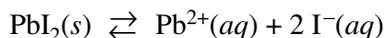


**AP<sup>®</sup> CHEMISTRY  
2006 SCORING GUIDELINES**

**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  $\text{PbI}_2(s)$  to distilled water to form 1.0 L of solution at  $25^\circ\text{C}$ . The concentration of  $\text{Pb}^{2+}(aq)$  in the saturated solution is found to be  $1.3 \times 10^{-3} M$ . The chemical equation for the dissolution of  $\text{PbI}_2(s)$  in water is shown below.



- (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.
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- (ii) Calculate the molar concentration of  $\text{I}^{-}(aq)$  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.
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- (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).
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- (b) A saturated solution is prepared by adding  $\text{PbI}_2(s)$  to distilled water to form 2.0 L of solution at  $25^\circ\text{C}$ . What are the molar concentrations of  $\text{Pb}^{2+}(aq)$  and  $\text{I}^{-}(aq)$  in the solution? Justify your answer.

The molar concentrations of $\text{Pb}^{2+}(aq)$ and $\text{I}^{-}(aq)$ 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.
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**Question 1 (continued)**

- (c) Solid NaI is added to a saturated solution of  $\text{PbI}_2$  at  $25^\circ\text{C}$ . Assuming that the volume of the solution does not change, does the molar concentration of  $\text{Pb}^{2+}(\text{aq})$  in the solution increase, decrease, or remain the same? Justify your answer.

<p><math>[\text{Pb}^{2+}]</math> will decrease.</p> <p>The <math>\text{NaI}(\text{s})</math> will dissolve, increasing <math>[\text{I}^-]</math>; more <math>\text{I}^-(\text{aq})</math> then combines with <math>\text{Pb}^{2+}(\text{aq})</math> to precipitate <math>\text{PbI}_2(\text{s})</math> so that the ion product <math>[\text{Pb}^{2+}][\text{I}^-]^2</math> will once again attain the value of <math>8.8 \times 10^{-9}</math> (<math>K_{sp}</math> at <math>25^\circ\text{C}</math>).</p>	<p>One point is earned for stating that <math>[\text{Pb}^{2+}]</math> will decrease.</p> <p>One point is earned for justification (can involve a Le Chatelier argument).</p>
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- (d) The value of  $K_{sp}$  for the salt  $\text{BaCrO}_4$  is  $1.2 \times 10^{-10}$ . When a 500. mL sample of  $8.2 \times 10^{-6} M$   $\text{Ba}(\text{NO}_3)_2$  is added to 500. mL of  $8.2 \times 10^{-6} M$   $\text{Na}_2\text{CrO}_4$ , no precipitate is observed.

- (i) Assuming that volumes are additive, calculate the molar concentrations of  $\text{Ba}^{2+}(\text{aq})$  and  $\text{CrO}_4^{2-}(\text{aq})$  in the 1.00 L of solution.

<p>New volume = 500. mL + 500. mL = 1.000 L, therefore <math>[\text{Ba}^{2+}]</math> in 1.000 L is one-half its initial value:</p> $[\text{Ba}^{2+}] = \frac{500. \text{ mL}}{1,000. \text{ mL}} \times (8.2 \times 10^{-6} M) = 4.1 \times 10^{-6} M$ $[\text{CrO}_4^{2-}] = \frac{500. \text{ mL}}{1,000. \text{ mL}} \times (8.2 \times 10^{-6} M) = 4.1 \times 10^{-6} M$	<p>One point is earned for the correct concentration.</p>
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- (ii) Use the molar concentrations of  $\text{Ba}^{2+}(\text{aq})$  ions and  $\text{CrO}_4^{2-}(\text{aq})$  ions as determined above to show why a precipitate does not form. You must include a calculation as part of your answer.

<p>The product <math>Q = [\text{Ba}^{2+}][\text{CrO}_4^{2-}]</math></p> $= (4.1 \times 10^{-6} M)(4.1 \times 10^{-6} M)$ $= 1.7 \times 10^{-11}$ <p>Because <math>Q = 1.7 \times 10^{-11} &lt; 1.2 \times 10^{-10} = K_{sp}</math>, no precipitate forms.</p>	<p>One point is earned for calculating a value of <math>Q</math> that is consistent with the concentration values in part (d)(i).</p> <p>One point is earned for using <math>Q</math> to explain why no precipitate forms.</p>
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