Question #: 1

Given the reaction \( \text{C}_3\text{H}_8(\text{g}) + 5\ \text{O}_2(\text{g}) \rightarrow 3\ \text{CO}_2(\text{g}) + 4\ \text{H}_2\text{O}(\text{g}) \), select all of the correct expressions of the rate law.

A. 
\[
\text{Rate} = -\frac{1}{5} \frac{\Delta[\text{O}_2]}{\Delta t}
\]

B. 
\[
\text{Rate} = \frac{\Delta[\text{C}_3\text{H}_8]}{\Delta t}
\]

C. 
\[
\text{Rate} = 3 \frac{\Delta[\text{CO}_2]}{\Delta t}
\]

D. 
\[
\text{Rate} = \frac{1}{4} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}
\]

Question #: 2

Given the reaction \( \text{Cl}_2(\text{g}) + 3\ \text{F}_2(\text{g}) \rightarrow 2\ \text{ClF}_3(\text{g}) \), select the two options that complete the table below.

<table>
<thead>
<tr>
<th>Rate</th>
<th>( \frac{\Delta[\text{Cl}_2]}{\Delta t} )</th>
<th>( \frac{\Delta[\text{F}_2]}{\Delta t} )</th>
<th>( \frac{\Delta[\text{ClF}_3]}{\Delta t} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( -0.006 \text{ M/s} )</td>
<td></td>
<td>( 0.012 \text{ M/s} )</td>
</tr>
</tbody>
</table>
Question #: 3

The rate law for the reaction
\[ A \rightarrow \text{product} \]
has the form
\[ \text{rate} = k[A]^n \]

For each description below, provide the value of the exponent \( n \). Possible values are \( n = 0, 1, 2 \) or 3.

When \([A]\) is doubled, the reaction rate increases by a factor of four. \( n = 1 \)

When \([A]\) is tripled, the reaction rate does not change. \( n = 2 \)

When \([A]\) is quadrupled (increased by a factor of four), the reaction rate quadruples. \( n = 3 \)

Question #: 4

The decomposition of azomethane, \( \text{CH}_3\text{N}_2\text{CH}_3 \), at 300 °C follows first-order kinetics with a rate constant of \( k = 2.55 \times 10^{-3} \text{ s}^{-1} \). How long must the reaction run for the final concentration of
azomethane to be 16% of the initial concentration?

\[ \text{CH}_3 \text{N}_2 \text{CH}_3(g) \rightarrow \text{N}_2(g) + \text{C}_2 \text{H}_6(g) \]

A. 110 minutes  
B. 760 minutes  
C. 12.0 minutes  
D. 3.00 minutes

Question #: 5

Identify the order of each reaction based on the graph below.

![Graph with concentration vs. time for reactions A, B, and C.]

Reaction A is \_1\_ order.  
Reaction B is \_2\_ order.  
Reaction C is \_3\_ order.

1. _____  
2. _____  
3. _____

Question #: 6

Consider the second-order reaction below. Calculate the half-life for this reaction when the starting concentration of \( \text{NO}_2 \) is 0.50 M.
The reaction is __________ [endothermic, exothermic].
The isomerization of cyclopropane to propene has an activation energy of 273 kJ/mol. When the reaction is run at 750 K, the rate constant, $k_1$, is $1.8 \times 10^{-4}$ s$^{-1}$. What is the value of the rate constant, $k_2$, at 850 K?

