Scientific Measurements

Making measurements is common in general, such as taking our temperature, checking the tire pressure on a car, or measuring the ingredients when cooking. Taking measurements is also the basis for recording experimental results. Since chemistry is an experimental science, taking measurements is fundamental to chemists. In the United States, both the metric, or SI, system and the English system of measurement are widely used, but for scientific purposes the metric system is used exclusively. In this laboratory exercise you will be introduced to the metric system of measurement, and will determine the relationship between the metric and English units of length, volume and mass. The importance of taking measurements properly and of knowing the significance of your measurements will be emphasized.

I. Length and Area

Objective: To recognize the number of significant figures in a measurement. To measure lengths in the metric system using a meter rule. To calculate areas in the metric system using a meter rule. To measure lengths in inches and to determine the factor for converting inches to centimeters.

Materials and Equipment: Meter stick and foot rule, graduated in tenths of an inch.

Procedure: Examine a meter stick and a foot rule. Measure the length and width of a standard piece of paper both in centimeters and in inches, and record your results on the laboratory report. State the number of significant figures in each measurement. Do the calculations, and report your answers to the correct number of significant figures.

II. Volume

The unit for measuring volume in the metric system is the liter (L). The volumes used in the laboratory are generally smaller than a liter. They are measured in milliliters (mL). A milliliter is one-thousandth of a liter, so

$$1000 \text{ mL} = 1 \text{ L} \qquad \text{or} \qquad 1 \text{ mL} = 10^{-3} \text{ L}$$

The cubic centimeter (cm^3), or 1 cc, is equal to the milliliter in volume, so

$$1 \text{ mL} = 1 \text{ cc}$$

Volume measurements are important in many experimental procedures. Sometimes volume measurements must be accurate, but at other times they can be approximate. Most volume measures in the laboratory are made using equipment calibrated in milliliters. Although some beakers have graduation marks, these marks are designed only for quick, rough estimates of volume. Accurate volumes must be measured with graduated cylinders, pipets, burets, or volumetric flasks.

Objective: To make volume measurements in the metric system using a graduated cylinder, graduated beaker, pipet, and volumetric flask. To calculate volumes in the metric system. To measure the volume of small, irregularly shaped solid objects.

Materials and Equipment: Small rocks, pieces of metal, 250 mL graduated beaker, 25 mL and 100 mL graduated cylinders, 10 mL graduated pipet, 25 mL volumetric pipet, 100 mL volumetric flask, small test tube, 250 mL Erlenmeyer flask, pipet pump, and tap water.

Procedure A. Making a Volume Measurement: Half fill a 100 mL graduated cylinder with water, and set the cylinder on your laboratory bench. Examine the surface of the water closely. Notice how the surface curves upward where the water contacts the cylinder walls. This curved surface is called a *meniscus*. A volume measurement is always read at the bottom of the meniscus with your eye at the same level as the liquid surface. To make the meniscus more visible, you can place your finger or a dark piece of paper behind and just below the meniscus while making the reading.

Graduated cylinders are available in many capacities. The 100 mL cylinder is marked in 1 mL divisions, and volumes can be estimated to the nearest 0.1 mL. Record the volume of water in your graduated cylinder in the laboratory report.

Procedure B. Measuring the Volume of a Small Irregularly Shaped Object: Select several small solid objects that will fit into your graduated cylinder. Half fill your graduated cylinder with water, and record the volume in the data table. This is your initial volume. Tilt your graduated cylinder, and allow an object to slide slowly, and without splashing, into the water. The object must be completely submerged. Place the cylinder on a level surface, and measure the new volume. This is the final volume. The difference between the final volume and the initial volume is the volume of the object. If there is still room in the cylinder, determine the volume of other objects. Record your results in the data table.

Procedure C. Measured Volume of a Test Tube: Fill a small test tube to the top with water. Pour the water into a clean, dry 100 mL graduated cylinder, and read and record the volume. Fill the test tube with water again, and add this to the water in the graduated cylinder. Read and record the new volume. Repeat the process three more times for a total of five samples. When all the volumes have been recorded in the data table, calculate an average volume for the test tube.

III. Mass

Mass is the quantity of matter an object contains. The SI unit of mass is the gram (g). In the laboratory, measurements of mass are made with a balance. The accurate determination of mass is a fundamental technique that must be mastered by students of chemistry.

Many kinds of balances are seen in chemistry laboratories. The most common types of balances found in introductory chemistry laboratories are the triple-beam or centigram balance, the top-loading balance, and the digital electronic balance. Note the capacity and sensitivity of the balances that you will use in the laboratory. Your laboratory instructor will describe and

demonstrate the operation of the balance in your laboratory. As you do this experiment, recall the general rules that were given in the introduction.

The following general rules apply to the use of all laboratory balances.

1. Check the balance before you start measuring mass. The balance pan should be empty and clean, and all controls should be set on zero. The balance must be level.
2. Objects to be placed directly on the balance pan must be clean, dry, and at room temperature. Solid chemicals and liquids must never be put directly on the balance pan. Liquid samples should be contained in beakers or sealed containers. Solid chemicals can be conveniently placed in beakers or on weigh boats.
3. The balance is a precision instrument that must be handled with care. If applicable, make sure the balance is in a secure position when objects are placed on or removed from the pan. Always use controls with care.
4. Never move or jar either a balance or the table it rests on.
5. If you spill a chemical on or near the balance, clean it up immediately, and inform your instructor.
6. Never attempt to measure the mass of an object with a mass greater than the maximum capacity of the balance.
7. When you finish, return all balance controls to zero, and make sure the balance pan is clean.

