

- 13.34** What is the mole fraction of water in a solution prepared by mixing 12.5 g of H<sub>2</sub>O with 220 g of acetone, C<sub>3</sub>H<sub>6</sub>O?  
 (a) 0.817 (d) 0.155  
 (b) 0.845 (e) none of these  
 (c) 0.183

- 13.35** In which of the following solvents would you expect the solubility of CaCl<sub>2</sub> to be greatest?  
 (a) CH<sub>3</sub>OH (c) CCl<sub>4</sub>  
 (b) C<sub>6</sub>H<sub>6</sub> (benzene) (d) H<sub>2</sub>O  
 (e) insufficient information to answer question

- 13.36** Given that  $K_b = 2.53^\circ\text{C}/m$  for benzene, which mass of acetone (CH<sub>3</sub>COCH<sub>3</sub>) must be dissolved in 200 g of benzene to raise the boiling point of benzene by 3.00 °C?  
 (a) 7.26 g (d) 0.138 g  
 (b) 0.0726 g (e) 13.8 g  
 (c) 2.56 g

- 13.37** The presence of a nonvolatile solute in a volatile solvent will result in which of the following?  
 (a) It will raise the freezing point and lower the vapor pressure and boiling point.  
 (b) It will lower the freezing point and raise the vapor pressure and boiling point.  
 (c) It will raise the freezing point, vapor pressure, and boiling point.  
 (d) It will lower the freezing point and vapor pressure and raise the boiling point.  
 (e) It will lower the boiling point and raise the freezing point and vapor pressure.

- 13.38** Which of the following substances might stabilize a colloidal suspension of oil in water?  
 (a) octane, C<sub>8</sub>H<sub>18</sub>  
 (b) sodium bicarbonate, NaHCO<sub>3</sub>  
 (c) sodium stearate, NaCO<sub>2</sub>(CH<sub>2</sub>)<sub>16</sub>CH<sub>3</sub>  
 (d) HCl  
 (e) CaCl<sub>2</sub>

- 13.39** Which of the following solutions has the largest osmotic pressure?  
 (a) 0.15 M NaCl (d) 0.05 M Al(NO<sub>3</sub>)<sub>3</sub>  
 (b) 0.10 M CaCl<sub>2</sub> (e) 0.20 M NH<sub>3</sub>  
 (c) 0.05 M Ba(NO<sub>3</sub>)<sub>2</sub>

- 13.40** When 0.200 g of a high-molecular-weight compound is dissolved in water to form 12.5 mL of solution at 25 °C, the osmotic pressure of the solution is found to be  $1.10 \times 10^{-3}$  atm. What is the molar mass of the compound?  
 (a)  $3.56 \times 10^5$  g (d)  $2.98 \times 10^3$  g  
 (b)  $3.56 \times 10^4$  g (e)  $3.00 \times 10^4$  g  
 (c)  $2.98 \times 10^4$  g

## SELF-TEST SOLUTIONS

**13.1** True.  $m = 0.12 \text{ mol}/0.500 \text{ kg} = 0.24$ . **13.2** True. Mass % =  $(10.0 \text{ g})/(10.0 \text{ g} + 190 \text{ g})(100) = 5.00\%$ . **13.3** False. In 1000 mL of water, 1.1 mol of CH<sub>3</sub>(CH<sub>2</sub>)<sub>3</sub>OH dissolves. Thus in 100 mL of water, 0.11 mol of CH<sub>3</sub>(CH<sub>2</sub>)<sub>3</sub>OH dissolves. **13.4** True. **13.5** True. **13.6** True. **13.7** False. A particle size of  $10^4 \text{ \AA}$  is too

large for a colloidal solution to form. **13.8** True. **13.9** True. **13.10** False. Water flows from the more dilute solution to the more concentrated solution until the osmotic pressures become equal. **13.11** False. Since LaCl<sub>3</sub> ionizes to form four particles, the total molality of the solution is  $4 \times 0.25 \text{ m} = 1.00 \text{ m}$ , not simply 0.25 m. Therefore,  $\Delta T = K_f(1.00 \text{ m})$ . **13.12** False. Vapor-pressure lowering is directly related to the mole fraction of solvent and vapor pressure of pure solvent. **13.13** True. **13.14** True. An ideal solution obeys Raoult's law which states that the vapor pressure of a solvent is directly proportional to the product of its mole fraction and vapor pressure as a pure liquid. Since the vapor pressure is directly related to the mole fraction of the solvent, this suggests that the solution is ideal. **13.15** False. 1 ppm corresponds to 1 mg of solute per liter of solution. Thus the concentration should be 0.30 ppm. **13.16** True. **13.17** True. **13.18** False. Inspect Table 13.5 in the text. You will see the opposite is true. This results from the slope of the solid—gas equilibrium line in a phase diagram being less than that of the liquid—gas equilibrium line. **13.19** False. Ion-pairs reduce the total number of solute species in solution; therefore, osmotic pressure decreases. **13.20** False. A hydrophilic species will have a highly charged region or a number of very polar regions. This is not the case for the given molecule. **13.21** True. A hydrophobic group will be non-polar and molecular hydrophobic properties are enhanced by a large non-polar group.

