VALENCIACOLLEGE

Experiment 13:
Mass, Volume, and Density
(One Lab Period)

Version 5

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In this experiment, you will use common glassware and equipment in order to study the physical property of density.

Objectives

- Recognize and utilize common glassware and equipment.
- Prepare solutions of different densities to identify unknowns.

Learning Outcomes

- Understand the nature of units of measurement and apply proper significant figure rules.
- Differentiate between accuracy and precision.
- Understand the nature of matter and its underlying physical and chemical characteristics.
- Employ conceptual learning outcomes and perform essential lab techniques in a laboratory setting.

Definitions

- **Accuracy –** refers to how close the measured value is to the true, correct, or accepted value

- **Balance –** an instrument to measure mass precisely

- **Buret –** a long glass tube with graduations and a stopcock for dispensing variable amounts of liquid, especially in titration

- **Certain digits –** for an analog instrument, they are unambiguous digits clearly indicated by the instruments; for a digital instrument, they are all digits displayed by the instrument except for the one furthest to the right

- **Concentration –** the amount of dissolved material in a unit of volume

- **Condition –** to rinse a piece of glassware with the solution to be contained, so that all contaminants are removed

- **Density –** the degree of compactness of a material; defined as the ratio of mass to volume, often reported in terms of g/mL or g/cm^3

- **Graduated Cylinder –** a narrow cylinder with graduations to measure volume

- **Homogeneous –** having uniform composition and properties throughout

- **Mean –** the arithmetic average of a set of values

- **Meniscus –** the curved shape of the top surface of a liquid in a cylinder or tube; it should be read at the bottom of the concave shape for most liquids although some such as mercury have a convex shape (read the top of the meniscus when it is convex)

- **Plastic –** a broad descriptor for a range of natural and synthetic materials that can be molded into shapes; they typically have high molecular mass components and are carbon-based

- **Precision –** refers to how close a series of measurements are to one another

- **Relative percent error –** a calculation that indicates the accuracy of an experimentally determined value against the true, correct, or accepted value

- **Significant figures (**or **significant digits) –** all the certain and uncertain digits in a measurement; they should be recorded and carried through calculations since the calculated value must reflect the precision of the measurements

- **Solute –** the substance dissolved in solvent in a solution

- **Solution –** a homogeneous mixture

- **Solvent –** the major component of a solution

- **Standard deviation –** a calculation that indicates the precision of a series of values by showing the variation around the average or mean

- **Tare –** the mass of an empty container; a balance with an empty container can be set to zero so that only materials added will be read in the mass

- **Uncertain digit –** the last digit of a measurement; it is always estimated, even in a digital instrument, and based upon the reliability of the instrument

- **Volumetric flask –** a long-neck flask for measuring one volume with great certainty

- **Volumetric pipet –** a pipet for measuring one volume only with great certainty

- **Weighing boat (**or **weighing paper) –** a container used for weighing samples

Techniques

- [Technique 1](#): Cleaning Glassware
- [Technique 2](#): Using a Balance
- [Technique 3](#): Transferring Liquids
- [Technique 4](#): Using a Graduated Cylinder
- [Technique 5](#) [Video Tech. 5](#): Solutions Using a Volumetric Pipet
- [Technique 11](#): Disposing Chemical Waste

Introduction

Plastics are incredibly versatile materials that have made much of modern life possible. Advocates highlight their use in everything from clothing, building materials, medical devices, and packaging to preserve food or allow aseptic technique.[1,2] They are lightweight compared to steel and glass, and so have decreased carbon dioxide emissions when shipping and when used to build vehicles. There are downsides to plastic too: often it is made from petroleum, and it can be disposed inappropriately, leading to extra waste in landfills and pollution in the environment such as on beaches (Figure 1)[3,4] and in the ocean such as the Great Pacific Garbage Patch.[5]

Figure 1. Plastic Debris on Hawaii's Big Island. Image from Daniel Cressey, Nature Publishing Group.

Although there is great interest in recycling, there is not enough recycled plastic for big companies to have a steady supply; some people still throw plastic into the waste bin and many cities do not have comprehensive recycling programs.[6] Currently, several major companies including Walmart® and Coca-Cola® have created the $100 million Closed Loop Foundation to give interest-free loans to cities and recycling companies to improve their recycling.

To recycle, scrap plastics are sorted per resin identification code (Table 1); usually, you can see the code inside the triangle symbols on the material. Once sorted, the plastic is cut into chips or flakes, washed, and then melted into pellets for reprocessing. If the wrong plastics are mixed, they can ruin a batch.

