1. What are the units of k in the following rate law? \( \text{Rate} = k[X][Y]^2 \)
   \( A) \frac{1}{M^3s} \quad B) \frac{1}{M^2s} \quad C) \frac{1}{Ms^2} \quad D) \frac{M^2}{s} \quad E) M^2s \)

2. Given the following balanced equation, determine the rate of reaction with respect to [O2]. \( 2 \text{O}_3(g) \rightarrow 3 \text{O}_2(g) \)
   \( A) \quad \text{Rate} = + \frac{1}{3} \frac{\Delta \text{[O}_2\text{]}}{\Delta t} \quad B) \quad \text{Rate} = + \frac{2}{2} \frac{\Delta \text{[O}_2\text{]}}{\Delta t} \quad C) \quad \text{Rate} = - \frac{2}{3} \frac{\Delta \text{[O}_2\text{]}}{\Delta t} \quad D) \quad \text{Rate} = - \frac{3}{3} \frac{\Delta \text{[O}_2\text{]}}{\Delta t} \)

3. Determine the rate law and the value of k for the following reaction using the data provided. \( \text{NO}_2(g) + \text{O}_3(g) \rightarrow \text{NO}_3(g) + \text{O}_2(g) \)
   \( \text{Rate} = 43 \text{M}^{-1}\text{s}^{-1} \text{[NO}_2\text{][O}_3\text{]} \)
   \[
   \begin{array}{|c|c|c|}
   \hline
   \text{[NO}_2\text{], (M)} & \text{[O}_3\text{], (M)} & \text{Initial Rate (M}^{-1}\text{s}^{-1}) \\
   \hline
   0.10 & 0.33 & 1.42 \\
   0.10 & 0.66 & 2.84 \\
   0.25 & 0.66 & 7.10 \\
   \hline
   \end{array}
   \]

4. The decomposition of dinitrogen pentoxide is described by the chemical equation \( 2 \text{N}_2\text{O}_5(g) \rightarrow 4 \text{NO}_2(g) + \text{O}_2(g) \)
   If the rate of disappearance of \( \text{N}_2\text{O}_5 \) is equal to 1.60 mol/min at a particular moment, what is the rate of appearance of \( \text{NO}_2 \) at that moment?
   A) 3.20 mol/min  B) 0.800 mol/min  C) 1.60 mol/min  D) 6.40 mol/min

5. Which of the following statements is FALSE?
   A) The half-life of a first order reaction is dependent on the initial concentration of reactant.
   B) The rate of zero order reactions are not dependent on concentration.
   C) It is not possible to determine the rate of a reaction from its balanced equation.
   D) The average rate of a reaction decreases during a reaction.
   E) None of the statements are FALSE.

6. The reaction below has a \( k_p \) value of \( 3.3 \times 10^{-6} \). What is the value of \( K_c \) for this reaction at 700 K?
   \( 2 \text{SO}_3(g) \leftrightarrow 2 \text{SO}_2(g) + \text{O}_2(g) \)
   A) \( 3.3 \times 10^{-5} \)
   B) \( 1.7 \times 10^{6} \)
   C) \( 1.9 \times 10^{-3} \)
   D) \( 5.7 \times 10^{-7} \)

7. For a first-order reaction, a plot of _____ versus _____ is linear.
   \( A) \quad t, \frac{1}{[A]_t} \quad B) \quad \text{ln}[A]_t, \frac{t}{[A]_t} \quad C) \quad \frac{1}{[A]_t}, t \quad D) \quad \text{ln}[A]_t, t \quad E) \quad [A]_t, t \)

8. The graph shown below depicts the relationship between concentration and time for the following chemical reaction.
   \[ \text{ln}[A] \]
   \[
   \begin{array}{|c|c|}
   \hline
   \text{[A], (M)} & \text{[A], (M)} \\
   \hline
   2.0 & 0.5 \\
   \hline
   \end{array}
   \]
   \( A) \quad -1/k \quad B) \quad 1/k \quad C) \quad -k \quad D) \quad k \quad E) \quad \text{ln}[A]_0 \)

9. As the temperature of a reaction is increased, the rate of the reaction increases because the ________.
   A) activation energy is lowered.
   B) reactant molecules collide more frequently and with greater energy per collision.
   C) reactant molecules collide more frequently and with greater energy per collision.
   D) reactant molecules collide less frequently.
   E) reactant molecules collide more frequently with less energy per collision.

