Chapter 10

Solutions

1. Distinguish between the terms solute and solvent. Give an example of a solution and identify each component.

The solvent is usually the substance in a solution that is in the greatest amount. A solute is a substance that is dissolved in the solvent to make a solution. Water is the solvent and NaCl is the solute in a salt water solution.

3. What is the concentration of nitrate ion in each of the following aqueous solutions?

a) 0.25 M KNO_3

$$[NO_3^{1-}] = \frac{0.25 \text{ mol } KNO_3}{L} \times \frac{1 \text{ mol } NO_3^{1-}}{\text{mol } KNO_3} = 0.25 \text{ M}$$

b) 0.10 M $Al(NO_3)_3$

$$[NO_3^{1-}] = \frac{0.10 \text{ mol } Al(NO_3)_3}{L} \times \frac{3 \text{ mol } NO_3^{1-}}{\text{mol } Al(NO_3)_3} = 0.30 \text{ M}$$

c) 0.20 M $Ca(NO_3)_2$

$$[NO_3^{1-}] = \frac{0.20 \text{ mol } Ca(NO_3)_2}{L} \times \frac{2 \text{ mol } NO_3^{1-}}{\text{mol } Ca(NO_3)_2} = 0.40 \text{ M}$$

5. A solution is prepared by dissolving 25.0 g of sodium sulfate in enough water to prepare 250. mL of solution.

a) What is the molarity of sodium sulfate in the solution?

M_m of Na_2SO_4 = 2 mol Na x 23.0 g/mol + 1 mol S x 32.0 g/mol + 4 mol O x 16.0 g/mol = 142.0 g/mol

$$25.0 \text{ g } Na_2SO_4 \times \frac{1 \text{ mol } Na_2SO_4}{142.0 \text{ g } Na_2SO_4} = 0.176 \text{ mol } Na_2SO_4$$

$$\text{Molarity} = \frac{\text{mol } Na_2SO_4}{\text{L of solution}} = \frac{0.176 \text{ mol}}{0.250 \text{ L}} = 0.704 \text{ M}$$

b) What are the molarities of the sodium and sulfate ions in the solution?

$$[Na^{1+}] = \frac{0.704 \text{ mol } Na_2SO_4}{\text{L of solution}} \times \frac{2 \text{ mol } Na^{1+}}{1 \text{ mol } Na_2SO_4} = 1.41 \text{ M}$$

$$[SO_4^{2-}] = \frac{0.704 \text{ mol } Na_2SO_4}{\text{L of solution}} \times \frac{1 \text{ mol } SO_4^{2-}}{1 \text{ mol } Na_2SO_4} = 0.704 \text{ M}$$

c) How many moles of sodium ions are present in 17 mL of the solution?

$$17 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1.41 \text{ mol } Na^{1+}}{L} = 0.024 \text{ mol } Na^{1+}$$

7. A solution of K_2SO_4, which has a volume of 75.0 mL, contains 0.0048 moles of potassium ions. What is the molarity of the K_2SO_4 solution?

$$\frac{0.0048 \text{ mol } K^{1+}}{0.075 \text{ L}} \times \frac{1 \text{ mol } K_2SO_4}{2 \text{ mol } K^{1+}} = 0.032 \text{ M } K_2SO_4$$

9. What are the two steps involved in solvation?

Solvation consists of creating cavities in the solvent and placing the solute particles in the cavities.

11. Explain the hydrophobic effect.

The CH_2 groups of organic compounds are nonpolar and interact very poorly with water. Compounds with many CH_2 groups interact so poorly with water that they are called hydrophobic. When a hydrophobic compound is placed in water, the water molecules orient so as to minimize their interaction with the compound. As a result, hydrophobic compounds are not soluble in water.

13. Indicate whether each of the following substances would be more soluble in H_2O or C_6H_{14}:

a) HF (H_2O) **b) CH_3OH** (H_2O) **c) $NaC_2H_3O_2$** (H_2O) **d) CH_4** (C_6H_{14})

Hydrogen bonding substances (HF and CH_3OH) and ionic substances ($NaC_2H_3O_2$) are more soluble in water than in a nonpolar solvents, while nonpolar substances (CH_4) are more soluble in nonpolar solvents.

