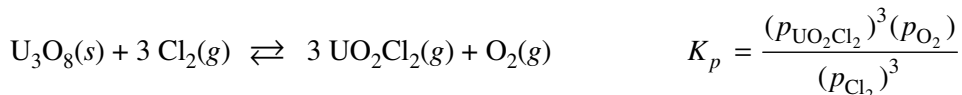


AP[®] CHEMISTRY
2007 SCORING GUIDELINES (Form B)

Question 1

A sample of solid U_3O_8 is placed in a rigid 1.500 L flask. Chlorine gas, $\text{Cl}_2(\text{g})$, 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.



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

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

$\text{U}_3\text{O}_8(\text{s}) + 3 \text{Cl}_2(\text{g}) \rightleftharpoons 3 \text{UO}_2\text{Cl}_2(\text{g}) + \text{O}_2(\text{g})$ <p>I C E</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;"></td> <td style="width: 15%; text-align: center;">---</td> <td style="width: 15%; text-align: center;">?</td> <td style="width: 15%; text-align: center;">0</td> <td style="width: 15%; text-align: center;">0</td> </tr> <tr> <td></td> <td style="text-align: center;">1.007 atm</td> <td style="text-align: center;">9.734×10^{-4} atm</td> <td style="text-align: center;">?</td> <td></td> </tr> </table> $9.734 \times 10^{-4} \text{ atm UO}_2\text{Cl}_2(\text{g}) \times \frac{(1 \text{ mol O}_2)}{(3 \text{ mol UO}_2\text{Cl}_2)} = 3.245 \times 10^{-4} \text{ atm O}_2(\text{g})$		---	?	0	0		1.007 atm	9.734×10^{-4} atm	?		<p style="text-align: center;">One point is earned for the correct answer.</p>
	---	?	0	0							
	1.007 atm	9.734×10^{-4} atm	?								

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

$K_p = \frac{(p_{\text{UO}_2\text{Cl}_2})^3 (p_{\text{O}_2})}{(p_{\text{Cl}_2})^3} = \frac{(9.734 \times 10^{-4})^3 (3.245 \times 10^{-4})}{(1.007)^3} = 2.931 \times 10^{-13}$	<p style="text-align: center;">One point is earned for the correct substitution.</p> <p style="text-align: center;">One point is earned for the correct answer.</p>
---	---

(c) Calculate the Gibbs free-energy change, ΔG° , for the reaction at 862°C .

$\begin{aligned} \Delta G^\circ &= -RT \ln K_p \\ &= (-8.31 \text{ J mol}^{-1} \text{ K}^{-1})(862+273 \text{ K})(\ln (2.931 \times 10^{-13})) \\ &= 272,000 \text{ J mol}^{-1} = 272 \text{ kJ mol}^{-1} \end{aligned}$	<p style="text-align: center;">One point is earned for the correct setup.</p> <p style="text-align: center;">One point is earned for the correct answer with units.</p>
--	---

AP[®] CHEMISTRY
2007 SCORING GUIDELINES (Form B)

Question 1 (continued)

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

ΔS° is <u>positive</u> 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, ΔH° , for the reaction at 862°C is positive, negative, or zero. Justify your answer.

Both ΔG° and ΔS° are positive, as determined in parts (c) and (d). Thus, ΔH° must be positive because ΔH° 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 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 <u>increase</u> 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.
--	--