Homework #3
Chapter 17
Properties of Solutions

13.
a) $HNO_3(s) \rightarrow H^+(aq) + NO_3^-(aq)$
b) $Na_2SO_4(s) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq)$
c) $Al(NO_3)_3(s) \rightarrow Al^{3+}(aq) + 3NO_3^-(aq)$
d) $SrBr_2(s) \rightarrow Sr^{2+}(aq) + 2Br^-(aq)$
e) $KClO_4(s) \rightarrow K^+(aq) + ClO_4^-(aq)$
f) $NH_4Br(s) \rightarrow NH_4^+(aq) + Br^-(aq)$
g) $NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$
h) $CuSO_4(s) \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$
i) $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

15. Need to find molarity (M), molality (m), and mole fraction (χ) of $C_2H_6O_2$

Know

Mass % $C_2H_6O_2$ = 40.0%

$$d_{solution} = 1.05\,\frac{g}{cm^3}$$

$$M_{C_2H_6O_2} = 62.08\,\frac{g}{mol}$$

$$M_{H_2O} = 18.02\,\frac{g}{mol}$$

All of the quantities that need to be calculated are intrinsic properties (do not depend on sample size), therefore, assume sample size of 100. g.

Calculate molarity

$$M = \frac{n_{C_2H_6O_2}}{V_{solution}}$$

Calculate the moles of $C_2H_6O_2$

$$n_{C_2H_6O_2} = \frac{m_{C_2H_6O_2}}{M_{C_2H_6O_2}}$$

Calculate the mass of $C_2H_6O_2$

$$40.0\% = \left(\frac{m_{C_2H_6O_2}}{m_{C_2H_6O_2} + m_{H_2O}}\right)100.\% \left(\frac{m_{C_2H_6O_2}}{100.\,g}\right)100.\%$$

Note: It was assumed that the total mass was 100 g

$$m_{C_2H_6O_2} = 40.0\,g$$

$$n_{C_2H_6O_2} = \frac{m_{C_2H_6O_2}}{M_{C_2H_6O_2}} = \frac{40.0\,g}{62.08\,\frac{g}{mol}} = 0.644\,mol$$

Calculate the volume of solution

$$V_{solution} = \frac{m_{solution}}{d_{solution}} = \frac{100.\,g}{1.05\,\frac{g}{cm^3}} = 95.2\,cm^3 = 0.0952\,L$$

$$M = \frac{n_{C_2H_6O_2}}{V_{solution}} = \frac{0.644\,mol}{0.0952\,L} = 6.76\,M$$

Calculate molality

$$m = \frac{n_{C_2H_6O_2}}{m_{H_2O}}$$

Calculate the mass of solvent (H_2O)

$$m_{H_2O} = m_{solution} - m_{C_2H_6O_2} = 100.0\,g - 40.0\,g = 60.0\,g = 0.0600\,kg$$

$$m = \frac{n_{C_2H_6O_2}}{m_{H_2O}} = \frac{0.644\,mol}{0.0600\,kg} = 10.7\,m$$

Calculate the mole fraction

$$\chi_{C_2H_6O_2} = \frac{n_{C_2H_6O_2}}{n_{C_2H_6O_2} + n_{H_2O}}$$

Calculate moles of H_2O

$$n_{H_2O} = \frac{m_{H_2O}}{M_{H_2O}} = \frac{60.\,g}{18.02\,\frac{g}{mol}} = 3.33\,mol$$

$$\chi_{C_2H_6O_2} = \frac{n_{C_2H_6O_2}}{n_{C_2H_6O_2} + n_{H_2O}} = \frac{0.644\,mol}{0.644\,mol + 3.33\,mol} = 0.162$$

16. Need to find molarity (M), molality (m), and mole fraction (χ) of $C_2H_6O_2$

In General

Know

Mass % solvent

$d_{solution}$

M_{solute}

$M_{solvent}$

of the quantities that need to be calculated are intrinsic properties (do not depend on sample size), therefore, assume sample size of 100. g.

Molarity

$$M = \frac{n_{solute}}{V_{solution}}$$

Molality

$$m = \frac{n_{solute}}{m_{solvent}}$$

Mole Fraction

$$\chi_{solute} = \frac{n_{solute}}{n_{solute} + n_{solvent}}$$

HCl

Calculate moles of solute (HCl) using mass %

$$38\% = \left(\frac{m_{solute}}{m_{solute} + m_{solvent}}\right)100.\% = \left(\frac{m_{solute}}{100.\ g}\right)100.\%$$

$$m_{solute} = 38\,g$$

$$n_{solute} = 38\,g\left(\frac{1\,mol\,HCl}{36.46\,g\,HCl}\right) = 1.0\,mol$$

Calculate the Volume of solution using density

$$V_{solution} = \frac{m_{solution}}{d_{solution}} = \frac{100.\,g}{1.19\,\frac{g}{cm^3}} = 84.0\,cm^3 = 0.0840\,L$$

Calculate the moles of solvent (H_2O)

$$m_{solvent} = m_{solution} - m_{solute} = 100.\,g - 38\,g = 62\,g$$

$$n_{solvent} = 62\,g\left(\frac{1\,mol\,H_2O}{18.02\,g\,H_2O}\right) = 3.4\,mol$$

Molarity

$$M = \frac{n_{solute}}{V_{solution}} = \frac{1.0\,mol}{0.0840\,L} = 12\,M$$

Molality

$$m = \frac{n_{solute}}{m_{solvent}} = \frac{1.0\,mol}{0.062\,kg} = 16\,m$$

Mole Fraction

$$\chi_{solute} = \frac{n_{solute}}{n_{solute} + n_{solvent}} = \frac{1.0\ mol}{1.0\ mol + 3.4\ mol} = 0.23$$

