

EXPERIMENT 2

Volume Measurements and the Determination of Density

INTRODUCTION

In this experiment, equipment for the measurement of volumes is described and used. Volume measurements are then combined with weight measurements, described in the previous experiment, to determine the density of a solid. Finally, a graphing procedure is combined with weight and volume measurements to determine the density of a liquid.

The basic SI unit of volume is the m^3 . Smaller derived units are the cubic decimeter (dm^3) and the cubic centimeter (cm^3). The cubic decimeter is commonly referred to as a liter ($1 \text{ dm}^3 = 1 \text{ L} = 10^{-3} \text{ m}^3$) and the cubic centimeter as a milliliter ($1 \text{ cm}^3 = 1 \text{ mL} = 10^{-6} \text{ m}^3$). In 1 liter there are 1000 mL.

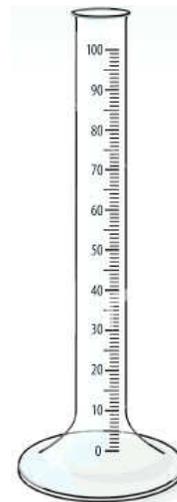
Volumetric Glassware

The most commonly used items of volumetric glassware are the graduated cylinder, buret, pipet, and volumetric flask.

As with the use of balances, the choice of volumetric glassware depends on the purpose of the measurement and the accuracy with which a volume must be measured.

Graduated Cylinders

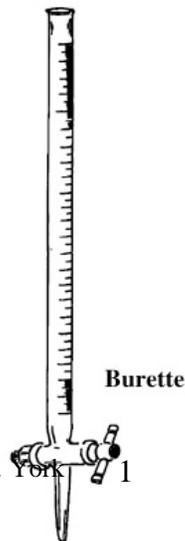
Graduated cylinders are available in many capacities from 5mL to 2000mL. Each size has different calibration units and can be read with different degrees of accuracy. Small sizes can at best be read to $\pm 0.1\text{mL}$ while larger sizes can only be read to ± 1 or 2 mL . Graduated cylinders are not used for very accurate quantitative measurements. They are convenient for measuring and transferring liquids where exact volumes are not required.



Burets

Burets are commonly used where volume measurements to the nearest 0.01 mL are required. The burets used in this course are calibrated in 0.1mL increments and have 50mL capacities.

The proper use of the buret involves the following steps. (1) Clean the buret. (2) Rinse the buret with 5–6mL of distilled water. To thoroughly rinse a buret, it should be rolled on its side until all surfaces have been wet. The stopcock is then opened and the buret is drained. (3) Rinse the buret with 5–6mL of the solution to be used in the buret. (4) Fill the buret with solution. When filled, the buret should be drained until no air bubbles remain above or below the stopcock. If air bubbles are present, the dispensing of solution will not be quantitative. (5) Place the buret vertically in a buret clamp supported by a ring stand. (6) Record the initial buret



reading to the nearest 0.01mL.

To read the buret, first note that the zero calibration line is at the top and the 50mL calibration is at the bottom of the buret. Volume readings are recorded before and after liquid is dispensed through the stopcock. The difference in these measurements gives the volume of liquid used.

The surface of the liquid in the buret is curved, not flat, due to the surface tension of the liquid. When recording a volume, read the liquid level at the bottom of the curved surface or meniscus. A blackened card placed behind the buret usually helps to improve the visibility of the meniscus.

Sample Buret Measurements	
Final Buret Reading	34.45 mL
Initial Buret Reading	0.52 mL
Volume Dispensed	33.93 mL

Pipets

Volumetric Pipets



Measuring Pipets

Mohr pipet

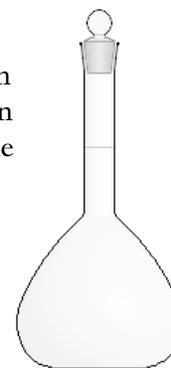


Pipets are used to dispense a known volume of solution quickly and accurately. Two types of pipets exist: transfer pipets and measuring pipets. Each type is available in many capacities. Measuring pipets are calibrated in small increments of the total capacity of the pipet. Each size has different calibration units. They are read in the same manner as burets. Transfer pipets have only one calibration mark. They deliver a set volume of liquid.

When using either type of pipet, liquid is drawn up the pipet by using a rubber suction bulb—**NEVER BY MOUTH**—until the level is above the desired graduation mark. The liquid is then carefully lowered, by releasing the suction, until the bottom of the meniscus just coincides with the graduation mark. Then the liquid is dispensed into the desired container by completely releasing the suction and allowing the pipet to drain. Many pipets are calibrated "to deliver" a specific volume when filled and drained completely. A drop usually remains in the tip of the pipet, again due to surface tension, and should not be forced out. Pipets that hold 1mL or more deliver the marked volumes with an error of ± 0.01 mL.