> *In a world of nearly seven billion souls and counting, we are not going to feed, clothe and house ourselves solely from wood, ore and stone; we need plastics. And in an era when we're concerned about our carbon footprint, we can appreciate that lightweight plastics take less energy to produce and transport than many other materials. Plastics also make possible green technology like solar panels and lighter cars and planes that burn less fuel. These "unnatural" synthetics, intelligently deployed, could turn out be nature's best ally.*
>
> *-Susan Freinkel*

To introduce the experiments for this laboratory, you will have a scenario to demonstrate a potential application of the chemical principles that you are learning. Today, you will play the role of technician at the I've Bin Recycling Company. The optical sorter at the Materials Recovery Center, which relies on infrared spectroscopy to separate the different plastics,[7] has failed. A batch of plastics has been made into chips from accidentally mixed plastics. You have been tasked to find a quick and easy way of separating the different plastic chips and objects until the optical sorter is fixed. By remembering a little bit of your undergraduate general chemistry, you can devise a system based upon densities.

To be an effective technician, you will need to record your observations and data to the appropriate significant figures based upon reliability of the instruments. Several instruments can be used to make the same measurement, but the accuracy of the measurement may be different. While approximate measurements are acceptable in some cases, you often will need to measure accurately.

Table 1. The Resin Identification Codes[a] to Recycle Plastics and Examples of Common Usage.

Type of Plastic	It starts as:	It is recycled into:
PET **Polyethylene Terephthalate** (1)	Water and soda bottles, jars, clamshells	Carpeting, tennis balls, water and soda bottles, clamshells
HDPE **High-Density Polyethylene** (2)	Grocery bags, juice and milk bottles, detergent and shampoo bottles	Plastic lumber, trash cans, toys
PVC **Polyvinyl chloride** (3)	Cleaning supply jugs, pipes, pool lining, sheeting	Pipe, floor mats, computer cords
LDPE **Low-Density Polyethylene** (4)	Food storage containers, squeeze bottles, trash bags, dry-cleaning bags, six-pack rings	Toys, lawn furniture, trash bags, shipping envelopes
PP **Polypropylene** (5)	Medicine bottles, yogurt containers, straws, hangers	Brooms, toothbrushes, speed bumps, flower pots, auto parts
PS **Polystyrene** (6)	Vitamin bottles, to-go containers, hot cups, CD cases, cartons	Building insulation, food service trays, picture frames
Other **Other Plastics** (7)	Acrylic, nylon, polycarbonate, PLA (polylactic acid/corn plastic), ABS (acrylonitrile butadiene styrene, found in Legos®)	Electronic housings, auto parts, pens, street signs

[a] Note that the Resin Identification Codes were updated from chasing arrows to triangles in 2013 by the American Section of the International Association for Testing Materials (ASTM International).[8]

Making and Recording Measurements

In a laboratory, the precision and accuracy of results are limited by both the instrument, and user proficiency for reading the instrument correctly. In this laboratory, you will use several instruments for measuring the volume of a liquid. Even the best instrument has some uncertainty associated with it. To properly record a measurement, read all digits that are certain plus the first uncertain digit. Both the certain digits and one uncertain digit are significant figures (or significant digits).

In a graduated cylinder, the measured liquid creates a meniscus, a curved shape in a cylinder; read from the bottom of the meniscus for most solutions. You can read all the indicated graduations plus make one estimate for the location of the bottom of the meniscus. For example, in Figure 2, notice graduations of 25 and 30 mL on the graduated cylinder. Now notice that there are four smaller markings between the two stated numbers, each representing 1 mL. The liquid is clearly on the 27-mL line, so those are certain digits. In addition, you can estimate one more digit between the graduations. Since the meniscus is on the line, record the volume as 27.0 mL. Make sure to view the graduated cylinder with your eye level to the meniscus, and the cylinder on an even surface.
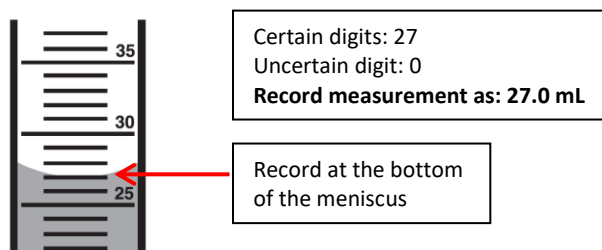
Figure 2. Reading a Graduated Cylinder.

