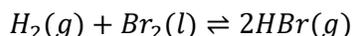


Chapter 15: Equilibria

Equilibrium Constant

15.1. Use the following reaction to answer



Which one of the following is the equilibrium constant expression for the reaction in Figure 15.1?

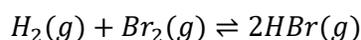
a. $k = \frac{[HBr]^2}{[H_2][Br_2]}$

b. $k = \frac{[HBr]^2}{[H_2]}$

c. $k = \frac{[HBr]}{[H_2]}$

d. None of the above

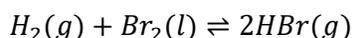
15.2. Use the following reaction to answer



What is the equilibrium concentration of HBr if H_2 and Br_2 are both 0.800M, and $K=8.00$ at $60^\circ C$.

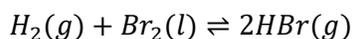
15.3. Why is Br_2 a liquid in question 15.1 and a gas in 15.2 when the pressure is constant?

15.4. Use the following reaction to answer



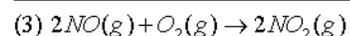
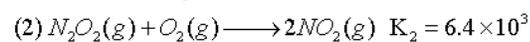
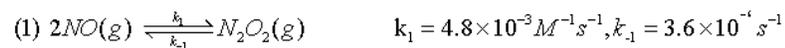
Calculate K_p at 25° for a system at equilibrium if: $P_{H_2} = 2.500 \times 10^{-2} \text{ atm}$, and $P_{HBr} = 1.500 \text{ atm}$?

15.5. Use the following reaction to answer



What is K_c for the system in question 15.4?

Figure 15.1: Use this reaction for question 6-8:



15.6. What is the value of K_c for reaction (1) in Figure 15.2?

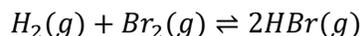
15.7. What is the value of K_c for step (3) of question 15.6?

Chapter 15: Equilibria

15.8. Does step 1 in question 15.6 favor reactants or products?

Calculations of Equilibrium Constant

Figure 15.2: Questions 9-14 deal with the following reaction:



15.9. In what direction will the reaction at 440°C proceed if:

$$[HBr]= 1.0 \times 10^{-2} M, [H_2]=5.0 \times 10^{-3} M, [Br_2]=1.5 \times 10^{-2} M \text{ and } K_{eq}=50 \text{ at } 440^\circ C.$$

15.10. What is the equilibrium concentration of Bromine at 440°C if:

$$[H_2]= 0.60 M, [HBr]=1.25 M \text{ and } [Br_2]=0$$

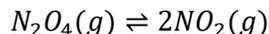
15.11. What is [HBr] after equilibrium is reached for the problem described in question 15.10?

15.12. Determine K_{eq} at a certain temperature if 0.80 mol HBr is produced after 0.50 mol H_2 and Br_2 react in a 2 L container.

15.13. At a certain temperature, $K_{eq}=6.30 \times 10^2$. What is the equilibrium concentration of H_2 if 4.50 mol of each of the three species were placed into a 3.00 L flask?

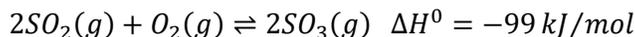
15.14. What is [HBr] after equilibrium is reached for the problem described in question 15.123?

15.15. Determine K_{eq} for the following reaction if 0.0500 M N_2O_4 is placed in a container and it decomposes to an equilibrium value of 0.0155 M.



Le Chatelier's Principle

Figure 15.3: Questions 15-20 deal with the following reaction:



15.16. If the temperature increases while the pressure is constant, the reaction will proceed towards which direction?

Chapter 15: Equilibria

15.17. For the same reaction, if the temperature is held constant and the pressure is increased, which direction will the reaction proceed?

15.18. If more oxygen is added, which direction will the reaction proceed?

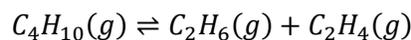
15.19. If the container in which the reaction occurs is enlarged, which direction will the reaction proceed?