A. $3.1 \times 10^{-2}$ s$^{-1}$
B. $1.2 \times 10^{-8}$ s$^{-1}$
C. $4.1 \times 10^{-4}$ s$^{-1}$
D. $2.7 \times 10^{-3}$ s$^{-1}$

In the figure below, the sucrase enzyme functions as a biological ___1___, which speeds up the reaction rate by ___2___ [raising, lowering] the activation energy, $E_a$ for the reaction. At body temperature, the uncatalyzed reaction ___3___ [does, does not] proceed to break sucrose down into glucose and fructose.
Question #: 10

Which choice best describes the functions of the selected reagents in the reaction mechanism below?

\[ S_{2}O_{8}^{2-} + 2 \text{Fe}^{2+} \rightarrow 2 \text{SO}_{4}^{2-} + 2 \text{Fe}^{3+} \quad \text{fast step} \]
\[ 2 \text{Fe}^{3+} + 2 \text{I}^{-} \rightarrow 2 \text{Fe}^{2+} + \text{I}_{2} \quad \text{slow step} \]

\[ S_{2}O_{8}^{2-} + 2 \text{I}^{-} \rightarrow 2 \text{SO}_{4}^{2-} + \text{I}_{2} \quad \text{overall reaction} \]

A. Fe\(^{2+}\) = catalyst, Fe\(^{3+}\) = reaction intermediate
B. Fe\(^{3+}\) = catalyst, Fe\(^{2+}\) = reaction intermediate
C. S\(_{2}O_{8}^{2-}\) = catalyst, SO\(_{4}^{2-}\) = reaction intermediate
D. I\(^{-}\) = catalyst, I\(_{2}\) = reaction intermediate
Which graph best describes the reaction below?

\[ \text{S}_2\text{O}_8^{2-} + 2 \text{Fe}^{2+} \rightarrow 2 \text{SO}_4^{2-} + 2 \text{Fe}^{3+} \quad \text{fast step} \]
\[ 2 \text{Fe}^{3+} + 2 \text{I}^- \rightarrow 2 \text{Fe}^{2+} + \text{I}_2 \quad \text{slow step} \]

\[ \text{S}_2\text{O}_8^{2-} + 2 \text{I}^- \rightarrow 2 \text{SO}_4^{2-} + \text{I}_2 \quad \text{overall reaction} \]

A.

![Graph A](image)

B.

![Graph B](image)

C.
Question #: 12

Starting with pure CH₄(g), the reaction below reaches a state of dynamic equilibrium. Which one of the following statements about the system at equilibrium is **false**?

\[ 2 \text{CH}_4(g) \rightleftharpoons C_2\text{H}_2(g) + 3 \text{H}_2(g) \quad K_c = 0.15 \]

A. The concentration of CH₄ is twice the concentration of C₂H₂.
B. The rates of the forward and reverse reactions are equal.
C. The concentrations of the reactants and products remain constant.
D. The concentration of H₂ is three times the concentration of C₂H₂.

---

Question #: 13

Initially, 2.0 M SO₃(g) is added to a reaction vessel. Given the balanced chemical equation and \( K_c \), what is true about the **equilibrium** concentrations of reactants and products?
\[ 2 \text{SO}_3(g) \rightleftharpoons 2 \text{SO}_2(g) + \text{O}_2(g) \quad K_c = 4.08 \times 10^{-2} \]

A. The equilibrium favors neither reactants nor products, so appreciable amounts of SO\(_3\), SO\(_2\), and O\(_2\) will all be present at equilibrium.
B. The equilibrium lies far to the right, so the concentrations of SO\(_2\) and O\(_2\) will be significantly higher than the concentration of SO\(_3\).
C. The equilibrium lies far to the right, so the concentrations of SO\(_2\) and O\(_2\) will be significantly lower than the concentration of SO\(_3\).
D. The equilibrium lies far to the left, so the concentrations of SO\(_2\) and O\(_2\) will be significantly lower than the concentration of SO\(_3\).
E. The equilibrium lies far to the left, so the concentrations of SO\(_2\) and O\(_2\) will be significantly higher than the concentration of SO\(_3\).

Question #: 14

Given
\[ 2 \text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{SO}_3(g) \quad K_{P1} = 4.84 \]
\[ \text{NO}(g) + \frac{1}{2} \text{O}_2(g) \rightleftharpoons \text{NO}_2(g) \quad K_{P2} = 0.25 \]

what is the value of \( K_{P3} \) for
\[ \text{SO}_2(g) + \text{NO}_2(g) \rightleftharpoons \text{SO}_3(g) + \text{NO}(g) \quad K_{P3} = \boxed{?} \]
Report your answer to two significant figures.