HNO_3

Calculate moles of solute (HNO_3) using mass %

$$70.\% = \left(\frac{m_{solute}}{m_{solute} + m_{solvent}}\right) 100.\% = \left(\frac{m_{solute}}{100.\ g}\right) 100.\%$$

$$m_{solute} = 70.\,g$$

$$n_{solute} = 70.\,g\left(\frac{1\ mol\ HNO_3}{63.02\ g\ HNO_3}\right) = 1.1\ mol$$

Calculate the Volume of solution using density

$$V_{solution} = \frac{m_{solution}}{d_{solution}} = \frac{100.\,g}{1.42\ \frac{g}{cm^3}} = 70.4\ cm^3 = 0.0704\ L$$

Calculate the moles of solvent (H_2O)

$$m_{solvent} = m_{solution} - m_{solute} = 100.\,g - 70.\,g = 30.\,g$$

$$n_{solvent} = 30.\,g\left(\frac{1\ mol\ H_2O}{18.02\ g\ H_2O}\right) = 1.7\ mol$$

Molarity

$$M = \frac{n_{solute}}{V_{solution}} = \frac{1.1\ mol}{0.0704\ L} = 16\ M$$

Molality

$$m = \frac{n_{solute}}{m_{solvent}} = \frac{1.1\ mol}{0.030\ kg} = 37\ m$$

Mole Fraction

$$\chi_{solute} = \frac{n_{solute}}{n_{solute} + n_{solvent}} = \frac{1.1\ mol}{1.1\ mol + 1.7\ mol} = 0.39$$

H_2SO_4

Calculate moles of solute (H_2SO_4) using mass %

$$95.\% = \left(\frac{m_{solute}}{m_{solute} + m_{solvent}}\right) 100.\% = \left(\frac{m_{solute}}{100.\ g}\right) 100.\%$$

$$m_{solute} = 95\ g$$

$$n_{solute} = 95\ g\left(\frac{1\ mol\ H_2SO_4}{98.09\ g\ H_2SO_4}\right) = 0.97\ mol$$

Calculate the Volume of solution using density

$$V_{solution} = \frac{m_{solution}}{d_{solution}} = \frac{100.\,g}{1.84\ \frac{g}{cm^3}} = 74.3\ cm^3 = 0.0543\ L$$

Calculate the moles of solvent (H_2O)

$$m_{solvent} = m_{solution} - m_{solute} = 100.\,g - 95\ g = 5\ g$$

$$n_{solvent} = 5\ g\left(\frac{1\ mol\ H_2O}{18.02\ g\ H_2O}\right) = 0.3\ mol$$

Molarity

$$M = \frac{n_{solute}}{V_{solution}} = \frac{0.97\ mol}{0.0543\ L} = 18\ M$$

Molality

$$m = \frac{n_{solute}}{m_{solvent}} = \frac{0.97\ mol}{0.005\ kg} = 200\ m$$

Mole Fraction

$$\chi_{solute} = \frac{n_{solute}}{n_{solute} + n_{solvent}} = \frac{0.97\ mol}{0.97\ mol + 0.3\ mol} = 0.76$$

$HC_2H_3O_2$

Calculate moles of solute ($HC_2H_3O_2$) using mass %

$$99.\% = \left(\frac{m_{solute}}{m_{solute} + m_{solvent}}\right) 100.\% = \left(\frac{m_{solute}}{100.\ g}\right) 100.\%$$

$$m_{solute} = 99\ g$$

$$n_{solute} = 99\ g \left(\frac{1\ mol\ HC_2H_3O_2}{61.07\ g\ HC_2H_3O_2}\right) = 1.6\ mol$$

Calculate the Volume of solution using density

$$V_{solution} = \frac{m_{solution}}{d_{solution}} = \frac{100.\ g}{1.05\ \frac{g}{cm^3}} = 95.2\ cm^3 = 0.0952\ L$$

Calculate the moles of solvent (H_2O)

$$m_{solvent} = m_{solution} - m_{solute} = 100.\ g - 99\ g = 1\ g$$

$$n_{solvent} = 1\ g \left(\frac{1\ mol\ H_2O}{18.02\ g\ H_2O}\right) = 0.06\ mol$$

Molarity

$$M = \frac{n_{solute}}{V_{solution}} = \frac{1.6\ mol}{0.0952\ L} = 17\ M$$

Molality

$$m = \frac{n_{solute}}{m_{solvent}} = \frac{1.6\ mol}{0.001\ kg} = 2000\ m$$

Mole Fraction

$$\chi_{solute} = \frac{n_{solute}}{n_{solute} + n_{solvent}} = \frac{1.6\ mol}{1.6\ mol + 0.06\ mol} = 0.96$$

NH_3

Calculate moles of solute (NH_3) using mass %

$$28.\% = \left(\frac{m_{solute}}{m_{solute} + m_{solvent}}\right) 100.\% = \left(\frac{m_{solute}}{100.\ g}\right) 100.\%$$

$$m_{solute} = 28\ g$$

$$n_{solute} = 28\ g \left(\frac{1\ mol\ NH_3}{17.04\ g\ NH_3}\right) = 1.6\ mol$$

Calculate the Volume of solution using density

$$V_{solution} = \frac{m_{solution}}{d_{solution}} = \frac{100.\ g}{0.90\ \frac{g}{cm^3}} = 110\ cm^3 = 0.110\ L$$

