

## What is the SI system of measurement?

### The Model—the International System of Units

#### SI Units of Measure

A series of international conferences on weights and measures has been held periodically since 1875 to refine the metric system. At the 11<sup>th</sup> conference held in France in 1960, a new system of units known as the ***International System of Units*** (abbreviated SI in all languages) was proposed as a replacement to the metric system. The five of the seven base units for the SI system are given in **Table 1**—missing from the table are electric current (ampere) and luminous intensity (candela), units that aren't of interest to us this year. You will need **to memorize the base unit and its symbol for each as shown in Tables 1 & 2** as they will be used extensively in chemistry.

**Table 1.** SI base units and their symbols

| Physical Quantity   | Name of base unit | Symbol |
|---------------------|-------------------|--------|
| Length              | Meter             | m      |
| Mass                | kilogram          | kg     |
| Time                | Second            | s      |
| Temperature         | Kelvin            | K      |
| Amount of substance | Mole              | mol    |

#### Derived SI Units

The units of every measurement in the SI system, no matter how simple or complex should be derived from one or more of the seven base units. For example, the preferred unit for volume is the cubic meter, m<sup>3</sup>, because volume has units of length cubed and the SI unit for length is the meter. Strict adherence to SI units would require changing directions such as “add 250 mL of water to a 1-Liter beaker” to add 0.00025 cubic meters of water to an 0.001 m<sup>3</sup> container. Because of this, a number of units that are not strictly acceptable under the SI convention are still in use. Some of the common non-SI units in common in use are in **Table 2**.

**Table 2.** Non-SI units in common use.

| Physical Quantity | Name of base unit         | Symbol      |
|-------------------|---------------------------|-------------|
| Volume            | Liter                     | L           |
| Temperature       | degree Celsius            | °C          |
| Concentration     | molarity                  | <i>M</i>    |
| Pressure          | Atmosphere<br>torr = mmHg | atm<br>mmHg |

**Table 3.** Common decimal prefixes used with SI units of measure that **should be memorized**

| Prefix | Prefix Symbol | Meaning    | Exponential Notation |
|--------|---------------|------------|----------------------|
| Mega   | M             | million    | $1 \times 10^6$      |
| Kilo   | k             | thousand   | $1 \times 10^3$      |
| Centi  | c             | hundredth  | $1 \times 10^{-2}$   |
| Milli  | m             | thousandth | $1 \times 10^{-3}$   |
| Micro  | $\mu$         | millionth  | $1 \times 10^{-6}$   |
| Nano   | n             | billionth  | $1 \times 10^{-9}$   |

Note the following examples:

- “milli” means one-thousandth; so a milliliter (symbol: mL) is one thousandth of a Liter and it takes 1000 mL to make 1 L; therefore  $1 \text{ L} = 1000 \text{ mL}$
- “kilo” means one thousand; so “kilogram” (kg) means one thousand grams:  $1 \text{ kg} = 1000 \text{ g}$ . One millionth of a gram would be represented by one microgram ( $\mu\text{g}$ ):  $1 \mu\text{g} = 10^{-6} \text{ g}$ . It takes one million micrograms to equal one gram:  $10^6 \mu\text{g} = 1 \text{ g}$
- one centimeter (1 cm) is equal to 0.01 m because one cm is “one hundredth of a meter”:  
 $1 \text{ cm} = 0.01 \text{ m} = 10^{-2} \text{ m}$

### *Key Questions*

1. How many milligrams are there in one kilogram?
2. How many meters are in 21.5 km?
3. Is it possible to answer this question: How many mg are in one km? Explain.
4. a.) What is the difference between a Mm and a mm?  
  
b.) Which is larger 1.0 Mm or 1.0 mm? Explain.

5. Complete the table below by indicating what physical quantity each measurement is measuring.

| Measurement         | Physical Quantity Measured |
|---------------------|----------------------------|
| 1.33 m <sup>3</sup> |                            |
| 298.6 K             |                            |
| 3.47 L              |                            |
| 44 µg               |                            |
| 8.75 mm             |                            |
| 760 torr            |                            |

| Measurement | Physical Quantity Measured |
|-------------|----------------------------|
| 22.8 °C     |                            |
| 2.0 M       |                            |
| 3.8 atm     |                            |
| 78.4 mL     |                            |
| 18.3 cm     |                            |
| 44.8 ng     |                            |

### *How does one convert from one unit of measure to another?*

#### **The Model: The Factor-label Method**

In scientific measurements, units usually follow the numerical value. When mathematically manipulating scientific measurements, you will often need to convert from one unit to another. When this is done, you must multiply what is given by one. In the **Factor-Label Method** (also called "dimensional analysis"), we multiply what is given by one or more conversion factors. In a conversion factor, what is in the numerator must be equivalent to what is in the denominator (otherwise, you're not multiplying by one!). You must apply conversion factors such that the units cancel appropriately. Therefore, you will constantly be asking the questions: "What units do I have? Is it in the numerator or in the denominator? What units can I convert to from what I have?"

**Units you have but no longer want will be written in the conversion factor  
on the opposite side of the division bar.**

For example, if the units you have but want to convert from are in the numerator, those units will be put in the denominator of the conversion factor.

**Example 1.** Using more than one conversion factor

By definition, 1 inch is equivalent to 2.54 centimeters, 1 foot is equivalent to 12 inches, and 1 mile is equivalent to 5280 feet. How many kilometers are in a mile?

$$1 \cancel{\text{mi}} \times \frac{5280 \cancel{\text{ft}}}{1 \cancel{\text{mi}}} \times \frac{12 \cancel{\text{in}}}{1 \cancel{\text{ft}}} \times \frac{2.54 \cancel{\text{cm}}}{1 \cancel{\text{in}}} \times \frac{1 \cancel{\text{m}}}{100 \cancel{\text{cm}}} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} = 1.609344 \text{ km}$$

What we've started with: the distance is 1 mile.

