Question #: 1

Select all of the correct rate expressions of the reaction $2 \text{C}_8\text{H}_{18}(g) + 25 \text{O}_2(g) \rightarrow 18 \text{H}_2\text{O}(g) + 16 \text{CO}_2(g)$.

A. \[ \text{Rate} = \frac{1}{2} \frac{\Delta[\text{C}_2\text{H}_{18}]}{\Delta t} \]

B. \[ \text{Rate} = 18 \frac{\Delta[\text{H}_2\text{O}]}{\Delta t} \]

C. \[ \text{Rate} = -\frac{1}{25} \frac{\Delta[\text{O}_2]}{\Delta t} \]

D. \[ \text{Rate} = \frac{1}{16} \frac{\Delta[\text{CO}_2]}{\Delta t} \]

Question #: 2

Sulfur and fluorine react to form sulfur hexafluoride.

$\text{S}(g) + 3 \text{F}_2(g) \rightarrow \text{SF}_6(g)$

If sulfur is consumed at a rate of 0.900 M/s, how fast is fluorine consumed?

A. 0.300 M/s
B. 0.600 M/s
C. 0.900 M/s
D. 2.70 M/s
**Question #**: 3

Given the following reaction and data for the bromination of acetone, C₃H₆O, what is the rate law for the reaction?

C₃H₆O(g) + Br₂(g) → C₃H₅OBr(g) + HBr(g)

<table>
<thead>
<tr>
<th>[C₃H₆O] (M)</th>
<th>[Br₂] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100</td>
<td>0.100</td>
<td>1.24 × 10⁻⁵</td>
</tr>
<tr>
<td>0.100</td>
<td>0.200</td>
<td>1.28 × 10⁻⁵</td>
</tr>
<tr>
<td>0.200</td>
<td>0.100</td>
<td>2.52 × 10⁻⁵</td>
</tr>
</tbody>
</table>

A. rate = k[Br₂]
B. rate = k[C₃H₆O][Br₂]
C. rate = k[C₃H₆O][Br₂]²
D. rate = k[C₃H₆O]

**Question #**: 4

Which plot shows ln[A] vs. time for the first-order conversion of reactant A to products?

A. [Graph of ln[A] vs time]
B. [Graph of ln[A] vs time]
c.

In[A] vs time

$k = - \text{slope}$

In[A] vs time

Time, sec

Time, sec

0 5 10 15 20

0 100 200 300
Question #: 5

The zero-order decomposition of ammonia on a hot tungsten surface has a rate constant \( k = 2.08 \times 10^{-4} \text{ M/s} \).

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

How long does it take for the concentration of ammonia to decrease from 1.10 M to 1.08 M?

\[ t = 1 \text{ seconds} \]

1. __________

Question #: 6

The decomposition of \( \text{N}_2\text{O}_5 \) is first-order with a rate constant \( k = 1.8 \text{ h}^{-1} \) at 45 °C. What is the concentration after 53 minutes if the original concentration is 0.400 M \( \text{N}_2\text{O}_5 \)? \( \text{N}_2\text{O}_5(g) \rightarrow 2 \text{NO}_2(g) + \frac{1}{2}\text{O}_2(g) \)

A. 0.082 M  
B. 0.22 M  
C. 0.034 M  
D. 0.13 M

Question #: 7

Which options would achieve the fastest reaction possible for a given system?

1. [low, high] temperature  
2. [low, high] frequency factor  
3. [small, large] activation energy  
4. [small, large] number of collisions

1. __________  
2. __________  
3. __________  
4. __________
**Question #: 8**

A certain reaction has an activation energy of 89.5 kJ/mol. At ___ Kelvin, the reaction will proceed 9.3 times faster than it did at 225 K. Report your answer with three significant figures. Do NOT include units in your answer.

1. ___________

**Question #: 9**

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

Step 1: \( \text{H}_2\text{O}_2 + \text{I}^- \rightarrow \text{H}_2\text{O} + \text{IO}^- \)

Step 2: \( \text{H}_2\text{O}_2 + \text{IO}^- \rightarrow \text{H}_2\text{O} + \text{O}_2 + \text{I}^- \)

Overall: \( 2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2 \)

A. \( \text{H}_2\text{O}_2 = \) catalyst, \( \text{O}_2 = \) reaction intermediate
B. \( \text{H}_2\text{O}_2 = \) catalyst, \( \text{H}_2\text{O} = \) reaction intermediate
C. \( \text{IO}^- = \) catalyst, \( \text{I}^- = \) reaction intermediate
D. \( \text{I}^- = \) catalyst, \( \text{IO}^- = \) reaction intermediate

**Question #: 10**

Which graph best describes the reaction below?

