APPENDIX C

# Systems and Techniques of Pharmaceutical Measurement

Knowledge and application of the systems of pharmaceutical measurement are essential to the practice of pharmacy. Whether applied to the compounding and dispensing of prescriptions in the community pharmacy, the filling of medication orders in the institutional pharmacy, or the large-scale industrial manufacture of pharmaceuticals, quantitative accuracy is essential in the preparation of safe and effective medications.

Pharmaceuticals prepared industrially undergo rigid in-process controls and final product assays to ensure conformance with the applicable standards for drug content. Prescriptions and medication orders filled extemporaneously in the community and institutional pharmacy often lack the advantage of control by assay, and thus the pharmacist must be absolutely certain of the accuracy of all calculations and measurements employed. Calculations should be double-checked by the pharmacist and, whenever possible, by a colleague. The importance of accurate calculations and measurements cannot be overstated. For example, an error in the placement of a decimal point represents a *minimum* error of a factor of 10, and if it is applicable to the active ingredient, a critical drug underdosage or overdosage results.

The pharmacy student must have a working knowledge of the systems of pharmaceutical measurement, their application in pharmaceutical calculations, the factors used for conversion between the systems, and the proper techniques of weighing and measuring.

## SYSTEMS OF PHARMACEUTICAL MEASUREMENT

Although pharmacy has moved toward the exclusive use of the metric system, two other systems of measurement, namely, the *apothecary system* and the *avoirdupois system*, occasionally may be encountered. The metric system includes units of weight, volume, and linear measure; the apothecary system includes units of weight and volume; and the avoirdupois system includes only units of weight. The metric system has replaced the apothecary system in virtually all pharmaceutical measurements and calculations, although some use remains, such as common reference to the dose of thyroid in *grains*, an apothecary system unit. The avoirdupois system is the *common* commercial system of weight used in the United States. It too is being replaced by the metric system, but at a much slower pace. The avoirdupois system is encountered by the pharmacist in the purchase of bulk chemicals and other items packaged and sold by the ounce or pound.

### The Metric System

The metric system is the most widely used system in pharmacy. It is the system used in the *United States Pharmacopeia* (USP) and *National Formulary (NF)*, by the federal Food and Drug Administration, in manufacturers' labeling of pharmaceutical products, and in most physicians' writing of prescriptions and medication orders.

In the metric system, the *gram* is the main unit of weight, the *liter* the main unit of volume, and the *meter* the main unit of length. Subunits and multiples of these basic units are indicated by the prefix notations and symbols shown in Table C.1.

In pharmacy, these are the most commonly used metric units:

*Weight* is expressed in terms of the kilogram (kg), gram (g), milligram (mg), or microgram (µg).
*Liquid measure* is expressed in terms of the liter (L) or milliliter (mL).

## Table C.1 METRIC SYSTEM UNIT PREFIXES

| MULTIPLICATION FACTOR | PREFIX | SYMBOL | TERM (USA) |
|---|---|---|---|
| 1 000 000 000 000 000 000 = $10^{18}$ | exa | E | one quintillion |
| 1 000 000 000 000 000 = $10^{15}$ | tera | T | one quadrillion |
| 1 000 000 000 000 = $10^{12}$ | giga | G | one trillion |
| 1 000 000 000 = $10^{9}$ | mega | M | one billion |
| 1 000 000 = $10^{6}$ | kilo | k | one million |
| 1 000 = $10^{3}$ | hecto | h | one thousand |
| 100 = $10^{2}$ | deka | da | one hundred |
| 10 = 10 | peta | P | ten |
| 0.1 = $10^{-1}$ | deci | d | one-tenth |
| 0.01 = $10^{-2}$ | centi | c | one-hundredth |
| 0.001 = $10^{-3}$ | milli | m | one-thousandth |
| 0.000 001 = $10^{-6}$ | micro | μ | one-millionth |
| 0.000 000 001 = $10^{-9}$ | nano | n | one-billionth |
| 0.000 000 000 001 = $10^{-12}$ | pico | p | one-trillionth |
| 0.000 000 000 000 001 = $10^{-15}$ | femto | f | one-quadrillionth |
| 0.000 000 000 000 000 001 = $10^{-18}$ | atto | a | one-quintillionth |

The table is based on the International System of Units (SI, from the French, Le Système International d'Unites), as modified for use in the United States by the Secretary of Commerce.

*Linear measure* is expressed in terms of the meter (m), centimeter (cm), or millimeter (mm).

