2

International System of Units

OBJECTIVES

Upon successful completion of this chapter, the student will be able to:

- Demonstrate an understanding of the International System of Units.
- Convert measures within the International System of Units.
- Convert measures between the International System of Units and other systems of measure used in pharmacy.
- Apply the International System of Units in pharmaceutical calculations.

Introduction

The ***International System of Units*** (*SI*), formerly called the ***metric system***, is the internationally recognized decimal system of weights and measures. The system was formulated in France in the late 18th century. Over the years, effort has been made in the United States to transition from use of the common systems of weights and measures (e.g., pounds, feet, gallons) to the international system. Today, the pharmaceutical research and manufacturing industry, the *United States Pharmacopeia–National Formulary*,[a] and all the health professions reflect conversion to the SI system. The advantages include the simplicity of the decimal system, the clarity provided by the base units and prefixes, and the ease of scientific and professional communications provided through the use of a universally accepted system.

The base units of the SI are the *meter* (for length), the *gram* (for weight), and the *liter* (for volume).[b] Subdivisions and multiples of these base units, their relative values, and their corresponding prefixes are shown in Table 2.1.

Guidelines for the Correct Use of the SI

The following are select guidelines for the correct use of the SI from the U.S. Metric Association, with additional considerations relevant to the practice of pharmacy[1,2]:

- Unit names and symbols are not capitalized except when used at the beginning of a sentence or in headings. However, the symbol for liter (L, l) may be capitalized or not. *For example*, for four grams, use 4 g and *not* 4 G; for 4 millimeters, use 4 mm and *not* 4 MM; but for 4 liters, 4 L or 4 l are acceptable.

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[a]The *United States Pharmacopeia—National Formulary* (USP–NF) establishes standards for the quality, purity, and strength of prescription and nonprescription medicines. These standards, which are recognized and used by more than 140 countries, are published in printed volumes and electronically. The Authors' Extra Point at the end of this chapter further describes the USP–NF and other national, regional, and international pharmacopeias.

[b]Although not included in this text, the SI includes measures of force, viscosity, electricity, luminance, and many others in a variety of disciplines.

TABLE 2.1 • PREFIXES AND RELATIVE VALUES OF THE INTERNATIONAL SYSTEM (SI)

Prefix	Meaning
Subdivisions	
atto-	one-quintillionth (10^{-18}) of the basic unit
femto-	one-quadrillionth (10^{-15}) of the basic unit
pico-	one-trillionth (10^{-12}) of the basic unit
nano-	one-billionth (10^{-9}) of the basic unit
micro-	one-millionth (10^{-6}) of the basic unit
milli-	one-thousandth (10^{-3}) of the basic unit
centi-	one-hundredth (10^{-2}) of the basic unit
deci-	one-tenth (10^{-1}) of the basic unit
Multiples	
deca-	10 times the basic unit
hecto-	100 times (10^{2}) the basic unit
kilo-	1000 times (10^{3}) the basic unit
myria-	10,000 times (10^{4}) the basic unit
mega-	1 million times (10^{6}) the basic unit
giga-	1 billion times (10^{9}) the basic unit
tera-	1 trillion times (10^{12}) the basic unit
peta-	1 quadrillion times (10^{15}) the basic unit
exa-	1 quintillion times (10^{18}) the basic unit

- In the United States, the decimal marker (or decimal point) is placed on the line with the number; however, in some countries, a comma or a raised dot is used, *for example*, 4.5 mL (United States) and 4,5 mL or 4·5 mL (non-United States).
- Periods are not used following SI symbols except at the end of a sentence, *for example*, 4 mL and 4 g, *not* 4 mL. and 4 g.
- A compound unit that is a ratio or quotient of two units is indicated by a solidus (/) or a negative exponent, *for example*, 5 mL/h or 5 $mL \cdot h^{-1}$.
- Symbols should not be combined with spelled-out terms in the same expression, *for example*, 3 mg/mL, *not* 3 mg/milliliter.
- Plurals of unit names, when spelled out, have an added "s." Symbols for units, however, are the same in singular and plural, *for example*, 5 milliliters or 5 mL, *not* 5 mLs.
- Two symbols exist for microgram: *mcg* and µg. Although the abbreviation "µg" is accepted in the SI units, "*mc*g" is more commonly used in pharmacy practice to avoid mistakes in handwritten units where the "µ" symbol may appear as an "m". *For example*, 12 µg when handwritten can be easily misread as 12 mg, and thereby result in a 1000-fold overdose.
- The symbol for square meter is m^2; for cubic centimeter, cm^3; and so forth. A cubic centimeter (cm^3) is considered equivalent to a milliliter (mL).[2] The symbol "cc," for cubic centimeter, is *not* an accepted SI symbol.
- Decimal fractions are used, not common fractions, *for example*, 5.25 g, *not* 5¼ g.
- A zero always should be placed in front of a leading decimal point to prevent medication errors caused by *uncertain* decimal points, *for example*, 0.5 g, *not* .5 g.
  It is critically important for pharmacists to recognize that a misplaced or misread decimal point can lead to an error in calculation of a minimum of one-tenth or 10 times the desired quantity.
- To prevent misreadings and medication errors, "trailing" zeros *should not* be placed following a whole number on prescriptions and medication orders, *for example*, 5 mg, *not* 5.0 mg. However, in some tables (such as those of the SI in this chapter), pharmaceutical formulas, and quantitative results, trailing zeros often are used to indicate exactness to a specific number of decimal places.

