

Measurements and Density of Matter

Experiment #2

Objective: To compare different pieces of equipment for making measurements to assess their precision and accuracy. You will also use different methods for determining volume of an object and determining the density of that object.

Introduction

One of the fundamental means we have to understand the properties of matter is measurement. The more accurate the instruments are that we use for making measurements, the better we will understand the various physical relationships of the substances we are studying. Using the wrong equipment for measurement can lead to large errors and major problems in many instances. Scientists and health professionals generally use the International System of Units, or *Système International* (SI), which is the official system throughout the world, except in the United States. The standard SI units and metric units used in chemistry for length, volume, mass and temperature were given in Table 1.1 (see Exp #1).

In addition to the standard units in the metric system, we also use prefixes to represent multiples of 10 times the unit as discussed in Experiment #1 (see Table 1.2). You should be familiar with these prefixes and units in order to succeed in chemistry and the health professions, so review them if you are not yet familiar with them. You should be familiar with the relative size of 1 mL or 1 cm³ or 1 cc, which are all the same and these units are often used to deliver specific dosages of liquid medications.

In this experiment you will compare different types of glassware or devices for measuring volume of water. Then you will determine the density of some different liquids using the most accurate measuring devices you have available and compare those with values found in standard tables of physical data that are available. You will also use different measuring devices to obtain information about the physical characteristics of different forms of matter. For example, you will use a ruler to measure the length, width and height of a rectangular solid object or to measure the diameter and length of a cylindrical solid object. You will then measure the volume of the same object by the amount of water it displaces in a graduated cylinder and compare your volume measurements. You will then determine the mass of these solid objects by weighing them on a balance and calculate the density of each object in order to identify the material these are made from by comparison of the known density with the density you found.

Some Useful Information Needed in this Experiment

The density of a material is derived by measuring its mass on a balance and dividing the mass by the volume, which you will measure by various methods.

Density = mass/volume the metric units for density would be g/mL or g/cm³ or g/cc

The volume of a cube or rectangular solid is equal to the length x width x height of that solid. If you use inches or millimeters to measure length, width and height of the solid, it would be best to convert those units to cm before calculating the volume. For example, the volume of a

cube that measures 15 mm on each side would be:

$$15 \text{ mm} \times 1 \text{ cm}/10 \text{ mm} = 1.5 \text{ cm}$$

$$V_{\text{rectangle}} = l \times w \times h = 1.5 \text{ cm} \times 1.5 \text{ cm} \times 1.5 \text{ cm} = 3.4 \text{ cm}^3$$

$$\text{Alternatively: } V = 15 \text{ mm} \times 15 \text{ mm} \times 15 \text{ mm} = 3375 \text{ mm}^3$$

$$1 \text{ cm}^3 = 10 \text{ mm} \times 10 \text{ mm} \times 10 \text{ mm} = 1000 \text{ mm}^3$$

$$\text{Therefore: } 3375 \text{ mm}^3 \times 1 \text{ cm}^3/1000 \text{ mm}^3 = 3.4 \text{ cm}^3 \text{ (significant figures)}$$

If the cube has a mass of 30.6 g, its density would be:

$$\text{Density} = 30.6 \text{ g}/3.4 \text{ cm}^3 = 9.0 \text{ g/cm}^3$$

The volume of a cylinder is: $V_{\text{cyl}} = \pi \times r^2 \times h$, where π is the mathematical constant equal to 3.14, the radius of the cylinder is r and the length or height of the cylinder is h . One would calculate the volume of a cylinder that has a diameter of 14 mm and a length of 100 mm as follows:

$$d = 14 \text{ mm} \times 1 \text{ cm}/10 \text{ mm} = 1.4 \text{ cm}$$

$$h = 100 \text{ mm} \times 1 \text{ cm}/10 \text{ mm} = 10 \text{ cm}$$

$$r = \text{diameter}/2 = 1.4 \text{ cm}/2 = 0.70 \text{ cm}$$

$$V_{\text{cyl}} = 3.14 \times (0.70 \text{ cm})^2 \times 10 \text{ cm} = 15 \text{ cm}^3$$

