CHEM 201 Self Quiz – 2 (Gravimetric analysis/Volumetric analysis)

Answer key

1. Calculate the solubility product constant for SrF_2 given the molar concentration of the saturated solution is 8.6×10^{-4} M.

$$SrF_2 \Leftrightarrow Sr^{2+} + 2F^-$$
$$K_{sp} = [Sr^{2+}][F^-]^2$$
$$[Sr^{2+}] = [SrF_2] = 8.6 \cdot 10^{-4}$$
$$[F^-] = 2 \cdot [SrF_2] = 2 \cdot 8.6 \cdot 10^{-4} = 17.2 \cdot 10^{-4}$$
$$K_{sp} = 8.6 \cdot 10^{-4} \cdot (17.2 \cdot 10^{-4})^2 = 1.5 \cdot 10^{-10}$$

2. Calcium fluoride, CaF_2, is a sparingly soluble salt with a $K_{sp} = 3.9 \times 10^{-11}$.

$$\begin{array}{ccc} CaF_2 \Leftrightarrow & Ca^{2+} + & 2F^- \\ x & x & 2x \end{array}$$

(a) Calculate its molar solubility in a saturated solution.

$$K_{sp} = [Ca^{2+}][F^-]^2 = x \cdot (2x)^2 = 4x^3$$
$$4x^3 = 3.9 \cdot 10^{-11} \Rightarrow x = \sqrt[3]{\frac{3.9 \cdot 10^{-11}}{4}} = 2.1 \cdot 10^{-4}$$

Molar solubility is 2.1×10^{-4} M

(b) Calculate its molar solubility in a saturated aqueous solution that is also 0.050 M in fluoride ion, F^-.

$$K_{sp} = (x)(2x + 0.05)^2$$
$$2x = 4.2 \cdot 10^{-4}$$

Assumption: $2x << 0.050$

$$K_{sp} = (x)(0.05)^2 = 0.0025x = 3.9 \cdot 10^{-11}$$

$$x = \frac{3.9 \cdot 10^{-11}}{0.0025} = 1.6 \cdot 10^{-8}$$

Molar solubility is 1.6×10^{-8} M. Solubility decreased.

3. A solution containing 250 mL of 2.00×10^{-4} M $Ni(NO_3)_2$ is mixed with 250 mL of a solution containing 4.00×10^{-8} M Na_2S. The solubility product constant (K_{sp}) for NiS is 3.00×10^{-21}. Show all your work.

$$Ni(NO_3)_2 + Na_2S \Leftrightarrow NiS + 2NaNO_3$$

(a) Write the net ionic reaction that occurs.

$$Ni^{2+} + S^{2-} \Leftrightarrow NiS \downarrow \qquad K_{sp} = 3.00 \cdot 10^{-21}$$

(b) What are the initial concentrations of the predominant species participating in the net ionic reaction (prior to the reaction)?

Total volume is: 250 ml + 250 ml = 500 ml

$$Ni^{2+} = 2.00 \cdot 10^{-4} \cdot \frac{250ml}{500ml} = 1.00 \cdot 10^{-4} M$$
$$S^{2-} = 4.00 \cdot 10^{-8} \cdot \frac{250ml}{500ml} = 2.00 \cdot 10^{-8} M$$

(c) Does a precipitate form? Justify your answer with the calculation that demonstrates whether, or not a precipitate forms.

$$Q = [Ni^{+2}][S^{-2}] = 1.00 \cdot 10^{-4} \cdot 2.00 \cdot 10^{-8} = 2.00 \cdot 10^{-12}$$

$Q > K_{sp}$: precipitate forms

4. Distinguish between end point and equivalence point.

Equivalence point: amount of titrant is equal to the amount of analyte.

End point: point where is the sudden change of physico-chemical property of the analyte occurs. It is located very close to the equivalence point.