15.20. The addition of catalyst will make the reaction shift towards which direction?

15.21. The addition of He gas will make the reaction shift towards which direction?

Equilibrium Constant

Figure 15.4: Questions 22-26 deal with the following reaction:



15.22. What is the concentration of C_4H_{10} at equilibrium if the concentrations of C_2H_6 and C_2H_4 are both 0.014M? $K_c = 0.07$

15.23. For the same reaction, if the initial concentration of C_4H_{10} is 0.035M, and there is no C_2H_6 C_2H_4 present initially. What is the equilibrium concentration of C_4H_{10} ?

15.24. Following Q 15.23, what is the equilibrium concentration of C_2H_6 ?

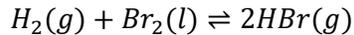
15.25. If the initial concentration of C_4H_{10} is 0.030M, and the ones of C_2H_6 and C_2H_4 are both 0.023M. At equilibrium, the concentration of C_4H_{10} becomes 0.018M, what is the value of K_c of the reaction.

15.26. For the same reaction, if the 2.0L container was evacuated, then pumped in with gases at the following pressure, $C_4H_{10} = 1.2\text{atm}$, C_2H_6 and $C_2H_4 = 0.6\text{atm}$. What is the partial pressure (in atm) of C_4H_{10} at equilibrium? $K_p = 0.64$.

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Equilibria Calculations Through “Completing the Power”

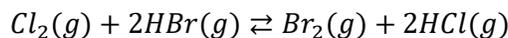
Figure 15.5: Questions 27-28 deal with the following reaction:



15.27. For the reaction, what is the equilibrium concentration of Br_2 at 4400C if initially $[H_2]= 0.60M$
 $[HBr]=1.25M$ $[Br_2]=0.6$ and $k=50$?

15.28. What is the equilibrium concentration of HBr?

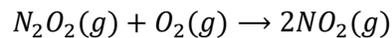
Figure 15.6: Questions 29-30 deal with the following reaction:



15.29. For the reaction, what is the equilibrium concentration of HCl if the initial $[Cl_2]=0.1M$,
 $[HBr]=0.20M$, $[Br_2]=[HCl]=0$ and $k=15$?

15.30. What is the equilibrium concentration of HBr in Q 15.29?

15.31. For the reaction, What is $[O_2]$ at equilibrium if 0.050mol of N_2O_2 , O_2 , and NO_2 are mixed in a
1.0L container? $k=25$



Relating K_p and K_c

15.32. What is the relationship between K_p and K_c ?

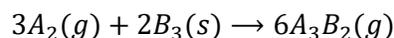
a. $K_p = K_c(RT)^{\Delta n}$

c. $K_p = K_c$

b. $K_c = K_p(RT)^{\Delta n}$

d. None of the above

Figure 15.7: Use the following equation for questions 33-36



15.33. What is the Δn for the equation above?

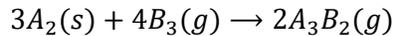
15.34. Solve for K_p , given $K_c = 2.3 \cdot 10^4$ at 30°C for the equation above?

15.35. Solve for K_c , given $K_p = 2.3 \cdot 10^4$ at 30°C for the equation above?

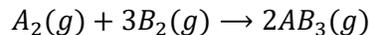
Chapter 15: Equilibria

15.36. Solve for K_c , given $K_p = 3.1 \times 10^4$ at 30°C for the equation above?

15.37. Solve for K_c , given $K_p = 3.2 \times 10^4$ at 30°C for the following equation:



15.38. What is the temperature, given $K_c = 3.5 \times 10^8$, and $K_p = 5.8 \times 10^5$ for the following equation?



General Questions

15.39. Which of the following is the relationship between the rate constants for the forward and reverse reactions and the equilibrium constant for a process?

