AP® Chemistry
2001 Sample Student Responses

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1A

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.

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 solubility of the chlorides of silver and lead.

(a) At 10°C, 8.9×10^{-5} g of $AgCl(s)$ will dissolve in 100. mL of water.

(i) Write the equation for the dissociation of $AgCl(s)$ in water.

(ii) Calculate the solubility, in mol L^{-1}, of $AgCl(s)$ in water at 10°C.

(iii) Calculate the value of the solubility-product constant, K_{sp}, for $AgCl(s)$ at 10°C.

(b) At 25°C, the value of K_{sp} for $PbCl_2(s)$ is 1.6×10^{-5} and the value of K_{sp} for $AgCl(s)$ is 1.8×10^{-10}.

(i) If 60.0 mL of 0.0400 *M* $NaCl(aq)$ is added to 60.0 mL of 0.0300 *M* $Pb(NO_3)_2(aq)$, will a precipitate form? Assume that volumes are additive. Show calculations to support your answer.

(ii) Calculate the equilibrium value of $[Pb^{2+}(aq)]$ in 1.00 L of saturated $PbCl_2$ solution to which 0.250 mole of $NaCl(s)$ has been added. Assume that no volume change occurs.

(iii) If 0.100 *M* $NaCl(aq)$ is added slowly to a beaker containing both 0.120 *M* $AgNO_3(aq)$ and 0.150 *M* $Pb(NO_3)_2(aq)$ at 25°C, which will precipitate first, $AgCl(s)$ or $PbCl_2(s)$? Show calculations to support your answer.

1. (a) (i) $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

(ii) 8.9×10^{-5} g AgCl / 143.5 g/mol = 6.2×10^{-7} mol AgCl

6.2×10^{-7} mol AgCl / .1 L = 6.2×10^{-6} M AgCl

6.2×10^{-6} mol L^{-1}

(iii) $K_{sp} = [Ag^+][Cl^-]^2$

$K_{sp} = (6.2 \times 10^{-6})^2 = 3.84 \times 10^{-11}$

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

(b)(i) .06 L X .04 M = .0024 mol Cl^- / .12 L = .02 M Cl^-

.06 L X .03 M = .0018 mol Pb^{+2} / .12 L = .015 M Pb^{+2}

$PbCl_2 \rightleftharpoons Pb^{+2} + 2Cl^-$

$Q = [Pb^{+2}][Cl^-]^2 = (.015\ M\ Pb^{+2})(.02\ M\ Cl^-)^2$

$Q = 6 \times 10^{-6}$

$K_{sp} = 1.6 \times 10^{-5}$

$K_{sp} > Q$

No precipitate will form.

(ii) $K_{sp} = 1.6 \times 10^{-5}$ .25 mol Cl^- / 1 L = .25 M Cl^-

$K_{sp} = [Pb^{+2}][Cl^-]^2$

$1.6 \times 10^{-5} = [Pb^{+2}][.25]^2$

$2.56 \times 10^{-4} = [Pb^{+2}]$

(iii) $AgCl \rightleftharpoons Ag^+ + Cl^-$ $K_{sp} = 1.8 \times 10^{-10}$

$Q = [Ag^+][Cl^-]$. Q must be greater than K_{sp}

$1.8 \times 10^{-10} < [Ag^+][Cl^-]$

$1.8 \times 10^{-10} < [.12\ M\ Ag^+][Cl^-]$

$1.5 \times 10^{-9} < [Cl^-]$

$PbCl_2 \rightleftharpoons Pb^{+2} + 2Cl^-$ $K_{sp} = 1.6 \times 10^{-5}$

$Q = [Pb^{+2}][Cl^-]^2$

$1.6 \times 10^{-5} < [Pb^{+2}][Cl^-]^2$

$1.6 \times 10^{-5} < [.15\ M\ Pb^{+2}][Cl^-]^2$

$1.03 \times 10^{-2} < [Cl^-]$

AgCl will precipitate first because a smaller concentration of Cl^- is necessary to form a precipitate.

1B

CHEMISTRY

Section II

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Part A

Time—40 minutes

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   (a) At 10°C, 8.9×10^{-5} g of $AgCl(s)$ will dissolve in 100. mL of water.

      (i) Write the equation for the dissociation of $AgCl(s)$ in water.

      (ii) Calculate the solubility, in mol L^{-1}, of $AgCl(s)$ in water at 10°C.

      (iii) Calculate the value of the solubility-product constant, K_{sp}, for $AgCl(s)$ at 10°C.

   (b) At 25°C, the value of K_{sp} for $PbCl_2(s)$ is 1.6×10^{-5} and the value of K_{sp} for $AgCl(s)$ is 1.8×10^{-10}.

      (i) If 60.0 mL of 0.0400 *M* $NaCl(aq)$ is added to 60.0 mL of 0.0300 *M* $Pb(NO_3)_2(aq)$, will a precipitate form? Assume that volumes are additive. Show calculations to support your answer.

      (ii) Calculate the equilibrium value of $[Pb^{2+}(aq)]$ in 1.00 L of saturated $PbCl_2$ solution to which 0.250 mole of $NaCl(s)$ has been added. Assume that no volume change occurs.

