These problems are intended to ***supplement*** the problems in the textbook, not ***replace*** them.

Questions

1. $CO(g) + Cl_2(g) \rightleftarrows COCl_2(g)$

   Equilibrium is established at 100.0 °C with these equilibrium values: $[CO]_E = 0.0145$ M, $[Cl_2]_E = 0.0546$ M, $[COCl_2]_E = 3.62\times10^{-6}$ M. Determine K_c and K_p.

2. $H_2(g) + I_2(g) \rightleftarrows 2\ HI(g)$

   Equilibrium is established at 448 °C with $[H_2]_E = 6.5\times10^{-5}$ M, $[I_2]_E = 1.063\times10^{-3}$ M, $[HI]_E = 1.87\times10^{-3}$ M, Determine K_c and K_p.

3. $2\ SO_3(g) \rightleftarrows 2\ SO_2(g) + O_2(g)$

   Equilibrium is established at 1000 K with equilibrium pressures of $P_{SO3} = 0.20$ atm, $P_{SO2} = 0.30$ atm, $P_{O2} = 0.15$ atm. Determine K_c and K_p.

4. $CaF_2(s) \rightleftarrows Ca^{2+}(aq) + 2\ F^-(aq)$

   At equilibrium, $[Ca^{2+}]_E = 0.010$ M, $[F^-]_E = 6.2\times10^{-5}$ M. Determine K_c.

The following questions refer to this reaction, for which $K_p = 1.25\text{x}10^{-5}$ at 22.00 °C:

$$I_2(s) + H_2S(g) \rightleftarrows 2\ HI(g) + S(s)$$

5. What is the value of K_c for the same reaction at 22.00 °C?

6. At 22.00 °C, does equilibrium favor I_2 and H_2S or HI and S?

7. What is the value of K_p at 22.00 °C for this reaction: $2\ HI(g) + S(s) \rightleftarrows I_2(s) + H_2S(g)$

8. What is the value of K_p at 22.00 °C for this reaction: $3\ I_2(s) + 3\ H_2S(g) \rightleftarrows 6\ HI(g) + 3\ S(s)$

9. What is the value of K_p at 22.00 °C for this reaction: $HI(g) + ½\ S(s) \rightleftarrows ½\ I_2(s) + ½\ H_2S(g)$

Evaluate the equilibrium constant, K_c for the following:

10. A mixture of 0.150 mol NO, 0.100 mol H_2 and 0.120 mol H_2O is placed in a 1.00 liter vessel. The following equilibrium is established, with $[NO]_E = 0.070$ M:

$$2\ NO(g) + 2\ H_2(g) \rightleftarrows N_2(g) + 2\ H_2O(g)$$

11. A mixture of 1.374 g H_2 and 70.31 g Br_2 is heated in a 2.000 liter vessel. The following equilibrium is established, with 0.5660 g H_2 present at equilibrium:

$$H_2(g) + Br_2(g) \rightleftarrows 2\ HBr(g)$$

12. Some ammonia and oxygen are combined in a sealed vessel, both at a concentration of 0.0150 M. The following equilibrium is established, with the concentration of nitrogen gas 0.00196 M at equilibrium:

$$4\ NH_3\,(g)\ +\ 3\ O_2(g)\ \rightleftarrows\ 2\ N_2\,(g)\ +\ 6\ H_2O\,(g)$$

13. When 2.00 mol of SO_2Cl_2 is placed in a 2.00 liter flask at 303 K, 56% of the SO_2Cl_2 decomposes to SO_2 and Cl_2:

$$SO_2Cl_2\,(g)\ \rightleftarrows\ SO_2\,(g)\ +\ Cl_2\,(g)$$

14. Pure ammonia, at 0.186 M is placed into a sealed vessel. When the system reaches equilibrium, it is found that 61.2% of the ammonia has decomposed to nitrogen and hydrogen. Find K_c for this reaction:

$$N_2\,(g)\ +\ 3\ H_2\,(g)\ \rightleftarrows\ 2\ NH_3\,(g)$$

Answer the following questions:

15. At 100 °C, K_c = 0.078 for the following reaction: $SO_2Cl_2\,(g)\ \rightleftarrows\ SO_2\,(g)\ +\ Cl_2\,(g)$

In an equilibrium mixture of the three gases, $[SO_2Cl_2]_E$ = 0.136 M and $[SO_2]_E$ = 0.072 M. What is the equilibrium concentration of chlorine?