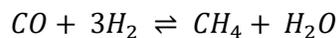
- a. $K = k_f + k_r$
- b. $K = k_f k_r$
- c. $K = k_f - k_r$

- d. $K = 1 / (k_f k_r)$
- e. $K = k_f / k_r$

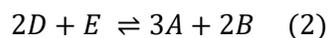
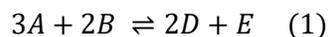
15.40. A flask of an aqueous equilibrium mixture of CoCl_4^{2-} , CoBr_4^{2-} , Cl^- , and Br^- is at 25°C . Which of the following actions will change the value of the equilibrium constant from that which currently describes the concentration relationships of the four species above?

- a. add more CoBr_4^{2-} to the solution
- b. add more CoCl_4^{2-} to the solution
- c. add more Br^- to the solution
- d. add more Cl^- to the solution
- e. put the flask into an 80°C water bath

15.41. What is the K_c for the following reaction?

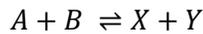


15.42. If the equilibrium constant for reaction (1) is 4.22×10^{-3} , what is the value of the equilibrium constant for the reaction (2) in the following mechanism?



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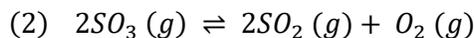
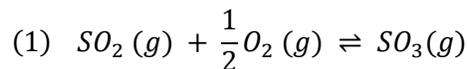
15.43. The reaction



has $K_c = 1977$ at 472 K. At equilibrium, _____.

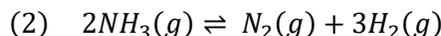
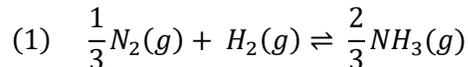
- | | |
|--------------------------|--|
| a. only products exist | e. roughly equal molar amounts of products and reactants are present |
| b. only reactants exist | |
| c. products predominate | |
| d. reactants predominate | |

15.44. The equilibrium constant for reaction (1) is K . What is the equilibrium constant for equation (2)?



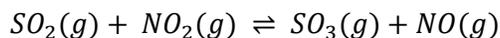
- | | |
|------------|-----------|
| a. $1/2K$ | d. K^2 |
| b. $1/K^2$ | e. $-K^2$ |
| c. $2K$ | |

15.45. If the equilibrium constant for reaction (1) is K , what is the equilibrium constant for (2)?

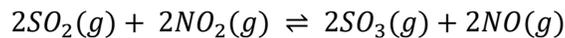


- | | |
|----------|------------|
| a. K^3 | d. $1/K^3$ |
| b. $3K$ | e. $-K^3$ |
| c. $K/3$ | |

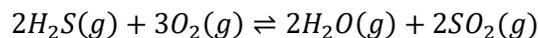
15.46. If the value of K_c for the following reaction is 0.25:



What is the value of K_c for the reaction below?



15.47. What is K_p for the following reaction at 25°C, $K_c = 3.0 \times 10^5$?

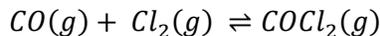


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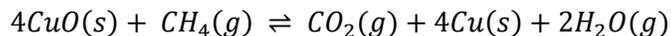
15.48. The value of K_c for the reaction below is 2.0×10^{-10} at 100°C .



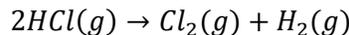
What is the value of K_c for the reverse reaction at 100°C ?



15.49. The value of K_c for the following reaction is 1.10 at 25.0°C . What is the value of K_p for this reaction?



15.50. What is the value of K_c for a flask at equilibrium that contains 0.0114 M HCl, 0.0931 M Cl_2 , and 0.0154 M H_2 at a certain temperature?



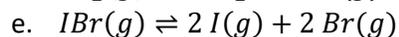
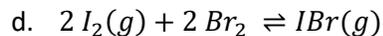
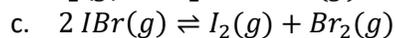
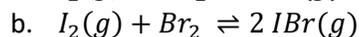
15.51. Consider the gaseous equilibrium: $2A \rightarrow 2B + C$

Determine the value of the missing B concentration at equilibrium.

