CENGAGE LABORATORY SERIES for
General, Organic, and Biochemistry

Safety-Scale Laboratory Experiments for Chemistry for Today

NINTH EDITION

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Michael R. Slabaugh
Maren S. Hansen

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for

Chemistry for Today: General, Organic, and Biochemistry

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Contents

Introduction

To the Student: A significant amount of your training in chemistry will take place in the laboratory. The following instructions should be read carefully before you attend the first laboratory session. These instructions will help you make efficient use of your time while in the laboratory and also promote laboratory safety.

PRE-LAB PREPARATION

Carefully read the experiment to be performed before you come to the laboratory. Your instructor might require you to complete the Pre-Lab Review Sheet found before the Data Sheet of each experiment and turn it in before you begin your lab work. Even if this is not a requirement, you are still advised to complete the Review Sheet. The questions have been chosen to draw your attention to specific techniques and precautions that you should be aware of before you start the experiment. The experiments are designed to allow you to collect the data in 3 hours or less. Students unable to do this have usually failed to prepare properly for the laboratory. Make sure you arrive on time, since your instructor will provide additional instructions for experiments as needed.

SAFETY PRECAUTIONS

In the laboratory, you will work with a variety of substances and equipment. The following precautions should be followed to minimize the chances for accidents.

1. Carefully note any special safety precautions stated in the experiment. They are identified as **Safety Alert** and are enclosed in boxes for easy recognition.
2. Approved safety glasses or goggles must be worn *at all times* in the lab.
3. Some chemicals used in experiments are toxic. Therefore, no eating, smoking, or drinking is allowed in the laboratory. After leaving the lab, you should wash your hands before eating, smoking, or drinking.
4. Never taste or smell anything in the lab unless you are specifically instructed to do so.
5. Use the hood when instructed to do so. Do *not* release noxious gases into the open lab.

6. No unauthorized experiments are to be performed. Follow directions carefully, using only the amounts of chemicals specified.
7. Always pour concentrated acid into water; *never* pour water into the acid.
8. No visitors are allowed in the lab unless specific permission is given by the instructor.
9. Clean up all chemical or solution spills immediately. Your work area should always be left clean at the end of the lab period.
10. Protect both hands when you insert glass tubing or thermometers into stoppers. Make sure the glass is well lubricated before such insertions are attempted. Your instructor will show you the correct procedure.

EMERGENCY FACILITIES AND PROCEDURES

Despite safety precautions, accidents sometimes occur. Even though the chance is small, it is important to know what to do in the event you are involved. Therefore, you should acquaint yourself with the location and use of the following emergency facilities. Your instructor will describe or demonstrate their operation.

1. Safety shower
2. Fire blanket
3. Safety eye-wash facility
4. Fire extinguisher

The following procedures should be followed if you are involved in an accident. Also be prepared to assist other students in the laboratory. In some instances, people involved in accidents become disoriented and frightened and forget what to do. Be ready to help.

1. Report all injuries—no matter how slight—to your instructor.
2. Splashes of corrosive or toxic substances should be washed immediately from skin and clothing, using copious amounts of cold water. Speed is especially important if the material has splashed into the eyes.
3. The best immediate treatment for a burn is to hold the injured area under cold water or to cover it with ice.
4. If your clothing catches fire, use the safety shower or blanket.
5. If a fire occurs on a bench area, use the fire extinguisher.
6. If you cut or burn yourself, call your instructor immediately for first aid.

GENERAL LABORATORY PROCEDURES

The following procedures will help you use your time efficiently and will help minimize the waste of chemicals and other supplies. Other techniques will be described to you as needed in later experiments.

1. Cleaning glassware: Scrub inside and out with a brush, detergent, and tap water. Rinse away all suds with tap water. Rinse the inside of the glassware two or three times with *minimal* amounts of distilled water. (Distilled water is expensive and should be used sparingly.) Shake out

as much rinse water as possible and dry the outside with a towel. If dry glassware is needed immediately, rinse the equipment twice with small amounts of acetone, then return the used acetone to the original container. The residual acetone in the equipment will vaporize quickly and leave no residue.

2. Disposal of used materials: Used chemicals and other materials must be disposed of appropriately. We will use three disposal methods in the experiments of this manual. Some used chemicals can be flushed down the sink drain with water. When this method is to be used, you will be notified as follows:

Disposal

[IDENTITY] IN SINK, WHERE [IDENTITY] IS THE MATERIAL YOU ARE DISPOSING.

Most used chemicals will be collected in labeled containers located in the lab. Your instructor or other qualified individuals will then properly dispose of the collected materials. This method will be indicated to you by a notification in bold type similar to the following:

Disposal

IRON CHLORIDE IN CONTAINER LABELED "EXP. 4, USED CHEMICALS."

You would then dispose of your used iron chloride by putting it into the container with the label matching the one given in the notification. A few materials used in the lab can be put into an ordinary wastebasket or other similar solidwaste receptacle. This will be indicated by the following in bold type:

Disposal

[IDENTITY] IN WASTEBASKET.

If you are not sure about the proper way to dispose of a used chemical or other material, ask your lab instructor for directions.

3. Smelling vapors and gases: *Never* smell a chemical by holding the container to your nose. Hold it about 6 to 12 inches away and carry the gas or vapor to your nose in your cupped hand.

4. Chemical use: To avoid waste, obtain only the amount of chemical called for in the experiment. Do not remove chemical containers (solids or liquids) from the designated dispensing area.

5. Dispensing solids: Solid chemicals can be poured easily from containers by gently rotating the container back and forth during the pouring process. Do not return excess chemical to the original container.

6. Dispensing liquids: When moderate to large amounts of liquid chemicals are needed, pour the amount needed from the bottle into an appropriate container (beaker, test tube, and so on). Do not lay the bottle stopper on the bench but hold it between your fingers as demonstrated by your lab instructor. When small amounts (drops) are needed, do not put your dropper into the container. Either use the dropper supplied with the container or pour a small amount into a small test tube or other container and fill your dropper from that supply. Never return a used liquid chemical to the original container.

DATA AND CALCULATIONS

Each experiment in this manual consists of three parts that provide information you will need to successfully complete the experiment. The *Introduction* contains background material and develops any theory, equation, etc. used in the experiment. The *Experimental Procedure* provides the actual steps you will follow to collect data (weights, volumes, observations and the like). The *Calculation and Report* part of the experiment contains directions for doing calculations or treating your data in other ways to prepare the final report of the experiment.

Each experiment includes a Data and Report Sheet. Data collected by following the *Experimental Procedure* should be recorded during the laboratory session directly on the sheet in the tables labeled ''data.'' Calculations and other treatment of the data should be done outside the laboratory according to the directions given in the *Calculations and Report* part of the experiment, and recorded in the tables labeled ''report.'' Unless you are directed to do otherwise, submit the completed Data and Report Sheets, including the completed questions, to your instructor at the next laboratory session. Note that the data tables and the report tables are located near each other for convenience when you do your calculations. However, complete only the data tables while you are in the laboratory. You may find it useful to remove the Data and Report Sheet from its location near the end of the experiment and keep it available for easy access when you have data to record. This will avoid the need to flip to the end of the experiment each time you record data.

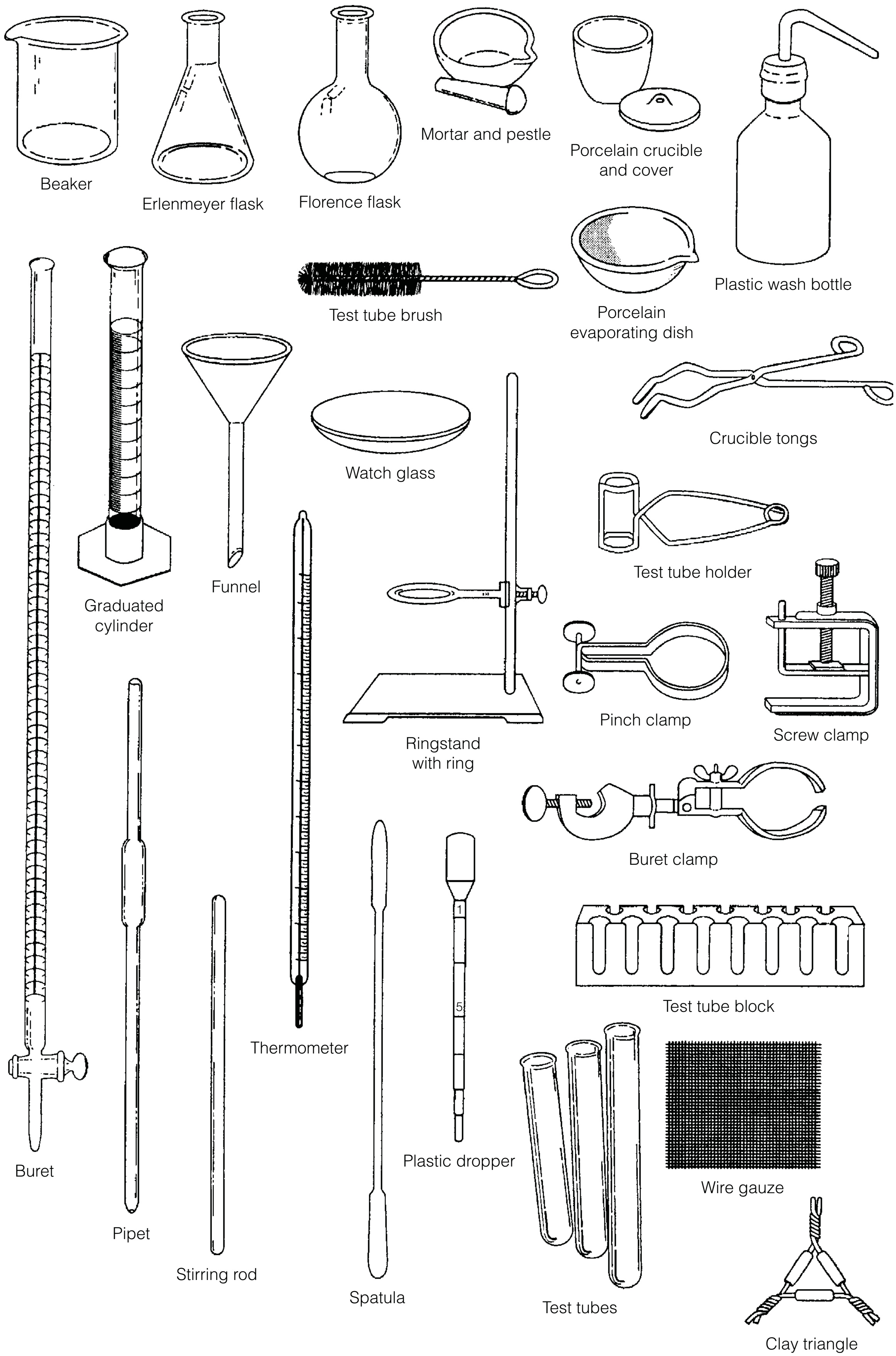
SCALE OF EXPERIMENTS

The experiments included in this manual represent a compromise between microscale approaches that minimize the amounts of chemicals used and macroscale approaches that require the use of relatively large amounts of chemicals. Microscale approaches have economic and safety advantages because of the small quantities of both chemicals required and wastes generated. However, such approaches often require specialized glassware and other equipment that must be purchased, a requirement that eliminates some of the economic advantage. Also, a completely microscale approach often fails to give students experience in the use of certain basic types of equipment such as burets and pipets.

