Dimensional Analysis

Dimensional analysis can be used to convert a measurement from one unit into another unit. To do this a ***conversion factor*** is used.

If you want to convert between inches and centimetres the conversion factor is 1 in = 2.54 cm.

This can be expressed as:

$$\left(\frac{1\,\text{in}}{2.54\,\text{cm}}\right) \text{ or } \left(\frac{2.54\,\text{cm}}{1\,\text{in}}\right).$$

If you want to convert from cm to inches you multiply your measurement by the first term in brackets, and if you want to convert from inches to cm you will multiply your measurement by the second term in brackets. Basically the unit that you *already have* should be in the denominator of the conversion factor and the unit you *want* should be in the numerator of the conversion factor.

Example 1: Convert 56.7 cm to inches.

$$56.7\,\text{cm}\left(\frac{1\,\text{in}}{2.54\,\text{cm}}\right) = 22.3\,\text{in}$$

Example 2: Convert 4.57 in to cm.

$$4.57\,\text{in}\left(\frac{2.54\,\text{cm}}{1\,\text{in}}\right) = 11.6\,\text{cm}$$

That's it! That is all there is to it.

See next page for another example!

If you want to convert grams to kilograms the conversion factor is 1 g = 0.001 kg or 1 kg = 1000 g (same thing).

This can be expressed as:

$$\left(\frac{1\,\mathrm{g}}{0.001\,\mathrm{kg}}\right) \text{ or } \left(\frac{0.001\,\mathrm{kg}}{1\,\mathrm{g}}\right) \qquad \left\{\text{alternatively } \left(\frac{1000\,\mathrm{g}}{1\,\mathrm{kg}}\right) \text{ or } \left(\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}}\right)\right\}$$

Example 3: Convert 108 g to kg.

$$108\,\mathrm{g}\left(\frac{0.001\,\mathrm{kg}}{1\,\mathrm{g}}\right) = 0.108\,\mathrm{kg} \qquad \left\{\text{alternatively } 108\,\mathrm{g}\left(\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}}\right) = 0.108\,\mathrm{kg}\right\}$$

Example 4: Convert 0.220 kg in to g.

$$0.220\,\mathrm{kg}\left(\frac{1\,\mathrm{g}}{0.001\,\mathrm{kg}}\right) = 220.\,\mathrm{g} \qquad \left\{\text{alternatively } 0.220\,\mathrm{kg}\left(\frac{1000\,\mathrm{g}}{1\,\mathrm{g}}\right) = 220.\,\mathrm{g}\right\}$$

<u>Using Dimensional Analysis and Mole Ratios to Convert Masses</u>

Scenario 1: Converting mass of one element in the mass of another element when both elements are in the SAME molecule, e.g., N_2O_5

There are four possible ***conversion factors*** we could write down and utilize. These come from the molar mass (found on the periodic table) and the mole ratio (given in the chemical formula).

1 mol of N = 14.01 g → molar mass of N → $\left(\frac{1\,\text{mol N}}{14.01\,\text{g N}}\right)\text{or}\left(\frac{14.01\,\text{g N}}{1\,\text{mol N}}\right)$

1 mol of O = 16.00 g → molar mass of O → $\left(\frac{1\,\text{mol O}}{16.00\,\text{g O}}\right)\text{or}\left(\frac{16.00\,\text{g O}}{1\,\text{mol O}}\right)$

1 mol of N_2O_5 = 108.0 g → molar mass of N_2O_5 → $\left(\frac{1\,\text{mol N}_2\text{O}_5}{108.0\,\text{g N}_2\text{O}_5}\right)\text{or}\left(\frac{108.0\,\text{g N}_2\text{O}_5}{1\,\text{mol N}_2\text{O}_5}\right)$

1 mol N_2O_5 = 2 mol N = 5 mol O → mole ratio given in the chemical formula

$\left\{\left(\frac{1\,\text{mol N}_2\text{O}_5}{2\,\text{mol N}}\right)\text{or}\left(\frac{2\,\text{mol N}}{1\,\text{mol N}_2\text{O}_5}\right)\right\}$ and $\left\{\left(\frac{1\,\text{mol N}_2\text{O}_5}{5\,\text{mol O}}\right)\text{or}\left(\frac{5\,\text{mol O}}{1\,\text{mol N}_2\text{O}_5}\right)\right\}$ and $\left\{\left(\frac{2\,\text{mol N}}{5\,\text{mol O}}\right)\text{or}\left(\frac{5\,\text{mol O}}{2\,\text{mol N}}\right)\right\}$

These ***conversion factors*** are then used to convert from grams of N to grams of O.