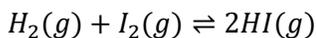
Exp #	[A] at equilibrium	[B] at equilibrium	[C] at equilibrium
1	0.10 M	0.10 M	0.20 M
2	0.20 M	0.50 M	0.032 M
3	0.35 M	?	0.15 M

15.52. Which of the following reactions at equilibrium has the following equilibrium constant expression?

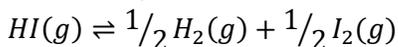
$$\frac{[\text{IBr}]^2}{[\text{I}_2][\text{Br}_2]}$$



15.53. The value of K_c for the following reaction at equilibrium is 54.0 at 427°C .

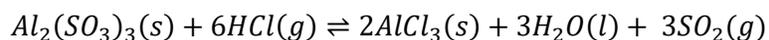


At this temperature, what is the value of K_c for:



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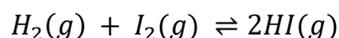
15.54. What is the equilibrium constant expression for the following reaction?



15.55. What is the equilibrium constant expression for the following reaction?

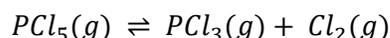


15.56. Consider the following chemical reaction:



At equilibrium, the concentrations of H_2 , I_2 , and HI were 0.15M, 0.033 M, and 0.55 M, respectively. What is the K_c for this reaction?

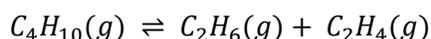
Figure 15.8: Use the following reaction to solve questions 57-58



15.57. From Figure 15.8: Initially, 1.26 mol of $PCl_5(g)$ was placed in a 1.0 L flask. At equilibrium, 1.08 mol of $PCl_5(g)$ was present. What is the value of K_c for this reaction at this temperature?

15.58. What is the equilibrium partial pressure of PCl_3 ? If in a 3.00 L vessel that was charged with 0.123 atm of PCl_5 has a K_p of 0.0121?

15.59. The value of K_c for the following reaction is 0.070. What is the equilibrium concentration (M) of C_4H_{10} if the equilibrium concentrations of C_2H_6 and C_2H_4 are both 0.035M?

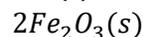
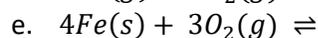
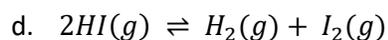
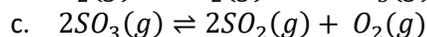
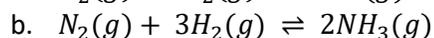
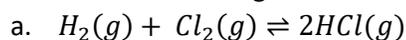


15.60. Nitrosyl bromide decomposes according to the following equation:



A sample of $NOBr$ (0.64 mol) was placed in a 1.00 L flask containing no NO or Br_2 . At equilibrium, the flask contained 0.46 mol of $NOBr$. How many moles of NO and Br_2 are in the flask at equilibrium?

15.61. Which of the following will shift to the left in response to a decrease in volume?



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15.62. For the endothermic reaction



only _____ would favor shifting the equilibrium position to form more CO_2 gas.

- both decreasing the system temperature and increasing the system pressure
- decreasing the system temperature
- increasing both the system temperature and the system pressure
- increasing the system pressure
- increasing the system temperature

15.63. Which of the following reactions would increase pressure at constant temperature not change the concentration of reactants and products?

- | | |
|---|---|
| a. $2\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{N}_2\text{O}(g)$ | d. $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$ |
| b. $\text{N}_2(g) + 2\text{O}_2(g) \rightleftharpoons 2\text{NO}_2(g)$ | e. $\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g)$ |
| c. $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$ | |

15.64. Consider the following reaction at equilibrium



The yield of $\text{CO}(g)$ in reaction can be maximized by carrying out the reaction _____.

- at high temperature and high pressure
- at high temperature and low pressure
- at low temperature and high pressure
- at low temperature and low pressure
- in the presence of solid carbon

15.65. The effect of a catalyst on a chemical reaction is to _____.

- accelerate the forward reaction only
- increase the entropy change associated with a reaction
- lower the energy of the transition state
- make reactions more exothermic
- react with product, effectively removing it and shifting the equilibrium to the right