Laboratory Experiments for General, Organic, and Biochemistry

fourth edition

Bettelheim & Landesberg

Experiment 1

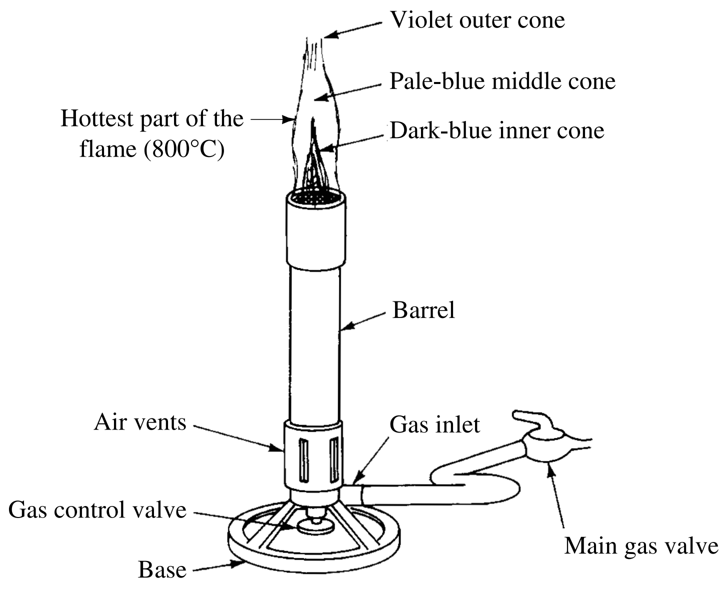
Laboratory techniques: use of the laboratory gas burner; basic glassworking

Background

The Laboratory Gas Burner

Tirrill or Bunsen burners provide a ready source of heat in the chemistry laboratory. In general, since chemical reactions proceed faster at elevated temperatures, the use of heat enables the experimenter to accomplish many experiments more quickly than would be possible at room temperature. The burner illustrated in Fig. 1.1 is typical of the burners used in most general chemistry laboratories.

Figure 1.1
The Bunsen burner.



A burner is designed to allow gas and air to mix in a controlled manner. The gas often used is "natural gas," mostly the highly flammable and odorless hydrocarbon methane, CH_4. When ignited, the flame's temperature can be adjusted by altering the various proportions of gas and air. The gas flow can be controlled either at the main gas valve or at the gas control valve at the base of the burner. Manipulation of the air vents at the bottom of the barrel allows air to enter and mix with the gas. The hottest flame has a violet outer cone, a pale-blue middle cone, and a dark-blue inner cone; the air vents, in this case, are opened sufficiently to assure complete combustion of the gas. Lack of air produces a cooler, luminous yellow flame. This flame lacks the inner cone and most likely is smoky, and often deposits soot on objects it contacts. Too much air blows out the flame.

Basic Glassworking

In the chemistry laboratory, it is often necessary to modify apparatus made from glass or to connect pieces of equipment with glass tubing. Following correct procedures for working with glass, especially glass tubing, is important.

Glass is a super-cooled liquid. Unlike crystalline solids which have sharp melting points, glass softens when heated, flows, and thus can be worked. Bending, molding, and blowing are standard operations in glassworking.

Not all glass is the same; there are different grades and compositions. Most laboratory glassware is made from borosilicate glass (containing silica and borax compounds). Commercially, this type of glass is known as *Pyrex* (made by Corning Glass) or *Kimax* (made by Kimble glass). This glass does not soften very much below 800°C and, therefore, requires a very hot flame in order to work it. A Bunsen burner flame provides a hot enough temperature for general glassworking. In addition, borosilicate glass has a low thermal coefficient of expansion. This refers to the material's change in volume per degree change in temperature. Borosilicate glass expands or contracts slowly when heated or cooled. Thus, glassware composed of this material can withstand rapid changes in temperature and can resist cracking.

Soft glass consists primarily of silica sand, SiO_2. Glass of this type softens in the region of 300–400°C, and because of this low softening temperature is not suitable for most laboratory work. It has another unfortunate property that makes it a poor material for laboratory glassware. Soft glass has a high thermal coefficient of expansion. This means that soft glass expands or contracts very rapidly when heated or cooled; sudden, rapid changes in temperature introduce too much stress into the material, and the glass cracks. While soft glass can be worked easily using a Bunsen burner, care must be taken to prevent breakage; with annealing, by first mildly reheating and then uniformly, gradually cooling, stresses and strains can be controlled.

Objectives

1. To learn how to use a Bunsen burner.
2. To learn basic glassworking by bending and fire-polishing glass tubing.

Procedure

The Laboratory Gas Burner; Use of the Bunsen Burner

1. Before connecting the Bunsen burner to the gas source, examine the burner and compare it to Fig. 1.1. Be sure to locate the gas control valve and the air vents and see how they work.