10. The following reaction represents what nuclear process?
    \( ^{137}_{55} \text{Cs} + ^{0}_{-1} \text{e} \rightarrow ^{137}_{54} \text{Xe} \)
    \( A) \gamma \text{ emission} \quad B) \beta \text{ emission} \quad C) \alpha \text{ capture} \quad D) \text{electron capture} \quad E) \text{beta emission} \)

11. Identify the missing particle in the following nuclear equation:
    \( ^{235}_{92} \text{U} \rightarrow ^{90}_{38} \text{Sr} + ? + ^{2}_0 \text{n} + ^{4}_0 \gamma \)
    \( A) \quad ^{144}_{52} \text{Te} \quad B) \quad ^{145}_{54} \text{Xe} \quad C) \quad ^{143}_{54} \text{Xe} \quad D) \quad ^{92}_{38} \text{Sr} \quad E) \quad ^{142}_{52} \text{Te} \)
12. In addition to a beta particle, what is the other product of beta decay of $^{235}_{92}U$?
   A) $^{218}_{84}Po$  B) $^{214}_{81}Tl$  C) $^{214}_{83}Bi$  D) $^{200}_{80}Hg$  E) $^{235}_{93}Np$

13. A reaction vessel is charged with hydrogen iodide, which partially decomposes to molecular hydrogen and iodine:
   $2HI (g) \rightleftharpoons H_2 (g) + I_2 (g)$
   When the system comes to equilibrium at 425°C, $P_{HI} = 0.708$ atm, and $P_{H_2} = P_{I_2} = 0.0960$ atm. The value of $K_p$ at this temperature is____.
   A) $1.30 \times 10^{-2}$  B) $1.84 \times 10^{-2}$  C) $K_p$ cannot be calculated  D) 54.3  E) 6.8

14. Given the following reaction at equilibrium, if $K_c = 6.44 \times 10^5$ at 230.0°C, $K_p = _____.
   $2NO (g) + O_2 (g) \rightleftharpoons 2NO_2 (g)$
   A) $3.67 \times 10^{-2}$  B) $6.44 \times 10^5$  C) $2.67 \times 10^{-7}$  D) $1.56 \times 10^4$  E) $2.66 \times 10^6$

15. The equilibrium constant for the gas phase reaction
   $N_2 (g) + 3H_2 (g) \rightleftharpoons 2NH_3 (g)$
   is $K_{eq} = 4.34 \times 10^{-3}$ at 300°C. At equilibrium, ______.
   A) only products are present  B) only reactants are present  C) reactants predominate  D) products predominate
   E) roughly equal amounts of products and reactants are present.

16. The equilibrium constant is given for one of the reactions below. Determine the value of the missing equilibrium constant.
   $H_2 (g) + Br_2 (g) \rightleftharpoons 2HBr (g)$
   $K_c = 3.8 \times 10^4$
   $4HBr (g) \rightleftharpoons 2 H_2 (g) + 2 Br_2 (g)$
   $K_c = ?$
   A) $1.6 \times 10^3$  B) $5.1 \times 10^{-3}$  C) $6.9 \times 10^{-10}$  D) $2.6 \times 10^{-5}$  E) $1.9 \times 10^4$

17. Determine the rate law and the value of $k$ for the following reaction using the data provided.
   $2N_2O_5(g) \rightarrow 4 NO_2(g) + O_2(g)$

<table>
<thead>
<tr>
<th>$[N_2O_5]$ (M)</th>
<th>Initial Rate (M$^{-1}$s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.093</td>
<td>$4.84 \times 10^{-4}$</td>
</tr>
<tr>
<td>0.084</td>
<td>$4.37 \times 10^{-4}$</td>
</tr>
<tr>
<td>0.224</td>
<td>$1.16 \times 10^{-3}$</td>
</tr>
</tbody>
</table>

   A) Rate $= 1.6 \times 10^{-3}$ M$^{-1/2}$s$^{-1}$ $[N_2O_5]$$^{1/2}$
   B) Rate $= 5.2 \times 10^{-3}$ s$^{-1}$ $[N_2O_5]$  
   C) Rate $= 5.6 \times 10^{-2}$ M$^{-1}$s$^{-1}$ $[N_2O_5]^2$  
   D) Rate $= 1.7 \times 10^{-2}$ M$^{-1/2}$s$^{-1}$ $[N_2O_5]^{3/2}$  

