Question 1

A sample of solid U_3O_8 is placed in a rigid 1.500 L flask. Chlorine gas, $Cl_2(g)$, 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.

$$U_3O_8(s) + 3\ Cl_2(g) \rightleftarrows 3\ UO_2Cl_2(g) + O_2(g) \qquad K_p = \frac{(p_{UO_2Cl_2})^3(p_{O_2})}{(p_{Cl_2})^3}$$

When the system is at equilibrium, the partial pressure of $Cl_2(g)$ is 1.007 atm and the partial pressure of $UO_2Cl_2(g)$ is 9.734×10^{-4} atm.

(a) Calculate the partial pressure of $O_2(g)$ at equilibrium at 862°C.

$U_3O_8(s)$ + $3\ Cl_2(g)$ ⇄ $3\ UO_2Cl_2(g)$ + $O_2(g)$ I: --- , ? , 0 , 0 C E: 1.007 atm , 9.734×10^{-4} atm , ? 9.734×10^{-4} atm $UO_2Cl_2(g) \times \frac{(1 \text{ mol } O_2)}{(3 \text{ mol } UO_2Cl_2)} = 3.245 \times 10^{-4}$ atm $O_2(g)$	One point is earned for the correct answer.

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

$K_p = \frac{(p_{UO_2Cl_2})^3(p_{O_2})}{(p_{Cl_2})^3} = \frac{(9.734\times10^{-4})^3(3.245\times10^{-4})}{(1.007)^3} = 2.931 \times 10^{-13}$	One point is earned for the correct substitution. One point is earned for the correct answer.

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

$\Delta G° = -RT \ln K_p$ $= (-8.31 \text{ J mol}^{-1} \text{ K}^{-1})((862+273) \text{ K})(\ln (2.931 \times 10^{-13}))$ $= 272{,}000 \text{ J mol}^{-1} = 272 \text{ kJ mol}^{-1}$	One point is earned for the correct setup. One point is earned for the correct answer with units.

Question 1 (continued)

(d) State whether the entropy change, $\Delta S°$, for the reaction at 862°C is positive, negative, or zero. Justify your answer.

$\Delta S°$ 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, $\Delta H°$, for the reaction at 862°C is positive, negative, or zero. Justify your answer.

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