Key

Unit Conversions and Problem Solving with Dimensional Analysis

Many problems in chemistry require converting a quantity from one unit to another. To perform this conversion, you must use a **conversion factor** or a series of conversion factors that relate two units. This method is called **dimensional analysis.**

Any equality can be written in the form of a fraction called a conversion factor. A conversion factor is easily distinguished from all other numbers because it is always a fraction that contains different units in the numerator and denominator.

Ex) In the United States we may need to convert inches to feet. Since we know the equality is 12 inches = 1 foot, two different conversion factors can be written as seen below. Note the difference units in the numerator and denominator, a requirement for all conversion factors.

Conversion factors: $\frac{\textit{Numerator}}{\textit{Denominator}}$ $\frac{1\ foot}{12\ inches}$ **OR** $\frac{12\ inches}{1\ foot}$

*links the units we are trying to convert between

PRACTICE:

Write the two conversion factors possible for each of the following equalities.

1 g = 1000 mg

$\frac{1g}{1000mg}$ or $\frac{1000mg}{1g}$

1 dozen = 12 eggs

$\frac{1\ dozen}{12\ eggs}$ or $\frac{12\ eggs}{1\ dozen}$

60 minutes = 1 hour

$\frac{60\ min}{1\ hr}$ OR $\frac{1\ hr}{60\ min}$

Dimensional Analysis is a general method for solving numerical problems in chemistry. In this method we follow the rule that when multiplying or dividing numbers, we must also multiply or divide units.

Solving problems with dimensional analysis is, in general, a three-step process.

1. Write down the given measurement; number with units.
2. Multiply the measurement by one or more conversion factors. The unit in each *denominator* of the conversation factor must cancel (or match) the preceding unit in each *numerator.*
3. Perform the calculation and report the answer to proper number of significant figures based on numbers given in the question (data record), not conversion factors used.

Sample Problem 1: Your friend is having a party and asks you to pick up 7 dozen donuts. How many donuts should you buy?

conversion factor

unit we want on top

$7\ \text{dozen} \times \frac{12\ \text{donuts}}{1\ \text{dozen}} = 84\ \text{donuts}$

given unit on bottom so it cancels

NOTE: The final answer is rounded to the significant figures represented in measured value given in the problem. The conversion factor was not used when determining the number of significant figures for the final answer.

*Conversion factors are certain/exact, so they are considered to have ∞ S.F.

Useful Conversion Factors
Length: 1 m = 1.094 yd
2.54 cm = 1 in.
1 mi = 5280 ft
1 mi = 1760 yd
Mass: 1 kg = 2.205 lb
453.6 g = 1 lb.
Volume: 1 L = 1.06 qt
$1\ ft^3 = 28.32\ L$

Your turn:

1. You **have been shrunken down to the size of ant. You're hungry, but you must crawl from your anthill to an apple core that was dropped 2.85 cm away. How many inches must you travel?** cm → inches; 2.54 cm = 1 in

$$2.85\ cm \times \frac{1\ in}{2.54\ cm} = 1.122047244$$

(2.85: 3 sf; 2.54: ∞ sf) round to 3 sf

$$= 1.12\ in$$

2. You are bored on a Friday night and decide to weigh your dog, who is on a diet. You put Fluffy on the bathroom scale and determine that he weighs 76.84 lb. Is he above or below his target weight of 30.0 kg? lbs → kg; 2.205 lb = 1 kg

$$76.84\ lb \times \frac{1\ kg}{2.205\ lb} = 34.84807256\ kg = 34.85\ kg$$

(76.84: 4 sf) round to 4 sf

Fluffy is above his target weight.

3. Your first period class is right next to the main entrance of school, which is great since you tend to be a late riser. The door to the classroom is approximately 5 m from the door to the main entrance. What is this distance in km? m → km; $10^3\ m = 1\ km$ ✱ see Ref. Table C!

$$5\ m \times \frac{1\ km}{10^3\ m} = 0.005\ km$$

(5: 1 sf) put into calc as (10^3 OR E3 NOT 10E3)

Multi-Step Problems

Sometimes there is not a single conversion factor that links the units you want to convert between. In this case, you need to set up a roadmap of conversion factors that will lead from the unit you are given to the unit you want.

Sample: Find the number of centimeters in 5 km. each arrow = 1 conversion factor you'll need to use.

Roadmap: km → m → cm

$10^3\ m = 1\ km$; $10^{-2}\ m = 1\ cm$

$$5\ km \times \frac{10^3\ m}{1\ km} \times \frac{1\ cm}{10^{-2}\ m} = 5 \times 10^5\ cm$$

(5: 1 sf)

Your turn:

4. How many inches are there in a football field that is 100. yards?

Roadmap: yrds → feet → in

1 yd = 3 ft 1 ft = 12 in

$100.\text{ yd} \times \frac{3\text{ ft}}{1\text{ yd}} \times \frac{12\text{ in}}{1\text{ ft}} = 3600 = \boxed{3.60 \times 10^3\text{ in}}$

(3 sf; round to 3 sf.)

5. Find the number of milligrams in 0.3 kg.

Roadmap: kg → g → mg

1 kg = 10^3 g 1 mg = 10^{-3} g

$0.3\text{ kg} \times \frac{10^3\text{ g}}{1\text{ kg}} \times \frac{1\text{ mg}}{10^{-3}\text{ g}} = \boxed{3 \times 10^5\text{ mg}}$

(1 sf)

6. According to the American Time Use Survey conducted by the Bureau of Labor Statistics, the average American spends 2.7 hours per day watching television. If the average life expectancy in the U.S. is 78.85 years, how much time would the average American spend watching T.V. over the course of his/her life?

Roadmap: yrs → days → hrs

1 yr = 365 days 1 day = 2.7 hrs TV

$78.85\text{ yrs} \times \frac{365\text{ days}}{1\text{ yr}} \times \frac{2.7\text{ hrs TV}}{1\text{ day}} = 77706.675 = \boxed{7.8 \times 10^4\text{ hrs}}$

(round to 2 sf.)

7. Your friend wants you to sign up to run a 5 km race. How many centimeters would you run in such a race?

Roadmap: km → m → cm

10^3 m = 1 km 10^{-2} m = 1 cm

(change to mm next yr.)

$5\text{ km} \times \frac{10^3\text{ m}}{1\text{ km}} \times \frac{1\text{ cm}}{10^{-2}\text{ m}} = \boxed{5 \times 10^5\text{ cm}}$

8. The bottle of cold medicine you are using contains 15 g. How many 5 mg doses are in the bottle?

Roadmap: g → mg → doses

10^{-3} g = 1 mg 5 mg = 1 dose

$15\text{ g} \times \frac{1\text{ mg}}{10^{-3}\text{ g}} \times \frac{1\text{ dose}}{5\text{ mg}} = 3000\text{ doses}$

(to 2 sf =)

$\boxed{3.0 \times 10^3\text{ doses}}$