**Turn off all cell phones. Be sure the person sitting on either side of you has a DIFFERENT COLORED exam. You may write on the exam. Be sure to write your name on the exam and on your Green Scantron and to include the COLOR of your exam on the Scantron. When finished, turn in both the exam and the Scantron.**

1. Which of the following statements is true in a reaction system at equilibrium?
   A) The number of collisions per unit time between reactants is equal to the number of collisions per unit time between products.
   B) Reactants are reacting to form products at the same rate as products are reacting to form reactants.
   C) The product of the concentrations of the products divided by the product of the concentrations of the reactants is always a constant.
   D) Reactants and products are present in equimolar amounts.
   E) The equilibrium constant is a positive number.

2. A 25.0-L vessel at 700 K initially contains $HI(g)$ at a pressure of 3.60 atm; at equilibrium, it is found that the partial pressure of $H_2(g)$ is 0.348 atm. What is the partial pressure of $HI(g)$ at equilibrium?
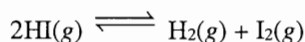
   $$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$
   A) 3.60 atm
   B) 3.25 atm
   C) 0.348 atm
   D) 2.90 atm
   E) 3.95 atm

3. Which of the following can we predict from an equilibrium constant for a reaction?
   1. The extent of a reaction
   2. Whether the reaction is fast or slow
   3. Whether the reaction is exothermic or endothermic
   A) 1 only
   B) 2 only
   C) 3 only
   D) 1 and 2 only
   E) 1 and 3 only

4. What is the expression for K_c for the following equilibrium?
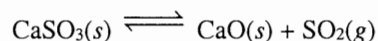
   $$CaSO_3(s) \rightleftharpoons CaO(s) + SO_2(g)$$
   A) $\dfrac{[CaO][SO_2]}{[CaSO_3]}$
   B) $[CaO][SO_2]$
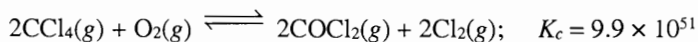   C) $[SO_2]$
   D) $\dfrac{1}{[SO_2]}$
   E) $\dfrac{[CaSO_3]}{[CaO][SO_2]}$

5. For the reaction $Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g)$, at equilibrium, it is found that the concentrations of Br_2, Cl_2, and $BrCl$ are 0.271 M, 0.191 M, and 1.25×10^{-3} M, respectively. What is the value of K_c?
   A) 2.41×10^{-2}
   B) 3.01×10^{-5}
   C) 3.32×10^4
   D) 1.20×10^{-4}
   E) 4.15×10^1

6. For which of the following reactions are the numerical values of K_p and K_c the same?

   1. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

   2. $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

   3. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
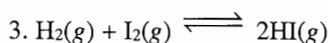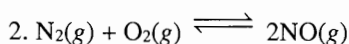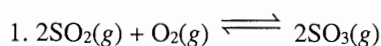
   A) 1 only
   B) 2 only
   C) 1 and 2 only
   D) 2 and 3 only
   E) 1, 2, and 3

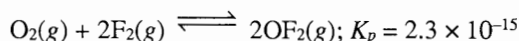7. Carbon tetrachloride may react with oxygen to produce chlorine and carbonyl chloride.

   $2CCl_4(g) + O_2(g) \rightleftharpoons 2COCl_2(g) + 2Cl_2(g); \quad K_c = 9.9 \times 10^{51}$
   What is K_c for the following equilibrium?

   $COCl_2(g) + Cl_2(g) \rightleftharpoons CCl_4(g) + \frac{1}{2}O_2(g)$
   A) -9.9×10^{51}
   B) 1.0×10^{-26}
   C) 9.9×10^{-51}
   D) 1.0×10^{-52}
   E) 5.0×10^{-53}

8. Consider the following equilibrium:

   $O_2(g) + 2F_2(g) \rightleftharpoons 2OF_2(g); K_p = 2.3 \times 10^{-15}$
   Which of the following statements is true?
   A) If the reaction mixture initially contains only $OF_2(g)$, then the total pressure at equilibrium will be less than the total initial pressure.
   B) If the reaction mixture initially contains only $O_2(g)$ and $F_2(g)$, then at equilibrium, the reaction mixture will consist of essentially only $OF_2(g)$.
   C) If the reaction mixture initially contains only $O_2(g)$ and $F_2(g)$, then the total pressure at equilibrium will be greater than the total initial pressure.
   D) If the reaction mixture initially contains only $OF_2(g)$, then at equilibrium, the reaction mixture will consist of essentially only $O_2(g)$ and $F_2(g)$.
   E) For this equilibrium, $K_c = K_p$.

9. For which of the following reactions will the reactant experience the largest degree of decomposition upon reaching equilibrium at 500 K?

   A) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g); K_p = 1.3 \times 10^{-5}$

   B) $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g); K_p = 1.7 \times 10^{-2}$

   C) $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g); K_p = 5.9 \times 10^{-5}$

   D) $2NOF(g) \rightleftharpoons 2NO(g) + F_2(g); K_p = 1.2 \times 10^{-26}$

   E) $2NO_2F(g) \rightleftharpoons 2NO_2(g) + F_2(g); K_p = 6.6 \times 10^{-22}$
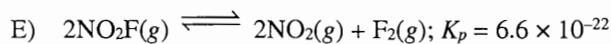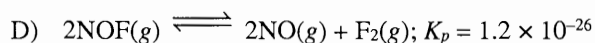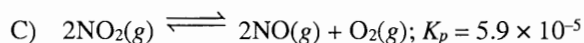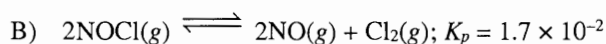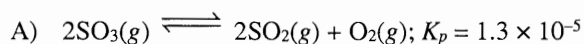
10. For the reaction $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$, $K_c = 9.1 \times 10^2$ at 750 K. What will happen when 0.10 mol of H_2S, 1.0 mol of H_2, and 1.5 mol of S_2 are added to a 1.0-L container and the system is brought to 750 K?
    A) Nothing; the system is at equilibrium.
    B) More H_2S will be formed.
    C) More H_2 will be formed than S_2.
    D) More S_2 will be formed than H_2.
    E) The amount of H_2 formed will be half the amount of S_2 formed.

