Answer the first twenty questions on your Scantron sheet. Be sure to include your name on both the Scantron and this test paper. Multiple choice questions are worth two points each.

1. Which of the following would you expect to have the highest boiling point at atmospheric pressure?
   a. CH₄
   b. CH₃Cl
   c. CHCl₃
   d. CH₂Cl₂

2. Which of the following molecules would you expect to NOT have significant dipole-dipole interactions in its condensed phase?
   a. CH₄
   b. CH₂Cl₂
   c. HCN
   d. NH₃
   e. H₂O

3. What are the intermolecular forces present in the compound:

   CH₃OCH₃

   a. only dispersion forces
   b. only dispersion forces and hydrogen bonding
   c. only dispersion forces, dipole-dipole, and hydrogen bonding
   d. only dispersion forces and dipole-dipole
   e. only dipole-dipole and hydrogen bonding

4. Which of the following aqueous solutions would be expected to have the lowest freezing point?
   a. 0.05 m NaOH
   b. 0.12 m Ba(OH)₂
   c. 0.18 m HF
   d. 0.15 m LiCl
   e. 0.10 m KNO₃

5. Properties of a solution that depend on the concentration of a solute and not its identity are called
   a. physical properties
   b. chemical properties
   c. colligative properties
   d. extensive properties
   e. intensive properties
6. The method of choice for determining the molecular weight of a large molecule, such as an enzyme, is:
   a. freezing point depression
   b. osmotic pressure
   c. vapor pressure lowering
   d. paper chromatography
   e. boiling point elevation

7. Suppose an initial rate experiment is performed on the reaction \( A + B \rightarrow \text{Products} \) in an effort to determine the rate law. The following results are obtained.

<table>
<thead>
<tr>
<th>Experiment #</th>
<th>[A]/M</th>
<th>[B]/M</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.15</td>
<td>0.00450</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.30</td>
<td>0.00900</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>0.15</td>
<td>0.01800</td>
</tr>
</tbody>
</table>

What is the rate law for the reaction?

a. \( \text{Rate} = k [A][B] \)
b. \( \text{Rate} = k [A]^2 [B] \)
c. \( \text{Rate} = k [A] [B]^2 \)
d. \( \text{Rate} = k [A]^2 [B]^2 \)

8. What is the value of the rate constant, including units, for the reaction in question 7?

a. \( 0.3 \text{ M}^{-1} \text{s}^{-1} \)
b. \( 3 \text{ M}^2 \text{s}^{-1} \)
c. \( 2 \text{ M}^2 \text{s}^{-1} \)
d. \( 20 \text{ M}^3 \text{s}^{-1} \)

9. For questions 9 – 11, consider the equilibrium:

\[
2 \text{ NO (g)} + \text{ O}_2 (g) \rightleftharpoons 2 \text{ NO}_2 (g) \quad \Delta H = -113 \text{ kJ/mol}
\]

A vessel contains the components above at equilibrium. Which of the following changes would result in an increase in the equilibrium amount of \( \text{NO}_2 \) present?

a. the addition of a catalyst
b. an increase in temperature
c. the addition of more \( \text{NO} \)
d. the removal of oxygen through an adsorption process
e. an increase in the volume of the container
10. If the vessel is initially at equilibrium (see question 9), which of the following changes would result in an increase in the equilibrium amount of NO present?
   
   a. an increase in temperature
   b. the removal of O₂ through an adsorption process
   c. a decrease in the volume of the container
   d. answers b and c
   e. answers a, b, and c

11. Suppose \( K_p \) for the above reaction (see question 9) is \( 1.48 \times 10^4 \) at 184 \( \text{E}^\circ \). Which of the following statements is true regarding \( K_p \) at a temperature of 250 \( \text{E}^\circ \)?
   
   a. The value of \( K_p \) would still be \( 1.48 \times 10^4 \) at 250 \( \text{E}^\circ \).
   b. The value of \( K_p \) would be smaller than \( 1.48 \times 10^4 \) at 250 \( \text{E}^\circ \).
   c. The value of \( K_p \) would be larger than \( 1.48 \times 10^4 \) at 250 \( \text{E}^\circ \).
   d. No conclusions regarding the relative size of \( K_p \) can be drawn.

12. A solution of which of the following substances will be acidic?
   
   a. NH₄NO₃
   b. KNO₃
   c. CaCl₂
   d. BaO
   e. NH₃

13. A solution of which of the following substances will be basic?
   
   a. NH₄NO₃
   b. BaCl₂
   c. FeCl₃
   d. NaC₂H₃O₂
   e. HBr

14. The titration of a weak base by a strong acid has the following characteristics:
   
   a. Initially high pH, equivalence point at pH = 7
   b. Initially high pH, equivalence point at pH < 7
   c. Initially high pH, equivalence point at pH > 7
   d. Initially low pH, equivalence point at pH < 7
   e. Initially low pH, equivalence point at pH > 7
15. The titration of a strong acid by a strong base has the following characteristics:
   a. Initially low pH, equivalence point at pH = 7
   b. Initially low pH, equivalence point at pH < 7
   c. Initially low pH, equivalence point at pH > 7
   d. Initially high pH, equivalence point at pH = 7
   e. Initially high pH, equivalence point at pH > 7