*Area measure* is expressed in terms of the square meter ($m^2$) or square centimeter ($cm^2$).

The metric weight scale in Figure C.1 is intended to depict the relationship between the units of weight in the metric system and to demonstrate an easy method of converting from one unit to another (1). In the example, 1.23 kg is to be converted to grams. On the scale, the gram position is three decimal places from the kilogram position. Thus, the decimal point is moved three places toward the right. In the other example, the

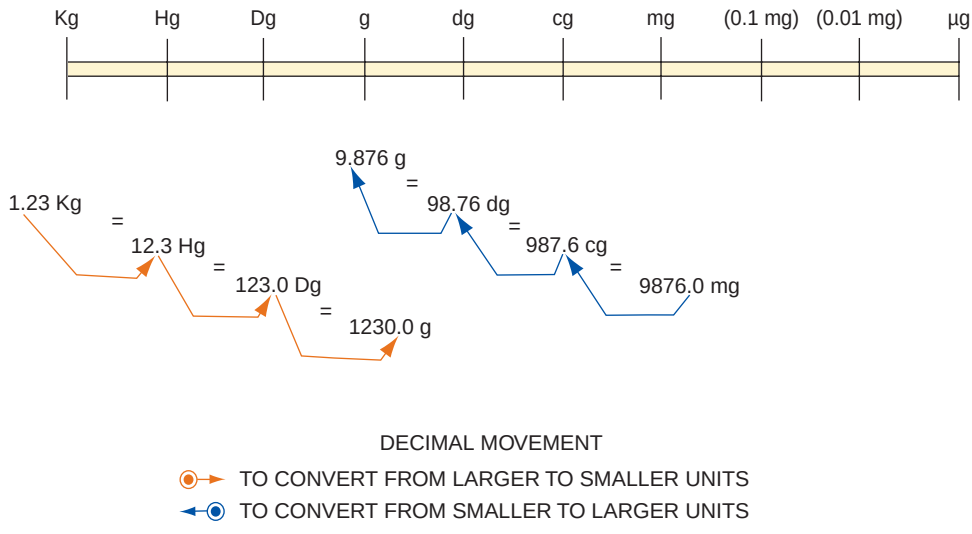


**FIGURE C.1** Metric weight scale.

conversion from milligrams to grams also requires movement of the decimal point three places, but this time to the left. The same method may be used to convert metric units of volume or length.

### Table of Metric Weight

1 kg = 1,000.000 g
1 hg = 100.000 g
1 Dg = 10.000 g
1 g = 1.000 g
1 dg = 0.100 g
1 cg = 0.010 g
1 mg = 0.001 g
1 µg = 0.000001 g
1 ng = 0.0000000001 g
1 pg = 0.000000000001 g

hg, hectogram; Dg, dekagram; dg, decigram; cg, centigram; ng, nanogram; pg, picogram.

or

1 g = 0.001 kg
= 0.010 hg
= 0.100 Dg
= 10 dg
= 100 cg
= 1,000 mg
= 1,000,000 µg
= 1,000,000,000 ng
= 1,000,000,000,000 pg

### Table of Metric Volume

1 kL = 1,000.000 L
1 hL = 100.000 L
1 DL = 10.000 L
1 L = 1.000 L
1 dL = 0.100 L
1 cL = 0.010 L
1 mL = 0.001 L
1 µL = 0.000001 L

kL, kiloliter; hL, hectoliter; DL, dekaliter; L, liter; dL, deciliter; cL, centiliter; mL, milliliter; µL, microliter.

or

1 L = 0.0001 kL
= 0.010 hL
= 0.100 DL
= 10 dL
= 100 cL
= 1,000 mL
= 1,000,000 µL

### Table of Metric Length

1 km = 1,000.000 m
1 hm = 100.000 m
1 Dm = 10.000 m
1 m = 1.000 m
1 dm = 0.100 m
1 cm = 0.010 m
1 mm = 0.001 m
1 µm = 0.000001 m
1 nm = 0.000000001 m

km, kilometer; hm, hectometer; Dm, dekameter; m, meter; dm, decimeter; cm, centimeter; mm, millimeter; µm, micrometer; nm, nanometer.

or

1 m = 0.001 km
= 0.010 hm
= 0.100 Dm
= 10 dm
= 100 cm
= 1,000 mm
= 1,000,000 µm
= 10,000,000,000 nm

## The Apothecary System

The apothecary system provides for the measurement of both weight and volume. The tables of the system are presented below.

