Review 6: Solubility Equilibria

Objectives:

1. Be able to write dissociation equations for ionic compounds dissolving in water.
2. Given Ksp, be able to determine the solubility of a substance in both mol/L and g/L.
3. Given solubility (in mol/L or g/L), determine the Ksp of a substance.
4. Calculate the solubility of a substance in a solution that contains a common ion.
5. Memorize and be able to apply the basic solubility rules to predict the formation of precipitates when solutions are mixed.
6. Write double displacement reactions, full and net ionic equations for precipitation reactions.
7. Use Qsp (Trial Ksp) to predict if a precipitate will form when two solutions are mixed.

Practice Multiple Choice Questions:

1. The ion concentrations in a 0.025 M solution of $Al_2(SO_4)_3$ are:

a) 0.025 M $Al^{3+}_{(aq)}$ and 0.025 M $SO_4^{2-}{}_{(aq)}$
b) 0.050 M $Al^{3+}_{(aq)}$ and 0.050 M $SO_4^{2-}{}_{(aq)}$
c) 0.050 M $Al^{3+}_{(aq)}$ and 0.075 M $SO_4^{2-}{}_{(aq)}$
d) 0.010 M $Al^{3+}_{(aq)}$ and 0.015 M $SO_4^{2-}{}_{(aq)}$

2. Which of the following does **not** define solubility?

a) the concentration of solute in a saturated solution
b) the maximum mass of solute that can dissolve in a given volume of solution
c) the minimum moles of solute needed to produce one litre of a saturated solution
d) the concentration of the ions in a solution

3. The solubility of SnS is 3.2×10^{-3} M. The value of K_{sp} is

a) 3.2×10^{-3}
b) 1.0×10^{-5}
c) 5.7×10^{-2}
d) 6.4×10^{-3}

4. Which of the following ions would most effectively remove Ca^{2+} ions from hard water?

a) CH_3COO^{1-} ions
b) CO_3^{2-} ions
c) SO_4^{2-} ions
d) ClO_3^{1-} ions

5. In a solubility equilibrium, the

a) rate of dissolving equals the rate of crystallization
b) mass of dissolved solute is greater than the mass of the solution
c) concentration of solute equals the concentration of solvent
d) neither dissolving nor crystallization are occurring

6. Which of the following will **not** produce a precipitate when the following solutions are mixed?

a) $NaCH_3COO$ and $Pb(NO_3)_2$
b) $Ca(NO_3)_2$ and K_3PO_4
c) KOH and $CaCl_2$
d) $Ba(OH)_2$ and $(NH_4)_2SO_4$

7. The solubility of CdS is 8.0×10^{-14}. The value of K_{sp} is

a) 8.0×10^{-14}
b) 2.8×10^{-7}
c) 6.4×10^{-27}
d) 1.6×10^{-13}

8. At 25°C, which of the following saturated solutions will have the greatest $[OH^{1-}]$?

a) $Fe(OH)_2$
b) $Ni(OH)_2$
c) $Cd(OH)_2$
d) $Pb(OH)_2$

9. When 0.010 moles of $CaCl_{2\,(s)}$ are added to 1.0 L of 0.0010 M KIO_3, the:

a) $Q_{sp} < K_{sp}$ and no precipitate forms
b) $Q_{sp} > K_{sp}$ and no precipitate forms
c) $Q_{sp} > K_{sp}$ and a precipitate forms
d) $Q_{sp} < K_{sp}$ and a precipitate forms

10. Calculate the $[Li^+]$ in 200.0 mL of 1.5 M Li_2SO_4

a) 0.30 M
b) 1.5 M
c) 3.0 M
d) 0.60 M

11. The FULL ionic equation for the reaction between solutions of $Cd(NO_3)_2$ and K_2S is

a) $Cd^{2+}(aq) + 2\,NO_3^{1-}(aq) + 2\,K^{1+}(aq) + S^{2-}(aq) \leftrightarrow Cd^{2+}(aq) + 2\,NO_3^{1-}(aq) + 2\,K^{1+}(aq) + S^{2-}(aq)$
b) $Cd^{2+}(aq) + NO_3^{1-}(aq) + K^{1+}(aq) + S^{2-}(aq) \leftrightarrow Cd^{2+}(aq) + NO_3^{1-}(aq)NO_3^{1-}(aq) + K^{1+}(aq) + S^{2-}(aq)$
c) $Cd^{2+}(aq) + 2\,NO_3^{1-}(aq) + 2\,K^{1+}(aq) + S^{2-}(aq) \leftrightarrow CdS\,(s) + 2\,NO_3^{1-}(aq) + 2\,K^{1+}(aq)$
d) $Cd^{2+}(aq) + NO_3^{1-}(aq) + K^{1+}(aq) + S^{2-}(aq) \leftrightarrow CdS\,(s) + NO_3^{1-}(aq) + KNO_3\,(aq)$

