CHAPTER TWO: INTERNATIONAL SYSTEM OF UNITS

Objectives

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

1. Demonstrate an understanding of the International System of Units.
2. Convert measures within the International System of Units.
3. State equivalent measures between the International System of Units and other systems of measure used in pharmacy practice.
4. Convert measures between the International System of Units and other systems of measure used in pharmacy.
5. Apply the International System of Units correctly in calculations.

International System of Units (SI)

- For length, the primary unit is the ***meter***
- For volume, the ***liter***
- For weight, the ***gram*** (although technically the *kilogram* is considered the historic base unit).

The standard subdivisions and multiples of the primary units are termed ***denominations***, and the number used in conjunction with a denomination is termed a ***denominate number***.

For example, in *5 milligrams,* 5 is the denominate number and milligrams is the denomination.

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	
deka-	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

The following are select guidelines for the correct use of the SI from the U.S.

1. Unit names and symbols generally are not capitalized except when used at the beginning of a sentence or in headings.

However, the symbol for liter (L) may be capitalized or not.

***Examples**:* 4 L or 4 l, 4 mm, and 4 g; *not* 4 Mm and 4 G.

2. In the United States, the decimal marker (or decimal point) is placed on the line with the denomination and denominate number; however, in some countries, a comma or a raised dot is used.

***Examples**:* 4.5 mL (U.S.); 4,5 mL or 4·5 mL (non-U.S.).

3. Periods are not used following SI symbols except at the end of a sentence.

***Examples**:* 4 mL and 4 g, *not* 4 mL. and 4 g.

4. A compound unit that is a ratio or quotient of two units is indicated by a solidus (/) or a negative exponent.

***Examples**:* 5 mL/h or 5 mL· h^{-1}, *not* 5 mL per hour.

5. Symbols should not be combined with spelled-out terms in the same expression.

***Examples**:* 3 mg/mL, *not* 3 mg/milliliter.

6. Plurals of unit names, when spelled out, have an added *s*. Symbols for units, however, are the same in singular and plural.

***Examples**:* 5 milliliters or 5 mL, *not* 5 mLs.

7. Two symbols exist for microgram: *mcg* (often used in pharmacy practice) and μ*g* (SI).

8. The symbol for square meter is m^2; for cubic centimeter, cm^3, and so forth. In pharmacy practice, cm^3 is considered equivalent to milliliter. The symbol cc, for cubic centimeter, is not an accepted SI symbol.

9. Decimal fractions are used, not common fractions. Examples: 5.25 g, not 5¼ g.

8. A zero should be placed in front of a leading decimal point to prevent medication errors caused by uncertain decimal points.

Example: 0.5 g, not .5 g.

8.

It is critically important for pharmacists to recognize that a misplaced or misread decimal point can lead to an error in calculation or in dispensing of a minimum of one tenth or ten times the desired quantity.

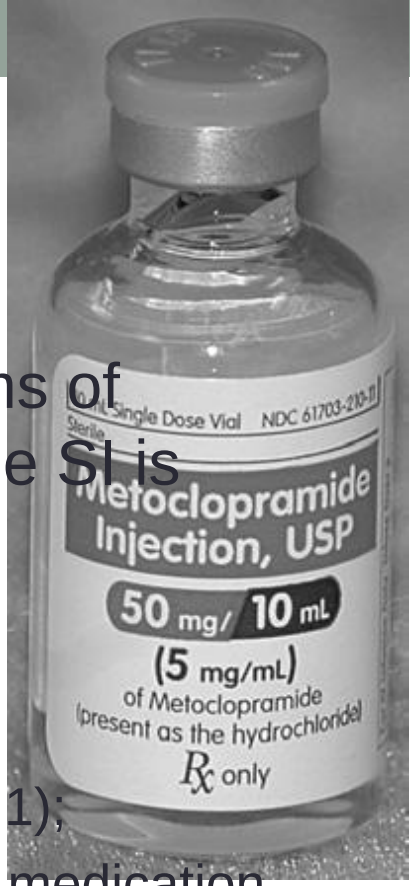
11. To prevent misreadings and medication errors, ‘‘trailing’’ zeros should not be placed following a whole number on prescriptions and medication orders. Example: 5 mg, not 5.0 mg.

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.

