AP Chemistry – PS#18 – ch. 11 – ANSWERS

11.5 As the temperature of a substance is increased, the average kinetic energy of the particles increases. In a collection of particles (molecules), the state is determined by the strength of interparticle forces relative to the average kinetic energy of the particles. As the average kinetic energy increases, more particles are able to overcome intermolecular attractive forces and move to a less ordered state, from solid to liquid to gas.

11.6 (a) At constant temperature, the average kinetic energy of a collection of particles is constant. Compression brings particles closer together and increases the number of particle-particle collisions. With more collisions, the likelihood of intermolecular attractions causing the particles to coalesce (liquefy) is greater.

(b) In both liquids and solids, the component particles are touching. Most of the empty space in the sample volume has been eliminated and the sample is condensed.

11.8 (a) London-dispersion forces (b) dipole-dipole and London-dispersion forces
(c) hydrogen bonding

11.14 For molecules with similar structures, the strength of dispersion forces increases with molecular size (molecular weight and number of electrons in the molecule).

(a) Br_2 (b) $CH_3CH_2CH_2SH$

(c) $CH_3CH_2CH_2Cl$. These two molecules have the same molecular formula and molecular weight (C_3H_7Cl, molecular weight = 78.5 amu), so the shapes of the molecules determine which has the stronger dispersion forces. According to Figure 11.6, the cylindrical (not branched) molecule will have stronger dispersion forces.

11.18 (a) Replacing a hydroxyl hydrogen with a CH_3 group eliminates hydrogen bonding in that part of the molecule. This reduces the strength of intermolecular forces and leads to a (much) lower boiling point.

(b) $CH_3OCH_2CH_2OCH_3$ is a larger, more polarizable molecule with stronger London-dispersion forces and thus a higher boiling point.

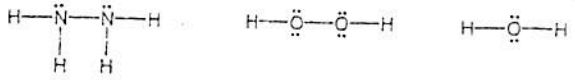
11.20 (a) C_6H_{14} – dispersion; C_8H_{18} – dispersion. C_8H_{18} has the higher boiling point due to greater molar mass and similar strength of forces.

(b) C_3H_8 – dispersion; CH_3OCH_3 – dipole-dipole and dispersion. CH_3OCH_3 has the higher boiling point due to stronger intermolecular forces and similar molar mass.

(c) CH_3OH – hydrogen bonding, dipole-dipole and dispersion; CH_3SH – dipole-dipole and dispersion. CH_3OH has the higher boiling point due to the influence of hydrogen bonding (Figure 11.7).

(d) NH_2NH_2 – hydrogen bonding, dipole-dipole and dispersion; CH_3CH_3 – dispersion. NH_2NH_2 has the higher boiling point due to much stronger intermolecular forces.

11.26 (a)



(b) All have bonds (N-H or O-H, respectively) capable of forming hydrogen bonds. Hydrogen bonding is the strongest intermolecular interaction between neutral molecules and leads to very strong cohesive forces in liquids. The stronger the cohesive forces in a liquid, the greater the surface tension.

Problem Set #19 — AP Chemistry

11.27 Endothermic: melting (s → l), vaporization (l → g), sublimation (s → g)
Exothermic: condensation (g → l), freezing (l → s), deposition (g → s)

11.30 (a) Liquid ethyl chloride at room temperature is far above its boiling point. When the liquid contacts the metal surface, heat sufficient to vaporize the liquid is transferred from the metal to the ethyl chloride, and the heat content of the molecules increases. At constant atmospheric pressure, $\Delta H = q$, so the heat content and the enthalpy content of $C_2H_5Cl(g)$ is higher than that of $C_2H_5Cl(l)$.

(b) Attractive intermolecular forces hold the C_2H_5Cl molecules in close contact in the liquid phase. In order to overcome these attractive forces and maintain separation in the gas phase, the enthalpy content of the C_2H_5Cl molecules must increase when they change from the liquid to the gaseous state.

11.35 (a) The critical pressure is the pressure required to cause liquefaction at the critical temperature. The critical temperature is the highest temperature at which a gas can be liquefied, regardless of pressure.

(b) As the force of attraction between molecules increases, the critical temperature of the compound increases.

