Answer the first twenty questions on your Scantron sheet. Be sure to include your name on both the Scantron and this test paper. Include your form letter (A or B) on the Scantron. Multiple choice questions are worth two points each.

1. An increase in temperature causes the rate of a reaction to increase because:
   a. reactant molecules collide less frequently
   b. the activation energy is lowered
   c. reactant molecules collide less frequently and with greater energy per collision
   d. reactant molecules collide more frequently and with less energy per collision
   e. reactant molecules collide with greater energy per collision

2. In the Arrhenius equation \( k = Ae^{\frac{-E_a}{RT}} \) the activation energy is represented by:
   a. \( A \)
   b. \( k \)
   c. \( E_a \)
   d. \( T \)
   e. \( R \)

3. In the Arrhenius equation (question 3), the units for \( k \) will be:
   a. the same as \( A \)
   b. the same as \( R \)
   c. \( \text{Ms}^{-1} \)
   d. \( \text{M}^{-1}\text{s}^{-1} \)
   e. \( \text{s}^{-1} \)

4. Consider a hypothetical reaction: \( 2 \text{A(g)} \rightleftharpoons \text{B(g)} \). Which of the following statements will be true when the system is at equilibrium?
   a. \([A] = [B]\)
   b. \([A] = 2[B]\)
   c. \(2[A] = [B]\)
   d. the rate of formation of A is twice that of B
   e. the rates of the forward and reverse reactions are equal.

5. The relationship between the equilibrium constant, \( K_c \), and the forward rate constant \( (k_f) \) and the reverse rate constant \( (k_r) \) is \( K_c = \)______:
   a. \( k_f + k_r \)
   b. \( \frac{k_f}{k_r} \)
   c. \( k_r - k_f \)
   d. \( k_fk_r \)
   e. \( \frac{k_r}{k_f} \)
6. The value of $K_c$ for the reaction below at a particular temperature is 0.25.

$$\text{SO}_2 (g) + \text{NO}_2 (g) \rightleftharpoons \text{SO}_3 (g) + \text{NO} (g)$$

What is the value of $K_c$ for the reaction:

$$2 \text{SO}_3 (g) + 2 \text{NO} (g) \rightleftharpoons 2 \text{SO}_2 (g) + 2 \text{NO}_2 (g)$$

a. 16.0  
b. 0.25  
c. 0.125  
d. 0.50  
e. 8.0

7. Which of the following equilibria will shift to the left in response to a decrease in volume?
   a. $\text{N}_2 (g) + 3 \text{H}_2 (g) \rightleftharpoons 2 \text{NH}_3 (g)$  
   b. $\text{H}_2 (g) + \text{Cl}_2 (g) \rightleftharpoons 2 \text{HCl} (g)$  
   c. $2 \text{SO}_3 (g) \rightleftharpoons 2 \text{SO}_2 (g) + \text{O}_2 (g)$  
   d. $2 \text{HI} (g) = \text{H}_2 (g) + \text{I}_2 (g)$  
   e. $4 \text{Fe} (s) + 3 \text{O}_2 (g) \rightleftharpoons 2 \text{Fe}_2\text{O}_3 (s)$

8. Consider the following reaction at equilibrium:

$$2 \text{SO}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2 \text{SO}_3 (g) + \text{heat}$$

LeChatelier’s principle predicts that an increase in temperature will result in

a. an increase in $K_c$  
b. a decrease in the number of moles of SO$_2$ present  
c. a decrease in the number of moles of SO$_3$ present  
d. no changes in the pressures of the components of the equilibrium  
e. a decrease in the number of moles of O$_2$ present

9. According to the Arrhenius concept of acids and bases,
   a. an acid generates hydrogen ions and a base generates hydroxide ions in water  
   b. an acid donates hydrogen ions and a base accepts hydrogen ions  
   c. an acid generates hydrogen ions and a base accepts hydroxide ions in water  
   d. an acid accepts hydrogen ions and a base donates hydrogen ions  
   e. an acid accepts an electron pair and a base donates an electron pair

10. According to the Bronsted-Lowry concept of acids and bases,
    a. an acid generates hydrogen ions and a base generates hydroxide ions in water  
    b. an acid donates hydrogen ions and a base accepts hydrogen ions  
    c. an acid generates hydrogen ions and a base accepts hydroxide ions in water  
    d. an acid accepts hydrogen ions and a base donates hydrogen ions  
    e. an acid accepts an electron pair and a base donates an electron pair
11. The pH of a particular solution is 5.04. Of the following list, which substance is the only one that could produce this solution?
   a. NaNO₃
   b. BaCl₂
   c. Ca(C₂H₃O₂)₂
   d. KF
   e. NH₄Cl

12. The substance Ca(NO₃)₂ in aqueous solution is:
   a. a salt, strong electrolyte, and soluble
   b. a salt, weak electrolyte, and soluble
   c. a salt, strong electrolyte, and insoluble
   d. a base, strong electrolyte, and soluble
   e. a salt, weak electrolyte, and insoluble