In a second example, shown in Figure 3, notice the graduations at 2 and 3 mL with nine markings between them, each corresponding to 0.1 mL. In addition, notice how this meniscus is not on a line but rather between 2.6 and 2.7 mL. The certain digits in this volume will be 2.6 mL. Using your best judgment, approximate how close the meniscus is to the next marking. Since the meniscus appears to be less than halfway between the sixth and seventh marking, the uncertain digit might be estimated to be 0.03 mL (i.e., to the hundredths place). Therefore, the volume would be recorded as 2.63 mL. Two people may make different estimates on this last digit, hence the uncertainty.
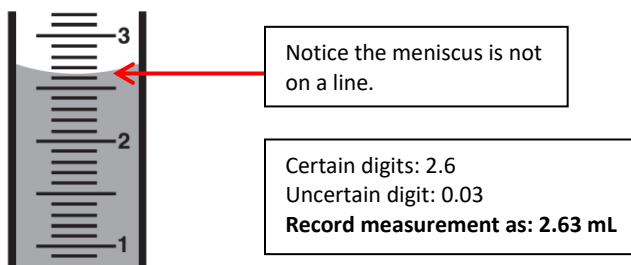

Figure 3. Estimating on a Graduated Cylinder.

When measuring, carefully note the units and graduations of each instrument. The graduations in a buret run in the opposite direction of the graduated cylinder since they measure liquid dispensed (Figure 4).
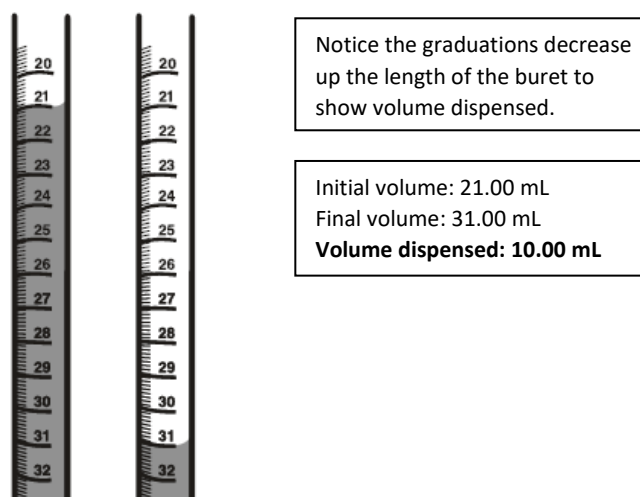

Figure 4. Reading a Buret.

To be more precise when measuring volume, you can use volumetric glassware - pipets or flasks (Figure 5). Volumetric pipets measure one volume only, with more certainty than a graduated cylinder. The tolerance of the glassware, which describes its accuracy, is indicated near the label, so a 1-mL pipet with tolerance of ±0.006 mL would be sure to measure between 0.994 mL and 1.006 mL; its volume is recorded as 1.000 mL. It is the microliter (the third decimal position) that is the first uncertain digit. If the tolerance is not listed on the glassware, assume it is accurate to ±0.01 mL. Laboratory Techniques 5 and 6 describe the steps for use of volumetric flasks and pipets.
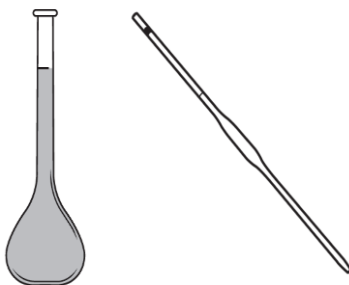

Figure 5. Volumetric Flask (left) and Pipet (right).

For digital or electronic measurements, such as mass on an analytical balance (Figure 6), record all digits as significant. The uncertain digit is the farthest to the right; you may notice it fluctuates a little as you make your readings. Laboratory Technique 2 describes the steps for measuring on the balance.

Figure 6. Analytical Balance.

Again, certain and uncertain digits are all significant. Increasing significant figures increases the certainty or precision of the measurement. The technique of recording all certain digits and the uncertain digit must be performed actively in the lab.

Density

Matter has mass and occupies space. The relationship between these two characteristics is called density; it is a measure of the compactness of matter. Since density is a physical property, it can be used to determine the identity of a substance, as you will do today. To calculate density (d), divide the mass (m) of the object by its volume (V). The most common units for density in chemistry are g/cm^3 for solids, g/mL for liquids, and g/L for gases.

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

Equation 1

For practice, you will measure known volumes and determine the density of water with both a volumetric pipet and a graduated cylinder. The interest is not only in determining the density of water, but also to check the precision and accuracy of the instruments - and your skills - by calculating relative percent error (rel. % error) and standard deviation. First, make several measurements and calculate the mean ($\bar{x}$) density to minimize random errors (errors that are unpredictable). The mean density can be calculated by adding together values for all trials and dividing by the number of trials, as seen in Equation 2:

$$Mean\ density: \qquad \bar{x} = \frac{d_{trial_1} + d_{trial_2} + d_{trial_3} + \cdots + d_{trial_n}}{n} \qquad\qquad Equation\ 2$$

where: d is density
   n is the number of trials

Relative percent error (Equation 3) will demonstrate how accurate a measurement is by comparing it to the true or accepted value. Since density is temperature- and pressure-dependent, use the density value based on the water temperature and barometric pressure from Appendix 1 as the accepted or true value. The formula for relative percent error is:

$$relative\ percent\ error = \left|\frac{true\ value - calculated\ value}{true\ value}\right| \times 100 \qquad\qquad Equation\ 3$$