2. Connect the gas inlet of your burner to the main gas valve by means of a short piece of thin-walled rubber tubing. Be sure the tubing is long enough to provide some slack for movement on the bench top. Close the gas control valve. If your burner has a screw-needle valve, turn the knob clockwise. Close the air vents. This can be done by rotating the barrel of the burner (or sliding the ring over the air vents if your burner is built this way).

3. Turn the main gas valve to the open position. Slowly open the gas control valve counterclockwise until you hear the hiss of gas. Quickly strike a match or use a gas striker to light the burner. With a lighted match, hold the flame to the top of the barrel. The gas should light. How would you describe the color of the flame? Hold a Pyrex test tube in this flame. What do you observe?

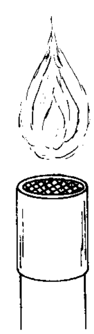
4. Carefully turn the gas control valve, first clockwise and then counterclockwise. What happens to the flame size? (If the flame should go out, or if the flame did not light initially, shut off the main gas valve and start over, as described above.)

5. With the flame on, adjust the air vents by rotating the barrel (or sliding the ring). What happens to the flame as the air vents open? Adjust the gas control valve and the air vents until you obtain a flame about 3 or 4 in. high, with an inner cone of blue (Fig. 1.1). The tip of the pale blue inner cone is the hottest part of the flame.

6. Too much air will blow out the flame. Should this occur, close the main gas valve immediately. Relight following the procedure in step 3.

7. Too much gas pressure will cause the flame to rise away from the burner and "roar" (Fig. 1.2). If this happens, reduce the gas flow by closing the gas control valve until a proper flame results.

Figure 1.2
The flame rises away from the burner.



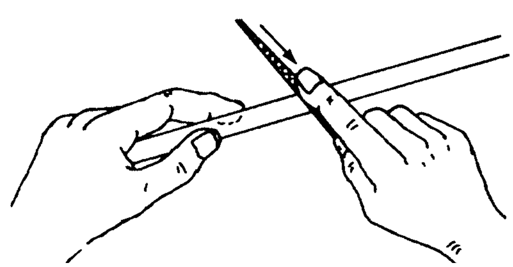
8. "Flashback" sometimes occurs. If so, the burner will have a flame at the bottom of the barrel. Quickly close the main gas valve. Allow the barrel to cool. Relight following the procedures in step no. 3.

Basic Glassworking; Working with Glass Tubing

Cutting glass tubing

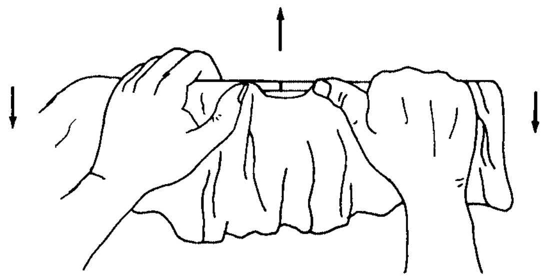
1. Obtain a length of glass tubing (5–6 mm in diameter). Place the tubing flat on the bench top, and with a grease pencil mark off a length of 30 cm. Grasp a triangular file with one hand, placing your index finger on a flat side of the file. With your other hand, hold the tubing firmly in place against the bench top. At the mark, press the edge of the file down firmly on the glass, and in one continuous motion scratch the glass (Fig. 1.3).

Figure 1.3
Cutting glass tubing with a triangular file.



2. Place a drop of water on the scratch (this seems to help the glass break). Wrap the tubing with cloth or paper towels and grasp with both hands, as shown in Fig. 1.4. Place your thumbs on the unscratched side of the tubing, one thumb on either side of the scratch. Position the scratch away from your body and face. Snap the tubing by simultaneously pushing with both thumbs and pulling with both hands toward your body. The tubing should break cleanly where the glass was scratched. Should the tubing not break, repeat the procedure described above.

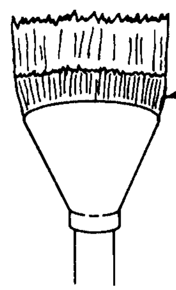
Figure 1.4
Breaking glass tubing.



Glass bends

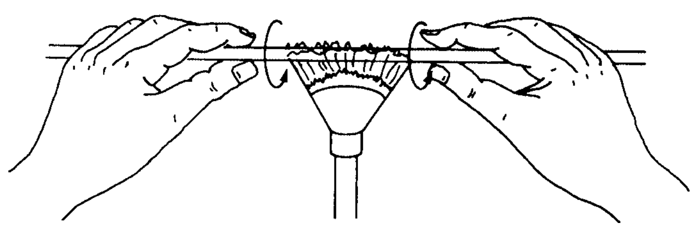
1. Turn off the Bunsen burner and place a wing top on the barrel. The wing top will spread out the flame so that a longer section of glass will be heated to softness. Relight the burner and adjust the flame until the blue inner cone appears along the width of the wing top (Fig. 1.5).

Figure 1.5
Wing top on the Bunsen burner.



2. Hold the midsection of the newly cut glass tubing in the flame. Keep the tubing in the hottest part of the flame, just above the spread-out blue cone (Fig. 1.6). Rotate the tubing continuously to obtain uniform heating. As the glass gets hot, the flame should become yellow; this color is due to sodium ions, which are present in the glass.

