COLLIGATIVE PROPERTIES

PROBLEM 614 A certain aqueous solution of a non-electrolytic solute freezes at – 0.6°C. For this solution estimate (a) normal boiling point (b) the vapour pressure at 25°C. (c) the osmotic pressure at 20°C. The vapour pressure of pure water at 25°C is 23.75 torr. $K_f = 1.86$ and $K_b = 0.52$.

PROBLEM 615 At 25°C, vapour pressure of pure benzene and pure toluene are 93.4 and 26.9 torr respectively. A solution is prepared by mixing 60 g of benzene and 40 g of toluene. What pressure should be maintained in the flask containing this solution so that it start boiling at 25°C.

PROBLEM 616 A urea solution in 250 g of water freezes at – 0.744°C. This solution was cooled to some temperature where some ice is formed. Solution was decanted-off and heated to 100°C where the vapour pressure was found to be 757.7 mm of Hg. Determine mass of ice formed and temperature to which solution was cooled. K_f of water is 1.86 kg/mol.

PROBLEM 617 At 27°C, 12 L of pure N_2 measured at 1.0 atmosphere are passes through an aqueous solution of a non-volatile solute, whereby the solution loses 0.25 g in weight. If vapour pressure of pure water is 23.75 mm of Hg and K_b is 0.52 kg/mol, determine boiling temperature of this solution.

PROBLEM 618 An aqueous solution containing 10 g mixture of urea and glucose boils at 100.58°C. Addition of a further 6.0 g glucose to the above solution causes it to boil at 100.77°C. Determine mass percentage of urea in the original mixture.

PROBLEM 619 A one litre solution is prepared by dissolving some solid lead-nitrate in water. The solution was found to boil at 100.15°C. To the resulting solution 0.2 mole NaCl was added. The resulting solution was found to freeze at – 0.83°C. Determine solubility product of $PbCl_2$. Given $K_b = 0.5$ and $K_f = 1.86$. Assume molality to be equal to molarity in all case.

Problem 620 Vapour pressure of a volatile substance *A* is 400 mm of Hg at 298 K. When some another volatile solvent *B* (V.P. = 500 mm at 298 K) is added to *A,* vapour pressure of the resulting solution was found to be 470 mm of Hg. To the resulting solution a third volatile solvent *C* (V.P. = 600 mm of Hg at 298 K) is added so that the vapour pressure of the resulting solution becomes equal to 496 mm of Hg. Determine mole fraction of each *A, B* and *C* in the vapour phase in equilibrium with the final solution.

Problem 621 A solution, prepared by dissolving 38.2 g of $Na_2B_4O_7 \cdot xH_2O$ in 250 g water has boiling point 100.582°C. Deduce formula of the salt. K_b of the water is 0.52 kg mol^{-1}. [Atomic mass of $B = 11$, $Na = 23$]

Problem 622 A mixture of NaCl and sucrose of combined mass 10.2 g is dissolved in enough water to make up a 250 mL solution. The osmotic pressure of the solution is 7.32 atm at 23°C. Calculate the mass percentage of NaCl in the mixture.

Problem 623 A certain organometallic complex contain carbon, hydrogen and a metal from the first transition series (one metal per molecule). In a non-protic complexing solvent like diethyl ether, this compound dissociate into ions. In a non-polar solvent like benzene, this compound does not dissociate. Below are data obtained from freezing point depression and boiling point elevation experiment carried out on the sample of this compound.

(a) Freezing point of benzene solution containing 1.5 g of complex in 36 g benzene is 4.35°C. (fr. pt of C_6H_6 is 5.5°C and K_f of benzene is 5.12)

(b) The b.pt of diethyl ether solution containing 0.48 g of the complex in 10 g of the solvent is 36.05°C (b.pt. of pure ether is 34.5°C, $K_b = 2.02$)

(c) Elemental analysis : 64.88% C and 5.45 %H.

In how many ions does the complex dissociated when dissolved in the complexing solvent? Write the molecular formula of the complex.

Problem 624 A glucose solution in 100 g of water boils at 100.26°C. If this solution is heated to 101°C, determine the mass of water left at equilibrium.

Problem 625 A 100 g 10% by weight urea solution is placed together with a 200 g 10% by weight glucose solution in a closed jar and allowed to attain the equilibrium. Determine mass percentage of urea in its solutions at equilibrium.