### Table of Apothecaries' Fluid Measure

60 ♏ = 1 f℥[a]
8 f℥ (480 ♏) = 1 f℔[a]
16 f℔ = 1 pt
2 pt (32 f℔) = 1 qt
4 qt (8 pt) = 1 gal

[a]When there is no doubt that the material referred to is a liquid, ℈ the *f* is usually omitted from this symbol. *Drachm* is also spelled *dram*.
♏, minim; f℥, fluidrachm; f℔, fluidounce; pt, pint; qt, quart; gal, gallon.

### Table of Apothecaries' Measure of Weight

20 gr = 1℈
3℈ (60 gr) = 1
8 ℥ (480 gr) = 1
12 (5,760 gr) = 1 lb

gr, grain; ℈, scruple; lb, pound.

## The Avoirdupois System

The avoirdupois system is used in commerce to supply bulk chemicals and other items by weight, in ounces or pounds (e.g., epsom salts).

The grain is the same weight in the apothecary and avoirdupois systems. However, the ounce and the pound in the two systems differ in the number of grains per unit. The apothecary ounce contains 480 grains, whereas the avoirdupois ounce contains 437.5 grains. The apothecary pound contains 5,760 grains, whereas the avoirdupois pound contains 7,000 grains. Also, the symbols for the ounce and pound are different in the two systems.

### *Table of Avoirdupois Measure of Weight*

| | | |
|---|---|---|
| 437.5 gr | = | 1 oz |
| 16 oz (7,000 gr) | = | 1 lb |

oz, avoirdupois ounce.

## Intersystem Conversion

A pharmacist may convert the weight, volume, or dimensions of length from one system to another with conversion factors. Depending on the circumstances and requirements for accuracy, conversion factors of different exactness may be used. The following is a table of the factors commonly used in prescription practice. They are exact equivalents rounded off for practical application. Exact equivalents, used in the conversion of specific quantities in pharmaceutical formulas, may be found in the USP.

### *Useful Conversion Equivalents of Weight*

| | | |
|---|---|---|
| 1 g | = | 15.432 gr |
| 1 kg | = | 2.2 lb (avoir) |
| 1 gr | = | 0.0648 g or 64.8 or 65 mg |
| 1 ʒ | = | 31.1 g |
| 1 oz (avoir) | = | 28.35 g |
| 1 lb (apoth) | = | 373.2 g |
| 1 lb (avoir) | = | 453.6 or 454 g |

### *Useful Conversion Equivalents of Volume*

| | | |
|---|---|---|
| 1 mL | = | 16.23 ♏ |
| 1♏ | = | 0.06 mL |
| 1 ♁ | = | 3.69 mL |
| 1 ʒ | = | 29.57 mL |
| 1 pt | = | 473 mL |
| 1 gal (US) | = | 3,785 mL |
| 1 gal (British Imperial) | = | 4,546 mL |

### *Useful Conversion Equivalents of Length*

| | | |
|---|---|---|
| 1 in | = | 2.54 cm |
| 1 m | = | 39.37 in |

Today, there are very few occasions on which intersystem conversion is needed, owing to the almost exclusive use of the metric system in both product formulation and prescription compounding. However, when conversion is necessary or desired, it is a simple matter of selecting and applying the appropriate intersystem conversion factor.

For example, if one wishes to determine the number of milliliters in 8 fʒ, the conversion factor that most directly relates milliliters and fluidounces is selected. That factor is 1 fʒ = 29.57 mL; thus, 8 fʒ = 8 × 29.57 mL, or 236.56 mL.

Another example: How many 30-mL containers may be filled from 10 gal of a formulation? 1 gal is equal to 3,785 mL. Thus, 10 gal = 10 × 3,785 mL, or 37,850 mL. By dividing this total number of milliliters by 30, the number of containers that may be filled is found to be 1,261.

Another example: How many 0.5-gr tablets may be prepared from 1 kg of a drug substance? Since 1 gr = 64.8 mg, 0.5 gr = 32.4 mg. Also, 1 kg = 1,000 g, or 1,000,000 mg. Since 32.4 mg is required for one tablet, 1,000,000 mg divided by 32.4 mg = 30,864 tablets. Hence, 30,864 tablets may be prepared from 1 kg of the drug substance.

A final example: If a transdermal patch measures 30 $mm^2$, what is this dimension in inches? The conversion factor, 1 in equals 2.54 cm, may be expressed as 1 in = 25.4 mm. Thus, by dividing 30 mm by 25.4 mm/in, one finds the patch is 1.18 $in^2$.