- In selecting symbols of unit dimensions, the choice generally is based on selection of the unit that will result in a numeric value between 1 and 1000, *for example*, 500 g, *rather than* 0.5 kg; 1.96 kg, *rather than* 1960 g; and 750 mL, *rather than* 0.75 L.

Special Considerations of the SI in Pharmacy

Although some remnants of the common systems of measurement (see Appendix A) in pharmacy remain, the use of the SI is nearly total. The SI system is used to manufacture and label pharmaceutical products (Fig. 2.1); write, fill, and compound prescriptions and institutional medication orders; dose patients; express clinical laboratory test results; and communicate both verbally and through scientific and professional literature.

In the large-scale manufacture of dosage forms, pharmaceutical ingredients are measured in kilogram and kiloliter quantities. In the community and institutional pharmacy, compounding and dispensing in milligram, gram, and milliliter quantities are more common. Drug doses are typically administered in milligram or microgram amounts and prepared in solid dosage forms, such as tablets or capsules, or in a stated volume of a liquid preparation, such as an oral solution (e.g., 30 mg/5 mL) or injection (e.g., 2 mg/mL). Doses for certain drugs are calculated on the basis of body weight and expressed as mg/kg, meaning a certain number of *milligrams of drug per kilogram of body weight*. Clinical laboratory values are in metric units and expressed, for example, as mg/dL, meaning *milligrams of drug per deciliter of body fluid* (such as blood).

Particle size and nanotechnology

Drug particle size has long been an important consideration in pharmaceutical technology. Through the milling and reduction of drug materials to micron size, the surface area of particles is increased (Fig. 2.2) and pharmaceutical and clinical benefits often accrue. These benefits may include the following[3]:

- Increased aqueous dissolution rates for poorly soluble substances
- Improved bioavailability, with increased rates of absorption of orally administered drugs
- Lower oral dosage possibilities with enhanced drug absorption

FIGURE 2.1. • Example of a pharmaceutical product with the label indicating the strength and quantity (50 mg/10 mL) in SI or metric units. (Reprinted with permission from Lacher BE. *Pharmaceutical Calculations for the Pharmacy Technician*. Philadelphia, PA: Lippincott Williams & Wilkins; 2008.)

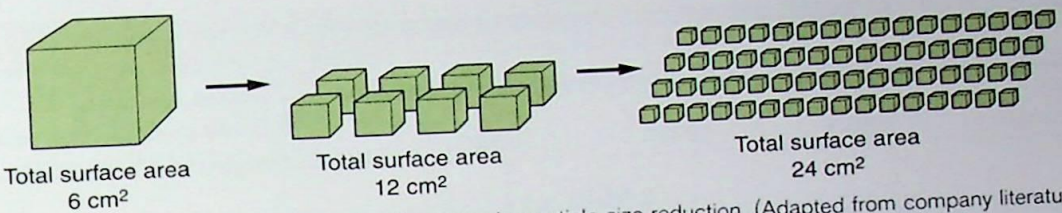

FIGURE 2.2. • Depiction of increased surface area by particle size reduction. (Adapted from company literature, Nanocrystal, Elan Drug Delivery, Inc.)

- Expanded formulation options in the preparation of stable and predictable pharmaceutical suspensions and colloidal dispersions for all routes of administration, including oral, parenteral, respiratory, ophthalmic, and nasal.

An area of technology with great potential is nanotechnology. ***Nanotechnology*** centers on the understanding and control of matter between approximately 1 and 100 nanometers (nm) in size, referred to as the ***nanoscale*** range.[4] For perspective, a nanometer is one-billionth of a meter; 25,400,000 nm equal 1 inch; the helix of DNA has a diameter of about 2 nm; and a typical bond between two atoms is about 0.15 nm.[5] Nanotechnology has applications for many potential products, including those that integrate chemistry, the biological sciences, medicine, and computer technology.