(c) The temperature of $N_2(l)$ is 77 K. All of the gases in Table 11.4 have critical temperatures higher than 77 K, so all of them can be liquefied at this temperature, given sufficient pressure.

11.41 (a) The water in the two pans is at the same temperature, the boiling point of water at the atmospheric pressure of the room. During a phase change, the temperature of a system is constant. All energy gained from the surroundings is used to accomplish the transition, in this case to vaporize the liquid water. The pan of water that is boiling vigorously is gaining more energy and the liquid is being vaporized more quickly than in the other pan, but the temperature of the phase change is the same.

(b) Vapor pressure does not depend on either volume or surface area of the liquid. As long as the containers are at the same temperature, the vapor pressures of water in the two containers are the same.

11.42 (a) On a humid day, there are more gaseous water molecules in the air and more are recaptured by the surface of the liquid, making evaporation slower.

(b) At high altitude, atmospheric pressure is lower and water boils at a lower temperature. The eggs must be cooked longer at the lower temperature.

11.48 (a) The triple point on a phase diagram represents the temperature at which the gas, liquid and solid phases are in equilibrium.

(b) No. A phase diagram represents a closed system, one where no matter can escape and no substance other than the one under consideration is present; air cannot be present in the system. Even if air is excluded, at 1 atm of external pressure, the triple point of water is inaccessible, regardless of temperature [see Sample Exercise 11.6(b)].

11.50 (a) Solid CO_2 sublimes to form $CO_2(g)$ at a temperature of about -60°C.

(b) Solid CO_2 melts to form $CO_2(l)$ at a temperature of about -50°C. The $CO_2(l)$ boils when the temperature reaches approximately -40°C.

11.58 (a) Ti: 8 corners × 1/8 sphere/corner + [1 center × 1 sphere/center] = 2 Ti atoms

O: 4 faces × 1/2 sphere/face + [2 interior × 1 sphere/interior] = 4 O atoms

Formula: Ti_2O_4

(b) Rutile is an ionic solid; ion-ion forces among Ti^{4+} cations and O^{2-} anions are quite strong, owing to the magnitudes of the charges, and lead to the ordered structure.

11.62 Avogadro's number is the number of KCl formula units in 74.55 g of KCl.

$$74.55 \text{ g KCl} \times \frac{1 \text{ cm}^3}{1.984 \text{ g}} \times \frac{(1 \times 10^{10} \text{ pm})^3}{1 \text{ cm}^3} \times \frac{4 \text{ KCl units}}{628^3 \text{ pm}^3} = 6.07 \times 10^{23} \text{ KCl formula units}$$

PS # 20 + 21 AP Chemistry

13.23 *Analyze/Plan*. Follow the logic in Sample Exercise 13.3. *Solve*:

(a) $$\text{mass \%} = \frac{\text{mass solute}}{\text{total mass solution}} \times 100 = \frac{11.7\text{ g } Na_2SO_4}{11.7\text{ g } Na_2SO_4 + 443\text{ g } H_2O} \times 100 = 2.57\%$$

(b) $$\text{ppm} = \frac{\text{mass solute}}{\text{total mass solution}} \times 10^6;\ \frac{5.95\text{ g Ag}}{1\text{ ton ore}} \times \frac{1\text{ ton}}{2000\text{ lb}} \times \frac{1\text{ lb}}{453.6\text{ g}} \times 10^6$$

$$= 6.56\text{ ppm}$$

13.24 (a) $$\text{mass \%} = \frac{\text{mass solute}}{\text{total mass solution}} \times 100$$

$$\text{mass solute} = 0.045\text{ mol } I_2 \times \frac{253.8\text{ g } I_2}{1\text{ mol } I_2} = 11.421 = 11\text{ g } I_2$$

$$\text{mass \% } I_2 = \frac{11.421\text{ g } I_2}{11.421\text{ g } I_2 + 115\text{ g } CCl_4} \times 100 = 9.034 = 9.0\%\ I_2$$

(b) $$\text{ppm} = \frac{\text{mass solute}}{\text{total mass solution}} \times 10^6 = \frac{0.0079\text{ g } Sr^{2+}}{1 \times 10^3\text{ g } H_2O} \times 10^6 = 7.9\text{ ppm } Sr^{2+}$$

