

# Solutions - Tutorial 4 of CL 250

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1. Let's assume  $\alpha$  is a phase with mostly turpentine ( $x_1 = 1$ ) and  $\beta$  be the phase with purely water ( $x_2 = 1$ ).

As  $x_1 \rightarrow 1$  we know that  $\gamma_1 = 1$ .

Hence,  $x_1^\alpha \gamma_1^\alpha P_1^{sat} = y_1 P \Rightarrow P_1^{sat} = y_1 P$ , similarly  $P_2^{sat} = y_2 P$ .

$P_1^{sat} = 0.177$  bar,  $P_2^{sat} = 1.013$  bar (given)

Using  $y_1 + y_2 = 1$ , we have  $P = P_1^{sat} + P_2^{sat} = 1.19$  bar

Hence,  $y_1 = \frac{0.177}{1.19} \approx 0.1487$

$y_2 = 1 - y_1 \approx 0.8513$

No. of moles of vapour ( $n$ ) =  $\frac{1}{18 \times 0.8513} \approx 0.06526$  Kmoles per sec

Weight of turpentine condensed =  $ny_1 M \approx 1.358$  kg per one kg of water.

2. Given,  $T = 348$  K.  $P_1^{sat} \approx 1.218$  and  $P_2^{sat} \approx 0.8827$

$\gamma_1 = e^{2.821(1-x_1)^2}$  and  $\gamma_2 = e^{2.821(1-x_2)^2}$

$x_1^\alpha \gamma_1^\alpha P_1^{sat} = x_1^\beta \gamma_1^\beta P_1^{sat} = y_1 P$  and  $x_2^\alpha \gamma_2^\alpha P_2^{sat} = x_2^\beta \gamma_2^\beta P_2^{sat} = y_2 P$

For a LLE,  $x_1^\alpha \gamma_1^\alpha = x_2^\alpha \gamma_2^\alpha \Rightarrow \frac{y_1 P}{y_2 P} = \frac{x_1^\alpha \gamma_1^\alpha P_1^{sat}}{x_2^\alpha \gamma_2^\alpha P_2^{sat}} = \frac{P_1^{sat}}{P_2^{sat}}$

Using,  $y_1 + y_2 = 1$  we have  $y_1 \approx 0.5795$ .

To solve for  $x_1^\alpha$  and  $x_1^\beta$  solve  $A(1 - 2x_1) = \ln(\frac{1-x_1}{x_1})$ , where A is 2.821. (this equation is taken from LLE solved problem 4)

After finding  $x_1^\alpha$  we can find P.

3. For a SLE,  $x_i \gamma_i = \psi_i$

$\psi = e^{\frac{\Delta H^{fus}}{RT_m} \frac{(T-T_m)}{T}} \Rightarrow \psi_i \approx 0.1264$

Hence,  $\gamma_i = \frac{\psi_i}{x_i} \approx 3.75 \times 10^8$

4. For ideal states,  $\gamma_i^l = \gamma_i^s = 1$ .

Hence,  $x_i = z_i \psi_i$ .

Using,  $x_1 + x_2 = 1$  and  $z_1 + z_2 = 1$  we have  $x_1 = \frac{\psi_1(1 - \psi_2)}{\psi_1 - \psi_2}$  and  $x_2 = \frac{\psi_2(1 - \psi_1)}{\psi_2 - \psi_1}$ .

We know,  $\psi = e^{\frac{\Delta H^{fus}}{RT_m} \frac{(T-T_m)}{T}}$ .

We can find  $\frac{x_1}{x_2}$  in terms of  $\psi$ , the only unknown being T. Using an appropriate solver (like desmos) we can find T.

5. For ideal solution,  $\gamma_i^l = 1$ . Assuming immisibility of species in solid state,  $z_i \gamma_i^s = 1$ .

Hence,  $x_i = \psi_i$ . Using  $x_1 + x_2 = 1$  we have  $\psi_1 + \psi_2 = 1$ .

We know,  $\psi = e^{\frac{\Delta H^{fus}}{RT_m} \frac{(T-T_m)}{T}}$ .

Substituting the above in  $\psi_1 + \psi_2 = 1$  and using a solver (like desmos) gives us  $T_e$ . (Eutectic temperature)

Using  $x_i = \psi_i$  we can find  $x_{1,e}$ .

6. Ideal solubility is given by  $\frac{P_i^{sat}}{P}$ . Given,  $T = 308$  K.  $P_1^{sat} = P_1^{sub} \approx 2.751 \times 10^{-4}$  bar.

$$\frac{P_1^{sat}}{P} = 2.751 \times 10^{-4} = \text{ideal solubility.}$$

7. Taking naphthalene as 1 and  $CO_2$  as 2. Solubility ( $x_1$ ) =  $\frac{P_1^{sat} E}{P}$ .

Assuming  $\phi_1^{sat} \approx 1$  as  $P_1^{sat} \approx 2.751 \times 10^{-4}$  bar (very low) as calculated in question 6.

We know that  $\ln \hat{\phi}_1 = \frac{P}{RT} (B_{11} + y_2^2 \delta_{12})$ .

Assuming  $y_2 \approx 1$  and taking  $P = 10$  bar and  $T = 308$  K we get  $\hat{\phi}_1 \approx 0.793$ .

Taking  $V_1^S = 112$  cc per mole, we get  $e^{\frac{V_1^S (P - P_1^{sat})}{RT}} \approx 1.044$ .

We know  $E = \frac{\phi_1^{sat}}{\hat{\phi}_1} e^{\frac{V_1^S (P - P_1^{sat})}{RT}} \approx 1.317$ . Hence,  $y_1 = 3.62 \times 10^{-5}$ .