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.

$$\text{PbI}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2 \text{I}^-(aq)$$

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

\[
K_{sp} = [\text{Pb}^{2+}][\text{I}^-]^2
\]

One point is earned for the correct expression.

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

By stoichiometry, $[\text{I}^-] = 2 \times [\text{Pb}^{2+}]$, thus $[\text{I}^-] = 2 \times (1.3 \times 10^{-3}) = 2.6 \times 10^{-3} \ M$

One point is earned for the correct concentration.

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

\[
K_{sp} = [\text{Pb}^{2+}][\text{I}^-]^2 = (1.3 \times 10^{-3})(2.6 \times 10^{-3})^2 = 8.8 \times 10^{-9}
\]

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.
(c) Solid NaI is added to a saturated solution of PbI₂ at 25°C. Assuming that the volume of the solution does not change, does the molar concentration of Pb²⁺(aq) in the solution increase, decrease, or remain the same? Justify your answer.

[\text{[Pb}^{2+}\text{]} \text{ will decrease.}]

The NaI(s) will dissolve, increasing [I⁻]; more I⁻(aq) then combines with Pb²⁺(aq) to precipitate PbI₂(s) so that the ion product [Pb²⁺][I⁻]² will once again attain the value of \(8.8 \times 10^{-9}\) (\(K_{sp}\) at 25°C).

One point is earned for stating that [Pb²⁺] will decrease.
One point is earned for justification (can involve a Le Chatelier argument).

(d) The value of \(K_{sp}\) for the salt BaCrO₄ is \(1.2 \times 10^{-10}\). When a 500. mL sample of \(8.2 \times 10^{-6}\) \(M\) Ba(NO₃)₂ is added to 500. mL of \(8.2 \times 10^{-6}\) \(M\) Na₂CrO₄, no precipitate is observed.

(i) Assuming that volumes are additive, calculate the molar concentrations of Ba²⁺(aq) and CrO₄²⁻(aq) in the 1.00 L of solution.

\[
\text{New volume} = 500. \text{ mL} + 500. \text{ mL} = 1.000 \text{ L}, \text{ therefore } [\text{Ba}^{2+}] \text{ in 1.000 L is one-half its initial value:}
\]

\[
[\text{Ba}^{2+}] = \frac{500. \text{ mL}}{1,000. \text{ mL}} \times (8.2 \times 10^{-6} \text{ M}) = 4.1 \times 10^{-6} \text{ M}
\]

\[
[\text{CrO}_4^{2-}] = \frac{500. \text{ mL}}{1,000. \text{ mL}} \times (8.2 \times 10^{-6} \text{ M}) = 4.1 \times 10^{-6} \text{ M}
\]

One point is earned for the correct concentration.

(ii) Use the molar concentrations of Ba²⁺(aq) ions and CrO₄²⁻(aq) ions as determined above to show why a precipitate does not form. You must include a calculation as part of your answer.

\[
\text{The product } Q = [\text{Ba}^{2+}][\text{CrO}_4^{2-}] = (4.1 \times 10^{-6} \text{ M})(4.1 \times 10^{-6} \text{ M}) = 1.7 \times 10^{-11}
\]

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.