CHEM FAX!
P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
www.flinnsci.com • E-mail: flinn@flinnsci.com

FLINN SCIENTIFIC, INC
"Your Safer Source for Science Supplies"

Catalog No. AP7059
Publication No. 7059

Measurement in the Laboratory

Student Laboratory Kit

Introduction

Measurement is a basic and essential component in any science laboratory investigation. Quantitative measurement is important in any society and the standardization of measurement units has become extremely important as a result of globalization.

Concepts

- Concentration
- Density
- Measuring skills
- International System of Units (SI)

Background

In order to interpret data and draw conclusions, the precise measurement of results is essential in most laboratory investigations. In any science classroom, students use basic scientific instrumentation to measure properties of objects. Measurements include those for mass, volume, length, temperature, and density.

The world around us may be examined either quantitatively or qualitatively. A qualitative observation is one that describes the characteristics or attributes of an object. "The table is black" or "the pencil is short" are qualitative observations. Quantitative observations are those that are measured. "The pencil has a mass of 5.4 g" or "the table is 2.1 m long" are quantitative observations.

Because the scientific method requires an experiment to be repeatable, observations and results must be reported quantitatively. In a science laboratory, the system of measurement used to make quantitative measurements is the International System of Units (SI), also known as the metric system. It is necessary to understand SI for performing many scientific activities.

SI uses units based on the number ten. It is very easy to change one unit into another by dividing or multiplying the unit by 10 or a multiple of 10. The meter (m) is used for length, the liter (L) is used for volume, the gram (g) is used for mass, and the degree Celsius (°C) is used for temperature. The following prefixes may be used with each unit.

Multiple	Prefix	Symbol	Scale	
10^{-9}	nano	n	Billionth	1/1 000 000 000
10^{-6}	micro	μ	Millionth	1/1 000 000
10^{-3}	milli	m	Thousandth	1/1 000
10^{-2}	centi	c	Hundredth	1/100
10^{-1}	deci	d	Tenth	1/10
10^{1}	deca	da	Ten	10
10^{2}	hecto	h	Hundred	100
10^{3}	kilo	k	Thousand	1 000
10^{6}	mega	M	Million	1 000 000

Length is a straight-line measurement of an object from one end to the other. The standard unit for length is the meter (m) and the most commonly used units for length include the millimeter, centimeter, meter, and kilometer. The conversions may be calculated using the chart above. For example, there are 1000 millimeters (mm) in a meter (m), 100 centimeters (cm) in a meter, and 1000 meters in a kilometer (km). Length can be measured using a meter stick, metric ruler, or tape.

Volume is the space an object takes up. The standard unit for volume is the liter (L) and the most commonly used units for volume include the milliliter (mL), microliter (μL), and liter. For example, there are 1000 milliliters in a liter and 1000 microliters

in a milliliter. The most common laboratory equipment used to measure volume is a graduated cylinder, beaker, flask, or graduated pipet. *Note:* The curved surface of the water in a graduated cylinder is called the *meniscus*. The bottom of the meniscus is the point at which the volume of the water should be read (see Figure 1).

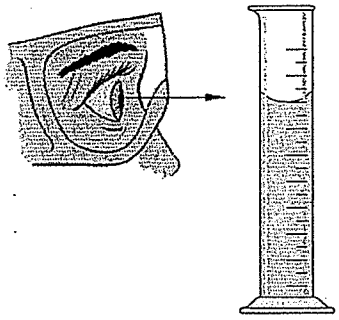

Figure 1.

Mass is the amount of matter in an object. The standard unit for mass is the gram (g) and the most commonly used units for mass include the microgram (μg), milligram (mg), gram (g), and kilogram (kg). For example, there are 1000 micrograms in a milligram, 1000 milligrams in a gram, and 1000 grams in a kilogram. The most common piece of laboratory equipment used to measure mass is a balance.

Density is the amount of mass an object contains compared to its volume. Density is equal to mass divided by volume or D = m/v. When calculating density, mass should be in grams and volume in cubic centimeters (1 cm^3 = 1 mL). Density is expressed in grams per cubic centimeter (g/cm^3).

Temperature is the measure of how hot or cold an object is and is measured in units called degrees Celsius (°C) typically using a thermometer. Most thermometers contain either alcohol or mercury in a sealed glass tube. As temperature increases, the liquid expands in the tube at a uniform rate.