Calculate the moles of solvent (H_2O)

$$m_{solvent} = m_{solution} - m_{solute} = 100.\ g - 28\ g = 72\ g$$

$$n_{solvent} = 72\ g \left(\frac{1\ mol\ H_2O}{18.02\ g\ H_2O}\right) = 4.0\ mol$$

Molarity

$$M = \frac{n_{solute}}{V_{solution}} = \frac{1.6\ mol}{0.110\ L} = 15\ M$$

Molality

$$m = \frac{n_{solute}}{m_{solvent}} = \frac{1.6\ mol}{0.072\ kg} = 22\ m$$

Mole Fraction

$$\chi_{solute} = \frac{n_{solute}}{n_{solute} + n_{solvent}} = \frac{1.6\ mol}{1.6\ mol + 4.0\ mol} = 0.29$$

17. Need to find molarity (M), molality (m), mole fraction (χ), and mass % of $C_6H_5CH_3$

Know

$$V_{C_6H_5CH_3} = 50.\, mL$$
$$d_{C_6H_5CH_3} = 0.867\,\frac{g}{cm^3}$$
$$V_{C_6H_6} = 125\, mL$$
$$d_{C_6H_6} = 0.874\,\frac{g}{cm^3}$$

Calculate mass%

$$mass\ \%\ C_6H_5CH_3 = \left(\frac{m_{C_6H_5CH_3}}{m_{total}}\right)100\%$$

Calculate the mass of toluene

$$m_{C_6H_5CH_3} = Vd_{C_6H_5CH_3} = (50\ cm^3)\left(0.867\,\frac{g}{cm^3}\right) = 43.4\ g$$

Calculate the mass of benzene

$$m_{C_6H_6} = Vd_{C_6H_6} = (125\ cm^3)\left(0.874\,\frac{g}{cm^3}\right) = 109\ g$$

Calculate the total mass

$$m_{total} = m_{C_6H_5CH_3} + m_{C_6H_6} = 43.4\ g + 109\ g = 152\ g$$
$$mass\ \%\ C_6H_5CH_3 = \left(\frac{m_{C_6H_5CH_3}}{m_{total}}\right)100\% = \left(\frac{43.4\ \mathrm{g}}{152\ \mathrm{g}}\right)100\% = 28.6\%$$

Calculate mole fraction

$$\chi_{C_6H_5CH_3} = \frac{n_{C_6H_5CH_3}}{n_{C_6H_5CH_3} + n_{C_6H_6}}$$

Calculate the moles of toluene

$$43.4\ g\ C_6H_5CH_3\left(\frac{1\ mol\ C_6H_5CH_3}{92.15\ g\ C_6H_5CH_3}\right) = 0.471\ mol\ C_6H_5CH_3$$

Calculate the moles of benzene

$$109\ g\ C_6H_6\left(\frac{1\ mol\ C_6H_6}{78.12\ g\ C_6H_6}\right) = 1.40\ mol\ C_6H_6$$
$$\chi_{C_6H_5CH_3} = \frac{n_{C_6H_5CH_3}}{n_{C_6H_5CH_3}+n_{C_6H_6}} = \frac{0.471\ mol}{0.471\ mol+1.40\ mol} = 0.252$$

Calculate molality

$$m = \frac{n_{C_6H_5CH_3}}{m_{C_6H_6}} = \frac{0.471\ mol}{0.109\ kg} = 4.32\ m$$

Calculate molarity

$$M = \frac{n_{C_6H_5CH_3}}{V_{solution}} = \frac{0.471\ mol}{0.175\ L} = 2.69\ M$$

32. The extent of hydration increases with increasing charge density. In general, the smaller the size, the larger the charge density. Also, the larger the charge, the higher the charge density.

a) Mg^{2+} b) Be^{2+} c) Fe^{3+}
d) F^- e) Cl^- f) SO_4^{2-}

33. a) NH_3 — NH_3 can H-bond with water while PH_3 cannot
b) CH_3CN — CH_3CN is polar and CH_3CH_3 is not
c) CH_3COOH — CH_3COOH can H-bond with water and CH_3COOCH_3 cannot

34. a) KrF_2 (linear) nonpolar dissolves in CCl_4
b) SF_2 (bent) polar dissolves in H_2O
c) SO_2 (bent) polar dissolves in H_2O
d) CO_2 (linear) nonpolar dissolves in CCl_4

e) MgF_2 ionic dissolves in H_2O
f) CH_2O polar dissolves in H_2O
g) CH_2CH_2 nonpolar dissolves in CCl_4

39. $P = k_H C$
$0.790\ atm = k_H(8.21 \times 10^{-4}\ M)$
$k_H = 962\ \frac{L\cdot atm}{mol}$
$1.10\ atm = \left(962\ \frac{L\cdot atm}{mol}\right) C$
$C = 0.00114\ M$

42. $P_{solution} = \chi_{solvent} P^{\circ}_{solvent}$
Calculate the mole fraction of H_2O
$$\chi_{H_2O} = \frac{n_{H_2O}}{n_{H_2O} + n_{C_3H_8O_3}}$$
Calculate the moles of H_2O
$$m_{H_2O} = Vd_{H_2O} = (338\ cm^3)\left(0.992\ \frac{g}{cm^3}\right) = 335\ g$$
$$335\ g\ H_2O \left(\frac{1\ mol\ H_2O}{18.02\ g\ H_2O}\right) = 18.6\ mol\ H_2O$$
Calculate the moles of $C_3H_8O_3$
$$164\ g\ C_3H_8O_3 \left(\frac{1\ mol\ C_3H_8O_3}{92.11\ g}\right) = 1.78\ mol\ C_3H_8O_3$$
$$\chi_{H_2O} = \frac{18.6\ mol}{18.6\ mol + 1.78\ mol} = 0.913$$
Calculate the vapor pressure of $H_2O/C_3H_8O_3$
$$P_{solution} = \chi_{solvent} P^{\circ}_{solvent} = (0.913)(54.74\ torr) = 50.0\ torr$$