Figure 1.6
Holding the glass tubing in the flame.



When the glass gets soft and feels as if it is going to sag, remove the glass from the flame. Hold it steady without twisting or pulling (Fig. 1.7), and quickly, but gently, bend it to the desired angle (Fig. 1.8).

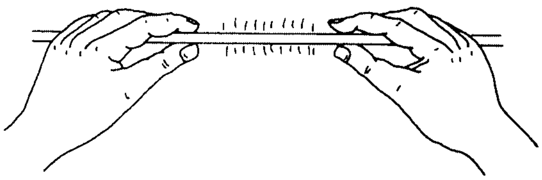


Figure 1.7 • Hold before bending.

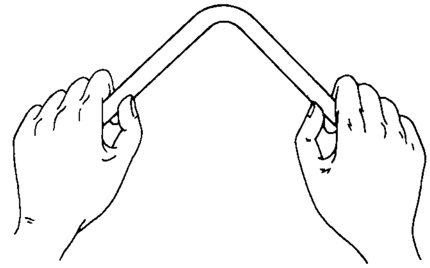
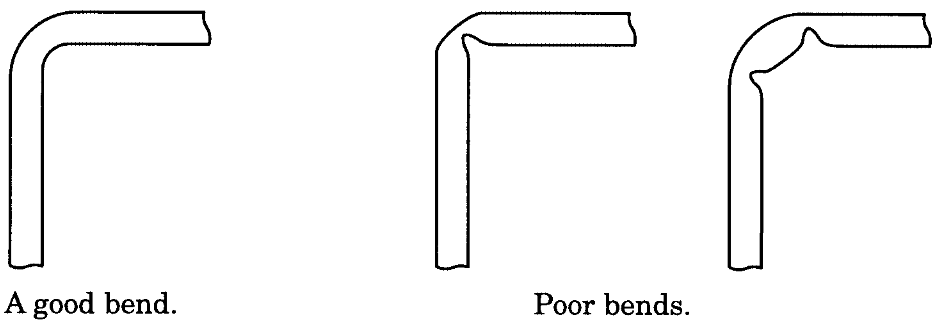


Figure 1.8 • Quickly bend.

A good bend has a smooth curve with no constrictions (Fig. 1.9).

Figure 1.9

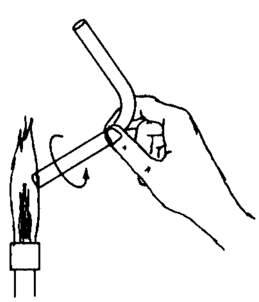


> **CAUTION!**
>
> Hot glass looks like cold glass. When finished with a piece of hot glass, place it out of the way on your bench top, on a piece of wire gauze. Glass cools slowly, so do not attempt to pick up any piece until you test it. Hold your hand above the glass without touching; you will be able to sense any heat. If your fingers get burnt by touching hot glass, immediately cool them with cold water and notify your instructor.

Fire polishing

1. To remove sharp edges from cut glass, a hot flame is needed to melt and thereby smooth out the glass.
2. If the wing top is on the burner, turn off the gas and carefully remove the wing top from the barrel with a pair of crucible tongs. The wing top may be hot.
3. Relight the gas and adjust to the hottest flame. Hold one end of the cooled tubing in the hottest part of the flame (just above the blue inner cone). Slowly rotate the tube (Fig. 1.10).

Figure 1.10
Fire polishing.



The flame above the glass tubing should become yellow as the glass gets hot and melts. Be careful not to overmelt the glass, in order to prevent the end from closing. After a short time (approx. 1 min.), remove the glass from the flame and examine the end; fire polishing will round the edges. Reheat if necessary to complete the polishing. When the end is completely smooth, lay the hot glass on a piece of wire gauze to cool. Be sure the glass is completely cooled before you attempt to polish the other end.

4. Show your instructor your glass bend with the ends completely fire polished.

Making stirring rods

Cut some solid glass rods (supplied by the instructor) into 20-cm lengths. Fire polish the ends.

Drawing capillary tubes

1. Cut a piece of glass tubing about 20 cm in length.
2. Heat the middle of the glass tubing in the flame just above the inner blue cone. Don't use a wing top. Rotate the tube in the flame until it softens (Fig. 1.11 A).

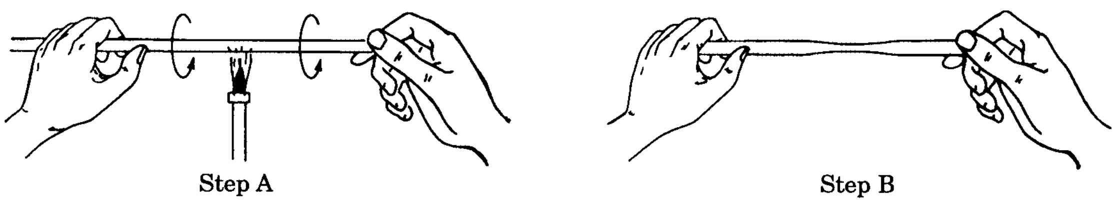


Figure 1.11 • Techniques for drawing capillary tubes.

