MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Nitrogen dioxide decomposes to nitric oxide and oxygen via the reaction:

\[ 2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2 \]

In a particular experiment at 300°C, [NO\textsubscript{2}] drops from 0.0100 to 0.00650 M in 100 s. The rate of disappearance of NO\textsubscript{2} for this period is __________ M/s.

A) 0.35  
B) 1.8 \times 10^{-3}  
C) \textbf{3.5} \times 10^{-5}  
D) 3.5 \times 10^{-3}  
E) 7.0 \times 10^{-3}

2) Which one of the following is not a valid expression for the rate of the reaction below?

\[ 4\text{NH}_3 + 7\text{O}_2 \rightarrow 4\text{NO}_2 + 6\text{H}_2\text{O} \]

A) \( \frac{1}{4} \frac{\Delta[\text{NO}_2]}{\Delta t} \)  
B) \( \frac{1}{6} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t} \)  
C) \(-\frac{1}{4} \frac{\Delta[\text{NH}_3]}{\Delta t} \)  
D) \(-\frac{1}{7} \frac{\Delta[\text{O}_2]}{\Delta t} \)  
E) All of the above are valid expressions of the reaction rate.

3) The rate law of a reaction is \( \text{rate} = k[D][X] \). The units of the rate constant are __________.

A) mol L\textsuperscript{-1}s\textsuperscript{-1}  
B) L\textsuperscript{2} mol\textsuperscript{-2}s\textsuperscript{-1}  
C) L mol\textsuperscript{-1}s\textsuperscript{-1}  
D) mol L\textsuperscript{-1}s\textsuperscript{-2}  
E) mol\textsuperscript{2} L\textsuperscript{-2}s\textsuperscript{-1}

The data in the table below were obtained for the reaction:

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

<table>
<thead>
<tr>
<th>Experiment Number</th>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial 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>

4) The rate law for this reaction is \text{rate} = __________.

A) k[A]\textsuperscript{2}[B]  
B) k[A]\textsuperscript{2}[B]\textsuperscript{2}  
C) k[A]\textsuperscript{2}  
D) k[P]  
E) k[A][B]
5) The rate law for a reaction is

\[
\text{rate} = k [A][B]^2
\]

Which one of the following statements is false?

A) The reaction is second order in B.
B) If [B] is doubled, the reaction rate will increase by a factor of 4.
C) \(k\) is the reaction rate constant
D) The reaction is first order in A.
E) The reaction is second order overall.

6) Under constant conditions, the half-life of a first-order reaction ________.

A) does not depend on the initial reactant concentration
B) can be calculated from the reaction rate constant
C) is constant
D) is the time necessary for the reactant concentration to drop to half its original value
E) All of the above are correct.

7) As the temperature of a reaction is increased, the rate of the reaction increases because the ________.

A) reactant molecules collide less frequently and with greater energy per collision
B) \textbf{reactant molecules collide more frequently and with greater energy per collision}
C) reactant molecules collide more frequently with less energy per collision
D) activation energy is lowered
E) reactant molecules collide less frequently

8) Which energy difference in the energy profile below corresponds to the activation energy for the forward reaction?

\[\text{Reaction pathway}\]

A) \(x\)  B) \(y\)  C) \(y - x\)  D) \(x + y\)  E) \(x - y\)

9) In the Arrhenius equation,

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

_________ is the frequency factor.

A) \(A\)  B) \(k\)  C) \(Ea\)  D) \(e\)  E) \(R\)
10) The mechanism for formation of the product X is:

\[
\begin{align*}
A + B & \rightarrow C + D \quad \text{(slow)} \\
B + D & \rightarrow X \quad \text{(fast)}
\end{align*}
\]

The intermediate reactant in the reaction is __________.  
A) A \hspace{1cm} B) B \hspace{1cm} C) C \hspace{1cm} D) D \hspace{1cm} E) X

11) For the elementary reaction

\[
\begin{align*}
\text{NO}_3 + \text{CO} & \rightarrow \text{NO}_2 + \text{CO}_2
\end{align*}
\]

the molecularity of the reaction is __________, and the rate law is \( \text{rate} = \) __________.  
A) 4, \( k[\text{NO}_3][\text{CO}][\text{NO}_2][\text{CO}_2] \)
B) 2, \( k[\text{NO}_3][\text{CO}][\text{NO}_2][\text{CO}_2] \)
C) 2, \( k[\text{NO}_3][\text{CO}] \)
D) 4, \( k[\text{NO}_2][\text{CO}_2][\text{NO}_3][\text{CO}] \)
E) 2, \( k[\text{NO}_2][\text{CO}_2] \)