Contaminants in water are usually measured in parts per million (ppm), parts per billion (ppb), and parts per trillion (ppt). Although these particles are not seen, they can be measured in a laboratory to determine water quality. The comparison is in terms of grams of pollutant to grams of water. Since the density of water is 1 gram per milliliter, there are one million grams of water in 1000 liters. If there is one gram of pollutant in 1000 liters, or 1 milligram of pollutant in 1 liter, then the result is a pollutant in a concentration of 1 ppm.

Experiment Overview

In this laboratory investigation the student will conduct six separate laboratory activities in which length, mass, volume, density, temperature, and concentration are quantitatively measured.

Pre-Lab Questions *(Use a separate sheet of paper to answer the following questions.)*

1. What instruments may be used to measure each of the following quantities?
   a. Length
   b. Mass
   c. Volume
   d. Temperature
2. What is density?
3. How might the concentration of a substance affect its ability to harm an organism?

Materials

Food dye, 10%, red, 1 mL
Isopropyl alcohol, $CH_3CHOHCH_3$, 70%, 30 mL
Sodium chloride solution (salt water), 20%, 30 mL
Balance
Cups, Styrofoam®, 3
Graduated cylinder, 100 mL
Graph paper (optional)
Heat lamp or sunlight
Marker
Medicine cups, 5
Metric ruler
Paper towels
Pipet, graduated
Sand, black
Sand, white
Screw
Stir rod
Stopwatch or clock
Test tube
Textbook
Thermometers, 2
Water

Safety Precautions

Isopropyl alcohol is a moderate fire risk and slightly toxic by ingestion or inhalation. To avoid burns, use extreme caution while using heating equipment. Lamps and bulbs get very hot and can cause burns. Do not leave the lamps unattended. Wear chemical splash goggles. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Activity 1. Measuring Length

1. Using a metric ruler, measure the length, width, and height of a textbook.
2. Record the measurements (in millimeters) on the Measurement in the Laboratory Worksheet.

Activity 2. Measuring Volume

Part A. Direct Method

1. Fill a test tube to the top with water.
2. Pour the water into a 100-mL graduated cylinder.
3. Record the volume of the water to the nearest milliliter on the worksheet.

Part B. Displacement Method

4. Fill the 100-mL graduated cylinder with water to the 50-mL mark.
5. Record the initial volume of water (in milliliters) on the worksheet.
6. Obtain a screw and carefully add the screw to the graduated cylinder. *Note:* To avoid cracking the graduated cylinder, tilt it slightly sideways then add the screw.
7. Record the final volume of water (in milliliters) on the worksheet.
8. Subtract the initial volume of water from the final volume of water and record the amount of water displaced (the volume of the screw in milliliters) on the worksheet.

Activity 3. Measuring Mass

1. Place a Styrofoam cup on the balance.
2. Record the mass of the Styrofoam cup (in grams) on the worksheet.
3. Measure 100 mL of water using a graduated cylinder.
4. Carefully pour all of the water from the graduated cylinder into the Styrofoam cup.
5. Record the mass of the water and cup on the worksheet.
6. Subtract the mass of the cup from the total mass and record the difference (mass of the water in grams) on the worksheet.

Activity 4. Determing Density

1. Record the mass of the Styrofoam cup (in grams) on the worksheet obtained in Activity 3, step 1.
2. Measure 30 mL of water using a 100-mL graduated cylinder.
3. Carefully pour the 30 mL of water into the Styrofoam cup.
4. Record the mass of the water and cup on the worksheet.
5. Subtract the mass of the cup from the total mass and record the difference (mass of the water in grams) on the worksheet.
6. Discard the water and dry the cup with paper towels.
7. Repeat steps 3 through 6 using 30 mL of salt water. Discard according to the teacher's instructions.

8. Repeat steps 3 through 6 using 30 mL of isopropyl alcohol. Discard according to the teacher's instructions.
9. Record all measurements on the worksheet.

Activity 5. Measuring Temperature

1. Use a ruler to measure from the bottom of a Styrofoam cup to a height of 3.5 cm.
2. Using a marker, draw a line on the Styrofoam cup at a height of 3.5 cm.
3. Repeat steps 1 and 2 with a second Styrofoam cup.
4. Fill one Styrofoam cup to the line with white sand. *Note:* This is approximately 125 g to 130 g. The sand should be level in the cup.
5. Fill the second cup to the line with black sand.
6. Place a thermometer in the center of each cup, halfway into the sand.
7. Record the initial temperature of the sand in each cup to the nearest 1.0 °C on the worksheet.
8. Place both cups under a heat lamp or in the sun, as directed by the teacher, so that they each receive an equal amount of light.
9. Using a stopwatch or clock, time the exposure for 8 minutes.
10. Record the temperature of each color of sand at 2-minute intervals during the 8-minute exposure on the worksheet.
11. Tip: Work on *Post-Lab Question* #8 during timing intervals.

