Instructions:

Do not begin until 8:30 AM. The exam must be turned in by 9:20 AM.

⇒ The exam has 25 questions. Each question is worth 4 points for a total of 100 points. A periodic table is located on the last page.

⇒ Use only a #2 pencil to mark the answer on the ScanTron sheet. You will turn in only the ScanTron sheet and you can keep the rest of the exam. Your exam results will be emailed to you. You can check your answers with the answer key that will be posted on-line immediately after the exam on my website under Exam Scores and Statistics.

⇒ On the ScanTron sheet print your name and identification number in the areas indicated. Indicate a four character code (any combination of letters and numbers) under "version#" for the purpose of reporting final grades.

Equations:

For the reaction: \[ aA + bB \rightarrow cC + dD \]

1st order reactions:

\[ \ln [A]_t = -kt + \ln [A]_o \]

\[ t_{1/2} = \frac{0.693}{k} \]

2nd order reactions:

\[ \frac{1}{[A]_t} = kt + \frac{1}{[A]_o} \]

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

Arrhenius:

\[ \ln k = -(E_a/RT) + \ln A \]

\[ \ln (k_1/k_2) = E_a/R (1/T_2 - 1/T_1) \]

\[ R = 8.314 \text{ J/mol·K} \]

\[ K_p = K_c(RT)^{Δn} \]

\[ (R = 0.0821 \text{ L·atm/mol·K}) \]

\[ K_w = 1.0 \times 10^{-14}; \text{ pH} = -\log[H^+] \]
1. A catalyst increases reaction rate ____________.
   a) by decreasing the heat of reaction
   b) by increasing the activation energy of the forward reaction
   c) by changing the average kinetic energy distribution of molecules
   d) by lowering the activation energy of the reaction

2. Nitrosyl bromide decomposes according to the following equation:

\[ 2 \text{NOBr}(g) \rightleftharpoons 2 \text{NO}(g) + \text{Br}_2(g) \]

A sample of NOBr (0.64 mol) was placed in a 1.00 L flask containing no NO or Br₂. At equilibrium the flask contained 0.46 mol of NOBr. How many moles of NO and Br₂, respectively, are in the flask at equilibrium?

a) 0.18, 0.18
   b) 0.46, 0.23
   c) 0.18, 0.090
   d) 0.18, 0.360

3. For a first order reaction, a plot of ____ versus ____ is linear.
   a) ln [A], 1/t
   b) ln [A], t
   c) 1/[A], t
   d) [A], t

4. What is the conjugate acid of NH₃?
   a) NH₂⁺
   b) NH₃⁺
   c) NH₄⁺
   d) NH₄OH

5. If the reaction 2A + 3B → products is first order in A and second order in B, then the rate law will be:
   a) Rate = k[A][B]
   b) Rate = k[A][B]²
   c) Rate = k[A]²[B]
   d) Rate = k[A]²[B]²
6. Which of the following does not play a part in determining the rate of a reaction?

   a) temperature
   b) the concentrations of reactants
   c) the presence of a catalyst
   d) the equilibrium constant

7. What is the pH of an aqueous solution at 25 °C in which [OH⁻] is 0.0025 M?

   a) +2.60
   b) -2.60
   c) +11.40
   d) -11.40

8. At a certain temperature, a flask at equilibrium contains 0.0114 M HCl, 0.0931 M Cl₂, and 0.0154 M H₂. What is the value of K_c for the equilibrium:

   \[ 2 \text{HCl}(g) \rightleftharpoons \text{Cl}_2(g) + \text{H}_2(g) \]

   a) 0.0909
   b) 11.0
   c) 1.63 \times 10^{-5}
   d) 0.126

9. Use the information below to determine the order of the reaction in reactant A.

   \[ \text{A} + \text{B} \rightarrow \text{P} \]

<table>
<thead>
<tr>
<th>Experiment Number</th>
<th><a href="M">A</a></th>
<th><a href="M">B</a></th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.273</td>
<td>0.763</td>
<td>2.83</td>
</tr>
<tr>
<td>2</td>
<td>0.273</td>
<td>1.526</td>
<td>2.83</td>
</tr>
<tr>
<td>3</td>
<td>0.819</td>
<td>0.763</td>
<td>25.47</td>
</tr>
</tbody>
</table>

   a) 1
   b) 4
   c) 2
   d) 3
10. The magnitude of $K_w$ at 25 °C indicates that:

a) water autoionizes very slowly  
b) water autoionizes very quickly  
c) water autoionizes only to a very small extent  
d) the autoionization of water is exothermic

