

Lecture 2

Weight and measure

Type of systems:

The International System of Units (SI), formerly called the **metric system**, is the internationally recognized decimal system of weights and measures. The International System of Units (**Système international d'unités or SI**). Today, the pharmaceutical research, manufacturing industry and the practice of pharmacy reflect conversion to the SI system.

THE METRIC SYSTEM

The metric system, which is federally mandated and appears in the official listing of drugs in the *United States Pharmacopoeia* (USP), is a logically organized system of measurement. It was first developed by the French. The basic units multiplied or divided by 10 comprise the metric system. Therefore, a knowledge of decimals, reviewed in Chapter 1, is useful for this system.

In the metric system, the three primary or fundamental units are: the meter for length, the liter for volume, and the gram for weight. In addition to these basic units, the metric system includes multiples of basic units with a prefix to indicate its relationship with the basic unit. For example, a milliliter represents 1/1000 or 0.001 part of a liter. A milligram represents 0.001 g and a kilogram represents 1000 times the gram. A pharmacist rarely uses the secondary or the derived units of the metric system. Therefore, secondary units such as Joules or Newton are not included in this book. The table of measurements in Table 2.1 is very important for the pharmacists.

➤ Centimetre-gram-second systems

Early metric systems were based on various **centimetre gram second** systems of units (CGS). Each table of the SI contains a definitive, or primary, unit.

- 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).

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

Metric weight

0.001 kilogram (kg)	=	1 gram (g)
0.01 hectogram (hg)	=	1 gram (g)
0.1 dekagram (dkg)	=	1 gram (g)
10 decigram (dg)	=	1 gram (g)
100 centigram (cg)	=	1 gram (g)
1000 milligram (mg)	=	1 gram (g)
1,000,000 microgram (μg)	=	1 gram (g)
1,000,000,000 nanogram (ng)	=	1 gram (g)

1 Kg = 1,000 g = 1,000,000 mg = 1,000,000,000 micrograms = 1,000,000,000,000 nanograms

1 g = 1,000 mg = 1,000,000 micrograms = 1,000,000,000 nanograms

1 mg = 1,000 micrograms = 1,000,000 nanograms

1 micrograms = 1,000 nanograms

Metric volume

0.001 kiloliter (kL)	=	1 liter (L)
0.01 hectoliter (hL)	=	1 liter (L)
0.1 dekaliter (dkL)	=	1 liter (L)
10 deciliter (dL)	=	1 liter (L)
100 centiliter (cL)	=	1 liter (L)
1000 milliliter (mL)	=	1 liter (L)
1,000,000 microliter (μL)	=	1 liter (L)
1,000,000,000 nanoliter (nL)	=	1 liter (L)

1 L = 1,000 mL = 1,000,000 microliter

1 mL = 1,000 microliter

Metric length

metre	= 1 metre
decametre	= 10 metres
hectometre	= 100 metres
kilometre	= 1000 metres
decimetre	= $\frac{1}{10}$ of a metre
centimetre	= $\frac{1}{100}$ of a metre
millimetre	= $\frac{1}{1000}$ of a metre

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.