1. \boxed{\text{______}}

Question #: 15

Given
\[ \text{CO}(g) + 2 \text{H}_2(g) \rightleftharpoons \text{CH}_3\text{OH}(g) \quad K_c = 26 \text{ at } 780 \text{ °C (1053 K)} \]

what is the value of \( K_p \) at 780 °C (1053 K)?

A. \(3.48 \times 10^{-3}\)
B. \(9.64 \times 10^5\)
C. \(1.49 \times 10^{-5}\)
D. \(2.67 \times 10^{-2}\)
Question #: 16

At 1000 °C, limestone, CaCO₃, decomposes to quicklime, CaO, and carbon dioxide according to the equation

\[ \text{CaCO}_3(s) \leftrightharpoons \text{CaO}(s) + \text{CO}_2(g) \]

What is the \( K_c \) expression for this reaction?

A. \( K_c = [\text{CO}_2] \)

B. \( K_c = \frac{[\text{CaO}][\text{CO}_2]}{[\text{CaCO}_3]} \)

C. \( K_c = \frac{[\text{CaO}]}{[\text{CaCO}_3]} \)

D. \( K_c = \frac{[\text{CO}_2]}{[\text{CaCO}_3]} \)

Question #: 17

Initially, 0.0500 M each of \( \text{CO}_2(g) \) and \( \text{H}_2(g) \) are added to a reaction vessel. The system is allowed to reach equilibrium according to the reaction

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

\( K_c = ? \)

At equilibrium, the concentration of \( \text{CO}_2 \) is 0.0467 M. What is \( K_c \) for this reaction?

A. \( 4.99 \times 10^{-3} \)

B. \( 2.10 \times 10^1 \)

C. \( 3.40 \times 10^{-6} \)

D. \( 9.08 \times 10^{-2} \)
The reaction
\[ \text{I}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2 \text{ICl}(g) \]
has an equilibrium constant, \( K_p = 81.9 \) at a certain temperature. If the reaction quotient, \( Q_p = 256 \) at that same temperature,

A. the reaction will proceed towards the reactants (to the left) to reach equilibrium.  
B. the reaction will proceed towards the products (to the right) to reach equilibrium.  
C. the reaction has reached equilibrium and no changes in concentrations occur.

---

Given
\[ 2 \text{NO}(g) + 2 \text{H}_2(g) \rightleftharpoons \text{N}_2(g) + 2 \text{H}_2\text{O}(g) \quad K_c = 6.5 \times 10^2 \]
If \([\text{NO}] = [\text{H}_2] = 0.400 \text{ M} \) and \([\text{H}_2\text{O}] = 2.20 \text{ M} \) at equilibrium, what is the equilibrium concentration of \( \text{N}_2 \)?

A. 5.72 M  
B. 0.249 M  
C. 3.44 M  
D. 18.1 M

---

Given
\[ 2 \text{NOCl}(g) \rightleftharpoons 2 \text{NO}(g) + \text{Cl}_2(g) \quad K_c = 4.7 \times 10^{-4} \]
what is the equilibrium concentration of \( \text{NO} \) when 2.0 moles of NOCl are injected into a 5.0 L reaction vessel?

A. 6.5 \times 10^{-5} \text{ M}  
B. 1.4 \times 10^{-3} \text{ M}  
C. 2.8 \times 10^{-4} \text{ M}
D. \(7.2 \times 10^{-2}\) M

Question #: 21

For this system at equilibrium,

\[ \text{O}_2(\text{g}) + 2 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{H}_2\text{O}(\text{g}) \quad \Delta H = -126 \text{ kJ/mol} \]

which way will the equilibrium shift for each of the changes below?