16. Representing the concentration of LaF₃ that dissolves by the letter “s”, the solubility of LaF₃ could be determined from the following expression where K_{sp} represents the solubility product of LaF₃.
   a. \( s = \sqrt{K_{sp}} \)
   b. \( s = \frac{4}{\sqrt{K_{sp}}} \)
   c. \( s = \frac{\sqrt{K_{sp}}}{9} \)
   d. \( s = \frac{\sqrt{K_{sp}}}{27} \)
   e. \( s = \frac{4}{\sqrt{27}K_{sp}} \)

17. The heat flow determined in bomb calorimetry is most directly related to:
   a. the enthalpy change in the combustion process
   b. the specific heats of the reactants of the combustion process
   c. the specific heats of the products of the combustion process
   d. the internal energy change in the combustion process
   e. the difference between specific heats of the products and reactants of the combustion process

18. During the course of a coffee cup calorimetry experiment, the temperature of 75.0-g of water changed from 25°C to 37.5°C. If the specific heat of water is 4.184 J/g°C, the process that heated the water evolved how much heat?
   a. 7845 J
   b. 224 J
   c. 25 J
   d. 0.7 J
   e. 3922 J
19. Given the data for the reaction below, \( \Delta H^E \) for the reaction:

\[
4 \text{NH}_3 (g) + 5 \text{O}_2 (g) \rightarrow 4 \text{NO} (g) + 6 \text{H}_2\text{O} (\text{R})
\]

is _______ kJ.

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \Delta H^E ) (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{H}_2\text{O} (\text{R}) )</td>
<td>-286</td>
</tr>
<tr>
<td>( \text{NO} (g) )</td>
<td>90</td>
</tr>
<tr>
<td>( \text{NH}_3 (g) )</td>
<td>-46</td>
</tr>
</tbody>
</table>

a. -1172  
b. -150  
c. -1540  
d. -1892  
e. The \( \Delta H^E \) of \( \text{O}_2 (g) \) is needed for the calculation.

20. Of the following, which is not a state function?

a. \( H \)  
b. \( E \)  
c. \( P \)  
d. \( T \)  
e. \( q \)

Problems. Show your work to receive full credit.

21. (6 points)

a. A particular first order reaction has a rate constant of \( 1.35 \times 10^{-3} \text{ s}^{-1} \). If the initial concentration of reactant A is 0.25 M, how much A would remain after 300 s?

b. What is the half-life of the reaction in part a of this question?
22.  (5 points)
50.0-mL of 0.100 M HCl are mixed with 50.0-mL of 0.100 M NaOH in a coffee cup calorimeter. The temperature of both solutions and the calorimeter is initially 24.5 °C. After the mixing takes place, the temperature of the mixture rises to 31.3 °C. Assume the heat capacity of the solution is the same as that of water – 4.184 J/g·°C and we can ignore the heat absorbed by the cup. Find the enthalpy change for the reaction of one mole of HCl with one mole of NaOH.

23.  (6 points) Thermochemical data are on the equation sheet.
   a. How many kJ will be evolved when 15.0-g of CO are reacted with oxygen according to the equation:
      
      \[
      2 \text{ CO (g) } + \text{ O}_2 (g) \rightarrow 2 \text{ CO}_2 (g)
      \]

   b. The enthalpy for the combustion of CH\text{4} is -890 kJ/mol. Using the thermochemical data on the equation page, find the ΔH\text{f}° for CH\text{4}.
24. (6 points) Appropriate $K_a$ and $K_b$ values are given on the equations page.

a. Find the pH of a solution of 0.125 M HCN.

b. Find the pH of a solution of 0.375 M NaOH.

c. Find the pH of a solution of 0.450 M NH$_4$Cl.

d. Find the pH of a solution that is 0.15 M HF and 0.075 M NaF.
Formulas to be given with Test #3 (CHEM 1474):

\[ P_A = X_A P_A^\circ \]

**K_a** values:
- HCN \( 4.9 \times 10^{-9} \)
- HF \( 6.8 \times 10^{-4} \)

\[ \Delta T_f = K_{a_m} \]

\[ \Delta T_b = K_{b_m} \]

**K_b** values:
- \( \text{NH}_3 \) \( 1.8 \times 10^{-5} \)

\[ \Pi = MRT \]

\[ \ln \left( \frac{[A]_b}{[A]} \right) = kt \]

\[ \frac{1}{[A]} - \frac{1}{[A]_o} = kt \]

\[ t_{1/2} = \frac{\ln 2}{k} \]

\[ t_{1/2} = \frac{1}{k[A]_o} \]

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

\[ \ln \frac{k_1}{k_2} = \frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right) \]

\[ pH = pK_a + \log \left( \frac{[X^-]}{[HX]} \right) \]

**Thermochemical data:**

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \Delta H_f^\circ ) (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_2) (g)</td>
<td>-393.5</td>
</tr>
<tr>
<td>H(_2)O (l)</td>
<td>-285.8</td>
</tr>
<tr>
<td>CO (g)</td>
<td>-110.5</td>
</tr>
</tbody>
</table>

\[ R = 0.08206 \text{ L} \cdot \text{atm/mol} \cdot \text{K} = 8.314 \text{ J/mol} \cdot \text{K} \]