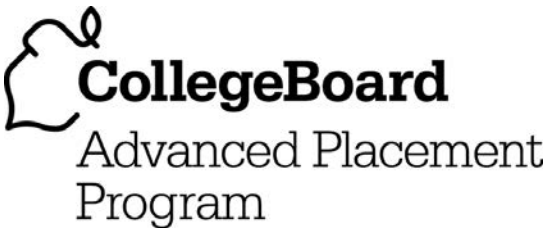

AP® Chemistry
2006 Scoring Guidelines

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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.

(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.

Question 2

$$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$$

2. The combustion of carbon monoxide is represented by the equation above.

(a) Determine the value of the standard enthalpy change, ΔH°_{rxn}, for the combustion of $CO(g)$ at 298 K using the following information.

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H^\circ_{298} = -110.5 \text{ kJ mol}^{-1}$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^\circ_{298} = -393.5 \text{ kJ mol}^{-1}$$

Reverse the first equation and add it to the second equation to obtain the third equation. $CO(g) \rightarrow \frac{1}{2}O_2(g) + C(s) \qquad \Delta H^\circ_{298} = +110.5 \text{ kJ mol}^{-1}$ $+ \; C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^\circ_{298} = -393.5 \text{ kJ mol}^{-1}$ $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H^\circ_{rxn} = 110.5 + (-393.5)$ $= -283.0 \text{ kJ mol}^{-1}$ **OR** $\Delta H^\circ_{rxn} = \Delta H^\circ_f$ of $CO_2(g) - \Delta H^\circ_f$ of $CO(g)$ $= -393.5 \text{ kJ mol}^{-1} - (-110.5 \text{ kJ mol}^{-1}) = -283.0 \text{ kJ mol}^{-1}$	One point is earned for reversing the first equation. One point is earned for the correct answer (with sign). **OR** Two points are earned for determining ΔH°_{rxn} from the enthalpies of formation. (If sign is incorrect, only one point is earned.)

(b) Determine the value of the standard entropy change, ΔS°_{rxn}, for the combustion of $CO(g)$ at 298 K using the information in the following table.

Substance	S°_{298} (J mol^{-1} K^{-1})
$CO(g)$	197.7
$CO_2(g)$	213.7
$O_2(g)$	205.1