What can we convert from miles to? In our list of givens, we are told that "1 mile is equivalent to 5280 feet." Since we have "mi" in the numerator, "mi" must be placed in the denominator in the conversion factor. Consequently, "ft" goes in the numerator. Since "1 mile is equivalent to 5280 feet," the number "5280" accompanies "ft" and "1" goes with "mi".

What can we convert from feet to? In our list of givens, we are told that "1 foot is equivalent to 12 inches." Since we have "ft" in the numerator, "ft" must be placed in the denominator in the conversion factor. Consequently, "in" goes in the numerator. Since "1 foot is equivalent to 12 inches," the number "12" accompanies "in" and "1" goes with "ft".

*etc.*

**Example 2.** Conversion factor raised to a power

The density of isopropyl alcohol is 6.56 pounds per gallon. What is the density of isopropyl alcohol in grams per cubic centimeter? (1 kg = 2.205 lb, 1 gal = 3.785 L, 1 L = 1 dm<sup>3</sup>)

$$\frac{6.56 \cancel{\text{lb}}}{1 \cancel{\text{gal}}} \times \frac{1 \cancel{\text{kg}}}{2.205 \cancel{\text{lb}}} \times \frac{1000 \text{ g}}{1 \cancel{\text{kg}}} \times \frac{1 \cancel{\text{gal}}}{3.785 \cancel{\text{L}}} \times \frac{1 \cancel{\text{L}}}{1 \cancel{\text{dm}^3}} \times \left( \frac{1 \text{ dm}}{10 \text{ cm}} \right)^3 = 0.786 \text{ g/cm}^3$$

What we've started with: the density is 6.56 pounds per gallon.

What can we convert from pounds to? In our list of givens, we are told that "1 kg = 2.205 lb." Since we have "lb" in the numerator, "lb" must be placed in the denominator in the conversion factor. Consequently, "kg" goes in the numerator. Since "1 kg = 2.205 lb," the number "1" accompanies "kg" and "2.205" goes with "lb".

*etc.*

Before this conversion factor, the units are g/dm<sup>3</sup>. So far "dm" is in the denominator. Therefore, in this conversion factor, "dm" must be in the numerator. Consequently, "cm" goes in the denominator. We know from the prefixes "deci" and "centi" that there are 10 centimeters in 1 decimeter, so the numbers of the conversion factor are "1" in the numerator and "10" in the denominator. But since the units of dm are cubed, we must cube dm in the conversion factor. To maintain that what is in the numerator is equal to what is in the denominator, the entire conversion factor is cubed.

**Key Questions**

6. What in the numerator of a conversion factor must be equivalent to what is in the denominator of the conversion factor. Explain why.
  
7. Consider the exercise: "How many seconds are there in 50 minutes?" Suppose it was solved in the following way:

$$50. \text{ min} \times \frac{1 \text{ min}}{60 \text{ s}} = 0.83 \text{ s}$$

- a.) Is the answer reasonable? Explain.

M. Davis

- b.) Comment on how the units were handled. What “rule” of the model (the factor-label method) was broken in the above solution?

### Exercises

Instructions: Show your work using the factor-label method. Circle your answers and use correct units and significant figures for all questions—no work, no credit. Use the table of SI – English conversion factors on the inside back cover of your text as needed.

8. Perform the following unit conversions Show your work in each case using the factor-label method. Circle your answers and use correct sig figs.

a.)  $15.60 \text{ cm} = \underline{\quad} \text{ m}$

b.)  $41.0 \text{ kg} = \underline{\quad} \mu\text{g}$

c.)  $9.2 \text{ mL} = \underline{\quad} \mu\text{L}$

d.)  $9.16 \times 10^{-5} \text{ m} = \underline{\quad} \text{ nm}$

9. The distance between two adjacent peaks on a wave is called the wavelength. The wavelength of visible light determines its color.

a.) The wavelength of a beam of green light is 545 nm. What is its wavelength in meters?

b.) The wavelength of a beam of red light is 683nm. What is its wavelength in inches?

10. A home fashions designer from Europe comes to the United States and decides to purchase some gorgeous fabric that she knows she cannot find back in her home town. She asks the salesperson at the fabric store to cut  $36 \text{ m}^2$  of the material. The salesperson unfortunately does not have a measuring tape that gives meters, but she has one that measures yards ( $1 \text{ yd} = 3 \text{ ft}$ ). How many square yards does the salesperson need to cut?

11. One manufacturer boasts that their car offers a gas mileage of 32 mi/gal. A European manufacturer advertises that their car has a gas mileage of 15 km/L. Which car would be more economical to operate on the basis of gas mileage? Justify your answer with the appropriate calculation(s).
12. The volume of a certain bacterial cell is  $1.72 \times \mu\text{m}^3$ .  
a.) What is the cell's volume in cubic millimeters,  $\text{mm}^3$ ?  
  
b.) What is the volume in liters of  $1.0 \times 10^5$  of these bacterial cells?
13. An Olympic-size pool is 50.0 m long and 25.0 m wide.  
a.) How many gallons of water (assume  $d_{\text{water}} = 1.00 \text{ g/mL}$ ) are needed to fill the pool to an average depth of 4.8 ft?  
  
b.) What is the mass in kg of water in the pool?
14. Nutritional tables give the potassium content of a standard apple (about 3 apples per pound, lb.) as 159 mg. How many grams of potassium are in 4.25 kg of apples?