The safety-scale experiments in this manual have been generally scaled down from macroscale in terms of the amounts of materials used to provide some of the economic and safety advantages of microscale. However, the amounts are large enough to allow the use of regular, small-sized laboratory glassware. Thus, most reactions are done using small (10-cm) test tubes, but pipets, burets, and other basic pieces of glassware are also used where it is appropriate. The small quantities of liquids required for most experiments are measured in drops and dispensed from dropper bottles.

We have found this compromise in scale to be an effective approach to teaching the chemistry laboratory. The students adapt to it very well, and the stockroom personnel who prepare materials for the experiments appreciate the small quantities involved.

Common Laboratory Equipment



Measurements and Significant Figures

IN THIS EXPERIMENT, YOU WILL

- ❑ Make measurements using devices having different uncertainties.
- ❑ Express measured quantities in a way that correctly shows the uncertainties of the measurements.
- ❑ Use significant figures to properly represent measured and calculated quantities.
- ❑ Investigate how to increase the number of significant figures in measured and calculated quantities by properly using measuring devices.

INTRODUCTION

Measurement is an important activity in most scientific studies. Every measurement contains an uncertainty that comes from the device or technique used to make the measurement. The numbers used to record a scientific measurement normally indicate the uncertainty in the measurement. For example, a mass recorded as 2.87 g indicates that the measurement has an uncertainty in the hundredths (.01) of a gram. This fact could be represented by recording the mass as $2.87 \pm .01$ g, but usually this is not done. The value is simply recognized as having an uncertainty of $+1$ or -1 in the last recorded number.

The numbers used to represent the certain part of a measurement (the 2 and 8 in the example), plus one number representing the uncertain part (the 7 in the example), are called **significant figures** or significant digits. Thus, the quantity 2.87 g contains three significant figures.

The necessity of using zeros to express measurements raises the question of when zeros are considered to be significant figures. The measured mass expressed as 2.87 g could also be expressed as .00287 kg. The significance of a measurement cannot be changed simply by changing the units used to express the measurement. Thus, .00287 kg must contain three significant figures just as 2.87 g does. This is an example of one rule concerning zeros. Zeros not preceded on the left by nonzeros do not count as significant figures. Other zeros, those located between nonzeros and those to the right of nonzeros (only when a decimal is present in the number), are counted as significant figures. Thus, 3.509 g and 2.870 g both contain four significant figures, and both indicate that the measurement uncertainty is $+.001$ or $-.001$ g.

In this experiment, you will make some measurements using different devices. You will express these measurements and results calculated from them using the correct number of significant figures.

EXPERIMENTAL PROCEDURE

A. Measurement with Ruler A

The area of a rectangle is equal to the product of the width, w, and length, l, (area $= w \times l$). The perimeter of a rectangle is equal to the sum of the four sides (perimeter $= w + w + l + l$). In this procedure, you will measure the length and width of four different rectangles. These quantities will be measured with a ruler that has divisions to the nearest centimeter. When measuring devices like rulers are used, the measurement uncertainty is expressed by estimating the value of the measured quantity to one decimal place more than the smallest scale division of the measuring device. Thus, all measurements made with ruler A should be expressed to the nearest .1 cm.

To calculate rectangular areas, you will have to multiply together two measured quantities. The area that results should be expressed using the correct number of significant figures. In the case of multiplication or division, the results of the calculation must have the same number of significant figures as the least significant measured number used in the calculation. For example, the product 1.1186×0.064 is equal to 0.07159. However, only two significant figures are used in the answer to match the two significant figures in 0.064. Thus, the answer is 0.072, where the last significant figure (1) was rounded up to 2 because the first number being dropped (5) was equal to 5. In general, the last significant figure retained during rounding will be increased by 1 in the rounded answer when the first number being dropped is equal to or greater than 5. When the first number being dropped is less than 5, the last significant figure in the rounded answer is not changed.

Rectangle perimeters are obtained by adding a series of numbers. When numbers are added or subtracted, significant figure rules require that the answer be rounded so that it contains the same number of places to the right of the decimal as the smallest number of places in the quantities added or subtracted. For example, the sum $3.527 + 0.041 + 7.12$ is equal to 10.688. However, in this answer only two places to the right of the decimal are used to match the two places in 7.12. When the same rounding rules given earlier are used, the correctly rounded answer is 10.69. Note that this answer has four significant figures, even though the numbers added had four, two, and three significant figures, respectively.

Procedure

1. Use a pair of scissors and carefully cut out ruler A from page 5. Cut inside the bottom line to remove the bottom line from the ruler. Do not cut out the rectangles.
2. Use ruler A to measure the length and width of rectangles W, X, Y, and Z that are drawn on page 5. Note that the smallest division on ruler A is 1 cm, so measured values should be estimated to the nearest .1 cm. Record your measured values in cm in Table 1.1 of the Data and Report Sheet, with the longest side designated as the length.

B. Measurement with Ruler B

Procedure

1. Use a pair of scissors and carefully cut out ruler B from page 5. Cut inside the bottom line to remove the bottom line from the ruler.
2. Use ruler B to measure the length and width of rectangles W, X, Y, and Z that are drawn on page 5. Note the smallest division on ruler B is 0.1 cm, so measured values should be estimated to the nearest .01 cm. Record your measured values in cm in Table 1.5 of the Data and Report Sheet.

C. Improving the Significance of Measurements

The number of significant figures in a measured quantity and in quantities calculated from measured quantities depends on the way the measuring device is used.

Procedure

1. Obtain 10 one-cent coins from the stockroom.
2. Use ruler B to measure the diameter of a single coin; be sure to make an appropriate estimate and include it in your value. Record the measured value in Table 1.9 of the Data and Report Sheet.
3. Use ruler B to measure the thickness of a single coin and the thickness (height) of stacks of coins containing 3, 5, 7, and 10 coins. Include appropriate estimates in your measurements and record the values in Table 1.9 of the Data and Report Sheet.

CALCULATIONS AND REPORT

A. Measurement with Ruler A

1. Transfer the measured length and width values from Table 1.1 to Table 1.2 of the Data and Report Sheet.
2. Complete Table 1.2 by writing the number of significant figures found in each measured quantity.
3. Refer to the rules given earlier for multiplication calculations, and determine the correct number of significant figures that should be used in the calculated area of each rectangle. Record that number in Table 1.3.
4. Calculate the area of each rectangle and record the unrounded value (the value given by your calculator) and the value rounded to the correct number of significant figures in Table 1.3.
5. Refer to the rules given earlier for addition calculations, and determine the correct number of places to the right of the decimal that should be used in the calculated perimeter of each rectangle. Record that number in Table 1.4.
6. Calculate the perimeter of each rectangle and record the unrounded and properly rounded values in Table 1.4.

B. Measurement with Ruler B

1. Transfer the measured length and width values from Table 1.5 to Table 1.6 of the Data and Report Sheet.
2. Complete Table 1.6 by writing the number of significant figures found in each measured quantity.

