

Problems - Chapter 15 (without solutions)

1) What is the significance of the equilibrium constant? What does a large equilibrium constant tell us about a reaction? A small one?

2) (15.18) Write equilibrium constants for K_C , and, if applicable, for K_p , for the following processes:

- a) $2 \text{CO}_2(\text{g}) \rightleftharpoons 2 \text{CO}(\text{g}) + \text{O}_2(\text{g})$
- b) $3 \text{O}_2(\text{g}) \rightleftharpoons 2 \text{O}_3(\text{g})$
- c) $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$
- d) $\text{H}_2\text{O}(\text{g}) + \text{C}(\text{s}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2(\text{g})$
- e) $\text{HCOOH}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCOO}^-(\text{aq})$
- f) $2 \text{HgO}(\text{s}) \rightleftharpoons 2 \text{Hg}(\ell) + \text{O}_2(\text{g})$

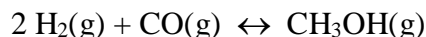
3) The reaction below has an equilibrium constant $K_p = 2.2 \times 10^6$ at 298. K



Calculate K_p for each of the reactions below (at the same temperature) and predict whether reactants or products will be favored at equilibrium

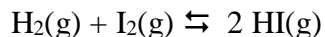
- a) $\text{COF}_2(\text{g}) \rightleftharpoons \frac{1}{2} \text{CO}_2(\text{g}) + \frac{1}{2} \text{CF}_4(\text{g})$
- b) $6 \text{COF}_2(\text{g}) \rightleftharpoons 3 \text{CO}_2(\text{g}) + 3 \text{CF}_4(\text{g})$
- c) $2 \text{CO}_2(\text{g}) + 2 \text{CF}_4(\text{g}) \rightleftharpoons 4 \text{COF}_2(\text{g})$

4) (15.12) The equilibrium constant for the reaction



is $K_C = 1.6 \times 10^{-2}$ at a certain temperature. It is found that there are 1.17×10^{-2} moles of H_2 and 3.46×10^{-7} moles of CH_3OH in a 5.60 L system at equilibrium at this temperature. What is the concentration of CO in the system?

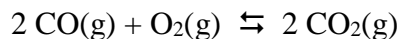
5) Consider the following reaction



Complete the table below. You may assume that all concentrations are equilibrium concentrations in units of mol/L.

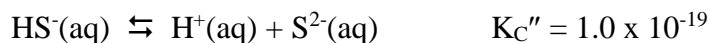
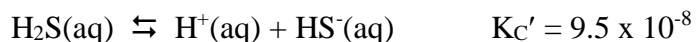
T(°C)	[H ₂]	[I ₂]	[HI]	K _C
25.0	0.0355	0.0388	0.922	----
340.0	----	0.0455	0.387	96.
445.0	0.0485	0.0468	----	50.2

6) (15.24) What is the numerical value for K_p at $T = 1273. \text{ }^\circ\text{C}$ for the reaction

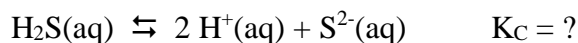


At this temperature $K_C = 2.24 \times 10^{22}$.

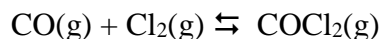
7) (15.34) The following equilibrium constants have been determined for hydrosulfuric acid at $T = 25.0 \text{ }^\circ\text{C}$



Find the equilibrium constant for the following reaction at the same temperature



8) For the reaction below, $K_C = 255$. at $T = 1000. \text{ K}$



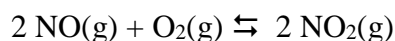
A reaction mixture (kept at $T = 1000. \text{ K}$) initially contains no COCl_2 . The initial concentrations of CO and Cl_2 are $[\text{CO}] = 0.1500 \text{ M}$, and $[\text{Cl}_2] = 0.1750 \text{ mol/L}$. What are the equilibrium concentrations of CO , Cl_2 , and COCl_2 ?

