1. Consider the reaction: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$
   Write the equilibrium constant for this reaction in terms of the equilibrium constants, Ka and Kb, for reactions 1 and 2 below:

   1. $N_2(g) + 2\ O_2(g) \rightleftharpoons N_2O_4(g)$ ..... K_a
   2. $1/2\ N_2(g) + O_2(g) \rightleftharpoons NO_2(g)$ ..... K_b

   a. K_a/K_b
   b. K_a^2/K_b
   c. K_b/K_a
   d. K_b/K_a^2
   e. K_b^2/K_a

2. The equilibrium constant, K_c, for the following reaction is 16.4 at 768 K:
   $$2\ NH_3(g) \rightleftharpoons N_2(g) + 3\ H_2(g)$$
   Calculate K_c at this temperature for:
   $$1/2\ N_2(g) + 3/2\ H_2(g) \rightleftharpoons NH_3(g)$$

   a. 268.96
   b. 4.05
   c. 0.25
   d. 0.06
   e. 0.03

3. Consider the following reaction where $K_c = 55.6$ at 698 K:
   $$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$$
   A reaction mixture was found to contain $4.05 \cdot 10^{-2}$ moles of $H_2(g)$, $4.21 \cdot 10^{-2}$ moles of $I_2(g)$ and 0.269 moles of HI(g), in a 1.00 Liter container. Which of the following statements is true?

   a. In order to reach equilibrium HI(g) must be consumed.
   b. In order to reach equilibrium K_c must decrease.
   c. In order to reach equilibrium H_2 must be produced.
   d. Q is less than K.
   e. The reaction is at equilibrium. No further reaction will occur.

4. The pH of an aqueous solution of 0.159 M sodium cyanide, NaCN (aq), is ($K_b(CN^-) = 2.5 \cdot 10^{-5}$)

   a. 0.80
   b. 2.70
   c. 4.60
   d. 9.40
   e. 11.30

5. We examine the following reaction at 250 ºC: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$. At equilibrium we find $[PCl_5] = 3.4 \times 10^{-5}$ M, $[PCl_3] = 1.3 \times 10^{-2}$ M, and $[Cl_2] = 1.0 \times 10^{-4}$ M. Calculate the equilibrium constant, K_C, for the reaction.

   a. 26
   b. 5.1
   c. 0.15
   d. 0.038
   e. 2.8×10^{-4}

6. A chemist prepared a sealed tube with 0.85 atm of PCl_5 at 500 K. The pressure increased as the following reaction occurred. When equilibrium was achieved, the pressure in the tube had increased to 1.25 atm. Calculate K_p.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

   a. 0.36
   b. 0.19
   c. 0.10
   d. 0.047
   e. 0.089

7. A mixture of 0.30 mol NO and 0.30 mole CO_2 is placed in a 2.00 L flask and allowed to reach equilibrium at a given temperature. Analysis of the equilibrium mixture indicated that 0.10 mol of CO was present. Calculate K_C for the reaction.

$$NO(g) + CO_2(g) \rightleftharpoons NO_2(g) + CO(g)$$

   a. 0.033
   b. 0.05
   c. 0.25
   d. 1.1
   e. 0.33

8. A 2.00 liter flask is filled with 1.5 mole SO_3, 2.5 mole SO_2, and 0.5 mole O_2, and allowed to reach equilibrium. At this temperature, $K_C = 1.0$. Predict the effect on the concentration of O_2 as equilibrium is being achieved by using Q, the reaction quotient.