Standard deviation of the density will demonstrate precision by showing the variation in a set of values around the mean. The formula for standard deviation (s) is:

$$Standard\ deviation:\ s = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}} \qquad\qquad Equation\ 4$$

where: n is the number of trials
   x_i is the individual result of each trial
   Σ is the sum
Note: Standard deviation has the same unit of measure as the mean and should be reported to the same number of decimal places as the mean (subtraction rule).

Appendix 8 provides examples on how to use of Equations 2, 3 and 4.

Scenario

For the I've Bin Recycling Company, you will determine the identity of your unknown plastic flakes and objects by density. You can measure object masses on the balance. For volume, you will find that some objects have regular sides, some are irregular, and some float on water, so you will need to find a protocol to use for each. Following are some suggested techniques for measuring volume.

Regular-shaped Object

For a regular-shaped object, you might be able to measure its volume with a ruler. The formula for a rectangular solid is:

$$V = l \times h \times w \qquad\qquad\qquad \textit{Equation 5}$$

where: l is length
h is height
w is width for the object

Irregular-shaped Object

For an irregular object, you might choose to measure its volume by water displacement (see Figure 7) if it can be submerged in water and displaces enough water to allow for precise measurements. An initial volume of water is measured. Then, the object is added, and the new volume is measured. The difference in volumes corresponds to the volume of the object.
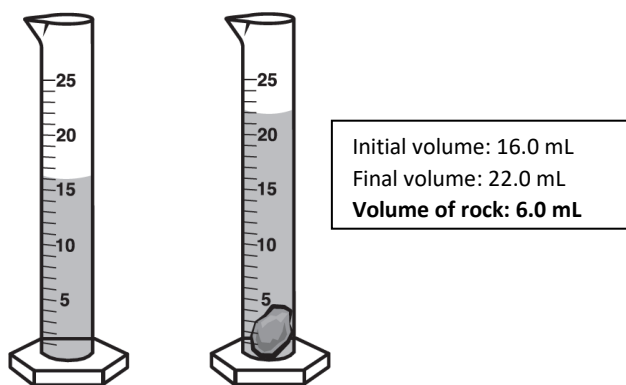
Figure 7. Measuring Volume by Water Displacement.

For an object that floats on water or is too thin to measure with a ruler, you will need to find a different liquid to estimate its density.[9] A solution or mixture will have different physical properties than each individual substance. So, by mixing water with other liquids or solids, a series of solutions with different densities can be prepared. Then, these can be used to examine which solids float and sink in each solution to estimate densities.

Typical densities of plastics and some useful solutions are given (Figure 8) so that you may identify the exact composition of your unknown once you estimate its density. For example,

Question: An unknown solid sinks in water, but floats in Solution 5 (13% w/w NaCl). Identify the solid.

