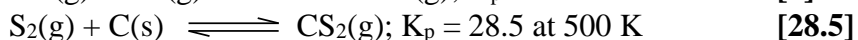
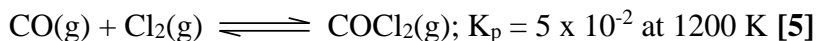


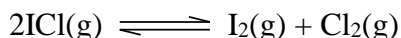
Equilibrium (no calculator)

(All questions may be completed without the use of a calculator. All answers given were generated without a calculator.)

- 1) Calculate K_c for each of the following equilibria:

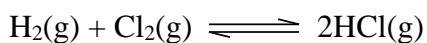


- 2) In an analysis of interhalogen reactivity, 0.500 mol of ICl was placed in a 5.00 L flask, where it decomposed at a high temperature:



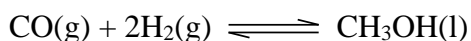
If $K_c = 1$ at the temperature used, calculate the equilibrium concentrations of all species.
(Answer: $[\text{I}_2] = [\text{Cl}_2] = [\text{ICl}] = 0.033 \text{ M}$)

- 3) At 25°C , $K_p = 4.0$ for the equilibrium:



The three gases, each at a partial pressure of 1.00 bar, are introduced into a reaction vessel.

- a) Determine the direction of the reaction. [**The reaction moves to the right to produce HCl**]
b) Determine the equilibrium partial pressure of each gas. [**$\text{H}_2 = \text{Cl}_2 = 0.75 \text{ bar}$ and $\text{HCl} = 1.50 \text{ bar}$**]
- 4) The formation of methanol is important in the processing of new fuels. At 298 K, $K_p = 2 \times 10^4$ for the reaction:

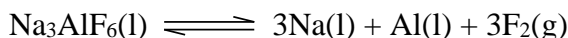


If $\Delta H^\circ_{\text{rxn}} = 128 \text{ kJ}$, calculate K_p at 125°C . (Answer: $K_p \cong 0.1$)

- 5) One of the most important industrial sources of ethanol is the reaction of steam with ethane derived from crude oil:

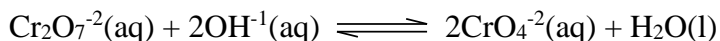


- a) At equilibrium, $P_{\text{C}_2\text{H}_5\text{OH}} = 200 \text{ bar}$ and $P_{\text{H}_2\text{O}} = 400 \text{ bar}$. Calculate $P_{\text{C}_2\text{H}_4}$ at equilibrium. **[$3 \times 10^{-3} \text{ atm}$]**
- b) Is the highest yield of ethanol obtained at high or low pressures, and at high or low temperatures? **[High pressure and low temperature]**
- c) Calculate K_c at 450 K. **[$K_c \approx 10^5$]**
- d) In manufacturing, the yield of ammonia is increased by condensing it to a liquid and removing it from the vessel. Would condensing the ethanol and removing it from the reaction vessel increase the yield? Explain. **[No.]**
- 6) Aluminum is one of the most versatile metals. It is produced by the Hall-Heroult process, in which cryolite, Na_3AlF_6 , is used as a solvent for the aluminum ore. Cryolite undergoes very slight decomposition with heat to produce a tiny amount of F_2 , which escapes into the atmosphere above the solvent. K_c is 2×10^{-104} at 1300 K for the reaction:



What is the concentration of $\text{F}_2(\text{g})$ over molten cryolite at this temperature? Give your answer in moles/L and in molecules/ km^3 . **(Answer: $[\text{F}_2] \approx 3 \times 10^{-35} \text{ M}$ or $16 \text{ molecules}/\text{km}^3$)**

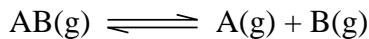
- 7) How will the color of the equilibrium mixture:



be affected by the addition of:

- a) sodium hydroxide. **(Answer: equilibrium will shift to the right (more yellow color))**
- b) hydrochloric acid. **(Answer: equilibrium will shift to the left (more orange color))**
- 8) A mixture of 3.00 volumes of H_2 and 1.00 volumes of N_2 reacts at 344°C to form ammonia. The equilibrium mixture at 100 bar contains 60% NH_3 by volume. Calculate K_p for the reaction, assuming the gases behave ideally. **(Answer: $K_p = 1.3 \times 10^{-2}$)**

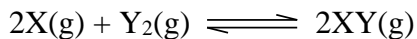
9) At 125°C K_p is 2.0 for the equilibrium



for which $\Delta H^\circ = +80 \text{ kJ}$. Calculate the approximate value of K_p at 225°C.

(Answer: $K_p \approx 2 \times 10^2$)

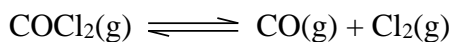
10) For the equilibrium



at 225°C, $K_p = 5 \times 10^{-2}$ and ΔH° for the reaction is -27 kJ. Estimate the value of K_p at 525°C.

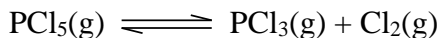
(Answer: $K_p \approx 5 \times 10^{-3}$)

11) For the equilibrium



K_c is 1×10^{-4} at 525°C and 2×10^{-10} at 125°C. Calculate the approximate ΔH° for this reaction. **(Answer: $\Delta H^\circ \approx +96 \text{ kJ}$)**

12) The equilibrium



was studied a series of temperatures. A plot of $\ln(K_p)$ vs $1/T$ gave a line with a slope = -1.1×10^4 .

- Is the reaction exothermic or endothermic? EXPLAIN.
- What are the units for the slope?
- Calculate ΔH for this reaction in kJ/mol. **(Answer: + 91 kJ/mol)**