44. $P_{solution} = \chi_{solvent} P^{\circ}_{solvent}$
Smallest Vapor Pressure → Largest Vapor Pressure
c<b<a<d
The vapor pressure of methanol is larger than that of water, therefore, solution d will have the largest vapor pressure.
Pure water will have the next largest vapor pressure.
Glucose is a non-electrolyte, therefore, it will not dissociate in water $\chi_{H_2O} = 0.99$
When NaCl dissociates in water it will form 2 ions Na^+ and Cl^-, therefore, $\chi_{H_2O} < 0.99$ causing solution c to have the smallest vapor pressure.

47. $P_{solution} = \chi_{solvent} P^{\circ}_{solvent}$
$0.900\ atm = \chi_{C_6H_6}(0.930\ atm)$
$\chi_{C_6H_6} = 0.968$
$$\chi_{C_6H_6} = \frac{n_{C_6H_6}}{n_{C_6H_6} + n_?}$$
Determine moles of C_6H_6
$$78.11\ g\ C_6H_6 \left(\frac{1\ mol\ C_6H_6}{78.12\ g}\right) = 1.00\ mol\ C_6H_6$$
$$\chi_{C_6H_6} = \frac{n_{C_6H_6}}{n_{C_6H_6} + n_?}$$

$$0.968 = \frac{1.00\ mol}{1.00\ mol + n_?}$$

$n_? = 0.03$

Determine molar mass of substance

$$M_? = \frac{m}{n} = \frac{10.0\ g}{0.03\ mol} = 300\ \frac{g}{mol}$$

49. a)

$$P_{solution} = \chi_{C_5H_{12}} P^{\circ}_{C_5H_{12}} + \chi_{C_6H_{14}} P^{\circ}_{C_6H_{14}}$$

$$P_{solution} = \frac{n_{C_5H_{12}}}{n_{C_5H_{12}} + n_{6H_{14}}} P^{\circ}_{C_5H_{12}} + \frac{n_{6H_{14}}}{n_{C_5H_{12}} + n_{6H_{14}}} P^{\circ}_{C_6H_{14}}$$

Calculate moles of C_5H_{12}

$$m_{C_5H_{12}} = Vd_{C_5H_{12}} = (25\ cm^3)\left(0.63\ \frac{g}{cm^3}\right) = 16\ g$$

$$16\ g\ C_5H_{12}\left(\frac{1\ mol\ C_5H_{12}}{72.12\ g\ C_5H_{12}}\right) = 0.22\ mol\ C_5H_{12}$$

Calculate moles of C_6H_{14}

$$m_{C_5H_{12}} = Vd_{C_6H_{14}} = (45\ cm^3)\left(0.66\ \frac{g}{cm^3}\right) = 30.\ g$$

$$30.\ g\ C_6H_{14}\left(\frac{1\ mol\ C_6H_{14}}{86.20\ g\ C_6H_{14}}\right) = 0.35\ mol\ C_6H_{14}$$

$$P_{solution} = \frac{n_{C_5H_{12}}}{n_{C_5H_{12}} + n_{C_6H_{14}}} P^{\circ}_{C_5H_{12}} + \frac{n_{C_6H_{14}}}{n_{C_5H_{12}} + n_{C_6H_{14}}} P^{\circ}_{C_6H_{14}}$$

$$P_{solution} = \frac{0.22\ mol}{0.22\ mol + 0.35\ mol}(511\ torr) + \frac{0.35\ mol}{0.22\ mol + 0.35\ mol}(150.\ torr) = 290\ torr$$

b) We need to calculate the mole fraction of pentane in the vapor phase. You cannot use the mole fraction that was calculated in part (a) because that is the mole fraction in the liquid phase.

In the gas phase

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$\chi_{C_5H_{12}} = \frac{n_{C_5H_{12}}}{n_{C_5H_{12}} + n_{6H_{14}}} = \frac{\frac{P_{C_5H_{12}}V}{RT}}{\frac{P_{total}V}{RT}} = \frac{P_{C_5H_{12}}}{P_{total}} = \frac{2.0 \times 10^2\ torr}{290\ torr} = 0.69$$

51. We need to find χ_{prop} and χ_{meth}

What we know

$$P_{solution} = \chi_{meth} P^{\circ}_{meth} + \chi_{prop} P^{\circ}_{prop}$$

$$174\ torr = \chi_{meth}(303\ torr) + \chi_{prop}(44.6\ torr) \qquad \text{(equation a)}$$

$$1 = \chi_{meth} + \chi_{prop} \qquad \text{(equation b)}$$

Solve for χ_{meth} in equation b

$$1 = \chi_{meth} + \chi_{prop}$$

$$\chi_{meth} = 1 - \chi_{prop}$$

Plug into equation (a) and solve for χ_{prop}

$$174\ torr = (1 - \chi_{prop})(303\ torr) + \chi_{prop}(44.6\ torr)$$

$$\chi_{prop} = 0.499$$

Solve for χ_{meth}

$$1 = \chi_{meth} + \chi_{prop}$$

$$1 = 0.499 + \chi_{meth}$$
$$\chi_{meth} = 0.501$$

52. Plot a shows a positive deviation from Raoult's law. This happens when there are unfavorable relationships between the solvent and the solute. This is the situation for situation d in which the solvent/solute have differences in polarity $CH_3CH_2CH_2CH_2CH_2CH_3$ is nonpolar and H_2O is polar. Therefore, each of the substances would be more stable by themselves and not in solution. It is also the case for b. Both of these species are capable of H-bonding individually, therefore, adding them together will not make a more stable situation.