Answer: It must have a density between that of water and Solution 5. Therefore, using Figure 8, the plastic must be polystyrene.
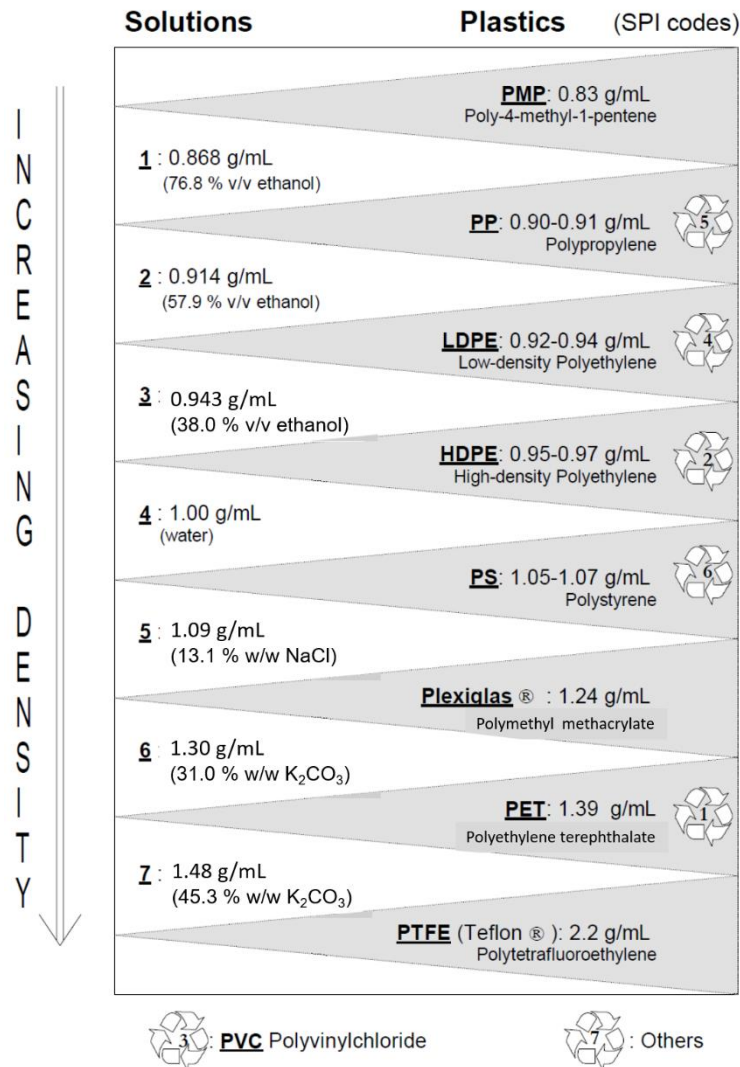
Figure 8. Densities of Plastics and Solutions for Comparison.
*% v/v and % w/w are measures of concentration. SPI Codes are now called Resin Identification Codes. Reprinted with permission from Hughes, E .A.; Ceretti, H. M.; Zalts, A. Floating Plastics: An Initial Chemistry Laboratory Experience. J. Chem. Ed., **2001**, 78 (4), 522. Copyright 2001 American Chemical Society.[9]*

The solution concentrations are given in % v/v, volume solute/volume solution percent or % w/w, weight solute/weight solution percent. For example:

$$76.8 \,\% \,{}^{v}/_{v} \; ethanol = \frac{76.8 \; mL \; of \; ethanol}{100.00 \; mL \; of \; solution \; (ethanol + water)} \times 100\%$$

$$45.3 \,\% \,{}^{w}/_{w} \; K_2CO_3 = \frac{33.110 \; g \; K_2CO_3}{73.113 \; g \; of \; solution \; (K_2CO_3 + water)} \times 100\%$$

You do not need to be able to perform these concentration calculations yet; all the solutions needed for this experiment will be ready for use in the laboratory.

You might like to start by observing whether your unknown plastics float in water. Then, decide which of the solutions (Table 2) to use in order to estimate density.

Table 2. Solutions for Density Comparison with Unknown Plastics.

Solution	Composition	Expected Density at 20 °C (g/mL)
1	76.8 % (v/v) Ethanol : water	0.868
2	57.9 % (v/v) Ethanol : water	0.914
3	38.0 % (v/v) Ethanol : water	0.943
4	Distilled water	1.00
5	13.1 % (w/w) sodium chloride (NaCl) : water	1.09
6	31.0 % (w/w) potassium carbonate (K_2CO_3) : water	1.30
7	45.3 % (w/w) potassium carbonate (K_2CO_3) : water	1.48

Experimental Procedure

Wear goggles and gloves at all times.

Part A Basic Laboratory Techniques: Reading Common Glassware

Record the data from this section in Data Table 1.

1. At a station labeled 'Knowns', there should be two graduated cylinders and a buret, each filled with liquid. The measured volume for each instrument should be provided. Read each meniscus, record the reading including significant figures and units, and see if you agree with the provided value. If your results agree, then proceed to the next step, if not, consult your instructor.
2. At a station labeled 'Unknowns', there should be two graduated cylinders and a buret. Read the meniscus level for each of the instruments to the appropriate significant figures including units. Record the volumes.

Part B Determining the Density of Water at Room Temperature

B1. Recording the Temperature and Pressure to Determine Accepted Density

Record the data from this section in Data Table 2.

1. Near the instructor's desk or demonstration bench, there should be a thermometer suspended in water. Read and record the temperature of water with appropriate significant figures and units.
2. Also, near the front of the room, locate the barometer and record the barometric pressure with appropriate significant figures and units.
3. Using Appendix 1, record the accepted density of water from the table at the closest temperature and pressure to your recorded values.

List of Chemicals

- deionized (DI) water

List of Equipment and Glassware

- two 125-ml Erlenmeyer flasks
- two 100-ml beakers
- 10-ml volumetric pipet
- one bulb
- 25-ml graduated cylinder
- transfer pipet

B2. Using a Volumetric Pipet to Experimentally Determine the Density of Water

Record the data from this section in Data Table 3.