      (iii) If 0.100 *M* $NaCl(aq)$ is added slowly to a beaker containing both 0.120 *M* $AgNO_3(aq)$ and 0.150 *M* $Pb(NO_3)_2(aq)$ at 25°C, which will precipitate first, $AgCl(s)$ or $PbCl_2(s)$? Show calculations to support your answer.

a) i. $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

ii. $\frac{8.9\times10^{-5}\,g}{100.\,mL}\left(\frac{1000\,mL}{1\,L}\right)\left(\frac{1\,mol}{143.4\,g}\right) = 6.2\times10^{-6}\,mol/L$

iii. $K_{sp} = [Ag^+][Cl^-]$

$= (6.2\times10^{-6}\,M)^2$

$= 3.9\times10^{-11}\,mol^2/L^2$

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

b) i. $2Cl^- + Pb^{2+} \longrightarrow PbCl_2$

$[Cl^-] = \frac{60.0\ mL\ (0.0400\ M)}{120.0\ mL}$

$= 0.0200\ M$

$[Pb^{2+}] = \frac{60.0\ mL\ (0.0300\ M)}{120.0\ mL}$

$= 0.0150\ M$

$Q = [Pb^{2+}][Cl^-]^2$

$= (0.0150\ M)(0.0200\ M)^2$

$= 6.00 \times 10^{-6}$

$K_{sp} = 1.6 \times 10^{-5}$

$K_{sp} > Q$ ∴ no precipitate will form

ii. $PbCl_2 \longrightarrow Pb^{2+} + 2Cl^-$

$[Cl^-] = \frac{0.250\ mol}{1.00\ L}$

$= 0.250\ M$

$K_{sp} = [Pb^{2+}][Cl^-]^2$

$[Pb^{2+}] = \frac{K_{sp}}{[Cl^-]^2}$

$= \frac{1.6 \times 10^{-5}}{(0.250)^2}$

$= 2.6 \times 10^{-4}\ M$

iii. when $Q = K_{sp}$, precipitate starts forming

Q for $AgCl = [Ag^+][Cl^-]$

$= (0.120\ M)[Cl^-]$

$[Cl^-]$ must be $= \frac{K_{sp}}{(0.120\ M)}$

$= \frac{1.8 \times 10^{-10}}{0.120\ M}$

$= 1.5 \times 10^{-9}\ M$

Q for $PbCl_2 = [Pb^{2+}][Cl^-]^2$

$= 0.150\ M\ [Cl^-]^2$

$[Cl^-]$ must be $= \sqrt{\frac{K_{sp}}{0.150\ M}}$

$= \sqrt{\frac{1.6 \times 10^{-5}}{0.150\ M}}$

$= 1.0 \times 10^{-2}\ M$

$PbCl_2$ will precipitate first

1C

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(b) At 25°C, the value of K_{sp} for $PbCl_2(s)$ is 1.6×10^{-5} and the value of K_{sp} for $AgCl(s)$ is 1.8×10^{-10}.

(i) If 60.0 mL of 0.0400 *M* $NaCl(aq)$ is added to 60.0 mL of 0.0300 *M* $Pb(NO_3)_2(aq)$, will a precipitate form? Assume that volumes are additive. Show calculations to support your answer.

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(iii) If 0.100 *M* $NaCl(aq)$ is added slowly to a beaker containing both 0.120 *M* $AgNO_3(aq)$ and 0.150 *M* $Pb(NO_3)_2(aq)$ at 25°C, which will precipitate first, $AgCl(s)$ or $PbCl_2(s)$? Show calculations to support your answer.

1.a) i) $AgCl(s) \longrightarrow Ag^+(aq) + Cl^-(aq)$

ii) # moles $AgCl(s) = 8.9 \times 10^{-5}\ g \times \frac{1\ mol}{143.323} = 6.20975 \times 10^{-7}$

$[AgCl] = \frac{6.20975 \times 10^{-7}}{0.100\ L} = 6.2098 \times 10^{-6}\ M \therefore 6.2 \times 10^{-6}\ M$

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

iii) $Ksp = [Ag^+][Cl^-]$

$= [6.2098 \times 10^{-6} M][6.2098 \times 10^{-6} M]$

$= 3.856 \times 10^{-11}$

$\therefore Ksp = 3.9 \times 10^{-11}$

b) i) $NaCl(aq) + Pb(NO_3)_2(aq) \longrightarrow 2NaNO_3(aq) + PbCl_2(s)$

moles Pb $= \frac{0.0300 \text{ mol}}{L} \times 0.0600L = 0.00180$ moles

moles Cl $= \frac{0.0400 \text{ mol}}{L} \times 0.0600 L = 0.0024$ mol

$\therefore$ 0.00120 moles of $PbCl_2$ will be formed, however this amount is so small that it is almost neglible

ii) $PbCl_{2(s)} \longrightarrow Pb^{2+} + 2Cl^-$ $\quad$ $Ksp(PbCl_2) = 1.6 \times 10^{-5} = [Pb^{2+}][Cl^-]^2$

$x \quad x$

$NaCl \longrightarrow Na^+ + Cl^-$ $\quad$ $1.6 \times 10^{-5} = [x][x + 0.250]^2$

$0 \quad 0.250 \quad 0.250$ $\quad$ assume $x + 0.250 \approx 0.250$

$\therefore 1.6 \times 10^{-5} = [x][0.250]^2$

$\therefore [Pb^{2+}] = 2.56 \times 10^{-4} M$ $\quad$ $x = 2.56 \times 10^{-4}$

iii) $NaCl + AgNO_3 \longrightarrow NaNO_3 + AgCl$; $2NaCl + Pb(NO_3)_2 \longrightarrow 2NaNO_3 + PbCl_2$

$Ksp(AgCl) = 1.8 \times 10^{-10}$; $Ksp(PbCl_2) = 1.6 \times 10^{-5}$

since AgCl has a lower solubility than $PbCl_2$ the $AgCl(s)$ will be precipitated out first.