12. In selecting symbols of unit dimensions, the choice generally is based on selecting the unit that will result in a numeric value between 1 and 1000.

Examples: 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 in pharmacy remain, the use of the SI is nearly total.

- The system is used to
  - manufacture and label pharmaceutical products (Fig. 2.1);
  - write, fill, and compound prescriptions and institutional medication orders;
  - Express doses of drugs
  - express clinical laboratory test results; and
  - communicate both verbally and through scientific and professional literature.

Particle size and Nanotechnology

Benefits of particle size reduction:

1. Increased aqueous dissolution rates for poorly soluble substances
2. Improved bioavailability, with increased rates of absorption of orally administered drugs
3. Lower oral dosage possibilities with enhanced drug absorption
4. 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.

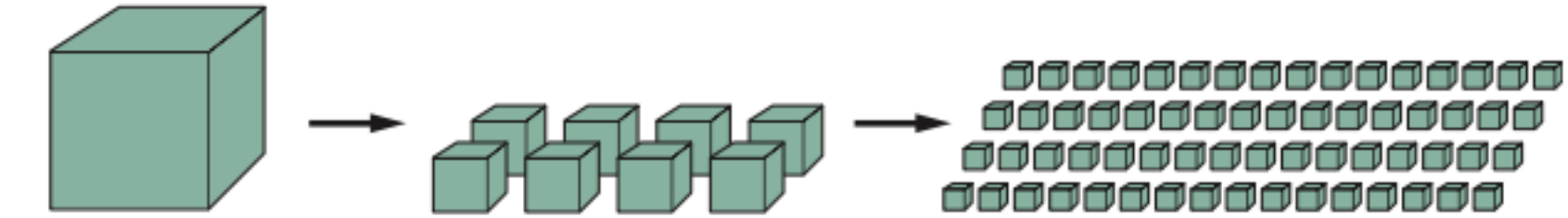


FIGURE 2.2 Depiction of increased surface area by particle size reduction. *(Adapted from company literature, Nanocrystal, Elan Drug Delivery, Inc.)*

- ***Nanotechnology*** may be defined as the development and use of materials on the nano-size scale.

- ***Molecular nanotechnology*** refers to the method of building organic and inorganic structures atom by atom or molecule by molecule.

- The term ***nanomedicine*** refers to the application of nanotechnology to the prevention and treatment of disease.

Measure of length

- The meter is the primary unit of length in the SI

→ The **table of metric length**:

- 1 kilometer (km) = 1000.000 meters
- 1 hectometer (hm) = 100.000 meters
- 1 dekameter (dam) = □ 10.000 meters

1 decimeter (dm) = 0.100 meter
1 centimeter (cm) = 0.010 meter
1 millimeter (mm) = 0.001 meter
1 micrometer (μm) = 0.000,001 meter
1 nanometer (nm) = 0.000,000,001 meter

The table may also be written:

1 meter = 0.001 kilometer
= 0.01 hectometer
= 0.1 dekameter
= 10 decimeters
= 100 centimeters
= 1000 millimeters
= 1,000,000 micrometers
= 1,000,000,000 nanometers

Equivalencies of the most common length denominations:

1000 millimeters (mm) = 100 centimeters (cm)
100 centimeters (cm) = 1 meter (m)

Measure of Volume

- The *liter* is the primary unit of volume.

- It represents the volume of the cube of one tenth of a meter, that is, of 1 dm^3.

The **table of metric volume**:

1 kiloliter (kL)	=	1000.000 liters
1 hectoliter (hL)	=	100.000 liters
1 dekaliter (daL)	=	10.000 liters
1 liter (L)	=	1.000 liter
1 deciliter (dL)	=	0.100 liter
1 centiliter (cL)	=	0.010 liter
1 milliliter (mL)	=	0.001 liter
1 microliter (μL)	=	0.000,001 liter

This table may also be written:

$$
\begin{aligned}
1 \text{ liter} &= 0.001 \text{ kiloliter} \\
&= 0.010 \text{ hectoliter} \\
&= 0.100 \text{ dekaliter} \\
&= 10 \text{ deciliters} \\
&= 100 \text{ centiliters} \\
&= 1000 \text{ milliliters} \\
&= 1{,}000{,}000 \text{ microliters}
\end{aligned}
$$

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.