1. Obtain and label a clean, dry 125-mL Erlenmeyer flask as 'Flask 1 water' (marking tape and wax pencils/markers are located in a designated area in your lab).
2. Measure the mass of this flask identified as 'Flask 1 water' on an analytical balance following appropriate technique (Technique 2 Using a Balance). Record all the digits from the balance and the unit of measure.
3. Fill a 100-mL beaker with deionized (DI) water.
4. Using a clean, dry 10-mL volumetric pipet, pipet 10.00 mL of water from the beaker into the 'Flask 1 water' following appropriate technique (Technique 5 Video Tech. 5 Solutions Using a Volumetric Pipet).
5. Measure and record the mass of the 'Flask 1 water' with the water in it (Technique 2 Using a Balance).
6. Calculate the density for these 10.00 mL of water. Report with the correct number of significant figures and unit. Show this answer to your instructor before proceeding.

Technique 2

Technique 5
Video Tech. 5

7. Repeat the process, measuring 10.00 mL DI water into Flask 1, and recording the mass each time until a total of 30.00 mL of water have been added to the flask. (Do not calculate the density yet. Proceed with next section).

B3. Using a Graduated Cylinder to Experimentally Determine the Density of Water

Record the data from this section in Data Table 4.

1. Obtain and label a clean, dry 125-mL Erlenmeyer flask as 'Flask 2 water'.
2. Measure the mass of this flask on an analytical balance and record the reading.
3. Using a 25-mL graduated cylinder, measure 10.00 mL of DI water from the beaker into 'Flask 2' (a transfer pipet may be useful to add or remove a few drops from the graduated cylinder, Technique 4 Using a Graduated Cylinder, Technique 3 Transferring Liquids). Record the mass of the flask with the water.
4. Repeat the process, measuring 10.0 mL DI water into the labeled flask, and recording the mass each time until a total of 30.0 mL of water has been added to the flask.

Technique 3

Technique 4

Part C Identifying Unknown Solids by Density

List of Chemicals

- deionized (DI) water
- three solutions of ethanol in water (38.0 %, 76.8 %, 57.9 %)
- two solutions of potassium carbonate (K_2CO_3) in water (31.0 %, 45.3 %)
- one solution of sodium chloride (NaCl) in water (13.1%)
- one set of five unknown plastics

List of Equipment and Glassware

- ruler
- 50-mL or 100-mL graduated cylinder
- seven 50-mL beakers with watch glasses
- two beakers for waste with watch glasses (one for organic: ethanol; the other for inorganic: K_2CO_3 and NaCl)
- transfer pipet
- tweezers or forceps

Safety Precautions

- Wear safety goggles and gloves at all times.
- Ethanol is a flammable liquid. It is harmful by ingestion, inhalation, or skin absorption. It is an irritant to the eyes, nose, throat, and skin. Keep beakers covered with a watch glass (Figure 9).
- Potassium carbonate (K_2CO_3) solution is a strongly basic solution in water that can cause skin irritation and eye damage.
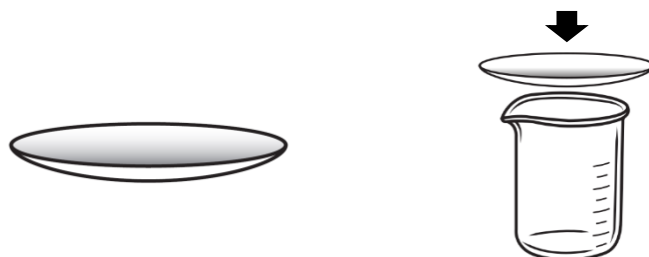
Safety

Figure 9. Watch Glass and Placement on Beaker.

Record all the data for this section in Data Table 6.

1. Collect the glassware needed. It must be clean and dry.
2. Collect a box containing five unknown plastics. Record the box number.
3. Examine each unknown plastic and write your observations of their appearance in your data table including their unknown number(s). Since you are analyzing a batch of plastics, it will help your instructor to know which object you are identifying with an accurate description of it.
4. Measure the mass of each one using the analytical balance and record all significant figures and the unit.
5. Determine which protocol would be best for measuring the volume of each plastic. Your options, which are explained in the Protocol section below, are:
   a. Measure with a ruler.
   b. Measure by water displacement.
   c. Too thin to measure accurately. Determine density by density comparison.
6. Record option selected (ruler, H_2O displacement, too small to measure) in the Volume column.
7. Proceed to measure those that you selected to use options a and b. Record measurements and calculate volume below the table. Record volume in the Volume column. (Make sure to apply rules for significant figures.) Proceed to perform comparisons using option c for those that are too small to measure.
8. Calculate density if you measured volume using options a or b. Option c does not allow for calculating density. Instead, write something similar to the example provided in the Data Table.
9. Determine and record identity of each plastic by comparing its density to those in Table 2 or approximation using Figure 8.