12. Silver chloride, AgCl, would be least soluble in

a) 1.0 M $AgNO_3$
b) 1.0 M $NaNO_3$
c) 1.0 M $ZnCl_2$
d) 1.0 M HCl

13. Which of the following saturated solutions will have the lowest $[Pb^{2+}]$?

a) $Pb(OH)_2$
b) $PbBr_2$
c) PbI_2
d) $Pb(NO_3)_2$

14. Consider the following equilibrium: $Fe(OH)_2\,(s) \leftrightarrow Fe^{2+}(aq) + 2\,OH^{1-}(aq)$
Which of the following will **NOT** cause the equilibrium to shift?

a) adding NaOH
b) adding $Fe(OH)_2\,(s)$
c) adding an acid
d) adding $Fe(NO_3)_2$

15. The net ionic equation that describes a saturated solution of Ag_2CrO_4 is:

a) $Ag_2CrO_{4(s)} \rightleftarrows Ag_2CrO_{4(aq)}$
b) $Ag_2CrO_{4(s)} \rightleftarrows 2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)}$
c) $2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)} + 2H_2O_{(\ell)} \rightleftarrows 2AgOH_{(s)} + H_2CrO_{4(aq)}$
d) $Ag_2CrO_{4(s)} \rightleftarrows 2Ag^+_{(aq)} + Cr^{6+}_{(aq)} + 4O^{2-}_{(aq)}$

16. Consider the following saturated solutions: Na_2SO_4, $BaSO_4$, $CaSO_4$
The order of cation concentration, from highest to lowest, is

a) $[Na^{1+}]>[Ca^{2+}]>[Ba^{2+}]$
b) $[Ba^{2+}]>[Ca^{2+}]>[Na^{1+}]$
c) $[Ca^{2+}]>[Na^{1+}]>[Ba^{2+}]$
d) $[Na^{1+}]>[Ba^{2+}]>[Ca^{2+}]$

17. The ion concentrations in 2.00L of 0.32M K_3PO_4 are:

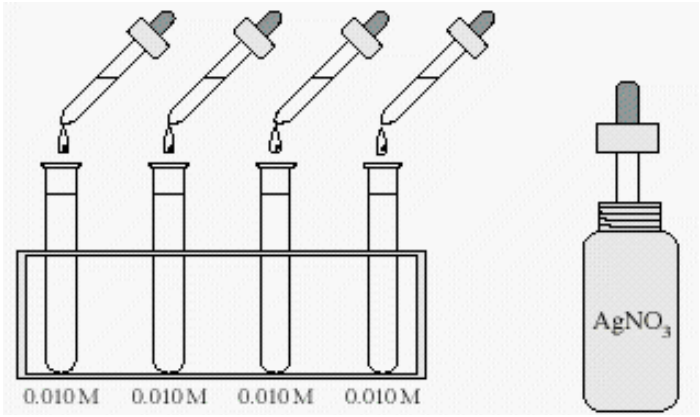
a) $[K^+] = 0.96$ M; $[PO_4^{3-}] = 0.32$ M
b) $[K^+] = 0.16$ M; $[PO_4^{3-}] = 0.16$ M
c) $[K^+] = 0.48$ M; $[PO_4^{3-}] = 0.16$ M
d) $[K^+] = 0.32$ M; $[PO_4^{3-}] = 0.32$ M

18. What is observed when H_2SO_4 is added to a saturated solution of $CaSO_4$?

a) the $[Ca^{2+}]$ increases
b) additional $CaSO_4$ precipitates
c) bubbles of H_2 are given off
d) the pH increases

19. In a solubility equilibrium, which of the following is true?
a) the concentration of solute and solvent are always equal
b) neither dissolving nor crystallization are occurring
c) the rate of dissolving equals the rate of crystallization
d) the mass of dissolved solute is greater than the mass of the solution

20. Consider the experiment shown to the right: Equal moles of $AgNO_3$ are added to each solution. It is observed that a precipitate forms in all but one solution. Which solution does **not** form a precipitate?
a) Cl^{1-}
b) S^{2-}
c) BrO_3^{1-}
d) ClO_3^{1-}