11. The activation energy of a first-order reaction that has a rate constant of $4.41 \times 10^{-3}$ s$^{-1}$ at 351K and rate constant of $9.79 \times 10^{-2}$ s$^{-1}$ at 588K is _______ kJ/mol.

a) 2.67  
b) 2.90  
c) 0.0589  
d) 22.4

12. The reaction $\text{CH}_3\text{-N}≡\text{C} \rightarrow \text{CH}_3\text{-C}≡\text{N}$ is a first-order reaction. At 230.3 °C, $k = 6.29 \times 10^{-4}$ s$^{-1}$. If $[\text{CH}_3\text{-N}≡\text{C}]_0$ is 0.00100 M, the $[\text{CH}_3\text{-N}≡\text{C}]$ in mol/L after $1.000 \times 10^3$ s is:

a) $5.33 \times 10^{-4}$  
b) $2.34 \times 10^{-4}$  
c) $2.05 \times 10^{-3}$  
d) $4.27 \times 10^{-3}$

13. The equilibrium constant for reaction (1) is $K$. What is the equilibrium constant for equation (2)?

$$\begin{align*}
(1) \text{SO}_2(g) + \frac{1}{2}\text{O}_2(g) & \rightleftharpoons \text{SO}_3(g) \\
(2) 2\text{SO}_2(g) + \text{O}_2(g) & \rightleftharpoons 2\text{SO}_3(g)
\end{align*}$$

a) $K^2$  
b) $2K$  
c) $1/2K$  
d) $1/K^2$

14. For the gas-phase reaction $\text{CO}(g) + 3\text{H}_2(g) \rightleftharpoons \text{CH}_4(g) + \text{H}_2\text{O}(g)$

$K_c$ is given by $K_c =$ _______________.

a) $[\text{CO}]^3[\text{H}_2]/[\text{CH}_4][\text{H}_2\text{O}]$  
b) $[\text{CO}][\text{H}_2]^3/[\text{CH}_4][\text{H}_2\text{O}]$  
c) $[\text{CH}_4][\text{H}_2\text{O}]/[\text{CO}][\text{H}_2]^3$  
d) $[\text{CH}_4][\text{H}_2\text{O}]/[\text{CO}]^3[\text{H}_2]$
15. A Bronsted-Lowry base is defined as a substance that __________.

a) increases \([H^+]\) when placed in \(H_2O\)
b) increases \([OH^-]\) when placed in \(H_2O\)
c) acts as a proton acceptor in any system
d) acts as a proton donor in any system

16. A second-order reaction has a half-life of 18 s when the initial concentration of reactant is 0.71 M. The rate constant for this reaction is __________ \(M^{-1}s^{-1}\).

a) 7.8 \(\times\) 10\(^{-2}\)
b) 3.8 \(\times\) 10\(^{-2}\)
c) 2.0 \(\times\) 10\(^{-2}\)
d) 1.3

17. The reaction \(A \rightarrow B\) is first order in \([A]\). Using the data below, the rate constant \((k)\) for this reaction is __________ \(s^{-1}\).

<table>
<thead>
<tr>
<th>Time(s)</th>
<th>(<a href="M">A</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.60</td>
</tr>
<tr>
<td>5.0</td>
<td>0.80</td>
</tr>
<tr>
<td>10.0</td>
<td>0.40</td>
</tr>
<tr>
<td>15.0</td>
<td>0.20</td>
</tr>
<tr>
<td>20.0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

a) 0.030
b) 0.14
c) 3.0
d) 3.1 \(\times\) 10\(^{-3}\)

18. In which of the following reactions would decreasing the volume of the reaction vessel at constant temperature not change the concentrations of reactants and products?

a) \(N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)\)
b) \(N_2O_4(g) \rightarrow 2NO_2(g)\)
c) \(N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)\)
d) \(N_2(g) + O_2(g) \rightarrow 2NO(g)\)
19. For which one of the following reactions are \( K_c \) and \( K_p \) the same?