5. Consider the following reaction

$$5\ H_2C_2O_4 + 2\ KMnO_4^- + 6\ H^+ \longrightarrow 10\ CO_2 + 2\ Mn^{2+} + 8\ H_2O$$

How many milliliters of 0.165 M $KMnO_4$ are needed to react with 108.0 mL of 0.165 M oxalic acid? How many milliliters of 0.165M oxalic acid are required to react with 108 mL of 0.165 M $KMnO_4$?

$$n\ of\ MnO_4^- = \frac{2 \cdot MnO_4^-}{5 \cdot C_2O_4^{2-}} \underbrace{(108.0ml \cdot 0.165M)}_{\text{volume and concentration of } C_2O_4^{2-}} = 7.128\ mmoles\ MnO_4^-$$

$$\frac{7.128\ mmoles}{0.165\ mmoles/ml} = 43.20\ ml\ of\ KMnO_4$$

How many milliliters of 0.165M oxalic acid are required to react with 108 mL of 0.165 M $KMnO_4$?

$$Volume\ of\ the\ C_2O_4^{2-} = \frac{5}{2}(volume\ of\ the\ KMnO4) = \frac{5}{2} \cdot 108\ ml = 270\ ml$$

6. Why solubility of an ionic compound increases as the ionic strength of the solution increases?

The net attraction between the cation with its ionic atmosphere and the anion with its ionic atmosphere is smaller than it would be between pure cation and anion in the absence of ionic atmosphere.

7. Find the activity coefficient of each ion at the indicated ionic strength:

(a) SO_4^{2-} (μ = 0.01 M)

$$\log \gamma_{SO_4^{2-}} = \frac{-0.51 z^2 \sqrt{\mu}}{1 + (\alpha\sqrt{\mu}/305)} = \frac{-0.51 \cdot 4 \cdot \sqrt{0.01}}{1 + (400\sqrt{0.01}/305)} = -0.18$$

$$\gamma_{SO_4^{2-}} = 10^{-0.18} = 0.66$$

(b) Sc^{3+} (μ = 0.005 M)

$$\log \gamma_{Sc^{3+}} = \frac{-0.51 z^2 \sqrt{\mu}}{1 + (\alpha\sqrt{\mu}/305)} = \frac{-0.51 \cdot 9 \cdot \sqrt{0.005}}{1 + (900\sqrt{0.005}/305)} = -0.27$$

$$\gamma_{Sc^{3+}} = 10^{-0.27} = 0.54$$

8. Calculate the concentration of Hg_2^{2+} in saturated solutions of Hg_2Br_2 in:
(a) 0.001 M KNO_3

Ionic strength of the KNO_3 is:

$$\mu = \frac{1}{2}\sum c_i z_i^2 = \frac{1}{2}(0.001 \cdot 1^2 + 0.001 \cdot 1^2) = 0.001$$

The solubility value product for the Hg_2Br_2 is:
$K_{sp} = 5.6 \times 10^{-23}$

$$[Hg_2^{2+}]\gamma_{Hg_2^{2+}}[Br^-]^2 \gamma_{Br-}^2 = x(0.867)(2x)^2(0.964)^2 = 5.6 \cdot 10^{-23}$$

$$x = [Hg_2^{2+}] = 2.6 \cdot 10^{-8} M$$

(b) 0.01 M KNO_3

Ionic strength of the KNO_3 is:

$$\mu = \frac{1}{2}\sum c_i z_i^2 = \frac{1}{2}(0.01 \cdot 1^2 + 0.01 \cdot 1^2) = 0.01$$

$$[Hg_2^{2+}]\gamma_{Hg_2^{2+}}[Br^-]^2 \gamma_{Br-}^2 = x(0.660)(2x)^2(0.899)^2 = 5.6 \cdot 10^{-23}$$

$$x = [Hg_2^{2+}] = 3.0 \cdot 10^{-8} M$$

(c) 0.1 M KNO_3

Ionic strength of the KNO_3 is:

$$\mu = \frac{1}{2}\sum c_i z_i^{\,2} = \frac{1}{2}(0.1\cdot 1^2 + 0.1\cdot 1^2) = 0.1$$

$$[Hg_2{}^{2+}]\gamma_{Hg_2{}^{2+}}[Br^-]^2\gamma_{Br-}{}^2 = x(0.355)(2x)^2(0.755)^2 = 5.6\cdot 10^{-23}$$

$$x = [Hg_2{}^{2+}] = 4.1\cdot 10^{-8}\,M$$