Equilibrium Study Guide

$$HgO(s) + 4\ I^-(aq) + H_2O(l) \rightarrow HgI_4^{2-}(aq) + 2\ OH^-(aq) \qquad \Delta H < 0$$

1. Consider the equilibrium above. Which of the following changes will increase the concentration of HgI_4^-?
   (A) Increasing the concentration of OH^-
   (B) Adding 6 M HNO_3
   (C) Increasing the mass of HgO present
   (D) Increasing the temperature
   (E) Adding a catalyst

2. In which of the following systems would the number of moles of substances present at equilibrium NOT be shifted by a change in the volume of the system at constant temperature?
   (A) $CO(g) + NO(g) \leftrightarrow CO_2(g) + \frac{1}{2} N_2(g)$
   (B) $N_2(g) + 3\ H_2(g) \leftrightarrow 2\ NH_3(g)$
   (C) $N_2(g) + 2\ O_2(g) \leftrightarrow 2\ NO_2(g)$
   (D) $N_2O_4(g) \leftrightarrow 2\ NO_2(g)$
   (E) $NO(g) + O_3(g) \leftrightarrow NO_2(g) + O_2(g)$

3. Which of the following is true for a redox reaction that is thermodynamically favorable at standard conditions?
   (A) $\Delta G° > 0$, $K_{eq} > 1$, $E°_{cell} > 0$
   (B) $\Delta G° > 0$, $K_{eq} > 1$, $E°_{cell} < 0$
   (C) $\Delta G° < 0$, $K_{eq} > 1$, $E°_{cell} > 0$
   (D) $\Delta G° < 0$, $K_{eq} < 1$, $E°_{cell} < 0$
   (E) $\Delta G° < 0$, $K_{eq} < 1$, $E°_{cell} > 0$

4. For the reaction $2\ A \leftrightarrow 4\ B$, $K_c = 2.0$. Determine K_c for $4\ B \leftrightarrow 2\ A$.

   A) 2.0
   B) 4.0
   C) 0.50
   D) 0.20
   E) 0.40

5.

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

Consider the equilibrium above with $K_c = 25$ at a certain temperature. A reaction vessel contains a mixture with the following concentrations: $[H_2] = 0.20$ M, $[Br_2] = 0.20$ M and $[HBr] = 0.10$ M. Which of the following statements concerning the reaction and the reaction quotient, Q, is true?

(A) $Q = K_c$
(B) $Q < K_c$; more HBr will be produced.
(C) $Q < K_c$; more H_2 and Br_2 will be produced.
(D) $Q > K_c$; more HBr will be produced.
(E) $Q > K_c$; more H_2 and Br_2 will be produced.

6.

$$PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g) + \text{energy}$$

Some PCl_3 and Cl_2 are mixed in a container at 200°C and the system reaches equilibrium according to the equation above. After equilibrium has been established some pure $Cl_2(g)$ is injected into the container. Once equilibrium is reestablished, which of the following has a lower value compared to its original equilibrium value?

(A) Moles of $PCl_3(g)$
(B) K_{eq} for the reaction
(C) Moles of $PCl_5(g)$
(D) Moles of $Cl_2(g)$

7. A saturated solution of $BaSO_4$ has a concentration of Ba^{2+} of 1×10^{-2} M. The Ksp of $BaSO_4$ is 1×10^{-10}. What is the concentration of SO_4^{2-}?

A) 1×10^{-10} M
B) 1×10^{-8} M
C) 1×10^{-5} M
D) 1×10^{-12} M

Questions 8-11 refer to the reaction below.

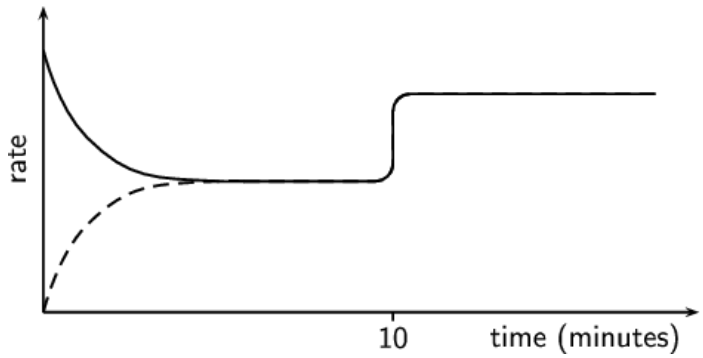
$$2\ NO(g) + O_2 \leftrightarrow 2\ NO_2(g) \qquad \Delta H < 0$$

8. Which of the following changes alone would cause the equilibrium partial pressure of $NO_2(g)$ to increase?
   (A) Decreasing temperature
   (B) Increasing volume
   (C) Adding a catalyst
   (D) Adding an inert gas, such as He

9. 3 mol of NO and 3 mol of O_2 are placed into a rigid, evacuated 1.0 L container at 500. K. Which of the following is true at equilibrium?
   (A) $[NO] = [O_2]$
   (B) $[NO] = [NO_2]$
   (C) $[NO] < [O_2]$
   (D) $[NO] > [O_2]$

