



AP[®] Chemistry (Operational) 2004 Sample Student Responses

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1A

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

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

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

$$2.6 \times 10^{-12} = (2x)^2 (x)$$

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

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

$$x = 8.7 \times 10^{-5} \text{ mol/L}$$

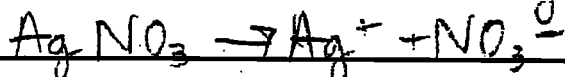
$$[Ag^+] = 2x = \boxed{1.7 \times 10^{-4} \text{ mol/L}}$$

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

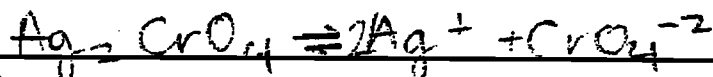
$$\text{Molar mass } Ag_2CrO_4 = 2(107.87) + 52.00 + 4(16.00) = 331.74 \text{ g/mol}$$

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

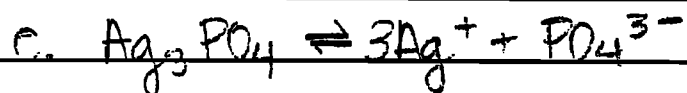
d. $AgNO_3$ dissociates according to the expression



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



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



$$f. K_{sp} = [Ag^+]^3 [PO_4^{3-}] \quad [Ag^+] = 5.3 \times 10^{-5} \quad [PO_4^{3-}] = \frac{[Ag^+]^3}{3} = 1.8 \times 10^{-5}$$

$$K_{sp} = (5.3 \times 10^{-5} \text{ M})^3 (1.8 \times 10^{-5})$$

$$K_{sp} = \boxed{2.6 \times 10^{-18}}$$

g. $[Ag^+]$ in the final solution will still be $5.3 \times 10^{-5} \text{ M}$.

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

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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.

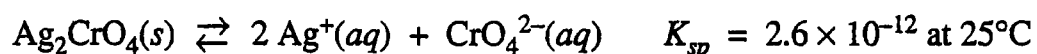
CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

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.

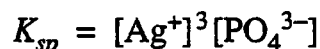
1. Answer the following questions relating to the solubilities of two silver compounds, Ag_2CrO_4 and Ag_3PO_4 .

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



- (a) Write the equilibrium-constant expression for the dissolving of $\text{Ag}_2\text{CrO}_4(s)$.
 $K_{sp} =$
- (b) Calculate the concentration, in mol L^{-1} , of $\text{Ag}^+(aq)$ 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 $[\text{CrO}_4^{2-}]$ increase, decrease, or remain the same? Justify your answer.

In a saturated solution of Ag_3PO_4 at 25°C , the concentration of $\text{Ag}^+(aq)$ is $5.3 \times 10^{-5} \text{ M}$. The equilibrium-constant expression for the dissolving of $\text{Ag}_3\text{PO}_4(s)$ in water is shown below.



- (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 $[\text{Ag}^+]$ in the solution? Justify your answer.

1. a. $K_{sp} = [\text{Ag}^+]^2[\text{CrO}_4^{2-}]$

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

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

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

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1B₂

$$s = \sqrt[3]{6.5 \times 10^{-13}} = 8.7 \times 10^{-5} \text{ M}$$

$$[\text{Ag}^+] = 2s = 2(8.7 \times 10^{-5}) = 17.4 \times 10^{-5} = 1.7 \times 10^{-4} \text{ M}$$

$$c. [\text{CrO}_4^{2-}] = 8.7 \times 10^{-5} \text{ M}$$

$$100 \text{ mL} = .1 \text{ L}$$

$$\frac{8.7 \times 10^{-5} \text{ mol CrO}_4^{2-}}{1 \text{ L}} \cdot .1 \text{ L} = 8.7 \times 10^{-6} \text{ mol CrO}_4^{2-} \times \frac{1 \text{ mol Ag}_2\text{CrO}_4}{1 \text{ mol CrO}_4^{2-}} =$$

