mass of beaker}}{\text{Mass of beaker + stoppers}} \times 100 = \%\ \text{beaker by mass}$$

B.3 Calculate the percent by mass for the stoppers.

$$\frac{\text{Mass of stoppers}}{\text{Mass of a beaker + stoppers}} \times 100 = \%\ \text{stoppers by mass}$$

B.4 Calculate the sum of the percentages (B.2 + B.3).

C. Mass and Weight (Metric and American Units)

Materials needed: Commercial products with mass/weight labels

C.1 ***Grams and pounds.*** Many labels on commercial products list the amount of the contents in both metric and American units. Obtain a commercial product and record the mass and weight of the contents. ***Do not weigh.*** If the weight is given in ounces, convert it to pounds. (1 lb = 16 oz)

$$\boxed{\quad} \text{ ounces} \times \frac{1\text{ lb}}{16\text{ oz}} = \text{lb}$$

Calculate a ratio of grams to pounds (g/lb) from the quantities on the label . Divide through by the number of pounds to obtain the number of grams that would be in 1 pound.

Your experimental result should be close to the standard value 454 g/lb.

C.2 ***Pounds and kilograms.*** If necessary, convert the mass on the label from grams to kilograms.

$$\boxed{\quad} \text{ grams} \times \frac{1\text{ kg}}{1000\text{ g}} = \text{kg}$$

Set up a ratio to show the number of pounds as the numerator (C.1) and the number of kilograms as the denominator (C.2). Divide through and report the answer as lb/kg with the correct number of significant figures. Your experimental result should be close to the standard value of 2.20 lb/kg.

D. Density of A Solid

Materials needed: Metal object, string or thread, graduated cylinder, and a balance

D.1 ***Mass of the solid*** Obtain a solid metal object. Determine its mass and record.

D.2 ***Volume of the solid by displacement*** Obtain a graduated cylinder that is large enough to hold the solid metal object. Add water until the cylinder is about half full. Read the water level carefully and record. If the solid object is heavy, you may want to lower it into the water by attaching a string or thread. While the solid object is submerged under the water, record the final volume level of the water. Calculate the volume of the solid.

Volume of solid = Final water level – initial water level

D.3 ***Calculating the density of the solid*** Calculate the density (g/mL) of the solid by dividing its mass (g) by its volume (mL). Be sure to determine the correct number of significant figures in your calculated density value.

$$\text{Density of solid} = \frac{\text{Mass (g) of solid}}{\text{Volume (mL) of solid}}$$

D.4 If your instructor indicates that the solid is made of one of the substances in Table 5.2, use the density you calculated in D.3 to identify the metal from the known values for density.

Table 5.2 Density Values of Some Metals

Substance	Density (g/mL)	Substance	Density (g/mL)
Aluminum	2.7	Brass	8.4
Zinc	7.1	Copper	8.9
Iron	7.9	Lead	11.4

E. Density of a Liquid

Materials needed: Graduated cylinder, liquids, and a laboratory balance
Disposal of liquids: Dispose of liquids properly as directed by your instructor.

E.1 **Volume of Liquid** Place about 20 mL of water in a 50-mL graduated cylinder. Record the volume of the liquid to the 0.1 mL. ***(Do not use the markings on beakers to measure volume; they are not accurate.)***

E.2 **Mass of Liquid** The mass of a liquid is found by weighing by difference. First, determine the mass of a small, dry beaker. Pour the water in E.1 into the beaker, and reweigh the combined mass. Record. **Write down all the figures in the measurements.** Calculate the mass of the liquid.

> ***Taring a container*** If an electronic balance is available, the beaker can first be *tared.* By pressing the *tare* bar, the mass of the container is set at 0. After a liquid is added to the beaker, the mass that is read on the balance is for the *liquid* only. (When a container is tared, it is not necessary to subtract the mass of the beaker.)

E.3 **Density of Liquid** Calculate the density of the liquid by dividing its mass (g) by the volume (mL) of the liquid that was used.

$$\text{Density of liquid} = \frac{\text{Mass (g) of liquid}}{\text{Volume (mL) of liquid}}$$

E.4 Repeat steps E.1-E.3 for one of the liquids assigned in the laboratory.

F. Specific Gravity

Materials needed: Water and the liquids in part E and hydrometers in each

F.1 Calculate the specific gravity (sp gr) of the liquid you used in E. Divide its density by the standard density of water (1.00 g/mL).

$$\text{Specific gravity} = \frac{\text{Density of a substance (g/mL)}}{\text{Density of water (1.00 g/mL)}}$$

F.2 Read the hydrometer set in a graduated cylinder containing the same liquid you used in the density section. Record the hydrometer reading for the liquid used in part E. Some hydrometers use the European decimal point which is a comma. The value 1,000 on a European scale is the same as 1.000. Record specific gravity as a decimal number.

Using a Hydrometer The specific gravity of a fluid is determined by using a hydrometer. Small hydrometers (urinometers) are used in the hospital to determine the specific gravity of urine. Another type of hydrometer is used to measure the specific gravity of the fluid in your car battery. A hydrometer placed in a liquid is spun slowly to keep it from sticking to the sides of the container. The scale on the hydrometer is read at the meniscus of the fluid. Read the specific gravity on the hydrometer to 0.001. (See Figure 5.1.)

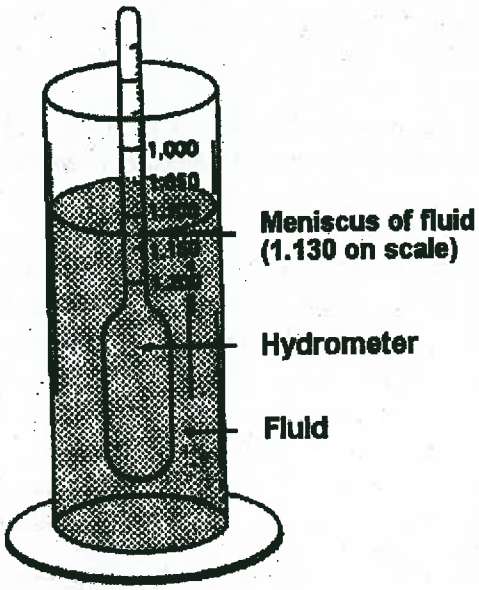

Figure 5.1 Measuring specific gravity using a hydrometer

F.3 Compare the *calculated* specific gravity (F.1) with the *measured value* of the hydrometer reading (F.2).