9) Consider the reaction



If the reaction (kept at $T = 227. \text{ }^\circ\text{C}$) initially contains $0.175 \text{ mol/L SO}_2\text{Cl}_2$ (and no SO_2 or Cl_2), what is the equilibrium concentration of Cl_2 ?

10) The equilibrium constant for the reaction



is $K_C = 6.9 \times 10^5$ at $T = 500. \text{ K}$. Consider a system at this temperature where the initial concentration of NO_2 is $[\text{NO}_2] = 0.1000 \text{ mol/L}$, and where no NO or O_2 are initially present. What are the concentrations of NO , O_2 , and NO_2 when equilibrium is reached?

11) In which direction will a reaction proceed for each of the following conditions:

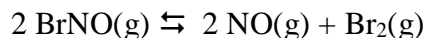
- a) $Q < K$ b) $Q > K$ c) $Q = K$

12) Consider the reaction



A reaction mixture contains 0.112 atm of H_2 , 0.055 atm of S_2 , and 0.445 atm of H_2S . Is the reaction mixture at equilibrium? If not, in what direction will the reaction proceed?

13) Consider this reaction at equilibrium



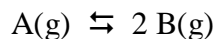
Predict whether the reaction will shift left, shift right, or remain unchanged after each disturbance.

- NO is added to the reaction mixture.
- BrNO is added to the reaction mixture.
- Br₂ is removed from the reaction mixture.

14) Each of the following reactions is allowed to come to equilibrium, and the volume is then changed as indicated. Predict the effect (shift right, shift left, or no effect) of the indicated volume change.

- $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$ volume is decreased
- $\text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{PCl}_5(\text{g})$ volume is increased
- $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ volume is increased

15) (15.86) Consider the following reaction



Data for this reaction for systems at equilibrium are given below.

T(°C)	[A] (M)	[B] (M)
200.0	0.0125	0.843
300.0	0.171	0.764
400.0	0.250	0.724

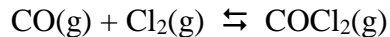
- Find the value for K_C and K_p at each of the above temperatures.
- Is the above reaction exothermic or endothermic? Justify your answer.

16) (15.47) Find ΔG° and K for the following equilibrium reaction at $T = 25.^\circ\text{C}$



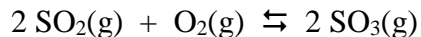
Also find ΔG for the reaction if $p(\text{PCl}_5) = 0.0029 \text{ atm}$, $p(\text{PCl}_3) = 0.27 \text{ atm}$, and $p(\text{Cl}_2) = 0.40 \text{ atm}$.

17) (15.50) The equilibrium constant for the reaction



is 5.62×10^{35} at $T = 25. \text{ }^\circ\text{C}$. Using only this information find the value for $\Delta G^\circ_{\text{rxn}}$ for this process at this temperature.

18) The gas phase reaction of sulfur dioxide (SO_2) with molecular oxygen (O_2) can produce sulfur trioxide (SO_3). The balanced equation for the reaction is

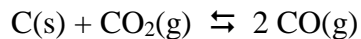


Thermodynamic data for the reactants and products are given below, at $T = 25. \text{ }^\circ\text{C}$.

Substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S° (J/mol·K)
$\text{O}_2\text{(g)}$	0.0	0.0	205.2
$\text{SO}_2\text{(g)}$	- 296.8	- 300.1	248.2
$\text{SO}_3\text{(g)}$	- 395.7	- 371.1	256.8

Based on this information find $\Delta G^\circ_{\text{rxn}}$ and K for the above reaction at $T = 25. \text{ }^\circ\text{C}$

19) The equilibrium constant for the reaction



measured at $T = 850. \text{ }^\circ\text{C}$, is $K_p = 1.2 \times 10^{14}$.

A system initially has $p_{\text{CO}} = 0.400 \text{ atm}$ and $p_{\text{CO}_2} = 0.300 \text{ atm}$. What are the pressures of CO and CO_2 when the system reaches equilibrium?