Stoichiometry & Density

Density can be included in stoichiometry problems because it can be used to calculate **mass** (grams) or **volume** (liters). Density units often are shown as **g/ml**, **g/cm³**, **g/L**, an **g/dm³**. It is important to remember that **cm³** and **ml** are interchangeable, just like **liters** and **dm³** are interchangeable.

For any gas at STP, the molar volume is 22.4 Liters.

Example #1: Find the density of oxygen gas using molar mass and molar volume.

$$\textbf{Density} = \frac{\textbf{mass}}{\textbf{volume}} = \frac{\left(\frac{32\ grams}{1\ mole}\right)}{\left(\frac{22.4\ Liters}{1\ mole}\right)} = \mathbf{1.429\ g/L}$$

Example #2: Using the density of oxygen gas from above, calculate the mass of magnesium required to react with 100. ml of oxygen.

2 Mg (s) + 1 O_2 (g) → 2 MgO (s)

$$\left(\frac{100\ ml\ O_2}{1}\right)\left(\frac{1\ Liter\ O_2}{1000\ ml\ O_2}\right)\boxed{\left(\frac{1.429\ g\ O_2}{1\ Liter\ O_2}\right)\left(\frac{1\ mole\ O_2}{32\ g\ O_2}\right)}\left(\frac{2\ moles\ Mg}{1\ moles\ O_2}\right)\left(\frac{24.3\ g\ Mg}{1\ mole\ Mg}\right) = \mathbf{0.106\ g\ Mg}$$

Notice in the purple box above that the density multiplied by the inverse of the molar mass equals the inverse of the molar volume.

$$\left(\frac{1.429\ g\ O_2}{1\ Liter\ O_2}\right)\left(\frac{1\ mole\ O_2}{32\ g\ O_2}\right) = \left(\frac{\mathbf{1\ mole}}{\mathbf{22.4\ Liters}}\right)$$

So technically, you can do this same problem without using density…

$$\left(\frac{100\ ml\ O_2}{1}\right)\left(\frac{1\ Liter\ O_2}{1000\ ml\ O_2}\right)\left(\frac{\mathbf{1\ mole}\ O_2}{\mathbf{22.4\ Liters}\ O_2}\right)\left(\frac{2\ moles\ Mg}{1\ moles\ O_2}\right)\left(\frac{24.3\ g\ Mg}{1\ mole\ Mg}\right) = \mathbf{0.106\ g\ Mg}$$

WARNING! Don't assume the density given is at STP, unless specifically told so in the problem.

Example #3: What mass of sodium azide must be included in an air bag to generate 68.0 L of N2? Use 0.916 g/L as the density of nitrogen gas.

$$2\ NaN_3\ (s) \rightarrow 2\ Na\ (s) + 3\ N_2\ (g)$$

$$\left(\frac{68\ L\ N_2}{1\ air\ bag}\right)\left(\frac{0.916\ g\ N_2}{1\ Liter\ N_2}\right)\left(\frac{1\ mole\ N_2}{28\ g\ N_2}\right)\left(\frac{2\ moles\ NaN_3}{3\ moles\ N_2}\right)\left(\frac{65\ g\ \ NaN_3}{1\ mole\ NaN_3}\right) = \mathbf{96.4\ g\ \ NaN_3}$$

The actual density of nitrogen gas is 1.25 g/L at STP. This word problem as it is given, is not at STP. You can verify this because molar mass divided by density <u>does not</u> equal molar volume.

$$\frac{\left(\frac{28\ g\ N_2}{1\ mole\ N_2}\right)}{\left(\frac{0.916\ g\ N_2}{1\ Liter\ N_2}\right)} = \left(\frac{\mathbf{30.6\ L\ N_2}}{\mathbf{1\ mole\ N_2}}\right) \quad \mathbf{NOT} \quad \left(\frac{\mathbf{22.4\ Liters}}{\mathbf{1\ mole}}\right)$$