AP® Chemistry (Operational)
2004 Sample Student Responses

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

a. $K_{sp} = [Ag^+]^2[CrO_4^{-2}]$

b. $K_{sp} = [Ag^+]^2[CrO_4^{-2}]$

$2.6\times10^{-12} = (2x)^2(x)$

$2.6\times10^{-12} = 4x^3$

$6.5\times10^{-13} = x^3$

$x = 8.7\times10^{-5}$ mol/L

$[Ag^+] = 2x = \boxed{1.7\times10^{-4}\text{ mol/L}}$

c. In saturated solution, 8.7×10^{-5} mol can be dissolved per liter → 8.7×10^{-6} mol can be dissolved per 100 mL

molar mass $Ag_2CrO_4 = 2(107.87) + 52.00 + 4(16.00) = 331.74$ g/mol

8.7×10^{-6} mol $\times$ 331.74 g/mol = $\boxed{.0029\text{ g}}$

d. $AgNO_3$ dissociates according to the expression

$AgNO_3 \rightarrow Ag^+ + NO_3^-$

Thus, adding $AgNO_3$ will increase the concentration of Ag^+ ions. This in turn will shift the equilibrium

$Ag_2CrO_4 \rightleftharpoons 2Ag^+ + CrO_4^{-2}$

to the left in accordance with Le Châtelier's principle, and $[CrO_4^{-2}]$ will decrease.

e. $Ag_3PO_4 \rightleftharpoons 3Ag^+ + PO_4^{3-}$

f. $K_{sp} = [Ag^+]^3[PO_4^{3-}]$ $\quad [Ag^+] = 5.3\times10^{-5}$ $\quad [PO_4^{3-}] = \frac{[Ag^+]}{3} = 1.8\times10^{-5}$

$K_{sp} = (5.3\times10^{-5}\text{ M})^3(1.8\times10^{-5})$

$K_{sp} = \boxed{2.6\times10^{-18}}$

g. $[Ag^+]$ in the final solution will still be 5.3×10^{-5} M. Due to the decrease in volume, some of the Ag_3PO_4 will precipitate. However, a solution of Ag_3PO_4 is saturated at $[Ag^+] = 5.3\times10^{-5}$ M, and the solution cannot become

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

more saturated, regardless of any evaporation.

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CHEMISTRY
Section II
(Total time—90 minutes)

1B1

Part A
Time—40 minutes
YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

Be sure to write all your answers to the questions on the lined pages following each question in the booklet with the pink cover. Do NOT write your answers on the green insert.

Answer Question 1 below. The Section II score weighting for this question is 20 percent.

1. Answer the following questions relating to the solubilities of two silver compounds, Ag_2CrO_4 and Ag_3PO_4.

Silver chromate dissociates in water according to the equation shown below.

$$Ag_2CrO_4(s) \rightleftarrows 2\,Ag^+(aq) + CrO_4^{2-}(aq) \qquad K_{sp} = 2.6 \times 10^{-12} \text{ at } 25°C$$

(a) Write the equilibrium-constant expression for the dissolving of $Ag_2CrO_4(s)$.

(b) Calculate the concentration, in mol L^{-1}, of $Ag^+(aq)$ in a saturated solution of Ag_2CrO_4 at 25°C.

(c) Calculate the maximum mass, in grams, of Ag_2CrO_4 that can dissolve in 100. mL of water at 25°C.

(d) A 0.100 mol sample of solid $AgNO_3$ is added to a 1.00 L saturated solution of Ag_2CrO_4. Assuming no volume change, does $[CrO_4^{2-}]$ increase, decrease, or remain the same? Justify your answer.

In a saturated solution of Ag_3PO_4 at 25°C, the concentration of $Ag^+(aq)$ is 5.3×10^{-5} *M*. The equilibrium-constant expression for the dissolving of $Ag_3PO_4(s)$ in water is shown below.

$$K_{sp} = [Ag^+]^3[PO_4^{3-}]$$

(e) Write the balanced equation for the dissolving of Ag_3PO_4 in water.

(f) Calculate the value of K_{sp} for Ag_3PO_4 at 25°C.

(g) A 1.00 L sample of saturated Ag_3PO_4 solution is allowed to evaporate at 25°C to a final volume of 500. mL. What is $[Ag^+]$ in the solution? Justify your answer.