Protocols:

a. Measuring with a Ruler – Use with a Regular-shaped Object

1. Align one edge of the object with the cm markings on the ruler. Set the end of the object at the zero marking.
2. Carefully measure the length, making sure to consider certain and uncertain digits. Record all significant figures and unit below the Data Table.
3. Repeat for each side of the object.
4. Calculate the volume using Equation 5. Note that 1 cm^3 = 1 mL.

b. Measuring Volume by Water Displacement – Use with an Irregular-shaped Object

1. Choose a graduated cylinder with a height and width that can fit the unknown object and leave room for water to be measured. Add enough water to the graduated cylinder so that the unknown solid will be submerged when added. Carefully measure the volume, making sure to consider certain and uncertain digits. Record all significant figures and unit below the Data Table.
2. Then, tip the cylinder and slide the object into the water gently so that it does not crack the cylinder. Wait a few seconds for the water to run back down the sides of the cylinder; you might need to tap the side of the cylinder to encourage any residual drops to fall. Measure and record the volume of the water and object.
3. Calculate the difference in volumes. This difference corresponds to the volume of the object.

c. Identification of Plastics by Density Comparison – Use with Thin Plastics
    The six solutions from Table 2 are available for you in the lab. You will also need DI water. Assume the densities of these solutions match those in Table 2.

1. Label seven 50-mL beakers clearly with the solution number or name listed in Table 2.
2. Place approximately 25 mL of the corresponding solution in each beaker. (Do not pour back into the solution bottles or place anything in the solution bottles.) Keep the beakers well covered with a watch glass to prevent contamination.
3. Carefully submerge one of your unknown samples of plastic in the beaker containing distilled or deionized (DI) water (tweezers or forceps should be used); shake gently to dislodge any trapped air. Observe if the sample sinks or floats in this liquid and record your observations.
4. Take out the sample. Dry the sample and the tweezers with a paper towel.
5. Decide which solution you should test it in next. You need to find two consecutive solutions: one in which it floats, and one in which it sinks. Test it in as many solutions as you deem necessary. After testing in a solution, take out the sample with the tweezers, rinse it (and the tweezers) with water into a waste beaker, and dry with a paper towel.
6. Estimate each unknown density as intermediate between the last solution in which it sinks, and the first in which it floats. Use this information to identify your unknown sample (see Figure 8 and the example in Data Table 6).

D. Calculations and Graphs

1. Complete the calculations requested in Data Table 3 and in Data Table 4:
    a. Calculate the mass of the water.
    b. Calculate the density of the water using Equation 1.
    c. Calculate the mean density of water and the standard deviation using Equation 2 and Equation 4, respectively.
    d. Calculate the relative percent error using Equation 3. The true value is the density recorded in Data Table 2.
    - Remember to use the rules for significant figures in all your calculations and to include units of measure.
    - Show one example of each type of calculation below each data table.
2. Create a graph in Excel (see Appendix 7 Using Excel) using the data from Data Table 3:
    a. Select scatter plot and graph the volume of water on the x-axis and the mass of water on the y-axis.
    b. Add the trend line.
    c. Add the line equation. The value of the slope (m) of the line equation (y= mx + b) is the density.
    d. Add the coefficient of determination (R-squared value).
    e. Add an appropriate title to the graph (note – Flask 1 or Table 3 are not an appropriate titles).
    f. Add titles and units to each axis.
3. Create a graph in Excel (see Appendix 7 Using Excel) using the data from Data Table 4:
    a. Following items 2a – 2f above, graph the volume of water on the x-axis and the mass of water on the y axis from Data Table 4.
4. Complete Data Table 5:
    a. Write the density obtained from the two graphs (remember – the slope from the line equation is the density) and the proper unit of measure.
    b. Calculate the Relative Percent Error of the density using Equation 3. The true value is the density recorded in Data Table 2.
    - Show one example of this calculation below Data Table 5.
5. Complete Data Table 6 and identify the plastics.

Clean up/Disposal

- Read the waste containers carefully to dispose the solutions in the correct container. Dispose the ethanol solutions in the Organic Waste container. Dispose the sodium chloride and potassium carbonate solutions in the Inorganic Waste container (Technique 11 Disposing Waste).
- Dispose the deionized water down the sink drain.
- Rinse and dry the five unknown plastics. Place them in their storage container and return the container to its original location.

Technique 11

- Rinse each piece of glassware with DI water and collect the rinses in your waste beaker.
- Pour the contents of your waste beaker into the designated waste container(s).
- Wash all glassware with soap and water, and then rinse with deionized water (Technique 1 Cleaning Glassware). Dry the outsides of the glassware. Return all glassware to its place.

