Chapter 18 – Solutions

Section 18.1 – Properties of Solutions

1.1. Name and distinguish between the two components of a solution. (q. 40)

The *solvent* is the substance in which the *solute* is dissolved.

1.2. Explain why the dissolved component does not settle out of a solution. (q. 41)

Random collisions of the solvent molecules with the solute particles provide enough force to overcome gravity.

1.3. Define *solubility, saturated solution,* and *unsaturated solution*. (q. 43)

Solubility is the amount of solute dissolved in a given amount of solvent to form a saturated solution at a given temperature. A *saturated* solution contains the maximum possible amount of solute at that temperature. An *unsaturated* solution contains less dissolved solute than a saturated solution.

1.4 If a saturated solution of sodium nitrate is cooled, what change might you observe? (q. 45)

Particles of solute crystallize.

Practice Problems

1. The solubility of a gas in water is 0.16 g/ L at 104 kPa of pressure. What is the solubility when the pressure of the gas is increased to 288 kPa? Assume the temperature remains constant.

Use Henry's law: $S_1/P_1 = S_2/P_2$; we know S_1 = 0.16 g/ L; P_1 = 104 kPa; P_2 = 288 kPa

S_2 = (0.16 g/L) (288 kPa)/ 104 kPa = 0.44 g/ L

2. A gas has a solubility in water at 0℃ of 3.6 g/ L at a pressure of 1.0 atm. What pressure is needed to produce an aqueous solution containing 9.5 g/ L of the same gas at 0℃?

Use Henry's law: S_1 = 3.6 g/ L; P_1 = 1.0 atm; S_2 = 9.5 g/ L

P_2 = (1.0 atm) (9.5 g/ L) / 3.6 g/ L = 2.63 atm

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3. Name three factors that influence the rate at which a solute dissolves in a solvent.

a. temperature b. particle size c. degree of agitation

4. How can you calculate the solubility of a gas in a liquid under different pressure conditions?

By using Henry's law

5. What mass of NaCl can be dissolved in 7.50×10^2 g of water at 25℃?

Use Table 18.1: we know that 36.0 g NaCl dissolves in 100 g water at 20℃

(7.50×10^2 g H_2O) x (36.0 g NaCl/ 100 g H_2O) = 260 g NaCl

6. What could you do to change

a. a saturated solution to an unsaturated solution?

Add more solvent.

b. an unsaturated solution to a saturated solution?

Add more solute and stir or heat up until no more will dissolve.

7. Use the solid substances listed in Table 18.1 on page 504 to make a general statement that relates a change in solubility of a solid to a change in temperature.

As the temperature of a solution increases, so does the solubility of a solute.

Section 18.2 – Concentrations of Solutions

2.1. Having a measure of the molarity of a solution is more meaningful than knowing whether a solution is dilute or concentrated. Explain. (q. 49)

Molarity provides the exact number of moles of solute per liter of solution. *Dilute* and *concentrated* are only relative terms and are not quantitative or precise.

2.2. Define *molarity*. (q. 51)

Molarity (M) defines the number of moles of solute dissolved in one liter solution.

Practice Problems

8. A solution has a volume of 2.0 L and contains 36.0 g of glucose. If the molar mass of glucose is 180 g/ mol, what is the molarity of the solution?

$$(36.0\ g\ glucose)\left(\frac{1\ mol\ glucose}{180.2\ g\ glucose}\right) = 0.200\ mol\ glucose \quad M = \frac{0.200\ mol\ glucose}{2.0\ L\ solution} = 0.10\ M$$

9. A solution has a volume of 250 mL, and contains 0.70 mol NaCl. What is its molarity?

$$M = \frac{0.70\ mol\ NaCl}{0.250\ L\ solution} = 2.8M$$

10. How many moles of ammonium nitrate are in 335 mL of 0.425M NH_4NO_3?

$$M = \frac{moles\ solute}{L\ solution}; \quad moles\ solute = (M)(L\ soln)$$

$$moles\ solute = \left(\frac{0.425\ mol\ NH_4NO_2}{1\ L\ soln}\right)(0.335\ L\ soln) = 0.142\ mol$$

11. How many moles of solute are in 250 mL of 2.0M $CaCl_2$? How many grams of $CaCl_2$ is this?

$$(0.250\ L\ soln)\left(\frac{2.0\ mol\ CaCl_2}{1\ L\ soln}\right) = 0.5\ mol\ CaCl_2;$$

$$(0.50\ mol\ CaCl_2)\left(\frac{111\ g\ CaCl_2}{1\ mol\ CaCl_2}\right) = 55.5\ g\ CaCl_2$$

12. How many milliliters of a stock solution of 4.00M KI would you need to prepare 250.0 mL of 0.760M KI?

Use $M_1V_1 = M_2V_2$; M_1=4.00 M; V_2=0.250 L; M_2 = 0.760 M; solve for V_1

$$V_1 = \frac{(0.760\ M)(0.250\ L)}{4.00\ M} = 0.0475\ L, or\ 47.5\ mL$$

13. Suppose you need 250 mL of 0.20M NaCl, but the only supply of sodium chloride you have is a solution of 1.0M NaCl. How do you prepare the required solution? Assume that you have the appropriate volume-measuring devices on hand.

