Experiment 2 Name: ______________________

DEN $\overset{14}{\text{Si}}$ TY

In this experiment, you will learn about density and practice the proper way to report measurements and calculated quantities.

Properties

Properties of a substance can be separated into chemical and physical properties. Physical properties can be further categorized as either intensive or extensive. Note that a property may be chemical or physical, but never both. Similarly, a property may be intensive or extensive, but never both.

Chemical properties are properties that can be observed by changing a substance into another substance. Examples include: (1) a metal's resistance to rusting which is determined by allowing the metal to form an oxide and (2) reactivity which is determined if a substance is allowed to react with another substance forming new substances.

Physical properties are properties that can be observed without changing the substance. Examples include: (1) appearance which is observed by visual inspection, (2) mass and volume which are measured without changing the sample and (3) boiling point which is determined by allowing a substance to change from liquid to gas but the identity and composition of the substance remaining the same.

Intensive properties do not depend on the size or amount of material. Examples include molecular weight, density, and freezing point.

Extensive properties are dependent on the size or amount of material. Examples include mass, volume, and number of atoms.

Density

You will determine the density of a cylindrical solid and of a liquid, use density to identify a material and determine the thickness of an aluminum foil.

Density (d) is a property of a substance equal to the ratio of its mass (m) to its volume (V):

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

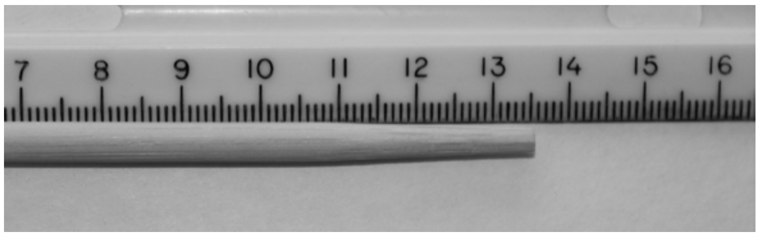
Density is expressed in units of mass per volume, such as g/cm^3 or g/mL.

Measurements

Measured values must be reported with a number that shows the accuracy of the measurement, followed by the unit of measurement. When reporting mass, for example, all digits shown in the balance's display must be reported and the unit of mass must be specified.

For measurements done with a device that has graduation marks such as a ruler or a graduated cylinder, the reported number must reflect the accuracy of the device's calibration. As a rule, report all certain digits and add one uncertain digit. The last digit shown on a balance is uncertain; more decimal places mean that the balance is more accurate.

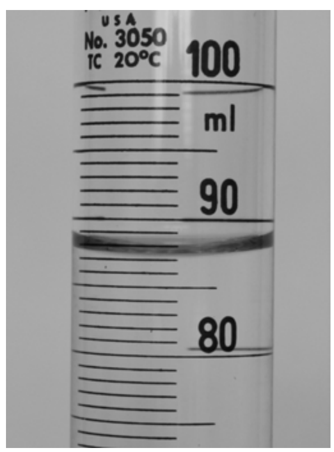
For example, in Figure 1, the ruler is marked every 0.1 cm so the ruler is certain to the first decimal place. When you use this ruler to measure a length in cm, the number must be reported to the second decimal place to include your uncertain or estimated digit. For example, the length of the object in Figure 1 is reported as 13.52 cm.



l = 13.52 cm

Figure 1. Length measurement

When measuring volume, the graduated cylinder must be placed on a stable, level surface. Read the volume from the bottom of the curved surface called meniscus. Your eye must be level with the bottom of the meniscus. In Figure 2, the 100-mL graduated cylinder is marked every 1 mL and thus certain to the ones digit. For the reported volume of 87.3 mL, one uncertain digit, the first decimal place, is included.



V = 87.3 mL

Figure 2. Volume measurement

When measurements are used in a calculation, the calculated quantity must be reported with the correct number of digits and the units. When adding or subtracting, the least number of decimal places in the numbers being added/subtracted determines the number of decimal places in the answer. When multiplying or dividing, the least number of significant figures in the numbers being multiplied/divided determines the number of significant figures in the answer. For mixed operations, these rules are applied stepwise.

When measuring using the ruler (see Figure 1), which has markings in the tenth place, the hundredth decimal is what is estimated. This results in the measurement by ruler having 2 decimals (when using cm). When measuring using the graduated cylinder (see Figure 2), the graduated cylinder has markings in the ones place, so the tenths place is what is estimated. This results in the measurement for the graduated cylinder having 1 decimal place. Therefore, the measurements by ruler are more precise. However, since the volume of the metal rod is measured more directly by water displacement in the graduated cylinder, that measurement is more accurate. It is possible for two different methods that measure the same thing to have different accuracy and precision.

Note that volume for the metal rod being measured by two different methods should have similar volumes; however, they may not be the exact same due to this difference in accuracy and precision of measurement.

