A sample of solid \( \text{U}_3\text{O}_8 \) is placed in a rigid 1.500 L flask. Chlorine gas, \( \text{Cl}_2(g) \), is added, and the flask is heated to 862°C. The equation for the reaction that takes place and the equilibrium-constant expression for the reaction are given below. 

\[
\text{U}_3\text{O}_8(s) + 3 \text{Cl}_2(g) \rightleftharpoons 3 \text{UO}_2\text{Cl}_2(g) + \text{O}_2(g) \quad K_p = \frac{(p_{\text{UO}_2\text{Cl}_2})^3(p_{\text{O}_2})}{(p_{\text{Cl}_2})^3}
\]

When the system is at equilibrium, the partial pressure of \( \text{Cl}_2(g) \) is 1.007 atm and the partial pressure of \( \text{UO}_2\text{Cl}_2(g) \) is \( 9.734 \times 10^{-4} \) atm.

(a) Calculate the partial pressure of \( \text{O}_2(g) \) at equilibrium at 862°C.

\[
\begin{align*}
\text{I} & : \quad \text{---} \quad 0 \quad 0 \\
\text{C} & : \quad 1.007 \text{ atm} \quad 9.734 \times 10^{-4} \text{ atm} \quad ? \\
\text{E} & : \quad 9.734 \times 10^{-4} \text{ atm} \quad \text{UO}_2\text{Cl}_2(g) \times \frac{(1 \text{ mol O}_2)}{(3 \text{ mol UO}_2\text{Cl}_2)} = 3.245 \times 10^{-4} \text{ atm O}_2(g)
\end{align*}
\]

(b) Calculate the value of the equilibrium constant, \( K_p \), for the system at 862°C.

\[
K_p = \frac{(p_{\text{UO}_2\text{Cl}_2})^3(p_{\text{O}_2})}{(p_{\text{Cl}_2})^3} = \frac{(9.734 \times 10^{-4})^3(3.245 \times 10^{-4})}{(1.007)^3} = 2.931 \times 10^{-13}
\]

(c) Calculate the Gibbs free-energy change, \( \Delta G^\circ \), for the reaction at 862°C.

\[
\begin{align*}
\Delta G^\circ &= -RT \ln K_p \\
&= (-8.31 \text{ J mol}^{-1} \text{ K}^{-1})(862+273 \text{ K})(\ln (2.931 \times 10^{-13})) \\
&= 272,000 \text{ J mol}^{-1} = 272 \text{ kJ mol}^{-1}
\end{align*}
\]
(d) State whether the entropy change, $\Delta S^\circ$, for the reaction at 862°C is positive, negative, or zero. Justify your answer.

| $\Delta S^\circ$ is positive because four moles of gaseous products are produced from three moles of gaseous reactants. | One point is earned for the correct explanation. |

(e) State whether the enthalpy change, $\Delta H^\circ$, for the reaction at 862°C is positive, negative, or zero. Justify your answer.

| Both $\Delta G^\circ$ and $\Delta S^\circ$ are positive, as determined in parts (c) and (d). Thus, $\Delta H^\circ$ must be positive because $\Delta H^\circ$ is the sum of two positive terms in the equation $\Delta H^\circ = \Delta G^\circ + T\Delta S^\circ$. | One point is earned for the correct explanation. One point is earned for a correct explanation. |

(f) After a certain period of time, 1.000 mol of $O_2(g)$ is added to the mixture in the flask. Does the mass of $U_3O_8(s)$ in the flask increase, decrease, or remain the same? Justify your answer.

| The mass of $U_3O_8(s)$ will increase because the reaction is at equilibrium, and the addition of a product creates a “stress” on the product (right) side of the reaction. The reaction will then proceed from right to left to reestablish equilibrium so that some $O_2(g)$ is consumed (tending to relieve the stress) as more $U_3O_8(s)$ is produced. | One point is earned for a correct explanation. |