13. The substance AgCl in aqueous solution is:
   a. a salt, strong electrolyte, and soluble
   b. a base, strong electrolyte, and soluble
   c. a salt, strong electrolyte, and insoluble
   d. a salt, weak electrolyte, and soluble
   e. a salt, weak electrolyte, and insoluble

14. The substance MnCl₂ in aqueous solution will produce
   a. an basic solution
   b. a neutral solution
   c. an acidic solution
   d. it is not soluble – will not produce a solution

15. When calculating the pH of a solution of NaC₂H₃O₂, the equation that represents the equilibrium of most interest is:
   a. HC₂H₃O₂ (aq) + HOH (l) = C₂H₃O₂⁻ (aq) + H₃O⁺ (aq)
   b. Na⁺ (aq) + HOH (l) = NaOH (aq) + H⁺ (aq)
   c. C₂H₃O₂⁻ (aq) + HOH (l) = HC₂H₃O₂ (aq) + OH⁻ (aq)
   d. Na⁺ (aq) + C₂H₃O₂⁻ (aq) = NaC₂H₃O₂ (aq)

16. An aqueous solution of 0.1 M HCN will have a pH that is:
   a. less than 1.0
   b. 1.0
   c. greater than 1.0 but less than 7.0
   d. greater than 7.0 but less than 13.0

17. An aqueous solution of 0.1 M NaOH will have pH that is:
   a. 1.0
   b. 13.0
   c. less than 1.0
   d. greater than 1.0 but less than 7.0
   e. greater than 7.0 but less than 13.0
18. Which of the following is the strongest acid?
   a. H₂Se
   b. HI
   c. HBr
   d. H₃As
   e. HCl

19. Consider the following equilibrium:

   \[ \text{N}_2\text{O}_4 (g) \rightleftharpoons 2 \text{NO}_2 (g) \]

   The equilibrium constant, \( K_c \), at a particular temperature is 0.211. A vessel is composed initially of 0.12 M NO₂ and 0.25 M N₂O₄. Which of the following will occur?
   a. More moles of NO₂ will be formed
   b. More moles of N₂O₄ will be formed
   c. The number of moles of N₂O₄ and NO₂ will remain the same

20. The base-dissociation constant, \( K_b \), for pyridine, C₅H₅N, is 1.4 \times 10^{-9}. The acid-dissociation constant, \( K_a \), for the pyridinium ion, C₅H₅NH⁺, is
   a. 1.0 \times 10^{-7}
   b. 1.4 \times 10^{-23}
   c. 7.1 \times 10^{-4}
   d. 1.4 \times 10^{-5}
   e. 7.1 \times 10^{-6}
Problems. Show your work on numerical problems to receive credit. Each problem is worth 10 points.

21. a. Give the formula for the conjugate base of each of the following acids.

- HCl __________
- HC$_2$H$_3$O$_2$ ______________
- HCO$_3^-$ __________
- H$_3$PO$_4$ ______________
- NH$_4^+$ __________

b. Give the formula for the conjugate acid of each of the following bases.

- H$_2$O __________
- HCO$_3^-$ __________
- NO$_2^-$ __________
- F$^-$ __________
- NH$_3$ __________

22. Consider the following equilibrium:

$$H_2 (g) + I_2 (g) \rightleftharpoons 2 HI (g)$$

A vessel is mixed initially with 0.10 M H$_2$, 0.20 M I$_2$, and no HI. After the system comes to equilibrium, the concentration of HI in the vessel is 0.15 M. What are the values of $K_c$ and $K_p$ for this reaction?
23. Find the pH, pOH, \([\text{H}_3\text{O}^+]\), and \([\text{OH}^-]\) for each of the following solutions. \(K_a\) and \(K_b\) values are found at the end of this document.

0.25 M \(\text{HClO}\):

0.125 M \(\text{Ba(NO}_2\text{)}_2\):

0.095 M \(\text{HONH}_2\):
24.  a.  A solution is made by dissolving HC₂H₃O₂ in a quantity of water.  The pH of the resulting solution is 3.00.  What is the concentration of the HC₂H₃O₂?

b.  Phenylacetic acid (HC₈H₇O₂) is one of the substances that accumulates in the blood of people with phenylketonuria, an inherited disorder.  A 0.085 M solution of HC₈H₇O₂ is found to have a pH of 2.68.  Calculate the Ka for this acid.
Information Sheet

\[ k = Ae^{-\frac{E_a}{RT}} \]

\( K_a \) for HClO = \( 3.0 \times 10^{-8} \)

\( K_a \) for HNO\(_2\) = \( 4.5 \times 10^{-4} \)

\( K_b \) for HONH\(_2\) = \( 1.1 \times 10^{-8} \)