The table of metric weight:

1 kilogram (kg)	= 1000.000 grams
1 hectogram (hg)	= 100.000 grams
1 dekagram (dag)	= 10.000 grams
1 gram (g)	= 1.000 gram
1 decigram (dg)	= 0.1000 gram
1 centigram (cg)	= 0.010 gram
1 milligram (mg)	= 0.001 gram
1 microgram (μg or mcg)	= 0.000,001 gram

1 nanogram (ng) = 0.000,000,001 gram
1 picogram (pg) = 0.000,000,000,001 gram
1 femtogram (fg) = 0.000,000,000,000,001 gram

This table may also be written:

1 gram = 0.001 kilogram
= 0.010 hectogram
= 0.100 dekagram
= 10 decigrams
= 100 centigrams
= 1000 milligrams
= 1,000,000 micrograms
= 1,000,000,000 nanograms
= 1,000,000,000,000 picograms
= 1,000,000,000,000,000 femtograms

Equivalencies of the most common weight denominations:

1000 micrograms (μg or mcg) = 1 milligram (mg)
1000 milligrams (mg) = 1 gram (g)
1000 grams (g) = 1 kilogram (kg)

Prescription writing style using the SI

Rx

Dextromethorphan HBr	320 mg
Guiafenesin	3.2 g
Cherry Syrup to make	240 mL

Fundamental Computations

To change a metric denomination to the next smaller denomination, move the decimal point one place to the right.

To change a metric denomination to the next larger denomination, move the decimal point one place to the left.

