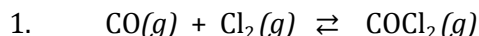


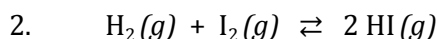
2. CHEMICAL EQUILIBRIUM

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

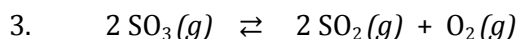
Questions



Equilibrium is established at 100.0 °C with these equilibrium values: $[\text{CO}]_E = 0.0145 \text{ M}$, $[\text{Cl}_2]_E = 0.0546 \text{ M}$, $[\text{COCl}_2]_E = 3.62 \times 10^{-6} \text{ M}$. Determine K_c and K_p .



Equilibrium is established at 448 °C with $[\text{H}_2]_E = 6.5 \times 10^{-5} \text{ M}$, $[\text{I}_2]_E = 1.063 \times 10^{-3} \text{ M}$, $[\text{HI}]_E = 1.87 \times 10^{-3} \text{ M}$. Determine K_c and K_p .

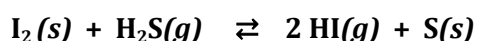


Equilibrium is established at 1000 K with equilibrium pressures of $P_{\text{SO}_3} = 0.20 \text{ atm}$, $P_{\text{SO}_2} = 0.30 \text{ atm}$, $P_{\text{O}_2} = 0.15 \text{ atm}$. Determine K_c and K_p .



At equilibrium, $[\text{Ca}^{2+}]_E = 0.010 \text{ M}$, $[\text{F}^{-}]_E = 6.2 \times 10^{-5} \text{ M}$. Determine K_c .

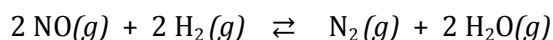
The following questions refer to this reaction, for which $K_p = 1.25 \times 10^{-5}$ at 22.00 °C:



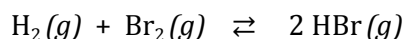
5. What is the value of K_c for the same reaction at 22.00 °C?
6. At 22.00 °C, does equilibrium favor I_2 and H_2S or HI and S ?
7. What is the value of K_p at 22.00 °C for this reaction: $2 \text{HI}(g) + \text{S}(s) \rightleftharpoons \text{I}_2(s) + \text{H}_2\text{S}(g)$
8. What is the value of K_p at 22.00 °C for this reaction: $3 \text{I}_2(s) + 3 \text{H}_2\text{S}(g) \rightleftharpoons 6 \text{HI}(g) + 3 \text{S}(s)$
9. What is the value of K_p at 22.00 °C for this reaction: $\text{HI}(g) + \frac{1}{2} \text{S}(s) \rightleftharpoons \frac{1}{2} \text{I}_2(s) + \frac{1}{2} \text{H}_2\text{S}(g)$

Evaluate the equilibrium constant, K_c for the following:

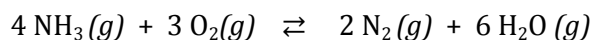
10. A mixture of 0.150 mol NO , 0.100 mol H_2 and 0.120 mol H_2O is placed in a 1.00 liter vessel. The following equilibrium is established, with $[\text{NO}]_E = 0.070 \text{ M}$:



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:



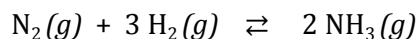
12. Some ammonia and oxygen are combined in a sealed vessel, both at a concentration of 0.0150 M. The following equilibrium is established, with the concentration of nitrogen gas 0.00196 M at equilibrium:



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 :



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:



Answer the following questions:

15. At 100 °C, $K_c = 0.078$ for the following reaction: $\text{SO}_2\text{Cl}_2(g) \rightleftharpoons \text{SO}_2(g) + \text{Cl}_2(g)$

In an equilibrium mixture of the three gases, $[\text{SO}_2\text{Cl}_2]_E = 0.136 \text{ M}$ and $[\text{SO}_2]_E = 0.072 \text{ M}$. What is the equilibrium concentration of chlorine?

16. At 1285 °C, $K_c = 0.00104$ for the following reaction: $\text{Br}_2(g) \rightleftharpoons 2 \text{Br}(g)$

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?

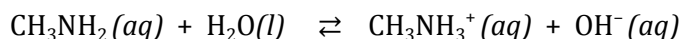
17. At 22 °C, $K_p = 0.070$ for the following reaction: $\text{NH}_4\text{SH}(s) \rightleftharpoons \text{NH}_3(g) + \text{H}_2\text{S}(g)$

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: $\text{Br}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2 \text{BrCl}(g)$

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, $K_c = 4.4 \times 10^{-4}$ for the following reaction:

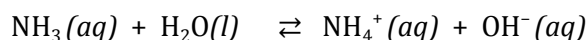


If initially $[\text{CH}_3\text{NH}_2] = 0.075 \text{ M}$ and $[\text{CH}_3\text{NH}_3^+] = 0.010 \text{ M}$, then what are equilibrium concentrations of all species?

20. At 25 °C, $K_c = 6.8 \times 10^{-4}$ for the following reaction: $\text{HF}(aq) \rightleftharpoons \text{H}^+(aq) + \text{F}^-(aq)$

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 $6.5 \times 10^{-4} \text{ M}$, then how many moles of fluoride ions must initially be present in the solution?

21. At 25 °C, $K_c = 1.8 \times 10^{-5}$ for the following reaction:



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, $[\text{OH}^-]_E = 2.0 \times 10^{-5} \text{ M}$?