12) A possible mechanism for the overall reaction

\[
\begin{align*}
\text{Br}_2 \ (g) + 2\text{NO} \ (g) & \rightarrow 2\text{NOBr} \ (g)
\end{align*}
\]
is

\[
\begin{align*}
\text{NO} \ (g) + \text{Br}_2 \ (g) & \xrightarrow{k_1} \text{NOBr}_2 \ (g) \quad \text{(fast)} \\
\text{NOBr}_2 \ (g) + \text{NO} \ (g) & \xrightleftharpoons{k_2} 2\text{NOBr} \quad \text{(slow)}
\end{align*}
\]

The rate law for formation of NOBr based on this mechanism is \( \text{rate} = \) __________.  
A) \( k_2k_1/k_{-1}[\text{NO}]^2[\text{Br}_2] \)
B) \( k_1k_{-1}^2[\text{NO}]^2 \)
C) \( k_1[\text{Br}_2]^{1/2} \)
D) \( k_1[\text{NO}]^{1/2} \)
E) \( k_2k_1^2[\text{NO}][\text{Br}_2]^2 \)

13) At equilibrium, __________.  
A) the rates of the forward and reverse reactions are equal  
B) all chemical reactions have ceased  
C) the rate constants of the forward and reverse reactions are equal  
D) the value of the equilibrium constant is 1  
E) the limiting reagent has been consumed
14) Which one of the following will change the value of an equilibrium constant?
   A) varying the initial concentrations of products
   B) adding other substances that do not react with any of the species involved in the equilibrium
   C) varying the initial concentrations of reactants
   D) **changing temperature**
   E) changing the volume of the reaction vessel

15) Given the following reaction at equilibrium, if $K_c = 6.44 \times 10^5$ at 230.0°C, $K_p =$ ________.

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

   A) 2.67 x $10^7$
   B) 6.44 x $10^5$
   C) 2.66 x $10^6$
   D) **1.56 x $10^4$**
   E) 3.67 x $10^{-2}$

16) Which of the following expressions is the correct equilibrium-constant expression for the reaction below?

   $$(\text{NH}_4)_2\text{Se} (s) \rightleftharpoons 2\text{NH}_3 (g) + \text{H}_2\text{Se} (g)$$

   A) $\frac{1}{[(\text{NH}_4)_2\text{Se}]}$
   B) $[\text{NH}_3]^2[\text{H}_2\text{Se}] / [(\text{NH}_4)_2\text{Se}]$
   C) $[(\text{NH}_4)_2\text{Se}] / [\text{NH}_3]^2[\text{H}_2\text{Se}]$
   D) $[\text{NH}_3][\text{H}_2\text{Se}] / [(\text{NH}_4)_2\text{Se}]$
   E) $[\text{NH}_3]^2[\text{H}_2\text{Se}]$

17) The equilibrium constant for the gas phase reaction

   $$\text{N}_2 (g) + 3\text{H}_2 (g) \rightleftharpoons 2\text{NH}_3 (g)$$

   is $K_{eq} = 4.34 \times 10^{-3}$ at 300°C. At equilibrium, __________.
   A) only products are present
   B) only reactants are present
   C) products predominate
   D) **reactants predominate**
   E) roughly equal amounts of products and reactants are present

18) The equilibrium constant for reaction 1 is $K$. The equilibrium constant for reaction 2 is ________.

   

   (1) $\text{SO}_2 (g) + (1/2) \text{O}_2 (g) \rightleftharpoons \text{SO}_3 (g)$
   (2) $2\text{SO}_3 (g) \rightleftharpoons 2\text{SO}_2 (g) + \text{O}_2 (g)$

   A) $K^2$
   B) $\frac{1}{K^2}$
   C) $\frac{1}{2K}$
   D) $-K^2$
   E) $2K$
19) Consider the following equilibrium.

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

The equilibrium **cannot** be established when __________ is/are placed in a 1.0- L container.

A) **0.75 mol SO}_2 (g)**
B) **0.25 mol of SO}_2 (g) and 0.25 mol of SO}_3 (g)**
C) **1.0 mol SO}_3 (g)**
D) **0.50 mol O}_2 (g) and 0.50 mol SO}_3 (g)**
E) **0.25 mol SO}_2 (g) and 0.25 mol O}_2 (g)**

20) Of the following equilibria, only __________ will shift to the left in response to a decrease in volume.