Problem 626 A 100 g 10% by weight urea solution is placed together with a 200 g glucose solution in a big jar and left for a very long time. The vapour pressure in the jar at equilibrium was found to be 23.6 mm of Hg. If the vapour pressure of pure water at experimental temperature is 24 mm of Hg, determine mass percentage of glucose in its solution.

Problem 627 The vapour pressure of a solution of methanol and ethanol at 20°C was found to be 70 mm of Hg. Adding 10 g of urea to 80 g of this solution lowers the vapour pressure to 64.6 mm of Hg. Determine composition of the original solution.

Problem 628 Vapour pressure of an equimolar mixture of benzene and toluene was found to be 80 torr. If the vapour above the liquid phase is condensed in a beaker, vapour pressure of this condensate was found to be 100 torr. Determine vapour pressure of pure benzene and pure toluene in the given condition.

Problem 629 Vapour pressure of methanol and ethanol are 94 and 44 mm Hg at 20°C. To a 50 g mixture containing equal weight of both methanol and ethanol, 11.85 g of a mixture of NaCl and urea was dissolved and vapour pressure of the resulting solution was found to be 58 mm of Hg. Determine mass percentage of urea and NaCl in the mixture.

Problem 630 Determine vapour pressure of water at 50°C if enthalpy of vaporization of water is 40.6 kJ/mol.

Problem 631 An aqueous solution of canesugar ($MW = 342$) has osmotic pressure equal to 1.5 atm at 18°C. What will be the V.P. of this solution at 40°C. If 100 g of this solution is cooled to – 2°C, what mass of ice will be separated out. (V.P. of H_2O = at 40°C = 55.324 mm of Hg, $K_f = 1.86$, density $= 1.0\ \text{g/mL}$)

Problem 632 Two elements A and B forms compounds having molecular AB_2 and AB_4. When dissolved in 20 g of benzene, 1.0 g of AB_2 lowers freezing point by 2.3 K whereas 1.0 g of AB_4 lowers the freezing point by 1.3 K. Determine atomic masses of A and B. The molal depression constant for benzene is 5.1 K kg mol^{-1}.

Problem 633 1.0 g of a monobasic acid when dissolved in 100 g of water lowers the freezing point by 0.168°C. 0.2 g of the same acid when dissolved and titrated, required 15.1 mL of N/10 alkali. Calculate degree of dissociation of the acid. K_f for water is 1.86.

Problem 634 A complex is represented as $CoCl_3 \cdot xH_2O$. Its 0.1 m solution in aqueous medium shows $\Delta T_f = -0.558$ K. K_f for water is 1.86 and assume 100% ionization of complex having coordination number 6, deduce the formula of the complex.

Problem 635 10 g of a weak monobasic acid in 100 g of benzene freezes at 3.35°C. Assume that acid undergoes complete association in benzene. Find the degree of dissociation of 10 g of acid in 100 g of water whose freezing point found to be – 1.75°C. K_f for water $= 1.86$. K_f for the benzene $= 5.12$ and freezing point of benzene $= 5.51°\text{C}$.

Problem 636 A saturated solution of a sparingly soluble salt MCl_2 has a vapour pressure of 31.78 mm of Hg at 30°C, while pure water exert a pressure of 31.82 mm of Hg at the same temperature. Calculate solubility product of the compound at this temperature.

Problem 637 A protein has been isolated as sodium salt with their molecular formula Na_xP (this notation means that $x\text{Na}^+$ ions are associated with a negatively charged protein P^{-x}). A solution of this salt was prepared by dissolving 0.25 g of this sodium salt of protein in 10 g of water and ebulliscopic analysis revealed that solution boils at temperature $5.93 \times 10^{-3}\ °\text{C}$ higher than the normal boiling point of pure water. K_b of water is 0.52 Kg mol^{-1}. Also elemental analysis revealed that the salt contain 1% sodium metal by weight. Deduce molecular formula and determine molecular weight of acidic form of protein H_xP.

Problem 638 A non-volatile organic compound X was used to make-up two solution. Solution A contains 5.0 g of X in 100 g of water and solution B contains 2.0 g of X in 100 g of benzene. Solution A has vapour pressure of 754.5 mm of Hg at normal boiling point of water and solution B has the same vapour pressure at the normal boiling point of benzene. Assuming X undergo partial dimerization in benzene, determine percentage of X dimerized in benzene solution.

