Answer on the question #54227 – Chemistry – Physical Chemistry

Question:

The vapour pressure of ethanol and methanol are 42.0 mm Hg and 88.5 mm Hg respectively. An ideal solution is formed at the same temperature by mixing 46.0 g of ethanol with 16.0 g of methanol. What is the mole fraction of methanol in the vapour? Please explain how.

Solution:

The content of the ideal solution and its saturated vapour are different. That means that the molar fraction of the component in the vapour and liquid phase are different.

According to Henry's law, the pressure of the solution component above the solution is proportional to its molar fraction:

$$p_i = p_i^0 x_i.$$

Full pressure above the binary solution is:

$$p = p_1 + p_2 = p_1^0 - (p_1^0 - p_2^0)x,$$

where $p_1^0$is the pressure above the pure ethanol, and $p_2^0$is the pressure above the pure methanol,

x is the molar fraction of methanol.

Molar fraction of the component (methanol) is simply the fraction of it's pressure:

$$y = \frac{p_2^0}{p}.$$

Then, using the expressions above, we can derive the equation for the molar fraction of methanol in the vapour:

$$y = \frac{p_2^0 x}{p_1^0 + x(p_2^0 - p_1^0)}.$$

Molar fraction of methanol in solution is:

$$x = \frac{n(MeOH)}{n(MeOH) + n(EtOH)}$$

$$n(MeOH) = \frac{m(MeOH)}{M(MeOH)} = \frac{16}{32.04} = 0.5\ mol$$

$$n(EtOH) = \frac{46}{46.06844} = 1\ mol$$

$$x = \frac{0.5}{1.5} = 0.33, or\ 33\%.$$

Molar fraction in the vapour is:

$$y = \frac{p_2^0 x}{p_1^0 + x(p_2^0 - p_1^0)} = \frac{88.5 * 0.33}{42.0 + 0.33 * (88.5 - 42.0)} = 0.51$$

Answer: 0.51, or 51% of methanol in the vapour above the solution.