Objective: To learn to use a laboratory balance. To determine the mass of an object by measuring its mass directly and by measuring its mass by difference.

Materials and Equipment: Various objects, pieces of metal, 100 mL beaker, and laboratory balance. You may use personal items as well as those provided by your instructor.

Procedure A. Measuring Mass Directly: Measure the mass of several solid objects directly on the balance pan, and record the masses as accurately as possible in the data table.

Procedure B. Measuring Mass by Difference: Most mass measurements in the chemistry laboratory are done by difference. Place a container such as the beaker on the balance pan, and measure its mass. Place an object whose mass you want to measure in the container, and then determine the combined mass. Finally, obtain the mass of the object by subtracting the mass of the container from the mass of the container and the object. Determine the mass of the same object by direct mass determination. Enter your results on the report sheet.

IV. Density

Density is an easily measured physical property that is very useful for the identification of unknown materials. Substances that have similar physical appearances often have quite different densities. In this experiment you will determine the densities of some common solids and liquids.

Density is the ratio of the mass of an object to its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Density has units of grams per cubic centimeter (g/cm^3) when mass is measured in grams and volume in cubic centimeters. Since 1 cm^3 is the same volume as 1 mL, densities are frequently reported in grams per milliliter (g/mL). To determine the density of a solid object, both its mass and its volume must first be determined. The mass can be obtained by direct weighing or by weighing by difference. The volume can be obtained either by displacement of water in a graduated cylinder (provided the substance to be measured is insoluble), or by calculation from its dimensions f it is a regular shape such as a cube, sphere, or cylinder.

Objective: To calculate the density of an object by measuring its mass and volume. To determine the density of a liquid.

Materials and Equipment: Isopropyl alcohol, distilled water, small cylindrical pieces of metal, lead shot, 25 mL graduated cylinder, laboratory balance, and 250 mL glass cylinder.

Procedure A. Density of a Solid: Determine the densities of a solid metal cylinder and lead supplied as lead shot. The measurements you must make are identified on the report sheet. Remember to include units in measurements.

Procedure B. Density of a Liquid: Determine the density of water and isopropyl alcohol. The measurements you need to make are indicated on the report sheet.

Scientific Measurements Laboratory Report

Page length: _____ cm Number of significant figures: _____
Page length: _____ in. Number of significant figures: _____

Page width: _____ cm Number of significant figures: _____
Page width: _____ in. Number of significant figures: _____

Area of paper (length X width)

_____ cm X _____ cm = _____ cm^2 (rounded off to the correct number of significant figures)

_____ in. X _____ in. = _____ $in.^2$ (rounded off to the correct number of significant figures)

Conversion factor: inches to centimeters

$\frac{\text{Page length (cm)}}{\text{Page length (in.)}} = \frac{\text{\_\_\_\_\_ cm}}{\text{\_\_\_\_\_ in.}} =$ _____ cm/in.

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Stated conversion factor from textbook: _____ cm/in.

Volume of water in the 100 mL graduated cylinder: _____

Volume of irregularly shaped object by displacement: _____, _____

Object	**Initial Volume**	**Final Volume**	**Volume of Object**

Measured Volume of test tube: _____
Volume of water in the graduated cylinder after:

First addition = _____ mL
Second addition = _____ mL
Third addition = _____ mL
Fourth addition = _____ mL
Fifth addition = _____ mL = final volume

Average volume = $\frac{\text{final volume}}{5}$ = _____ mL = _____ mL
5

Type and Name of balance used: _____

Balance sensitivity: _____ Maximum capacity: _____

A. Measuring Mass Directly

	Object	Mass measurement
a)	_____	_____
b)	_____	_____
c)	_____	_____
d)	_____	_____

B. Measuring Mass by Difference

Mass of empty beaker: _____
Mass of beaker and object: _____
Mass of object (by difference): _____
Mass of object (direct): _____
Mass error between the two methods _____

Density of a Solid

A. Metal cylinder

Mass of metal cylinder (direct): _____
Length of cylinder: _____
Diameter of cylinder: _____
Volume of cylinder (calculated): _____
Density of metal cylinder: _____

B. Lead shot

Mass of beaker: _____
Mass of beaker and lead shot: _____
Mass of lead shot (about 50 g): _____
Initial volume in graduated cylinder: _____
Final volume in graduated cylinder: _____
Volume of lead shot: _____
Density of lead shot: _____

Density of a Liquid

A. Water

Volume of water: _____
Mass of water: _____
Density of water: _____

B. Isopropyl alcohol

Volume of isopropyl alcohol: _____
Mass of isopropyl alcohol: _____
Density of isopropyl alcohol: _____

1. The base unit of length in the metric system is _____?
2. How many centimeters are in a meter?
3. How many millimeters are in a centimeter?
4. The base unit of volume in the metric system is _____?
5. What is the formula for the volume of a cylinder?
6. Given the volumes 25.76 mL, 25.32 mL, and 25.51 mL, calculate the average volume.
7. What are the two types of pipets used in the laboratory? Which is more accurate?
8. What is the purpose of wiping the pipet stem between transfers?
9. Why must you never put chemicals directly on the laboratory balance pan?
10. You measure the mass of an empty beaker on a balance and use a different balance to measure the mass of the same beaker after you have put some sodium chloride into it. You then report the mass of sodium chloride by difference. Comment on this procedure and what was done wrong.
11. What is the preferred method, measuring the mass of an object directly or by difference? Give reasons for your choice.
12. Why must an object be at room temperature when you measure its mass on a balance?
13. How is Density defined?
14. What are the units of density?
15. What is specific gravity? Cite a use of specific gravity measurements in hospitals.