***Chemistry***

**13: Fundamental Equilibrium Concepts**

**13.2: Equilibrium Constants**

7. Explain why an equilibrium between Br2(*l*) and Br2(*g*) would not be established if the container were not a closed vessel shown in Figure 13.5.

Solution

Equilibrium cannot be established between the liquid and the gas phase if the top is removed from the bottle because the system is not closed; one of the components of the equilibrium, the Br2 vapor, would escape from the bottle until all liquid disappeared. Thus, more liquid would evaporate than can condense back from the gas phase to the liquid phase.

9. Among the solubility rules previously discussed is the statement: All chlorides are soluble except Hg2Cl2, AgCl, PbCl2, and CuCl.

(a) Write the expression for the equilibrium constant for the reaction represented by the equation

. Is *Kc* > 1, < 1, or ≈ 1? Explain your answer.

(b) Write the expression for the equilibrium constant for the reaction represented by the equation

. Is *Kc* > 1, < 1, or ≈ 1? Explain your answer.

Solution

(a) *Kc* = [Ag+][Cl–] < 1. AgCl is insoluble; thus, the concentrations of ions are much less than 1 *M*; (b)  > 1 because PbCl2 is insoluble and formation of the solid will reduce the concentration of ions to a low level (< 1 *M*).

11. Benzene is one of the compounds used as octane enhancers in unleaded gasoline. It is manufactured by the catalytic conversion of acetylene to benzene: . Which value of *Kc* would make this reaction most useful commercially? *Kc* ≈ 0.01, *Kc* ≈ 1, or *Kc* ≈ 10. Explain your answer.

Solution

Since , a value of *Kc* ≈ 10 means that C6H6 predominates over C2H2. In such a case, the reaction would be commercially feasible if the rate to equilibrium is suitable.

13. For a titration to be effective, the reaction must be rapid and the yield of the reaction must essentially be 100%. Is *Kc* > 1, < 1, or ≈ 1 for a titration reaction?

Solution

*Kc*> 1; the product must be formed in overwhelmingly large proportions.

15. Write the mathematical expression for the reaction quotient, *Qc*, for each of the following reactions:

(a) 

(b) 

(c) 

(d) 

(e) 

(f) 

(g) 

(h) 

Solution

(a) ; (b) ; (c) ; (d) *Qc*= [SO2]; (e) ; (f) ; (g) ; (h) *Qc*= [H2O]5

17. The initial concentrations or pressures of reactants and products are given for each of the following systems. Calculate the reaction quotient and determine the direction in which each system will proceed to reach equilibrium.

(a) ; [NH3] = 0.20 *M*, [N2] = 1.00 *M*, [H2] = 1.00 *M*

(b) ; initial pressures: NH3 = 3.0 atm, N2 = 2.0 atm, H2 = 1.0 atm

(c) ; [SO3] = 0.00 *M*, [SO2] = 1.00 *M*, [O2] = 1.00 *M*

(d) ; initial pressures: SO3 = 1.00 atm, SO2 = 1.00 atm, O2 = 1.00 atm

(e) ; [NO] = 1.00 *M*, [Cl2] = 1.00 *M*, [NOCl] = 0 *M*

(f) ; initial pressures: NO = 10.0 atm, N2 = O2 = 5 atm

Solution

(a) 

*Qc* < *Kc*, proceeds left;

(b) 

*QP* < *KP*, proceeds right;

(c) 

*Qc* > *Kc*, proceeds left;

(d) 

*QP* > *KP*, proceeds right;

(e) 

*QP* < *KP*, proceeds right;

(f) *Qc*>*Kc*, proceeds left

19. The following reaction has *KP* = 4.50  10–5 at 720 K.



If a reaction vessel is filled with each gas to the partial pressures listed, in which direction will it shift to reach equilibrium? *P*(NH3) = 93 atm, *P*(N2) = 48 atm, and *P*(H2) = 52

Solution

The reaction quotient expression for this problem is . Plugging in the given values of partial pressures gives, so *Qp* = 1.3  10–3. Since this value is larger than *KP* (4.50  10–5), the system will shift toward the reactants to reach equilibrium.

21. Which of the systems described in Exercise 15 give homogeneous equilibria? Which give heterogeneous equilibria?

Solution

(a) homogenous; (b) homogenous; (c) homogenous; (d) heterogeneous; (e) heterogeneous; (f) homogenous; (g) heterogeneous; (h) heterogeneous

23. For which of the reactions in Exercise 15 does *Kc* (calculated using concentrations) equal *KP* (calculated using pressures)?

Solution

When the number of gaseous components are the same on both sides of the equilibrium expression, *Kc* will equal *KP*. This situation occurs in (a) and (b).

25. Convert the values of *Kc* to values of *KP* or the values of *KP* to values of *Kc*.

(a) 

(b) 

(c) 

(d) 

Solution

, where Δ*n* is the sum of gaseous products minus the sum of gaseous reactants. (a) Δ*n* = (2) – (1 + 3) = –2, *KP* = 0.50[0.08206  673.15]–2 = 1.6  10–4; (b) Δ*n* = (2) – (1 + 1) = 0, *KP* = *Kc*(*RT*)0 = *Kc*= 50.2; (c) Δ*n* = (10) – (0) = 10, *Kc* = *KP*(*RT*)–Δ*n*, *Kc* = 4.08  10–25[0.08206  298.15]–10 = 5.31  10–39; (d) Δ*n* = (1) – (0) = 1, *Kc* = 0.122(0.08206  323.15)–1 = 4.60  10–3

27. What is the value of the equilibrium constant expression for the change  at 30 °C? (see Appendix E)

Solution

The equilibrium expression for this transformation is . The vapor pressure of H2O at 30 ºC is 31.8 torr. Converting to atmospheres gives . Therefore, .

29. Write the reaction quotient expression for the ionization of NH3 in water.

Solution

. Because the concentration of water is a constant, the term [H2O] is normally incorporated into the reaction quotient as well as the final equilibrium constant. 

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