3. As the glass sags, remove the tubing from the flame. Gently pull on each end, as straight as possible, until the capillary is as small as desired (Fig. 1.11 B).
4. Carefully place the tubing on the bench top and allow the glass to cool.
5. With a triangular file, carefully cut a piece of the drawn-out capillary tube (approx. 10 cm). Seal one end by placing it in the flame. Show your instructor your sealed capillary tube.

Chemicals and Equipment

1. Glass tubing (6-mm and 8-mm OD)
2. Glass rod (6-mm OD)
3. Bunsen burner
4. Wing top
5. Wire gauze
6. Crucible tongs

NAME SECTION DATE

PARTNER GRADE

Experiment 1

PRE-LAB QUESTIONS

1. Why are chemical reactions often heated in the laboratory?

2. How can the temperature of a Bunsen flame be adjusted?

3. Which flame is hotter: a blue flame or a yellow flame?

4. Describe the physical state and characteristics of glass.

5. What are the characteristics of soft glass? How do these characteristics affect the performance of glassware in the laboratory?

NAME ____________________ SECTION __________ DATE __________

PARTNER ____________________ GRADE ____________________

Experiment 1

REPORT SHEET

Bunsen burner

1. What is the color of the flame when the air vents are closed?

2. What happened to the Pyrex test tube in this flame?

3. What happens to the flame when the gas control valve is turned?

4. Describe the effect on the flame as the air vents were opened.

Glassworking

Let the instructor comment on your glass experiments.

1. 90° angle bend:

2. Fire polishing:

3. Glass stirring rod:

4. Capillary tube:

POST-LAB QUESTIONS

1. A student's Bunsen flame rises away from the burner. What should be done to get a proper flame?

2. Now the student's Bunsen flame is yellow and smoky. What adjustment to the Bunsen burner should the student make to get a blue, hot flame?

3. If the flame of the burner "flashes back" and shows a flame at the bottom of the barrel, what should be done?

4. Why must glass tubing be wrapped with a cloth or paper towel before breaking?

5. Which is better for laboratory glassware: soft glass or Pyrex glass? Explain your choice.

Experiment 2

Laboratory measurements

Background

Units of Measurement

The metric system of weights and measures is used by scientists of all fields, including chemists. This system uses the base 10 for measurements; for conversions, measurements may be multiplied or divided by 10. Table 2.1 lists the most frequently used factors in the laboratory which are based on powers of 10.

Table 2.1 Frequently Used Factors

Prefix	Power of 10	Decimal Equivalent	Abbreviation
Micro	10^{-6}	0.000001	μ
Milli	10^{-3}	0.001	m
Centi	10^{-2}	0.01	c
Kilo	10^{3}	1000	k

The measures of length, volume, mass, energy, and temperature are used to evaluate our physical and chemical environment. Table 2.2 compares the metric system with the more recently accepted SI system (International System of Units). The laboratory equipment associated with obtaining these measures is also listed.

Table 2.2 Units and Equipment

Measure	SI Unit	Metric Unit	Equipment
Length	Meter (m)	Meter (m)	Meterstick
Volume	Cubic meter (m^3)	Liter (L)	Pipet, graduated cylinder, Erlenmeyer flask, beaker
Mass	Kilogram (kg)	Gram (g)	Balance
Energy	Joule (J)	Calorie (cal)	Calorimeter
Temperature	Kelvin (K)	Degree Celsius (°C)	Thermometer

Accuracy, precision, and significant figures

Chemistry is a science that depends on experience and observation for data. It is an empirical science. An experiment that yields data requires the appropriate measuring devices in order to get accurate measurements. Once the data is in hand, calculations are done with the numbers obtained. How good the calculations are depends on a number of factors: (1) how careful you are in taking the measurements (laboratory techniques), (2) how good your measuring device is in getting a true measure (accuracy), and (3) how reproducible the measurement is (precision).

The measuring device usually contains a scale. The scale, with its subdivisions or graduations, tells the limits of the device's accuracy. You cannot expect to obtain a measurement better than your instrument is capable of reading. Consider the portion of the ruler shown in Fig. 2.1.

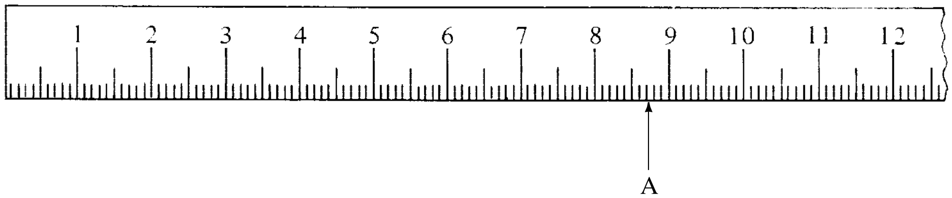


Figure 2.1 • Reading a metric ruler.