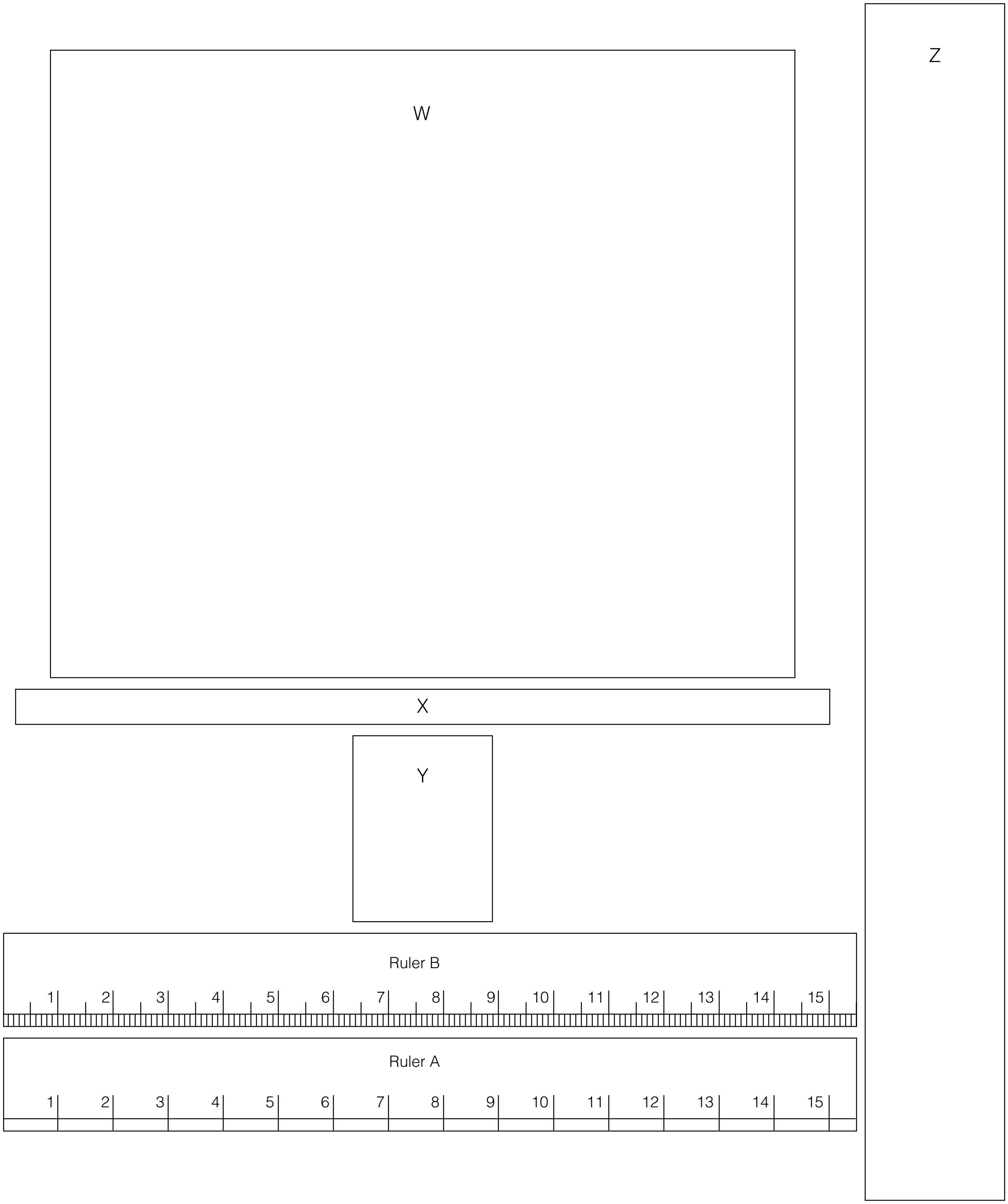
3. Refer to the rules given earlier for multiplication calculations, and determine the correct number of significant figures that should be used in the calculated area of each rectangle. Record that number in Table 1.7.
4. Calculate the area of each rectangle and record the unrounded and properly rounded values in Table 1.7.
5. Refer to the rules given earlier for addition calculations, and determine the correct number of places to the right of the decimal that should be used in the calculated perimeter of each rectangle. Record that number in Table 1.8.
6. Calculate the perimeter of each rectangle and record the unrounded and properly rounded values in Table 1.8.

C. Improving the Significance of Measurements

1. Transfer the measured thickness values for each coin stack from Table 1.9 to Table 1.10 of the Data and Report Sheet.
2. Determine the number of significant figures in each thickness value and record that number in Table 1.10.
3. Refer to the rules given earlier for division calculations, and determine the correct number of significant figures that should be used in a calculated value of the average thickness of a coin. This average is obtained by dividing the measured thickness of a stack by the number of coins in the stack. The number of coins in a stack is a counting number that is known exactly and does not influence the number of significant figures used in the calculated value. Record the correct number of significant figures in Table 1.10.
4. Calculate the average thickness of a coin from the data for each stack and record the unrounded and properly rounded values in Table 1.10.
5. The volume of a coin is given by

$$V = \frac{1}{4}\pi d^2 t$$

   where $\pi = 3.1416$, $d =$ the measured diameter, $t =$ the calculated average thickness, and 1/4 is an exact fraction that does not influence the number of significant figures used in the calculated volume. Use the most significant calculated value for the average coin thickness t recorded in Table 1.10, the measured diameter d from Table 1.9, and determine the correct number of significant figures that should be used in a calculated volume V. If two or more coins have the same number of significant figures in their calculated average thickness, either value can be used in the volume calculation. Record the correct number of significant figures that should be used for the volume in Table 1.11.
6. Calculate the volume of a coin and record the unrounded and properly rounded values in Table 1.11.


Z
W
X
Y
Ruler B
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Ruler A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

name ______ section ______ date ______

1 **E X P E R I M E N T 1**

Pre-Lab Review

MEASUREMENTS AND SIGNIFICANT FIGURES

1. Are any specific safety alerts given in the experiment? List any that are given.

____

2. Are any specific disposal directions given in the experiment? List any that are given.

____

3. A quantity has a measured value of 8.4126. Which of the five numbers in the measured value has an uncertainty?

____

4. How many significant figures are contained in each of the following measurements?

2.46 g ______ 10.00 mL ______ 0.0109 cm ______

5. What uncertainty ($\pm$ an amount) is represented by the following measurements?

1.0569 g ______ 7.56 mL ______ 1.815 cm ______

6. You are measuring a quantity with a measuring device on which the smallest scale division is 0.1 unit. A measurement appears to have a value of exactly 3.2 units. How should you record the measurement in order to properly indicate where the uncertainty is located? ______________

7. Round the following numbers so they contain the number of significant figures indicated in parentheses.

1.513 (3) ______ 0.0155 (2) ______ 1.494 (1) ______
0.9866 (2) ______ 12.689 (2) ______ 0.04020 (3) ______

8. Carry out the following calculations and write each result using the correct number of significant figures. Assume all numbers represent measured quantities.

$0.521 \times 2.1 =$ ______ $\dfrac{4.400}{3.92} =$ ______

$0.713 + 6.12 + 11.2 =$ ______ $5.472 - 4.001 + 0.0119 =$ ______

name section date

1 EXPERIMENT 1

Data and Report Sheet

MEASUREMENTS AND SIGNIFICANT FIGURES

A. Measurement with Ruler A

Table 1.1 *(data)*

	Rectangle W	*Rectangle X*	*Rectangle Y*	*Rectangle Z*
Measured length (cm)				
Measured width (cm)				

Table 1.2 *(report)*

Rectangle	*Measured Length (cm)*	*Number of Sig. Figures in Length*	*Measured Width (cm)*	*Number of Sig. Figures in Width*
W				
X				
Y				
Z				

Table 1.3 *(report)*

Rectangle	*Correct Number of Sig. Figures in Calculated Area*	*Calculated Area Unrounded (cm^2)*	*Calculated Area Rounded (cm^2)*
W			
X			
Y			
Z			

Table 1.4 *(report)*

Rectangle	*Correct Number of Decimal Places for Calculated Perimeter*	*Calculated Perimeter Unrounded (cm)*	*Calculated Perimeter Rounded (cm)*
W			
X			
Y			
Z			

B. Measurement with Ruler B

Table 1.5 *(data)*

	Rectangle W	*Rectangle X*	*Rectangle Y*	*Rectangle Z*
Measured length (cm)				
Measured width (cm)				

Table 1.6 *(report)*

Rectangle	*Measured Length (cm)*	*Number of Sig. Figures in Length*	*Measured Width (cm)*	*Number of Sig. Figures in Width*
W				
X				
Y				
Z				

Table 1.7 *(report)*

Rectangle	*Correct Number of Sig. Figures in Calculated Area*	*Calculated Area Unrounded (cm^2)*	*Calculated Area Rounded (cm^2)*
W			
X			
Y			
Z			

Table 1.8 *(report)*

Rectangle	*Correct Number of Decimal Places for Calculated Perimeter*	*Calculated Perimeter Unrounded (cm)*	*Calculated Perimeter Rounded (cm)*
W			
X			
Y			
Z			

C. Improving the Significance of Measurements

Table 1.9 *(data)*

Measured coin diameter (cm)					
Number of coins in stack	1	3	5	7	10
Measured stack thickness (cm)					

Table 1.10 *(report)*

Number of Coins in Stack	*Measured Stack Thickness (cm)*	*Number of Sig. Figures in Measured Thickness*	*Correct Number of Sig. Figures in Calculated Avg. Thickness*	*Calculated Avg. Thickness Unrounded (cm)*	*Calculated Avg. Thickness Rounded (cm)*
1					
3					
5					
7					
10					

Table 1.11 *(report)*

Correct number of significant figures in a calculated coin volume	
Calculated coin volume—unrounded (cm^3)	
Calculated coin volume—rounded (cm^3)	

Questions

1. Suppose the area of rectangle Y was calculated using the length from Table 1.1 and the width from Table 1.5. How many significant figures would be correct in the calculated area?

a. 1 b. 2 c. 3 d. 4

Explain your answer: ______________________________

____

2. Suppose the perimeter of rectangle X was calculated using the length from Table 1.1 and the width from Table 1.5. How many significant figures would be found in the calculated perimeter after proper rounding?

a. 1 b. 2 c. 3 d. 4

Explain your answer: ______________________________

____

3. A buret is a tubular device used to deliver measured volumes of liquids. The smallest division on the scale of a buret is 0.1 mL. Suppose a buret reading was exactly on the 10-mL mark. How should this reading be recorded?

a. 10 mL b. 10.0 mL c. 10.00 mL d. 10.000 mL

Explain your answer: ______________________________

____

4. Refer to Table 1.10. How can the number of significant figures in a measurement be increased without changing the measuring device?

a. Estimate two decimals beyond the smallest scale division of the measuring device.

b. Increase the size of the quantity being measured.

c. Decrease the size of the quantity being measured.

Explain your answer: ______________________________

____

5. What is the shortest length that could be measured with ruler B that would contain four significant figures?

a. Exactly 1 cm b. Exactly 5 cm c. Exactly 10 cm d. Exactly 15 cm

Explain your answer: ______________________________

____

The Use of Chemical Balances

IN THIS EXPERIMENT, YOU WILL

- ❏ Learn to use centigram balances and electronic balances.
- ❏ Practice using the balances by measuring the mass of a coin, the mass of a group of several coins, and the mass of an unknown.
- ❏ Practice your graphing skills.
- ❏ Demonstrate the two techniques of weighing: direct weighing and weighing by difference.
- ❏ Practice the procedure used to weigh chemical samples.

INTRODUCTION

In experimental work, it is often necessary to measure mass. In some instances, only approximate values are needed, while in others the mass must be determined quite accurately. The maximum accuracy possible in a mass determination is limited by the sensitivity of the balance that is used.

EXPERIMENTAL PROCEDURE

A. The Centigram Balance

The centigram balance shown in Figure 2.1(a) has a sensitivity of 0.01 g. This means that the balance can be used to detect masses as small as 0.01 g, but no smaller. Thus, accurate weighings done on a centigram balance should be recorded to the nearest .01 g. Do not attempt to use the balance until your lab instructor has demonstrated the proper techniques to utilize.