2 NO → H\(_2\)O\(_2\)  fast step
H\(_2\)O\(_2\) + H\(_2\) → N\(_2\)O + H\(_2\)O  slow step
N\(_2\)O + H\(_2\) → N\(_2\) + H\(_2\)O  fast step

2 NO + 2 H\(_2\) → N\(_2\) + 2 H\(_2\)O  overall reaction
Question #: 11

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.

1. __________
2. __________
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 true?

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

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 are equal.
D. The concentration of CH$_4(g)$ is twice that of C$_2$H$_2(g)$.

Question #: 13

BrCl($g$) is added to a reaction vessel at a pressure of 0.10 atm at 150 K. What is true about the equilibrium concentrations of reactants and products?

The equilibrium lies to the _____, so the concentration of BrCl will be _____ than the concentrations of Br$_2$ and Cl$_2$.

$$\text{Br}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2 \text{BrCl}(g) \quad K_p = 1.1 \times 10^{-4} \text{ at 150 K}$$

A. right; higher
B. right; lower
C. left; lower
D. left; higher
Question #: 14

Given

\[ \text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO}(g) \quad K_{c1} = 1.0 \times 10^{-30} \]

\[ \text{N}_2(g) + \text{O}_2(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{NOBr}(g) \quad K_{c2} = 2.0 \times 10^{-27} \]

what is the value of \( K_{c3} \) for

\[ 2 \text{NO}(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{NOBr}(g) \quad K_{c3} = ? \]

A. 2.0 \times 10^3
B. 5.0 \times 10^5
C. 2.0 \times 10^{-6}
D. 5.0 \times 10^{-58}

---

Question #: 15

Given

\[ \text{CH}_3\text{OH}(g) \rightleftharpoons \text{CO}(g) + 2 \text{H}_2(g) \quad K_c = 3.85 \times 10^{-2} \text{ at } 780 \text{ °C (1053 K)} \]

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. 4.21 \times 10^{-3}
D. 2.87 \times 10^2
Question #: 16

Elemental phosphorus reacts with chlorine gas according to the equation

\[ \text{P}_4(\text{s}) + 6 \text{Cl}_2(\text{g}) \rightleftharpoons 4 \text{PCl}_3(\text{l}). \]

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

A. \( K_p = \left( \text{PCl}_2 \right)^6 \)

B. \[ K_p = \frac{(\text{P}_4)(\text{PCl}_2)^6}{(\text{PCl}_3)^4} \]

C. \[ K_p = \frac{(\text{PCl}_3)^4}{(\text{P}_4)(\text{PCl}_2)^6} \]

D. \[ K_p = \frac{1}{(\text{PCl}_2)^6} \]

Question #: 17

Consider the reaction below.

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

A sealed flask is charged with 0.050 M \( \text{H}_2 \) and 0.050 M \( \text{I}_2 \). When the system reaches equilibrium, the concentration of \( \text{HI} \) is 0.080 M. What is the value of \( K_c \) at this temperature? Report your answer to \textbf{two} significant figures and do \textbf{not} use scientific notation. 

\[ K_c = \frac{1}{1} \]

1. \__________
Question #: 18

Consider the equilibrium decomposition of ammonium hydrosulfide below.
\[ \text{NH}_4\text{HS(s)} \rightleftharpoons \text{NH}_3(g) + \text{H}_2\text{S(g)} \]

At a certain temperature, \( K_c = 8.5 \times 10^{-3} \). At this temperature, there are concentrations of \([\text{NH}_3] = [\text{H}_2\text{S}] = 0.097 \text{ M} \) above a sample of solid NH\(_4\)HS. Which of the following statements is correct?

A. The system is at equilibrium.
B. More NH\(_4\)HS(s) will decompose in order to reach equilibrium.
C. More NH\(_4\)HS(s) will form in order to reach equilibrium.
D. The answer cannot be determined from the information given.

