AP® CHEMISTRY
2006 SCORING GUIDELINES

Question 1

1. Answer the following questions that relate to solubility of salts of lead and barium.

(a) A saturated solution is prepared by adding excess $PbI_2(s)$ to distilled water to form 1.0 L of solution at 25°C. The concentration of $Pb^{2+}(aq)$ in the saturated solution is found to be $1.3 \times 10^{-3}\ M$. The chemical equation for the dissolution of $PbI_2(s)$ in water is shown below.

$$PbI_2(s) \rightleftarrows Pb^{2+}(aq) + 2\ I^-(aq)$$

(i) Write the equilibrium-constant expression for the equation.

$K_{sp} = [Pb^{2+}][I^-]^2$	One point is earned for the correct expression.

(ii) Calculate the molar concentration of $I^-(aq)$ in the solution.

By stoichiometry, $[I^-] = 2 \times [Pb^{2+}]$, thus $[I^-] = 2 \times (1.3 \times 10^{-3}) = 2.6 \times 10^{-3}\ M$	One point is earned for the correct concentration.

(iii) Calculate the value of the equilibrium constant, K_{sp}.

$K_{sp} = [Pb^{2+}][I^-]^2 = (1.3 \times 10^{-3})(2.6 \times 10^{-3})^2$ $= 8.8 \times 10^{-9}$	One point is earned for a value of K_{sp} that is consistent with the answers in parts (a)(i) and (a)(ii).

(b) A saturated solution is prepared by adding $PbI_2(s)$ to distilled water to form 2.0 L of solution at 25°C. What are the molar concentrations of $Pb^{2+}(aq)$ and $I^-(aq)$ in the solution? Justify your answer.

The molar concentrations of $Pb^{2+}(aq)$ and $I^-(aq)$ would be the same as in the 1.0 L solution in part (a) (i.e., $1.3 \times 10^{-3}\ M$ and $2.6 \times 10^{-3}\ M$, respectively). The concentrations of solute particles in a saturated solution are a function of the constant, K_{sp}, which is independent of volume.	One point is earned for the concentrations (or stating they are the same as in the solution described in part (a)) and justification.

Question 1 (continued)

(c) Solid NaI is added to a saturated solution of PbI_2 at 25°C. Assuming that the volume of the solution does not change, does the molar concentration of $Pb^{2+}(aq)$ in the solution increase, decrease, or remain the same? Justify your answer.

$[Pb^{2+}]$ will decrease. The $NaI(s)$ will dissolve, increasing $[I^-]$; more $I^-(aq)$ then combines with $Pb^{2+}(aq)$ to precipitate $PbI_2(s)$ so that the ion product $[Pb^{2+}][I^-]^2$ will once again attain the value of 8.8×10^{-9} (K_{sp} at 25°C).	One point is earned for stating that $[Pb^{2+}]$ will decrease. One point is earned for justification (can involve a Le Chatelier argument).

(d) The value of K_{sp} for the salt $BaCrO_4$ is 1.2×10^{-10}. When a 500. mL sample of $8.2 \times 10^{-6}\ M$ $Ba(NO_3)_2$ is added to 500. mL of $8.2 \times 10^{-6}\ M$ Na_2CrO_4, no precipitate is observed.

(i) Assuming that volumes are additive, calculate the molar concentrations of $Ba^{2+}(aq)$ and $CrO_4^{2-}(aq)$ in the 1.00 L of solution.

New volume = 500. mL + 500. mL = 1.000 L, therefore $[Ba^{2+}]$ in 1.000 L is one-half its initial value: $[Ba^{2+}] = \frac{500.\text{ mL}}{1{,}000.\text{ mL}} \times (8.2 \times 10^{-6}\ M) = 4.1 \times 10^{-6}\ M$ $[CrO_4^{2-}] = \frac{500.\text{ mL}}{1{,}000.\text{ mL}} \times (8.2 \times 10^{-6}\ M) = 4.1 \times 10^{-6}\ M$	One point is earned for the correct concentration.

(ii) Use the molar concentrations of $Ba^{2+}(aq)$ ions and $CrO_4^{2-}(aq)$ ions as determined above to show why a precipitate does not form. You must include a calculation as part of your answer.

The product $Q = [Ba^{2+}][CrO_4^{2-}]$ $= (4.1 \times 10^{-6}\ M)(4.1 \times 10^{-6}\ M)$ $= 1.7 \times 10^{-11}$ Because $Q = 1.7 \times 10^{-11} < 1.2 \times 10^{-10} = K_{sp}$, no precipitate forms.	One point is earned for calculating a value of Q that is consistent with the concentration values in part (d)(i). One point is earned for using Q to explain why no precipitate forms.