15. Differentiate between a monolayer and a micelle. Under what conditions is a detergent expected to form each?

The hydrophobic tail of a detergent avoids interacting with water in one of two ways. If the concentration of the detergent is very small, then the tails do not enter the water. Rather, the polar head interacts with the water while the hydrophobic tail sticks out of the water forming a monolayer across the top of the water. With an increase in concentration and some agitation, the tails are forced into the water where they interact with one another by forming small spheres called micelles. The surface of the spheres is composed of the polar heads, which interact with the water while the interior of the micelles consists of an organic solvent comprised of the hydrophobic tails.

17. Identify each of the following as a weak, strong, or nonelectrolyte:

a)	CCl_4	nonelectrolyte	**b)**	NH_4NO_3	strong
c)	H_2CO_3	weak (an acid, but not strong)	**d)**	HNO_3	strong (strong acid)
e)	CH_3OH	nonelectrolyte			

19. What are the predominant solute species in aqueous solutions of the following? Write the molecule or the separated ions as appropriate.

a)	CO_2	CO_2	**b)**	$CaCl_2$	$Ca^{2+} + 2Cl^{1-}$
c)	PF_3	PF_3	**d)**	$K_2Cr_2O_7$	$2K^{1+} + Cr_2O_7^{2-}$
e)	KOH	$K^{1+} + OH^{1-}$			

21. What is the ratio of the force of attraction experienced by Ca^{2+} and SO_4^{2-} to that experienced by Al^{3+} and Cl^{1-}? Assume that the ions are the same distance apart and in the same medium.

According to Coulombs law, $F = \frac{kq_1q_2}{\varepsilon r^2}$. If the ions are in the same medium, then the value of ε is the same.

Thus, the ratio of the force of attraction of the two sets of ions is $\frac{F}{F'} = \frac{q_1q_2}{q_1'q_2'} = \frac{(+2)(-2)}{(+3)(-1)} = \frac{-4}{-3} = 1.3$

The force of attraction between a calcium ion and a sulfate ion is 1.3 times greater than the force of attraction between an aluminum ion and a chloride ion.

23. What property of water makes it a good solvent for ionic compounds? How is this property expressed in Coulomb's Law?

Water is a good solvent for ionic compounds because it is a very polar molecule. This property of water is expressed by the dielectric constant, ε, in Coulomb's law.

25. Indicate all of the following compounds that could be used to make a 0.1-M solution of Zn^{2+} ions:

a)	$Zn(ClO_4)_2$	yes	Rule 2	**b)**	$ZnCl_2$	yes	Rule 3
c)	$ZnCrO_4$	no	Rule 5	**d)**	$ZnCO_3$	no	Rule 5
e)	ZnS	no	Rule 5				

27. Indicate all of the following compounds that could be used to make a 0.1-M solution of CrO_4^{2-} ions:

a)	$ZnCrO_4$	no	Rule 5	**b)**	K_2CrO_4	yes	Rule 1
c)	$CuCrO_4$	no	Rule 5	**d)**	$BaCrO_4$	no	Rule 5
e)	$FeCrO_4$	no	Rule 5				

29. A solution is known to contain one of the following cations: Na^{1+}, Ag^{1+}, or Fe^{2+}. The addition of chloride ion to part of the solution had no apparent effect, but addition of CrO_4^{2-} ion resulted in a precipitate. What is the identity of the cation in the original solution?

No precipitate formed when Cl^{1-} ion was added, so the solution does not contain Ag^{1+}. The precipitate that forms with the addition of CrO_4^{2-} ions must be $FeCrO_4$ because Na_2CrO_4 is soluble. Thus, the solution contains Fe^{2+} ions.

31. Write net equations for any precipitation reactions that occur when the following 0.1-M solutions are mixed. Indicate "no reaction" where appropriate.

a)	**manganese(II) chloride + sodium sulfide**	$Mn^{2+}(aq) + S^{2-}(aq) \rightarrow MnS(s)$
b)	**iron(III) chloride + sodium carbonate**	$2Fe^{3+}(aq) + 3CO_3^{2-}(aq) \rightarrow Fe_2(CO_3)_3(s)$
c)	**potassium sulfide + zinc nitrate**	$Zn^{2+}(aq) + S^{2-}(aq) \rightarrow ZnS(s)$

d) silver sulfate + barium iodide $Ag^{1+}(aq) + I^{1-}(aq) \rightarrow AgI(s)$ & $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

e) lead acetate + lithium hydroxide $Pb^{2+}(aq) + 2OH^{1-}(aq) \rightarrow Pb(OH)_2(s)$

f) ammonium phosphate + copper(II) sulfate $3Cu^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Cu_3(PO_4)_2(s)$