18. For which reaction will $K_p = K_c$?
   A) $H_2CO_3 (s) \rightleftharpoons H_2O (l) + CO_2 (g)$
   B) $CaCO_3 (s) \rightleftharpoons CaO (s) + CO_2 (g)$
   C) $2HgO (s) \rightleftharpoons Hg (l) + O_2 (g)$
   D) $2 H_2O (l) \rightleftharpoons 2 H_2 (g) + O_2 (g)$
   E) $C (s) + O_2 (g) \rightleftharpoons CO_2 (g)$

19. The following reaction is exothermic. Which change will shift the equilibrium to the left?
   $2 SO_2 (g) + O_2 (g) \rightleftharpoons 2 SO_3 (g)$
   A) raising the temperature  B) removing $O_2$  C) adding $SO_3$  D) A, B, C
   E) none

20. Consider the following reaction at equilibrium. What effect will increasing the volume of the reaction mixture have on the system?
   $2H_2S (g) + 3 O_2 (g) \rightleftharpoons 2 H_2O (g) + 2 SO_2 (g)$
   A) shift left to reactants  B) shift right to products  C) no affect
   D) $K_{eq}$ will increase

21. Determine the value of $K_c$ for the following reaction if the equilibrium concentrations are as follows: $[HCl]_{eq} = 0.13$ M, $[HI]_{eq} = 5.6 \times 10^{-16}$ M, $[Cl_2]_{eq} = 0.0019$ M.
   $2 HI (g) + Cl_2 (g) \rightleftharpoons 2 HCl (g) + I_2 (s)$
   A) $3.5 \times 10^{-32}$  B) $2.8 \times 10^{31}$  C) $1.2 \times 10^{-17}$  D) $8.2 \times 10^{-18}$  E) $1.4 \times 10^{-19}$

22. An equilibrium mixture of CO, O$_2$ and CO$_2$ at a certain temperature contains 0.0010 M CO$_2$ and 0.0100 M O$_2$. At this temperature, $K_c$ equals $1.4 \times 10^2$ for the reaction: $2 CO (g) + O_2 (g) \rightleftharpoons 2 CO_2 (g)$
   - What is the equilibrium concentration of CO?
   A) $8.4 \times 10^{-4}$ M  B) $1.4 \times 10^{-2}$ M  C) $7.1 \times 10^{-7}$ M  D) $1.2 \times 10^{-1}$ M

23. A reaction was found to be second order in carbon monoxide concentration. The rate of the reaction ________ if the [CO] is doubled, with everything else kept the same.
   A) remains unchanged  B) triples  C) doubles  D) is reduced by a factor of 2  E) increases by a factor of 4

24. The first-order decomposition of N$_2$O at 1000 K has a rate constant of 0.76 s$^{-1}$. If the initial concentration of N$_2$O is 10.9 M, what is the concentration of N$_2$O after 9.6 s?
   A) $1.0 \times 10^{-3}$ M  B) $1.4 \times 10^{-3}$ M  C) $8.7 \times 10^{-3}$ M  D) $7.4 \times 10^{-3}$ M
25. The rate of disappearance of HBr in the gas phase reaction 
\[ 2 \text{HBr (g)} \rightarrow \text{H}_2 \text{(g)} + \text{Br}_2 \text{(g)} \]
is 0.301 M s\(^{-1}\) at 150°C. The rate of appearance of \( \text{Br}_2 \) is ________ M \( \text{s}^{-1} \).
A) 1.66   B) 0.602   C) 0.151   D) 0.0906   E) 0.549

26. How does the presence of a catalyst affect the enthalpy change of a reaction?
A) A catalyst increases the enthalpy change of a reaction.
B) A catalyst decreases the enthalpy change of a reaction.
C) A catalyst does not affect the enthalpy change of a reaction.
D) It depends on whether you are talking about the forward or the reverse reaction.

27. Which of the following statements is TRUE?
A) The rate constant does not depend on the activation energy for a reaction where the products are lower in energy than the reactants.
B) The addition of a homogeneous catalyst does not change the activation energy of a given reaction.
C) A catalyst raises the activation energy of a reaction.
D) Rate constants are temperature dependent.
E) None of the above are true.

