Calculate the mole fraction of ethanol in octane in a 10% by volume mixture (like you would purchase at the gas pump). The densities of octane and ethanol are 0.702 and 0.789 gm/cm$^3$, respectively.

Calculate the mole fraction of ethanol in octane in a 10% by volume mixture (like you would purchase at the gas pump). The densities of octane and ethanol are 0.702 and 0.789 gm/cm$^3$, respectively.

Solution: This problem involves a new conversion since we did not discuss volume conversions. However, the principle is the same. We can write the number of moles as:

$$n_2 = \rho_2 V_2 / M_{m,2}$$

Where $\rho_2$ and $V_2$ are the densty and volume of the solute. Since

$$x_2 = \frac{n_2}{n_1 + n_2}$$

Calculate the mole fraction of ethanol in octane in a 10% by volume mixture.

We can substitute in the expressions for solvent and solute to find

$$x_2 = \frac{\rho_2 V_2 / M_{m,2}}{\rho_1 V_1 / M_{m,1} + \rho_2 V_2 / M_{m,2}}$$

Where for octane

$$\rho_1 = 0.702\ gm/cm^3$$

and for ethanol

$$\rho_2 = 0.789\frac{gm}{cm^3}$$

Then we assume that the volumes are equal to the volume fractions. This is equivalent to assuming that we have 1 L of solution. The total volume cancels.

Calculate the mole fraction of ethanol in octane in a 10% by volume mixture.

The most convenient way to write this is to solve for the numbers of moles first. For octane

$$n_1 = \frac{\rho_1 V_1}{M_{m,1}} = \frac{(0.702)(0.9)}{114} = 0.005542$$

And for ethanol

$$n_2 = \frac{\rho_2 V_2}{M_{m,2}} = \frac{(0.789)(0.1)}{46} = 0.001715$$

The mole fraction is:

$$x_2 = \frac{0.001715}{0.005542 + 0.001715} = 0.236$$

In other words the fuel you purchase is nearly 25% ethanol on a per mole basis.