PROBLEM 639 1.32 g of a mixture of cyclohexane and naphthalene is dissolved in 20 g of benzene and solution freezes at 2.2°C. Calculate composition of the mixture, given K_f of benzene is 5.12 kg mol^{-1} and freezing point of benzene is 5.51°C.

PROBLEM 640 When 1.0 of urea is dissolved in 200 g of an unknown solvent *X,* the *X* freezing point is lowered by 0.25°C. When 1.5 g of an unknown, non-electrolytic solute *Y* is dissolved in 125 g of same solvent *X,* freezing point is lowered by 0.2°C and vapour pressure is lowered by 1%. If freezing point of *X,* is 12°C, determine molar enthalpy of fusion of *X.*

PROBLEM 641 Chloroform boils at 62°C. For a solution containing 0.4 g of naphthalene in 25 g of chloroform, boiling point is elevated by 0.45 K. If chloroform is to be distilled at 50°C in order to avoid any decomposition during distillation, what maximum pressure can be maintained in the flask?

PROBLEM 642 Phenol undergoes partial dimerization in bromoform. When 2.5 g of phenol is dissolved in 100 g bromoform, freezing point is lowered to 6.4°C. Pure bromoform freezes at 8.4°C and its K_f is 14 Kkg mol^{-1}. Determine K_c (equilibrium constant) for the following dimerization reaction if the density of solution is 0.88 g/mL;

$$2C_6H_5OH \rightleftharpoons (C_6H_5OH)_2$$

PROBLEM 643 6.0 g of a mixture of anthracene ($C_{14}H_{10}$) and naphthalene ($C_{10}H_8$) when dissolved in 300 g of benzene, freezing point is lowered by 0.7°C. Normal freezing point of benzene is 5.5°C and its K_f is 5.12 Kkg mol^{-1}. Determine percentage composition of mixture and mass of solid benzene that will be produced if the above solution is cooled to 4.5°C.

PROBLEM 644 A 1.0 m aqueous solution of HF freezes at -1.9°C. K_f of water is 1.86 Kkg mol^{-1}. If the density of solutions is 1.12 g/mL, determine pH of solution and ionization constant of HF.

COLLIGATIVE PROPERTIES

614. (a) $-\Delta T_f = 0.6 = K_f \cdot m$

$$\Delta T_b = K_b \cdot m \quad \Rightarrow \quad \frac{0.6}{\Delta T_b} = \frac{K_f}{K_b} = \frac{1.86}{0.52} \quad \Rightarrow \quad \boldsymbol{\Delta T_b = 0.167}$$

(b) $$-\Delta T_f = 0.6 = K_f m = 1.86 \times \frac{n_2}{18 n_1} \times 1000 \quad \Rightarrow \quad \frac{n_2}{n_1} = 5.8 \times 10^{-3}$$

$$\Rightarrow \qquad x_1 = \frac{n_1}{n_1 + n_2} = \frac{1}{1 + \frac{n_2}{n_1}} = 0.9942$$

$$\Rightarrow \qquad P = P_0 x_1 = 23.75 \times 0.9942 = \mathbf{23.61\ torr.}$$

(c) $$m = \frac{0.6}{1.86} = 0.32 \approx \text{Molarity}$$

$$\pi = MRT = 0.32 \times 0.082 \times 293 = \mathbf{7.688\ bar.}$$

615. Mole fraction of benzene $= \dfrac{\frac{60}{78}}{\frac{60}{78} + \frac{40}{92}} = 0.638 \quad \Rightarrow \quad$ Mole fraction of toluene $= 0.362$

$$\text{V.P.} = 0.638 \times 93.4 + 0.362 \times 26.9 = \mathbf{69.327\ mm}$$

616. $$+0.744 = 1.86 \cdot \frac{n_2}{250} \times 1000 \quad \Rightarrow \quad n_2 = 0.1$$

Also, $$752.7 = 760 \cdot \frac{n_1}{n_1 + 0.1} \quad \Rightarrow \quad n_1 = 10.31$$

$\Rightarrow$ Mass of ice formed $= 250 - 10.31 \times 18 =$ **64.42 g.**

$$-\Delta T_f = 1.86 \times \frac{0.1}{185.58} \times 1000 = 1 \quad \Rightarrow \quad \boldsymbol{T_f = -1^\circ C.}$$