**13.22**

$$\begin{aligned} \pi &= MRT \\ &= \frac{g}{(M)(V)} RT = \frac{gRT}{(M)(V)} \\ M &= \frac{gRT}{\pi V} \\ &= \frac{(20.0 \text{ g})(0.082 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K})(298 \text{ K})}{(5.43 \text{ atm})(0.500 \text{ L})} \\ &= 180 \text{ g/mol} \end{aligned}$$

**13.23**

(a)

$$\begin{aligned} m &= \frac{\text{moles Na}_2\text{CO}_3}{\text{kg of solvent}} \\ &= \frac{(142 \text{ g Na}_2\text{CO}_3) \left( \frac{1 \text{ mol}}{106.0 \text{ g}} \right)}{2.00 \text{ kg H}_2\text{O}} \\ &= 0.670 \text{ molal} \end{aligned}$$

(b)

$$\begin{aligned} m &= \frac{\text{moles codeine}}{\text{kg of solvent}} \\ &= \frac{(24.50 \text{ g codeine}) \left( \frac{1 \text{ mol}}{299.4 \text{ g}} \right)}{(150.5 \text{ g ethanol}) \left( \frac{1 \text{ kg}}{1000 \text{ g}} \right)} \\ &= 0.5437 \text{ molal} \end{aligned}$$

$$\begin{aligned}
 \text{(c)} \quad X(\text{NaCl}) &= \frac{\text{mol NaCl}}{\text{mol NaCl} + \text{mol H}_2\text{O}} \\
 &= \frac{(32.3 \text{ g NaCl}) \left( \frac{1 \text{ mol}}{58.4 \text{ g}} \right)}{\left[ (32.3 \text{ g NaCl}) \left( \frac{1 \text{ mol}}{58.5 \text{ g}} \right) + (265.0 \text{ g H}_2\text{O}) \left( \frac{1 \text{ mol}}{18.01 \text{ g}} \right) \right]} \\
 &= \frac{0.533 \text{ mol}}{0.552 \text{ mol} + 14.71 \text{ mol}} = 0.0362
 \end{aligned}$$

$$\begin{aligned}
 \text{(d)} \quad \% \text{ HCl} &= \frac{140 \text{ g HCl}}{140 \text{ g HCl} + 800 \text{ g H}_2\text{O}} \times 100 \\
 &= 14.9\% \text{ HCl}
 \end{aligned}$$

**13.24** This problem requires the following conversions: mass of HCl  $\rightarrow$  mass of solution  $\rightarrow$  volume of solution. The first conversion is accomplished by using 37.2% HCl-by-mass because there are 37.2 g of HCl per 100.0 g of solution

$$(150 \text{ g HCl}) \left( \frac{100.0 \text{ g solution}}{37.2 \text{ g HCl}} \right) = 403 \text{ g solution}$$

Density is used to convert from mass of solution to volume of solution.

$$(403 \text{ g solution}) \left( \frac{1 \text{ mL solution}}{1.19 \text{ g solution}} \right) = 339 \text{ mL solution}$$

**13.25** The  $\Delta T$  lowering for a 0.01 *m* weak electrolyte solution is approximately  $\Delta T_f = K_f m = (1.86 \text{ }^\circ\text{C}/m)(0.01 \text{ } m) = 0.0186 \text{ }^\circ\text{C}$ . Only the 0.01 *m*  $\text{CH}_3\text{COOH}$  solution has a  $\Delta T_f$  approximately equal to 0.0186  $^\circ\text{C}$ ; it is the only weak electrolyte. The other salt solutions produce freezing-point depressions significantly greater than that of acetic acid; thus they are all strong electrolytes. Since the 0.01 *m* solution of  $\text{Co}(\text{NH}_3)_6\text{Cl}_2$  produces the greatest  $\Delta T_f$  lowering, the molality of all species in the solution is the largest; it forms the greatest number of ions in solution. **13.26** The solutions are isotonic if they have the same osmotic pressure. The osmotic pressure of 0.157 *M* NaCl is calculated using the expression  $\pi = MRT$ . The value of *M* is 2(0.157 *M*) because there are two ions per NaCl formula:

$$\pi = (0.314 \text{ } M) \left( 0.082 \frac{\text{L}\cdot\text{atm}}{\text{K}\cdot\text{mol}} \right) (298 \text{ K}) = 7.7 \text{ atm}$$