Plot b shows a negative deviation from Raoult's law. This happens when there are favorable relationships between the solvent and the solute. This is the situation for situation a, because CH_3COCH_3 would not be able to H-bond on its own. However, when water is present it can participate in H-bonding making the intermolecular forces in the solution stronger than the individual intermolecular forces.

Plot c shows the ideal Raoult's law. This happens when the intermolecular forces are the same between the individual parts of the solutions as with the solution. This is the case for c. Both $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ and $CH_3CH_2CH_2CH_2CH_2CH_3$ have nearly identical intermolecular forces resulting in an ideal situation when they are mixed.

53. Need to find $P_{solution}$, $\chi^V_{CH_3COCH_3}$, and $\chi^V_{CH_3OH}$ (V stands for the mole fraction in the vapor phase)

$$P_{solution} = \chi_{CH_3COCH_3} P^\circ_{CH_3COCH_3} + \chi_{CH_3OH} P^\circ_{CH_3OH}$$

$$P_{solution} = \frac{n_{CH_3COCH_3}}{n_{CH_3COCH_3} + n_{CH_3OH}} P^\circ_{CH_3COCH_3} + \frac{n_{CH_3OH}}{n_{CH_3COCH_3} + n_{CH_3OH}} P^\circ_{CH_3OH}$$

Calculate moles of acetone

$$50.0\ g\ CH_3COCH_3 \left(\frac{1\ mol\ CH_3COCH_3}{58.09\ g\ CH_3COCH_3}\right) = 0.861\ mol\ CH_3COCH_3$$

Calculate moles of methanol

$$50.0\ g\ CH_3OH \left(\frac{1\ mol\ CH_3OH}{32.05\ g\ CH_3OH}\right) = 1.56\ mol\ CH_3OH$$

$$P_{solution} = \frac{0.861\ mol}{0.861\ mol + 1.56\ mol}(271\ torr) + \frac{1.56\ mol}{0.861\ mol + 1.56\ mol}(143\ torr)$$
$$= 188.5\ torr$$

Calculate the mole fraction of acetone in the vapor phase

$$\chi^V_{CH_3COCH_3} = \frac{n_{CH_3COCH_3}}{n_{CH_3COCH_3} + n_{CH_3OH}}$$

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

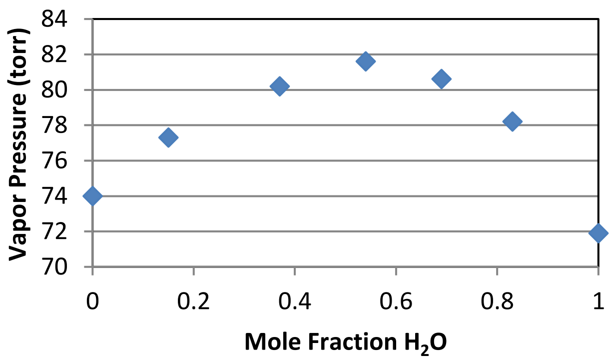
$$\chi^V_{CH_3COCH_3} = \frac{n_{CH_3COCH_3}}{n_{CH_3COCH_3} + n_{CH_3OH}} = \frac{\frac{P_{CH_3COCH_3}V}{RT}}{\frac{P_{total}V}{RT}} = \frac{P_{CH_3COCH_3}}{P_{total}} = \frac{96.5\ torr}{188.6\ torr} = 0.512$$

Calculate the mole fraction of methanol in the vapor phase

$$\chi^V_{CH_3COCH_3} = \frac{n_{CH_3OH}}{n_{CH_3COCH_3} + n_{CH_3OH}} = \frac{P_{CH_3OH}}{P_{total}} = \frac{92.1\ torr}{188.6\ torr} = 0.488$$

Since the actual vapor pressure is less than the total vapor pressure (negative deviation to Raoult's Law) there must be favorable solute-solvent interaction. Solute-solvent interactions are stronger than solute-solute and solvent-solvent interactions.

54.



a) In order to be an ideal solution when you plot vapor pressure vs. mole fraction a straight line should be observed. Therefore, the solution is not ideal.

b) The vapor pressure is higher than the ideal vapor pressure therefore, there is a positive deviation from Raoult's law. This means that there are unfavorable interactions between solute and solvent and ΔH is positive.

c) The positive deviation from Raoult's law shows that the vapor pressure is higher than the ideal case; this implies weaker interaction between propanol and the water than the pure substance.

d) The higher the vapor pressure, the lower the boiling point. Therefore, the lowest boiling point is when $\chi_{H_2O} = 0.54$

55. If the container feels warm it means that the solution released heat when it was formed. At constant pressure $q = \Delta H$, therefore, ΔH is negative. This implies that there will be a negative deviation to Raoult's law and the solution is not ideal. Note: This problem is incorrect because methanol and water would have a positive deviation, which would make the solution cool to the touch.

57. a) True b) True c) True d) True

e) False The smaller the vapor pressure, the higher the boiling point.