16. At 1285 °C, K_c = 0.00104 for the following reaction: $Br_2\,(g)\ \rightleftarrows\ 2\ Br\,(g)$

A 2.00 liter vessel containing an equilibrium mixture of gases has 24.5 g Br_2 in it. What is the mass of Br in the vessel at equilibrium?

17. At 22 °C, K_p = 0.070 for the following reaction: $NH_4SH\,(s)\ \rightleftarrows\ NH_3\,(g)\ +\ H_2S\,(g)$

If 2.00 g NH_4SH is placed into a 3.00 liter vessel at 22 °C, and decomposes, then what are the equilibrium partial pressures of NH_3 and H_2S?

18. At 400 K, K_c = 7.0 for the following reaction: $Br_2\,(g)\ +\ Cl_2\,(g)\ \rightleftarrows\ 2\ BrCl\,(g)$

If 0.050 mol Br_2 and 0.075 mol Cl_2 are introduced into a 1.50 liter vessel at 400 K, what is the equilibrium concentration of BrCl?

19. At 25 °C, $K_c = 4.4\times10^{-4}$ for the following reaction:

$$CH_3NH_2\,(aq)\ +\ H_2O(l)\ \rightleftarrows\ CH_3NH_3^+\,(aq)\ +\ OH^-\,(aq)$$

If initially $[CH_3NH_2]$ = 0.075 M and $[CH_3NH_3^+]$ = 0.010 M, then what are equilibrium concentrations of all species?

20. At 25 °C, $K_c = 6.8\times10^{-4}$ for the following reaction: $HF\,(aq)\ \rightleftarrows\ H^+\,(aq)\ +\ F^-\,(aq)$

Initially 2.00 L of a solution contains both HF and F^-. If the initial concentration of HF is 0.150 M, and the equilibrium concentration of H^+ is 6.5×10^{-4} M, then how many moles of fluoride ions must initially be present in the solution?

21. At 25 °C, $K_c = 1.8\times10^{-5}$ for the following reaction:

$$NH_3\,(aq)\ +\ H_2O(l)\ \rightleftarrows\ NH_4^+\,(aq)\ +\ OH^-\,(aq)$$

How many grams of NH_4Cl must be added to 4.00 liters of a 0.200 M NH_3 solution for the mixture to have an equilibrium hydroxide concentration, $[OH^-]_E = 2.0\times10^{-5}$ M?

22. At 400 K, $K_c = 0.914$ for the following reaction: $NO_2\,(g) + NO(g) \rightleftarrows N_2O\,(g) + O_2\,(g)$

Equal amounts of NO_2 and NO are to be placed in a 5.00 liter vessel, and when the system reaches equilibrium, $[N_2O]_E = 0.050$ M. How many moles of NO_2 and NO must be placed in the vessel initially?

Predict which direction each reaction will proceed in order to achieve equilibrium.

23. $K_c = 0.00122$ for this reaction: $2\,Cl_2\,(g) + 2\,H_2O(g) \rightleftarrows 4\,HCl\,(g) + O_2\,(g)$

$[Cl_2] = 0.125$ M, $[H_2O] = 0.750$ M, $[HCl] = 0.033$ M, $[O_2] = 0.468$ M

24. $K_p = 0.497$ for this reaction: $PCl_5\,(g) \rightleftarrows PCl_3\,(g) + Cl_2\,(g)$

$P_{PCl5} = 0.970$ atm, $P_{PCl3} = 0.693$ atm, $P_{Cl2} = 0.821$ atm

25. $K_p = 9.45\times10^{-5}$ for this reaction: $N_2\,(g) + 3\,H_2(g) \rightleftarrows 2\,NH_3\,(g)$