Objects may be weighed two different ways. A **direct weighing** is done by placing the object directly on the balance and obtaining the mass from the balance readings. Certain balance errors are eliminated by using a second technique called **weighing by difference.** When an object is weighed by difference, a container such as a beaker, a plastic weighing dish, or a piece of paper is placed on the balance and weighed. The object is then placed in the container, and the two are weighed together. The mass of the object is obtained by subtracting the mass of the empty container from the combined mass of object and container. Example 2.1 illustrates the advantage of weighing by difference.

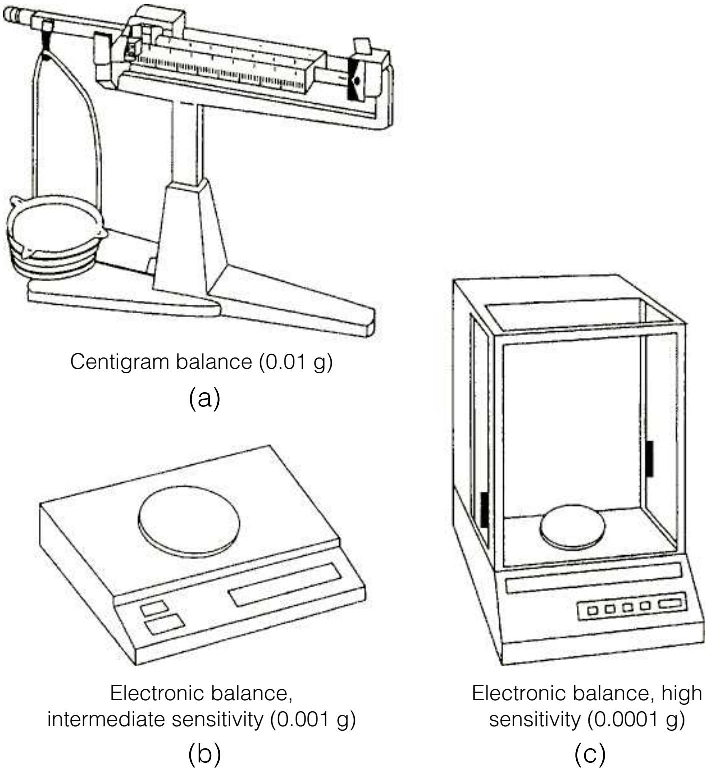


Figure 2.1
Chemical balances

Example 2.1

Unknown to you, the centigram balance you are using has been zeroed incorrectly, and every reading is 0.09 g too high. You weigh a coin by direct weighing and by difference. The resulting data are given below. Determine the coin mass in each case. Which mass is more accurate?

Direct Weighing	**Weighing by Difference**
Coin mass = 5.76 g	Mass of beaker + coin = 32.31 g
	Mass of empty beaker = 26.64 g
	Mass by difference = 5.67 g

Solution The coin mass by direct weighing is 5.76 g. The mass by difference is

$$32.31 \text{ g} - 26.64 \text{ g} = 5.67 \text{ g}.$$

We see that the mass by difference is 0.09 g less than that obtained by the direct method. The reason is that both masses measured using the difference technique are high by 0.09 g, but this error subtracts out and does not appear in the final result. The mass of 5.67 g is more accurate because it does not contain the 0.09 g error.

Procedure

1. Weigh a coin on a centigram balance, using the direct-weighing technique. Record the coin mass in Table 2.1 of the Data and Report Sheet.

2. Weigh the same coin directly on another centigram balance. Record the mass in Table 2.1.
3. Weigh the same coin by difference. First, determine the mass of an empty 50-mL beaker. Then place the coin in the beaker and determine the combined mass. Record the data in Table 2.2.
4. Use a different centigram balance and again determine the coin mass by difference. Record the data in Table 2.2. Keep the same coin available for use in Part B.
5. Obtain an unknown mass from the stockroom and record its identification number (ID) in Table 2.3.
6. Determine the mass of the unknown by direct weighing and by difference. Record the data in Table 2.3.

B. The Electronic Balance

Electronic balances such as those shown in Figure 2.1(b) and (c) have the greatest sensitivity of the balances you will use, and are the most delicate balances in the laboratory. They must be handled carefully, used correctly, and not abused. Your instructor will demonstrate the proper technique to use. The same balance should be used for any series of related weighings you might make.

Procedure

1. Determine the mass of the same coin used in Part A by direct weighing and by difference, using an electronic balance. Record the data in Table 2.6, using the correct number of figures based on the sensitivity of the balance you used.
2. Determine the mass of your unknown by direct weighing and by difference, using an electronic balance. Record the data in Table 2.6, using the correct number of figures according to the sensitivity of the balance you used.

C. The Average Mass of a Coin

The speed of electronic balances makes them very useful in studies that involve the measurement of numerous masses. In this part of the experiment you will measure the mass of various numbers of one-cent coins, determine the value of the average mass mathematically, then graph the collected data and determine the value of the average mass graphically.

Procedure

1. Obtain 5 one-cent coins from the stockroom.
2. Use an electronic balance and direct weighing to determine the mass of a single coin, then the mass of two coins together, then three coins together, etc., until you finally measure the mass of all five coins together. Record the data in Table 2.8, using the correct number of figures according to the sensitivity of the balance.

D. Weighing Solid Chemicals

In numerous future experiments, you will weigh out small samples of solid chemicals. In some cases, it will be necessary to know the sample masses quite accurately. In others, only approximate samples will be needed. Accurate masses will usually be determined with either electronic or centigram balances. Samples with approximate masses will be weighed on centigram balances. The procedures to follow are illustrated in Example 2.2. Approximate masses will not be recorded on the data sheet. Therefore, when a mass is to be recorded, you should recognize that it must be known accurately. In such cases, you must determine and record the mass as accurately as possible, consistent with the balance used. Be sure you read through the following example carefully before you attempt to do the weighings.

Example 2.2

Explain how you would use chemical balances to make weighings consistent with the following directions. (NOTE: This is only an example. Do *not* do the weighings, just read through the example so you understand the procedures.)

a. Use a centigram balance and accurately weigh out a sample of solid oxalic acid in the range of 0.20 to 0.25 g. Record the data on the Data and Report Sheet.

b. Weigh out three samples of table salt weighing approximately 0.1 g.

c. Use an electronic balance and weigh a sample of sugar in the range of 0.5 to 0.6 g. Record the data on the Data and Report Sheet.

Solution

a. The directions indicate that this is an accurate weighing. Therefore, place a piece of paper or an empty container on the balance and weigh to 0.01 g. Record this mass, then adjust the weights to add about 0.2 g to the balance reading. Carefully add solid oxalic acid to the container until the balance just trips. Then adjust the weights to get the accurate mass of the container plus sample. Record this mass. Subtract the accurate container mass from the accurate container-plus-sample mass to get an accurate sample mass. Notice that no attempt was made to get a sample of some predetermined exact mass. We simply want the mass to be in the range given (0.20 to 0.25 g) and we want to know accurately what it is.

b. The directions indicate that these sample masses are approximate and will not be recorded. Place a piece of paper or a container on the chemical balance and adjust the weights until approximate balance is indicated. Then adjust the weights to increase the balance reading by 0.1 g. Carefully add table salt to the paper or container until the balance just trips. None of the balance readings are recorded.

c. This is an accurate weighing and should be done by difference. The procedure is similar to that used with centigram balances. Obtain slightly more than 0.5 g of sugar in a small test tube (you might do this by using a centigram balance to weigh it approximately). Put a piece of paper or empty container on a previously zeroed electronic balance. Record the accurate container mass, then add sugar to the container until the reading indicates that between 0.5 and 0.6 g have been added. Record the accurate combined mass of container and sugar.

Procedure

1. Use a centigram balance to accurately weigh a sample of sodium chloride (table salt) in the range of 1.0 to 1.2 g. Record the appropriate data in Table 2.10 of the Data and Report Sheet.

2. Put about 1.5 cm of sodium chloride into a 10-cm test tube. Use the sample and an electronic balance to accurately weigh a sample of sodium chloride in the 1.0 to 1.2 g range (see Part C of Example 2.2 above). Record the data in Table 2.11.
3. Use a centigram balance and prepare a sample of sodium chloride with a mass of approximately 0.20 g. Show it to your instructor, who will then initial your Data and Report Sheet (Table 2.12).

Disposal

SODIUM CHLORIDE IN SINK.

CALCULATIONS AND REPORT

A. The Centigram Balance

1. Record in Table 2.4 all direct coin masses obtained in Table 2.1 of the Data and Report Sheet.
2. Use data from Table 2.2 and calculate the coin mass by difference measured on two balances. Record these masses in Table 2.4.
3. Fill in the remaining blanks of Table 2.4.
4. Record the unknown mass identification number in Table 2.5.
5. Use the data of Table 2.3 and calculate the mass of the unknown determined by direct weighing and by difference. Record the results in Table 2.5.
6. Fill in the remaining blank of Table 2.5.

B. The Electronic Balance

1. Use the data of Table 2.6 and calculate the coin and unknown masses as determined by direct weighing and by difference. Record these results and the unknown identification number in Table 2.7.
2. Fill in the remaining blanks of Table 2.7.

C. The Average Mass of a Coin

1. Use the data of Table 2.8 to calculate the average mass of a one-cent coin for each group of coins you weighed. This is done by dividing the total mass of the group by the number of coins in the group. Use the correct number of significant figures for each average mass calculated, and record the results in Table 2.9.
2. Refer once again to the data in Table 2.8. Plot the data of Table 2.8 on the graph paper provided on the Data and Report Sheet. If you need a review of the techniques used to draw graphs from data, refer to Appendix A of this manual. Plot the number of coins weighed in each group along the x (horizontal) axis of the graph paper, and the corresponding mass of each group rounded to the nearest 0.1 g along the y (vertical) axis of the graph paper. Note that on the graph, two small squares on the vertical axis correspond to 0.5 g. Remember, each value for the number of coins in a group and the corresponding mass of the group will form one point on your graph.
3. The resulting graph should be linear. Use a straight-edged ruler to draw the best straight line you can through the points. Determine the slope of the resulting straight line by dividing the rise (vertical value) by the run (horizontal value). See Figure A.5 of Appendix A for details

of this procedure. The slope of the line will have the units g/coin, which is the units of the mass of a single coin. Because all of the coin groups have been used in graphing the line, this value is a form of average value per coin. Round this value to the nearest 0.1 g and record the rounded average graphical value in the blank of Table 2.9.

