Non Sibi High School

Andover's Chem 550/580: Advanced Chemistry

Chapter 21, Review Quiz 1 Answers

1

Calculate the mass of caffeine, $C_8H_{10}N_4O_2$, that must be dissolved in 75.0 grams of dichloromethane, CH_2Cl_2, to create a 0.103 m solution.

$$75.0\,\mathrm{g\,CH_2Cl_2}\left(\frac{1\,\mathrm{kg\,CH_2Cl_2}}{1000\,\mathrm{g\,CH_2Cl_2}}\right)\left(\frac{0.103\,\mathrm{mol\,C_8H_{10}N_4O_2}}{1\,\mathrm{kg\,CH_2Cl_2}}\right)\left(\frac{194.2\,\mathrm{g\,C_8H_{10}N_4O_2}}{1\,\mathrm{mol\,C_8H_{10}N_4O_2}}\right) = 1.50\,\mathrm{g\,C_8H_{10}N_4O_2}$$

2

To create a 0.22 m solution, how many grams of carbon disulfide must be used to dissolve 2.7 grams of Br_2?

$$2.7\,\mathrm{g\,Br_2}\left(\frac{1\,\mathrm{mol\,Br_2}}{159.8\,\mathrm{g\,Br_2}}\right)\left(\frac{1\,\mathrm{kg\,CS_2}}{0.22\,\mathrm{mol\,Br_2}}\right)\left(\frac{1000\,\mathrm{g\,CS_2}}{1\,\mathrm{kg\,CS_2}}\right) = 77\,\mathrm{g\,CS_2}$$

3

The freezing point of benzene, C_6H_6, is 5.5°C and the boiling point of benzene is 80.1°. Given that $K_f = 5.12°C/m$ and $K_b = 2.53°C/m$ for benzene, calculate the molality, the freezing point, and the boiling point of a solution containing 17 grams of camphor, $C_{10}H_{16}O$, dissolved in 66 grams of benzene.

$$17\,\mathrm{g\,C_{10}H_{16}O}\left(\frac{1\,\mathrm{mol\,C_{10}H_{16}O}}{152.2\,\mathrm{g\,C_{10}H_{16}O}}\right) = 0.112\,\mathrm{mol\,C_{10}H_{16}O}$$

$$66\,\mathrm{g\,C_6H_6}\left(\frac{1\,\mathrm{kg\,C_6H_6}}{1000\,\mathrm{g\,C_6H_6}}\right) = 0.066\,\mathrm{kg\,C_6H_6}$$

$$\frac{0.112\,\mathrm{mol\,C_{10}H_{16}O}}{0.066\,\mathrm{kg\,C_6H_6}} = 1.7\,\mathrm{mol/kg\ or\ }1.7\,m$$

$$\Delta t_f = (5.12°\mathrm{C}/m)(1.7\,m) = 8.7°\mathrm{C}$$

$$5.5°\mathrm{C} - 8.7°\mathrm{C} = -3.2°\mathrm{C}$$

$$\Delta t_b = (2.53°\mathrm{C}/m)(1.7\,m) = 4.3°\mathrm{C}$$

$$80.1°\mathrm{C} + 4.3°\mathrm{C} = 84.4°\mathrm{C}$$

4

Rank the following aqueous solutions in order from lowest to highest freezing point and from lowest to highest boiling point without performing detailed calculations:

$$0.018\,m\,\mathrm{K_3PO_4}$$
$$0.020\,m\,\mathrm{SrBr_2}$$
$$0.025\,m\,\mathrm{C_6H_{12}O_6}$$
$$0.025\,m\,\mathrm{HI}$$
$$0.025\,m\,\mathrm{HNO_2}$$