13.28 (a) $$M = \frac{\text{mol solute}}{\text{L soln}};\ \frac{15.0\text{ g } Al_2(SO_4)_3}{0.350\text{ L soln}} \times \frac{1\text{ mol } Al_2(SO_4)_3}{342.2\text{ g } Al_2(SO_4)_3} = 0.125\ M\ Al_2(SO_4)_3$$

(b) $$\frac{5.25\text{ g } Mn(NO_3)_2 \cdot 2H_2O}{0.175\text{ L soln}} \times \frac{1\text{ mol } Mn(NO_3)_2 \cdot 2H_2O}{215.0\text{ g } Mn(NO_3)_2 \cdot 2H_2O} = 0.140\ M\ Mn(NO_3)_2$$

(c) $M_c \times L_c = M_d \times L_d$; $9.00\ M\ H_2SO_4 \times 0.0350\text{ L} = ?M\ H_2SO_4 \times 0.500\text{ L}$

500 mL of 0.630 M H_2SO_4

13.29 *Analyze/Plan*. Follow the logic in Sample Exercise 13.4. *Solve*:

(a) $$m = \frac{\text{mol solute}}{\text{kg solvent}};\ \frac{10.5\text{ g } C_6H_6}{18.5\text{ g } CCl_4} \times \frac{1\text{ mol } C_6H_6}{78.11\text{ g } C_6H_6} \times \frac{1000\text{ g } CCl_4}{1\text{ kg } CCl_4} = 7.27\ m\ C_6H_6$$

(b) The density of H_2O = 0.997 g/mL = 0.997 kg/L.

$$\frac{4.15\text{ g NaCl}}{0.250\text{ L } H_2O} \times \frac{1\text{ mol NaCl}}{58.44\text{ g NaCl}} \times \frac{1\text{ L } H_2O}{0.997\text{ kg } H_2O} = 0.285\ m\ \text{NaCl}$$

13.31 *Analyze/Plan*. Assume 1 L of solution. Density gives the total mass of 1 L of solution. The g H_2SO_4/L are also given in the problem. Mass % = mass solute/total mass solution. Calculate mass solvent from mass solution and mass solute. Calculate moles solute and solvent and use the appropriate definitions to calculate mole fraction, molality and molarity. *Solve*:

(a) $$\frac{571.6\text{ g } H_2SO_4}{1\text{ L soln}} \times \frac{1\text{ L soln}}{1329\text{ g soln}} = 0.430098\text{ g } H_2SO_4/\text{g soln}$$

mass percent is thus 0.4301 × 100 = 43.01% H_2SO_4

(b) In a liter of solution there are 1329 - 571.6 = 757.4 = 757 g H_2O.

$$\frac{571.6\text{ g } H_2SO_4}{98.09\text{ g/mol}} = 5.827\text{ mol } H_2SO_4;\ \frac{757.4\text{ g } H_2O}{18.02\text{ g/mol}} = 42.03 = 42.0\text{ mol } H_2O$$

$$\chi_{H_2SO_4} = \frac{5.827}{42.03 + 5.827} = 0.122$$

(The result has 3 sig figs because 42.0 mol H_2O limits the denominator to 3 sig figs.)

(c) $$\text{molality} = \frac{5.827 \text{ mol } H_2SO_4}{0.7574 \text{ kg } H_2O} = 7.693 = 7.69\ m\ H_2SO_4$$

(d) $$\text{molarity} = \frac{5.827 \text{ mol } H_2SO_4}{1 \text{ L soln}} = 5.827\ M\ H_2SO_4$$

13.32 (a) $$\text{mass \%} = \frac{\text{mass } C_6H_8O_6}{\text{total mass solution}} \times 100;$$

$$\frac{80.5 \text{ g } C_6H_8O_6}{80.5 \text{ g } C_6H_8O_6 + 210 \text{ g } H_2O} \times 100 = 27.71 = 27.7\%\ C_6H_8O_6$$