A) **2 \text{SO}_3 (g) \rightleftharpoons 2 \text{SO}_2 (g) + \text{O}_2 (g)**
B) **2\text{HI} (g) \rightleftharpoons \text{H}_2 (g) + \text{I}_2 (g)**
C) **\text{H}_2 (g) + \text{Cl}_2 (g) \rightleftharpoons 2 \text{HCl} (g)**
D) **\text{N}_2 (g) + 3 \text{H}_2 (g) \rightleftharpoons 2 \text{NH}_3 (g)**
E) **4 \text{Fe} (s) + 3 \text{O}_2 (g) \rightleftharpoons 2 \text{Fe}_2\text{O}_3 (s)**

21) For the endothermic reaction

$$\text{CaCO}_3 (s) \rightleftharpoons \text{CaO} (s) + \text{CO}_2 (g)$$

Le Châtelier’s principle predicts that __________ will result in an increase in the number of moles of CO\(_2\).

A) decreasing the temperature
B) increasing the pressure
C) removing some of the CaCO\(_3\) (s)
D) increasing the temperature
E) none of the above

22) A Brønsted- Lowry acid is defined as a substance that __________.

A) increases \( K_a \) when placed in H\(_2\)O
B) acts as a proton acceptor
C) increases [OH\(^-\)] when placed in H\(_2\)O
D) decreases [H\(^+\)] when placed in H\(_2\)O
E) acts as a proton donor

23) A substance that is capable of acting as both an acid and as a base is __________.

A) conjugated
B) miscible
C) saturated
D) **amphoteric**
E) autosomal
24) The magnitude of $K_w$ indicates that __________.
   A) water autoionizes very slowly
   B) water autoionizes very quickly
   C) the autoionization of water is exothermic
   D) water autoionizes only to a very small extent

25) Which one of the following is the weakest acid?
   A) HF ($K_a = 6.8 \times 10^{-4}$)
   B) Acetic acid ($K_a = 1.8 \times 10^{-5}$)
   C) HClO ($K_a = 3.0 \times 10^{-8}$)
   D) HCN ($K_a = 4.9 \times 10^{-10}$)
   E) HNO₂ ($K_a = 4.5 \times 10^{-4}$)

26) Ammonia is a __________.
   A) strong acid
   B) salt
   C) strong base
   D) weak acid
   E) weak base

27) Of the following, which is the strongest acid?
   A) HIO
   B) HIO₃
   C) HIO₄
   D) HIO₂
   E) The acid strength of all of the above is the same.

28) The conjugate base of $\text{HSO}_4^-$ is __________.
   A) $\text{H}_2\text{SO}_4$
   B) $\text{H}_3\text{SO}_4^+$
   C) $\text{H}_2\text{SO}_4^+$
   D) $\text{SO}_4^{2-}$
   E) $\text{OH}^-$

29) What is the pH of an aqueous solution at 25.0 °C that contains $3.98 \times 10^{-9}$ M hydroxide ion?
   A) 3.98
   B) 8.40
   C) 7.00
   D) **5.60**
   E) 9.00

30) What is the concentration (in M) of hydronium ions in a solution at 25.0 °C with pH = 4.282?
   A) 9.71
   B) **5.22 \times 10^{-5}**
   C) 4.28
   D) $1.66 \times 10^4$
   E) **1.92 \times 10^{-10}**
31) A mixture of 0.300 mol of NO and 0.300 mol of H₂ is placed in an evacuated 1.00 L vessel at 300 K. The following equilibrium is established:

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

At equilibrium \([\text{N}_2]\) = 0.120 M

a. Calculate the equilibrium concentrations of NO, H₂, and H₂O. [Make an ICE table ]

b. Calculate \(K_c\).

7
c. In general, does an equilibrium mixture of NO, H₂, N₂, and H₂O at 300 K favor products or reactants?
32) The decomposition of dimethyl ether (CH$_3$)$_2$O at 510°C is a first order process with a rate constant of 6.8 x 10$^{-4}$/s if the initial pressure of (CH$_3$)$_2$O is 135 torr, what is the partial pressure after 1420 s

$$(\text{CH}_3\text{O}_2 \text{g}) \rightarrow \text{CH}_4 \text{g} + \text{H}_2\text{g} + \text{CO}\text{g}$$