1. Cooling the reaction mixture
2. Adding \(\text{H}_2\text{O}(\text{g})\)
3. Adding \(\text{Ne}(\text{g})\)
4. Decreasing total pressure

Question #: 22

According to Brønsted-Lowry acid-base theory, in this reaction

\[ \text{C}_5\text{H}_5\text{N}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_5\text{H}_5\text{NH}^+(aq) + \text{OH}^-(aq) \]

\(\text{H}_2\text{O}\) acts as a(n) ___ [acid, base].

\(\text{C}_5\text{H}_5\text{NH}^+\) is the conjugate ___ [acid, base] of \(\text{C}_5\text{H}_5\text{N}\).

Question #: 23

Which of the following is(are) strong acid(s)? Select all that apply.

A. \(\text{HBr}\)
B. \(\text{HClO}_4\)
C. \(\text{HF}\)
Question #: 24

Which acid is the **weakest**?

A. arsenous acid, $\text{H}_3\text{AsO}_3$, $K_a = 5.1 \times 10^{-10}$
B. hypochlorous acid, $\text{HOCl}$, $K_a = 2.9 \times 10^{-8}$
C. benzoic acid, $\text{HC}_7\text{H}_5\text{O}_2$, $K_a = 6.5 \times 10^{-5}$
D. acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, $K_a = 1.8 \times 10^{-5}$

Question #: 25

Calculate the pH of pure water at 40 °C and report it to **two** places to the right of the decimal point:

$$2\text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \quad K_w = 2.92 \times 10^{-14} \text{ at } 40 ^\circ\text{C}$$

Based on this information, is the autoionization of water endothermic or exothermic? **2**

1. ________
2. ________
Question #: 1

Given the reaction \( \text{C}_3\text{H}_8(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{g}) \), select all of the correct expressions of the rate law.

✓A. 
\[
\text{Rate} = -\frac{1}{5} \frac{\Delta[\text{O}_2]}{\Delta t}
\]

B. 
\[
\text{Rate} = \frac{\Delta[\text{C}_3\text{H}_8]}{\Delta t}
\]

C. 
\[
\text{Rate} = 3 \frac{\Delta[\text{CO}_2]}{\Delta t}
\]

✓D. 
\[
\text{Rate} = \frac{1}{4} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}
\]

Question #: 2

Given the reaction \( \text{Cl}_2(\text{g}) + 3 \text{F}_2(\text{g}) \rightarrow 2 \text{ClF}_3(\text{g}) \), select the two options that complete the table below.

<table>
<thead>
<tr>
<th>Rate</th>
<th>( \frac{\Delta[\text{Cl}_2]}{\Delta t} )</th>
<th>( \frac{\Delta[\text{F}_2]}{\Delta t} )</th>
<th>( \frac{\Delta[\text{ClF}_3]}{\Delta t} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( -0.006 \text{ M/s} )</td>
<td></td>
<td>( 0.012 \text{ M/s} )</td>
</tr>
</tbody>
</table>
Question #: 3

The rate law for the reaction

\[ \text{A} \rightarrow \text{product} \]

has the form

\[ \text{rate} = k[A]^n \]

For each description below, provide the value of the exponent \( n \). Possible values are \( n = 0, 1, 2 \) or \( 3 \).

When [A] is doubled, the reaction rate increases by a factor of four. \( n = 1 \)

When [A] is tripled, the reaction rate does not change. \( n = 2 \)

When [A] is quadrupled (increased by a factor of four), the reaction rate quadruples. \( n = 3 \)

1. 2
2. 0
3. 1

Question #: 4

The decomposition of azomethane, \( \text{CH}_3\text{N}_2\text{CH}_3 \), at 300 °C follows first-order kinetics with a rate constant of \( k = 2.55 \times 10^{-3} \text{ s}^{-1} \). How long must the reaction run for the final concentration of
azomethane to be 16% of the initial concentration?

\[
\text{CH}_3\text{N}_2\text{CH}_3(g) \rightarrow \text{N}_2(g) + \text{C}_2\text{H}_6(g)
\]

A. 110 minutes
B. 760 minutes
✓C. 12.0 minutes
D. 3.00 minutes

**Question #: 5**

Identify the order of each reaction based on the graph below.