There are major divisions labeled at intervals of 1 cm and subdivisions of 0.1 cm or 1 mm. The accuracy of the ruler is to 0.1 cm (or 1 mm); that is the measurement that is known for certain. However, it is possible to estimate to 0.01 cm (or 0.1 mm) by reading in between the subdivisions; this number is less accurate and of course, is less certain. In general, you should be able to record the measured value to one more place than the scale is marked. For example, in Fig. 2.1 there is a reading marked on the ruler. This value is 8.75 cm: two numbers are known with certainty, *8.7*, and one number, 0.0*5*, is uncertain since it is the *best estimate* of the fractional part of the subdivision. The number recorded, 8.75, contains 3 significant figures, 2 certain plus 1 uncertain. When dealing with *significant figures*, remember: (1) the uncertainty is in the last recorded digit, and (2) the number of significant figures contains the number of digits definitely known, plus one more that is estimated.

The manipulation of significant figures in multiplication, division, addition, and subtraction is important. It is particularly important when using electronic calculators which give many more digits than are useful or significant. If you keep in mind the principle that the final answer can be no more accurate than the least accurate measurement, you should not go wrong. A few examples will demonstrate this.

EXAMPLE 1

Divide 9.3 by 4.05. If this calculation is done by a calculator, the answer found is 2.296296296. However, a division should have as an answer the same number of significant figures as the least accurately known (fewest significant figures) of the numbers being divided. One of the numbers, 9.3, contains only 2 significant figures. Therefore, the answer can only have 2 significant figures, i.e., 2.3 (rounded off).

EXAMPLE 2

Multiply 0.31 by 2.563. Using a calculator, the answer is 0.79453. As in division, a multiplication can have as an answer the same number of significant figures as the least accurately known (fewest significant figures) of the numbers being multiplied. The number 0.31 has 2 significant figures (the zero fixes the decimal point), therefore, the answer can only have 2 significant figures, i.e., 0.79 (rounded off).

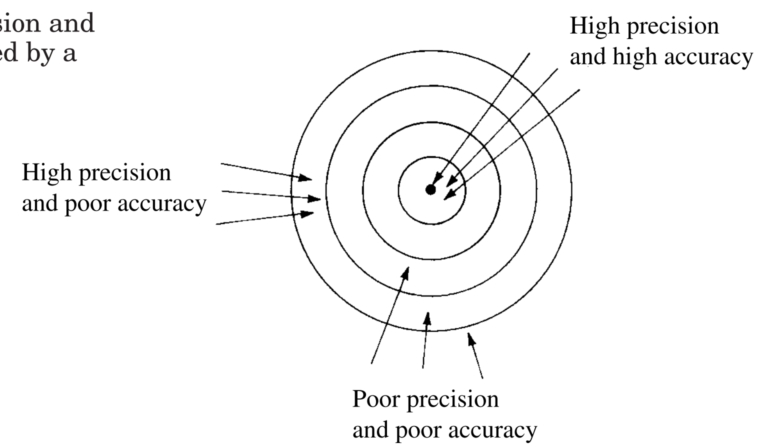
EXAMPLE 3

Add 3.56 + 4.321 + 5.9436. A calculator gives 13.8246. With addition (or subtraction), the answer is significant to the least number of decimal places of the numbers added (or subtracted). The least accurate number is 3.56, measured only to the hundredth's place. The answer should be to this accuracy, i.e., 13.82 (rounded off to the hundredth's place).

Finally, how do precision and accuracy compare? *Precision* is a determination of the reproducibility of a measurement. It tells you how closely several measurements agree with one another. Several measurements of the same quantity showing high precision will cluster together with little or no variation in value; however, if the measurements show a wide variation, the precision is low. *Random errors* are errors which lead to differences in successive values of a measurement and affect precision; some values will be off in one direction or another. One can estimate the precision for a set of values for a given quantity as follows: estimate = $\pm\Delta/2$, where Δ is the difference between the highest and lowest values.

Accuracy is a measure of how closely the value determined agrees with a known or accepted value. Accuracy is subject to *systematic errors*. These errors cause measurements to vary from the known value and will be off in the same direction, either too high or too low. A consistent error in a measuring device will affect the accuracy, but always in the same direction. It is important to use properly calibrated measuring devices. If a measuring device is not properly calibrated, it may give high precision, but with none of the measurements being accurate. However, a properly calibrated measuring device will be both precise and accurate. (See Fig. 2.2.) A systematic error is expressed as the difference between the known value and the average of the values obtained by measurement in a number of trials.

Figure 2.2 • Precision and accuracy illustrated by a target.



Objectives

1. To learn how to use simple, common equipment found in the laboratory.
2. To learn to take measurements.
3. To be able to record these measurements with precision and accuracy using the proper number of significant figures.

Procedure

Length: use of the meterstick (or metric ruler)

1. The meterstick is used to measure length. Examine the meterstick in your kit. You will notice that one side has its divisions in inches (in.) with subdivisions in sixteenths of an inch; the other side is in centimeters (cm) with subdivisions in millimeters (mm). Some useful conversion factors are listed below.