11. For the following reaction system at equilibrium, which one of the changes below would cause the equilibrium to shift to the right?

$Br_2(g) + 2NO(g) \rightleftharpoons 2NOBr(g)$; $\Delta H° = -30$ kJ
A) Increase the volume of the reaction vessel.
B) Remove some NO.
C) Add some NOBr.
D) Remove some Br_2.
E) Decrease the temperature.

12. What is a conjugate acid–base pair for the following equilibrium?

$H_2O(l) + HPO_4^{2-}(aq) \rightleftharpoons H_2PO_4^-(aq) + OH^-(aq)$
A) H_2O is an acid and OH^- is its conjugate base.
B) H_2O is an acid and HPO_4^{2-} is its conjugate base.
C) HPO_4^{2-} is an acid and OH^- is its conjugate base.
D) HPO_4^{2-} is an acid and $H_2PO_4^-$ is its conjugate base.
E) HPO_4^{2-} is an acid and H_2O is its conjugate base.

13. Which of the following species cannot act as a Lewis base?
A) Be^{2+}
B) O^{2-}
C) OH^-
D) H_2O
E) H_2O_2

14. What is the leveling effect?
A) All acids are 100% ionized in solvents other than water.
B) All strong acids are 100% ionized in water.
C) An acid with a higher concentration in water has a lower pH than an acid with a lower concentration in water.
D) A base with a higher concentration in water has a lower pH than a base with a lower concentration in water.
E) All bases are 100% ionized in water.

15. At 0°C, the ion-product constant of water, K_w, is 1.23×10^{-15}. What is the pH of pure water at 0°C?
A) 7.000
B) 7.555
C) 6.875
D) 7.455
E) none of these

16. What is the pOH of a 0.027 M HI solution?
A) 15.57
B) 1.57
C) 10.39
D) 12.43
E) 3.61

17. Which solution has the highest pH?
A) 0.1 M HCl
B) 0.1 M Ba(OH)$_2$
C) 0.1 M NH$_3$
D) 0.1 M CH$_3$COOH
E) 0.1 M NaOH

18. Rank acetic acid ($HC_2H_3O_2$), hydrocyanic acid (HOCN), and hydrofluoric acid (HF) in order of increasing strength.

Acid	K_a
$HC_2H_3O_2$	1.8×10^{-5}
HOCN	3.5×10^{-4}
HF	6.8×10^{-4}

   A) $HC_2H_3O_2 < HOCN < HF$
   B) $HOCN < HC_2H_3O_2 < HF$
   C) $HF < HOCN < HC_2H_3O_2$
   D) $HF < HC_2H_3O_2 < HOCN$
   E) $HOCN < HF < HC_2H_3O_2$

19. What is the percent ionization of a 0.13 M butanoic acid, $HC_4H_7O_2$, solution ($K_a = 1.5 \times 10^{-5}$) at 25°C?
   A) 0.13%
   B) 1.1%
   C) 3.0%
   D) 2.3%
   E) 5.5%

20. What is the hydronium-ion concentration of a 0.25 M solution of HCN ($K_a = 4.9 \times 10^{-10}$) at 25°C?
   A) $2.1 \times 10^{-6}\ M$
   B) $3.3 \times 10^{-6}\ M$
   C) $1.1 \times 10^{-5}\ M$
   D) $4.4 \times 10^{-5}\ M$
   E) $1.6 \times 10^{-4}\ M$

21. What is the hydronium-ion concentration in a 0.028 M solution of carbonic acid, H_2CO_3? For carbonic acid, $K_{a1} = 4.2 \times 10^{-7}$ and $K_{a2} = 4.8 \times 10^{-11}$.
   A) $5.4 \times 10^{-5}\ M$
   B) $2.8 \times 10^{-2}\ M$
   C) $4.8 \times 10^{-11}\ M$
   D) $1.1 \times 10^{-4}\ M$
   E) $4.2 \times 10^{-7}\ M$

22. What is the pOH of a 0.30 M solution of pyridine ($K_b = 1.4 \times 10^{-9}$) at 25°C?
   A) 10.80
   B) 4.69
   C) 8.85
   D) 4.17
   E) 1.05

23. Which of the following equilibria best represents the hydrolysis reaction that occurs in an aqueous solution of KNO_2?

   A) $K^+(aq) + H_2O(l) \rightleftharpoons KOH(aq) + H^+(aq)$

   B) $NO_2^-(aq) + H_2O(l) \rightleftharpoons HNO_2(aq) + OH^-(aq)$

   C) $K^+(aq) + NO_2^-(aq) + H_2O(l) \rightleftharpoons KOH(aq) + HNO_2(aq)$

   D) $NO_2^-(aq) + H_2O(l) \rightleftharpoons HNO_3(aq) + 2H^+(aq)$

   E) $NO_2^-(aq) + H_3O^+(aq) \rightleftharpoons HNO_2(aq) + H_2O(l)$

24. Which of the following salts will produce a basic solution when added to pure water?
   A) NH_4Br
   B) NaCl
   C) $KHSO_4$
   D) Li_2S
   E) CsI