61. They want you to find T_b

The boiling point of pure water is 100°C

$T_b = 100.0°C + \Delta T_b$

Calculate the change in boiling point

$\Delta T_b = imK_b$

Calculate the molality

$m = \frac{n}{m}$

Calculate the moles of urea

$$27.0\ g\ (NH_2)_2CO \left(\frac{1\ mol\ (NH_2)_2CO}{60.07\ g\ (NH_2)_2CO}\right) = 0.499\ mol\ (NH_2)_2CO$$

$$m = \frac{n}{m} = \frac{0.499\ mol}{0.1500\ kg} = 3.00\ m$$

$\Delta T_b = imK_b$

I= 1 because non electrolyte

$K_b = 0.51 \frac{°C \cdot kg}{mol}$

$\Delta T_b = imK_b = (1)(3.00\ m)\left(0.51 \frac{°C \cdot kg}{mol}\right) = 1.5°C$

$T_b = 100.0°C + \Delta T_b = 100.0°C + 1.5°C = 101.5°C$

62. Need to determine $m_{C_3H_8O_3}$

Find ΔT_f

$T_f = 0.00°C - \Delta T_f$

$-1.50°C = 0.00°C - \Delta T_f$

$\Delta T_f = 1.50°C$

Find m

$\Delta T_f = imK_f$

$C_3H_8O_3$ is a non-electrolyte i=1

$1.50°C = (1)m\left(1.86 \frac{°C \cdot kg}{mol}\right)$

$m = 0.806\ m$

Find $m_{C_3H_8O_3}$

$$m = \frac{n_{C_3H_8O_3}}{m_{H_2O}}$$

$$0.806\ m = \frac{n_{C_3H_8O_3}}{0.200\ kg}$$

$n_{C_3H_8O_3} = 0.161\ mol\ C_3H_8O_3$

$$m_{C_3H_8O_3} = 0.161\ mol\ C_3H_8O_3 \left(\frac{92.11\ g\ C_3H_8O_3}{1\ mol\ C_3H_8O_3}\right) = 14.8\ g\ C_3H_8O_3$$

63. Need to find T_f and T_b

$T_f = 0.00°C - \Delta T_f$

Calculate ΔT_f

$\Delta T_f = imK_f$

Ethylene glycol is a non-electrolyte, i=1

Calculate m

$$m = \frac{n_{C_2H_6O_2}}{m_{H_2O}}$$

Assume 1.00 kg of solution
0.500 kg $C_2H_6O_2$
0.500 kg H_2O

$$500.\ g\ C_2H_6O_2\left(\frac{1\ mol\ C_2H_6O_2}{62.08\ g\ C_2H_6O_2}\right) = 8.05\ mol\ C_2H_6O_2$$

$$m = \frac{n_{C_2H_6O_2}}{m_{H_2O}} = \frac{8.04\ mol}{0.500\ kg} = 16.1\ m$$

$$\Delta T_f = imK_f = (1)(16.1\ m)\left(1.86\ \frac{℃\cdot kg}{mol}\right) = 30.0℃$$

$$T_f = 0.00℃ - \Delta T_f = 0.00℃ - 30.0℃ = -30.0℃$$

$$T_b = 100.0℃ + \Delta T_b$$

Calculate ΔT_b

$$\Delta T_b = imK_b = (1)(16.1\ m)\left(0.51\ \frac{℃\cdot kg}{mol}\right) = 8.21℃$$

$$T_b = 100.0℃ + \Delta T_b = 100.0℃ + 8.21℃ = 108.2℃$$

70. Need to calculate $V_{C_2H_6O_2}$

$$T_f = 0.00℃ - \Delta T_f$$

$$-30.0℃ = 0.00℃ - \Delta T_f$$

$$\Delta T_f = 30.0℃$$

Calculate $m_{C_2H_6O_2}$

$$\Delta T_f = imK_f$$

Ethylene glycol is a non-electrolyte, i=1

$$30.0℃ = (1)m\left(1.86\ \frac{℃\cdot kg}{mol}\right)$$

$$m = 16.1\ m$$

Calculate $n_{C_2H_6O_2}$

$$m = \frac{n_{C_2H_6O_2}}{m_{H_2O}}$$

Calculate m_{H_2O}

$$15.0\ L\left(\frac{1000\ mL}{1\ L}\right)\left(\frac{1\ cm^3}{1\ mL}\right)\left(\frac{1.00\ g}{1\ cm^3}\right) = 15{,}000 = 15.0\ kg$$

$$16.1\ m = \frac{n_{C_2H_6O_2}}{15.0\ \text{kg}}$$

$$n_{C_2H_6O_2} = 242\ mol$$

Calculate mass of $C_2H_6O_2$

$$m_{C_2H_6O_2} = 242\ mol\ C_2H_6O_2\left(\frac{62.08\ g\ C_2H_6O_2}{1\ mol\ C_2H_6O_2}\right) = 1.50 \times 10^4\ g\ C_2H_6O_2$$

Calculate $V_{C_2H_6O_2}$

$$1.50 \times 10^4\ g\ C_2H_6O_2\left(\frac{1\ cm^3}{1.11\ g}\right)\left(\frac{1\ mL}{1\ cm^3}\right) = 13{,}500\ mL = 13.5\ L$$