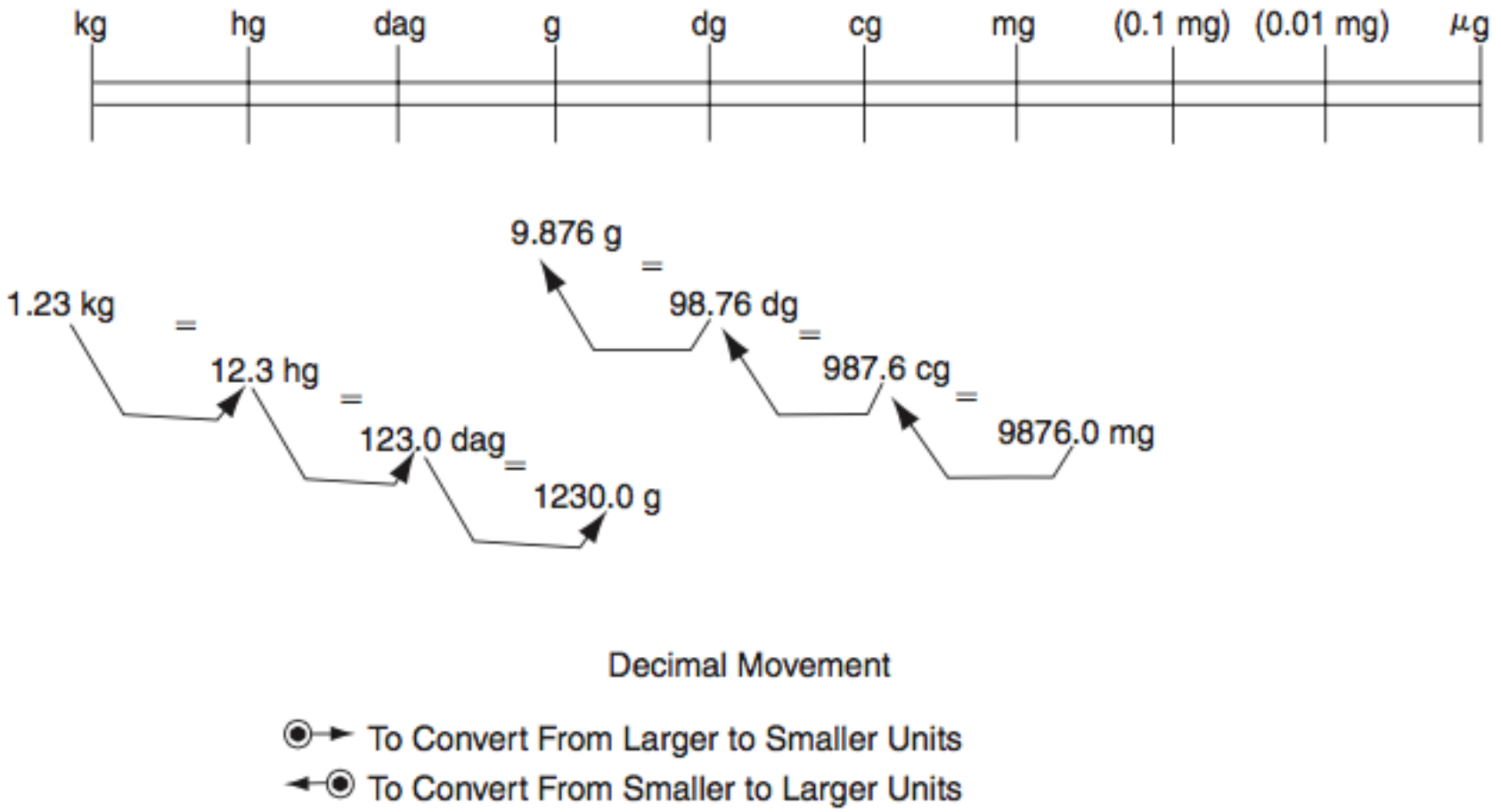


FIGURE 2.5 Position scale of units of weight.

Try these …

1. *Reduce 1.23 kilograms to grams.*
2. *Reduce 9876 milligrams to grams*
3. *Reduce 85 micrometers to centimeters.*
1. *Reduce 2.525 liters to microliters.*

Addition and subtraction

Try These !!

- ***A capsule contains the following amounts of medicinal substances: 0.075 g, 20 mg, 0.0005 g, 4 mg, and 500 □ g. What is the total weight of the substances in the capsule?***

- ***A prescription calls for 0.06 g of one ingredient, 2.5 mg of another, and enough of a third to make 0.5 g. How many milligrams of the third ingredient should be used?***

Multiplication and Division

Try these …

- ***Multiply 820 mL by 12.5 and express the result in liters.***

- ***Divide 0.465 g by 15 and express the result in milligrams.***

Case ‘1’

- **A nurse telephones a pharmacy regarding the proper quantity of an injection to administer to a pediatric patient from a 1-mL vial containing 0.1 mg of digoxin.**

- **The attending physician has quantity of an injection to administer to a pediatric patient from a 1-mL vial containing 0.1 mg of digoxin. The attending physician had prescribed a dose of 25 mcg.**

- **How many milliliters should be the pharmacist’s response?**

Relation of the SI to other systems of measurement

TABLE 2.3 SOME USEFUL EQUIVALENTS

Equivalents of Length		
1 inch	=	2.54 cm
1 meter (m)	=	39.37 in
Equivalents of Volume		
1 fluidounce (fl. oz.)	=	29.57 mL
1 pint (16 fl. oz.)	=	473 mL
1 quart (32 fl. oz.)	=	946 mL
1 gallon, US (128 fl. oz.)	=	3785 mL
1 gallon, UK	=	4545 mL
Equivalents of Weight		
1 pound (lb, Avoirdupois)	=	454 g
1 kilogram (kg)	=	2.2 lb

Some questions …

- A low-strength children's/adult chewable aspirin tablet contains 81 mg of aspirin per tablet. How many tablets may be prepared from 1 kg of aspirin?
- An inhalation aerosol contains 225mg of metaproterenol sulfate, which is sufficient for 300 inhalations. How many micrograms of metaproterenol sulfate would be contained in each inhalation?
- A vial contains 80 mg of drug in 2 mL of injection. How many milliliters of the injection should be administered to obtain 0.02 g of drug?
- A 125-mL container of amoxicillin contains 600 mg/5 mL. How many milliliters would be used to administer 400 mg of amoxicillin?

Case ‘2’

- **A hospital pharmacist is asked to prepare an intravenous infusion of dopamine. Based on the patient’s weight, the pharmacist calculates a dose of 500 mcg/min for continuous infusion.**

- **The concentration of a premixed dopamine infusion is 400 mg/250 mL. What is the concentration of the infusion on a mcg/mL basis? How many milligrams of dopamine is the patient to receive in the first hour of treatment? How long will the infusion last?**