---

Question #: 19

What is the equilibrium concentration of N\(_2\) if \([\text{NH}_3] = 0.015 \text{ M} \) and \([\text{H}_2\text{S}] = 0.92 \text{ M} \) at equilibrium for the reaction below?
\[ \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \quad K_c = 3.7 \times 10^{-3} \]

A. 2.8 \times 10^{-4} \text{ M}
B. 0.17 \text{ M}
C. 7.8 \times 10^{-2} \text{ M}
D. 6.5 \text{ M}
**Question #**: 20

Given

\[ \text{2 NOCl}(g) \rightleftharpoons \text{2 NO}(g) + \text{Cl}_2(g) \quad K_c = 4.7 \times 10^{-4} \]

what is the equilibrium concentration of \( \text{Cl}_2 \) when 1.0 mole of NOCl is injected into a 5.0 L reaction vessel?

A. \( 6.5 \times 10^{-5} \) M  
B. \( 1.7 \times 10^{-2} \) M  
C. \( 2.8 \times 10^{-4} \) M  
D. \( 4.2 \times 10^{-2} \) M

**Question #**: 21

Consider the reaction below at equilibrium at a fixed temperature.

\[ \text{XeF}_4(g) \rightleftharpoons \text{Xe}(g) + 2 \text{F}_2(g) \]

Select **two** of the following disturbances that will cause the reaction to shift to the **left** (towards reactants) in order to reestablish equilibrium.

A. decrease in volume  
B. increase in volume  
C. increase in the number of moles of \( \text{F}_2 \)  
D. decrease in the number of moles of \( \text{Xe} \)  
E. pressure increase by addition of an inert gas
Question #: 22

Reaction 1: \( \text{PH}_3(g) + \text{HI}(g) \rightarrow \text{PH}_4\text{I}(s) \)
Reaction 2: \( \text{NaOH}(aq) + \text{H}_2\text{S}(aq) \rightarrow \text{NaSH}(aq) + \text{H}_2\text{O}(l) \)

Reaction 1 is best described by the ___ theory; ___ is the base and ___ is the acid.
Reaction 2 is best described by the ___ theory; ___ is the base and ___ is the acid.

A. Brønsted-Lowry; PH\(_3\); HI
   Arrhenius; NaOH; H\(_2\)S
B. Arrhenius; PH\(_3\); HI

Brønsted-Lowry; NaOH; H\(_2\)S
C. Brønsted-Lowry; HI; PH\(_3\)
   Arrhenius; NaOH; H\(_2\)S
D. Arrhenius theory; PH\(_3\); HI

Brønsted-Lowry; H\(_2\)S; NaOH

Question #: 23

Match the acids on the left with the descriptions on the right by entering the letter A, B, C or D for each acid.

<table>
<thead>
<tr>
<th></th>
<th>1. H(_2)SO(_4)</th>
<th>2. HF</th>
<th>3. HBr</th>
<th>4. H(_2)CO(_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td>A. monoprotic strong acid</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td>B. diprotic strong acid</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td>C. diprotic weak acid</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td>D. monoprotic weak acid</td>
</tr>
</tbody>
</table>

1. __________  
2. __________  
3. __________  
4. __________
Question #: 24

For the acids listed in the table below, __1__ is the strongest acid and __2__ is the strongest conjugate base.
Write the names of the acids or conjugate base ions as they appear in the table. Partial credit will not be awarded if an acid is written in place of the conjugate base for your answer, or vice versa. You must correctly identify the acid or the base.

<table>
<thead>
<tr>
<th>Acid / Conjugate Base</th>
<th>$K_a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>phenol / phenolate ion</td>
<td>$1.3 \times 10^{-10}$</td>
</tr>
<tr>
<td>formic acid / formate ion</td>
<td>$1.8 \times 10^{-4}$</td>
</tr>
<tr>
<td>nitrous acid / nitrite ion</td>
<td>$4.6 \times 10^{-4}$</td>
</tr>
<tr>
<td>benzoic acid / benzoate ion</td>
<td>$6.5 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

1. __________
2. __________

Question #: 25

$[H^+] = __1__$ M in pure water at 30 °C.
At 30 °C, $K_w = 1.5 \times 10^{-14}$.
Report your answer with one digit to the right of the decimal in scientific notation with the format $2.2E2$ or $2.2E-2$.