D. Weighing Solid Chemicals

1. Use data from Table 2.10 and calculate the accurate mass of the sodium chloride sample weighed on the centigram balance. Record this result in Table 2.12, using the correct number of significant figures.
2. Use data from Table 2.11 and calculate the accurate mass of the sodium chloride sample weighed on the electronic balance. Record this result in Table 2.12, using the correct number of significant figures.

name ______ section ______ date ______

2 EXPERIMENT 2

Pre-Lab Review

THE USE OF CHEMICAL BALANCES

1. Are any specific safety alerts given in the experiment? List any that are given.

____

2. Are any specific disposal directions given in the experiment? List any that are given.

____

3. An object has a mass of 2.62114 g. The object is weighed accurately on the three types of balances described in this experiment. What mass value would be shown by each balance?

   Centigram balance ______________ Electronic balance (intermediate sensitivity) ______________

   Electronic balance (high sensitivity) ______________

4. A group of four one-cent coins is weighed on an electronic balance of intermediate sensitivity and has a mass of 10.147 g. What mass in grams should be reported for the average mass of a single coin of the group? ______________

5. The mass of the group of four coins described in Question 4 is to be used as one point in a graph constructed as described in the Calculation and Report directions of Part C. What are the x and y values that would be used to represent this point on the graph? $x =$ ________ $y =$ ________

6. Describe the procedures used in making direct weighings and indirect weighings (weighing by difference).

____

____

____

____

____

____

____

7. Which method, direct weighing or weighing by difference, is used when an accurate mass is to be obtained? Explain why.

8. How can you tell from the directions in the experiment whether a mass is to be determined accurately or approximately?

9. Describe the procedures used to weigh a chemical sample approximately and accurately using a centigram balance.

name | section | date

2 EXPERIMENT 2

Data and Report Sheet

THE USE OF CHEMICAL BALANCES

A. The Centigram Balance

Table 2.1 *(data)*

Coin mass (direct) 1st balance	
Coin mass (direct) 2nd balance	

Table 2.2 *(data)*

	1st Balance	*2nd Balance*
Mass of coin + beaker		
Mass of empty beaker		

Table 2.3 *(data)*

Unknown ID number	
Unknown mass (direct)	
Mass of unknown + beaker	
Mass of empty beaker	

Table 2.4 *(report)*

	1st Balance	*2nd Balance*
Coin mass (direct)		
Coin mass (by difference)		
Difference in mass (direct) between two balances		
Difference in mass (by difference) between two balances		

Table 2.5 *(report)*

Unknown ID number	
Unknown mass (direct)	
Unknown mass (by difference)	
Difference in unknown mass by two methods	

B. The Electronic Balance

Table 2.6 *(data)*

Coin mass (direct)	
Mass of coin + beaker	
Mass of empty beaker	
Unknown mass (direct)	
Mass of unknown + beaker	
Mass of empty beaker	

Table 2.7 *(report)*

Coin mass (direct)	
Coin mass (by difference)	
Difference in coin mass by two methods	
Unknown ID number	
Unknown mass (direct)	
Unknown mass (by difference)	
Difference in unknown mass by two methods	

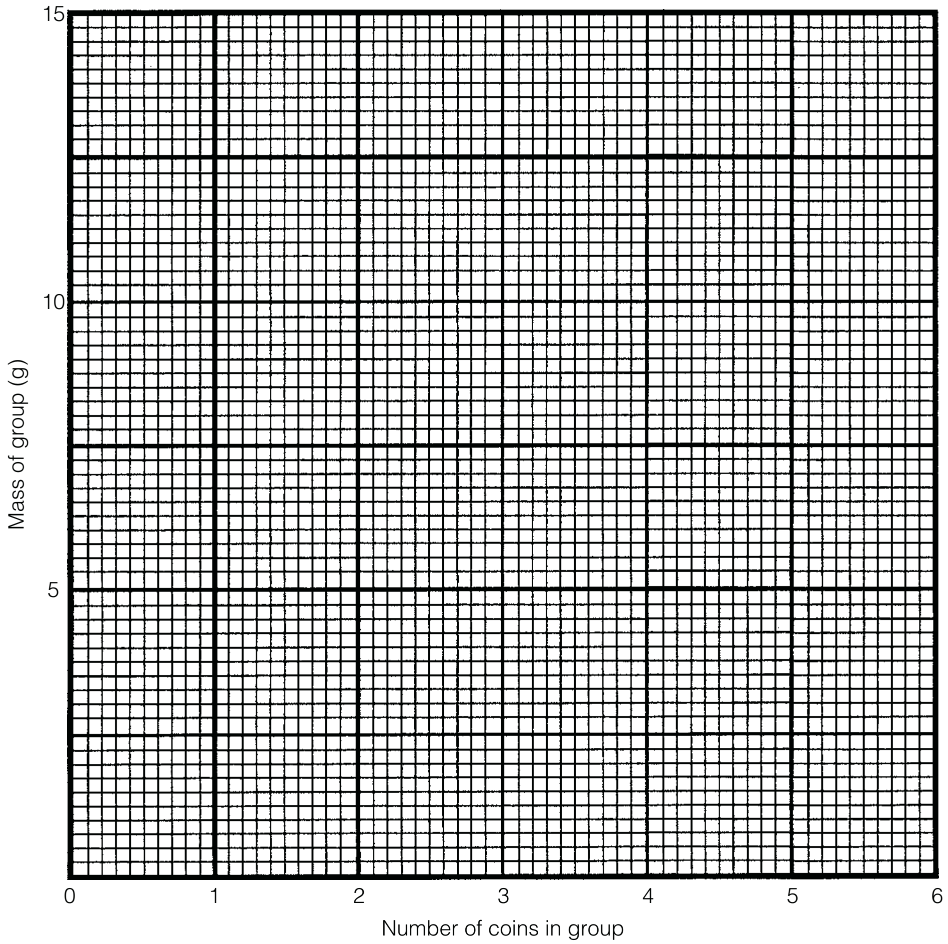
C. The Average Mass of a Coin

Table 2.8 *(data)*

Number of coins in group	1	2	3	4	5
Mass of group					

Table 2.9 *(report)*

Number of coins in group	1	2	3	4	5
Average coin mass					
Graphical average coin mass (slope of graph)					



D. Weighing Solid Chemicals

Table 2.10 *(data)*

Mass of sample + container	
Mass of empty container	

Table 2.11 *(data)*

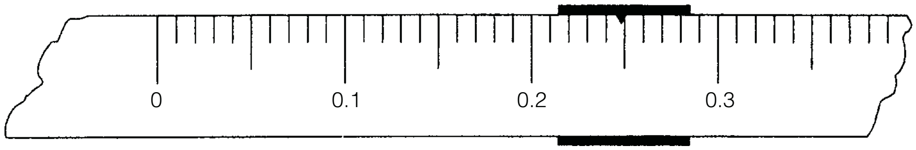
Mass of sample + container	
Mass of empty container	

Table 2.12 *(report)*

Accurate sample mass (centigram)	
Accurate sample mass (electronic)	
Instructor approval of 0.20 g approximate sample	

Questions

1. The following represents a portion of the smallest scale of a centigram balance. For an accurate reading, how should the scale value be recorded?



a. 0.2 g b. 0.25 g c. 0.248 g d. 0.24 g

Explain your answer: ______________________________

2. An object was weighed by direct weighing on two different centigram balances. The balance readings were 19.48 g and 19.56 g. Which mass would you assume to be the more correct?

a. 19.48 g b. 19.56 g c. Neither

Explain your answer: ______________________________

3. A student weighed an unknown mass directly on an electronic balance of intermediate sensitivity, and got a result of 28.774 g. The student then realized a mistake had been made, and weighed the same unknown by difference on the same balance with the following results:

Mass of beaker plus unknown = 59.121 g
Mass of empty beaker = 30.346 g.

When the sensitivity of the balance is taken into account (± 0.001 g), the two values obtained for the unknown mass are considered to be:

a. Different b. The same

Explain your answer: ______________________________

4. Two one-cent coins were weighed on an electronic balance of high sensitivity, and an average mass per coin of 2.4918 g was obtained from the data. How could you use an electronic balance of intermediate sensitivity to obtain an average mass per coin that contained the same number of significant figures as the value obtained using the high sensitivity balance?

a. Weigh a group containing more than two coins.

b. Weigh a two-coin group but estimate the balance reading to 0.0001 g.

c. Weigh the two-coin group on two different intermediate sensitivity balances, and average the results.

d. None of the three techniques described above will work.

Explain your answer: ______________________________

____

____

5. According to the masses recorded in Table 2.9, how do the average coin masses compare to the average coin mass determined from the slope of the graph?

a. Most average masses were larger than the slope average.

b. Most average masses were smaller than the slope average.

c. Most average masses were about the same as the slope average.

Explain your answer: ______________________________

____

____

6. Using the difference technique, you want to accurately weigh a sample of a solid with a mass of about 0.50 g. A container is placed on a centigram balance and weighs 0.71 g. What would you set the balance to read before adding the solid to the container?

a. 0.50 g   b. 1.21 g   c. 0.21 g   d. 0.71 g

Explain your answer: ______________________________

____

____

____

____

The Use of Volumetric Ware and the Determination of Density

IN THIS EXPERIMENT, YOU WILL

- ❑ Learn how to make volume measurements using a graduated cylinder, pipet, and buret.
- ❑ Practice using the equipment listed above.
- ❑ Use volumetric ware to determine the average volume of a drop of water.
- ❑ Practice your graphing skills.
- ❑ Use the results of volume and mass measurements to determine the density of a liquid and a solid.

INTRODUCTION

The measurement of liquid volumes is an important part of many experiments. In some experiments, volumes must be measured quite accurately, while in others less accuracy is required. The maximum accuracy possible is determined by the type of volumetric equipment used (Figure 3.1).

