Question 1
(10 points)

Answer the following questions about the solubility and reactions of the ionic compounds $M(OH)_2$ and MCO_3, where M represents an unidentified metal.

(a) Identify the charge of the M ion in the ionic compounds above.

2+	1 point is earned for the correct charge.

(b) At 25°C, a saturated solution of $M(OH)_2$ has a pH of 9.15.

    (i) Calculate the molar concentration of $OH^-(aq)$ in the saturated solution.

pOH = 14 − pH pOH = 14 − 9.15 = 4.85 $[OH^-] = 10^{-4.85} = 1.4 \times 10^{-5}\ M$	1 point is earned for the correct concentration.

    (ii) Write the solubility-product constant expression for $M(OH)_2$.

$K_{sp} = [M^{2+}]\,[OH^-]^2$	1 point is earned for the correct expression.

    (iii) Calculate the value of the solubility-product constant, K_{sp}, for $M(OH)_2$ at 25°C.

$[M^{2+}] = \frac{1}{2}[OH^-] = \frac{1}{2}(1.4 \times 10^{-5}\ M) = 7.0 \times 10^{-6}\ M$ $K_{sp} = [M^{2+}]\,[OH^-]^2 = (7.0 \times 10^{-6})(1.4 \times 10^{-5})^2$ $= 1.4 \times 10^{-15}$	1 point is earned for the correct relationship between $[M^{2+}]$ and $[OH^-]$. 1 point is earned for the correct value.

(c) For the metal carbonate, MCO_3, the value of the solubility-product constant, K_{sp}, is 7.4×10^{-14} at 25°C. On the basis of this information and your results in part (b), which compound, $M(OH)_2$ or MCO_3, has the greater molar solubility in water at 25°C ? Justify your answer with a calculation.

For $M(OH)_2$: $[M^{2+}]$ and molar solubility $= 7.0 \times 10^{-6}\ M$ For MCO_3: $K_{sp} = 7.4 \times 10^{-14} = [M^{2+}][CO_3^{2-}]$ $[M^{2+}]$ and molar solubility $= 2.7 \times 10^{-7}\ M$ Because $7.0 \times 10^{-6}\ M > 2.7 \times 10^{-7}\ M$, $M(OH)_2$ has the greater molar solubility.	1 point is earned for the molar solubility of MCO_3. 1 point is earned for an answer consistent with the calculated molar solubility.

Question 1 (continued)

(d) MCO_3 decomposes at high temperatures, as shown by the reaction represented below.

$$MCO_3(s) \rightleftarrows MO(s) + CO_2(g)$$

A sample of MCO_3 is placed in a previously evacuated container, heated to 423 K, and allowed to come to equilibrium. Some solid MCO_3 remains in the container. The value of K_p for the reaction at 423 K is 0.0012.

   (i) Write the equilibrium-constant expression for K_p of the reaction.

$K_p = P_{CO_2}$	1 point is earned for the correct expression.

   (ii) Determine the pressure, in atm, of $CO_2(g)$ in the container at equilibrium at 423 K.

$P_{CO_2} = 0.0012$ atm	1 point is earned for the correct pressure.

   (iii) Indicate whether the value of $\Delta G°$ for the reaction at 423 K is positive, negative, or zero. Justify your answer.

$\Delta G° = -RT \ln K$ $K = 0.0012 < 1$, thus $\ln K$ is negative; therefore $\Delta G°$ is positive.	1 point is earned for the correct answer with justification.