10. Initially, $NO_2(g)$ at a pressure of 2.0 atm is placed into a rigid, evacuated flask at 700. K. After the reaction reaches equilibrium at 700. K, the total pressure in the flask is 2.5 atm. What is the value of Kp for the reaction at 700. K?
    (A) 0.50
    (B) 1.0
    (C) 1.5
    (D) 2.0

11. An equal increase in both forward and reverse reaction rates as shown below at time = 10 minutes, is most likely due to which of the following?
    (A) Increasing the concentration of reactants
    (B) Increasing the volume of the container
    (C) Increasing the temperature
    (D) Adding a catalyst



12. Which of the following is the correct solubility constant, Ksp, expression for $Fe(OH)_2$?

A) Ksp = $\frac{[Fe^{2+}]\,[OH^-]}{[Fe(OH)_2]}$

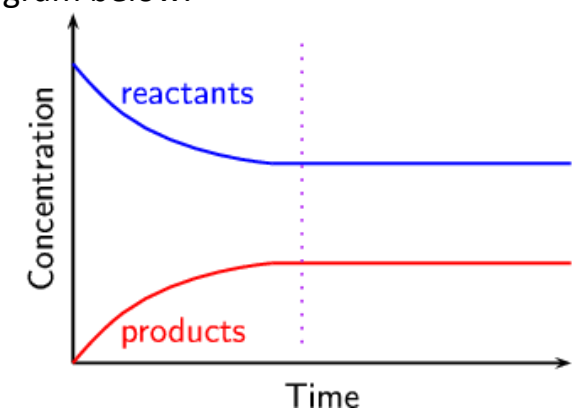
B) Ksp = $\frac{[Fe^{2+}]\,[OH^-]^2}{[Fe(OH)_2]}$

C) Ksp = $[Fe^{2+}]\,[OH^-]^2$

D) Ksp = $[Fe^{2+}]\,[2OH^-]^2$

E) Ksp = $[Fe^{2+}]^2\,[OH^-]^2$

13. Which of the following statements is true regarding the reversible reaction depicted in the diagram below.



A) K > 1; the reaction is product favored
B) K > 1; the reaction is reactant favored
C) K < 1; the reaction is product favored
D) K < 1; the reaction is reactant favored

14. $NH_4HS(s) \leftrightarrow NH_3(g) + H_2S(g)$

The equilibrium shown above has a Kc = 1 at 100 K. Which of the following is the best approximation of Kp at 100 K?

(A) 1
(B) 8
(C) 16
(D) 24
(E) 64

15.The following two-step process has equilibrium constants K_1 and K_2.

Step 1: $H_2(g) + ICl(g) \leftrightarrow HI(g) + HCl(g)$ K_1

Step 2: $HI(g) + ICl(g) \leftrightarrow HCl(g) + I_2(g)$ K_2

Overall: $H_2(g) + 2ICl(g) \leftrightarrow 2HCl(g) + I_2(g)$ K_3

What is the expression for the equilibrium constant for the overall reaction, K_3?

A) $K_3 = K_1K_2$

B) $K_3 = K_1 + K_2$

C) $K_3 = \frac{K_1}{K_2}$

D) $K_3 = \frac{1}{{K_1}^2}$

E) $K_3 = \frac{K_2}{K_1}$

Free Response

$$MgF_2(s) \leftrightarrow Mg^{2+}(aq) + 2\ F^-(aq)$$

1. In a saturated solution of MgF_2 at 18°C, the concentration of Mg^{2+} is 1.21 x 10^{-3} molar. The equilibrium is represented by the equation above.
   (a) Write the equilibrium expression for the solubility product constant, Ksp, and calculate its value at 18°C.
   (b) Calculate the equilibrium concentration of Mg^{2+} in 1.000 liter of saturated MgF_2 solution at 18°C to which 0.100 mole of solid KF has been added. The KF dissolves completely. Assume the volume change is negligible.
   (c) Predict whether a precipitate of MgF_2 will form when 100.0 milliliters of 3.00 x 10^{-3} molar $Mg(NO_3)_2$ solution is mixed with 200.0 milliliters of a 2.00 x 10^{-3} molar NaF solution at 18°C. Calculations to support your prediction must be shown.
   (d) At 27°C the concentration of Mg^{2+} in a saturated solution of MgF_2 is 1.17 x 10^{-3} molar. Is the dissolving of MgF_2 in water an endothermic or an exothermic process? Give an explanation to support your conclusion.

2. Sulfuryl chloride, SO_2Cl_2, is a highly reactive gaseous compound. When heated, it decomposes as follows:

$$SO_2Cl_2(g) \leftrightarrow SO_2(g) + Cl_2(g)$$

   This decomposition is endothermic. As sample of 3.509 grams of SO_2Cl_2 is placed in an evacuated 1.00 liter bulb and the temperature is raised to 375 K.
   (a) What would be the pressure in atmospheres in the bulb if no dissociation of the $SO_2Cl_2(g)$ occurred?
   (b) When the system has come to equilibrium at 375 K, the total pressure in the bulb is found to be 1.43 atmospheres. Calculate the partial pressure of SO_2, Cl_2, and SO_2Cl_2 at equilibrium at 375 K.
   (c) Write the Kp expression.
   (d) Calculate the value of Kp at 375 K.
   (e) If the temperature were raised to 500 K, what effect would this have on the equilibrium constant? Explain your reasoning.