617. V.P. of solution $= \dfrac{0.25 \times 0.082 \times 300 \times 760}{18 \times 12} = 21.638$ mm.

$$\Rightarrow \qquad 21.638 = 23.75 \cdot \frac{n_1}{n_1 + n_2} \quad \Rightarrow \quad \frac{n_2}{n_1} = 9.76 \times 10^{-2}$$

$$\Delta T_b = K_b \cdot m = 0.52 \times \left(\frac{n_2}{n_1}\right) \times \frac{1000}{18} = \mathbf{2.82}$$

618. $$\frac{0.77}{0.58} = \frac{\frac{x+6}{180} + \frac{10-x}{60}}{\frac{x}{180} + \frac{10-x}{60}} \quad \Rightarrow \quad x = \mathbf{5.843\ g}$$

619. $$\Delta T_b = i K_b m \quad \Rightarrow \quad 0.15 = 3 \times 0.5 \times m \quad \Rightarrow \quad m = 0.1$$

Now,
$$\begin{array}{cccc} Pb(NO_3)_2 + & 2NaCl & \longrightarrow PbCl_2 + & 2NaNO_3 \\ 0.1 & 0.2 & 0 & 0 \\ 0 & 0 & 0.1 & 0.2 \end{array}$$

Now, the solution contains two salts $NaNO_3$ and $PbCl_2$.

$$-\Delta T_f = 0.83 = K_f(2\times 0.2 + 3S) \text{ where } S \text{ is molar solubility of } PbCl_2.$$

$$S = 1.54\times 10^{-2} \quad \Rightarrow \quad K_{sp} = 4S^3 = \mathbf{1.46\times 10^{-5}.}$$

620. In mixture of A and B if mole fraction of $A = x$, then :

$$400x + 500(1-x) = 470 \quad \Rightarrow \quad x = 0.3$$

In final mixture, if combined mole fraction of A and B = y, then

$$470y + (1-y)600 = 496 \quad \Rightarrow y = 0.8$$

Therefore, in the final mixture, mole fractions are : $A = 0.24, B = 0.56, C = 0.2$

$\Rightarrow$ Mole fraction in vapour phase are :

$$A = \frac{x_A \cdot P_A^0}{P} = \frac{0.24\times 400}{496} = \mathbf{0.1935,} \qquad B = \frac{x_B P_B^0}{P} = \frac{0.56\times 500}{496} = \mathbf{0.5645}$$

$$C = 1-(0.1935+0.5645) = \mathbf{0.242}$$

621.
$$\text{Moles of solute } = \frac{38.2}{202+18x}$$

$$\text{Mass of } H_2O = \frac{38.2\times 18x}{202+18x} + 250$$

$$\Rightarrow \qquad 0.582 = 3\times 0.52\times \frac{38.2\times 1000}{(202+18x)\left(250+\dfrac{38.2\times 18x}{202+18x}\right)}$$

$$\Rightarrow \qquad x = 10, \quad \text{formula} = \mathbf{Na_2B_4O_7\cdot 10H_2O}$$

622.
$$\pi = \pi(\text{NaCl}) + \pi(\text{sucrose}) \quad \Rightarrow \quad 7.32 = \left[2\times\frac{x}{58.5}\times 4 + \frac{10.2-x}{342}\right]RT$$

$$\Rightarrow \qquad 342\times 8x + 58.2(10.2-x) = \frac{7.32\times 58.5\times 342}{0.082\times 296} \quad \Rightarrow \quad x = 2.03\text{ g}$$

$$\boldsymbol{m\%}\ \mathbf{NaCl = 19.9}$$

623. In benzene solvent : $1.15 = 5.12\times \dfrac{1.5}{M\times 36}\times 1000 \quad \Rightarrow \quad M = 185.5$ amu.

In diethyl ether : $1.55 = i\times 2.02\times \dfrac{0.48\times 1000}{185.5\times 10} \quad \Rightarrow \quad i = 3$

Hence, per molecule of complex, three particles are produced on dissociation in diethyl ether.