Use $M_1V_1 = M_2V_2$; M_1=1.0 M; V_2=0.250 L; M_2 = 0.20 M; solve for V_1

Take 50 mL of 1.0 M solution and add enough solvent to dilute to 250 mL total

$V_1 = \frac{(0.20\ M)(0.250\ L)}{1.0\ M} = 0.050\ L, or\ 50.\ mL$

14. If 10 mL of pure acetone is diluted with water to a total solution volume of 200 mL, what is the percent by volume of acetone in the solution?

$\%\frac{v}{v} = \frac{10\ mL\ acetone}{200\ mL\ soln}\ x\ 100 = 5\%\ by\ volume$

15. A bottle of hydrogen peroxide antiseptic is labeled 3.0% (v/v). How many mL H_2O_2 are in a 400.0-mL bottle of this solution?

$volume\ solute = \frac{(3.0\%)(400.0\ mL\ solution)}{100\%} = 12\ mL\ solute$

16. Calculate the grams of solute required to make 250 mL of 0.10% $MgSO_4$ (m/v).

$mass\ of\ solute = \frac{(0.10\%)(250 mL)}{100\%} = 0.25\ g\ MgSO_4$

17. A solution contains 2.7 g $CuSO_4$ in 75 mL of solution. What is the percent (mass/ volume) of the solution?

$\%\frac{m}{v} = \frac{2.7\ g\ CuSO_4}{75\ mL\ soln} x\ 100 = 3.6\%\ by\ mass$

Section Review 18.2

18. How are problems involving solution molarity solved?

Molarity is found by dividing the number of moles of solute by the number of liters of solution.

19. Describe how dilute solutions are prepared from more concentrated solutions of known molarity.

Solvent is added to the concentrated solution until the desired molarity is achieved.

20. Distinguish between percent (v/ v) and percent (m/ v) solutions.

Percent by volume equals the volume of solute per volume of solution. Percent (mass/ volume) equals the mass of solute (in grams) per volume of solution (in mL).

21. Calculate the molarity of each solution.

a. 400 g $CuSO_4$ in 4.00 L of solution

0.627M $CuSO_4$

b. 0.060 mol $NaHCO_3$ in 1500 mL of solution

0.040M $NaHCO_3$

22. You have the following stock solutions available: 2.00M NaCl, 4.0M KNO_3, and 0.50M $MgSO_4$. Calculate the volumes you must dilute to make the following solutions.

Use $M_1V_1 = M_2V_2$

Since you know the starting and final molarities and the final volume, rearrange the equation to solve for initial volume (V_1)

a. 500.0 ml of 0.500M NaCl

$$V_1 = \frac{(0.500M\ NaCl)(0.5000L\ soln)}{2.00M\ NaCl} = 0.125\ L\ or\ 125\ mL$$

b. 2.0 L of 0.20M $MgSO_4$

$$V_1 = \frac{(0.20M\ MgSO_4)(2.0\ L\ soln)}{0.50M\ MgSO_4} = 0.80\ L$$

c. 50.0 mL of 0.20M KNO_3

$$V_1 = \frac{(0.20M\ KNO_3)(0.050\ L\ soln)}{4.0M\ KNO_3} = 0.0025\ L\ or\ 2.5\ mL$$

23. What is the concentration, in percent (m/ v), of a solution with 75 g K_2SO_4 in 1500 mL of solution?

$$\%\frac{m}{v} = \frac{75\ g\ solute}{1500\ mL} x\ 100 = 5.0\%$$

Section 18.3 – Colligative Properties of Solutions

Section Review 18.3

24. Why does a solution have a lower vapor pressure than the pure solvent of that solution?

The introduction of solute molecules reduces the number of solvent molecules with enough kinetic energy to escape.

25. Why does a solution have an elevated boiling point and a depressed freezing point compared with the pure solvent?

Because vapor pressure has been reduced, more kinetic energy is needed to reach the boiling point. For a solution to freeze, it must lose more kinetic energy than the pure solvent does.

26. Would a dilute or a concentrated sodium fluoride solution have a higher boiling point? Explain.

Concentrated; the concentrated solution has more dissolved particles. Boiling-point elevation is proportional to the number of dissolved particles.

27. An equal number of moles of KI and MgF_2 are dissolved in equal volumes of water. Which solution has the higher

a. boiling point? $MgF_2(aq)$

b. vapor pressure? KI(aq)

c. freezing point? KI(aq)

Section 18.4 – Calculations Involving Colligative Properties

Practice Problems

28. How many grams of sodium fluoride are needed to prepare a 0.400m NaF solution that contains 750.0 g of water?

$$\frac{0.400\ mol\ NaF}{kg\ solvent} x\ 0.750\ kg\ water\ x\ \frac{42.0\ g\ NaF}{1\ mol\ NaF} = 12.6\ grams\ NaF$$

29. Calculate the molality of a solution prepared by dissolving 10.0 g NaCl in 600 g of water.

$$(10.0\ g\ NaCl)\left(\frac{1\ mol\ NaCl}{58.44\ g\ NaCl}\right)\left(\frac{1}{0.600\ kg\ water}\right) = 0.285m$$

30. What is the mole fraction of each component in a solution made by mixing 300 g of ethanol (C_2H_5OH) and 500 g of water?