Activity 6. Measuring Low Concentrations of Water Pollutants

1. Using a marker, label five medicine cups 1 through 5.
2. Using a graduated pipet, add 9 mL of water to each cup.
3. Using a graduated pipet, add 1 mL of red food dye to cup 1.
4. Stir well to mix the solution.
5. Record the percent concentration on the worksheet.
6. Flush the pipet with water.
7. Using the pipet, transfer 1 mL of solution from cup 1 to cup 2.
8. Repeat steps 4 through 7 for the remaining medicine cups, transferring 1 mL of solution to each successive cup and flushing the pipet with water each time.

Disposal

Consult your instructor for appropriate disposal procedures.

Name: _____

Measurement in the Laboratory Worksheet

Activity 1. Measuring Length

Textbook Measurement			
Dimension	**Millimeters (mm)**	**Centimeters (cm)**	**Meters (m)**
Length			
Width			
Height			

Activity 2. Measuring Volume

Part A. Direct Method			
	Milliliters (mL)	**Microliters (μL)**	**Liters (L)**
Water			

Part B. Displacement Method		
Initial water volume (mL)	**Final water volume (mL)**	**Water displaced (volume of screw) (mL)**

Activity 3. Measuring Mass

Water Measurement		
Mass of cup (g)	**Mass of cup and 100 mL of water (g)**	**Mass of 100 mL of water (g)**

Name: _____

Activity 4. Measuring Density

Density Measurement					
Substance	Mass of Cup (g)	Mass of Cup and Substance (g)	Mass of Substance (g)	Volume of Substance (mL)	Density of Substance (g/cm^3)
Water					
Salt Water					
Isopropyl Alcohol					

Activity 5. Measuring Temperature

Temperature Measurement		
Time (minutes)	Black Sand Temperature °C	White Sand Temperature °C
Initial		
2		
4		
6		
8		

Activity 6. Measuring Low Concentrations of Water Pollutants

Concentration of Red Dye		
Solution	Percent	Concentration (ppm)
Cup 1		
Cup 2		
Cup 3		
Cup 4		
Cup 5		

Post-Lab Questions *(Answer questions 1–3 and 10 on the Measurement in the Laboratory Worksheet. Use a separate sheet of paper to answer the remaining questions.)*

1. Convert the data from Activity 1 from millimeters to centimeters and meters. Record answers in the Activity 1 data table of the worksheet.
2. Convert the data from Activity 2 to microliters and liters. Record answers in the Activity 2 data table.
3. Convert the length measurements of the textbook in Activity 1 to volume by multiplying length, width and height. Record the answer in cubic centimeters.
4. Calculate the density of each liquid in Activity 4 by dividing the mass by volume. Record the values in the Activity 4 data table on the worksheet.
5. In Activity 3 the mass of 100-mL of water was determined. Using this data, calculate the density of the water. *Note:* Give answer in either g/mL of g/cm^3.
6. How does the density of water calculated in Question 5 compare to the density value obtained in Activity 4?
7. Which liquid in Activity 4 has a greater density than water? Which liquid has a density less than water?
8. In Activity 5 the temperature of two different colors of sand, black and white, were compared. Using the data from Activity 5, graph the temperature values for the 8-minute exposure of each color of sand. *Note:* Graph both sand colors on the same graph using a different colored pen or pencil for each. Use the horizontal (x) axis for the time and vertical (y) for the temperature. Label each axis—do not forget the *units*—make sure the scale is clearly marked. Draw two best fit lines, one for each color of sand through the data points.
9. Compare and contrast the temperature change of each color sand after 8 minutes. Explain the difference.
10. Determine the parts per million of red solution in each cup by multiplying the percent (as a decimal) by one million. Record answers in the Activity 6 data table on the worksheet.
11. Janet received a small fish tank for her birthday. However, it did not say how many liters of water it holds. Based on the measurement methods in this lab name two ways Janet could figure out how many liters of water her fish tank holds.