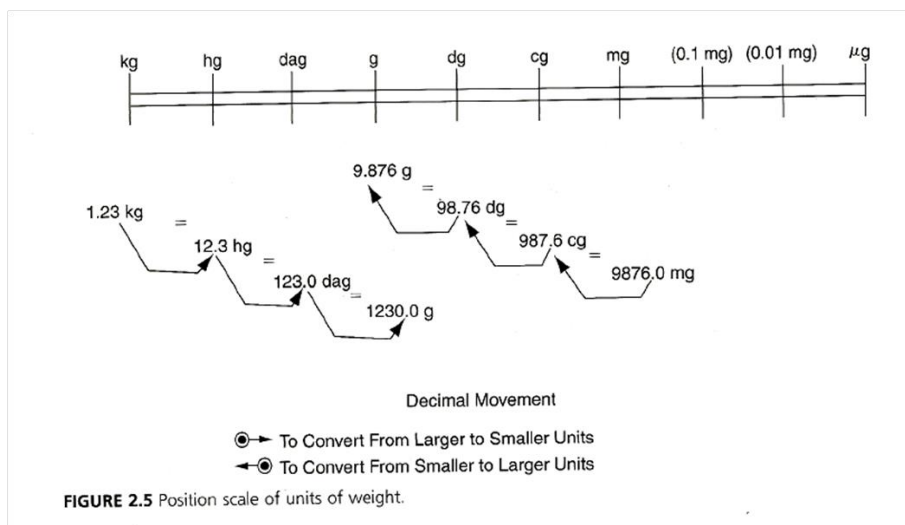
To change a metric denomination to the next smaller denomination, move the decimal point one place to the right.

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

Examples:

Reduce 1.23 kilograms to grams.

$$1.23 \text{ kg} = 1230 \text{ g, answer.}$$



Addition and Subtraction

To add or subtract quantities in the SI, reduce them to a *common denomination*, preferably a base unit, and arrange their denominate numbers for addition or subtraction as ordinary decimals.

Examples:

Add 1 kg, 250 mg, and 7.5 g. Express the total in grams.

$$\begin{array}{rcl}
 1 \text{ kg} & = & 1000. \text{ g} \\
 250 \text{ mg} & = & 0.25 \text{ g} \\
 7.5 \text{ g} & = & \underline{7.5 \text{ g}} \\
 \hline
 1007.75 \text{ g} & \text{or} & 1008 \text{ g, answer.}
 \end{array}$$

Add 4 L, 375 mL, and 0.75 L. Express the total in milliliters.

Guidelines for the correct use of the SI

The following are selected guidelines for the correct use of the SI:

- 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:

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

- 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.).

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

Examples:

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

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

Examples:

5 mL/h or $5\text{mL} \cdot \text{h}^{-1}$, **not** 5 mL per hour.

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

Examples:

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

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

Examples:

5milliliters or 5mL, Not 5mLs.

- Two symbols exist for microgram: **mcg** (often used in pharmacy practice) and **µg** (SI).
- The symbol for square meter is **m²**; for cubic centimeter, **cm³**; and so forth.
- In pharmacy practice, **cm³** is considered equivalent to **milliliter**. The symbol **cc**, for cubic centimeter, is **not** an accepted SI symbol.
- Decimal fractions are used, not common fractions.

Example:

5.25g, not 5 1/4 g.

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

Example:

0.5g, not .5g.

- 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.

To prevent misreadings and medication errors, “trailing” zeros should not be placed following a whole number on prescriptions and medication orders.

Example:

5mg, not 5.0mg.

- 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:

500g, rather than 0.5k;

1.96kg, rather than 1960g; and

750 mL, rather than 0.75L.

Example 1:

If a chlorpheniramine maleate tablet weighs 0.26 gram, one-fourth of the same tablet weighs how many milligrams?

Since the answer is required in milligrams, convert the weight of the tablet into milligrams first.

$$0.26 \text{ g} = 0.26 \times 1000 = 260 \text{ mg}$$

$$1/4 \times 260 \text{ mg} = 65 \text{ mg}$$

answer: 65 mg

Example 2:

If a vial of gentamycin contains 80 mg of drug in 2 mL, how many micrograms of the drug are present in 0.025 mL?

$$80 \text{ mg} = 80,000 \text{ } \mu\text{g}$$

By the method of proportion, if 80,000 μg are contained in 2 mL, how many micrograms are contained in 0.025 mL?

$$2 \text{ mL}/80,000 = 0.025 \text{ mL}/X$$

answer: $X = 1000 \text{ } \mu\text{g}$

In addition to metric system, other systems (**apothecaries and avoirdupois** so called common systems of measurement) are encountered in pharmacy and must be recognised and understood.