   a) \( \text{Br}_2 (g) + \text{Cl}_2 (g) \rightleftharpoons 2 \text{BrCl} (g) \)
   
   b) \( 2\text{SO}_3 (g) \rightleftharpoons 2\text{SO}_2(g) + \text{O}_2(g) \)
   
   c) \( \text{N}_2\text{O}_4 (g) \rightleftharpoons 2\text{NO}_2(g) \)
   
   d) \( \text{C}(s) + \text{CO}_2 (g) \rightleftharpoons 2\text{CO}(g) \)

20. Consider the following reaction at equilibrium:

   \[
   2\text{CO}_2(g) \rightleftharpoons 2\text{CO}(g) + \text{O}_2(g) \quad \Delta H^\circ = -514 \text{ kJ}
   \]

   Increasing the temperature will ________.

   a) decrease the concentration of \( \text{CO}_2(g) \) at equilibrium
   
   b) shift the reaction to the left
   
   c) shift the reaction to the right
   
   d) increase the concentration of \( \text{CO}(g) \) at equilibrium

21. The stoichiometric equation for a reaction is:

   \[
   2\text{A} + 2\text{B} \rightarrow \text{C}
   \]

   The mechanism for this reaction is:

   (1) \( \text{A} + \text{B} \rightarrow \text{D} \quad \text{(slow)} \)
   
   (2) \( \text{D} + \text{B} \rightarrow \text{E} \quad \text{(fast)} \)
   
   (3) \( \text{A} + \text{E} \rightarrow \text{C} \quad \text{(fast)} \)

   Of the following rate laws, ________ is the correct rate law for this mechanism.

   a) \( \text{Rate} = k_1[\text{A}]^2[\text{B}]^2 \)
   
   b) \( \text{Rate} = k_2[\text{A}][\text{E}] \)
   
   c) \( \text{Rate} = k_1[\text{A}][\text{B}] \)
   
   d) \( \text{Rate} = k_2[\text{D}][\text{B}] \)
22. Based on the table of data shown below, the average rate of the reaction between 0 s and 10 s is _________ M/s.

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>[A] (mol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.200</td>
</tr>
<tr>
<td>5.0</td>
<td>0.140</td>
</tr>
<tr>
<td>10.0</td>
<td>0.100</td>
</tr>
<tr>
<td>15.0</td>
<td>0.071</td>
</tr>
<tr>
<td>20.0</td>
<td>0.050</td>
</tr>
</tbody>
</table>

A → B

a) 5.0 × 10^{-2}
b) 8.0 × 10^{-3}
c) 1.0 × 10^{-2}
d) 2.5 × 10^{-3}

23. For the following reaction at 25 °C, $K_c = 3.0 \times 10^5$. What is $K_p$?

$$2 \text{H}_2\text{S (g) } + 3 \text{O}_2 (g) \rightleftharpoons 2 \text{H}_2\text{O (g) } + 2 \text{SO}_2 (g)$$

a) 1.2 × 10^4
b) 8.2 × 10^{-5}
c) 3.3 × 10^{-6}
d) 3.0 × 10^5

24. The expression for $K_c$ for the reaction below is _______________.

$$\text{NiCO}_3(s) + 2\text{H}^+(aq) \rightleftharpoons \text{Ni}^{2+}(aq) + \text{CO}_2(g) + \text{H}_2\text{O(l)}$$

a) $[\text{Ni}^{2+}]/[\text{NiCO}_3]$
b) $[\text{NiCO}_3]/[\text{Ni}^{2+}]$
c) $[\text{Ni}^{2+}][\text{CO}_2]/[\text{H}^+]^2$
d) $[\text{Ni}^{2+}][\text{H}^+]^2$
25. Consider the following reaction:

\[ \text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \]

Initially, 0.96 mol of PCl\(_5\)(g) was placed in a 1.0 L flask at 25 °C. At equilibrium, 0.42 mol of PCl\(_5\)(g) was present. The value of \( K_c \) for this reaction at 25 °C is ___________.

a) 0.54  
b) 0.29  
c) 0.69  
d) 0.12
The periodic table of elements is an arrangement of chemical elements in which the elements are organized by their atomic number, electron configurations, and periodic trends. The table extends from hydrogen (1) at the top left to uranium (92) at the bottom right. Each element is represented by its symbol and atomic number. The table is divided into periods (horizontal rows) and groups (vertical columns). The groups are divided into main groups (A and B) and transition metals. The periodic table also shows the electronic configurations of the elements, with the valence electrons highlighted in the outermost shell. The table is used to predict the chemical behavior of elements based on their position in the periodic table.