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1.1 Chemistry & Measurements

Scientists throughout the world use the International System of Units, abbreviated SI, for their measurements. There are seven base units in the SI system.

TABLE 1.3 The Seven Fundamental SI Units of Measure

Physical quantity	Name of unit	Abbreviation
Mass	kilogram	kg
Length	meter	m
Temperature	kelvin	K
Amount of substance	mole	mol
Time	second	s
Electric current	ampere	A
Luminous intensity	candela	cd

Measurements can involve very large or very small units that do not correspond with the base SI units. SI units are conveniently modified by a series of prefixes that represent multiples of the base units. Thus 1/1000th of a meter (or 0.001m) becomes 1 millimeter or simply 1 mm.

TABLE 1.4 Some Prefixes for Multiples of SI Units

Factor	Prefix	Symbol	Example
$1{,}000{,}000{,}000 = 10^9$	giga	G	1 gigameter (Gm) $= 10^9$ m
$1{,}000{,}000 = 10^6$	mega	M	1 megameter (Mm) $= 10^6$ m
$1{,}000 = 10^3$	kilo	k	1 kilogram (kg) $= 10^3$ g
$100 = 10^2$	hecto	h	1 hectogram (hg) = 100 g
$10 = 10^1$	deka	da	1 dekagram (dag) = 10 g
$0.1 = 10^{-1}$	deci	d	1 decimeter (dm) = 0.1 m
$0.01 = 10^{-2}$	centi	c	1 centimeter (cm) = 0.01 m
$0.001 = 10^{-3}$	milli	m	1 milligram (mg) = 0.001 g
*$0.000\ 001 = 10^{-6}$	micro	μ	1 micrometer (μm) $= 10^{-6}$ m
*$0.000\ 000\ 001 = 10^{-9}$	nano	n	1 nanosecond (ns) $= 10^{-9}$ s
*$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	p	1 picosecond (ps) $= 10^{-12}$ s

*For very small numbers, it is becoming common in scientific work to leave a thin space every three digits to the right of the decimal point.

Because the numbers chemists use are often very small or very large, it is convenient to express these numbers in scientific notation. Notice also that all measurements contain both a number and the unit of measure.

1.2 Measuring Mass

Mass is defined as the amount of matter in an object. The standard SI unit of mass is the kilogram (1 kg weighs 2.205 lb). Smaller mass units are frequently used in chemistry.

$$1 \text{ gram} = 0.001 \text{ kg} = 1.0 \times 10^{-3} \text{ kg}$$

$$1 \text{ milligram (1 mg)} = 1.0 \times 10^{-3} \text{ g}$$

$$1 \text{ microgram (1μg)} = 1.0 \times 10^{-6} \text{ g}$$

Note that the terms mass and weight are used interchangeably, but they do have different

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meanings. Mass is the amount of matter in an object, while weight is a measure of the pull of gravity on an object.

1.3 Measuring Length

The standard unit of length in the SI system is the meter, abbreviated m (1 m = 39.37 in). A meter, like a kilogram, is too large a unit of measure for most chemistry work. Chemists frequently use the following smaller units of measure:

1 centimeter (1 cm) = 0.01 m = 1.0×10^{-2} m

1 millimeter (1mm) = 1.0×10^{-3} m

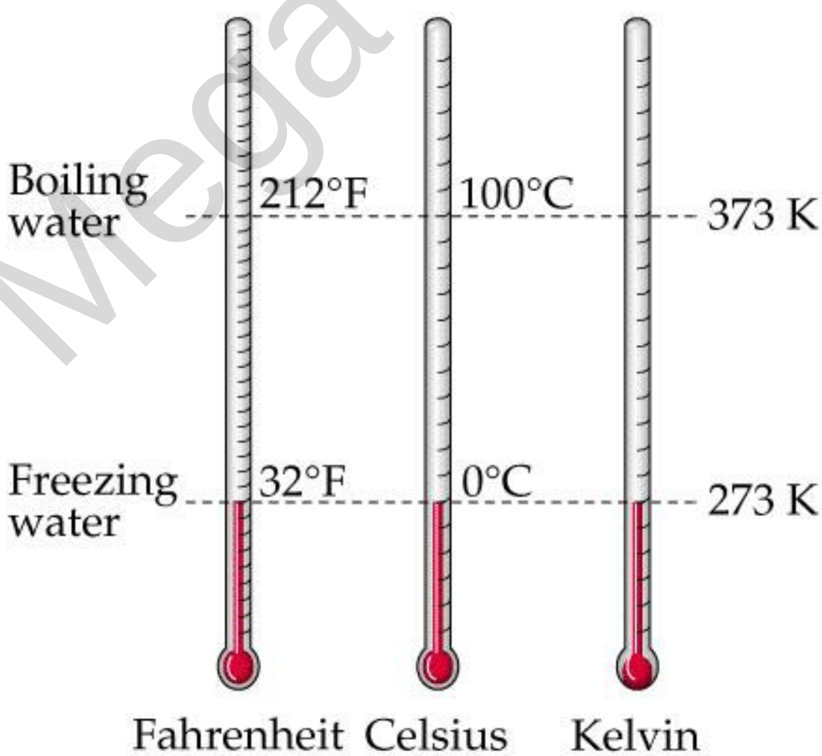
1 micrometer (1μm) = 1.0×10^{-6} m

1 nanometer (1nm) = 1.0×10^{-9} m

1 picometer (1 pm) = 1.0×10^{-12} m

1.4 Measuring Temperature

Of the three common temperature scales, the Kelvin scale is generally used for scientific work. Much of the world uses the Celsius scale, except the United States which uses the Fahrenheit scale. The kelvin (abbreviated K), as the unit of measure is called, is the same physical increment as a Celsius degree (abbreviated °C). The difference between the two units of measure is that the corresponding temperature scales are offset by a fixed amount. The Fahrenheit degree (abbreviated °F) is smaller than the Kelvin and Celsius degrees, and the Fahrenheit scale is offset by a different amount.