Apothecary is a historical name for a medical practitioner who formulates and dispenses medical materials to physicians, surgeons and patients — a role now served by a pharmacist.

Unlike **the metric system** which has units for **weight, volume, and length**, **the apothecaries' system** has units for **weight and volume only**. This is an old system and its use is rapidly declining. However, **some physicians still prescribe using this system**. A few drug labels that were originally produced under the apothecaries' system, still state the apothecaries' equivalent on the label. As a few examples, phenobarbital, aspirin, codeine, sodium bicarbonate, and potassium iodide labels appear in the metric as well as apothecary units. Moreover, a few questions have also appeared in the apothecaries' units in pharmacist licensing examinations. Therefore, pharmacists are still required to learn this system.

The basic unit **for weight is grain (gr)** and that of **volume is minim (m)**. Unlike the metric units, **the amount is expressed in Roman numerals after the apothecaries' symbol**. For example, $\frac{1}{2}$ grain is expressed as gr ss but not $\frac{1}{2}$ gr. Twenty minims is expressed as m xx. Sometimes physicians also use Arabic numerals in the apothecary system. For example 12 ounces can be written as ̄ XII or 4 ounces as 4 ̄. Tables 2.4 and 2.5 show the relationships between measures of liquid volume and solid weight in the apothecaries' system.

Apothecaries' Fluid measures

Unit	Symbol	Division	Minims	Millilitres
Gallon	gal.	4 quarts	61440	3785
Quarts	qt	2 pints	15360	946
Pint	pt.	16 fluidounces	7680	473
Fluidounce	(oz.) ʒ	8 fluidrachms	480	29.57
fluidrachm	(dr.) ʒ	60 minims	60	3.69
Minim			1	0.06

Apothecaries' weight measures

Unit	Symbol	Division	Grains	Grams
Pound	lb	12 ounces	5760	373.2
Ounce	ʒ	8 drams	480	31.1
Drachm	ʒ	3 scruples	60	3.9
Scruple	ʒ	20 grains	20	1.3
Grain	gr		1	0.065

Example 1:

If a prescription calls for gr ii thyroid desiccated tablets and the pharmacist has gr ss tablets in stock, how many tablets of gr ss should be provided?

$$\text{gr ii} = 2 \text{ grains}$$

$$\text{gr ss} = \frac{1}{2} \text{ grain}$$

$$2 \div \frac{1}{2} = 4 \text{ tablets of gr ss}$$

answer: 4 tablets of gr ss

Example 2:

How many doses of $\frac{z}{iv}$ are present in O iiss of Maalox®?

$$\text{O iiss} = 2\frac{1}{2} \text{ pints}$$

$$= 2.5 \times 16 \text{ ounces} = 40 \text{ ounces}$$

$$= 40 \times 8 = 320 \text{ fluidrams}$$

$$= 320/4 = 80 \text{ doses}$$

answer: 80 doses

THE AVOIRDUPOIS SYSTEM

The avoirdupois system is also an old system used by the pharmacist, in the past, for ordering bulk chemicals. Since this system is no longer used, practice problems on this topic will not be provided. However, for reference considerations, the following conversions of avoirdupois weights are provided:

It is the everyday system of weight used in the United States, Canada and the United Kingdom.

Unit	Symbol	Division	Grains	Grams
Pound	lb	16 ounces	7000	454
Ounce	$\frac{z}{i}$		437.5	28.35
Grain	gr		1	0.065

