

# 1 Volume and Density

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- Measure volumes and masses.
- Perform unit conversion calculations.
- Determine the density of a substance.

## DISCUSSION

**Prerequisite.** Before doing this experiment you should be able to use dimensional analysis to convert a measurement from one metric unit to either another metric unit or to an English unit.

**Volume.** Volume is a measurement of space. The liter (L) is a metric unit of volume and is equal to 1.057 U.S. quarts (qt), one cubic decimeter (dm<sup>3</sup>), 1000 milliliters (mL), or 1000 cubic centimeters (cm<sup>3</sup> or cc).

Containers used to measure volumes of liquid are calibrated so that you obtain the volume by reading the bottom of the curved liquid surface, or *meniscus*, at eye level. Due to adhesive forces, water is attracted to glass causing aqueous solutions to creep up the sides of the glass in a container and form this meniscus. Usually the bottom of the meniscus will not be exactly on a line of a graduated cylinder or a burette, and so you will need to interpolate (estimate the value between two lines).

Glassware used to measure precise volumes should *never* be heated in an open flame since the glass could crack. Also, the glass could soften, changing the volume slightly.

**Mass.** Mass is a measurement of the amount of matter. In the metric system, the gram (*g*) is a unit of convenient size to measure the masses of chemicals. The gram is defined as the mass of one milliliter (*mL*) of pure water at 3.98 °C. Other metric units of mass are the kilogram (*kg*) which is equal to 1000 grams, the centigram (*cg*) which is one hundredth of a gram and the milligram (*mg*) which is one thousandth of a gram.

You will use a *balance* (not scale) to measure mass. Your instructor will

demonstrate for you how to operate the balances in your laboratory.

**Density.** Density is a characteristic physical property of substances and is defined as mass per unit volume. The

density formula is  $d = \frac{m}{V}$ , where *d* is

the density, *m* the mass and *V* the volume. Since mass is usually measured in grams (*g*) and the volume in milliliters (*mL*), common units of density would be grams per milliliter (*g/mL*).

To obtain the density of an object, determine both its mass and volume by measurement and then divide the mass by the volume.

**Specific Gravity.** Specific gravity is the ratio of a mass of a substance compared to the mass of an equal volume of pure water. Since, for all normal purposes, the density of pure water is 1.0 *g/mL*, its mass in *grams* is equal to its volume in *milliliters*. Thus, the numerical value of a substance's density is the same as its specific gravity provided the units of density are *grams per milliliter*.

**Percent Error.** The percent error is calculated by with the formula below. A positive percent error indicates that your measurement is above the accepted value, and the opposite is true for a negative percent error.

$$\% \text{ Error} = \frac{\text{Experimental} - \text{Accepted}}{\text{Accepted}} \times 100\%$$

## PROCEDURE

**Volume Measurements****Volume of a canning jar.**

1. Canning jars are supposed to contain a volume of one quart. Verify this by filling one to the brim with tap water. Then, without losing a single drop, transfer the water to a one liter graduated cylinder, and measure the volume in milliliters.

2. Determine the number of liters per quart from your measurement.

3. From the fact that there are 1.057 quarts per liter, calculate the accepted value for liters per quart.

4. Find the percent error between the accepted value of liters per quart and your experimental result. (This number, if large, does not necessarily criticize your technique; rather it tests the accuracy of the jar's labeled volume.)

**Density Measurements****A. Density of a liquid.**

5. Measure the mass of your clean, dry 50 mL graduated cylinder to the nearest centigram.

6. Add about 25 mL saturated aqueous sodium chloride solution (brine) to the graduated cylinder, and measure its mass again.

7. Record the volume to the nearest 0.1 mL.

8. Calculate the density of the brine solution.

9. Perform Steps 6-8 again and calculate an average density of the brine solution.

10. Find the percent error from the accepted value of 1.19 g/mL.

**B. Density of an irregular solid.**

11. Fill your 50 mL graduated cylinder about half full with tap water, and measure the mass of the container and the water to the nearest centigram.

12. Record the volume of the water to the nearest 0.1 mL.

13. Carefully slide three or four pieces of galena—at least enough to make the displaced volume more than 4 mL—into the water in the graduated

cylinder. Do not splash any water or break the graduated cylinder. Check for trapped air bubbles. If present, remove them by gentle shaking. Record the new mass.