$$\text{Alternatively: } V_{\text{cyl}} = 3.14 \times (7.0 \text{ mm})^2 \times 100 \text{ mm} = 15386 \text{ mm}^3$$

$$15386 \text{ mm}^3 \times 1 \text{ cm}^3/1000 \text{ mm}^3 = 15 \text{ cm}^3$$

If the cylinder has a mass of 41.5 grams, its density would be:

$$\text{Density} = 41.5 \text{ g}/15 \text{ cm}^3 = 2.8 \text{ g/cm}^3$$

Materials

Graduated cylinders (10 mL and 50 mL), beakers (50 mL and 150 mL with gradation marks for 10 mL), unknown solids (rectangular and cylindrical), ethanol, heptane, 6 inch rulers.

Procedure

A. Using the correct glassware for volume measurements

1. Measure 10 mL of water in your 50 mL beaker as accurately as you can.
2. Transfer that 10 mL of water to your 10 mL graduated cylinder and see how accurate you were.

If the volume is less than 10 mL, measure the volume as accurately as you can to at least 0.1 mL. If the volume is more than 10 mL, go to step 3. Record the volume on the report sheet.

3. If the volume goes above the 10 mL mark on the graduated cylinder use a disposable pipet to remove the extra water to leave exactly 10.0 mL of water in the graduated cylinder. Always keep the plastic pipet upright, it will not leak as long as you don't squeeze the bulb. Dump the 10.0 mL water from the graduated cylinder back into the beaker and add the water in the plastic pipet to the empty graduated cylinder to get an accurate volume of the excess and record the total volume on the report sheet (10.0 mL plus the volume of the excess). This should give a more accurate volume measurement of the 10 mL of water that you measured in the beaker initially. Discard the water in the 50 mL beaker into the sink and repeat the procedure as in step 4.
4. Repeat the procedure two more times for a total of three trials to determine how precise your measurements of volume are in the beaker. Precision is determined by the value you get each time when you repeat the measurement the same way. Accuracy is determined by how your measurement compares with the actual value. You may measure the 10 mL of water in the beaker with precision at 9.6 mL each time, but that does not make your measurement accurate.
5. Answer the questions for this part on the report sheet.

B. Determining the density of a liquid

1. Weigh a clean and dry 10 mL graduated cylinder on the analytical balance. Be sure to zero the balance before placing the graduated cylinder on it to obtain the correct mass to the nearest 0.01 grams and record the mass on the report sheet (second line (b) of the table).
2. Measure exactly 10.0 mL of water in your 10 mL graduated cylinder, reweigh the graduated cylinder with 10.0 mL water in it and record the total mass on the report sheet (first line (a) of the table).
3. Subtract the initial mass of the empty cylinder from the final mass with water to obtain the mass of water and record it on the report sheet (third line (c) of the table).
4. Determine the density of water by dividing the mass by the volume and record it on the report sheet (fourth line of the table).
5. Empty the graduated cylinder and repeat steps 1 thru 4 and record the data for the second trial in the appropriate space on the report sheet and take the average of the two determinations as indicated (fifth line).
6. After determining the density of water twice, you will determine the density of alcohol (ethanol) by following the same procedure in steps 1 thru 4 above, substituting ethanol for water and recording the data in the appropriate spaces on the report sheet. Be sure to remove as much water as possible from the graduated cylinder before each trial. Discard the ethanol in the sink.

- After completing two trials for ethanol, repeat the procedure using heptane and record the data for heptane in the appropriate spaces on the report sheet. Discard the heptane in the hazardous waste bottle in the hood.
- Compare your results with the known values for density of water, ethanol and heptane given below and answer the questions for this part on the report sheet.