Conversion between systems

UNIT	PRACTICAL PHARMACY EQUIVALENT	PRECISE EQUIVALENT ^a	
Conversion Equivalents of Length			
1 m	39.37 in	39.37008	in
1 in	2.54 cm (exact)		
Conversion Equivalents of Volume			
1 mL	16.23 mL	16.23073	mL
1 mL	0.06 mL	0.06161152	mL
1 f $\bar{3}$	3.69 mL	3.696691	mL
1 f $\bar{5}$	29.57 mL	29.57353	mL
1 pt.	473 mL	473.1765	mL
1 gal. (U.S.) ^b	3785 mL	3785.412	mL
Conversion Equivalents of Weight			
1 g	15.432 gr	15.43236	gr
1 kg	2.20 lb (avoir.)	2.204623	lb (avoir.)
1 gr	0.065 g (65 mg)	0.06479891	g
1 oz. (avoir.)	28.35 g	28.349523125	g
1 $\bar{5}$	31.1 g	31.1034768	g
1 lb (avoir.)	454 g	453.59237	g
1 lb (apoth.)	373 g	373.2417216	g
Other Useful Equivalents			
1 oz. (avoir.)	437.5 gr (exact)		
1 $\bar{5}$	480 gr (exact)		
1 gal. (U.S.)	128 f $\bar{5}$ (exact)		

^a Precise equivalents from the National Institute of Standards and Technology. Available at: <http://ts.nist.gov/htdocs/200/2002/mpohome.htm>. Accessed September 25, 2008.

^b The U.S. gallon is specified because the British imperial gallon and other counterpart measures differ substantially, as follows: British imperial gallon, 4545 mL; pint, 568.25 mL; f $\bar{5}$, 28.412 mL; f $\bar{3}$, 3.55 mL; and mL , 0.059 mL. Note, however, that the SI is used in both the *United States Pharmacopeia* and the *British Pharmacopeia*.

Pharmaceutical Calculations

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 ounce (oz, Avoirdupois)	=	28.35 g
1 kilogram (kg)	=	2.2 lb

THE HOUSEHOLD SYSTEM

Though inaccurate, the use of the household system of measurements is on the rise because of an increased home health care delivery. In this system, the patients use household measuring devices such as the teaspoon, dessertspoon, tablespoon, wine-glass, coffee cup, etc. In the past, a drop has been used as an equivalent of a minim. But such a measure should be discouraged because of many factors affecting the drop size which include the density of the medication, temperature, surface tension, diameter and opening of the dropper, and the angle of the dropper. The official medicinal dropper (USP-NF) has an external diameter of 3 mm, and delivers 20 drops per mL of water at 25°C. Some manufacturers provide specially calibrated droppers with their products. A few examples of medications containing droppers include Tylenol® pediatric drops, Advil® pediatric drops, and Neosynephrine® nasal drops. Several ear, nose, and eye medications are now available in calibrated containers which provide drops by gently pressing the containers. Sometimes, the health care professional has to calibrate the dropper for measuring small quantities such as 0.1 mL or 0.15 mL, when the calibrated dropper is not supplied by the manufacturer. The calibration procedure is outlined in the following section.

Household Measures.

1 teaspoonful* (tsp)	=	5 mL
1 dessertspoonful (dssp)	=	8 mL
1 tablespoonful (tbsp)	=	15 mL
1 ounce	=	2 tbsp or 30 mL
1 wine-glass	=	1 ounce
1 coffee cup	=	6 fluidounces
1 glass	=	8 fluidounces
1 quart (qt)	=	1 liter

* Some physicians denote this by $\bar{5}$. If this symbol appears in the directions for patient, it is equivalent to 5 mL. If the symbol appears in the compounding or the enlargement/reduction of formulae, it is equivalent to 3.69 mL by the apothecary measure.

Calibration of the Medicinal Dropper

A dropper is calibrated by counting the number of drops required to transfer 2 mL of the intended liquid from its original container to a 5-mL measuring cylinder. For example, if it takes 40 drops to measure 2 mL of a liquid, then the number of drops to measure 0.15 mL of the liquid is obtained by the method of proportion as follows:

$$40 \text{ drops}/2 \text{ mL} = X \text{ drops}/0.15$$

$$X = 3 \text{ drops}$$

answer: 3 drops