Each solution has the same solvent and, therefore, will have the same value of $\mathrm{K_f}$ in the equation $\Delta\mathrm{t_f} = i\mathrm{K_f}m$ and the same value of $\mathrm{K_b}$ in the equation $\Delta\mathrm{t_f} = i\mathrm{K_b}m$. As such, a solution with a larger product of $(i \times m)$ will have a larger freezing point depression and a larger boiling point elevation. The solutions can be ranked from smallest $\Delta\mathrm{t_f}$ and $\Delta\mathrm{t_b}$ at the top to largest $\Delta\mathrm{t_f}$ and $\Delta\mathrm{t_b}$ at the bottom as follows:

0.025 m $C_6H_{12}O_6$=molecular (no ionization), i=1: $i \times m = 1 \times 0.025\,m = 0.025\,m$

0.025 m HNO_2=monoprotic weak acid, $1 < i < 2$: $0.025\,m < i \times m < 0.050\,m$

0.025 m HI=monoprotic strong acid, i=2 (H^+ + Cl^-): $i \times m = 2 \times 0.025\,m = 0.050\,m$

0.020 m $SrBr_2$=ionic, i=3 (Sr^{2+} + $2Br^-$): $i \times m = 3 \times 0.020\,m = 0.060\,m$

0.018 m K_3PO_4=ionic, i=4 ($3K^+$ + $PO_4{}^{3-}$): $i \times m = 4 \times 0.018\,m = 0.072\,m$

A solution with a larger $\Delta\mathrm{t_f}$ will have a lower freezing point. Therefore, the solutions will be ranked from lowest to highest freezing point as follows:

0.018 m K_3PO_4 < 0.020 m $SrBr_2$ < 0.025 m HI < 0.025 m HNO_2 < 0.025 m $C_6H_{12}O_6$

A solution with a larger $\Delta\mathrm{t_b}$ will have a higher boiling point. Therefore, the solutions will be ranked from lowest to highest boiling point as follows:

0.025 m $C_6H_{12}O_6$ < 0.025 m HNO_2 < 0.025 m HI < 0.020 m $SrBr_2$ < 0.018 m K_3PO_4

5

a. A molecular solute that does not ionize was found to be 38.7% carbon and 9.7% hydrogen by mass, with the remainder being oxygen. Determine the empirical formula of the solute.

$$100\% - 38.7\%\,\mathrm{C} - 9.7\%\,\mathrm{H} = 51.6\%\,\mathrm{O}$$

Assume one hundred grams of solute:

$$38.7\,\mathrm{g\,C}\left(\frac{1\,\mathrm{mol}}{12.01\,\mathrm{g}}\right) = 3.222\,\mathrm{mol\,C}$$

$$9.7\,\mathrm{g\,H}\left(\frac{1\,\mathrm{mol}}{1.008\,\mathrm{g}}\right) = 9.62\,\mathrm{mol\,H}$$

$$51.6\,\mathrm{g\,O}\left(\frac{1\,\mathrm{mol}}{16.00\,\mathrm{g}}\right) = 3.225\,\mathrm{mol\,O}$$

$$\frac{3.222}{3.222}\,\mathrm{mol\,C} : \frac{9.62}{3.222}\,\mathrm{mol\,H} : \frac{3.225}{3.222}\,\mathrm{mol\,O}$$

$$\mathrm{empirical\,formula} = \mathrm{CH_3O}$$

b. A solution containing 1.6 grams of the solute dissolved in 9.8 grams of water was found to freeze at -4.9°C. If K_f for water is 1.86°C/m, determine the molar mass and molecular formula of the solute.