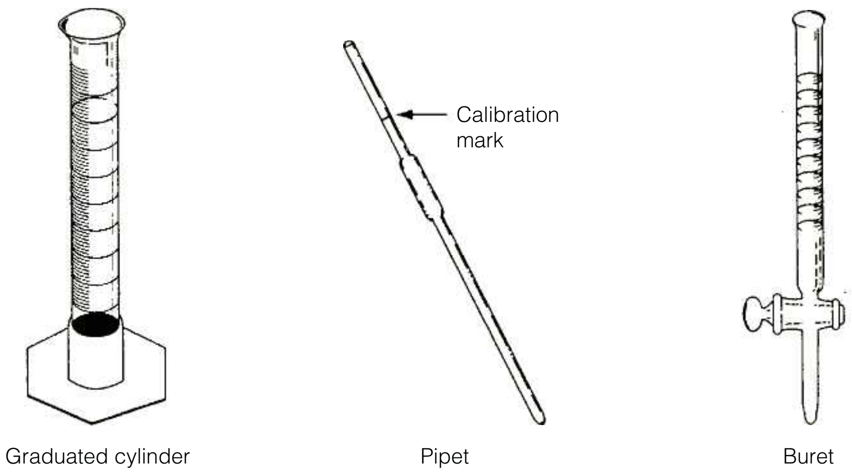


Figure 3.1
Commonly used volumetric glassware

EXPERIMENTAL PROCEDURE

A. The Graduated Cylinder

To properly use graduated cylinders and other volumetric ware, it is necessary to understand a little of the nature of the liquids involved. Water and most other liquids wet the surface of clean glass and, as a result, form a curved surface in glass containers. This curved surface, called a **meniscus,** becomes more apparent in narrow containers, as shown in Figure 3.2. Volumetric readings are made at the bottom of the meniscus, as represented in Figure 3.2(c).

Graduated cylinders are designed to measure any liquid volume up to the cylinder capacity. The volume contained in a graduated cylinder is estimated to one decimal place more than the smallest division on the cylinder. For example, a 50-mL cylinder has divisions corresponding to 1 mL. Volumes can be estimated to the nearest 0.1 mL by estimating between the marks, as shown in Figure 3.3.

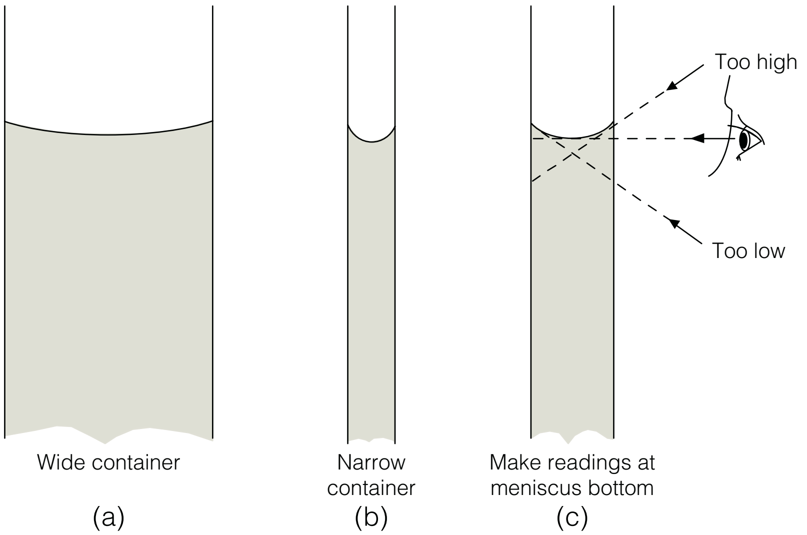


Figure 3.2
The appearance of a meniscus in volumetric glassware

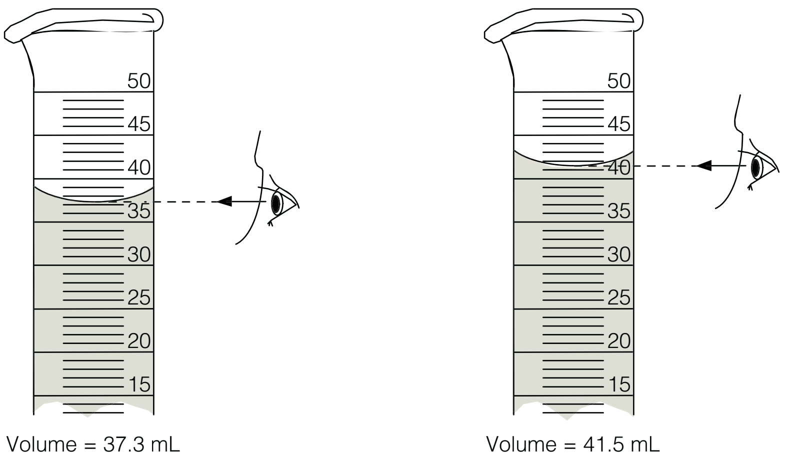


Figure 3.3
Volume measurements using a graduated cylinder

Procedure

1. Obtain a 25- or 50-mL graduated cylinder from your desk equipment or the stockroom.
2. Weigh a clean, dry 50-mL beaker on a centigram or electronic balance and record the mass in Table 3.1 of the Data and Report Sheet.
3. Use your wash bottle or a dropper to add distilled water carefully to the graduated cylinder until, in your judgment, it contains exactly 10.0 mL. Remember to read the volume at the bottom of the meniscus. Record this volume in Table 3.1.
4. Pour the water sample from the cylinder into the weighed beaker.
5. Weigh the beaker and contained water on the same balance used in Step 2, and record the mass in Table 3.1.
6. Without emptying the beaker, add a second carefully measured 10.0-mL sample of water from your graduated cylinder.
7. Weigh the beaker and contained water of both samples on the same balance used before and record the mass in Table 3.1.

B. The Pipet

Pipets are designed to deliver a specific volume of liquid and therefore have only a single calibration mark that is located on the narrow neck above the bulb (see Figure 3.1).

Safety Alert

PIPETS SHOULD NEVER BE FILLED BY APPLYING SUCTION WITH YOUR MOUTH. A SUCTION BULB SHOULD ALWAYS BE USED. THE PROPER PROCEDURE WILL BE DEMONSTRATED BY YOUR INSTRUCTOR.

Procedure

1. Obtain a 10-mL pipet from your desk equipment or the stockroom. Record the pipet volume in Table 3.3, using four significant figures (record to the second decimal), in the Data and Report Sheet.
2. Weigh a clean, dry 50-mL beaker on a centigram or electronic balance and record the mass in Table 3.3.
3. Place about 50 mL of distilled water into a clean 100-mL beaker.
4. Use a suction bulb and draw the distilled water from the 100-mL beaker into the pipet to a level above the calibration mark.
5. Quickly remove the bulb and place your forefinger tightly over the top end of the pipet to keep the water from flowing out.
6. Control the flow of water out of the pipet by adjusting the pressure exerted by your finger. Carefully allow the water meniscus to drop to the level of the calibration mark (but no lower).
7. Touch the pipet tip to the side of the container of distilled water to remove the attached drop.
8. Allow the pipet to drain into the weighed beaker. When the pipet stops draining, touch the tip to the side of the beaker to remove some of the water in the tip. Any water that remains in the pipet after this procedure is not to be blown out. The pipet is designed to deliver the stated volume even though a small amount remains in the tip.

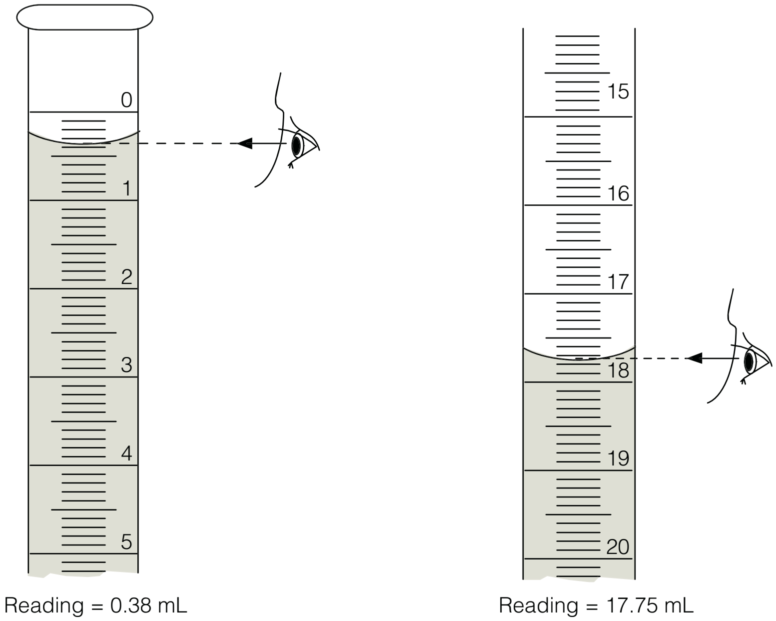


Figure 3.4
Examples of buret readings

9. Weigh the beaker and water on the same balance used in Step 2. Record the combined mass in Table 3.3.
10. Without emptying the beaker, repeat Steps 4 to 9. Record the mass of the beaker containing the two water samples in Table 3.3.

C. The Buret

Burets are designed to deliver any precisely measured volume of liquid up to a maximum of the buret capacity. Once again, estimation between scale divisions is necessary. Both 25- and 50-mL burets have scale divisions corresponding to 0.1 mL. Therefore, estimates between scale divisions will be written in terms of the next smaller decimal, 0.01 mL. Buret scales increase downward, so estimations between divisions must also increase downward. Refer to Figure 3.4 for examples of buret readings and ask your instructor for assistance as needed.

Procedure

1. Obtain a 25- or 50-mL buret from the stockroom.
2. Mount the buret on a ringstand by means of a buret clamp as shown in Figure 3.5.
3. Fill the buret nearly to the top with distilled water.
4. Carefully open and close the stopcock a few times to acquaint yourself with its operation and also to remove any air bubbles from the tip of the buret. If any difficulties are encountered, ask your instructor for assistance.
5. When you are ready to proceed, refill the buret and adjust the level of the meniscus to be somewhere between 0.00 and 1.00 mL.
6. Read the water level to the nearest 0.01 mL and record this initial reading in Table 3.5 in the blank corresponding to Sample 1.
7. Weigh a dry 50-mL beaker on a centigram or electronic balance and record the mass in Table 3.5.
8. Carefully add 10 to 12 mL of water from the buret into the beaker.

