Chapter 5 Homework Solutions

5.1 Initial: Determination of n_W (moles water) and n_E (moles ethanol).
Assume 1 L = 1000 cm^3 of solution.

$$m_{tot} = 1000\,mL \cdot \frac{0.914\,g}{1\,mL} = 914\,g$$

m_W = 0.50 x 914 = 457 g
m_E = 0.50 x 914 = 457 g

$$n_w = 457\,g \cdot \frac{1\,mol}{18\,g} = 25.4\,mol$$

$$n_E = 457\,g \cdot \frac{1\,mol}{46\,g} = 9.93\,mol$$

Calculation of V_E (Partial Molar Volume of Ethanol in solution)
V = 1000 cm^3
V_W = 17.4 cm^3/mol
V_E = ??

$$V = n_E V_E + n_w V_w \;\rightarrow\; V_E = \frac{V - n_w V_w}{n_E}$$

$$V_E = \frac{1000\,cm^3 - (25.4\,mol)(17.4\,cm^3/mol)}{9.93\,mol} = 56.2\,cm^3/mol$$

Note: The arbitrary assumption of 1000 cm^3 solution has no effect on answer. For example, if we started with 100 cm^3, the volume would be reduced by factor of 10. However, the numbers of moles of both components would be reduced by same factor. The final result would be the same.

5.2 We will determine the (i) the mole fraction of Benzene, (ii) the number of moles of X, (iii) the Molar Mass of X, in that order.

(i) x_X (mole fraction of the unknown, X)

$$p_B = x_B p_B^o \;\rightarrow\; x_B = \frac{p_B}{p_B^o} = \frac{51.5\,kPa}{53.3\,kPa} = 0.966$$

(ii) n_X

$$n_B = 500\,g \cdot \frac{1\,mol}{78\,g} = 6.41\,mol$$

$$x_B = \frac{n_B}{n_B + n_X} \;\rightarrow\; 0.966 = \frac{6.41}{6.41 + n_X}$$

$$n_X = \frac{6.41 - 6.41(0.966)}{0.966} = 0.226\,mol\;X$$

(iii) M_X

$$M_X = \frac{m_X}{n_X} = \frac{19\,g}{0.226\,mol} = 84\,g/mol$$

5.3 $T_f^o(CCl_4)$ = -22.9 ^oC , $K_f(CCl_4)$ = 30 $^oC/m$, T_f = -33.4 ^oC

$\Delta T_f = T_f^o - T_f$ = -22.9 ^oC - (-33.4 ^oC) = 10.5 ^oC

We will determine the (i) the molality of the unknown, X, (ii) the number of moles of X, (iii) the Molar Mass of X, in that order.

(i) m_X (molality)

$$m_X = \frac{\Delta T_f}{K_f} = \frac{10.5\,^oC}{30\,^oC/m} = 0.35\,m = 0.35\,mol\ X / kg\ CCl_4$$

(ii) n_X

$$n_X = 0.35\,mol\ X / kg\ CCl_4 \cdot 0.75\,kg\ CCl_4 = 0.26\,mol\ X$$

(iii) M_X

$$M_X = \frac{mass_X}{n_X} = \frac{100\,g}{0.26\,mol} = 380\,g/mol$$

5.4 K_b(Benz) = 2.13 $^oC/m$. mass(Benz) = 600 grams = 0.60 kg , T_b^o = 80.1 ^oC , T_b = 81.3 ^oC

$\Delta T_b = T_b - T_b^o$ = 81.3 ^oC - 80.1 ^oC = 1.2 ^oC.

We will determine the (i) the molality of Nap , (ii) the number of moles of Nap, (iii) the the number of grams of Nap , in that order.