## Quantitative Product Strength

The quantitative composition of certain pharmaceuticals, particularly liquids and semisolid dosage forms, often is expressed in terms of the *percentage strength* of the active and sometimes inactive ingredients. For some dilute solutions, the strength may be expressed in terms of their *ratio strength*. For most injections, many oral liquids, and some semisolid dosage forms, the quantity of active ingredient commonly is expressed as weight of drug per unit volume basis, such as milligrams of drug per milliliter of injection or oral liquid, or as weight of drug per unit weight of preparation, such as milligrams of drug per gram of ointment. The strength of solid dosage forms is given as the drug content (e.g., 5 mg) per dosage unit (e.g., tablets and capsules).

*Percent*, by definition, means parts per hundred. In pharmacy, percentage concentrations have specific meanings based on the physical character of the particular product or formulation, that is,

> *Percent weight in volume*: Expressed % w/v, this defines grams of a constituent in 100 mL of a preparation (generally a liquid).
> *Percent volume in volume*: Expressed % v/v, this defines milliliters of a constituent in 100 mL of a preparation (generally a liquid).
> *Percent weight in weight*: Expressed % w/w, this defines grams of a constituent in 100 g of a preparation (generally a solid or semisolid, but also for liquid preparations prepared by weight).

Thus, a 5% w/v solution or suspension of a drug contains 5 g of the substance in each 100 mL of the product, a 5% v/v preparation contains 5 mL of the substance in each 100 mL of the product, and a 5% w/w preparation contains 5 g of the substance in each 100 g of the product.

In the manufacture or compounding of pharmaceutical preparations, the pharmacist may calculate (*a*) the strength of an individual component in a product or (*b*) the amount of a component needed to achieve a desired percentage strength.

For example, what is the percentage strength, w/v, of a solution containing 15 g of drug in 500 mL? Since by definition percentage strength is in parts per hundred, just determine how many grams of the drug are present in each 100 mL solution. Solving by proportion: 15 g/500 mL = (×) g/100 mL. The answer is 3 g, and thus, the solution is 3% w/v in strength.

Other examples: 3 mL of a liquid in 1 L of solution = 0.3% v/v, 4 g of drug in 250 mL = 1.6% w/v, and 8 g of drug in 40 g of product = 20% w/w.

How many grams of drug are needed to prepare 400 mL of a 5% w/v preparation? In w/v problems, the specific gravity *of the preparation* is assumed to be the same as that of water (sp. gr. 1.0), so 1 mL is assumed to weigh 1 g. Therefore, in the problem example, the 400 mL is assumed to weigh 400 g, and 5% of 400 g = 20 g, the amount of drug needed.

A v/v problem example: How many mL of a liquid is needed to make 1 pt of a 0.1% v/v solution? 1 pt is equal to 473 mL, and 0.1% of that is 0.473 mL, the answer.

A w/w problem example: How many grams of zinc oxide powder should be used in preparing 120 g of a 20% w/w ointment? The answer is 20% of 120 g = 24 g.

*Ratio strength* is sometimes used to express the strength of or to calculate the amount of a component needed to make a relatively dilute preparation. Compared to percentage strength designations, for example, a 0.1% w/v preparation (0.1 g/100 mL) is equivalent to 1 g/1,000 mL and may be expressed as a ratio strength of 1:1,000 w/v. Ratio strength expressions use the w/v, v/v, and w/w designations in the same manner as percentage strength expressions. For example:

> *A 1:1,000 w/v preparation of a solid constituent in a liquid preparation* = 1 g of the solid constituent in 1,000 mL of preparation.
> *A 1:1,000 v/v preparation of a liquid constituent in a liquid preparation* = 1 mL of the constituent in 1,000 mL of preparation.
> *A 1:1,000 w/w preparation of a solid constituent in a solid or semisolid preparation* = 1 g of the constituent in 1,000 g of preparation.

A ratio strength calculation: What is the ratio strength of 6,000 mL of solution

containing 3 g of drug? Whenever possible, it is preferable for ratio strengths to be expressed as 1. In this example, if 3 g of drug is in 6,000 mL of solution, 1 g of drug is contained in 2,000 mL, and thus, the ratio strength is 1:2,000 w/v. Sometimes, the answers do not come out as evenly, for example, what is the ratio strength of 0.3 mL of a liquid in 1 L of solution? In this instance, there is 0.3 mL in 1,000 mL, equivalent to 3 mL in 10,000 mL, or a ratio strength of 3:10,000 v/v, or 1:3,333.3 v/v.