Calculate the boiling point of the solution

$$T_b = 100.00℃ + \Delta T_b$$

Calculate ΔT_b

$$\Delta T_b = imK_b = (1)(16.1\ m)\left(0.51\ \frac{℃\cdot kg}{mol}\right) = 8.2℃$$

$$T_b = 100.00℃ + 8.2℃ = 108.2℃$$

71. a) Need to calculate ΔT_f and π

$$\Delta T_f = imK_f$$

Calculate m

$$m = \frac{n_{\text{protein}}}{m_{H_2O}}$$

$d_{solution} = 1.0\,\frac{g}{cm^3}$

Therefore, if you have 1.0 L of solution it will weight 1000 g

In 1 L of solution there is 1.0 g of protein

Therefore, in a 1.0 L solution there is 1.0 g of protein and 999 g of H_2O

Calculate $n_{protein}$

Assume 1 L solution

$$1.0\text{ g}\left(\frac{1\,mol}{9.0\times10^4\,g}\right) = 1.1\times10^{-5}\,mol$$

$$m = \frac{n_{\text{protein}}}{m_{H_2O}} = \frac{1.1\times10^{-5}\,mol}{0.999\,kg} = 1.1\times10^{-5}\,m$$

$$\Delta T_f = imK_f = (1)(1.1\times10^{-5}\,m)\left(1.86\,\frac{℃\cdot kg}{mol}\right) = 2.1\times10^{-5}℃$$

$$\pi = iMRT$$

Calculate M

$$M = \frac{n_{\text{protein}}}{V_{\text{solution}}} = \frac{1.1\times10^{-5}\,mol}{1.0\,L} = 1.1\times10^{-5}\,M$$

$$\pi = iMRT = (1)(1.1\times10^{-5}\,M)\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(298K) = 2.7\times10^{-4}\,atm = 0.20\,torr$$

b) It would be better to use osmotic pressure because that is a larger number and will be easier to detect.

74. Need to calculate mass% $C_{10}H_8$, and $C_{14}H_{10}$

$$mass\ \%\ C_{10}H_8 = \left(\frac{m_{C_{10}H_8}}{m_{total}}\right)100\% = \left(\frac{m_{C_{10}H_8}}{1.60\,g}\right)100\%$$

$$mass\ \%\ C_{14}H_{10} = 100\% - mass\ \%\ C_{10}H_8$$

Find mass of $C_{10}H_8$

Know

$$1.60 = m_{C_{10}H_8} + m_{C_{14}H_{10}}$$

$$T_f = 2.81℃$$

Calculate ΔT_f

$$T_f = 5.51℃ - \Delta T_f$$

$$2.81℃ = 5.51℃ - \Delta T_f$$

$$\Delta T_f = 2.70℃$$

Solve for mass of $C_{10}H_8$

$$\Delta T_f = imK_f$$

$$2.70℃ = (1)\left(\frac{\frac{m_{C_{10}H_8}}{M_{C_{10}H_8}} + \frac{m_{C_{14}H_{10}}}{M_{C_{14}H_{10}}}}{0.0200\,kg}\right)\left(5.12\,\frac{℃\cdot kg}{mol}\right)$$

$$0.0105\,mol = \frac{m_{C_{10}H_8}}{128.18\,\frac{g}{mol}} + \frac{m_{C_{14}H_{10}}}{178.24\,\frac{g}{mol}} = \frac{178.24\,\frac{g}{mol}\left(m_{C_{10}H_8}\right) + 128.18\,\frac{g}{mol}\left(m_{C_{14}H_{10}}\right)}{22{,}846\,\frac{g^2}{mol^2}}$$

$$240\,\frac{g^2}{mol} = 178.24\,\frac{g}{mol}\left(m_{C_{10}H_8}\right) + 128.18\,\frac{g}{mol}\left(m_{C_{14}H_{10}}\right)$$

$$m_{C_{14}H_{10}} = 1.60\,g - m_{C_{10}H_8}$$

$$240\,\frac{g^2}{mol} = 178.24\,\frac{g}{mol}(m_{C_{10}H_8}) + 128.18\,\frac{g}{mol}(1.60\ g - m_{C_{10}H_8})$$
$$35\,\frac{g^2}{mol} = 50.06\,\frac{g}{mol} m_{C_{10}H_8}$$
$$m_{C_{10}H_8} = 0.70\ g$$
$$mass\ \%\ C_{10}H_8 = \left(\frac{m_{C_{10}H_8}}{m_{total}}\right)100\% = \left(\frac{0.70\ g}{1.60\ g}\right)100\% = 44\%\ C_{10}H_8$$

Find mass % $C_{10}H_8$

$$mass\ \%\ C_{14}H_{10} = 100\% - mass\ \%\ C_{10}H_8 = 100\% - 44\% = 56\%\ C_{14}H_{10}$$

79. Need to calculate χ_{NaCl} and vapor pressure of solution

Know

$P_{solution} = 19.6\ torr$ at 25°C

$P_{H_2O} = 23.8\ torr$ at 25°C

$P_{H_2O} = 71.9\ torr$ at 45°C

$$P_{solution} = \chi_{solvent} P^{\circ}_{solvent}$$
$$19.6\ torr = \chi_{H_2O}(23.8\ torr)$$
$$\chi_{H_2O} = 0.824 = \frac{n_{H_2O}}{n_{H_2O} + n_{Na^+} + n_{Cl^-}}$$
$$1 = \chi_{H_2O} + \chi_{Na^+} + \chi_{Cl^-}$$
$$1 = 0.824 + \chi_{Na^+} + \chi_{Cl^-}$$
$$\chi_{Na^+} + \chi_{Cl^-} = 0.176$$

NaCl→ Na^+ + Cl^- Therefore, the mole fractions of Na^+ and Cl^- must be equal and it must equal the mole fraction of NaCl

$$\chi_{Na^+} = \chi_{Cl^-} = \chi_{NaCl} = \frac{0.176}{2} = 0.0880$$
$$P_{solution} = \chi_{solvent} P^{\circ}_{solvent} = (0.824)(71.9\ torr) = 59.2\ torr$$

81.