First convert both of these quantities to moles:

$$(300\ g\ ethanol)\left(\frac{1\ mol\ ethanol}{46.07\ g\ ethanol}\right) = 6.51\ mol; (500\ g\ water)\left(\frac{1\ mol\ water}{18.0\ g\ water}\right) = 27.8\ mol$$

Calculate mole fraction of each:

$$X_{ethanol} = \frac{6.51\ mol}{6.51\ mol + 27.8\ mol} = 0.190;\ X_{water} = \frac{27.8\ mol}{6.51\ mol + 27.8\ mol} = 0.810$$

31. A solution contains 50.0 g of carbon tetrachloride (CCl_4) and 50.0 g of chloroform ($CHCl_3$). Calculate the mole fraction of each component in the solution.

First convert both of these quantities to moles:

$$(50.0\ g\ CCl_4)\left(\frac{1\ mol\ CCl_4}{153.82\ g\ CCl_4}\right) = 0.325\ mol; (50\ g\ CHCl_3)\left(\frac{1\ mol\ CHCl_3}{119.4\ g\ CHCl_3}\right) = 0.419\ mol$$

Calculate mole fraction of each:

$$X_{CCl_4} = \frac{0.325\ mol}{0.325\ mol + 0.419\ mol} = 0.437;\ X_{CHCl_3} = \frac{0.419\ mol}{0.325\ mol + 0.419\ mol} = 0.563$$

32. What is the boiling point of a solution that contains 1.25 mol $CaCl_2$ in 1400 g of water?

$$\Delta T_b = \frac{0.512\ °C}{m} x\ 0.893m\ x\ 3 = 1.37$$

100 ℃ + 1.37 = 101.37 ℃

Calculate molality (m) of solution first, then use $\Delta T_b = K_b mi$

Where K_b is the molal boiling-point elevation constant, and *i* is the Van't Hoff factor.

Since $CaCl_2$ breaks into three particles, *i* = 3.

33. What mass of NaCl would have to be dissolved in 1.000 x 10^3 g of water to raise the boiling point by 2.00 ℃?

$$m = \frac{2.00\ ℃}{(\frac{0.512\ ℃}{m})(2)} = 1.95 \qquad mol\ solute = (1.95m)(1.000\ kg\ water) = 1.95\ mol\ NaCl$$

$$(1.95\ mol\ NaCl)\left(\frac{58.44\ g\ NaCl}{1\ mol\ NaCl}\right) = 114\ g\ NaCl$$

34. The freezing point of the water is lowered to -0.390℃ when 3.90 g of a nonvolatile molecular solute is dissolved in 475 g of water. Calculate the molar mass of the solute.

Use $\Delta T_f = K_f mi$

$$m = \frac{0.390\ ℃}{\left(\frac{1.86℃}{m}\right)(1)} = 0.210 \quad ; mol\ solute = (0.210m)(0.475\ kg) = 0.0998\ mol$$

Molar mass = 3.90 g solute/ 0.0998 mol = 39.1 g/ mol

35. A solution containing 16.9 g of a nonvolatile molecular compound in 250 g of water has a freezing point of -0.744℃. What is the molar mass of the substance?

Solve as above; Answer is 169 g/ mol

Section Review 18.4

36. How many kilograms of water must be added to 9.0 g of oxalic acid ($H_2C_2O_4$) to prepare a 0.025 m solution?

$$(9.0\ g\ oxalic\ acid)\left(\frac{1\ mol\ oxalic\ acid}{90.0\ g\ oxalic\ acid}\right) = 0.10\ mol; kg\ solvent = \frac{0.10\ mol\ oxalic\ acid}{\frac{0.025\ mol\ oxalic\ acid}{kg\ solvent}} = 4.0\ kg\ water$$

37. One mole of a compound of iron and chlorine is dissolved in 1 kg of water. The boiling point of this aqueous solution is 102.05℃. The freezing point of this aqueous solution is -7.44℃. What is the formula of the solute compound?

$FeCl_3$

38. How are boiling point elevation and freezing point depression related to molality?

The molality of a solution is directly proportional to its boiling-point elevation and freezing-point depression, as evidenced by their respective equations, $\Delta T_b = K_b mi$ and, $\Delta T_f = K_f mi$

39. Estimate the freezing point of a solution of 12.0 g of carbon tetrachloride dissolved in 750 g of benzene (which has a freezing point of 5.48℃).

First convert 12.0 g of carbon tetrachloride to mol. Then calculate molality.

$$(12.0\ g\ CCl_4)\left(\frac{1\ mol\ CCl_4}{153.82\ g\ CCl_4}\right)\left(\frac{1}{0.750\ kg}\right) = 0.104m$$

$$\Delta T_f = \left(\frac{5.12\ ℃}{m}\right)(0.104m)(1) = 0.532; \quad Freezing\ point = 5.48\ ℃ - 0.532\ ℃ = 4.95\ ℃$$