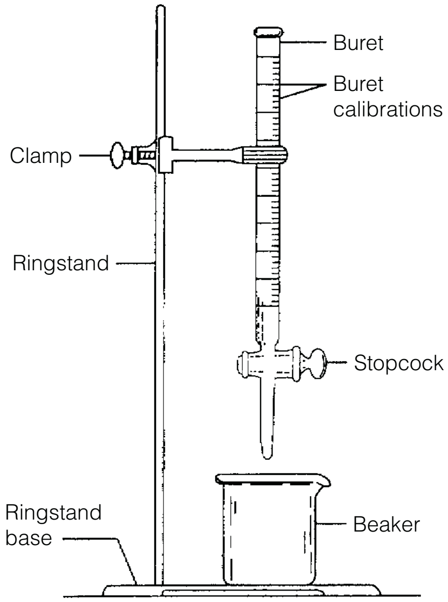


Figure 3.5
A buret mounted on a ringstand

9. Read the water level in the buret to the nearest 0.01 mL and record this final reading in Table 3.5 in the blank corresponding to Sample 1.
10. Weigh the beaker and contained water on the same balance used in Step 7 and record the mass in Table 3.5.
11. Do not refill the buret or empty the first water sample from the beaker.
12. Record the final buret reading from the first sample as the initial reading for the second sample in Table 3.5.
13. Add another 10 to 12 mL of water from the buret to the beaker.
14. Read the new water level in the buret to the nearest 0.01 mL and record it in Table 3.5 as the final reading for Sample 2.
15. Weigh the beaker and contained water on the same balance used before and record the mass in Table 3.5.

D. The Volume of a Drop

It is often convenient to measure the quantity of liquids in terms of a specific number of drops. However, the volume contained in a single drop depends on the device used to deliver the drop and the way the device is used.

Procedure

1. Put about 20 mL of distilled water into a 50-mL beaker.
2. Obtain a plastic dropper and a 10-mL graduated cylinder from your desk equipment or the stockroom. Make certain the graduated cylinder is dry.
3. Fill your plastic dropper with distilled water from the 50-mL beaker and, while holding the dropper vertical, add 25 counted drops of distilled water to the dry 10-mL graduated cylinder.
4. Read the volume of water contained in the graduated cylinder and record the volume and the number of drops in Table 3.7. (NOTE: If necessary, review Figure 3.3 and the discussion that explains how to read graduated cylinders. Also, look carefully at your 10-mL cylinder. Some have smallest divisions of 0.1 mL, and others have 0.2 mL divisions. In either case, the volume readings should be estimated to the nearest

0.1 mL. Just be aware that in the case of the 0.2 mL divisions, a reading half way between two divisions corresponds to 0.1 mL. Ask your instructor for assistance if necessary.

5. Without emptying the graduated cylinder, add an additional 25 drops of distilled water, being careful to hold the dropper in a vertical position above the graduated cylinder.
6. Read the total volume of water now contained in the graduated cylinder. Record the total volume and the total number of drops added (50) in Table 3.7.
7. Empty and dry your 10-mL graduated cylinder, then repeat Steps 3–6 but with the dropper held in a horizontal position when the drops of water are added to the graduated cylinder. Record the collected data in Table 3.7.
8. If you have not yet done Part C of the experiment, review Figures 3.4 and 3.5 and the directions for using a buret. Obtain a 25- or 50-mL buret from your desk equipment or the stockroom and set it up as shown in Figure 3.5.
9. Fill your buret with distilled water, open the stopcock and remove any air bubbles from the tip, then adjust the level of the meniscus in the buret to a value between 0.00 and 1.00 mL.
10. Read the level of water in the buret and record the reading in the blank labeled ''Initial buret reading'' in Table 3.7.
11. Carefully open the stopcock of the buret until individual drops are formed and fall from the tip. Allow 25 counted drops to fall from the tip, then close the stopcock and read the level of the meniscus. Record the reading in Table 3.7, along with the number of drops delivered from the buret (25).
12. Carefully open the stopcock of the buret again and allow another 25 drops to fall. Close the stopcock, read the buret, and record in Table 3.7 the reading and total number of drops delivered (50).
13. Repeat Step 12 twice and record in Table 3.7 the volume readings and total number of drops delivered.

E. Density of an Unknown Liquid

To evaluate a density, both the volume (V) and mass (m) of a sample of substance must be determined experimentally. The density (d) is the ratio of these two experimental quantities:

$$d = \frac{m}{V} \qquad \text{(Eq. 3.1)}$$

Procedure

1. Obtain a 30-mL sample of unknown liquid from the stockroom and record the identification number in Table 3.10.
2. Clean and dry a 50-mL beaker.
3. Weigh the dry beaker on a centigram or electronic balance and record the mass in Table 3.10.
4. Use the suction bulb to draw 3 to 4 mL of the unknown liquid into your 10-mL pipet. Put your finger over the pipet top, then invert the pipet and allow the liquid to flow out the top into the sink. This procedure will rinse the entire pipet with the unknown liquid.

5. Use the suction bulb and the rinsed pipet to deliver a 10.00-mL sample of unknown liquid into the weighed beaker. Record the sample volume (pipet volume) in Table 3.10.
6. Weigh the beaker and contents on the same balance used in Step 3. Record the mass in Table 3.10.
7. Add another 10.00 mL of unknown liquid to the beaker without emptying it first.
8. Weigh the beaker and contents on the same balance used in Step 3 and record the mass in Table 3.10.
9. Rinse your pipet thoroughly with tap water and then distilled water before you store it with your equipment or return it to the stockroom.

Disposal

UNKNOWN LIQUID IN SINK.

F. Density of a Solid

Solids can be weighed quite easily, but volume determinations are somewhat more difficult. If the solid has a regular geometric shape such as a cube or sphere, the volume can be calculated from the dimensions. You will work with an irregular solid and determine the volume another way.

Procedure

1. Obtain a solid no. 1 rubber stopper from your desk or the stockroom.
2. Weigh a dry 50-mL beaker on a centigram or electronic balance and record the mass in Table 3.12.
3. Place the rubber stopper in the weighed beaker, weigh them together, and record the combined mass in Table 3.12.
4. Fill a 50- or 100-mL graduated cylinder approximately halfway with distilled water.
5. Read the water level in the cylinder (remember to estimate to 0.1 mL) and record the value in Table 3.12 in the blank labeled ''cylinder reading without stopper.''
6. Carefully put the stopper into the cylinder without splashing out any water. This is best done by tilting the cylinder and letting the stopper slide down the inside wall.
7. Tap the cylinder so the stopper sinks to the bottom. Swirl the water gently to remove any clinging air bubbles from the stopper.
8. Read the water level in the cylinder that now contains the stopper. Record the level in Table 3.12.

CALCULATIONS AND REPORT

A. The Graduated Cylinder

With rearrangement, Equation 3.1 can be written

$$V = \frac{m}{d} \qquad \text{(Eq. 3.2)}$$

Thus, the volume of a liquid sample is equal to the mass of the sample divided by the liquid density. We will use this relationship and the measured masses of water samples to calculate the volume of each sample. These calculated volumes will then be compared with the volumes obtained by reading the volumetric equipment. In each calculation, the density of water will be assumed to have a value of 1.0000 g/mL. Thus, the volume calculated in milliliters will be numerically equal to the mass measured in grams. Example 3.1 illustrates the type of calculations that are to be done.

Example 3.1

Use the following data to calculate the volume of water contained in a graduated cylinder on a reading basis and a mass basis. Calculate (1) the difference in volume between the mass and reading basis and (2) the percent difference.

Volume of water in cylinder	10.0 mL
Mass of beaker + 1st sample	36.66 g
Mass of empty beaker	26.48 g

Solution The volume of water contained on a reading basis is simply the cylinder reading of 10.0 mL. The volume on a mass basis is calculated using the water mass, the water density of 1.0000 g/mL, and Equation 3.2. The mass of water is obtained by subtracting the mass of the empty beaker from the mass of beaker plus sample:

$$36.66 \text{ g} - 26.48 \text{ g} = 10.18 \text{ g}.$$

The volume of this sample is obtained by using Equation 3.2 and the water density:

$$V = \frac{m}{d} = \frac{10.18 \text{ g}}{1.0000 \text{ g/mL}} = 10.18 \text{ mL}.$$

Thus, the water volume in milliliters is equal to the water mass in grams.

The difference in volume between the mass and reading bases is

$$10.18 \text{ mL} - 10.0 \text{ mL} = 0.18 \text{ mL} = 0.2 \text{ mL},$$

where the last value has been rounded to the correct number of significant figures.

The percent difference is calculated using a form of Equation 3.3, given below in Step 5.

$$\% \text{ Difference} = \frac{\text{volume difference}}{\text{volume on a reading basis}} \times 100 = \frac{0.2 \text{ mL}}{10.0 \text{ mL}} \times 100 = 2\%$$

---

1. Record in Table 3.2 the volume of water delivered according to the readings taken from the graduated cylinder. Note that this will be 10 mL in each case recorded using the proper number of significant figures.
2. Use Equation 3.2 and the water mass data in Table 3.1 to calculate the volume of water delivered (the volume on a mass basis). Note that the mass of the second water sample is obtained by subtracting the mass of the beaker containing the first sample from the mass of the beaker containing both samples. Record the calculated volumes in Table 3.2.

3. Determine the difference between the water volume on a mass basis and the volume on a reading basis for each sample. Record the difference in Table 3.2. If the reading basis volume is larger than the mass basis, this value of their difference will have a negative sign, which should be recorded.
4. Calculate and record the average difference in volume by averaging the two values obtained in Step 3. Remember to take into account any negative values recorded in Step 3.
5. Calculate the average percent difference between volumes on a mass and reading basis, using the following equation:

$$\text{Average \% difference} = \frac{\text{avg. volume difference}}{\text{volume on a reading basis}} \times 100 \qquad \text{(Eq. 3.3)}$$

   Note that if you obtained a negative value for your average in Step 4, the average percent difference will also be negative. This simply reflects the fact that your volumes on a reading basis were larger than those on a mass basis.
6. Record the average percent difference in Table 3.2.