0.010 m Na_3PO_4	i= 4	0.040 m (for all ions/molecules)
0.020 m $CaBr_2$	i= 3	0.060 m (for all ions/molecules)
0.020 m KCl	i=2	0.040 m (for all ions/molecules)
0.020 m HF	i~1	0.020 m (for all ions/molecules) Since HF is a weak acid most of the HF will be HF and not H^+ and F^-

a) $C_6H_{12}O_6$ is a non-electrolyte, i=1 0.040 m (for all ions/molecules)
Therefore the Na_3PO_4 and the KCl solution will have the same boiling points the $C_6H_{12}O_6$ solution.

b) The solution with the highest vapor pressure will be the solution that has the smallest molality for all ions/molecules. Therefore, the HF solution will have the highest vapor pressure.

c) The solution with the largest freezing point depression will be the solution that has the largest molality for all ions/molecules. Therefore, the $CaBr_2$ solution will have the largest freezing point depression.

82.

Pure Water		χ=0.00 (all ions/molecules)
$C_6H_{12}O_6$ (χ=0.01)	i=1	χ=0.01 (all ions/molecules)
NaCl (χ=0.01)	i=1	χ=0.02 (all ions/molecules)
$CaCl_2$(χ=0.01)	i=3	χ=0.03 (all ions/molecules)

a) lowest χ pure water

b) highest χ $CaCl_2$ solution

c) highest χ $CaCl_2$ solution
d) lowest χ pure water
c) highest χ $CaCl_2$ solution

117. Need to calculate mass % $MgCl_2$

$$mass\ \%\ MgCl_{Cl} = \left(\frac{m_{MgCl_2}}{m_{total}}\right)100\% = \left(\frac{m_{MgCl_2}}{0.500\ g}\right)100\%$$

Find mass of $MgCl_2$

Know

$$0.500\ g = m_{MgCl_2} + m_{NaCl}$$
$$\pi = 0.3950\ atm$$
$$\pi = iMRT$$
$$\pi = \left(i_{MgCl_2}M_{MgCl_2} + i_{NaCl}M_{NaCl}\right)RT$$

The upper case M is the molarity

$$0.3950\ atm = \left(3\frac{\frac{m_{MgCl_2}}{M_{MgCl_2}}}{V_{solution}} + 2\frac{\frac{m_{NaCl}}{M_{NaCl}}}{V_{solution}}\right)\left(0.08206\ \frac{L{\cdot}atm}{mol{\cdot}K}\right)(298K)$$

The upper case M is the molar mass

$$0.3950\ atm = \left(3\frac{\frac{m_{MgCl_2}}{M_{MgCl_2}}}{1.0000\ L} + 2\frac{\frac{m_{NaCl}}{M_{NaCl}}}{1.0000\ L}\right)\left(0.08206\ \frac{L{\cdot}atm}{mol{\cdot}K}\right)(298K)$$

$$0.01615\ mol = 3\frac{m_{MgCl_2}}{95.218\ \frac{g}{mol}} + 2\frac{m_{NaCl}}{58.443\ \frac{g}{mol}}$$

$$= \frac{\left(175.33\ \frac{g}{mol}\right)m_{MgCl_2} + \left(190.44\ \frac{g}{mol}\right)m_{NaCl}}{5{,}564.8\ \frac{g^2}{mol^2}}$$

$$89.87\ \frac{g^2}{mol} = \left(175.33\ \frac{g}{mol}\right)m_{MgCl_2} + \left(190.44\ \frac{g}{mol}\right)m_{NaCl}$$

Plug $m_{NaCl} = 0.500 - m_{MgCl_2}$ for mass of MgCl2

$$89.87\ \frac{g^2}{mol} = \left(175.33\ \frac{g}{mol}\right)m_{MgCl_2} + \left(190.44\ \frac{g}{mol}\right)\left(0.500 - m_{MgCl_2}\right)$$
$$-5.35\ \frac{g^2}{mol} = -\left(15.11\ \frac{g}{mol}\right)m_{MgCl_2}$$
$$m_{MgCl_2} = 0.354\ g$$

$$mass\ \%\ MgCl_2 = \left(\frac{m_{MgCl_2}}{m_{total}}\right)100\% = \left(\frac{0.354}{0.500\ g}\right)100\% = 70.8\%$$

124. Need to find T_b

$$T_b = 99.725°\text{C} + \Delta T_b$$

Calculate ΔT_b

$$\Delta T_b = imK_b$$

Non-electrolyte, i=1

Calculate m

$$m = \frac{n_{\text{solute}}}{m_{H_2O}}$$

$$35.0\ g\left(\frac{1\ mol}{58.0\ g}\right) = 0.603\ mol$$

$$m = \frac{n_{\text{solute}}}{m_{H_2O}} = \frac{0.603\ mol}{0.600\ kg} = 1.01\ m$$

$$\Delta T_b = imK_b = (1)(1.01\ m)\left(0.51\ \frac{\text{℃}\cdot kg}{mol}\right) = 0.52\text{℃}$$

$$T_b = 99.725\text{℃} + \Delta T_b = 99.725\text{℃} + 0.52\text{℃} = 100.25\text{℃}$$