Rules for Significant Figures

1. All nonzero digits are significant
2. Zeroes between two significant figures are themselves significant
3. Zeroes at the beginning of a number are never significant
4. Zeroes at the end of a number are significant if a decimal point is written in the number

   In order for zero at the end of a number to be significant, the zero must be the final digit in the number AND follow the decimal

How many significant digits are in each number?

1.36	3 significant digits (all non-zero digits)
8026	4 significant digits (the zero is sandwiched between non-zero digits)
0.028	2 significant digits (the first two zeroes don't count)
100	1 significant digit (the last two zeroes don't count)
100.0	4 significant digits (all zeroes count since there is a zero following the decimal)
0.0067020	5 significant digits (the first three zeroes don't count)

Adding and Subtracting

When addition or subtraction is performed, answers are rounded to the least amount of decimal places

ex. 0.2075 +2.18 = 2.39

ex. 1.098 – 0.00685 =1.091

Multiplying and Dividing

When multiplication or division is performed, answers are rounded to the number of digits that corresponds to the least number of significant figures in any of the numbers used in the calculation

ex. 0.1075 x 653 = 70.2

ex. 1.095 / 0.34 = 3.2

PROCEDURE

I. Density of a Cylindrical Solid

In this part, you will determine the mass and volume of a cylindrical solid and then calculate its density, which will allow identification of the material the sample is made of. Two methods of volume determination will be used.

A. **Direct Measurement** – Volume is determined by measuring the dimensions of the solid and calculating the volume. This method is useful for solids with a regular shape. This experiment uses a metal sample with cylindrical shape. The volume is calculated using the formula $\mathbf{V = \pi r^2 h}$, where r is the radius and h is the height.

   1. Obtain a cylindrical sample. Weigh and record its mass (in grams).

   2. With a ruler, measure the length and diameter (in cm) of the sample. The radius is half the diameter.

B. **Water Displacement –** The volume of the sample is equal to the volume of the water it displaces, indicated by the rise in liquid level. This method is especially useful for fairly dense objects that are irregularly-shaped.

   1. Add ~30 mL water to a 50 mL or 100 mL graduated cylinder. Read the volume and record to the appropriate number of significant figures.

   2. Tilt the graduated cylinder towards horizontal position. Place the cylindrical sample used in Part A into the opening then push it in lightly. Very slowly and carefully put the graduated cylinder back to upright position to allow the cylindrical sample to lower to the bottom of the graduated cylinder with no water splashing out. Make sure there are no air bubbles. Read the new volume.

   The volumes obtained for both methods A and B above should be close because they are for the same sample. If not, double-check your measurements and calculations.

> **Note that when comparing two quantities they must be in the same units.**
> Also, 1.0 cm^3 is equal to 1.0 mL.

II. Density of a Liquid

In this part, you will determine the density of a liquid by weighing a specified volume of the liquid.

1. Obtain ~50 mL of an unknown liquid into a 100-mL beaker. Record the unknown label on your worksheet.

2. Follow the instructions on the following pages to practice using a 10-mL volumetric pipet and pipet pump. Then condition the pipet using the unknown liquid.

A pipet is used to transfer a specified volume of liquid from one container to another. Used correctly, this 10-mL pipet accurately transfers 10.00 mL of liquid.

General pipet instructions. A pipet pump is used to draw liquid into a pipet; never use your mouth. A pipet pump attached to a pipet is shown in Figure 3. Depress the plunger of the pipet pump all the way down. Hold the pipet with the pointed tip down, and securely insert the top of the pipet into the pipet pump collar. Place the tip of the pipet into the container with the liquid you want to transfer. Hold the pipet pump as shown in Figure 3. With your thumb, roll the wheel downwards to draw liquid up to the desired level, making sure the pipet tip stays immersed in the liquid to avoid introducing air bubbles. The plunger rises as you do this. The liquid can then be released three ways: (1) by rolling the wheel upwards, (2) by pressing the release lever, and (3) by depressing the plunger.

CAUTION: When drawing liquid, **do not let the liquid rise past the top of the pipet**. The liquid will go into the pipet pump and contaminate it.

Conditioning a pipet. A pipet needs to be conditioned to minimize errors due to contaminants by rinsing the inside walls with the liquid you will transfer. Draw out liquid into the pipet past the calibration mark. Drain the liquid into a waste beaker by pressing the release lever and then depressing the plunger.

