Chemistry 192
Problem Set 6
Spring, 2017

1. The solubility product of $Al(OH)_3$ is 1.1×10^{-15}. Calculate the concentrations of aluminum ions, hydroxide ions and hydronium ions in a saturated aqueous solution of aluminum hydroxide.
   Answer: $[Al^{3+}]=8.0 \times 10^{-5}$ M, $[OH^-]= 2.4 \times 10^{-4}$ M, $[H_3O^+]= 4.2 \times 10^{-11}$ M

2. The solubility product of Ag_2S is 1.6×10^{-49}. Calculate the molar solubility of silver sulfide in water.
   Answer: 3.4×10^{-17} M

3. The solubility of Ag_3AsO_4 in water is 8.5×10^{-4} g mL^{-1}. Calculate the solubility product of silver arsenate.
   Answer: $K_{sp} = 3.1 \times 10^{-19}$.

4. The solubility product of Ag_2CO_3 is $K_{sp} = 5.0 \times 10^{-12}$. Calculate the molar solubility of silver carbonate in a) water and b) a 0.20 M aqueous $AgNO_3$ solution (silver nitrate is 100% ionized).
   Answer: 1.1×10^{-4} M and 1.3×10^{-10} M

5. The solubility product of AgCl is $K_{sp} = 1.1 \times 10^{-10}$. Calculate the weight of silver nitrate that must be added to 10. mL of a 0.10 M sodium chloride solution to initiate the silver chloride precipitation reaction.
   Answer: 1.9×10^{-9} g.

6. The solubility product of Ag_2SO_4 is 7.0×10^{-5}. A laboratory student mixes 10. mL of a 0.010 M silver nitrate solution with 10. mL of a 0.020 M sodium sulfate (Na_2SO_4) solution. Calculate a suitable reaction quotient to determine if silver sulfate precipitate should form when the two solutions are mixed.
   Answer: $Q = 2.5 \times 10^{-7}$

7. The solubility product of $Cu(OH)_2$ is 1.0×10^{-16}. Calculate

   (a) the pH of a saturated solution of copper (II) hydroxide in water;
   Answer: pH=8.77

(b) the molar solubility of copper (II) hydroxide in a solution having pH=1.00;

(c) the molar solubility of copper (II) hydroxide in a solution having pH=13.00.
Answer: 1.0×10^{-14} M

8. Problem 54, page 814 textbook.
Answer: 9.2×10^{-18} M

9. Problem 56, page 814 textbook.
Answer: $Q = 4.5 \times 10^{-21}$

10. Aqueous silver ions form a coordination complex with thiosulfate anions according to the reaction
$$\mathrm{Ag}^{+}_{(aq)} + 2\mathrm{S_2O}^{2-}_{3(aq)} \rightleftharpoons \mathrm{Ag(S_2O_3)}^{3-}_{2(aq)},$$
where the formation equilibrium constant for the complex is $K_f = 1.7 \times 10^{13}$. Given the solubility product of silver iodide, AgI, is $K_{sp} = 8.5 \times 10^{-17}$, calculate the molar solubility of silver iodide in a solution that is 0.100 M in thiosulfate.
Answer: 3.4×10^{-2} M

11. Zinc ions form a complex in cyanide solutions according to the reaction
$$\mathrm{Zn}^{2+}_{(aq)} + 4\mathrm{CN}^{-}_{(aq)} \rightleftharpoons \mathrm{Zn(CN)}^{2-}_{4(aq)}$$
with a formation constant $K_f = 1.0 \times 10^{18}$. It is found that the solubility of solid zinc selenide (ZnSe) in a 0.100 M cyanide solution is 6.0×10^{-5} M. Calculate the solubility of zinc selenide in water.
Answer: 6.0×10^{-12} M

12. The silver cyanide coordination complex, $\mathrm{Ag(CN)}^{-}_{2}$ forms by the reaction
$$\mathrm{Ag}^{+}_{(aq)} + 2\mathrm{CN}^{-}_{(aq)} \rightleftharpoons \mathrm{Ag(CN)}^{-}_{2(aq)}$$
with associated equilibrium constant $K_f = 5.6 \times 10^{18}$. Given the solubility product of silver iodide (AgI) is $K_{sp} = 8.5 \times 10^{-17}$, calculate the solubility of silver iodide in a solution having $[\mathrm{CN}^-]$=0.500 M.
Answer: 0.24 M.

13. Zinc ions form a coordination complex in aqueous ammonia
$$\mathrm{Zn}^{2+}_{(aq)} + 4\mathrm{NH}_{3(aq)} \rightleftharpoons \mathrm{Zn(NH_3)}^{2+}_{4(aq)}$$
having formation equilibrium constant $K_f = 4.1 \times 10^{8}$. Zinc sulfide (ZnS) is only sparingly soluble in water with solubility product constant $K_{sp} = 2.0 \times 10^{-25}$. Calculate the molar solubility of zinc sulfide in a 0.10 M aqueous ammonia solution. **Answer**: 9.1×10^{-11} M

14. Silver ions (Ag^+) react with thiocyanate ions (SCN^-) in aqueous solution to form the coordination complex $Ag(SCN)_4^{3-}$ with associated formation constant $K_f = 1.2 \times 10^{10}$. Consider a solution that is made by adding 0.050 moles of silver ions to 0.250 L of a 2.50 M thiocyanate solution. Calculate the concentration of free silver ions (Ag^+) when equilibrium is reached.
Answer: 2.0×10^{-12} M.

15. The formation equilibrium constant for the cobalt ammonia complex $[Co(NH_3)_6^{3+}]$ is $K_f = 4.5 \times 10^{33}$. Calculate the molar concentration of free $Co^{3+}_{(aq)}$ in a solution made by mixing 0.100 L of 0.0500 M Co^{3+} to 0.500 L of 0.250 M aqueous ammonia. Approximations work for this problem.
Answer: 1.2×10^{-31} M

16. The solubility product constant for zinc oxalate (ZnC_2O_4) is 2.7×10^{-8} and the formation constant for the zinc cyanide coordination complex $[Zn(CN)_4^{2-}]$ is 1.0×10^{18}. Consider a mixture that is formed by combing 0.25 L of a 1.0×10^{-4} M CN^- solution and 0.35 L of a 6.0×10^{-6} M Zn^{2+} solution. After the solutions are mixed 0.50 moles of oxalate ions are added to the solution. Assuming the added oxalate does not change the total volume of the solution, determine if a zinc oxalate precipitate will form. Approximations work for this problem.
Answer: Yes