Also, in one mole complex, mass : $C = 185.5\times 0.6488 \approx \mathbf{120}$

$$H = 185.5\times 0.0545 \approx \mathbf{10} \quad \Rightarrow \quad \textbf{Molecular formula} = \boldsymbol{M}\mathbf{(CH)_{10}}$$

624.
$$0.26 = K_b \cdot \frac{n_2}{100} \times 1000 \qquad \ldots(i)$$
$$1 = K_b \cdot \frac{n_2}{W_1} \times 1000 \qquad \ldots(ii)$$

Solving Eqs. (i) and (ii), $\boldsymbol{W_1 = 26\ \mathbf{g}}$

625.
$$\text{Mole fraction of urea } = \frac{\frac{10}{60}}{\frac{10}{60}+5} = 0.0322$$
$$\text{Mole fraction of glucose} = \frac{\frac{20}{180}}{\frac{20}{180}+10} = 0.01$$

∵ mole fraction of glucose is less, vapour pressure above the glucose solution will be higher than the vapour pressure above urea solution. To establish equilibrium, some $H_2O(v)$ molecule will migrate from the glucose side to urea side in order to make the solutions of equal mole fraction.

$$\Rightarrow \qquad \frac{\frac{10}{60}}{\frac{10}{60}+5+x} = \frac{\frac{20}{180}}{\frac{20}{180}+10-x}$$

Solving, $x = 4$

So, now in urea solution mass of water $= 90 + 72 = 162\ \text{g}$

$$\text{m\%} = \frac{100}{162} \times 100 = \mathbf{6.17}$$

626. At equilibrium : $23.6 = 24 \times \dfrac{n_{H_2O}}{n_{H_2O} + n_{\text{urea}}} \;\Rightarrow\; n_{H_2O} = 9.833 \;\Rightarrow\; m(H_2O) = 177\ \text{g}.$

$\Rightarrow$ Mass of $H_2O(v)$ migrated from the glucose solution $= 177 - 90 = 87\ \text{g}$.

$$\Rightarrow \qquad 23.6 = 24 \times \frac{n_1}{n_1 + n_2} \;\Rightarrow\; \frac{n_2}{n_1} = 16.95 \times 10^{-3} \qquad \ldots(i)$$

Also, $18n_1 + 180n_2 = 113 \;\Rightarrow\; n_1 + 10n_2 = 6.277$ ...(ii)

Solving, Eqs. (i) and (ii), $n_1 = 5.367$ and $n_2 = 0.09 \Rightarrow$ mass of glucose $= 16.2\ \text{g}$.

***m*% glucose in original solution = 8.1**

627.
$$64.6 = 70 \cdot \frac{n_1}{n_1 + n_2} \quad \text{where} \quad n_1 = \text{moles of (methanol + ethanol)}$$
$$\Rightarrow \qquad \frac{n_2}{n_1} = 0.0836 \;\Rightarrow\; n_1 = 1.9938 = \frac{x}{32} + \frac{80-x}{46} \;\Rightarrow\; \boldsymbol{x = 26.78\ \mathbf{g}\ \mathbf{CH_3OH}}$$

628.
$$\frac{1}{2}P_B^0 + \frac{1}{2}P_T^0 = 80 \;\Rightarrow\; P_B^0 + P_T^0 = 160 \qquad \ldots(i)$$

Mole fractions of benzene and toluene in the vapour phase :

$$x_B = \frac{P_B^0}{160} \quad \text{and} \quad x_T = \frac{P_T^0}{160}$$

Now, these mole fractions will be the mole fractions of benzene and toluene in the liquid phase of condensate.

$$\Rightarrow \qquad \frac{P_B^0}{160} \cdot P_B^0 + \frac{P_T^0}{160} \cdot P_T^0 = 100 \quad \Rightarrow \quad P_B^{0_2} + P_T^{0_2} = 160 \times 100 \qquad \ldots\text{(ii)}$$

Solving, Eqs. (i) and (ii)

$$P_B^0 = \mathbf{120\ torr} \quad \text{and} \quad P_T^0 = \mathbf{40\ torr.}$$

629. V.P. of mixed solvents $= \left(\dfrac{\frac{25}{32}}{\frac{25}{32}+\frac{25}{46}}\right) \times 94 + \left(\dfrac{\frac{25}{46}}{\frac{25}{32}+\frac{25}{46}}\right) 44 = 73.48$ mm