Measure of Length

The *meter* is the primary unit of length in the SI, and the prefixes listed in Table 2.1 are used to designate fractions or multiples of this basic unit. Examples of the use of linear measurement in pharmacy include the dimensions of transdermal skin patches, expressed in cm^2; a patient's height in cm or m; and the clinical reference to the size of a patient's physical structure, such as a tumor, usually measured in mm or cm. As a point of reference, 1 inch is equivalent to 2.54 centimeters or 25.4 millimeters (Fig. 2.3).

Another application of linear measurement is in *distance exercise*, undertaken as a component of maintaining good health status. These programs are typically measured by both time and distance in miles or kilometers, the relationship of which is demonstrated in Table 2.2.

Measure of Volume

The *liter* is the primary unit of volume, and the prefixes listed in Table 2.1 are used to designate fractions or multiples of this basic unit as well. One liter represents the volume of the cube of one-tenth of a meter, that is, of 1 dm^3. Furthermore, one milliliter (mL) is equivalent to one cubic centimeter (cm^3).[2]

Measurement of volume is commonplace for the pharmacist in preparing and dispensing liquid medications and for the patient in measuring dosage. The most common unit used in measuring volume in the health care setting is the milliliter (mL). Examples of pharmaceutical graduates for measuring volume are shown in Figure 2.4.

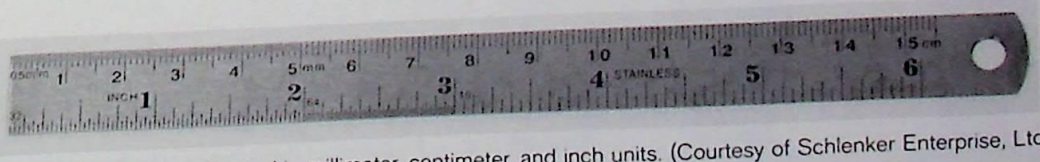

FIGURE 2.3. • Ruler calibrated in millimeter, centimeter, and inch units. (Courtesy of Schlenker Enterprise, Ltd.)

TABLE 2.2 • DEMONSTRATIONS OF LINEAR RELATIONSHIPS

	Feet	Yards	Miles	Meters	Kilometers
1 mile	5280	1760	1	1609.3	1.6093
1 kilometer	3280.8	1093.6	0.62137	1000	1

Measure of Weight

The primary unit of weight in the SI is the *gram*, which is the weight of 1 cm^3 of water at 4°C, its temperature of greatest density. **For practical purposes, 1 cm^3 of water ≈ 1 mL ≈ 1 g of weight.** As with units of length and volume mentioned previously, the prefixes listed in Table 2.1 are used to designate fractions or multiples of the gram.

The weighing of components in the manufacture of a pharmaceutical product and in the compounding of a prescription or medication order is a usual function of a pharmacist. And, since most therapeutic agents are solid substances (i.e., powders), their doses are determined and expressed in units of weight, most often in milligrams. An example of a metric set of weights is shown in Chapter 3.

Prescription Writing Style Using the SI

Prescriptions written in the SI use Arabic numerals *before* the abbreviations for the denominations (e.g., 6 g). Quantities of weight are usually written as grams and milligrams, and volumes as milliliters:

℞

Dextromethorphan HBr	320 mg
Guaifenesin	3.2 g
Cherry syrup, to make	240 mL

Fundamental Computations

Converting SI units to lower or higher denominations by using a unit position scale

The metric system is based on the decimal system; therefore, conversion from one denomination to another can be done simply by moving the decimal point as demonstrated in Figure 2.5.

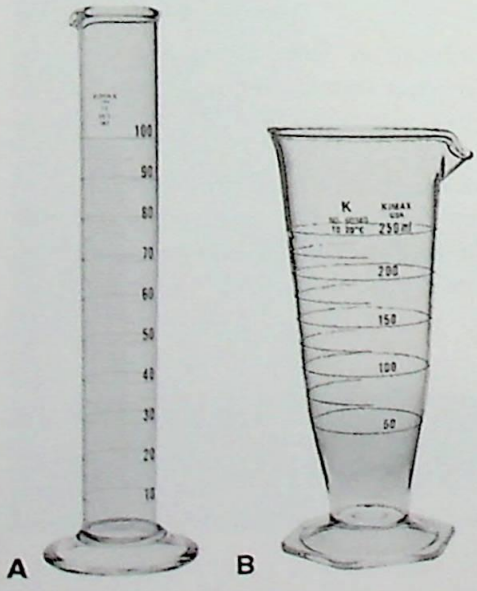

FIGURE 2.4. • Examples of metric-scale cylindrical **(A)** and conical pharmaceutical graduates **(B)**. (Courtesy of DWK Life Sciences.)