$P_{N2} = 175$ torr, $P_{H2} = 224$ torr, $P_{NH3} = 398$ torr

26. $K_c = 6.2\times10^{-8}$ for this reaction: $H_2PO_4^-\,(aq) + H_2O(l) \rightleftarrows HPO_4^{2-}\,(aq) + H_3O^+(aq)$

$[H_2PO_4^-] = 1.40$ M, $[HPO_4^{2-}] = 0.067$ M, $[H_3O^+] = 1.3\times10^{-6}$ M

27. $K_c = 5\times10^3$ for this reaction: $Cd^{2+}\,(aq) + 4\,Br^-(aq) \rightleftarrows CdBr_4^{2-}\,(aq)$

$[Cd^{2+}] = 0.100$ M, $[Br^-] = 0.225$ M, $[CdBr_4^{2-}] = 0.750$ M

28. $K_c = 4\times10^{-38}$ for this reaction: $Fe(OH)_3\,(s) \rightleftarrows Fe^{3+}\,(aq) + 3\,OH^-\,(aq)$

$[FeCl_3] = 0.0200$ M, $[Ba(OH)_2] = 0.00500$ M, 0.500 g $Fe(OH)_3$

Predict the effect of decreasing the volume of the container at constant temperature on the equilibrium yield of product for the following reactions:

29. $2\,SO_3\,(g) + 2\,Cl_2\,(g) \rightleftarrows 2\,SO_2Cl_2\,(g) + O_2\,(g)$

30. $O_2\,(g) + 2\,F_2\,(g) \rightleftarrows 2\,OF_2\,(g)$

31. $2\,NO\,(g) + O_2\,(g) \rightleftarrows 2\,NO_2\,(g)$

32. $4\,NH_3\,(g) + 5\,O_2\,(g) \rightleftarrows 4\,NO\,(g) + 6\,H_2O\,(g)$

33. $C\,(s) + H_2O\,(g) \rightleftarrows CO(g) + H_2\,(g)$

Predict the effect of decreasing the temperature on the equilibrium yield of product for the following reactions:

34. $2\,O_3\,(g) \rightleftarrows 3\,O_2\,(g)$ $\Delta H° = -285.4$ kJ

35. $C\,(s) + 2\,H_2\,(g) \rightleftarrows CH_4\,(g)$ $\Delta H° = -74.85$ kJ

36. $NH_4Cl\,(s) \rightleftarrows NH_4^+(aq) + Cl^-(aq)$ $\Delta H° = +14.7$ kJ

Answers

If you cannot figure out how to get the correct answer, go to your instructor, Science Tutoring Center, etc.

1. $K_c = 0.00457$ and $K_p = 1.49\times10^{-4}$
2. $K_c = 51$ and $K_p = 51$
3. $K_c = 0.0041$ and $K_p = 0.34$
4. 3.8×10^{-11}
5. 5.16×10^{-7}
6. I_2 and H_2S
7. 8.00×10^{4}
8. 1.95×10^{-15}
9. 283
10. $K_c = 8.2\times10^{2}$
11. $K_c = 58.4$
12. $K_c = 5.90\times10^{-6}$
13. 0.71
14. 18.3
15. 0.15 M Cl_2
16. 1.43 g Br
17. $P_{NH3} = P_{H2S} = 0.26$ atm
18. 0.046 M BrCl
19. $[CH_3NH_2]_E = 0.072$ M, $[CH_3NH_3^+]_E = 0.013$ M, $[OH^-]_E = 0.0026$ M
20. 0.32 mol F^-
21. 39 g NH_4Cl
22. 0.510 mol of each
23. $Q_c = 6.3\times10^{-5} < K_c \Rightarrow$ RIGHT
24. $Q_p = 0.587 > K_p \Rightarrow$ LEFT
25. $Q_p = 46.5 > K_p \Rightarrow$ LEFT
26. $Q_c = 6.2\times10^{-8} = K_c \Rightarrow$ AT EQUILIBRIUM ALREADY
27. $Q_c = 2.93\times10^{3} < K_c \Rightarrow$ RIGHT
28. $Q_c = 2.00\times10^{-8} > K_c \Rightarrow$ LEFT
29. increase
30. increase
31. increase
32. decrease
33. decrease
34. increase
35. increase
36. decrease