Example 1: How many grams of O will be present in N_2O_5 if there are 0.450 g of N present?

$$0.450\,\text{g N}\left(\frac{1\,\text{mol N}}{14.01\,\text{g N}}\right)\left(\frac{5\,\text{mol O}}{2\,\text{mol N}}\right)\left(\frac{16.00\,\text{g O}}{1\,\text{mol O}}\right)=1.28\,\text{g O}$$

Example 2: How many grams of N will be present in N_2O_5 if there are 0.678 g of O present?

$$0.678\,\text{g O}\left(\frac{1\,\text{mol O}}{16.00\,\text{g O}}\right)\left(\frac{2\,\text{mol N}}{5\,\text{mol O}}\right)\left(\frac{14.01\,\text{g N}}{1\,\text{mol N}}\right)=0.237\,\text{g N}$$

Example 3: How many grams of O will be present in 2.50 g of N_2O_5?

$$2.50\,\text{g N}_2\text{O}_5\left(\frac{1\,\text{mol N}_2\text{O}_5}{108.0\,\text{g N}_2\text{O}_5}\right)\left(\frac{5\,\text{mol O}}{1\,\text{mol N}_2\text{O}_5}\right)\left(\frac{16.00\,\text{g O}}{1\,\text{mol O}}\right)=1.85\,\text{g O}$$

Scenario 2: Converting mass of one atom or molecule into the mass of another atom or molecule when both elements are in a reaction, e.g., $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

There are several ***conversion factors*** we could write down and utilize. These come from the molar mass (found on the periodic table) and the mole ratio (given in the chemical formula).

1 mol of C_3H_8 = (3 x 12.01 g) + (8 x 1.008 g) = 44.09 g	→ molar mass of C_3H_8
1 mol of O_2 = (2 x 16.00 g) = 32.00 g	→ molar mass of O_2
1 mol of CO_2 = (1 x 12.01 g) + (2 x 16.00 g) = 44.01 g	→ molar mass of CO_2
1 mol of H_2O = (2 x 1.008 g) + (1 x 16.00 g) = 18.02 g	→ molar mass of H_2O
1 mol C_3H_8 = 5 mol O_2 = 3 mol CO_2 = 4 mol H_2O	→ mole ratio given in the chemical equation.

Try writing down the two possible conversion factors on your own.

These ***conversion factors*** are then used to convert from grams of **ANY** of the reactants or products into any other reactant or product.

Example 1: How many grams of O_2 will be needed to produce 25.0 g of CO_2?

$$25.0\,\mathrm{g\,CO_2}\left(\frac{1\,\mathrm{mol\,CO_2}}{44.09\,\mathrm{g\,CO_2}}\right)\left(\frac{5\,\mathrm{mol\,O_2}}{3\,\mathrm{mol\,CO_2}}\right)\left(\frac{32.00\,\mathrm{g\,O_2}}{1\,\mathrm{mol\,O_2}}\right)=30.2\,\mathrm{g\,O_2}$$

Example 2: How many grams of O_2 are required of we have 30.5g of CO_2 present?

$$30.5\mathrm{g\,C_3H_8}\left(\frac{1\,\mathrm{mol\,C_3H_8}}{44.09\,\mathrm{g\,C_3H_8}}\right)\left(\frac{5\,\mathrm{mol\,O_2}}{1\,\mathrm{mol\,C_3H_8}}\right)\left(\frac{32.00\,\mathrm{g\,O_2}}{1\,\mathrm{mol\,O_2}}\right)=111.\,\mathrm{g\,O_2}$$

Example 3: How many grams of CO_2 will be produced from 150. g of C_3H_8?

$$150.\,\mathrm{g\,C_3H_8}\left(\frac{1\,\mathrm{mol\,C_3H_8}}{44.09\,\mathrm{g\,C_3H_8}}\right)\left(\frac{3\,\mathrm{mol\,CO_2}}{1\,\mathrm{mol\,C_3H_8}}\right)\left(\frac{44.01\,\mathrm{g\,CO_2}}{1\,\mathrm{mol\,CO_2}}\right)=449\,\mathrm{g\,CO_2}$$