

Name: _____

Period: ____

Solubility Equilibrium

(1) Write the solubility equilibrium and K_{sp} expression for each of the following solutes.

(a) CuCl

(d) iron (III) hydroxide

(b) Ag_2SO_4

(e) aluminum carbonate

(c) NiS

(f) zirconium phosphate

(2) What is the concentration of Ba^{2+} ions present in a saturated solution with $[F^-] = 0.015$ M.
(barium fluoride has $K_{sp} = 2.4 \times 10^{-5}$)

(3) What is the concentration of SO_4^{2-} ions present in a saturated solution with $[Ca^{2+}] = 0.20$ M.
(calcium sulphate has $K_{sp} = 6.1 \times 10^{-5}$)

(4) What is the concentration of Ag^+ ions present in a saturated solution with $[Na_3PO_4] = 6.5 \times 10^{-3}$ M.
(silver phosphate has $K_{sp} = 1.8 \times 10^{-18}$)

(5) The solubility for silver iodide is 9.1×10^{-9} mol/L. Determine K_{sp} .

(6) The solubility for iron (II) hydroxide is 5.3×10^{-4} g/L. Determine K_{sp} .

(7) The solubility for calcium phosphate is 7.1×10^{-7} mol/L. Determine K_{sp} .

(8) The K_{sp} for strontium chromate is 3.6×10^{-5} . Determine the solubility in mol/L. What is the concentration of each ion at equilibrium?

(9) The K_{sp} for lead (II) fluoride is 4.0×10^{-8} . Determine the solubility in mol/L. What is the concentration of each ion at equilibrium? What is the solubility in g/L?

(10) The K_{sp} for magnesium hydroxide is 1.2×10^{-11} . Determine the solubility in mol/L. What is the concentration of each ion at equilibrium? What mass of magnesium hydroxide dissolve in 500 mL of water?

(11) The K_{sp} for cadmium phosphate is 2.5×10^{-33} . Determine the solubility in mol/L. What is the concentration of each ion at equilibrium? What mass of cadmium phosphate would dissolve in 250 mL of water?

(12) Rank the following substances from highest to lowest solubility.

tin (II) sulphide ($K_{sp} = 1.0 \times 10^{-26}$)

nickel (II) sulphide ($K_{sp} = 3.0 \times 10^{-20}$)

cobalt (II) sulphide ($K_{sp} = 5.0 \times 10^{-22}$)

(13) Rank the following substances from highest to lowest solubility.

yttrium (III) carbonate ($K_{sp} = 1.0 \times 10^{-31}$)

barium carbonate ($K_{sp} = 2.6 \times 10^{-28}$)

silver carbonate ($K_{sp} = 8.5 \times 10^{-12}$)

(14) What is the solubility of silver cyanide ($K_{sp} = 1.2 \times 10^{-16}$) in a 0.0120 M solution of sodium cyanide in mol/L?

(15) What is the solubility of calcium carbonate ($K_{sp} = 2.8 \times 10^{-9}$) in a 0.104 M solution of calcium nitrate in mol/L? What is the solubility in g/L?

- (16) What is the solubility of silver chloride ($K_{sp} = 1.8 \times 10^{-10}$) in a 0.150 M solution of calcium chloride?
- (17) What is the solubility of chromium (III) fluoride ($K_{sp} = 6.6 \times 10^{-11}$) in a 0.215 M solution of chromium (III) nitrate?
- (18) Will a precipitate form if 105 mL of 0.0120 M cadmium nitrate is mixed with 225 mL of 0.0110 M sodium carbonate (cadmium carbonate has $K_{sp} = 5.2 \times 10^{-12}$)?
- (19) Will a precipitate form if 5.0 mL of 6.0×10^{-4} M lead (II) nitrate is mixed with 10 mL of 4.2×10^{-3} M sodium iodide (lead (II) iodide has $K_{sp} = 1.4 \times 10^{-8}$)?
- (20) Will a precipitate form if 15 mL of 1.2×10^{-2} M zinc nitrate is mixed with 25 mL of 2.5×10^{-3} M sodium oxalate (zinc oxalate has $K_{sp} = 2.7 \times 10^{-8}$)?. Calculate $[Zn^{2+}]$ and $[C_2O_4^{2-}]$ at equilibrium.
- (21) Will a precipitate form if 120 mL of 4.5×10^{-2} M silver nitrate is mixed with 180 mL of 5.2×10^{-2} M sodium chromate (silver chromate has $K_{sp} = 1.9 \times 10^{-12}$)? Calculate $[Ag^+]$ and $[CrO_4^{2-}]$ at equilibrium.
- (22) A solution contains 2.0×10^{-3} M Ba^{2+} and 3.2×10^{-3} M Mg^{2+} . If F^- is gradually added to the solution, will BaF_2 ($K_{sp} = 1.7 \times 10^{-6}$) or MgF_2 ($K_{sp} = 6.6 \times 10^{-9}$) precipitate first? What concentration of F^- is necessary to precipitate each salt?
- (23) A solution contains 2.5×10^{-3} M CO_3^{2-} , 1.8×10^{-3} M CrO_4^{2-} , and 1.2×10^{-3} M Br^- . If Ag^+ is gradually added to the solution, will Ag_2CO_3 ($K_{sp} = 6.2 \times 10^{-12}$), Ag_2CrO_4 ($K_{sp} = 1.9 \times 10^{-12}$), or $AgBr$ ($K_{sp} = 7.7 \times 10^{-13}$) precipitate first? What concentration of Ag^+ is necessary to precipitate each salt?