14. Record the new volume.

15. Obtain the mass of the galena alone.

16. Find the volume of the galena.

17. Calculate the density of the galena.

18. Perform Steps 11-17 again and calculate an average density for the galena.

19. Determine the percent error from the accepted value of 7.5 g/mL. Place the wet galena in the appropriate container assigned for that purpose.

**C. Density of a regular solid.**

20-27. Obtain an aluminum cylinder, and find its density by the water displacement method as outlined in steps 11 to 17 above. Aluminum's accepted density is 2.70 g/mL.

28. Obtain the density of the cylinder via a different route. First measure the radius of the cylinder in centimeters.

29. Measure the height of the cylinder.

30. Calculate its volume using the formula  $V = \pi r^2 h$ , where  $V$  is the volume of the cylinder, and  $r$  and  $h$  are its radius and height, respectively.

31. Divide the mass (from step 24) by this volume to find the density.

32. Compare your result with the accepted value.

33. Based on your results, which of the two methods is the more accurate?

**D. Density of an unknown.**

34. Obtain a metal cylinder of unknown density from the stockroom. Record the unknown's identification number.

35. Measure its density as accurately as you can. Briefly describe your procedure. List and label all appropriate data, calculations, and results.

Material	Density (g/mL)
Brine	1.19
Galena	7.5
Aluminum	2.70
Lead	11.3

# 1 Volume and Density

Name \_\_\_\_\_

Partner \_\_\_\_\_

Section \_\_\_\_\_ Locker \_\_\_\_\_

Instructor \_\_\_\_\_

Enter the data or answer the questions *according to the corresponding step in the procedure*

## VOLUME MEASUREMENTS

### A. Volume of a canning jar

1. Volume of canning jar	
2. Measured number of liters per quart	
3. Calculated number of liters per quart	
4. Percent error in jar's volume	

## CALCULATIONS

## DENSITY MEASUREMENTS

### Density of a liquid

5. Mass of 50 mL graduated cylinder			
6. Mass of graduated cylinder and brine solution			
7. Volume of brine solution			
8. Density of brine solution			
9. Average density			
10. Percent error in measured density			

## CALCULATIONS

**Density of an irregular solid**

11. Mass of graduated cylinder and water			
12. Volume of water			
13. Mass of graduated cylinder, water, and galena			
14. Volume with galena added			
15. Mass of galena			
16. Volume of galena			
17. Density of galena			
18. Average density			
19. Percent error in measured density			

**CALCULATIONS****Density of a regular solid**

20. Mass of graduated cylinder and water	
21. Volume of water	
22. Mass of graduated cylinder, water, and metal	
23. Volume with metal added	
24. Mass of metal	
25. Volume of metal (by displacement)	
26. Density of metal (by displacement)	
27. Percent error in measured density	
28. Radius of metal cylinder	
29. Height of metal cylinder	
30. Volume of metal (by measurement)	
31. Density of metal (by measurement)	
32. Percent error in measured density	
33. The more accurate method	

**CALCULATIONS****Density of an unknown**

36. Unknown's number	
37. Density of unknown	

**DATA, CALCULATIONS, AND RESULTS**

**APPLICATION OF PRINCIPLES**

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1. If there are 32 fluid ounces in a quart and 1.057 quarts in a liter, how many milliliters are there in one fluid ounce?
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2. If you weighed your samples to the nearest milligram instead of the nearest centigram, and all other measurements were carried out as before, would the density determinations be more accurate? Explain.
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3. What would you do to modify your density determination procedure if the irregular solid was a water soluble substance like sugar or salt?
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4. Determine the density of some steel shavings if 48.0 g changed the water level in a 50 mL graduate from 28.0 mL to 36.0 mL.
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5. When 25.0 mL of a fluid is placed in a beaker with a mass of 30.36 g, the resulting mass of both beaker and fluid is 61.89 g. Determine the density of the fluid.

## Appendix A: Equipment

- 1-quart canning jar
- 1000-mL graduated cylinder
- 50-mL graduated cylinder
- saturated sodium chloride solution in dropper bottle (waste container also)
- galena (collection container also)
- aluminum cylinder
- unknown metal cylinder
- ruler