Technique 1

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Pre-lab

The pre-lab assignment must be completed before you come to the lab.

Figure 10

1. Record the volumes (in mL) of Figure 10 to the appropriate significant figures.

2. Briefly explain how to use a volumetric pipet.

3. The mass of an Erlenmeyer flask is 85.135 g. After 10.00 mL of water is added to the flask, the mass of the flask and the water is 95.023 g. Calculate the density (in g/mL) of water.

4. Using the density calculated in question 3, calculate the relative percent error if the accepted density at this temperature is 0.9992 g/mL.

5. What does homogeneous mean? What do you think this means for the appearance of the solutions that you will use?

6. The mass of a volumetric flask is 40.638 g. After adding 15.0 mL of 95% ethanol and adding enough water to complete the volume to 50.00 mL, the flask weighed 88.219 g. What is the density of the mixture?

7. Print the data tables in the pages below and bring them to lab. Make sure you can access the experimental procedure during lab (printed or downloaded into an e-reader or laptop).
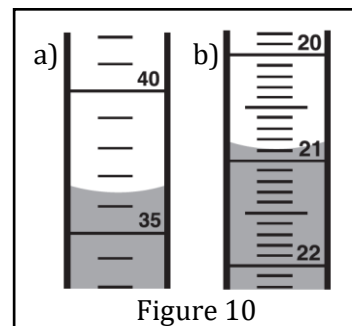
Post-lab

Your stapled report should include of all of the following in this order:

- Data Tables 1-6 with calculations.

- Two graphs.

- Answers to the following questions:

  1. Instruments that were used to measure volume included a graduated cylinder, a volumetric pipet, and a buret, whereas a beaker does not provide volume with any reasonable certainty. Provide one explanation as to why this is true.

  2. Among the two instruments that you used to measure density of water in Part B Determining the Density of Water at Room Temperature, which one was most accurate? What in the data or calculations supports your argument?

  3. Which method, mean or graph, was more accurate in determining the density of water? Support your choice.

  4. Which has a greater effect on density of water: temperature or pressure? How do you know?

  5. Briefly explain a process for how you would scale up your density technique to sort a whole batch of mixed plastics for recycling.

VALENCIACOLLEGE

Experiment 13: Mass, Volume, and Density
Experimental Data and Calculations

Name: _____ **Date:** _____

Lab Partner: _____ **Section:** _____

Print the data tables before lab. Remember to include units of measure with each entry, and to read and record each measurement to the full precision allowed by the instrument used. Make your work neat and legible so that you may communicate your results to others such as your instructor.

Data Table 1. Reading Common Glassware.

	10 mL grad. cylinder	50 mL grad. cylinder	buret
Known Readings			
Unknown Readings Unk. #_____ (if given)	10 mL grad. cylinder	50 mL grad. cylinder	buret

Data Table 2. Temperature and Pressure Measurements.

Barometric Pressure	
Water Temperature	
Density from Appendix 1	

Note: The clear cells should contain your data; the lightly shaded cells will contain calculated values or text; dark shaded cells are not used.

Data Table 3. Measuring Volume with a Volumetric Pipet to Determine Density of Water.

Mass of flask 1				
Mass of flask 1 + H_2O				
Mass of H_2O	0.000 g			
Total Volume of H_2O	0.00 mL	10.00 mL	20.00 mL	30.00 mL
Density of H_2O				
Mean of Density				
Standard Deviation				
Relative Percent Error				

Show your work for one example of each type of calculation in Data Table 3.

Data Table 4. Measuring Volume with a Graduated Cylinder to Determine Density of Water.

Mass of flask 2				
Mass of flask 2 + H_2O				
Mass of H_2O	0.000 g			
Total Volume H_2O (check the sig figs of your graduated cylinder)	0.0 mL	10.0 mL	20.0 mL	30.0 mL
Density of H_2O				
Mean of Density				
Standard Deviation				
Relative Percent Error				

Show your work for one example of each type of calculation in Data Table 4:

Data Table 5. Relative Percent Error for the Density of Water.

	Density from Excel Plot	Relative Percent Error
Flask 1 (using pipet)		
Flask 2 (using graduated cylinder)		

Show your work for one example of the calculations:

Data Table 6. Density and Identity of Unknown Plastics in Set Number _____.

Unknowns	Observations	Mass	Volume	Density	Identity
example object	clear, colorless flake	0.2790 g	too small to measure by ruler or displacement	• floats on water • sinks in sol'n 3 • density must be between 0.945 and 1.00 g/mL	HDPE
Object 1					
Object 2					
Object 3					
Object 4					
Object 5					

Show your work for one example of each type of calculation: