3.5 Unit Conversion (Dimensional Analysis)

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Dimensional Analysis is a *problem-solving method* that uses the fact that any number with a unit can be changed into another number with a different but *equally proportional.* This proportion is called unit factors and may be made from any two terms that describe equivalent amounts of what we are interested in.

For example:

Given: 1 inch = 2.54 centimeters

We can make two unit factors from this information, and set it up as a proportion.

$$\frac{1 \text{ inch}}{2.54 \text{ centimeters}} \quad \text{or} \quad \frac{2.54 \text{ centimeters}}{1 \text{ inch}}$$

If we know these proportions then we can take one unit and change it to another by setting our values equal to the information that you are given. *The problem is solved by multiplying the given data and its units by the appropriate unit factors so that only the desired units are present at the end.*

For example:

How many centimeters are in 6.00 inches?

$$? \text{ cm} = 6.00 \cancel{\text{in}} \times \frac{2.54 \text{ cm}}{1 \cancel{\text{in}}} = 15.2 \text{ cm (to 3 significant figures)}$$

Express 24.0 cm in inches.

$$? \text{ in} = 24.0 \cancel{\text{cm}} \times \frac{1 \text{ in}}{2.54 \cancel{\text{cm}}} = 9.45 \text{ in (to 3 significant figures)}$$

How many seconds are in 2.0 years?

$$? \text{ s} = 2.0 \cancel{\text{yr}} \times \frac{365 \cancel{\text{days}}}{1 \cancel{\text{yr}}} \times \frac{24 \cancel{\text{hr}}}{1 \cancel{\text{day}}} \times \frac{60 \cancel{\text{min}}}{1 \cancel{\text{hr}}} \times \frac{60 \text{ s}}{1 \cancel{\text{min}}}$$
$$= 6.3 \times 10^7 \text{ s (to 2 significant figures)}$$

Unit Prefixes

For the metric system there are prefixes to units that tell how big that unit is proportional to a common order of magnitude. Typically we use this to change dimensions of similar units such as going from a unit of meters to kilometers or a unit of milliliters to liters.

Prefix	Abbreviation	Meaning	Example
mega-	M	10^6	1 megameter (Mm) = 1 x 10^6 m
kilo-	k	10^3	1 kilogram (kg) = 1 x 10^3 g
centi-	c	10^{-2}	1 centimeter (cm) = 1 x 10^{-2} m
milli-	m	10^{-3}	1 milligram (mg) = 1 x 10^{-3} g
micro-	μ	10^{-6}	1 micrometer (μg) = 1 x 10^{-6} μg
nano-	n	10^{-9}	1 nanogram (ng) = 1 x 10^{-9} g

For example:

Convert 50.0 mL to liters. (This is a very common conversion.)

$$? \text{ L} = 50.0 \cancel{\text{mL}} \times \frac{1 \text{ L}}{1000 \cancel{\text{mL}}} = 0.0500 \text{ L (to 3 significant figures)}$$

What is the density of mercury (13.6 g/cm^3) in units of kg/m^3?

$$? \text{ D}\left(\frac{\text{kg}}{\text{m}^3}\right) = \frac{13.6 \text{ g}}{1 \text{ cm}^3} \times \frac{(100 \text{ cm})^3}{(1 \text{ m})^3} \times \frac{1 \text{ kg}}{1000 \text{ g}}$$
$$= \frac{13.6 \cancel{\text{g}}}{1 \cancel{\text{cm}^3}} \times \frac{1 \times 10^6 \cancel{\text{cm}^3}}{1 \text{ m}^3} \times \frac{1 \text{ kg}}{1000 \cancel{\text{g}}}$$
$$= 1.36 \times 10^4 \text{ kg/m}^3$$

We also can use dimensional analysis for solving problems, that are a little bit more difficult, let’s look at this one from a common chemistry problem.

For example:

How many atoms of hydrogen can be found in 45 g of ammonia, NH_3?

We will need three unit factors to do this calculation, derived from the following information:

1. 1 mole of NH_3 has a mass of 17 grams.
2. 1 mole of NH_3 contains 6.02×10^{23} molecules of NH_3.
3. 1 molecule of NH_3 has 3 atoms of hydrogen in it.

$$\text{? atoms H} = 45 \text{ g } NH_3 \times \underbrace{\frac{1 \text{ mol } NH_3}{17 \text{ g } NH_3}}_{\text{STEP 1}} \times \underbrace{\frac{6.02 \times 10^{23} \text{ molecules } NH_3}{1 \text{ mol } NH_3}}_{\text{STEP 2}} \times \underbrace{\frac{3 \text{ atoms H}}{1 \text{ molecule } NH_3}}_{\text{STEP 3}}$$

$$= 4.8 \times 10^{24} \text{ atoms H (2 significant figures)}$$