Volumetric Flasks

The volumetric flask is used for preparing solutions. It is available in various capacities and has a single graduation mark on the neck of the flask. When filled so that the bottom of the meniscus coincides with the graduation mark, the volumetric flask contains the specified volume of liquid.



Density Determination

Density is a basic property of all pure substances. It is defined as mass (M) per unit volume (V).

$$D = \frac{M}{V}$$

If the mass and volume of a substance can be measured, the density can be calculated directly using this definition. Alternatively, the density of a material (and many other results) can be obtained from the proper graph of experimental data. Graphing allows the data to be presented visually and provides a means of averaging the data while obtaining the desired result. In the first part of this experiment, the density of a metal is calculated directly. In the second part, the density of a liquid is determined from an appropriate plot of the experimental data.

In order to determine density by graphing, the density equation is rearranged to the more useful form

$$M = D V$$

This relation has the same form as the general equation for a straight line

$$y = m x + b$$

where $y = M$, $x = V$, $m = D$, and $b = 0$. A plot of y versus x gives a straight line of slope m and intercept b . Likewise, a plot of M versus V should give a straight line of slope D and intercept zero.

To prepare the graph, the masses of several volumes of the unknown liquid are measured. Each pair of data for M and V is plotted and the best straight line is drawn through the experimental points. The line need not pass exactly through each point but should be the best fit possible.

The slope of the line is calculated using any two points on the line and the relation

$$\text{slope} = m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

The slope gives the density that would be obtained if each pair of data for M and V had been used to calculate D , and the values of D had been averaged.

PROCEDURE

Determination of the Density of an Unknown Metal

1. Obtain an unknown metal sample and weigh it on the quadruple beam balance. Record the unknown number and weight on the data sheet.
2. Measure the volume of the metal by noting the displacement of water in a 50mL graduated cylinder. The amount of water displaced by the metal is determined as follows: Fill the graduated cylinder until it is about one-half full. Record the initial volume. Then, gently slide the metal sample down the side of the cylinder while holding the cylinder at a slight angle. Take care not to lose any water. Place the cylinder upright and record the final volume. The difference between the final and initial volumes is the volume of the metal sample.
3. Calculate the density of the metal to the correct number of significant digits.

Determination of the Density of an Unknown Liquid

1. Obtain an unknown from the instructor. Record the unknown number on your data sheet.
2. Attach a buret clamp to a ringstand. Obtain a buret from the stockroom. Rinse the buret with about 5mL of distilled water and then 5mL of the unknown. Allow a portion of each to drain through the buret tip. Check that the stopcock operates properly.
3. Fill the buret with the unknown liquid. Hold the buret at an angle over the sink and open the stopcock quickly to fill the buret tip and remove any air bubbles. Place the buret in the buret clamp.
4. Weigh a 100mL beaker to the nearest 0.0001 g on the analytical balance. Record the weight on the data sheet.
5. Note and record the initial buret reading to ± 0.01 mL.
6. Dispense about 5mL of the liquid from the buret into the weighed 100mL beaker. Note and record the new buret reading to ± 0.01 mL.
7. Weigh the beaker **with the liquid** on the analytical balance. Record the weight.
8. **Retain** the liquid in the weighed 100 mL beaker and repeat steps 6 and 7 three more times: Each time add about 5mL more of unknown liquid to the beaker. Record the **new** buret reading and weight on the data sheet after each addition.
9. Plot a graph of mass versus volume on the graph paper provided. Draw the best straight line through the data points and calculate the density of the unknown liquid to three significant figures.

Lab 2: VOLUME MEASUREMENTS AND THE DETERMINATION OF DENSITY

Name _____

Section _____

I. DATA

A. Determination of the Density of an Unknown Metal

Unknown Number _____

weight of unknown metal	
initial graduated cylinder reading (without unknown metal)	
final graduated cylinder reading (with unknown metal)	

B. Determination of the Density of an Unknown Liquid

Unknown Number _____

Initial buret reading		weight of beaker	
Buret reading after 1st liquid sample removed		weight of beaker + liquid after 1st sample added	
Buret reading after 2nd liquid sample removed		weight of beaker + liquid after 2nd sample added	
Buret reading after 3rd liquid sample removed		weight of beaker + liquid after 3rd sample added	
Buret reading after 4th liquid sample removed		weight of beaker + liquid after 4th sample added	

II. RESULTS

A. Determination of the Density of an Unknown Metal

Volume of metal	
Density of metal	

(Density should be expressed to the proper number of significant figures warranted by the data.)

