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

1) The mechanism for formation of the product \(X\) is:

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

The intermediate reactant in the reaction is __________.

A) A  
B) B  
C) C  
D) D  
E) X

2) The overall reactions and rate laws for several reactions are given below. Of these, only __________ could represent an elementary step.

A) \(A + B + C \to P \quad \text{rate} = k[A][C]\)
B) \(2A \to P \quad \text{rate} = k[A]\)
C) \(A + B \to P \quad \text{rate} = k[A][B]\)
D) \(A + 2B \to P \quad \text{rate} = k[A]^2\)
E) \(A + 2B \to P \quad \text{rate} = k[A][B]\)

3) A catalyst can increase the rate of a reaction __________.

A) by providing an alternative pathway with a lower activation energy
B) by lowering the overall activation energy \((E_a)\) of the reaction
C) by changing the value of the frequency factor \((A)\)
D) by lowering the activation energy of the reverse reaction
E) All of these are ways that a catalyst might act to increase the rate of reaction.

4) At equilibrium, __________.

A) the rates of the forward and reverse reactions are equal
B) the rate constants of the forward and reverse reactions are equal
C) all chemical reactions have ceased
D) the value of the equilibrium constant is 1
E) the limiting reagent has been consumed

5) The relationship between the rate constants for the forward and reverse reactions and the equilibrium constant for the process is \(K_{eq} = \) __________.

A) \(k_f + k_r\)  
B) \(k_f k_r\)  
C) \(k_f - k_r\)  
D) \(k_f k_r\)  
E) \(k_r / k_f\)
6) The equilibrium constant for the gas phase reaction

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

is \(K_{\text{eq}} = 230\) at 300 °C. At equilibrium, __________.

A) roughly equal amounts of products and reactants are present
B) only reactants are present
C) reactants predominate
D) products predominate
E) only products are present

7) 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 \(\text{SO}_2 (g)\)
B) 0.25 mol \(\text{SO}_2 (g)\) and 0.25 mol \(\text{O}_2 (g)\)
C) 0.25 mol of \(\text{SO}_2 (g)\) and 0.25 mol of \(\text{SO}_3 (g)\)
D) 1.0 mol \(\text{SO}_3 (g)\)
E) 0.50 mol \(\text{O}_2 (g)\) and 0.50 mol \(\text{SO}_3 (g)\)

8) The equilibrium-constant expression for the reaction

\[ \text{Ti} (s) + 2\text{Cl}_2 (g) \rightleftharpoons \text{TiCl}_4 (l) \]

is given by

A) \(\frac{[\text{Ti}(s)][\text{Cl}_2(g)]^2}{[\text{TiCl}_4(l)]}\)

B) \(1/[\text{Cl}_2(g)]^2\)

C) \(\frac{[\text{TiCl}_4(l)]}{[\text{Ti}(s)][\text{Cl}_2(g)]^2}\)

D) \(\frac{[\text{TiCl}_4(l)]}{[\text{Cl}_2(g)]^2}\)

E) \(\frac{[\text{TiCl}_4(l)]}{[\text{Ti}(s)][\text{Cl}_2(g)]}\)
9) Consider the following reaction at equilibrium:

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

Le Chatelier's principle predicts that the moles of \( \text{H}_2 \) in the reaction container will increase with ________

A) a decrease in the total volume of the reaction vessel (T constant)
B) addition of some \( \text{N}_2 \) to the reaction vessel (V and T constant)
C) some removal of \( \text{NH}_3 \) from the reaction vessel (V and T constant)
D) an increase in total pressure by the addition of helium gas (V and T constant)
E) a decrease in the total pressure (T constant)

10) The conjugate acid of \( \text{HSO}_4^- \) is ________

A) \( \text{SO}_4^{2-} \)  
B) \( \text{HSO}_3^+ \)  
C) \( \text{H}^+ \)  
D) \( \text{H}_2\text{SO}_4 \)  
E) \( \text{HSO}_4^+ \)

11) A substance that is capable of acting as both an acid and as a base is ________

A) amphoteric  
B) saturated  
C) miscible  
D) conjugated  
E) autosomal

12) In balancing the nuclear reaction \( ^{293}_92 \text{U} \rightarrow ^{234}_90 \text{E} + ^4_2 \text{He} \), the identity of element E is ________

A) Pu.  
B) U.  
C) Th.  
D) Np.  
E) Pa.

13) What is the largest number of protons that can exist in a nucleus and still be stable ________?

A) 83  
B) 84  
C) 206  
D) 50  
E) 92

14) In the nuclear transmutation represented by \( ^{16}_8 \text{O}(p, \alpha)^{13}_7 \text{N} \), the emitted particle is ________

A) a beta particle.  
B) a positron.  
C) a proton.  
D) a neutron.  
E) an alpha particle.
At 448 °C the equilibrium constant $K_c$ of the reaction

$$ \text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI} (\text{g}) $$

is 50.5

Predict in which direction the reaction will proceed to reach the equilibrium if we start with $2.0 \times 10^{-2}$ mol of HI, $1.0 \times 10^{-2}$ mol of $\text{H}_2$, and $3.0 \times 10^{-2}$ mol of $\text{I}_2$ in a 2.00 L container.