22. At 400 K, $K_c = 0.914$ for the following reaction: $\text{NO}_2(g) + \text{NO}(g) \rightleftharpoons \text{N}_2\text{O}(g) + \text{O}_2(g)$
 Equal amounts of NO_2 and NO are to be placed in a 5.00 liter vessel, and when the system reaches equilibrium, $[\text{N}_2\text{O}]_E = 0.050 \text{ M}$. 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: $2 \text{Cl}_2(g) + 2 \text{H}_2\text{O}(g) \rightleftharpoons 4 \text{HCl}(g) + \text{O}_2(g)$
 $[\text{Cl}_2] = 0.125 \text{ M}$, $[\text{H}_2\text{O}] = 0.750 \text{ M}$, $[\text{HCl}] = 0.033 \text{ M}$, $[\text{O}_2] = 0.468 \text{ M}$
24. $K_p = 0.497$ for this reaction: $\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)$
 $P_{\text{PCl}_5} = 0.970 \text{ atm}$, $P_{\text{PCl}_3} = 0.693 \text{ atm}$, $P_{\text{Cl}_2} = 0.821 \text{ atm}$
25. $K_p = 9.45 \times 10^{-5}$ for this reaction: $\text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g)$
 $P_{\text{N}_2} = 175 \text{ torr}$, $P_{\text{H}_2} = 224 \text{ torr}$, $P_{\text{NH}_3} = 398 \text{ torr}$
26. $K_c = 6.2 \times 10^{-8}$ for this reaction: $\text{H}_2\text{PO}_4^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HPO}_4^{2-}(aq) + \text{H}_3\text{O}^+(aq)$
 $[\text{H}_2\text{PO}_4^-] = 1.40 \text{ M}$, $[\text{HPO}_4^{2-}] = 0.067 \text{ M}$, $[\text{H}_3\text{O}^+] = 1.3 \times 10^{-6} \text{ M}$
27. $K_c = 5 \times 10^3$ for this reaction: $\text{Cd}^{2+}(aq) + 4 \text{Br}^-(aq) \rightleftharpoons \text{CdBr}_4^{2-}(aq)$
 $[\text{Cd}^{2+}] = 0.100 \text{ M}$, $[\text{Br}^-] = 0.225 \text{ M}$, $[\text{CdBr}_4^{2-}] = 0.750 \text{ M}$
28. $K_c = 4 \times 10^{-38}$ for this reaction: $\text{Fe}(\text{OH})_3(s) \rightleftharpoons \text{Fe}^{3+}(aq) + 3 \text{OH}^-(aq)$
 $[\text{FeCl}_3] = 0.0200 \text{ M}$, $[\text{Ba}(\text{OH})_2] = 0.00500 \text{ M}$, $0.500 \text{ g Fe}(\text{OH})_3$

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

29. $2 \text{SO}_3(g) + 2 \text{Cl}_2(g) \rightleftharpoons 2 \text{SO}_2\text{Cl}_2(g) + \text{O}_2(g)$
30. $\text{O}_2(g) + 2 \text{F}_2(g) \rightleftharpoons 2 \text{OF}_2(g)$
31. $2 \text{NO}(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO}_2(g)$
32. $4 \text{NH}_3(g) + 5 \text{O}_2(g) \rightleftharpoons 4 \text{NO}(g) + 6 \text{H}_2\text{O}(g)$
33. $\text{C}(s) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + \text{H}_2(g)$

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

34. $2 \text{O}_3(g) \rightleftharpoons 3 \text{O}_2(g) \quad \Delta H^\circ = -285.4 \text{ kJ}$
35. $\text{C}(s) + 2 \text{H}_2(g) \rightleftharpoons \text{CH}_4(g) \quad \Delta H^\circ = -74.85 \text{ kJ}$
36. $\text{NH}_4\text{Cl}(s) \rightleftharpoons \text{NH}_4^+(aq) + \text{Cl}^-(aq) \quad \Delta H^\circ = +14.7 \text{ kJ}$

Answers

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

- $K_c = 0.00457$ and $K_p = 1.49 \times 10^{-4}$
- $K_c = 51$ and $K_p = 51$
- $K_c = 0.0041$ and $K_p = 0.34$
- 3.8×10^{-11}
- 5.16×10^{-7}
- I_2 and H_2S
- 8.00×10^4
- 1.95×10^{-15}
- 283
- $K_c = 8.2 \times 10^2$
- $K_c = 58.4$
- $K_c = 5.90 \times 10^{-6}$
- 0.71
- 18.3
- 0.15 M Cl_2
- 1.43 g Br
- $P_{NH_3} = P_{H_2S} = 0.26$ atm
- 0.046 M BrCl
- $[CH_3NH_2]_E = 0.072$ M, $[CH_3NH_3^+]_E = 0.013$ M, $[OH^-]_E = 0.0026$ M
- 0.32 mol F^-
- 39 g NH_4Cl
- 0.510 mol of each
- $Q_c = 6.3 \times 10^{-5} < K_c \Rightarrow$ RIGHT
- $Q_p = 0.587 > K_p \Rightarrow$ LEFT
- $Q_p = 46.5 > K_p \Rightarrow$ LEFT
- $Q_c = 6.2 \times 10^{-8} = K_c \Rightarrow$ AT EQUILIBRIUM ALREADY
- $Q_c = 2.93 \times 10^3 < K_c \Rightarrow$ RIGHT
- $Q_c = 2.00 \times 10^{-8} > K_c \Rightarrow$ LEFT
- increase
- increase
- increase
- decrease
- decrease
- increase
- increase
- decrease