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AP Free Response Practice ~~#2~~ [2011B #1, modified, 9 points]

1. Answer the following questions about the solubility and reactions of the ionic compounds $M(OH)_2$ and MCO_3, where M represents an unidentified metal.

   a. Identify the charge of the M ion in the ionic compounds above. [1 point]

   b. At 25°C, a saturated solution of $M(OH)_2$ ~~has a molar concentration of~~ $[OH^-] = 1.4 \times 10^{-5}$ M.

      i. Write the solubility-product constant expression for $M(OH)_2$. [1 point]

      ii. Calculate the value of the solubility-product constant, K_{sp}, for $M(OH)_2$ at 25°C. [2 points]

   c. For the metal carbonate, MCO_3, the value of the solubility-product constant, K_{sp}, is 7.4×10^{-14} at 25°C. On the basis of this information and your results in part (b), which compound, $M(OH)_2$ or MCO_3, has the greater molar solubility in water at 25°C? Justify your answer with a calculation. [2 points]

   d. MCO_3 decomposes at high temperatures, as shown by the reaction represented below.

$$MCO_3(s) \leftrightarrow MO(s) + CO_2(g)$$

   A sample of MCO_3 is placed in a previously evacuated container, heated to 423 K, and allowed to come to equilibrium. Some solid MCO_3 remains in the container. The value of K_p for the reaction at 423 K is 0.0012.

      i. Write the equilibrium-constant expression for K_p of the reaction. [1 point]

      ii. Determine the pressure, in atm, of $CO_2(g)$ in the container at equilibrium at 423 K. [1 point]

      iii. Indicate whether the value of $\Delta G°$ for the reaction at 423 K is positive, negative, or zero. Justify your answer. [1 point]

(a) +2 or M^{2+}

(b)(i) $K_{sp} = [M^{2+}][OH^-]^2$

(ii) $[M^{2+}] = \frac{1}{2}[OH^-] = \frac{1}{2}(1.4E-5) = 7.0E-6\ M$

$\Rightarrow K_{sp} = [M^{2+}][OH^-]^2$

$= (7.0E-6)(1.4E-5)^2 = \boxed{1.4 \times 10^{-15}}$

(c) for $M(OH)_2$, $K_{sp} = 4x^3 = 1.4E-15 \Rightarrow x = \sqrt[3]{\frac{1.4E-15}{4}} = 7.0E-6\ M$

for MCO_3, $K_{sp} = x^2 = 7.4E-14 \Rightarrow x = \sqrt{7.4E-14} = 2.7E-7\ M$

Because $7.0E-6\ M > 2.7E-7\ M$, $M(OH)_2$ has the greater molar solubility.

(d) (i) $K_p = P_{CO_2}$

(ii) $K_p = 0.0012 = P_{CO_2} \Rightarrow P_{CO_2} = \boxed{0.0012 \text{ atm}}$

(iii) $K_p < 1$, so $\Delta G = +$ (since $\Delta G = -RT \ln K$)