1. __________
Question #: 1

Select **all** of the correct rate expressions of the reaction $2 \text{C}_8\text{H}_{18}(g) + 25 \text{O}_2(g) \rightarrow 18 \text{H}_2\text{O}(g) + 16 \text{CO}_2(g)$.

A. 

$$\text{Rate} = \frac{1}{2} \frac{\Delta[\text{C}_2\text{H}_{18}]}{\Delta t}$$

B. 

$$\text{Rate} = 18 \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}$$

✓C.
Question #: 2

Sulfur and fluorine react to form sulfur hexafluoride.
\[ \text{S}(g) + 3 \text{F}_2(g) \rightarrow \text{SF}_6(g) \]
If sulfur is consumed at a rate of 0.900 M/s, how fast is fluorine consumed?

A. 0.300 M/s
B. 0.600 M/s
C. 0.900 M/s
✓D. 2.70 M/s

Question #: 3

Given the following reaction and data for the bromination of acetone, C\textsubscript{3}H\textsubscript{6}O, what is the \textbf{rate law} for the reaction?
\[ \text{C}_3\text{H}_6\text{O}(g) + \text{Br}_2(g) \rightarrow \text{C}_3\text{H}_5\text{OBr}(g) + \text{HBr}(g) \]

<table>
<thead>
<tr>
<th>[C\textsubscript{3}H\textsubscript{6}O] (M)</th>
<th>[Br\textsubscript{2}] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100</td>
<td>0.100</td>
<td>(1.24 \times 10^{-5})</td>
</tr>
<tr>
<td>0.100</td>
<td>0.200</td>
<td>(1.28 \times 10^{-5})</td>
</tr>
<tr>
<td>0.200</td>
<td>0.100</td>
<td>(2.52 \times 10^{-5})</td>
</tr>
</tbody>
</table>

A. \text{rate} = k[Br\textsubscript{2}]
B. \text{rate} = k[C\textsubscript{3}H\textsubscript{6}O][Br\textsubscript{2}]
C. \text{rate} = k[C\textsubscript{3}H\textsubscript{6}O][Br\textsubscript{2}]^2
Which plot shows $\ln[A]$ vs. time for the **first-order** conversion of reactant A to products?

A. 

![Graph A](image)

B. 

![Graph B](image)

C. 

D. rate = $k[C_3H_6O]$
The zero-order decomposition of ammonia on a hot tungsten surface has a rate constant \( k = 2.08 \times 10^{-4} \text{ M/s} \).

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

How long does it take for the concentration of ammonia to decrease from 1.10 M to 1.08 M?

\[ t = \quad \text{1} \quad \text{seconds} \]

\[ 1.962 \]

The decomposition of \( \text{N}_2\text{O}_5 \) is first-order with a rate constant \( k = 1.8 \text{ h}^{-1} \) at 45 °C. What is the concentration after 53 minutes if the original concentration is 0.400 M \( \text{N}_2\text{O}_5 \)?

\[ \text{N}_2\text{O}_5(g) \rightarrow 2 \text{NO}_2(g) + \frac{1}{2}\text{O}_2(g) \]

\[ \checkmark \] A. 0.082 M  
B. 0.22 M  
C. 0.034 M  
D. 0.13 M
Question #: 7

Which options would achieve the fastest reaction possible for a given system?

1. [low, high] temperature
2. [low, high] frequency factor
3. [small, large] activation energy
4. [small, large] number of collisions

1. high
2. high
3. small
4. large

Question #: 8

A certain reaction has an activation energy of 89.5 kJ/mol. At __1__ Kelvin, the reaction will proceed 9.3 times faster than it did at 225 K.

Report your answer with three significant figures. Do NOT include units in your answer.