Now, $\quad 58 = 73.48 \dfrac{n_1}{n_1 + n_2} \quad$ where, $n_1 =$ moles of solvent $= 1.324$

$$\Rightarrow \quad n_2 = \text{moles of solute} = 0.35$$

$$n_2 = 2 \times \text{moles of NaCl} + \text{moles of urea} = \frac{2 \times x}{58.5} + \frac{11.85 - x}{60} = 0.35 \quad \Rightarrow \quad x = 8.7\,\text{g}$$

630. $\ln \dfrac{P_2}{P_1} = \dfrac{\Delta H}{R}\left(\dfrac{T_2 - T_1}{T_1 T_2}\right)$ and V.P. of H_2O at 100°C is 760 mm

$$\Rightarrow \qquad \ln \frac{760}{P_1} = \frac{40.6 \times 10^3}{8.314}\left(\frac{50}{373 \times 323}\right) \quad \Rightarrow \quad P_1 = \mathbf{100.15\ mm}$$

631. $\pi = CRT \quad \Rightarrow \quad C = 6.286 \times 10^{-2}$ M

$$\Rightarrow \qquad P = 55.324 \times \frac{55.55}{55.55 + 6.286 \times 10^{-2}} = \mathbf{55.26\ mm}$$

Also, $\quad 2 = 1.86 \times \dfrac{6.286 \times 10^{-3} \times 1000}{w_1} \quad \Rightarrow \quad w_1 = 5.84$

Initial amount of water $= 100 - 2.15 = 97.85$

Mass of ice formed $= 97.85 - 5.84 = \mathbf{92.01\ g}$

632.

$$2.3 = 5.1 \times \frac{1}{M_A + 2M_B} \times \frac{1000}{20} \qquad \ldots\text{(i)}$$

$$1.3 = 5.1 \times \frac{1}{M_A + 4M_B} \times \frac{1000}{20} \qquad \ldots\text{(ii)}$$

Solving, Eqs. (i) and (ii)

$$M_A = \mathbf{25.58} \quad \text{and} \quad M_B = \mathbf{42.64}$$

633. Mol. wt. of acid : $\frac{0.2}{M} = 15.1 \times 0.1 \times 10^{-3} \quad \Rightarrow \quad M = 132.45$

$$\Rightarrow \qquad 0.168 = (1+\alpha) \times 1.86 \times \frac{1}{132.45} \times \frac{1000}{100} \quad \Rightarrow \quad \alpha = \mathbf{0.196}$$

634. $0.558 = i \times 1.86 \times 0.1 \quad \Rightarrow \quad i = 3 \quad \Rightarrow \quad \text{Formula} = \mathbf{[Co(H_2O)_5Cl]Cl_2}$

635. In benzene $i = \frac{1}{2} \quad \Rightarrow \quad -\Delta T_f = 2.16 = \frac{1}{2} \times 5.12 \times \frac{10}{M} \times \frac{1000}{100} \quad \Rightarrow \quad M = 118.5$

In water : $-\Delta T_f = 1.75 = (1+\alpha) \times 1.86 \times \frac{10}{118.5} \times \frac{1000}{10} \quad \Rightarrow \quad \alpha = \mathbf{0.115}$

636.

$$\underset{\text{Solubility } = S}{\text{MCl}_2} \rightleftharpoons \underset{S}{M^{2+}} + \underset{2S}{2\text{Cl}^-}$$

$$\Rightarrow \qquad 31.78 = 31.82 \times \frac{55.55}{55.55 + 3S} \quad \Rightarrow \quad S = 2.33 \times 10^{-2}$$

$$\Rightarrow \qquad K_{sp} = 4S^3 = \mathbf{5.06 \times 10^{-5}}$$

637.

$$5.93 \times 10^{-3} = (x+1) \times 0.52 \times \frac{0.25}{M} \times \frac{1000}{10} \qquad \ldots(\text{i})$$

$$\frac{M}{100} = 23x \qquad \ldots(\text{ii})$$

From Eqs. (i) and (ii) $\quad x = 20.3 \approx 20$

$$\text{Formula of protein} = \mathbf{H_{20}}\boldsymbol{P}$$

$$\text{Mol. wt.} = 2300 \times 20 - 23 \times 20 + 23 = \mathbf{45563 \text{ amu}}$$

638.

$$754.5 = 760 \times \frac{100}{18\left(\frac{100}{18} + \frac{5}{M}\right)} \quad \Rightarrow \quad M = 123.46$$