28. Consider the following reaction and its equilibrium constant:
\[ \text{I}_2 \text{(g)} + \text{Br}_2 \text{(g)} \rightleftharpoons 2 \text{IBr} \text{(g)} \]
\[ K_c = 1.1 \times 10^2 \]
A reaction mixture contains 0.35 M \( \text{I}_2 \), 3.1 M \( \text{Br}_2 \) and 3.5 M \( \text{IBr} \). Which of the following statements is TRUE concerning this system?
A) The reaction will shift in the direction of products.
B) The reaction will shift in the direction of reactants.
C) The equilibrium constant will increase.
D) The system is at equilibrium.

29. Calculate the equilibrium constant, \( K_{eq} \), for the following reaction at 25 °C, if \([\text{NO}]_{eq} = 0.106 \text{ M}, [\text{O}_2]_{eq} = 0.122 \text{ M}\) and \([\text{NO}_2]_{eq} = 0.129 \text{ M}\).
\[ 2 \text{NO (g)} + \text{O}_2 \text{(g)} \rightleftharpoons 2 \text{NO}_2 \text{(g)} \]
\[ K_{eq} = 12.1 \]

30. At a particular temperature, for the reaction:
\[ \text{H}_2 + \text{I}_2 \rightleftharpoons 2 \text{HI} \text{(g)} \]
the \( K_{eq} = 55.6 \)
If the initial \([\text{H}_2] = 0.200 \text{ M}\) and \([\text{I}_2] = 0.200 \text{ M}\), what is the equilibrium \([\text{HI}]\)\?
\([\text{HI}]_{eq} = 0.315 \text{ M}\)

31. Consider the following reaction, equilibrium concentrations, and equilibrium constant at a particular temperature. Determine the equilibrium concentration of \( \text{CO}_2 \text{(g)} \). 
\[ \text{NH}_2\text{COONH}_4 \text{(s)} \rightleftharpoons 2 \text{NH}_3 \text{(g)} + \text{CO}_2 \text{(g)} \]
\[ K_c = 1.58 \times 10^{-8} \]
\([\text{NH}_3]_{eq} = 2.1 \times 10^{-3} \text{ M}\)
3.6 \times 10^{-3} \text{ M}

32. Phosphorus pentachloride decomposes to phosphorus trichloride at high temperatures according to the equation:
\[ \text{PCl}_5 \text{(g)} \rightarrow \text{PCl}_3 \text{(g)} + \text{Cl}_2 \text{(g)} \]
At 250° 0.125 M \( \text{PCl}_5 \) is added to the flask. If \( K_c = 1.80 \), what are the equilibrium concentrations of each gas?
A) \([\text{PCl}_5] = 3.96 \text{ M}, [\text{PCl}_3] = 3.83 \text{ M}, \text{ and } [\text{Cl}_2] = 3.83 \text{ M}\)
B) \([\text{PCl}_5] = 0.0625 \text{ M}, [\text{PCl}_3] = 0.335 \text{ M}, \text{ and } [\text{Cl}_2] = 0.335 \text{ M}\)
C) \([\text{PCl}_5] = 1.80 \text{ M}, [\text{PCl}_3] = 1.80 \text{ M}, \text{ and } [\text{Cl}_2] = 1.80 \text{ M}\)
D) \([\text{PCl}_5] = 0.00765 \text{ M}, [\text{PCl}_3] = 0.117 \text{ M}, \text{ and } [\text{Cl}_2] = 0.117 \text{ M}\)

33. Which of the following statements is FALSE?
A) \( K >> 1 \) implies that the reaction is very fast at producing products.
B) When \( K << 1 \), the reverse reaction is favored and the forward reaction does not proceed to a great extent.
C) When \( K \approx 1 \), neither the forward or reverse reaction is strongly favored, and about the same amount of reactants and products exist at equilibrium.
D) When \( K >> 1 \), the forward reaction is favored and essentially goes to completion.
E) None of the above.

34. The first-order reaction, \( \text{SO}_2\text{Cl}_2 \rightarrow \text{SO}_2 + \text{Cl}_2 \), has a half-life of 8.75 hours at 593 K. How long will it take for the concentration of \( \text{SO}_2\text{Cl}_2 \) to fall to 16.5% of its initial value?
A) 6.99 hr
B) 2.28 hr
C) 0.143 hr
D) 22.7 hr