Another ratio strength calculation: In grams, how much drug is needed to make 5 L of a 1:400 w/v solution? By definition (of 1:400 w/v), 1 g of drug is needed for each 400 mL of the solution. Since 5 L, or 5,000 mL, of solution is to be prepared, the amount of drug required is found by solving 1 g/400 mL = (×) g/5,000 mL, or 12.5 g.

Rather than being expressed in terms of percentage strength or ratio strength, the strength of some pharmaceutical preparations, particularly injections and sometimes oral liquids, is based on drug content per unit of volume, as milligrams per milliliter. Thus, flexibility in dosing can be achieved by administering the volume of preparation that contains the desired dose.

## Reducing and Enlarging Formulas

In the course of pharmaceutical manufacturing and in professional practice activities, it is often necessary to reduce or enlarge a pharmaceutical formulation to prepare the desired amount of product. A standard manufacturing formulation, or *master formula*, contains the quantitative amounts of each ingredient needed to prepare a specified quantity of product. When preparing other quantities, larger or smaller, the *quantitative relationship* of each component to the other in the formula must be maintained. For example, if there is 2 g of ingredient A and 10 mL of ingredient B (among other ingredients) in a formula for 1,000 mL, one must use 0.2 g of ingredient A and 1 mL of ingredient B to make 100 mL, or one-tenth of the formula. If, on the other hand, a formula is to be enlarged—for example, from 1 L (1,000 mL) of product to a gallon (3,785 mL)—the amount of each ingredient required is 3.785 times that needed to prepare 1 L of product.

In these examples, the quantity of product prepared is reduced or enlarged, but the quantitative relationship between each ingredient and the product strength remains unchanged.

## Dosage Units

Drug dosage is selected by the prescriber based upon clinical considerations and the characteristics of the pharmacologic agent. Dosage forms (e.g., tablets, injections, transdermal patches) are used to administer the drug to the patient. Solid dosage forms, such as tablets and capsules, are generally prepared in various strengths to allow flexibility in dosing. The desired dose for a drug prepared in a liquid form may be provided by the volume administered. For example, if a liquid dosage form contains 5 mg of drug per milliliter and if a dose of 25 mg of drug is desired, 5 mL of the liquid may be administered. Commercially manufactured products are formulated to provide the drug in dosage forms and amounts convenient for administration. When the desired dosage or dosage form is commercially unavailable, the pharmacist may be called upon to compound the desired preparation.

## Common Household Measure

Liquid and powder medications not packaged in unit-dose systems are usually measured at home by the patient with common household measuring devices, such as the teaspoon or tablespoon. Although the household teaspoon may vary in volume capacity from approximately 3 to 8 mL, the American Standard Teaspoon has been established as having a volume of 4.93 ± 0.24 mL by the American National Standards Institute. For practical purposes, most pharmacy practitioners and pharmacy references use 5 mL as the capacity of the teaspoon. This is approximately equivalent to 1.33 ʒ, although physicians commonly use the drachm symbol to indicate a teaspoonful in their prescription directions to be transcribed by the pharmacist to the patient. The tablespoon is considered to have a capacity of 15 mL, equivalent to three teaspoonfuls or approximately 0.5 fʒ.

Occasionally, the pharmacist will provide a special medicinal spoon for the patient to use

**FIGURE C.2** Medicinal spoons of various shapes and capacities, calibrated medicine droppers, an oral medication tube, and a disposable medication cup.

**FIGURE C.3** Prescription balances: Torbal torsion balance (*left*) and Ohaus electronic balance. (Courtesy of Total Pharmacy Supply.)

in measuring this medication. These spoons are available in half-teaspoon, teaspoon, and tablespoon capacities. Some manufacturers provide specially designed devices to be used by the patient in measuring medication. These include specially calibrated droppers, oral syringes, measuring wells or tubes, and calibrated bottle caps. In health care institutions, disposable measuring cups and unit-dose containers are commonly employed in administering liquid medication. Examples of measuring devices are shown in Figure C.2.

## TECHNIQUES OF PHARMACEUTICAL MEASUREMENT

### Weighing and the Prescription Balance

In weighing materials, the selection of the instrument is based on the amount of material and the accuracy desired. In the large-scale manufacture of pharmaceuticals, large industrial *scales* of varying capacity and sensitivity are employed, and, later, highly sensitive analytical balances are used in the quality control and analytical work.