B. Determination of the Density of an Unknown Liquid

	Total Volume of Liquid in Beaker	Total Weight of Liquid in Beaker
After 1st sample added to beaker		
After 2nd sample added to beaker		
After 3rd sample added to beaker		
After 4th sample added to beaker		

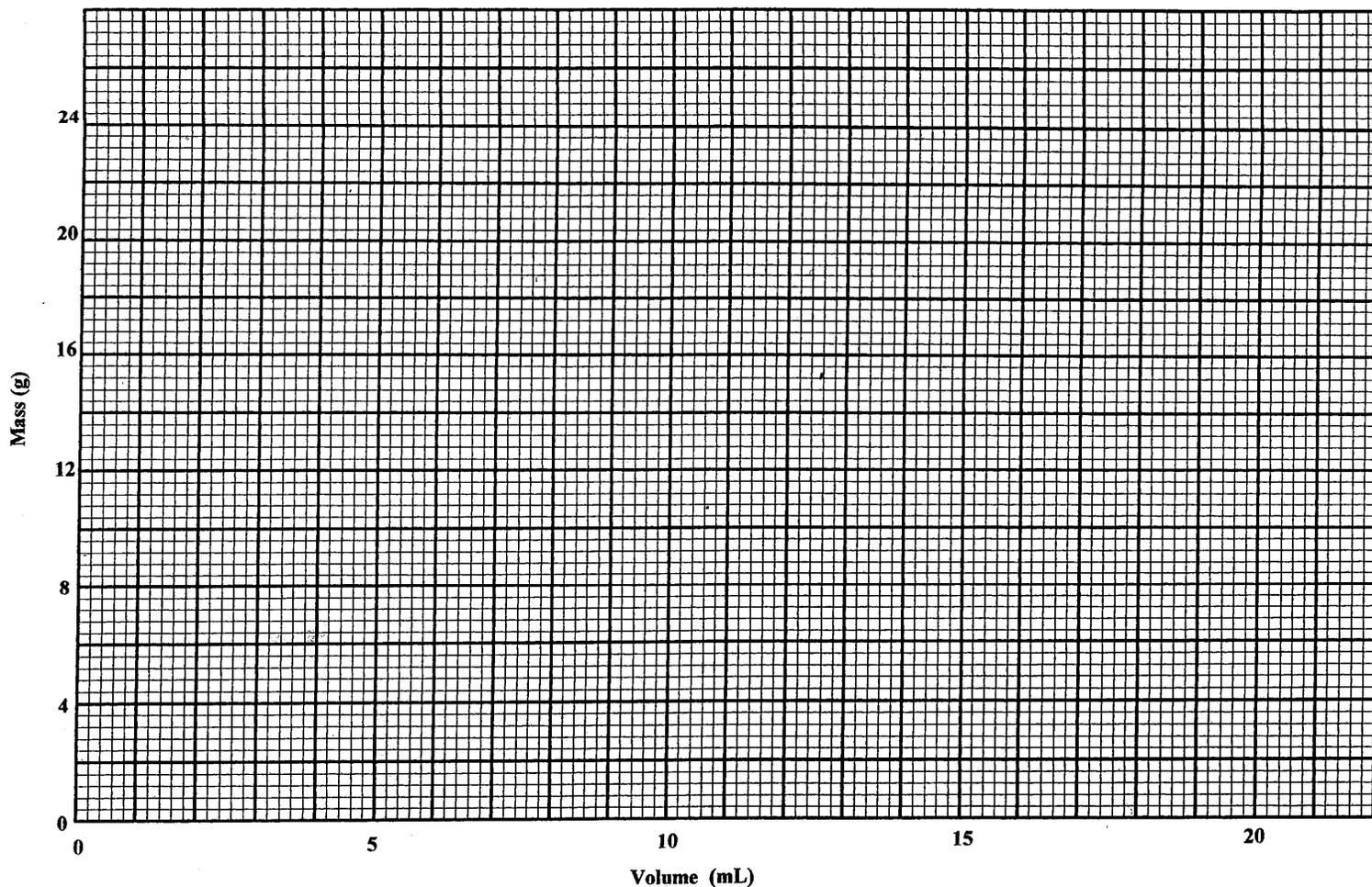
Slope of line resulting from the plot of M versus V _____

Density of unknown liquid _____

Show calculation of slope:

Show calculation of density:

Title:



III. QUESTIONS

1. Which item of volumetric equipment should be use to...

a. measure approximately 10mL of solution?

b. measure 10.10mL of solution?

2. Why is it necessary to rinse a buret or pipet with the liquid to be measured?

3. Indicate whether the following errors are random or systematic.

a. The graduation mark on a pipet is incorrect by +0.11mL.

b. Three students read a buret and obtain values of 25.10, 25.12, and 25.09ml.

c. The balance is not zeroed and a series of weighings are made with the balance initially at 0.0200 g.