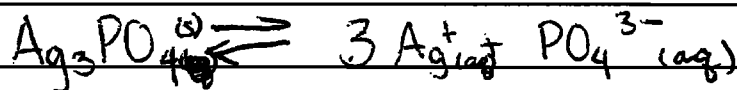
$$8.7 \times 10^{-6} \text{ mol Ag}_2\text{CrO}_4 \times \frac{330 \text{ g}}{1 \text{ mol Ag}_2\text{CrO}_4} = 2.9 \times 10^{-3} \text{ g Ag}_2\text{CrO}_4$$

d. ~~k_{sp} = 8.2 × 10⁻¹²~~ $k_{sp} = [1]^2 [\text{CrO}_4^{2-}]$
 $2.6 \times 10^{-12} = [1]^2 [\text{CrO}_4^{2-}]$

$$[\text{CrO}_4^{2-}] = \frac{2.6 \times 10^{-12}}{1} = 2.6 \times 10^{-10} \text{ M}$$

the ~~total~~ molarity of CrO_4^{2-} decreases because the k_{sp} doesn't change, so ~~one~~ when the molarity of Ag^+ increases CrO_4^{2-} must decrease

e.



$$f. k_{sp} = [\text{Ag}^+]^3 [\text{PO}_4^{3-}]$$

$$k_{sp} = [5.3 \times 10^{-5}]^3 \left[\frac{5.3 \times 10^{-5}}{3} \right]$$

$$k_{sp} = 2.6 \times 10^{-18}$$

$$5.3 \times 10^{-5} \text{ M Ag}^+ \times \frac{1 \text{ M PO}_4^{3-}}{3 \text{ M Ag}^+} = \frac{5.3 \times 10^{-5}}{3} \text{ M PO}_4^{3-}$$

g. $[\text{Ag}^+] = 5.3 \times 10^{-5} \text{ M}$ because the ratio of mols to ~~the~~ 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)

Part A

Time—40 minutes

YOU MAY USE YOUR CALCULATOR FOR PART A.

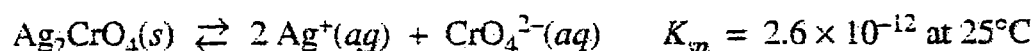
CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

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

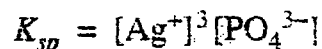
1. Answer the following questions relating to the solubilities of two silver compounds, Ag_2CrO_4 and Ag_3PO_4 .

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



- (a) Write the equilibrium-constant expression for the dissolving of $\text{Ag}_2\text{CrO}_4(s)$.
- (b) Calculate the concentration, in mol L^{-1} , of $\text{Ag}^+(aq)$ 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 $[\text{CrO}_4^{2-}]$ increase, decrease, or remain the same? Justify your answer.

In a saturated solution of Ag_3PO_4 at 25°C , the concentration of $\text{Ag}^+(aq)$ is $5.3 \times 10^{-5} \text{ M}$. The equilibrium-constant expression for the dissolving of $\text{Ag}_3\text{PO}_4(s)$ in water is shown below.



- (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 $[\text{Ag}^+]$ in the solution? Justify your answer.

a) $K_{sp} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$

b) $K_{sp} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$

$$2.6 \times 10^{-12} = (4x^2)(x)$$

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

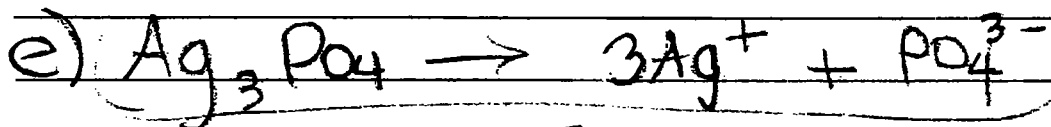
$$x = 8.66 \times 10^{-5}, [\text{Ag}^+] = 4x^2 = 3.0 \times 10^{-8} \text{ M}$$

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c) $K_{sp} =$

d) $\frac{1 \text{ mol AgNO}_3}{1 \text{ L}} = .1 \text{ M AgNO}_3$ added

Since .1 M AgNO₃ is added, the concentration of Ag⁺ increases which makes the concentration of PO₄³⁻ decrease in order for the K_{sp} to remain the same.



f) $K_{sp} = [\text{Ag}^+]^3 [\text{PO}_4^{3-}]$
 $K_{sp} = [5.3 \times 10^{-5}]^3 [1.747 \times 10^{-5}]$
 $K_{sp} = 2.6 \times 10^{-18}$

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

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

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