1 km = 1000 m	1 in. = 2.54 cm
1 m = 100 cm	1 ft. = 30.48 cm
1 cm = 10 mm	1 yd. = 91.44 cm
1 m = 1000 mm	1 mi. = 1.6 km

The meterstick can normally measure to 0.001 m, 0.1 cm, or 1 mm.

2. With your meterstick (or metric ruler), measure the length and width of this laboratory manual. Take the measurements in inches (to the nearest sixteenth of an inch) and in centimeters (to the nearest 0.1 cm). Record your response on the Report Sheet (1).

3. Convert the readings in cm to mm and m (2).

4. Calculate the area of the manual in in^2, cm^2, and mm^2 (3). Be sure to express your answers to the proper number of significant figures.

EXAMPLE 4

A student measured a piece of paper and found it to be 20.3 cm by 29.2 cm. The area was found to be

$$20.3\ \text{cm} \times 29.2\ \text{cm} = 593\ \text{cm}^2$$

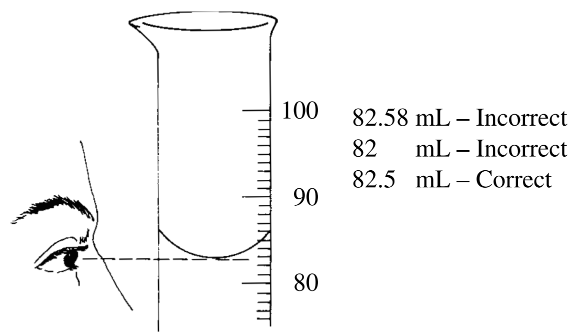
Volume: use of a graduated cylinder, an Erlenmeyer flask, and a beaker

1. Volume in the metric system is expressed in liters (L) and milliliters (mL). Another way of expressing milliliters is in cubic centimeters (cm^3 or cc). Several conversion factors for volume measurements are listed below.

1 L = 1000 mL	1 qt. = 0.96 L
1 mL = 1 cm^3 = 1 cc	1 gal. = 3.79 L
1 L = 0.26 gal.	1 fl. oz. = 29.6 mL

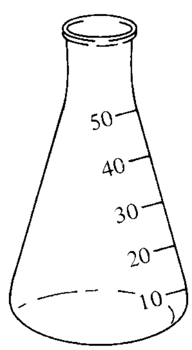
2. The graduated cylinder is a piece of glassware used for measuring the volume of a liquid. Graduated cylinders come in various sizes with different degrees of accuracy. A convenient size for this experiment is the 100-mL graduated cylinder. Note that this cylinder is marked in units of 1 mL; major divisions are of 10 mL and subdivisions are of 1 mL. Estimates can be made to the nearest 0.1 mL. When a liquid is in the graduated cylinder, you will see that the level in the cylinder is curved with the lowest point at the center. This is the *meniscus*, or the dividing line between liquid and air. When reading the meniscus for the volume, be sure to read the *lowest* point on the curve and not the upper edge. To avoid errors in reading the meniscus, the eye's line of sight must be perpendicular to the scale (Fig. 2.3). In steps 3 and 4, use the graduated cylinder to see how well the marks on an Erlenmeyer flask and a beaker measure the indicated volume.

Figure 2.3
Reading the meniscus on a graduated cylinder.



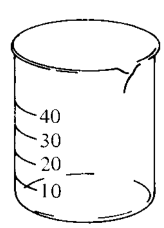
3. Take a 50-mL graduated Erlenmeyer flask (Fig. 2.4) and fill with water to the 50 mL mark. Transfer the water, completely and without spilling, to a 100-mL graduated cylinder. Record the volume on the Report Sheet (4) to the nearest 0.1 mL; convert to L.

Figure 2.4
A 50-mL graduated Erlenmeyer flask.



4. Take a 50-mL graduated beaker (Fig. 2.5), and fill with water to the 40-mL mark. Transfer the water, completely and without spilling, to a dry 100-mL graduated cylinder. Record the volume on the Report Sheet (5) to the nearest 0.1 mL; convert to L.

Figure 2.5
A 50-mL graduated beaker.



5. What is the error in mL and in percent for obtaining 50.0 mL for the Erlenmeyer flask and 40.0 mL for the beaker (6)?

6. Which piece of glassware will give you a more accurate measure of liquid: the graduated cylinder, the Erlenmeyer flask, or the beaker (7)?

Mass: use of the laboratory balance

1. Mass measurements of objects are carried out with the laboratory balance. Many types of balances are available for laboratory use. The proper choice of a balance depends upon what degree of accuracy is needed for a measurement. The standard units of mass are the kilogram (kg) in the SI system and the gram (g) in the metric system. Some conversion factors are listed below.

