Chemistry 30 – Solubility Equilibrium – Unit Homework

Solutions and Solubility of Ionic Compounds

1. Indicate if each substance is soluble or has low solubility. Write the dissociation equation for each, using the proper arrow (→ or ⇌)
   a. $Al(OH)_3\ (s) \rightleftharpoons Al^{3+}\ (aq) + 3\ OH^-\ (aq)$ (low solubility)
   b. $KOH\ (s) \rightarrow K^+\ (aq) + OH^-\ (aq)$ (soluble)
   c. $Na_2SO_4\ (s) \rightarrow 2\ Na^+\ (aq) + SO_4^{2-}\ (aq)$ (soluble)
   d. $PbCl_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2\ Cl^-\ (aq)$ (low solubility)
   e. $FePO_4\ (s) \rightleftharpoons Fe^{3+}\ (aq) + PO_4^{3-}\ (aq)$ (low solubility)
   f. $Ba(NO_3)_2\ (s) \rightarrow Ba^{2+}\ (aq) + 2\ NO_3^-\ (aq)$ (soluble)
   g. $(NH_4)_3PO_4(s) \rightarrow 3\ NH_4^+\ (aq) + PO_4^{3-}\ (aq)$ (soluble)
   h. $MgBr_2\ (s) \rightarrow Mg^{2+}\ (aq) + 2\ Br^-\ (aq)$ (soluble)
   i. $Sn(NO_3)_4\ (s) \rightarrow Sn^{4+}\ (aq) + 4\ NO_3^-\ (aq)$ (soluble)
   j. $CuCO_3\ (s) \rightleftharpoons Cu^{2+}\ (aq) + CO_3^{2-}\ (aq)$ (low solubility)

2. For each, write the molecular, total ionic and net ionic equations for the reaction. Remember that a complete equation includes coefficients, ion charges and states. Be sure to balance each reaction.
   a. $SrBr_2\ (aq) + K_2SO_4\ (aq) \rightleftharpoons 2\ KBr\ (aq) + SrSO_4\ (s)$
      $Sr^{2+}\ (aq) + 2Br^-\ (aq) + 2\ K^+\ (aq) + SO_4^{2-}\ (aq) \rightleftharpoons 2\ K^+\ (aq) + 2\ Br^-\ (aq) + SrSO_4\ (s)$
      $Sr^{2+}\ (aq) + SO_4^{2-}\ (aq) \rightleftharpoons SrSO_4\ (s)$
   b. $AgNO_3\ (aq) + KCl\ (aq) \rightleftharpoons AgCl\ (s) + KNO_3\ (aq)$
      $Ag^+\ (aq) + NO_3^-\ (aq) + K^+\ (aq) + Cl^-\ (aq) \rightleftharpoons AgCl\ (s) + K^+\ (aq) + NO_3^-\ (aq)$
      $Ag^+\ (aq) + Cl^-\ (aq) \rightleftharpoons AgCl\ (s)$
   c. $Mg(NO_3)_2\ (aq) + Na_2CO_3\ (aq) \rightleftharpoons MgCO_3\ (s) + 2\ NaNO_3\ (aq)$
      $Mg^{2+}\ (aq) + 2\ NO_3^-\ (aq) + 2\ Na^+\ (aq) + CO_3^{2-}\ (aq) \rightleftharpoons MgCO_3\ (s) + 2\ Na^+ + 2\ NO_3^-\ (aq)$
      $Mg^{2+}\ (aq) + CO_3^{2-}\ (aq) \rightleftharpoons MgCO_3\ (s)$
   d. $MnCl_2\ (aq) + (NH_4)_2CO_3\ (aq) \rightleftharpoons MnCO_3\ (s) + 2\ NH_4Cl\ (aq)$
      $Mn^{2+}\ (aq) + 2\ Cl^-\ (aq) + 2\ NH_4^+\ (aq) + CO_3^{2-}\ (aq) \rightleftharpoons MnCO_3\ (s) + 2\ NH_4^+\ (aq) + 2\ Cl^-\ (aq)$
      $Mn^{2+}\ (aq) + CO_3^{2-}\ (aq) \rightleftharpoons MnCO_3\ (s)$