The solutions are isotonic. **13.27**  $\text{VPL} = X_{\text{sucrose}} P_{\text{H}_2\text{O}}^\circ$ ;  $X_{\text{sucrose}} = \text{mol sucrose}/(\text{mol sucrose} + \text{mol H}_2\text{O})$ . For very dilute solutions, such as this one in which the number of moles of  $\text{H}_2\text{O}$  is far greater in magnitude than number of moles of sucrose, we can assume that  $(\text{mol sucrose} + \text{mol H}_2\text{O}) \approx \text{mol H}_2\text{O}$ .

$$\text{VLP} = X_{\text{sucrose}} P_{\text{H}_2\text{O}}^\circ = \left( \frac{\text{mol sucrose}}{\text{mol H}_2\text{O}} \right) P_{\text{H}_2\text{O}}^\circ$$

$$\text{VLP} = \left[ \frac{(\text{grams sucrose}) \left( \frac{1 \text{ mol sucrose}}{\mathcal{M} \text{ sucrose}} \right)}{(\text{grams H}_2\text{O}) \left( \frac{1 \text{ mol H}_2\text{O}}{\mathcal{M} \text{ H}_2\text{O}} \right)} \right] P_{\text{H}_2\text{O}}^\circ$$

$$\begin{aligned}
 \mathcal{M} \text{ sucrose} &= \left( \frac{\text{grams sucrose}}{\text{grams H}_2\text{O}} \right) \left( \frac{1 \text{ mol sucrose}}{1 \text{ mol H}_2\text{O}} \right) \\
 &\times \left( \frac{P_{\text{H}_2\text{O}}^\circ}{\text{VPL}} \right) (\mathcal{M} \text{ H}_2\text{O}) \\
 &= \left( \frac{20.00 \text{ g}}{100.00 \text{ g}} \right) \left( \frac{1 \text{ mol}}{1 \text{ mol}} \right) \\
 &\times \left( \frac{17.54 \text{ mm Hg}}{0.185 \text{ mm Hg}} \right) \left( \frac{18.0 \text{ g}}{1 \text{ mol}} \right) \\
 &= 341 \text{ g}
 \end{aligned}$$

**13.28** There are two primary reasons why hydrophilic colloidal particles do not settle out of a solution. The charge on all colloidal solution particles is the same, and repulsions between the similarly charged particles keep them separated. Also, their small size results in a high kinetic energy, which counteracts gravitational forces. **13.29**  $\text{NH}_3(l)$  is a polar solvent. The most polar substance of each pair will be the most soluble. (a)  $\text{NaCl}(s)$  is more soluble because it contains ions;  $\text{H}_2(g)$  is nonpolar. (b)  $\text{CH}_3\text{OH}(l)$  is more soluble because it is polar;  $\text{CCl}_4(l)$  is nonpolar. **13.30** (a) Sublimation of solid  $\text{CO}_2$  involves an increase in randomness because of change from organized crystal lattice to random nature of particles in gaseous state. (b) The freezing of liquid ammonia results in a decrease in randomness because a solid has a more organized arrangement of particles than a liquid. (c) With an increase in pressure, more  $\text{N}_2(g)$  molecules dissolve. These dissolved particles are more confined and have less random movement than when they were in the gas phase. Therefore, there is a decrease in disorder. **13.31** A protein folds itself in such a way that the polar units are exposed to polar water and the nonpolar units are tucked away inside the structure. The nonpolar units are in this way prevented from interacting with polar water molecules. This is another application of the "likes dissolve likes" concept. **13.32** To calculate the solubility of KBr in units of grams per 100 mL of  $\text{H}_2\text{O}$ , use the definitions of density and molality. From the density of  $\text{H}_2\text{O}$ , you calculate the mass of 100 mL of  $\text{H}_2\text{O}$  to be 0.099987 kg. From the definition of molality, the number of moles of KBr in 100 mL of water is calculated as follows:

$$\begin{aligned}
 \text{Moles KBr in 100 mL H}_2\text{O} &= (\text{molality}) \left( \frac{0.099987 \text{ kg}}{100 \text{ mL H}_2\text{O}} \right) \\
 &= \left( \frac{0.4499 \text{ mol}}{\text{kg}} \right) \left( \frac{0.099987 \text{ kg}}{100 \text{ mL H}_2\text{O}} \right) \\
 &= 0.04498 \text{ mol}/100 \text{ mL H}_2\text{O}
 \end{aligned}$$