**Initial concentrations**

$$\begin{align*}
\text{HI} &= \frac{2.0 \times 10^{-2}}{2 L} = 1.0 \times 10^{-3} \text{M} \\
\text{H}_2 &= \frac{1.0 \times 10^{-2}}{2 L} = 5 \times 10^{-3} \\
\text{I}_2 &= \frac{3.0 \times 10^{-2}}{2 L} = 1.5 \times 10^{-2} \\
Q_c &= \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = \frac{(1.0 \times 10^{-3})^2}{(5 \times 10^{-3})(1.5 \times 10^{-2})} = 1.3
\end{align*}$$

$Q_c < K_c$ so the reaction proceeds from the left to right as the reaction proceeds toward the equilibrium. --- 2 points

The decomposition of Nitric oxide is believed to occur by a two step mechanism:

$$ \text{N}_2\text{O} (\text{g}) \rightarrow \text{N}_2 (\text{g}) + \text{O} (\text{g}) \quad \text{(Slow)} $$

$$ \text{N}_2\text{O}(\text{g}) + \text{O}(\text{g}) \rightarrow \text{N}_2 (\text{g}) + \text{O}_2(\text{g}) \quad \text{(Fast)} $$

**a)** write the equation for the overall reaction.

$$2\text{N}_2\text{O} (\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{N}_2 (\text{g}) + \text{O}_2(\text{g})$$

2 $\text{N}_2\text{O}$ (g) $\rightarrow$ 2$\text{N}_2$ (g) + $\text{O}_2$ (g) --2.5 points

**b)** Write the rate law of the overall reaction.

$$\text{Rate} = k[N_2\text{O}]$$

This takes into consideration only the slow step.
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

17) $^{131}\text{I}$ has a half-life of 8.04 days. Assuming you start with a 1.53 mg sample of $^{131}\text{I}$, how many mg will remain after 13.0 days  

\[ \text{_______} \]

A) 0.440  
B)  
C)  
D)  
E)  

\[ k = \frac{0.693}{8.04} = 0.0862/\text{day} \]

\[ \ln \frac{N_t}{N_0} = -kt \]

\[ \ln N_t - \ln N_0 = -kt \]

\[ \ln N_t - \ln 1.53 = -0.0862/\text{day} \times 13 \text{ days} \]

\[ \ln N_t - 0.42526 = -1.12047 \]

\[ \ln N_t = -1.54609 \]

\[ N_t = 0.499 \text{ mg} \]

In this problem \[ \ln N_t = -0.69521 \] so \[ N_t = 0.499 \text{ mg} \]

I am not able to just make the correction and I do not want to retype the full thing.

1 point for \( k \) and 4 points for the rest of the problem.

ESSAY. Write your answer in the space provided or on a separate sheet of paper.

18) A mixture of 0.2000 mol of CO\(_2\), 0.1000 mol of H\(_2\) and 0.1600 mol of H\(_2\)O is placed in a 2.000 L vessel. The following equilibrium is established at 500K:

\[ \text{CO}_2(g) + \text{H}_2(g) \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}(g) \]

TO GET CREDIT FOR THIS PROBLEM YOU MUST DRAW THE TABLE

a) Calculate the initial partial pressure of CO\(_2\), H\(_2\), and H\(_2\)O.

\[ \begin{align*}
P_{\text{CO}_2} &= \frac{n}{V} \times \frac{0.2 \text{ mol}}{2 \text{ L}} \times 0.08211 \text{ atm/mol.K} \times 500\text{ K} = 4.11 \text{ atm} \\
P_{\text{H}_2} &= \frac{n}{V} \times \frac{0.2 \text{ mol}}{2 \text{ L}} \times 0.08211 \text{ atm/mol.K} \times 500\text{ K} = 2.05 \text{ atm} \\
P_{\text{H}_2\text{O}} &= \frac{n}{V} \times \frac{0.16 \text{ mol}}{2 \text{ L}} \times 0.08211 \text{ atm/mol.K} \times 500\text{ K} = 3.28 \text{ atm} \\
\end{align*} \]

5 points

b). At equilibrium \( P_{\text{H}_2\text{O}} = 3.51 \text{ atm} \).

Calculate the equilibrium partial pressures of CO\(_2\), H\(_2\), and CO.

<table>
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<tr>
<th>( \text{CO}_2(g) )</th>
<th>( + )</th>
<th>( \text{H}_2(g) )</th>
<th>( \text{CO}(g) )</th>
<th>( + )</th>
<th>( \text{H}_2\text{O}(g) )</th>
</tr>
</thead>
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<tr>
<td>initial</td>
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<td>2.05 atm</td>
<td>0</td>
<td>3.28 atm</td>
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<tr>
<td>Change</td>
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<td>-0.23 atm</td>
<td>+0.23 atm</td>
<td>+0.23 atm</td>
<td></td>
</tr>
<tr>
<td>Equilibrium</td>
<td>3.88 atm</td>
<td>1.82 atm</td>
<td>0.23 atm</td>
<td>3.51 atm</td>
<td></td>
</tr>
</tbody>
</table>

5 points
c) Calculate the $K_p$ for the reaction

$$K_p = \frac{P_{\text{CO}} P_{\text{H}_2\text{O}}}{P_{\text{H}_2} P_{\text{CO}_2}} = \frac{0.23 \times 3.51}{1.82 \times 3.875} = 0.11$$

5 points
Answer Key
Testname: TEST 3 KEY

1) D
2) C
3) A
4) A
5) B
6) D
7) A
8) B
9) E
10) D
11) A
12) C
13) A
14) E
15)
16)
17) B
18)