3. For each pair of reactants…
   a. aluminum chloride (aq) + mercury(II) iodide (aq)
      NO REACTION
   b. potassium nitrate (aq) + silver phosphate (s)
      $3\ AgNO_3\ (aq) + K_3PO_4\ (aq) \rightleftharpoons Ag_3PO_4\ (s) + 3\ KNO_3\ (aq)$
      $3\ Ag^+\ (aq) + PO_4^{3-}\ (aq) \rightleftharpoons Ag_3PO_4\ (s)$
   c. copper(II) chloride (aq) + aluminum bromide (aq)
      NO REACTION
   d. calcium carbonate (s) + sodium acetate (aq)
      $Ca(C_2H_3O_2)_2\ (aq) + Na_2CO_3\ (aq) \rightleftharpoons CaCO_3\ (s) + 2\ NaC_2H_3O_2\ (aq)$
      $Ca^{2+}\ (aq) + CO_3^{2-}\ (aq) \rightleftharpoons CaCO_3\ (s)$
   e. ammonium acetate (aq) + mercury(I) chloride (s)
      $NH_4Cl\ (aq) + HgC_2H_3O_2\ (aq) \rightleftharpoons NH_4C_2H_3O_2\ (aq) + HgCl\ (s)$

Cl^- (aq) + Hg^+ (aq) ⇌ HgCl (s)

f. calcium chloride (aq) + hydrogen nitrate (aq)
NO REACTION

g. iron(II) chloride (aq) + hydrogen sulfide (aq)
NO REACTION

h. copper(II) acetate (aq) + water (l)
NO REACTION

i. magnesium phosphate (s) + water (l)
3 $Mg(OH)_2$ (aq) + 2 H_3PO_4 (aq) ⇌ $Mg_3(PO_4)_2$ (s) + 6 H_2O (l)
3 Mg^{2+} (aq) + 2 $PO_4^{3=}$ (aq) ⇌ $Mg_3(PO_4)_2$ (s)

j. zinc hydroxide (s) + potassium bromide (aq)
$ZnBr_2$ (aq) + 2KOH (aq) ⇌ $Zn(OH)_2$ (s) + 2KBr (aq)
Zn^{2+} (aq) + 2 OH^- (aq) ⇌ $Zn(OH)_2$ (s)

Solubility Equilibrium

4. Higher K_{sp} means a substance is more soluble.
5. For each compound, write…
   a. $CuCl$ (s) ⇌ Cu^+ (aq) + Cl^- (aq)
   $K_{sp} = [Cu^+][Cl^-]$
   b. $PbSO_4$ (s) ⇌ Pb^{2+} (aq) + SO_4^{2-} (aq)
   $K_{sp} = [Pb^{2+}][SO_4^{2-}]$
   c. $Zn(OH)_2$ (s) ⇌ Zn^{2+} (aq) + 2 OH^- (aq)
   $K_{sp} = [Zn^{2+}][OH^-]^2$
   d. $Ca_3(PO_4)_2$ (s) ⇌ 3 Ca^{2+}(aq) + 2 PO_4^{3-} (aq)
   $K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$
6. Calculate the K_{sp}…
   a. $K_{sp} = 2.5 \times 10^{-5}$
   b. $K_{sp} = 7.8 \times 10^{-8}$
   c. $K_{sp} = 3.7 \times 10^{-12}$
7. For silver carbonate…
   $[Ag_2CO_3] = 1.3 \times 10^{-4}$ M
   $[FeS] = 2.5 \times 10^{-9}$ M
   $[CaCO_3] = 7.1 \times 10^{-5}$ M
8. Consider these slightly soluble…
   a. PbS
   b. $[PbSO_4] = 1.3 \times 10^{-4}$ M
   c. m = 0.041 g
   d. Add $[SO_4^{2-}]$ (for example by adding sulfuric acid), decrease temperature of solution
9. Given these slightly soluble salts…
   a. AgCl, AgBr, AgI
   b. $m_{AgBr} = 1.4 \times 10^{-4}$ g
   $m_{AgCl} = 1.9 \times 10^{-3}$ g
   $m_{AgI} = 2.2 \times 10^{-6}$ g
10. For a saturated solution of silver carbonate…
   a. $[Ag^+] = 2.5 \times 10^{-4}$ M ($2x$)

b. m_{Ag2CO3} = 0.017 g

11. Determine if a precipitate…
    a. No
    b. Yes
12. Determine if a precipitate will form…
    a. No
    b. Yes
13. Will a precipitate form if 200.0 mL…
    Yes
14. Will a precipitate form if 25.0 mL…
    No
15. Will a precipitate form if equal volumes…
    Yes