In the hospital and community pharmacy, most weighing is done on either a *prescription balance* or an *electronic balance* (Figure C.3). Prescription balances are termed *class III* (formerly class A) balances, which meet the prescribed standards of the National Institute of Standards and Technology. Every prescription department is required by law to have a prescription or electronic balance. The sensitivity of a balance is usually represented by the term *sensitivity requirement* (SR), the maximum change in load that will cause a specified change, one subdivision on the index plate, in the position of rest of the indicating element of the balance. The SR is determined in the following manner: (*a*) Level the balance, (*b*) determine the rest point, (*c*) place a 6-mg weight on one of the empty pans, and (*d*) look at the readout. The rest point should shift *not less than* one division on the index plate. The entire operation is repeated with a 10-g weight placed in the center of each balance pan. A class III balance has an SR of 6 mg with no load as well as with 10 g on each pan. This means that under these conditions, the addition of 6 mg of weight to one pan of the balance will disturb the equilibrium and move the balance pointer one division marking on the scale.

The USP directs that to avoid weighing errors of 5% or greater, which may be due to the limits of accuracy of the prescription balance, one must weigh a minimum of 120 mg of any material in each weighing (5% of 120 mg being the 6 mg SR, or error inherent with the balance). If a smaller weight of the material is desired, it is directed that the pharmacist mix a larger calculated weight of the ingredient (120 mg or more), dilute it with a known weight of an inert dry diluent (as lactose), mix the two uniformly, and weigh an aliquot portion of the mixture (again 120 mg or more) calculated to contain the desired amount of agent. The class III balance with a capacity of 120 g should be used for all weighing required in prescription compounding.

The electronic balance is available in various sensitivities. The one most commonly used in prescription compounding has a readability of 0.001 mg; consequently, the least amount that can be weighed is 20 times that, or 20 mg. The electronic balance is much faster and easier to use than the prescription balance. The digital readout is easy to read and the balance is quite versatile and easy to clean, and it has a relatively small footprint.

## Weights

Today, most pharmacies have a set of metric weights. Some commercial weight sets contain both the metric and apothecary systems. Prescription weights meet the National Bureau of Standards' specifications for analytical weights. Metric weights of 1 g and more and apothecaries' weights of 1 scruple and more are generally conical, with a narrow neck and head that allow them to be easily picked up with small forceps. Most of these weights are made of polished brass, and some are coated with nickel, chromium, or another material to resist corrosion. Fractional gram weights are made of aluminum and are generally square and flat with one raised end or corner for picking up with the forceps (Figure C.4). Apothecaries' weights of 0.5 scruple are frequently coin-shaped brass, and those of 5 gr and less are usually bent aluminum wires, with each straight side representing 1 gr of weight. The half-grain weight is usually a smaller gauge wire bent in half.

To prevent moisture and oils from the fingertips being deposited on the weights, all weights should be transferred with the forceps provided in each weight set.

**FIGURE C.4** Set of metric weights. (Courtesy of Mettler-Toledo, Inc.)

## Care and Use of a Balance

First and foremost, the balance should be kept in a well-lighted location, placed on a firm level counter approximately waist high to the operator. The area should be as free from dust as possible and in an area that is draft-free. There should be no corrosive vapors, high humidity, or vibration. When not in use, the balance should be clean and covered with the balance cover. Any agent spilled on the balance during use should be wiped off immediately with a soft brush or cloth. When not in use, the balance should always be kept with the weights off and the beam in the fixed or locked (arrested) position.

Before weighing an article, the balance must be made level. This is accomplished with the leveling screws on the bottom of the balance, according to the instructions accompanying the balance. The balance should be level both front to back and side to side, as indicated by the leveling bubble.

In using a prescription balance, neither the weights nor the substance to be weighed should be placed on the balance while the beam is free to oscillate. Before weighing, powder papers or weigh boats of equal size should be placed on both pans of the balance and the equilibrium of the balance tested by releasing the arresting knob. If the balance is off because of differences in the weight, additional weight may be added to the light pan by adding small tearings of powder papers. When balanced, the balance is placed in the arrested position, and the desired weight added to the right-hand pan. Then, an amount of substance considered to be approximately the desired weight is carefully placed on the left-hand pan with a spatula. The beam should then be slowly released by means of the locking device in the front of the balance. If the substance is in excess, the beam is fixed again, and a small portion of the substance removed with the spatula. The process is continued until the two pans balance, as indicated by the central position of the balance pointer. If the amount of weight on the balance is initially too little, the reverse process is undertaken. The powder paper used on the left-hand pan, intended

to hold the substance to be weighed, is usually folded diagonally, or its edges are turned up to contain the material being weighed.