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An understanding of the three temperature scales will help you make temperature conversions without blindly applying a formula. Look at the number of degrees that separate the freezing point of water and the boiling point of water on the Fahrenheit scale: There are 180 degrees. This same temperature interval is separated by 100°C and 100 K. Thus, one °F is 100/180 or 5/9 the size of a kelvin or °C. That is, there are fewer Celsius degrees than Fahrenheit degrees in the same range because Celsius degrees are "fatter". The Fahrenheit scale is offset from the Celsius scale by 32°F. These facts lead to the following conversion equations:

$$°F = \left(\frac{9°F}{5°F}\right)(°C) + 32°F$$

$$°C = \left(\frac{5°F}{9°F}\right)(°F - 32°F)$$

The Kelvin scale is offset from the Celsius scale by 273.15. Thus,

$$\text{Temperature in K} = \text{Temperature in °C} + 273.15$$

$$\text{Temperature in °C} = \text{Temperature in K} - 273.15$$

Let's convert a temperature commonly used in baking—350°F—to °C and to kelvins. Our conversion path will be to convert from °F to °C, then perform a second conversion from °C to K. To convert from °F to °C, we first subtract the offset of 32.

$$350°F – 32 = 318°F$$

Next we convert the size of the degrees.

$$318°F (5°C/9°C) = 177°C$$

To convert °C to kelvins, we simply add 273.15, the Kelvin scale offset.

$$177 + 273.15 = 450 \text{ K}$$

1.5 Derived Units: Measuring Volume

The seven fundamental SI units are not sufficient to describe units of measurement for such things as area, volume, density, etc. These units are called derived units because they can be expressed using one or more of the seven base units.

TABLE 1.5 Some Derived Quantities

Quantity	Definition	Derived Unit (Name)
Area	Length times length	m^2
Volume	Area times length	m^3
Density	Mass per unit volume	kg/m^3
Speed	Distance per unit time	m/s
Acceleration	Change in speed per unit time	m/s^2
Force	Mass times acceleration	$(kg \cdot m)/s^2$ (newton, N)
Pressure	Force per unit area	$kg/(m \cdot s^2)$ (pascal, Pa)
Energy	Force times distance	$(kg \cdot m^2)/s^2$ (joule, J)

Volume, the amount of space occupied by an object, is measured in SI units by the cubic meter, abbreviated m^3. Smaller, more convenient measures of volume are frequently used.

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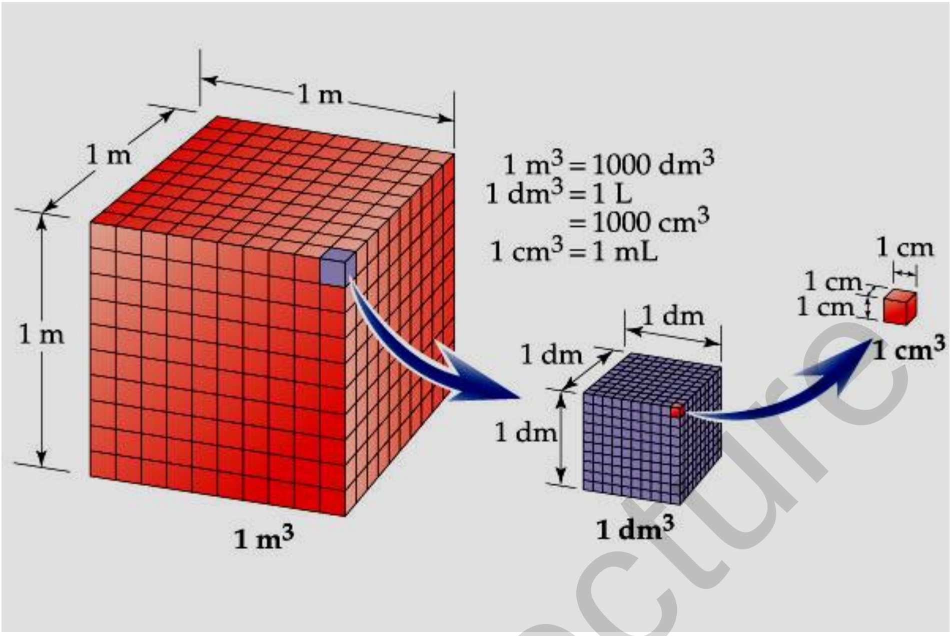
$1\ dm^3 = 1$ liter (1 L)

$1\ cm^3 = 1$ milliliter (1 mL)



Measuring liquid volume is a common laboratory task. Some of the specialized glassware used in chemistry labs is shown below. Which one is the buret?

(a)

(b)

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1.6 Derived Units: Measuring Density

Density is an intensive physical property that relates the mass of an object to its volume.

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (mL or cm}^3\text{)}}$$

Notice the wide range of densities of common substances listed in the table below.

TABLE 1.6 Densities of Some Common Materials

Substance	Density (g/cm^3)	Substance	Density (g/cm^3)
Ice (0°C)	0.917	Human fat	0.94
Water (4.0°C)	1.0000	Cork	0.22–0.26
Gold	19.31	Table sugar	1.59
Helium (25°C)	0.000 164	Balsa wood	0.12
Air (25°C)	0.001 185	Earth	5.54

The volume of many substances changes with temperature, so densities, too, are temperature dependent.

Density provides a useful link in the laboratory between the mass of a substance and its volume. It is sometimes simpler to use volumetric glassware to measure a particular volume of a substance, and then to convert that volume to mass.

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