(b) $$\text{mol } C_6H_8O_6 = \frac{80.5 \text{ g } C_6H_8O_6}{176.1 \text{ g/mol}} = 0.4571 = 0.457 \text{ mol } C_6H_8O_6$$

$$\text{mol } H_2O = \frac{210 \text{ g } H_2O}{18.02 \text{ g/mol}} = 11.654 = 11.7 \text{ mol } H_2O$$

$$\chi_{C_6H_8O_6} = \frac{0.4571 \text{ mol } C_6H_8O_6}{0.4571 \text{ mol } C_6H_8O_6 + 11.654 \text{ mol } H_2O} = 0.0377$$

(c) $$m = \frac{0.4571 \text{ mol } C_6H_8O_6}{0.210 \text{ kg } H_2O} = 2.18\ m\ C_6H_8O_6$$

(d) $$M = \frac{\text{mol } C_6H_8O_6}{\text{L solution}};\ 290.5 \text{ g soln} \times \frac{1 \text{ mL}}{1.22 \text{ g}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.2381 = 0.238 \text{ L}$$

$$M = \frac{0.4571 \text{ mol } C_6H_8O_6}{0.2381 \text{ L soln}} = 1.92\ M\ C_6H_8O_6$$

13.38 (a) $$\frac{0.110 \text{ mol } (NH_4)_2SO_4}{1 \text{ L soln}} \times 1.50 \text{ L} \times \frac{132.2 \text{ g } (NH_4)_2SO_4}{1 \text{ mol } (NH_4)_2SO_4} = 21.81 = 21.8 \text{ g } (NH_4)_2SO_4$$

Weigh 21.8 g $(NH_4)_2SO_4$, dissolve in a small amount of water, continue adding water with thorough mixing up to a total solution volume of 1.50 L.

(b) Determine the mass fraction of Na_2CO_3 in the solution:

$$\frac{0.65 \text{ mol } Na_2CO_3}{1000 \text{ g } H_2O} \times \frac{106.0 \text{ g } Na_2CO_3}{1 \text{ mol } Na_2CO_3} = 68.9 \text{ g} = \frac{69 \text{ g } Na_2CO_3}{1000 \text{ g } H_2O}$$

$$\text{mass fraction} = \frac{68.9 \text{ g } Na_2CO_3}{1000 \text{ g } H_2O + 68.9 \text{ g } Na_2CO_3} = 0.06446 = 0.064$$

In 120 g of solution, there are 0.06446(120) = 7.735 = 7.7 g Na_2CO_3.

Weigh out 7.7 g Na_2CO_3 and dissolve it in 120 - 7.7 = 112.3 g H_2O to make exactly 120 g of solution.

(112.3 g H_2O/0.997 g H_2O/mL @ 25° = 112.6 mL H_2O)

(c) $$1.20 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.16 \text{ g}}{1 \text{ mL}} = 1392 \text{ g solution};\ 0.150(1392 \text{ g soln}) = 209 \text{ g } Pb(NO_3)_2$$

Weigh 209 g $Pb(NO_3)$ and add (1392 - 209) = 1183 g H_2O to make exactly (1392 = 1.39×10^3) g or 1.20 L of solution.

(1183 g H_2O/0.997 g/mL @ 25°C = 1187 mL H_2O)

(The result has 3 sig figs because 42.0 mol H_2O limits the denominator to 3 sig figs.)

(c) $$\text{molality} = \frac{5.827 \text{ mol } H_2SO_4}{0.7574 \text{ kg } H_2O} = 7.693 = 7.69\ m\ H_2SO_4$$

(d) $$\text{molarity} = \frac{5.827 \text{ mol } H_2SO_4}{1 \text{ L soln}} = 5.827\ M\ H_2SO_4$$

13.32 (a) $$\text{mass \%} = \frac{\text{mass } C_6H_8O_6}{\text{total mass solution}} \times 100;$$

$$\frac{80.5 \text{ g } C_6H_8O_6}{80.5 \text{ g } C_6H_8O_6 + 210 \text{ g } H_2O} \times 100 = 27.71 = 27.7\%\ C_6H_8O_6$$