21. The solubility of $Mn(IO_3)_2$ is 4.8×10^{-3} M. What is the value of K_{sp}?
a) 4.4×10^{-7}
b) 7.1×10^{-6}
c) 1.1×10^{-7}
d) 4.6×10^{-5}

22. A saturated solution of NaCl contains 36.4 g of salt in 100.0 mL of solution. The solubility of NaCl is:
a) 3.64 M
b) 1.60 M
c) 6.23 M
d) 0.364 M

23. A solution contains equal concentrations of $Ba(NO_3)_2$, $Cd(NO_3)_2$, $Ca(NO_3)_2$ and $Fe(NO_3)_2$. If a solution of NaF is added drop by drop, which compound will precipitate out first?
a) BaF_2
b) CaF_2
c) CdF_2
d) FeF_2

24. Which of the following compounds is the **least** soluble in water?
a) $KMnO_4$
b) CuCl
c) $Fe(OH)_3$
d) $(NH4)_2S$

25. According to the general solubility rules, which of the following **will** form a precipitate when the solutions are combined?
a) LiI and Na_2CO_3
b) $Mg(NO_3)_2$ and KCl
c) $Ba(ClO_3)_2$ and $CuCH_3COO$
d) SrS and NH_4OH

26. The Ksp of SrF_2 is 4.3×10^{-9}. Calculate the solubility of SrF_2.
a) 6.6×10^{-5} M
b) 4.3×10^{-9} M
c) 1.6×10^{-3} M
d) 1.0×10^{-3} M

27. How many moles of FeS are dissolved in 200.0mL of a saturated solution of FeS? The K_{sp} of FeS at 25ºC is 6.0×10^{-19}.
a) 1.5×10^{-10}
b) 1.2×10^{-19}
c) 3.9×10^{-9}
d) 7.7×10^{-10}

28. A solution contains equal concentrations of Na_2CO_3, Na_2SO_4, $NaClO_3$ and Na_2CrO_4. If a solution of $Ba(NO_3)_2$ is added drop by drop, which compound will precipitate out first?

a) $BaCO_3$
b) $Ba(ClO_3)_2$
c) $BaSO_4$
d) $BaCrO_4$

29. When 10.0 mL of 0.100 M $BaCl_2$ is added to 50.0 mL of 0.025 M Na_2SO_4, the:

a) $Q_{sp} < K_{sp}$ and no precipitate forms
b) $Q_{sp} > K_{sp}$ and no precipitate forms
c) $Q_{sp} > K_{sp}$ and a precipitate forms
d) $Q_{sp} < K_{sp}$ and a precipitate forms

30. Which of the following units could be used to indicate solubility?

I) mL/ºC
II) mg/L
III) mol/mL
IV) L/s

a) I and II only
b) II and III only
c) I, II and III only
d) II, III and IV only

31. Which of the following substances will have the smallest Ksp?

a) K_2BO_3
b) $Ni(CH_3COO)_2$
c) $(NH_4)_2CO_3$
d) Cu_2S

32. The solubility product expression for tin(II) hydroxide, $Sn(OH)_2$, is

a) $[Sn^{2+}][OH^-]$
b) $[Sn^{2+}][OH^-]^2$
c) $[Sn^{2+}]^2[OH^-]$
d) $[Sn^{1+}][OH^{2-}]$

33. The solubility product expression for silver sulfide is:

a) $[Ag^+]^2\,[S^{2-}]$
b) $[Ag^+]\,[S^{2-}]^2$
c) $[Ag^+]\,[S^{2-}]$
d) $[Ag^+]^2\,[S^{2-}]^2$

34. According to the Ksp values given, the chromate compound that is the **most** soluble in water is:

a) $CdCrO_4$
b) $BaCrO_4$
c) $PbCrO_4$
d) $SrCrO_4$

$CdCrO_4$	Ksp = 9.0×10^{-12}
$BaCrO_4$	Ksp = 1.12×10^{-10}
$PbCrO_4$	Ksp = 2.3×10^{-13}
$SrCrO_4$	Ksp = 2.1×10^{-14}

35. The molar solubility of $PbBr_2$ is 2.17×10^{-3} M at a certain temperature. Calculate K_{sp} for $PbBr_2$ at this temperature.

a) 6.2×10^{-6}
b) 4.1×10^{-8}
c) 9.4×10^{-6}
d) 1.0×10^{-8}

36. The solubility of silver sulfate in water at 100ºC is approximately 1.4 g per 100 mL. What is the solubility product (Ksp) of this salt at 100ºC?