![Graph showing concentration vs. time for reactions A, B, and C.]

Reaction A is __1__ order.
Reaction B is __2__ order.
Reaction C is __3__ order.

1. second|Second|2|2nd|
2. first|First|1|1st|
3. zero|Zero|0|

**Question #: 6**

Consider the second-order reaction below. Calculate the half-life for this reaction when the starting concentration of \( \text{NO}_2 \) is 0.50 M.
\[ 2 \text{NO}_2(g) \rightarrow 2 \text{NO}(g) + \text{O}_2(g) \quad k = 0.34 \text{ M}^{-1}\text{s}^{-1} \]

A. 0.64 seconds
B. 19 seconds
✓ C. 5.9 seconds
D. 1.3 seconds

**Question #7**

The diagram shows the energy of a system as the reaction progresses. Label the diagram using the possible choices listed after each blank.

1. \[\text{reactants, products}\]
2. \[\text{Ea, delta H}\]
3. \[\text{Ea, delta H}\]
4. \[\text{reactants, products}\]

The reaction is \[\text{exothermic, endothermic}\].

1. reactants|Reactants|reactant|Reactant|
2. Ea|ea|EA|E a|
3. delta H|Delta H|delta h|deltaH|DeltaH|deltah|Deltah|
4. products|Products|product|Product|
5. exothermic|Exothermic|
Question #: 8

The isomerization of cyclopropane to propene has an activation energy of 273 kJ/mol. When the reaction is run at 750 K, the rate constant, \( k_1 \), is \( 1.8 \times 10^{-4} \text{ s}^{-1} \). What is the value of the rate constant, \( k_2 \), at 850 K?

✓ A. \( 3.1 \times 10^{-2} \text{ s}^{-1} \)  
   B. \( 1.2 \times 10^{-8} \text{ s}^{-1} \)  
   C. \( 4.1 \times 10^{-4} \text{ s}^{-1} \)  
   D. \( 2.7 \times 10^{-3} \text{ s}^{-1} \)

Question #: 9

In the figure below, the sucrase enzyme functions as a biological ___1___, which speeds up the reaction rate by ___2___ [raising, lowering] the activation energy, \( E_a \), for the reaction. At body temperature, the uncatalyzed reaction ___3___ [does, does not] proceed to break sucrose down into glucose and fructose.
Which choice best describes the functions of the selected reagents in the reaction mechanism below?

\[ S_2O_8^{2-} + 2 Fe^{2+} \rightarrow 2 SO_4^{2-} + 2 Fe^{3+} \quad \text{fast step} \]
\[ 2 Fe^{3+} + 2 I^- \rightarrow 2 Fe^{2+} + I_2 \quad \text{slow step} \]
\[ S_2O_8^{2-} + 2 I^- \rightarrow 2 SO_4^{2-} + I_2 \quad \text{overall reaction} \]

A. Fe^{2+} = catalyst, Fe^{3+} = reaction intermediate
B. Fe^{3+} = catalyst, Fe^{2+} = reaction intermediate
C. S_2O_8^{2-} = catalyst, SO_4^{2-} = reaction intermediate
D. I^- = catalyst, I_2 = reaction intermediate
Which **graph** best describes the reaction below?

\[ \text{S}_2\text{O}_8^{2-} + 2 \text{Fe}^{2+} \rightarrow 2 \text{SO}_4^{2-} + 2 \text{Fe}^{3+} \quad \text{fast step} \]

\[ 2 \text{Fe}^{3+} + 2 \text{I}^- \rightarrow 2 \text{Fe}^{2+} + \text{I}_2 \quad \text{slow step} \]

\[ \text{S}_2\text{O}_8^{2-} + 2 \text{I}^- \rightarrow 2 \text{SO}_4^{2-} + \text{I}_2 \quad \text{overall reaction} \]

A. 