In transferring material by spatula, the material may be lightly tapped from the spatula when the correct amount to be measured is approached. Usually this is done by holding the spatula with a small amount of material on it in the right hand and tapping the spatula with the forefinger. As material comes off the spatula, the left hand is working the balance-arresting mechanism, and the status of the weight is observed alternately with the tapping of the spatula. Most balances have a damping mechanism that slows down the oscillations and permits more rapid determinations of the balance or imbalance positions of the pans.

Once the material has been weighed, the balance beam is again put in the fixed position, and the paper or weigh boat holding the weighed substance carefully removed. If more than a single weighing is to be performed, the paper or weigh boat is usually marked with the name of the substance it holds. After the final weighing, all weights are removed with the forceps and the balance is cleaned, closed, and covered.

Most prescription balances contain built-in mechanisms whereby external weights are not required for weighing <1 g. Some balances use a rider, which may be shifted from the zero position toward the right side of the balance to add increments of weight marked on the scale in 10-mg units, up to 1 g. Another type of balance uses a central dial, calibrated in 10-mg units, to add weight up to 1 g. Both types of devices add the weight to the right-hand pan internally. In each case, the pharmacist may use a combination of the internal and external weights. For instance, if 1.2 g is to be weighed, the pharmacist can place a 1-g weight on the right-hand pan and place the rider or adjust the dial to add 0.2 g. Care must always be exercised to bring the rider or dial to zero between weighings to maintain accuracy.

Most use of the prescription balance is weighing of powders or semisolid materials, such as ointments. However, liquids may also be weighed in tared (weighed) vessels of appropriate size. The pharmacist must always be certain to account for the weight of the vessel in calculating the amount of liquid weighed.

Materials should never be downweighed, that is, substances should never be placed on the pan with the balance in the unarrested position, forcing the pan to drop suddenly and forcefully. The sudden slamming down of the pan can do serious damage to the balance, affecting its sensitivity and accuracy.

The most common type of prescription balance is the torsion balance. It operates on the tension of taut wires, which, when twisted by addition of weight, tend to twist back to the original position (Figure C.3).

In using an electronic balance, first make sure the balance is clean and level. The balance should be calibrated daily. Many of these balances have internal calibration, and some use an external 200- or 300-g weight. After calibration, a weighing boat or paper is placed on the balance pan, and the tare button is depressed to a reading of 0.000. Then, the required quantity of material is added to the weighing boat or paper; the dial constantly reads out the weight of material on the pan. Material can be easily removed or added to obtain the desired quantity.

## Measuring Volume

The common instruments for pharmaceutical measurement are presented in Figure C.5. Two types of graduates, *conical* and *cylindrical*, are used in pharmacy. Cylindrical graduates are generally calibrated in metric units, whereas conical graduates may be graduated in both metric and apothecary units or with a single scale of either of the systems. Graduates of both shapes are available in a wide variety of capacities, ranging from 5 to 1,000 mL or more. Most graduates are made of a good-quality heat-treated glass, although graduates of polypropylene are also available. In measuring small volumes of liquids, <1.5 mL, the pharmacist should use a pipet as the one shown in Figure C.5. The bulky-looking device shown with the pipet is a pipet filler, used for drawing acids or other toxic solutions into the pipet without the mouth. The device, without being removed from the pipet, also allows for accurate delivery of the liquid.

In measuring volumes of liquids, the pharmacist should select the measuring

**FIGURE C.5** Typical equipment for the pharmaceutical measurement of volume. *Left*: Conical graduates. *Right*: Cylindrical graduates. *Front:* A pipet for measurement of small volumes. Behind the pipet is a pipet filler used instead of the mouth to draw acids and other dangerous liquids into the pipet.

device most appropriate to the volume of liquid to be measured and the desired degree of accuracy. With liquids, the more narrow the column of the liquid, the more accurate is likely to be the measurement. Figure C.6 demonstrates this point. A reading error of the same dimension will produce a small-volume error with a pipet, a greater-volume error with a cylindrical graduate, and the largest error of volume with conical graduate. The greater the flare in the design of the conical graduate, the greater is the volume error.