$$0.0^\circ\mathrm{C} - (-4.9^\circ\mathrm{C}) = 4.9^\circ\mathrm{C}$$

$$9.8\,\mathrm{g\,H_2O}\left(\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}}\right) = 0.0098\,\mathrm{kg}$$

$$4.9^\circ\mathrm{C} = \frac{1.86^\circ\mathrm{C}\cdot\mathrm{kg}}{1\,\mathrm{mol}}\left(\frac{\mathrm{n_{solute}}}{0.0098\,\mathrm{kg}}\right)$$

$$\mathrm{n_{solute}} = 0.0258\,\mathrm{mol}$$

$$M = \frac{1.6\,\mathrm{g}}{0.0258\,\mathrm{mol}} = 62\,\mathrm{g/mol}$$

$$\frac{M}{EM} = \frac{62}{31.03} = 2$$

$$\mathrm{molecular\,formula} = \mathrm{CH_3O} \times 2 = \mathrm{C_2H_6O_2}$$

6

The vapor pressure of pure water at 27°C is 26.7 mmHg. Calculate the vapor pressure of water and the total vapor pressure above a solution containing 105 grams of nonvolatile glucose, $C_6H_{12}O_6$, dissolved in 765 grams of water at 27°C.

$$105\,\mathrm{g}\,\mathrm{C_6H_{12}O_6}\left(\frac{1\,\mathrm{mol}}{180.2\,\mathrm{g}}\right) = 0.5827\,\mathrm{mol}\,\mathrm{C_6H_{12}O_6}$$

$$765\,\mathrm{g}\,\mathrm{H_2O}\left(\frac{1\,\mathrm{mol}}{18.02\,\mathrm{g}}\right) = 42.45\,\mathrm{mol}\,\mathrm{H_2O}$$

$$\mathrm{P_{H_2O}} = \left(\frac{42.45\,\mathrm{mol}\,\mathrm{H_2O}}{42.45\,\mathrm{mol}\,\mathrm{H_2O} + 0.5827\,\mathrm{mol}\,\mathrm{C_6H_{12}O_6}}\right)(26.7\,\mathrm{mmHg}) = 26.3\,\mathrm{mmHg}$$

7

The vapor pressure of pure ethanol, C_2H_5OH, at 40°C is 128.6 mmHg. The vapor pressure of pure propanol, C_3H_7OH, at 40°C is 36.4 mmHg. For a liquid mixture containing 388 grams of ethanol and 323 grams of propanol at 40°C, calculate:

a. The partial vapor pressures of ethanol and propanol above the mixture.

$$388\,\mathrm{g}\,\mathrm{C_2H_5OH}\left(\frac{1\,\mathrm{mol}}{46.07\,\mathrm{g}}\right) = 8.422\,\mathrm{mol}\,\mathrm{C_2H_5OH}$$

$$323\,\mathrm{g}\,\mathrm{C_3H_7OH}\left(\frac{1\,\mathrm{mol}}{60.09\,\mathrm{g}}\right) = 5.375\,\mathrm{mol}\,\mathrm{C_3H_7OH}$$

$$\mathrm{P_{C_2H_5OH}} = \left(\frac{8.422\,\mathrm{mol}\,\mathrm{C_2H_5OH}}{8.422\,\mathrm{mol}\,\mathrm{C_2H_5OH} + 5.375\,\mathrm{mol}\,\mathrm{C_3H_7OH}}\right)(128.6\,\mathrm{mmHg}) = 78.5\,\mathrm{mmHg}$$

$$\mathrm{P_{C_3H_7OH}} = \left(\frac{5.375\,\mathrm{mol}\,\mathrm{C_3H_7OH}}{8.422\,\mathrm{mol}\,\mathrm{C_2H_5OH} + 5.375\,\mathrm{mol}\,\mathrm{C_3H_7OH}}\right)(36.4\,\mathrm{mmHg}) = 14.2\,\mathrm{mmHg}$$

b. The total vapor pressure above the mixture.

$$\mathrm{P_{total}} = 78.5\,\mathrm{mmHg} + 14.2\,\mathrm{mmHg} = 92.7\,\mathrm{mmHg}$$

c. The mole fractions of ethanol vapor and propanol vapor above the mixture.

$$x_{\mathrm{C_2H_5OH(g)}} = \frac{78.5}{92.7} = 0.847$$

$$x_{\mathrm{C_3H_7OH(g)}} = 1 - 0.847 = 0.153$$

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