The solubility of KBr in units of grams per 100 mL of  $\text{H}_2\text{O}$  is calculated as follows:

$$\begin{aligned}
 &\left( \frac{0.04498 \text{ mol KBr}}{100 \text{ mL H}_2\text{O}} \right) \left( \frac{119.01 \text{ g KBr}}{1 \text{ mol KBr}} \right) \\
 &= 5.354 \text{ g KBr}/100 \text{ mL H}_2\text{O}
 \end{aligned}$$

13.33

$$(a) \quad m = \frac{(5.00 \text{ g C}_2\text{H}_4(\text{OH})_2) \left( \frac{1 \text{ mol C}_2\text{H}_4(\text{OH})_2}{62.07 \text{ g C}_2\text{H}_4(\text{OH})_2} \right)}{(125 \text{ g H}_2\text{O}) \left( \frac{1 \text{ kg}}{1000 \text{ g}} \right)}$$

$$= 0.644$$

13.34

$$(d) \quad X_{\text{H}_2\text{O}} = \frac{(12.5 \text{ g H}_2\text{O}) \left( \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} \right)}{\left[ (12.5 \text{ g H}_2\text{O}) \left( \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} \right) + (220 \text{ g C}_3\text{H}_6\text{O}) \left( \frac{1 \text{ mol C}_3\text{H}_6\text{O}}{58.09 \text{ g C}_3\text{H}_6\text{O}} \right) \right]}$$

$$= 0.155$$

13.35 (d).  $\text{CaCl}_2$  is an ionic substance and will dissolve best in the most polar solvent, water.

13.36 (e).

$$\Delta T = K_b m = K_b \left( \frac{\text{moles acetone}}{1 \text{ kg benzene}} \right)$$

$$\text{Moles acetone} = \left( \frac{\Delta T}{K_b} \right) (1 \text{ kg benzene})$$

$$= \left( \frac{3.00 \text{ }^\circ\text{C}}{2.53 \text{ }^\circ\text{C}/m} \right) (1 \text{ kg benzene})$$

$$= \left( \frac{1.19 \text{ mol acetone}}{1 \text{ kg benzene}} \right) (1 \text{ kg benzene})$$

$$= 1.19 \text{ mol}$$

The number of moles of acetone in 200 g of benzene is calculated as follows:

$$\frac{1.19 \text{ mol acetone}}{\text{moles acetone}} = \frac{100 \text{ g benzene}}{200 \text{ g benzene}}$$

$$\text{Moles acetone} = 0.238 \text{ mol}$$

$$\text{Mass acetone} = (0.238 \text{ mol acetone})$$

$$\times \left( \frac{58.09 \text{ g acetone}}{1 \text{ mol acetone}} \right)$$

$$= 13.8 \text{ g}$$

13.37 (d). 13.38 (c). 13.39 (b). The solution with the highest molarity of particles has largest osmotic pressure.

$$13.40 (a). \quad M = \frac{\pi}{RT} = \frac{1.10 \times 10^{-3} \text{ atm}}{\left( 0.082 \frac{\text{L}\cdot\text{atm}}{\text{K}\cdot\text{mol}} \right) (298 \text{ K})}$$

$$= 4.50 \times 10^{-5} \text{ mol/L}$$

The number of moles in 0.200 g of the compound in 12.5 mL is:

$$\text{Moles} = \left( 4.50 \times 10^{-5} \frac{\text{mol}}{\text{L}} \right) \left( \frac{1 \text{ mol}}{1000 \text{ mL}} \right) (12.5 \text{ mL})$$

$$= 5.62 \times 10^{-7} \text{ mol}$$

The molar mass of the compound is calculated as follows:

$$\frac{0.200 \text{ g}}{\text{mass of 1 mol}} = \frac{5.62 \times 10^{-7} \text{ mol}}{1 \text{ mol}}$$

$$\text{Molar mass} = (0.200 \text{ g}) \left( \frac{1 \text{ mol}}{5.62 \times 10^{-7} \text{ mol}} \right)$$

$$= 3.56 \times 10^5 \text{ g}$$