1 kg = 1000 g	1 lb. = 454 g
1 g = 1000 mg	1 oz. = 28.35 g

Three types of balances are illustrated in Figs. 2.6, 2.8, and 2.10. A platform triple beam balance is shown in Fig. 2.6. This balance can weigh objects up to 610 g. Since the scale is marked in 0.1-g divisions, it is mostly used for rough weighing; weights to 0.01 g can be estimated. Figure 2.7 illustrates how to take a reading on this balance.

Figure 2.6
A platform triple beam balance.

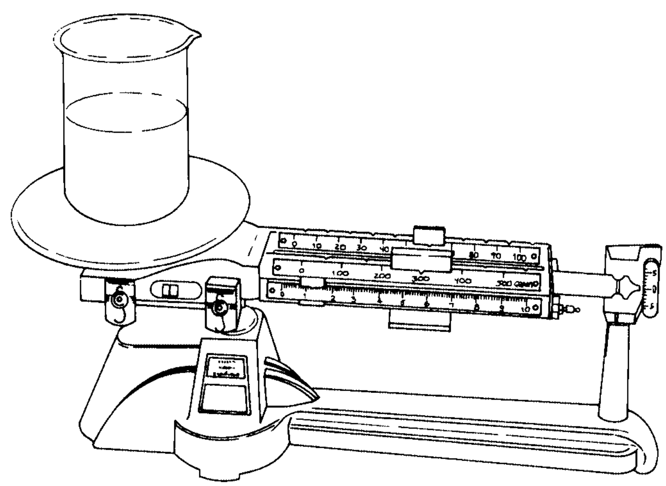
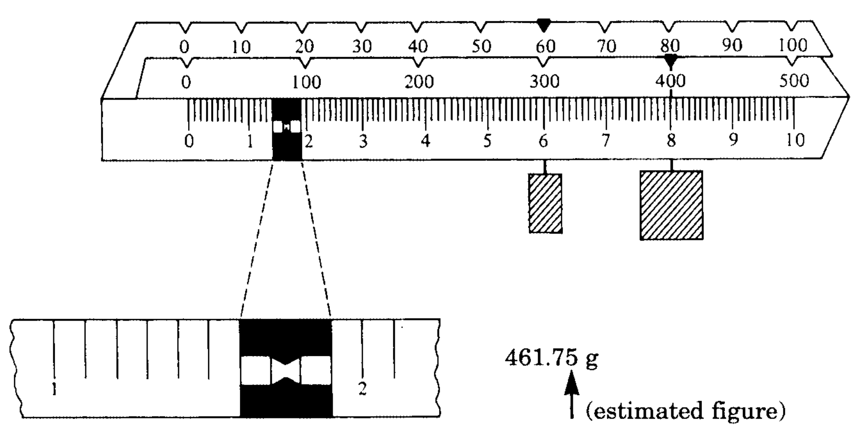
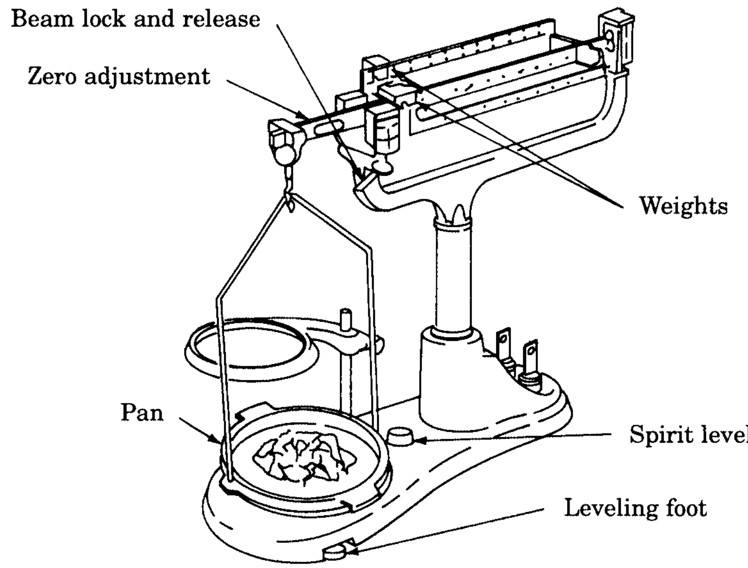


Figure 2.7
Reading on a platform triple beam balance.



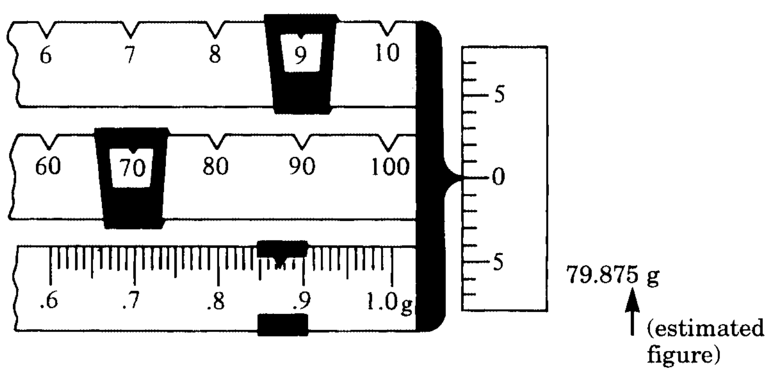
The single pan, triple beam (or Centogram) balance is shown in Fig. 2.8. This Centogram balance has a higher degree of accuracy since the divisions are marked in 0.01-g (estimates can be made to 0.001 g) increments.