Also,

$$754.5 = 760 \times \frac{100}{78\left(\frac{100}{78} + \left(1 - \frac{\alpha}{2}\right) \times \frac{2}{123.46}\right)}$$

$$\Rightarrow \qquad \alpha = 0.846 \quad \Rightarrow \quad \%\text{ dimerization} = \mathbf{84.6}$$

639.

$$3.31 = 5.12 \times \frac{n_2}{20} \times 1000 \quad \Rightarrow \quad n_2 = 12.93 \times 10^{-3}$$

Let the mixture contain x g cyclohexane.

$$\frac{x}{84} + \frac{1.32 - x}{128} = 12.93 \times 10^{-3} \quad \Rightarrow \quad x = \mathbf{0.64\ g}$$

640.

$$0.25 = K_f \cdot \frac{1}{60 \times 200} \times 1000 \quad \Rightarrow \quad K_f = 3$$

Also,

$$0.2 = 3 \times \frac{1.5}{M_y \times 125} \times 1000 \quad \Rightarrow \quad M_y = 180$$

and $99 = 100 \times \dfrac{n_1}{n_1 + n_2} \quad \Rightarrow \quad \dfrac{n_2}{n_1} = \dfrac{1}{99} \quad \Rightarrow \quad n_1 = 99n_2 = 99 \times \dfrac{1.5}{180} = 0.825$

$$\Rightarrow \qquad M\,(\text{Solvent}) = \frac{125}{0.825} = 151.51\text{ amu}$$

$$\therefore \quad K_f = 3 = \frac{M_1 R T_f^{0_2}}{\Delta H_f} = \frac{151.51 \times 10^{-3} \times 8.314 \times (285)^2}{\Delta H_f} \quad \Rightarrow \quad \Delta H_f = \mathbf{34.1\ kJ\ mol^{-1}}$$

641.

$$0.45 = K_b \cdot \frac{0.4}{128 \times 25} \times 1000 \quad \Rightarrow \quad K_b = 3.6$$

Also, $\quad K_b = 3.6 = \dfrac{M_1 (RT_f^0)^2}{\Delta H_v} = \dfrac{119.5 \times 10^{-3} \times 8.314 \times (335)^2}{\Delta H_v}$

$$\Rightarrow \qquad \Delta H_v = 30.97\text{ kJ mol}^{-1}$$

Now, $\quad \ln \dfrac{P_2}{P_1} = \dfrac{\Delta H_v}{R} \left(\dfrac{T_2 - T_1}{T_1 T_2} \right)$

$$\Rightarrow \qquad \ln \frac{760}{P_1} = \frac{30.97 \times 10^3}{8.314} \left(\frac{12}{335 \times 323} \right)$$

$$\Rightarrow \qquad P_1 = \mathbf{502.8\ mm\ of\ Hg.}$$

642.

$$-\Delta T_f = 2 = \left(1 - \frac{\alpha}{2}\right) \times 14 \times \frac{2.5}{94} \times \frac{1000}{100} \quad \Rightarrow \quad \alpha = 0.925$$

$$\text{Mass of solution} = 102.5\text{ g} \quad \Rightarrow \quad V = \frac{m}{f} = 116.5\text{ mL}$$

$$\Rightarrow \qquad \text{Initial molarity} = \frac{2.5}{94} \times \frac{1000}{116.5} = 0.228\text{ M}$$

$$K_c = \frac{\alpha}{2C(1-\alpha)^2} = \mathbf{360.6}$$

643.

$$0.7 = 5.12\,\frac{n_2}{300} \times 1000 \quad \Rightarrow \quad n_2 = 0.041$$

Let mixture contain x g anthracene, then

$$\frac{x}{178} + \frac{6-x}{128} = 0.041 \quad \Rightarrow \quad x = 2.677\text{ g.}$$

After cooling to 4.5°C, $\; -\Delta T_f = 1 = 5.12 \times \dfrac{0.041}{w_1} \times 1000$

$$\Rightarrow \qquad w_1 = 209.92\text{ g} \quad \Rightarrow \quad \text{mass of solid benzene produced} = \mathbf{90.08\ g}$$

644.

$$1.9 = (1 + \alpha) \times 1.86 \quad \Rightarrow \quad \alpha = 0.0215$$

$$\text{Molarity} = 1.098 \quad \Rightarrow \quad K_a = \frac{C\alpha^2}{1-\alpha} = \mathbf{5.18 \times 10^{-4}.}$$