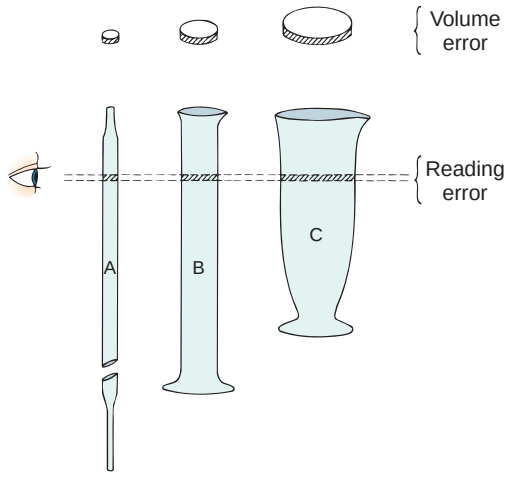


**FIGURE C.6** The difference in the volume error occurring with the same reading error in measuring devices of different diameters.

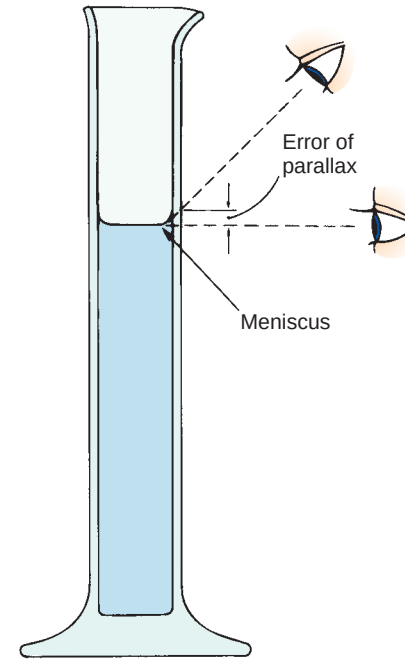


**Figure C.7** Error in reading the meniscus of a liquid in a graduated cylinder when the reading is made from above the level of the liquid rather than at the same level.

In reading the level of liquid in a graduate, it is important to recognize the possibility of parallax error. Figure C.7 depicts this point. A liquid in a graduate tends to be drawn to the inner surface of the graduate and rises slightly against that surface and above its true meniscus. If one measures looking downward, it appears that the meniscus of the liquid is at this upper level, whereas it is slightly lower, at the actual level of the liquid, the center of the graduate. Thus, measurements of liquids in graduates should be taken with the eyesight level with the liquid in the graduate.

If a pharmacist misreads a graduate, the *percentage of error* is affected by the volume of liquid. According to the USP, an acceptable 10-mL graduate cylinder with an internal diameter of 1.18 cm contains 0.109 mL of liquid in each millimeter of column. A reading error of 1 mm causes a percentage error of only 1.09% when 10 mL is being measured, 2.18% when 5 mL is being measured, 4.36% when 2.5 mL is being measured, and 7.26% when 1.5 mL is being measured. It is apparent that the greatest

percentage error occurs when the smallest amount is being measured. Thus, the rule of thumb for measuring liquids in graduates is that a graduate should be used having a capacity *equal to or just exceeding* the volume to be measured.

According to Goldstein and Mattocks (2), based on a deviation of 1 mm from the mark and an allowable error of 2.5%, the smallest amounts that should be measured in cylindrical graduates having the stated internal diameters are as follows:

| GRADUATE CYLINDER SIZE (ML) | INTERNAL DIAMETER (CM) | DEVIATION IN ACTUAL VOLUME (ML) | MINIMUM VOLUME MEASURABLE (ML) |
|---|---|---|---|
| 5 | 0.98 | 0.075 | 3.00 |
| 10 | 1.18 | 0.109 | 4.36 |
| 25 | 1.95 | 0.296 | 11.84 |
| 50 | 2.24 | 0.394 | 15.76 |
| 100 | 2.58 | 0.522 | 20.88 |

For a 5% error, the minimum volumes measurable would be one-half of those stated. It is apparent that for accuracy, one should not use a graduate when the measurement would use only the bottom portion of the scale.

In using graduates, the pharmacist pours the liquid into the graduate slowly, observing the level. In measuring viscous liquids, adequate time must be allowed for the liquid to settle in the graduate, as some may run slowly down the inner sides of the graduate. It is best to attempt to pour such liquids toward the center of the graduate, avoiding contact with the sides. In emptying the graduate of its measured contents, adequate drain time should be allowed.

When pouring liquids from bottles, good pharmaceutical technique is to keep the label on the bottle facing up; this avoids the possibility of any errant liquid running down over the label as the bottle is righted after use. The bottle orifice should be wiped clean after each use.

## REFERENCES

1. Ansel HC. Pharmaceutical Calculations. 13th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010.
2. Goldstein SW, Mattocks AM. How to measure accurately. J Am Pharm 1951;23:421.