1. a. $Ksp = [Ag^+]^2[CrO_4]^{2-}$

b. $Ksp = 2.6 \times 10^{-12} = [2s]^2[s] = 4s^3$

$\frac{2.6 \times 10^{-12}}{4} = s^3$

$s^3 = 6.5 \times 10^{-13}$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

$s = \sqrt[3]{6.5\times10^{-13}} = 8.7\times10^{-5}$ M

$[Ag^+] = 2s = 2(8.7\times10^{-5}) = 17.4\times10^{-5} = 1.7\times10^{-4}$ M

c. $[CrO_4^{-2}] = 8.7\times10^{-5}$ M 100 mL = .1 L

$$\frac{8.7\times10^{-5}\ \text{mol}\ CrO_4^{-}}{1\ \text{L}} \cdot \frac{.1\ \text{L}}{1} = 8.7\times10^{-6}\ \text{mol}\ CrO_4^{-} \times \frac{1\ \text{mol}\ Ag_2CrO_4}{1\ \text{mol}\ CrO_4^{-}} =$$

$$8.7\times10^{-6}\ \text{mol}\ Ag_2CrO_4 \times \frac{330\ \text{g}}{1\ \text{mol}\ Ag_2CrO_4} = 2.9\times10^{-3}\ \text{g}\ Ag_2CrO_4$$

d. $K_{sp} = [.1]^2[CrO_4^{-}]$

$2.6\times10^{-12} = [.1]^2[CrO_4^{-2}]$

$$[CrO_4^{-2}] = \frac{2.6\times10^{-12}}{.01} = 2.6\times10^{-10}\ \text{M}$$

the molarity of CrO_4^{-2} decreases because the the Ksp doesn't change, so when the molarity of Ag^+ increases CrO_4^{-2} must decrease

e.

$$Ag_3PO_4 \rightleftharpoons 3Ag^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

f. $K_{sp} = [Ag^+]^3[PO_4^{3-}]$

$K_{sp} = [5.3\times10^{-5}]^3\left[\frac{5.3\times10^{-5}}{3}\right]$

$K_{sp} = 2.6\times10^{-18}$

$5.3\times10^{-5}\ \text{M}\ Ag^+ \times \frac{1\ \text{M}\ PO_4^{3-}}{3\ \text{M}\ Ag^+} = \frac{5.3\times10^{-5}}{3}\ \text{M}\ PO_4^{3-}$

g. $[Ag^+] = 5.3\times10^{-5}$ M because the ratio of mols to volume has not been changed although the volume has changed because when the solution evaporated ions were removed also.

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CHEMISTRY
Section II
(Total time—90 minutes)

1C1

Part A
Time—40 minutes
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Silver chromate dissociates in water according to the equation shown below.

$$Ag_2CrO_4(s) \rightleftarrows 2\,Ag^+(aq) + CrO_4^{2-}(aq) \qquad K_{sp} = 2.6 \times 10^{-12} \text{ at } 25°C$$

(a) Write the equilibrium-constant expression for the dissolving of $Ag_2CrO_4(s)$.

(b) Calculate the concentration, in mol L^{-1}, of $Ag^+(aq)$ in a saturated solution of Ag_2CrO_4 at 25°C.

(c) Calculate the maximum mass, in grams, of Ag_2CrO_4 that can dissolve in 100. mL of water at 25°C.

(d) A 0.100 mol sample of solid $AgNO_3$ is added to a 1.00 L saturated solution of Ag_2CrO_4. Assuming no volume change, does $[CrO_4^{2-}]$ increase, decrease, or remain the same? Justify your answer.

In a saturated solution of Ag_3PO_4 at 25°C, the concentration of $Ag^+(aq)$ is 5.3×10^{-5} *M*. The equilibrium-constant expression for the dissolving of $Ag_3PO_4(s)$ in water is shown below.

$$K_{sp} = [Ag^+]^3[PO_4^{3-}]$$

(e) Write the balanced equation for the dissolving of Ag_3PO_4 in water.

(f) Calculate the value of K_{sp} for Ag_3PO_4 at 25°C.

(g) A 1.00 L sample of saturated Ag_3PO_4 solution is allowed to evaporate at 25°C to a final volume of 500. mL. What is $[Ag^+]$ in the solution? Justify your answer.

a) $K_{sp} = [Ag^+]^2[CrO_4^{2-}]$

b) $K_{sp} = [Ag^+]^2[CrO_4^{2-}]$
$2.6\times10^{-12} = (4x^2)(x)$
$2.6\times10^{-12} = 4x^3$ $\quad x = 8.606\times10^{-5}$, $[Ag^+] = 4x^2 = \boxed{3.0\times10^{-8}\ M}$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

c) K_{sp} =

d) $\frac{.1 \text{ mol } AgNO_3}{1 \text{ L}} = .1 \text{ M } AgNO_3$ added

Since .1 M $AgNO_3$ is added, the concentration of Ag^+ increased which makes the concentration of PO_4^{2-} decrease in order for the Ksp to remain the same.

e) $Ag_3PO_4 \rightarrow 3Ag^+ + PO_4^{3-}$

f) $K_{sp} = [Ag^+]^3 [PO_4^{3-}]$

$K_{sp} = [5.3 \times 10^{-5}]^3 [1.707 \times 10^{-5}]$

$K_{sp} = 2.16 \times 10^{-18}$

g) $[5.3 \times 10^{-5}]^3 = 1.48877 \times 10^{-13}$ mol Ag^+

$\frac{1.48877 \times 10^{-13} \text{ mol } Ag^+}{.5 \text{ L}} = 2.98 \times 10^{-13} \text{ M } Ag^+$

The molarity increases due to decreasing the volume from 1 L to .5 L.

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