![Graph A](image)

B. 

![Graph B](image)

✓C. 

![Graph C](image)
Question #: 12

Starting with pure CH$_4$(g), the reaction below reaches a state of dynamic equilibrium. Which one of the following statements about the system at equilibrium is false?

$$2 \text{CH}_4(g) \rightleftharpoons \text{C}_2\text{H}_2(g) + 3 \text{H}_2(g) \quad K_c = 0.15$$

✓A. The concentration of CH$_4$ is twice the concentration of C$_2$H$_2$.
B. The rates of the forward and reverse reactions are equal.
C. The concentrations of the reactants and products remain constant.
D. The concentration of H$_2$ is three times the concentration of C$_2$H$_2$.

Question #: 13

Initially, 2.0 M SO$_3$(g) is added to a reaction vessel. Given the balanced chemical equation and $K_c$, what is true about the equilibrium concentrations of reactants and products?
\[ 2 \text{SO}_3(g) \rightleftharpoons 2 \text{SO}_2(g) + \text{O}_2(g) \quad K_c = 4.08 \times 10^{-2} \]

A. The equilibrium favors neither reactants nor products, so appreciable amounts of SO$_3$, SO$_2$, and O$_2$ will all be present at equilibrium.

B. The equilibrium lies far to the right, so the concentrations of SO$_2$ and O$_2$ will be significantly higher than the concentration of SO$_3$.

C. The equilibrium lies far to the right, so the concentrations of SO$_2$ and O$_2$ will be significantly lower than the concentration of SO$_3$.

✓D. The equilibrium lies far to the left, so the concentrations of SO$_2$ and O$_2$ will be significantly lower than the concentration of SO$_3$.

E. The equilibrium lies far to the left, so the concentrations of SO$_2$ and O$_2$ will be significantly higher than the concentration of SO$_3$.

---

**Question #**: 14

Given

\[ 2 \text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{SO}_3(g) \quad K_{P1} = 4.84 \]

\[ \text{NO}(g) + \frac{1}{2} \text{O}_2(g) \rightleftharpoons \text{NO}_2(g) \quad K_{P2} = 0.25 \]

what is the value of $K_{P3}$ for

\[ \text{SO}_2(g) + \text{NO}_2(g) \rightleftharpoons \text{SO}_3(g) + \text{NO}(g) \quad K_{P3} = \text{?} \]

Report your answer to two significant figures.

1. 8.8

---

**Question #**: 15

Given

\[ \text{CO}(g) + 2 \text{H}_2(g) \rightleftharpoons \text{CH}_3\text{OH}(g) \quad K_c = 26 \text{ at } 780 \text{ °C (1053 K)} \]

what is the value of $K_p$ at 780 °C (1053 K)?

✓A. $3.48 \times 10^{-3}$

B. $9.64 \times 10^5$

C. $1.49 \times 10^{-5}$

D. $2.67 \times 10^{-2}$
Question #: 16

At 1000 °C, limestone, CaCO₃, decomposes to quicklime, CaO, and carbon dioxide according to the equation

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

What is the \( K_c \) expression for this reaction?

✓ A. \( K_c = [\text{CO}_2] \)

B. \( K_c = \frac{[\text{CaO}][\text{CO}_2]}{[\text{CaCO}_3]} \)

C. \( K_c = \frac{[\text{CaO}]}{[\text{CaCO}_3]} \)

D. \( K_c = \frac{[\text{CO}_2]}{[\text{CaCO}_3]} \)

Question #: 17

Initially, 0.0500 M each of CO₂(g) and H₂(g) are added to a reaction vessel. The system is allowed to reach equilibrium according to the reaction

\[
\text{CO}_2(g) + \text{H}_2(g) \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}(g) \quad K_c = ?
\]

At equilibrium, the concentration of CO₂ is 0.0467 M. What is \( K_c \) for this reaction?