Densities of test liquids at 24°C and atmospheric pressure:

Liquid	Water	Ethanol	Heptane
Density	0.997 g/mL	0.786 g/mL	0.684 g/mL

C. Measuring the volume and density of a rectangular solid

- Obtain a rectangular solid and record the type of metal or material on the report sheet.
- Weigh the solid as accurately as possible on the balance and record the mass to the nearest 0.01 grams on the report sheet.
- Measure the length, width and height of the rectangular metal solid in millimeters, using a ruler provided, and record the values in the appropriate space on the report sheet.
- Convert the measurements made in mm into cm in the appropriate spaces on the report sheet and calculate the volume of the solid in cm³.
- Add about 25 mL of water to your 50 mL graduated cylinder and record the volume as accurately as possible on the report sheet. The volume does not have to be exactly 25 mL, but you should record the volume as accurately as possible.
- Tilt the graduated cylinder and carefully slide the rectangular metal solid down the side of the graduated cylinder to avoid it hitting the bottom too hard and breaking the graduated cylinder.

DO NOT DROP THE METAL SOLID INTO THE GRADUATED CYLINDER OR IT WILL BREAK THE GLASS – AND YOU WILL HAVE TO PAY FOR IT!!

- Measure the volume of water in the graduated cylinder after adding the metal to it. Make sure the water level is above the top of the metal bar. If it is not, you will have to repeat steps 6 and 7 with more water in the graduated cylinder. Record the final volume of water with the metal in it on the report sheet and determine the volume of the metal.
- Calculate the density of the metal bar in the appropriate spaces on the report sheet and compare your values for the density determined by different methods. How do they compare? How does your answer compare with the known density of the metal? A table of densities is given at the end of the Procedure section (next page).

9. Answer questions for this part on the report sheet.

D. Measuring the volume and density of a cylindrical solid

1. Obtain a metal cylindrical solid and record the type of metal on the report sheet.
2. Weigh the metal cylinder as accurately as possible on the balance and record the mass to the nearest 0.01 g on the report sheet.
3. Measure the diameter and height of the cylinder in millimeters and record the values in the appropriate space on the report sheet.
4. Convert the measurements made in mm into cm in the appropriate spaces on the report sheet, determine the radius in cm and calculate the volume of the cylinder. [area = $\pi \times r^2 \times h$]
5. Add about 25 mL of water to your 50 mL graduated cylinder and record the volume as accurately as possible on the report sheet. The volume does not have to be exactly 25 mL, but you should record the volume as accurately as possible.
6. Tilt the graduated cylinder and carefully slide the rectangular metal solid down the side of the graduated cylinder to avoid it hitting the bottom too hard and breaking the graduated cylinder.

DO NOT DROP THE METAL SOLID INTO THE GRADUATED CYLINDER OR IT WILL BREAK THE GLASS AND YOU WILL BE CHARGED FOR IT!!!

7. Measure the volume of water in the graduated cylinder after adding the metal to it. Make sure the water level is above the top of the metal bar. Record the final volume of water with the metal in it on the report sheet and determine the volume of the metal.
8. Calculate the density of the metal cylinder in the appropriate spaces on the report sheet and compare your values for the density determined by different methods. How do they compare? How does your answer compare with the known density of the metal found in the table below?
9. Answer questions for this part on the report sheet.

Densities of Selected Metals at 25°C				
Metal	Aluminum	Copper	Iron	Lead
Density (g/cm ³)	2.71	8.50	7.86	11.35
Metal	Zinc	Brass	Tin	
Density (g/cm ³)	7.14	8.55	7.31	

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Measurements and Density of Matter

Experiment #2

Prelab Exercise

1. Convert the following measurements from a blood or urine analysis to different units as indicated (give all answers with the proper number of significant figures). Show work in the space below or beside each entry.

a) Cholesterol: 220 mg/dL = _____ g/L

b) Iron: 110 mcg/dL = _____ mg/L

c) Glucose: 135 mg/dL = _____ % (w/v)

2. A block of wood has the dimensions of 125 mm by 60 mm by 15 mm. Note the number of significant figures.

a) Calculate the volume of this block of wood with units of mm^3 . (Show work)

b) Calculate the volume of this block of wood with units of cm^3 . (Show work)

c) If this block of wood has a mass of 125 grams, what is the density of this block of wood in g/cm^3 ?

d) Would this piece of wood float or sink when placed in a bucket of water?