Figure 2.8
A single pan, triple beam balance (Centogram).



Smaller quantities of material can be weighed on this balance (to a maximum of 311 g). Figure 2.9 illustrates how a reading on this balance would be taken.

Figure 2.9
Reading on a single pan, triple beam balance.



Top loading balances show the highest accuracy (Fig. 2.10). Objects can be weighed very rapidly with these balances because the total weight, to the nearest 0.001 g, can be read directly off either an optical scale (Fig. 2.11) or a digital readout. Balances of this type are very expensive and one should be used only after the instructor has demonstrated their use.

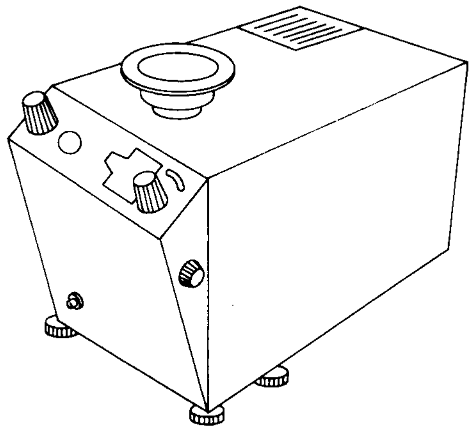


Figure 2.10
A top loading balance.

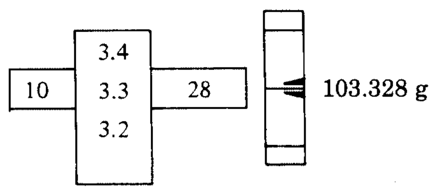


Figure 2.11
Reading on a top loading balance.

> **CAUTION!**
>
> When using any balance, never drop an object onto the pan; place it gently in the center of the pan. Never place chemicals directly on the pan; use either a glass container (watch glass, beaker, weighing bottle) or weighing paper. Never weigh a hot object; hot objects may mar the pan. Buoyancy effects will cause incorrect weights. Clean up any chemical spills in the balance area to prevent damage to the balance.

2. Weigh a quarter, a test tube (100 × 13 mm), and a 125-mL Erlenmeyer flask. Express each weight to the proper number of significant figures. Use a platform triple beam balance, a single pan, triple beam balance (Centogram), and a top loading balance for these measurements. Use the table on the Report Sheet to record each weight.

3. The single pan, triple beam balance (Centogram) (Fig. 2.8) is operated in the following way.

   a. Place the balance on a level surface; use the leveling foot to level.

   b. Move all the weights to the zero position at left.

   c. Release the beam lock.

d. The pointer should swing freely in an equal distance up and down from the zero or center mark on the scale. Use the zero adjustment to make any correction to the swing.

e. Place the object on the pan (remember the caution).

f. Move the weight on the middle beam until the pointer drops; make sure the weight falls into the "V" notch. Move the weight back one notch until the pointer swings up. This beam weighs up to 10 g, in 1-g increments.

g. Now move the weights on the back beam until the pointer drops; again be sure the weight falls into the "V" notch. Move the weight back one notch until the pointer swings up. This beam weighs up to 1 g, in 0.1-g increments.

h. Lastly, move the smallest weight (the cursor) on the front beam until the pointer balances, that is, swings up and down an equal distance from the zero or center mark on the scale. This last beam weighs to 0.1 g, in 0.01-g increments.

i. The weight of the object on the pan is equal to the weights shown on each of the three beams (Fig. 2.8). Weights to 0.001 g may be estimated.

j. Repeat the movement of the cursor to check your precision.

k. When finished, move the weights to the left, back to zero, and arrest the balance with the beam lock.

Temperature: use of the thermometer

1. Routine measurements of temperature are done with a thermometer. Thermometers found in chemistry laboratories may use either mercury or a colored fluid as the liquid, and degrees Celsius (°C) as the units of measurement. The fixed reference points on this scale are the freezing point of water, 0°C, and the boiling point of water, 100°C. Between these two reference points, the scale is divided into 100 units, with each unit equal to 1°C. Temperature can be estimated to 0.1°C. Other thermometers use either the Fahrenheit (°F) or the Kelvin (K) temperature scale and use the same reference points, that is, the freezing and boiling points of water. Conversion between the scales can be accomplished using the formulas below.

$$°F = \frac{9}{5}°C + 32.0 \qquad °C = \frac{5}{9}(°F - 32.0) \qquad K = °C + 273.15$$

EXAMPLE 5

Convert 37.0°C to °F and K.

$$°F = \frac{9}{5}(37.0°C) + 32.0 = 98.6°F$$
$$K = 37.0°C + 273.15 = 310.2\ K$$