✓ A. 4.99 × 10⁻³

B. 2.10 × 10¹

C. 3.40 × 10⁻⁶

D. 9.08 × 10⁻²
Question #: 18

The reaction
\[ I_2(g) + Cl_2(g) \rightleftharpoons 2 ICl(g) \]
has an equilibrium constant, \( K_p = 81.9 \) at a certain temperature. If the reaction quotient, \( Q_p = 256 \) at that same temperature,

\[ \checkmark \text{A. the reaction will proceed towards the reactants (to the left) to reach equilibrium.} \]
\[ \text{B. the reaction will proceed towards the products (to the right) to reach equilibrium.} \]
\[ \text{C. the reaction has reached equilibrium and no changes in concentrations occur.} \]

Question #: 19

Given
\[ 2 \text{NO}(g) + 2 \text{H}_2(g) \rightleftharpoons \text{N}_2(g) + 2 \text{H}_2\text{O}(g) \quad K_c = 6.5 \times 10^2 \]
If \([\text{NO}] = [\text{H}_2] = 0.400 \text{ M} \) and \([\text{H}_2\text{O}] = 2.20 \text{ M} \) at equilibrium, what is the equilibrium concentration of \( \text{N}_2 \)?

A. 5.72 M
B. 0.249 M
\[ \checkmark \text{C. 3.44 M} \]
D. 18.1 M

Question #: 20

Given
\[ 2 \text{NOCl}(g) \rightleftharpoons 2 \text{NO}(g) + \text{Cl}_2(g) \quad K_c = 4.7 \times 10^{-4} \]
what is the equilibrium concentration of \( \text{NO} \) when 2.0 moles of \( \text{NOCl} \) are injected into a 5.0 L reaction vessel?

A. \(6.5 \times 10^{-5} \text{ M} \)
B. \(1.4 \times 10^{-3} \text{ M} \)
C. \(2.8 \times 10^{-4} \text{ M} \)
Question #: 21

For this system at equilibrium,
\[
O_2(g) + 2 \text{H}_2(g) \rightleftharpoons 2 \text{H}_2\text{O}(g) \quad \Delta H = -126 \text{ kJ/mol}
\]
which way will the equilibrium shift for each of the changes below?

1. Cooling the reaction mixture
2. Adding H\textsubscript{2}O(g)
3. Adding Ne(g)
4. Decreasing total pressure

1. right 2. right 3. neither 4. left

Question #: 22

According to Brønsted-Lowry acid-base theory, in this reaction
\[
\text{C}_5\text{H}_5\text{N}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_5\text{H}_5\text{NH}^+(aq) + \text{OH}^-(aq)
\]
H\textsubscript{2}O acts as a(n)

1. acid 2. base

C\textsubscript{5}H\textsubscript{5}\text{NH}\textsuperscript{+} is the conjugate

1. acid 2. base

Question #: 23

Which of the following is(are) strong acid(s)? Select all that apply.

✓ A. HBr  
✓ B. HClO  
C. HF
Question #: 24

Which acid is the weakest?

✓ A. arsenous acid, \( \text{H}_3\text{AsO}_3 \), \( K_a = 5.1 \times 10^{-10} \)

B. hypochlorous acid, \( \text{HOCl} \), \( K_a = 2.9 \times 10^{-8} \)

C. benzoic acid, \( \text{HC}_7\text{H}_5\text{O}_2 \), \( K_a = 6.5 \times 10^{-5} \)

D. acetic acid, \( \text{HC}_2\text{H}_3\text{O}_2 \), \( K_a = 1.8 \times 10^{-5} \)

Question #: 25

Calculate the pH of pure water at 40 °C and report it to two places to the right of the decimal point:

\[
2 \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \quad K_w = 2.92 \times 10^{-14} \text{ at } 40 \degree\text{C}
\]

Based on this information, is the autoionization of water endothermic or exothermic?

1. 6.77

2. endothermic|Endothermic|endo|Endo|