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3. a) The mass of 25 mL of a liquid is 33.25 g. Calculate the density of this liquid in g/cm^3 giving the answer in the proper number of significant figures.
- b) If this liquid does not mix with water, would you expect this liquid to float on top of water or sink to the bottom when added to 25 mL of water in a beaker?
4. a) A rectangular metal bar has the dimensions of 22 mm x 10 mm x 40 mm. Calculate the volume of this bar in cm^3 .
- b) If the metal bar has a mass of 66.74 g, calculate the density of the metal bar in g/cm^3 .
- c) A similar looking bar with a mass of 50.85 g was found to displace 6.0 mL of water. What is the density of this bar?
- d) Would you expect the second bar to be made of the same metal as the first bar or a different metal?

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Measurements and Density of Matter**Experiment #2****Report Sheet****Part A. Using the correct glassware for volume measurements**

				Average
Volume measured in 50 mL beaker	10 mL	10 mL	10 mL	10 mL
Volume measured in 10 mL graduated cylinder				

A1. Which of the pieces of glassware used for this part do you believe is more accurate? Explain why you think one piece of glassware would be more accurate than the other.

A2. Comment on the precision of your measurements in the 50 mL beaker when attempting to measure 10 mL of water. Was there a large variation or was the measurement consistently the same?

Part B. Determining the density of a liquid

	Water		Alcohol		Heptane	
	1 st trial	2 nd trial	1 st trial	2 nd trial	1 st trial	2 nd trial
(a) Mass of empty grad cylinder (g)						
(b) Mass of grad. cylinder with 10 mL of liquid (g)						
(c) Mass of liquid (g) [line b- line a]						
(d) Density of liquid [line c/10 mL] (g/mL)						
Average Density (g/mL)						

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B1. Compare your results for the density of each liquid with the known values given at the end of the procedure for part B. Explain why your results may differ from the expected values, if they did differ. What may be a reason for differences? You should be aware of significant figures in your measurements. If you feel your measurements were accurate, say so. What percent is the difference?

C. Measuring the Volume and Density of a Rectangular Solid

Rectangular bar: Type of metal _____ Mass of bar _____ grams

	Length	Width	Height	Volume
millimeters				mm ³
centimeters				cm ³
Density _____				g/cm ³

a) Volume of water in 50mL grad cylinder before adding metal bar _____ mL

b) Volume of water in grad cylinder after adding metal bar _____ mL

c) Volume of rectangular bar by water displacement (b-a): _____ mL

Density of rectangular bar by water displacement: _____ g/cm³

C1. Since the mass of the bar is the same for both density determinations, which method for determining the volume of the rectangular solid would be more accurate: measuring its volume by water displacement or measuring its dimensions in millimeters using a ruler?

C2. How does the density you obtained by measuring dimensions vs water displacement compare with the actual density of the metal bar according to the values given at the end of the procedure? Would you say that one of your methods was accurate in determining the density of the metal or were all methods not accurate?

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D. Measuring the Volume and Density of a Cylindrical Solid

Cylindrical Bar: Type of metal _____ Mass of Bar _____ grams

	Diameter	Radius	Height	Volume
millimeters				mm ³
centimeters				cm ³
Density				g/cm ³

Volume of water in grad cylinder before bar _____ mL; after adding bar _____ mL

Volume of cylinder by water displacement: _____ mL

Density of cylinder by water displacement: _____ g/cm³

D1. Which method for determining the volume of the cylinder is more accurate: measuring its volume by water displacement or measuring its dimensions in millimeters using a ruler?

D2. How does the density you obtained for the cylindrical metal bar by these two methods (measuring dimensions vs water displacement) compare with the actual density of the metal bar according to the density values for metals given at the end of the procedure? Would you say that one of your methods was accurate in determining the density of the metal or were all methods not accurate?

D3. Discuss any possible reasons for error in this determination of density.

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