33. Write the reaction for dissolving the following salts in water and give the K_{sp} expression for each:

a) FeS $FeS(s) \rightarrow Fe^{2+}(aq) + S^{2-}(aq)$ $K_{sp} = [Fe^{2+}][S^{2-}]$

b) $PbCl_2$ $PbCl_2(s) \rightarrow Pb^{2+}(aq) + 2Cl^{1-}(aq)$ $K_{sp} = [Pb^{2+}][Cl^{1-}]^2$

c) $Ca_3(PO_4)_2$ $Ca_3(PO_4)_2(s) \rightarrow 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$ $K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$

35. The K_{sp} of iron(II) hydroxide is 8.0 x 10^{-16}. What is the maximum concentration of Fe^{2+} ions that can exist in a solution in which $[OH^{1-}]$ = 1.0 x 10^{-7} M?

First, write the equilibrium reaction and the K_{sp} expression

$Fe(OH)_2(s) \rightleftharpoons Fe^{2+}(aq) + 2OH^{1-}(aq)$ $K_{sp} = [Fe^{2+}][OH^{1-}]^2 = 8.0 \times 10^{-16}$

Next, solve the K_{sp} expression for the concentration of Fe^{2+} and substitute the know values.

$$[Fe^{2+}] = \frac{K_{sp}}{[OH^{1-}]^2} = \frac{8.0\times10^{-16}}{(1.0\times10^{-7})^2} = 8.0 \times 10^{-2}\ M$$

37. What is the K_{sp} of AgCN if the concentrations of silver and cyanide ions in a saturated solution of silver cyanide are each 1.1 x 10^{-8} M?

$AgCN(s) \rightleftharpoons Ag^{1+}(aq) + CN^{1-}(aq)$; $K_{sp} = [Ag^{1+}][CN^{1-}] = (1.1\times10^{-8})(1.1\times10^{-8}) = 1.2 \times 10^{-16}$

39. A student mixes 1.50 L of 0.20 M K_2CrO_4 and 1.20 L of 0.30 M $AgNO_3$.

a) Write the net reaction that occurs. $2Ag^{1+}(aq) + CrO_4^{2-}(aq)$ □ $Ag_2CrO_4(s)$

b) How many moles of CrO_4^{2-} ion were added? $1.5\ L\times\frac{0.20\ mol\ CrO_4^{2-}}{L} = 0.30\ mol\ CrO_4^{2-}$

c) How many moles of Ag^{1+} ion were added? $1.20\ L\times\frac{0.30\ mol\ Ag^{1+}}{L} = 0.36\ mol\ CrO_4^{2-}$

d) How many moles of Ag_2CrO_4 precipitate?

Ag^{1+} is the limiting reactant; $0.36\ mol\ Ag^{1+}\times\frac{1\ mol\ Ag_2CrO_4}{2\ mol\ Ag^{1+}} = 0.18\ mol\ Ag_2CrO_4$

e) How many grams of Ag_2CrO_4 precipitate?

M_m = 2(108) + 52 + 4(16) = 332 g/mol; 0.18 mol Ag_2CrO_4 × 332 g/mol = 60 g

41. A student mixes 0.36 L of 0.10 M $Ba(ClO_4)_2$ and 0.52 L of 0.10 M Na_2SO_4.

a) Write the net reaction that occurs. $Ba^{2+}(aq) + SO_4^{2-}(aq)$ □ $BaSO_4(s)$

b) How many moles of SO_4^{2-} ion were added? $0.52\ L\times\frac{0.10\ mol\ SO_4^{2-}}{L} = 0.052\ mol\ SO_4^{2-}$

c) How many moles of Ba^{2+} ion were added? $0.36\ L\times\frac{0.10\ mol\ Ba^{2+}}{L} = 0.036\ mol\ Ba^{2+}$

d) How many moles of $BaSO_4$ precipitate?

Ba^{2+} is the limiting reactant. $0.036\ mol\ Ba^{2+}\times\frac{1\ mol\ BaSO_4}{mol\ Ba^{2+}} = 0.036\ mol\ BaSO_4$

e) How many grams of $BaSO_4$ precipitate?

M_m = 137.3 + 32.1 + 4(16.0) = 233.4 g/mol 0.036 mol x 233.4 g/mol = 8.4 g $BaSO_4$