(b) $$\text{mol } C_6H_8O_6 = \frac{80.5 \text{ g } C_6H_8O_6}{176.1 \text{ g/mol}} = 0.4571 = 0.457 \text{ mol } C_6H_8O_6$$

$$\text{mol } H_2O = \frac{210 \text{ g } H_2O}{18.02 \text{ g/mol}} = 11.654 = 11.7 \text{ mol } H_2O$$

$$\chi_{C_6H_8O_6} = \frac{0.4571 \text{ mol } C_6H_8O_6}{0.4571 \text{ mol } C_6H_8O_6 + 11.654 \text{ mol } H_2O} = 0.0377$$

(c) $$m = \frac{0.4571 \text{ mol } C_6H_8O_6}{0.210 \text{ kg } H_2O} = 2.18\ m\ C_6H_8O_6$$

(d) $$M = \frac{\text{mol } C_6H_8O_6}{\text{L solution}};\ 290.5 \text{ g soln} \times \frac{1 \text{ mL}}{1.22 \text{ g}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.2381 = 0.238 \text{ L}$$

$$M = \frac{0.4571 \text{ mol } C_6H_8O_6}{0.2381 \text{ L soln}} = 1.92\ M\ C_6H_8O_6$$

13.38 (a) $$\frac{0.110 \text{ mol } (NH_4)_2SO_4}{1 \text{ L soln}} \times 1.50 \text{ L} \times \frac{132.2 \text{ g } (NH_4)_2SO_4}{1 \text{ mol } (NH_4)_2SO_4} = 21.81 = 21.8 \text{ g } (NH_4)_2SO_4$$

Weigh 21.8 g $(NH_4)_2SO_4$, dissolve in a small amount of water, continue adding water with thorough mixing up to a total solution volume of 1.50 L.

(b) Determine the mass fraction of Na_2CO_3 in the solution:

$$\frac{0.65 \text{ mol } Na_2CO_3}{1000 \text{ g } H_2O} \times \frac{106.0 \text{ g } Na_2CO_3}{1 \text{ mol } Na_2CO_3} = 68.9 \text{ g} = \frac{69 \text{ g } Na_2CO_3}{1000 \text{ g } H_2O}$$

$$\text{mass fraction} = \frac{68.9 \text{ g } Na_2CO_3}{1000 \text{ g } H_2O + 68.9 \text{ g } Na_2CO_3} = 0.06446 = 0.064$$

In 120 g of solution, there are 0.06446(120) = 7.735 = 7.7 g Na_2CO_3.

Weigh out 7.7 g Na_2CO_3 and dissolve it in 120 - 7.7 = 112.3 g H_2O to make exactly 120 g of solution.

(112.3 g H_2O/0.997 g H_2O/mL @ 25° = 112.6 mL H_2O)

(c) $$1.20 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.16 \text{ g}}{1 \text{ mL}} = 1392 \text{ g solution};\ 0.150(1392 \text{ g soln}) = 209 \text{ g } Pb(NO_3)_2$$

Weigh 209 g $Pb(NO_3)$ and add (1392 - 209) = 1183 g H_2O to make exactly ($1392 = 1.39 \times 10^3$) g or 1.20 L of solution.

(1183 g H_2O/0.997 g/mL @ 25°C = 1187 mL H_2O)

13.38 cont.

(d) Calculate the mol HCl necessary to neutralize 5.5 g $Ba(OH)_2$.

$Ba(OH)_2(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

$$5.5 \text{ g } Ba(OH)_2 \times \frac{1 \text{ mol } Ba(OH)_2}{171 \text{ g } Ba(OH)_2} \times \frac{2 \text{ mol HCl}}{1 \text{ mol } Ba(OH)_2} = 0.0643 = 0.064 \text{ mol HCl}$$

$$M = \frac{\text{mol}}{\text{L}};\ \text{L} = \frac{\text{mol}}{M} = \frac{0.0643 \text{ mol HCl}}{0.50\ M \text{ HCl}} = 0.1287 = 0.13 \text{ L} = 130 \text{ mL}$$

130 mL of 0.50 M HCl are needed.

$M_c \times L_c = M_d \times L_d$; 6.0 $M \times L_c$ = 0.50 $M \times 0.1287$ L; L_c = 0.01072 L = 11 mL

Using a pipette, measure exactly 11 mL of 6.0 M HCl and dilute with water to a total volume of 130 mL.