B. The Pipet

Use the data in Table 3.3 and complete Table 3.4 as you did Table 3.2. Assume the pipet delivers exactly 10.00 mL when it is correctly filled.

C. The Buret

Use the data in Table 3.5 and complete Table 3.6, using the following equation for each sample:

$$\text{\% Difference} = \frac{\text{volume difference}}{\text{volume on a reading basis}} \times 100 \qquad \text{(Eq. 3.4)}$$

Note that the volume of water delivered according to buret readings (volume on a reading basis) is equal to the final reading minus the initial reading for each sample. The average percent difference is obtained by averaging the two calculated percent differences.

D. The Volume of a Drop

Use the data recorded for the dropper and graduated cylinder experiments in Table 3.7 to calculate four values for the volume of a single drop of water. Do the calculation by dividing each recorded volume (graduated cylinder reading) by the corresponding total number of drops. Record in Table 3.8 the calculated single-drop volumes together with the total number of drops used.

The data recorded in Table 3.7 for the drop-size experiment done with a buret will be used in two different ways to calculate the volume of a single water drop. Record in Table 3.9 the total number of drops delivered up to each point in the experiment, as recorded in Table 3.7, and the corresponding total volume of water delivered to each point. The total volume of water at each point is equal to the buret reading at that point minus the initial buret reading that is also recorded in Table 3.7. Calculate and record in Table 3.9 the volume of a single drop from the data at each point by dividing the total volume at each point by the corresponding total number of drops.

The data recorded in Table 3.9 will now be graphed, and the volume of a single drop will be determined from the graph. If you need a review of the techniques used to draw graphs from data, refer to Appendix A of this manual. Plot the total number of drops delivered at each point in the experiment along the x (horizontal) axis of the graph paper provided on the Data and Report Sheet. Plot the corresponding total volume of water delivered at each point on the y (vertical) axis. Remember, each value for the total number of drops and the corresponding total volume delivered will form one point on your graph. The resulting graph should be linear. Draw a straight line through the points and determine the slope of the resulting straight line by dividing the rise (vertical value) by the run (horizontal value). See Figure A.5 of Appendix A for an example of slope determination. Do your slope calculations in the space to the right of the graph. The slope will be a value for the volume of a single drop. Record this graphical value of the volume of a single drop in Table 3.9.

E. Density of an Unknown Liquid

1. Record the unknown identification number in Table 3.11.
2. Record the volume of liquid (the pipet volume) used in each sample.
3. Use the data of Table 3.10 and determine the mass of each sample. Record the results in Table 3.11.
4. Use Equation 3.1 and the volume and mass obtained in Steps 2 and 3 and calculate the density of each sample. Record these results and the average of the two values in Table 3.11.

F. Density of a Solid

1. Use data from Table 3.12 and calculate the mass of the rubber stopper. Record the result in Table 3.13.
2. Use the two graduated cylinder readings of Table 3.12 to calculate the volume of water displaced by the stopper. Record this stopper volume.
3. Calculate and record the stopper density, using the mass and volume determined in Steps 1 and 2 and Equation 3.1.

G. Summary

Summarize the results of your volumetric measurements by completing Table 3.14. Record only the average percent difference for the buret measurements.

name section date

3 EXPERIMENT 3

Pre-Lab Review

THE USE OF VOLUMETRIC WARE AND THE DETERMINATION OF DENSITY

1. Are any specific safety alerts given in the experiment? List any that are given.

2. Are any specific disposal directions given in the experiment? List any that are given.

3. What is a meniscus?

4. Where is a liquid volume reading taken in relation to a meniscus?

5. Describe the steps followed when a pipet is used to measure a sample of liquid.

6. Describe the steps followed when a buret is used to measure a sample of liquid.

7. What type of weighing technique (direct weighing or weighing by difference) is used to determine the mass of water samples in this experiment? ___________________

8. Describe how to rinse the entire inside of a pipet with your density unknown in Part E.

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9. Suppose you sequentially add 10 drops of water to a graduated cylinder and read the volume, add 10 more drops, read, and so on. How many total drops will have been added after you do this four times? ___________________

10. A water sample has a volume of exactly 12.0000 mL. How would this volume be recorded if it were measured from (a) a 50-mL graduated cylinder? (b) a buret?

Graduated cylinder: _________________________ Buret: _________________________

11. Describe how the volume of an irregular solid can be determined.

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name ____________ section ____________ date ____________

3 EXPERIMENT 3

Data and Report Sheet

THE USE OF VOLUMETRIC WARE AND THE DETERMINATION OF DENSITY

A. The Graduated Cylinder

Table 3.1 *(data)*

Volume of water in cylinder	
Mass of beaker + both samples	
Mass of beaker + first sample	
Mass of empty beaker	

Table 3.2 *(report)*

	Sample 1	*Sample 2*
Water volume (reading basis)		
Water volume (mass basis)		
Volume difference		
Average volume difference		
Average % difference		

B. The Pipet

Table 3.3 *(data)*

Pipet volume	
Mass of beaker + both samples	
Mass of beaker + first sample	
Mass of empty beaker	

Table 3.4 *(report)*

	Sample 1	*Sample 2*
Water volume (reading basis)		
Water volume (mass basis)		
Volume difference		
Average volume difference		
Average % difference		

C. The Buret

Table 3.5 *(data)*

	Sample 1	*Sample 2*
Final buret reading		
Initial buret reading		
Mass of beaker + both samples		
Mass of beaker + first sample		
Mass of empty beaker		

Table 3.6 *(report)*

	Sample 1	*Sample 2*
Water volume (reading basis)		
Water volume (mass basis)		
Volume difference		
% Difference		
Average % difference		

D. The Volume of a Drop

Table 3.7 *(data)*

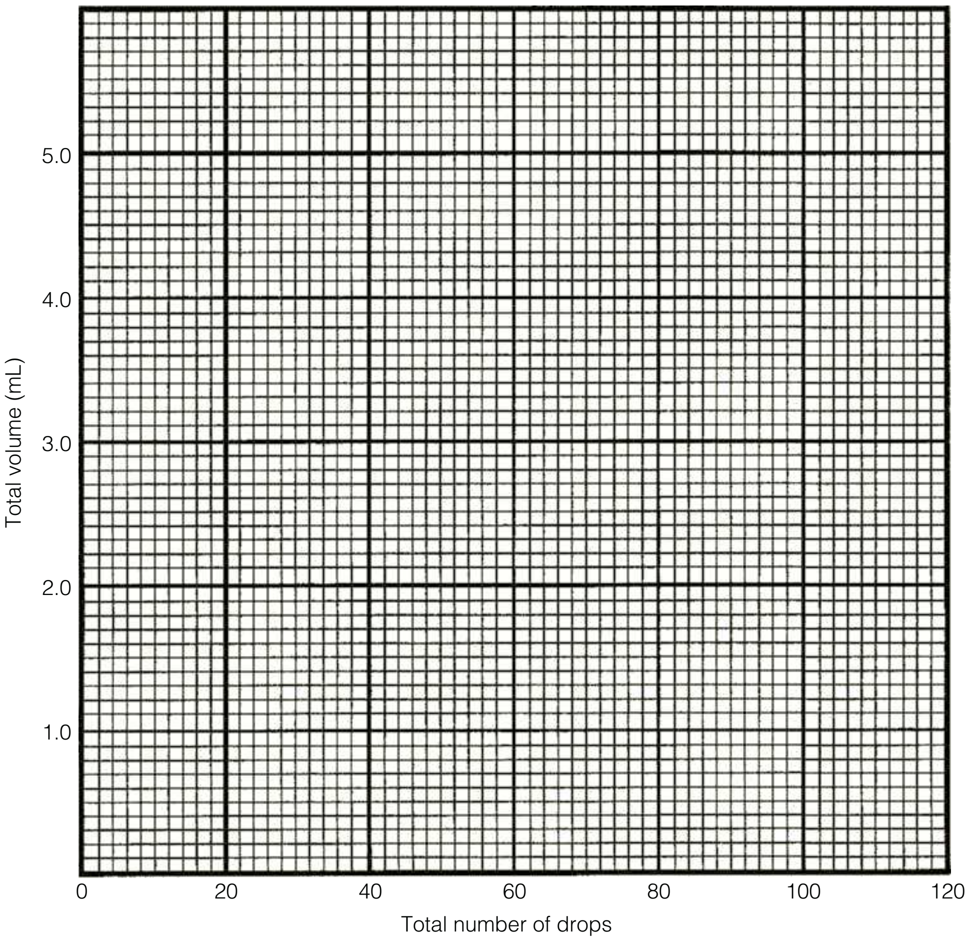
Dropper Held Vertically			*Dropper Held Horizontally*	
Total number of drops	Grad. cyl. reading		Total number of drops	Grad. cyl. reading
Buret				
Initial buret reading				
Total number of drops				
Buret reading				

Table 3.8 *(report)*

Dropper Held Vertically			*Dropper Held Horizontally*	
Total number of drops	Volume of a drop		Total number of drops	Volume of a drop

Table 3.9 *(report)*

Total number of drops				
Total volume of water				
Volume of a drop				
Graphically determined volume of a single drop				



Do calculations below

E. Density of an Unknown Liquid

Table 3.10 *(data)*

Unknown ID number	
Pipet volume	
Mass of beaker + both samples	
Mass of beaker + first sample	
Mass of empty beaker	

Table 3.11 *(report)*

Unknown ID number		
	Sample 1	*Sample 2*
Sample volume		
Sample mass		
Sample density		
Average sample density		

F. Density of a Solid

Table 3.12 *(data)*

Mass of beaker + stopper	
Mass of empty beaker	
Cylinder reading with stopper	
Cylinder reading without stopper	

Table 3.13 *(report)*

Stopper mass	
Stopper volume	
Stopper density	

G. Summary

Table 3.14 *(report)*

	Average Volume Difference	*Average Percent Difference*
Graduated cylinder		
Pipet		
Buret		