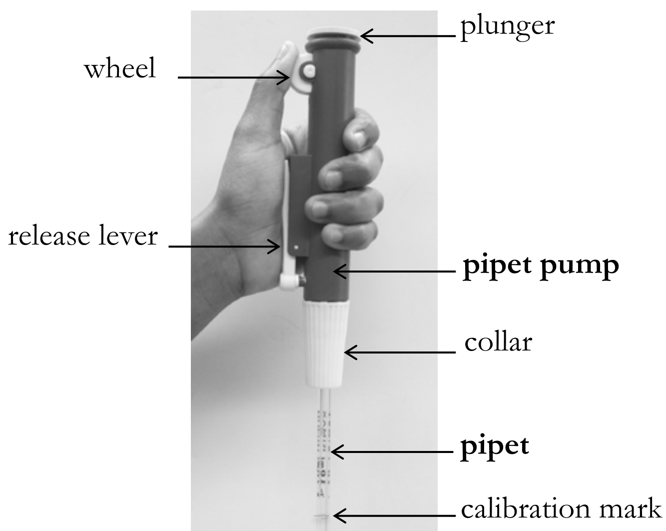


Figure 3. Pipet pump and pipet

3. Obtain a clean, dry 125-mL Erlenmeyer flask. Weigh.

4. Using the pipet, obtain 10.00 mL of the unknown liquid and drain into the Erlenmeyer flask. Weigh.

Transferring liquids using a pipet. With the pipet pump plunger fully depressed, place the tip of the conditioned pipet into the liquid and draw liquid such that the bottom of the meniscus coincides with the calibration mark on the neck of the pipet. When checking the meniscus, the pipet tip must be raised above the liquid and the calibration mark must be at eye level. If the liquid level goes past the mark, you can release liquid slowly by rolling the wheel upwards. Transfer the pipet into the target container, then drain the liquid by pressing the release lever. **When liquid stops flowing from the pipet, a small amount of liquid remains at the tip. Do NOT blow this out with the plunger** because the pipet you are using is calibrated to deliver the specified amount of liquid by draining, taking into account the retained liquid.

5. Add another 10.00 mL of the unknown liquid to the same Erlenmeyer flask with the pipet for a total volume of 20.00 mL. Weigh.

6. Dispose of the unknown liquid in the appropriate waste container.

III. Thickness of Aluminum Foil

In this part, you will determine the thickness of aluminum foil by measuring its length and width and mass. To calculate the thickness, use the density of aluminum (2.70 g/cm^3), the density equation $\mathbf{d = m/V}$, and the volume of a rectangular prism ($\mathbf{V = l} \times \mathbf{w} \times \mathbf{h}$; where l, w, and h are the length, width, and height (thickness), respectively).

1. Obtain a square/rectangular sheet of aluminum foil. The length of each side should be around 20 cm. Make sure no corners are ripped off.

2. Measure the length and width (in cm) of the foil using a ruler.

3. Fold the foil several times to fit onto the balance pan. Weigh.

CLEAN-UP

- Unknown liquid goes into the appropriate waste container.
- Water goes down the drain. Aluminum foil goes to the trash.
- Wash all glassware used. Return materials and equipment where they belong.

Name: ____________________ Date: ____________

DENSITY

Report all your measurements and answers in the **correct number of significant figures and units**. Show clearly the complete calculations.

DATA AND CALCULATIONS

I. Density of a Cylindrical Solid

A. Direct Measurement:

Mass = ______________

Length = ______________

Diameter = ______________

1. Calculate the volume of the metal rod.

2. Calculate the density of the metal rod.

B. Water Displacement:

Mass (from part A) __________________

Initial volume reading __________________

Final volume reading __________________

Volume change __________________

1. Calculate the density of the metal rod.

2. Calculate the difference between the calculated densities using direct measurement (Part A2) and using water displacement (Part B1).

3. Based on your knowledge of density and given that you measured the same object two different ways, should there be a difference between the densities calculated in A2 and B1? Why or why not?

4. Average the densities you got for A2 and B1 and compare it to the table below.

Table 1: Densities of different metals

Metal	Aluminum	Steel	Brass	Copper
Density (g/cm^3 or g/mL)	2.70	7.87	8.60	8.96

Based on the density you calculated, which of these metals is your cylindrical sample made of?

II. Density of a Liquid

Unknown label: ___________

	Trial 1 (10.00 mL liquid)	Trial 2 (20.00 mL liquid)
Mass of flask and liquid	________________	________________
Mass of flask	________________	________________
Mass of liquid	________________	________________

Density calculation for Trial 1:

Density calculation for Trial 2:

III. Thickness of Aluminum Foil

Length = ____________________

Width = ____________________

Mass = ____________________

a. Calculate the thickness of the foil in cm. The density of Al is 2.70 g/cm^3.

b. What is the thickness of the foil in m? in μm?

________________________ m ________________________ μm

POST-LAB QUESTIONS

1. Classify density as a physical or a chemical property. **Explain your choice based on what you did or observed** in this experiment.

2. Classify density as an intensive or an extensive property. **Provide an example from the experiments you conducted** to explain why?