Answers:

- (1) (a) $CuCl(s) \rightleftharpoons Cu^+(aq) + Cl^-(aq)$; $K_{sp} = [Cu^+][Cl^-]$ (b) $Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq)$; $K_{sp} = [Ag^+]^2[SO_4^{2-}]$
(c) $NiS(s) \rightleftharpoons Ni^{2+}(aq) + S^{2-}(aq)$; $K_{sp} = [Ni^{2+}][S^{2-}]$ (d) $Fe(OH)_3 \rightleftharpoons Fe^{3+}(aq) + 3OH^-(aq)$; $K_{sp} = [Fe^{3+}][OH^-]^3$
(e) $Al_2(CO_3)_3 \rightleftharpoons 2Al^{3+}(aq) + 3CO_3^{2-}(aq)$; $K_{sp} = [Al^{3+}]^2[CO_3^{2-}]^3$ (f) $Zr_3(PO_4)_4 \rightleftharpoons 3Zr^{4+}(aq) + 3PO_4^{3-}(aq)$; $K_{sp} = [Zr^{4+}]^3[PO_4^{3-}]^4$
(2) $[Ba^{2+}] = 0.11$ M (3) $[SO_4^{2-}] = 3.1 \times 10^{-4}$ M (4) $[Ag^+] = 6.5 \times 10^{-6}$ M
(5) $K_{sp} = 8.3 \times 10^{-17}$ (6) $K_{sp} = 8.5 \times 10^{-16}$ (7) $K_{sp} = 1.8 \times 10^{-29}$
(8) solubility = 6.0×10^{-3} mol/L; $[Sr^{2+}] = 6.0 \times 10^{-3}$ M and $[CrO_4^{2-}] = 6.0 \times 10^{-3}$ M
(9) solubility = 0.54 g/L; $[Pb^{2+}] = 2.2 \times 10^{-3}$ M and $[F^-] = 4.4 \times 10^{-3}$ M
(10) solubility = 1.4×10^{-4} mol/L; $[Mg^{2+}] = 1.4 \times 10^{-4}$ M and $[OH^-] = 2.8 \times 10^{-4}$ M; 4.1×10^{-3} g/500mL
(11) solubility = 1.2×10^{-7} mol/L; $[Cd^{2+}] = 2.4 \times 10^{-7}$ M and $[PO_4^{3-}] = 3.6 \times 10^{-7}$ M; 1.6×10^{-5} g/250mL
(12) $NiS > CoS > SnS$
(13) Ag_2CO_3 (solubility = 1.3×10^{-4} mol/L) $>$ $Y_2(CO_3)_3$ (solubility = 2.5×10^{-7} mol/L) $>$ $BaCO_3$ (solubility = 1.6×10^{-14} mol/L)
(14) 1.0×10^{-14} M (15) 2.7×10^{-8} M (16) 6.0×10^{-10} M (17) 2.2×10^{-4} M
(18) $Q = 2.9 \times 10^{-5} > K_{sp}$, so a ppt will form (19) $Q = 1.6 \times 10^{-9} < K_{sp}$, so a ppt will not form
(20) $Q = 7.2 \times 10^{-6} > K_{sp}$, so a ppt will form; $[Zn^{2+}] = 3.1 \times 10^{-3}$ M and $[C_2O_4^{2-}] = 9.0 \times 10^{-6}$ M
(21) $Q = 1.0 \times 10^{-5} > K_{sp}$, so a ppt will form; $[Ag^+] = 9.2 \times 10^{-6}$ M and $[CrO_4^{2-}] = 2.2 \times 10^{-2}$ M
(22) BaF_2 will ppt first (requires $[F^-] = 2.9 \times 10^{-2}$ M); MgF_2 will ppt second (requires $[F^-] = 1.4 \times 10^{-3}$ M);
(23) $AgBr$ will ppt first (requires $[Ag^+] = 6.4 \times 10^{-10}$ M); Ag_2CrO_4 will ppt second (requires $[Ag^+] = 3.2 \times 10^{-5}$ M); Ag_2CO_3 will ppt third (requires $[Ag^+] = 5.0 \times 10^{-5}$ M)