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$$

   a. $[O_2]$ will increase because $Q < K$
   b. $[O_2]$ will increase because $Q > K$
   c. $[O_2]$ will decrease because $Q < K$
   d. $[O_2]$ will decrease because $Q > K$
   e. $[O_2]$ will remain the same because $Q = K$

9. Consider the reaction $2A(g) \rightleftharpoons B(g)$ where $K_C = 0.5$ at the temperature of the reaction. If 2.0 moles of A and 2.0 moles of B are introduced into a 1.00 liter flask, what change in concentrations (if any) would occur in time?

a. [A] increases and [B] increases
b. [A] increases and [B] decreases
c. [A] decreases and [B] increases
d. [A] decreases and [B] decreases
e. [A] and [B] remain the same

10. Consider the reaction $A(g) \rightleftharpoons 2B(g)$ where $K_C = 1.5$ at the temperature of the reaction. If 3.0 moles of A and 3.0 moles of B are introduced into a 1.00 liter flask, what change in concentrations (if any) would occur in time?

a. [A] increases and [B] increases
b. [A] increases and [B] decreases
c. [A] decreases and [B] increases
d. [A] decreases and [B] decreases
e. [A] and [B] remain the same

11. Exactly 0.50 mole of sulfur trioxide, 0.10 mole of sulfur dioxide, 0.20 mole of nitrogen monoxide and 0.30 mole nitrogen dioxide are sealed in a 1.0-L flask at 1500 ºC. The equilibrium constant K_C is 0.24 for the following reaction.

$$SO_3(g) + NO(g) \rightleftharpoons SO_2(g) + NO_2(g) \qquad K_C = 0.24$$

When equilibrium is achieved, what changes in concentrations of SO_3 and NO will be observed?

a. [SO_3] increases; [NO] increases
b. [SO_3] increases; [NO] decreases
c. [SO_3] decreases; [NO] decreases
d. [SO_3] decreases; [NO] increases
e. all concentrations remain the same

12. A flask contains the following system at equilibrium:

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2\ OH^-(aq)$$

Which of the following reagents could be added to increase the solubility of $Mg(OH)_2$?

a. NH_3
b. NaOH
c. HCl
d. H_2O
e. $MgCl_2$

13. All of the following can function both as an acid and base **EXCEPT**

a. HPO_4^{2-}
b. $H_2PO_4^-$
c. HCO_2^-
d. OH^-
e. CH_3COO^-

14. The $K_a(HCO_3^-)$ is the equilibrium constant for the reaction

a. $H_2CO_3 + H_2O \rightleftharpoons H_3O^+ + HCO_3^-$
b. $HCO_3^- + H_2O \rightleftharpoons H_3O^+ + CO_3^{2-}$
c. $HCO_3^- + H_2O \rightleftharpoons H_2CO^- + OH^-$
d. $HCO_3^- + H_3O^+ \rightleftharpoons H_2CO^- + H_2O$
e. $HCO_3^- + OH^- \rightleftharpoons CO_3^{2-} + H_2O$

15. What is the pH of a 0.054 M NaOH solution at 25 ºC?

a. 1.14
b. 1.27
c. 8.64
d. 12.73
e. 13.95

16. We have a 4.63×10^{-4} M solution of HCl. What is the pH of this solution at 25 ºC?

a. 3.33
b. 4.00
c. 4.63
d. 8.37
e. 9.25

17. A 0.20 M solution of an acid, HA, has a pH of 3.82 at 25 ºC. What is K_a for this acid?

a. 7.6×10^{-4}
b. 4.5×10^{-5}
c. 1.1×10^{-7}
d. 2.3×10^{-8}
e. 4.5×10^{-9}

18. What is the pH of a 1.86 M $CH_3CH_2CO_2H$ solution at 25 ºC? $K_a = 1.3 \cdot 10^{-5}$

a. 4.92
b. 4.88
c. 2.42
d. 2.31
e. 2.08

19. In the following reaction

$$NH_4^+(aq) + H_2O(l) \leftrightarrow NH_3(aq) + H_3O^+(aq)$$

a. NH_4^+ is an acid and NH_3 is its conjugate base.
b. H_2O is an acid and H_3O^+ is its conjugate base.
c. NH_4^+ is an acid and H_3O^+ is its conjugate base.
d. H_2O is an acid and NH_4^+ is its conjugate base.
e. NH_3 is an acid and NH_4^+ is its conjugate base.

20. At 25 ºC, what is the pH of a 3.25 M solution of ammonium chloride, NH_4Cl? $K_a(NH_4^+) = 5.6 \cdot 10^{-10}$

a. 2.37
b. 4.37
c. 4.62
d. 9.37
e. 9.63