a) 5.7×10^{-8}
b) 4.1×10^{-5}
c) 8.3×10^{-6}
d) 3.6×10^{-4}

37. For $Cu(OH)_2$, $K_{sp} = 1.6 \times 10^{-19}$. What is the molar solubility of $Cu(OH)_2$?

a) 3.4×10^{-7} M
b) 5.4×10^{-7} M
c) 6.4×10^{-7} M
d) 4.3×10^{-7} M

38. Ag_3PO_4 would be **least** soluble at 25°C in

a) 0.1 M $NaNO_3$
b) 0.1 M $NaClO_3$
c) 0.1 M $NaCH_3COO$
d) 0.1 M Na_3PO_4

39. The Ksp of $PbCl_2$ is 1.2×10^{-5}. The molar solubility of $PbCl_2$ in 0.20 M $Pb(NO_3)_2$ solution is:

a) 1.4×10^{-2} M
b) 3.1×10^{-2} M
c) 9.2×10^{-3} M
d) 3.9×10^{-3} M

40. Which of the following pairs of compounds gives a precipitate when aqueous solutions of them are mixed?

a) $CaBr_2$ and K_2CO_3
b) $BaCl_2$ and $KClO_4$
c) HNO_3 and NH_4I
d) Na_2CO_3 and H_2SO_4

41. Which solid will precipitate first if an aqueous solution of Na_2CrO_4 at 25°C is slowly added to an aqueous solution containing 0.0010 M $Pb(ClO_3)_2$ and 0.0010 M $Ba(NO_3)_2$ at 25°C?

a) $BaCrO_4(s)$
b) $PbCrO_4(s)$
c) $NaNO_3$ (s)
d) $NaClO_3$ (s)

Short and Long Answer Practice Questions:

1. Write the dissociation equations that occur when the following salts are dissolved in water.

a) Na_2S (s)
b) $CaCl_2$ (s)
c) $Ba(NO_3)_2$ (s)
d) $(NH_4)_3PO_4$ (s)

2. Using the solubility rules that you have **MEMORIZED**, classify the following substances as either soluble or insoluble (slightly soluble):

a) $Pb(OH)_2$
b) $Sr(CH_3COO)_2$
c) $AgNO_3$
d) $BaCO_3$
e) $CaSO_4$
f) $(NH_4)_2S$

3. A solution contains a mixture of 0.10 M CO_3^{2-} ions, 0.10 M SO_4^{2-} ions and 0.10 M IO_3^{1-} ions. $Ba(NO_3)_2$ solution is added slowly to the mixture. Identify the order in which the barium salts will precipitate.

4. Write balanced chemical equations for the double displacement reactions that occur when the following solutions are mixed. Identify any possible precipitates by including the states of all species. Write net ionic equations for any precipitation reactions.

a) sodium hydroxide + silver acetate

b) ammonium sulfate + potassium phosphate

c) lithium carbonate + lead (II) nitrate

d) potassium sulfide + silver chlorate

5. An ionic solid A_2B_3 dissolves in water according to the following equation:

$$A_2B_3(s) \quad \leftrightarrow \quad 2\ A^{3+}(aq) \quad + \quad 3\ B^{2-}(aq)$$

If the solubility of the solid is 0.20 $mol \cdot L^{-1}$, calculate the solubility product, K_{sp}, for A_2B_3.

6. Calculate the molar solubility of lead (II) iodate, $Pb(IO_3)_2$, in water. Then, express the solubility as the number of milligrams per litre. K_{sp} for lead (II) iodate is 2.6×10^{-13}.

7. Determine whether a precipitate will form when 1.00 mL of 0.025 M sodium sulfate is mixed with 50.0 mL of 0.050 M calcium nitrate solution.

8. In a lab, a student takes 20.0 mL of 0.10 mol/L $Ba(NO_3)_2$ solution and adds it to 50.0 mL of 0.20 mol/L of Na_2CO_3 solution. Will a precipitate form?

9. What is the solubility of $BaSO_4$ in a 1.20 M solution of H_2SO_4?

10. What is the solubility of $CaCO_3$ in a 0.500 M solution of $Ca(NO_3)_2$?

11.a) What is the solubility of BaF_2 in water? Express your answer as grams per litre.

b) When BaF_2 dissolves in water, it produces heat. Will BaF_2 be more soluble in hot or cold water? Explain.