(i) m_{Nap} (molality)

$$m_{Nap} = \frac{\Delta T_f}{K_f} = \frac{1.2\,^oC}{2.13\,^oC/m} = 0.56\,m = 0.56\,mol\ Nap / kg\ Benz$$

(ii) n_{Nap}

$$n_{Nap} = 0.56\,mol\ Nap / kg\ Benz \cdot 0.60\,kg\ Benz = 0.34\,mol\ Nap$$

(iii) $Mass_{Nap}$

$$Mass(Nap) = n_{Nap} \bullet M(Nap) = 0.34\,mol \bullet 128\,g/mol = 43.3\,g$$

5.5 Π=0.65 kPa V = 0.10 L T = 298 K $mass_X$ = 0.15 g

$$\Pi = [X]RT \rightarrow [X] = \frac{\Pi}{RT} = \frac{0.65\,kPa}{(8.31\,kPa \cdot L/mol \cdot K)(298\,K)} = 2.62x10^{-4}\,mol/L$$

n_X = 2.62x10^{-4} mol/L x 0.10 L = 2.62x10^{-5} mol

$$M_X = \frac{mass_X}{n_X} = \frac{0.15\,g}{2.62x10^{-5}\,mol} = 5730\,g/mol \approx 5700\,g/mol$$

5.6 N_2: V = 5 L, T = 30 ^oC = 303 K, p = 2.0 atm

$$n_{N_2} = \frac{p_{N_2}V_{N_2}}{RT} = \frac{(2.0\,atm)(5.0\,L)}{(0.082\,L\cdot atm/mol\cdot K)(303\,K)} = 0.40\,mol$$

N_2: V = 10 L, T = 30 ^oC = 303 K, p = 2.0 atm

$$n_{H_2} = \frac{p_{H_2}V_{H_2}}{RT} = \frac{(2.0\,atm)(10.0\,L)}{(0.082\,L\cdot atm/mol\cdot K)(303\,K)} = 0.80\,mol$$

$n_{tot} = n_{N2} + n_{H2}$ - 1.20 mol

$$x_{N_2} = {n_{N_2}}/{n_{tot}} = 0.40/1.20 = 0.33\;,\; x_{H_2} = {n_{H_2}}/{n_{tot}} = 0.80/1.20 = 0.67$$

$$\begin{aligned}\Delta_{mix}S &= -nR\left[x_{N_2}\ln x_{N_2} + x_{H_2}\ln x_{H_2}\right]\\ &= -(1.20\,mol)(8.31\,J/mol\cdot K)\left[0.33\ln(0.33)+0.67\ln(0.67)\right]\\ &= +6.35\,J/K\end{aligned}$$

$$\begin{aligned}\Delta_{mix}G &= +nRT\left[x_{N_2}\ln x_{N_2} + x_{H_2}\ln x_{H_2}\right]\\ &= +(1.20\,mol)(8.31\,J/mol\cdot K)(303\,K)\left[0.33\ln(0.33)+0.67\ln(0.67)\right]\\ &= -1920\,J = -1.92\,kJ/mol\end{aligned}$$

5.7 n = 5 mol , x_{N2} = 0.78 , x_{O2} = 0.21 , x_{Ar} = 0.01
We'll calculate the entropy of mixing for n = 1 mol (i.e. the Molar Entropy of Mixing)

$$\begin{aligned}\Delta_{mix}S &= -nR\sum x_i\ln x_i = -nR\left[x_{N_2}\ln x_{N_2} + x_{O_2}\ln x_{O_2} + x_{Ar}\ln x_{Ar}\right]\\ &= -(5\,mol)(8.31\,J/mol\cdot K)[0.78\ln(0.78)+0.21\ln(0.21)+0.01\ln(0.01)]\\ &= +23.6\,J/K\end{aligned}$$

5.8 T_f^o = 25.8 ^oC , T_f = 21.5 ^oC , ΔT_f(exp) = T_f^o - T_f = 25.8 - 21.5 = 4.3 ^oC
mass(but) = 650 g = 0.65 kg

Calculation of ΔT_f(cal)
n(acet) = 4.0 g/41 g/mol = 0.0976 mol
m(acet) = 0.0976 mol/0.65 kg = 0.150 m
ΔT_f(cal) = K_f m(acet) = 8.2 ^oC/m x 0.150 m = 1.23 ^oC

Calculation of γ

$$\Delta T_f\,(exp) = K_f a = K_f \gamma m = \gamma \Delta T_f\,(cal)$$

$$\gamma = \frac{\Delta T_f\,(exp)}{\Delta T_f\,(cal)} = \frac{4.3\,^oC}{1.23\,^oC} = 3.50$$