1. 236

Question #: 9

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

Step 1: \( \text{H}_2\text{O}_2 + \text{I}^- \rightarrow \text{H}_2\text{O} + \text{IO}^- \)
Step 2: \( \text{H}_2\text{O}_2 + \text{IO}^- \rightarrow \text{H}_2\text{O} + \text{O}_2 + \text{I}^- \)
Overall: \( 2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2 \)

A. \( \text{H}_2\text{O}_2 \) = catalyst, \( \text{O}_2 \) = reaction intermediate
B. \( \text{H}_2\text{O}_2 \) = catalyst, \( \text{H}_2\text{O} \) = reaction intermediate
C. \( \text{IO}^- \) = catalyst, \( \text{I}^- \) = reaction intermediate
D. \( \text{I}^- \) = catalyst, \( \text{IO}^- \) = reaction intermediate

✓ D. \( \text{I}^- \) = catalyst, \( \text{IO}^- \) = reaction intermediate
Question #: 10

Which graph best describes the reaction below?

\[
\begin{align*}
2 \text{ NO} & \rightarrow \text{H}_2\text{O}_2 \quad \text{fast step} \\
\text{H}_2\text{O}_2 + \text{H}_2 & \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O} \quad \text{slow step} \\
\text{N}_2\text{O} + \text{H}_2 & \rightarrow \text{N}_2 + \text{H}_2\text{O} \quad \text{fast step}
\end{align*}
\]

\[
\begin{align*}
2 \text{ NO} + 2 \text{ H}_2 & \rightarrow \text{N}_2 + 2 \text{ H}_2\text{O} \quad \text{overall reaction}
\end{align*}
\]

A. 

B. 

C.
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.
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 true?

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

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 are equal.

D. The concentration of CH\(_4\)(g) is twice that of C\(_2\)H\(_2\)(g).

Question #: 13

BrCl(g) is added to a reaction vessel at a pressure of 0.10 atm at 150 K. What is true about the equilibrium concentrations of reactants and products?
The equilibrium lies to the _____, so the concentration of BrCl will be _____ than the concentrations of Br₂ and Cl₂.

\[ \text{Br}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2 \text{BrCl}(g) \quad K_p = 1.1 \times 10^{-4} \text{ at } 150 \text{ K} \]

A. right; higher  
B. right; lower  
✓C. left; lower  
D. left; higher

---

**Question #14**

Given

\[ \text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO}(g) \quad K_{c1} = 1.0 \times 10^{-30} \]

\[ \text{N}_2(g) + \text{O}_2(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{NOBr}(g) \quad K_{c2} = 2.0 \times 10^{-27} \]

what is the value of \( K_{c3} \) for

\[ 2 \text{NO}(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{NOBr}(g) \quad K_{c3} = ? \]

✓A. \( 2.0 \times 10^{3} \)  
B. \( 5.0 \times 10^{5} \)  
C. \( 2.0 \times 10^{-6} \)  
D. \( 5.0 \times 10^{-58} \)

---

**Question #15**
Given

\[ \text{CH}_3\text{OH}(g) \rightleftharpoons \text{CO}(g) + 2 \text{H}_2(g) \quad K_c = 3.85 \times 10^{-2} \text{ at } 780 \degree \text{C (1053 K)} \]

what is the value of \( K_p \) at 780 \degree \text{C (1053 K)}?

A. \(3.48 \times 10^3\)  
B. \(9.64 \times 10^5\)  
C. \(4.21 \times 10^{-3}\)  
D. \(2.87 \times 10^2\)  

\[\checkmark\text{D. } 2.87 \times 10^2\]

---

**Question #: 16**

Elemental phosphorus reacts with chlorine gas according to the equation

\[ \text{P}_4(s) + 6 \text{Cl}_2(g) \rightleftharpoons 4 \text{PCl}_3(l) \]

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

A. \[K_p = (\text{PCl}_2)^6\]

B. \[K_p = \frac{(\text{P}_4)(\text{PCl}_2)^6}{(\text{PCl}_3)^4}\]

C. \[K_p = \frac{(\text{PCl}_3)^4}{(\text{P}_4)(\text{PCl}_2)^6}\]

\[\checkmark\text{D. } \frac{1}{(\text{PCl}_2)^6}\]
Question #: 17

Consider the reaction below.

\[
H_2(g) + I_2(g) \rightleftharpoons 2 HI(g)
\]

A sealed flask is charged with 0.050 M H₂ and 0.050 M I₂. When the system reaches equilibrium, the concentration of HI is 0.080 M. What is the value of \( K_c \) at this temperature? Report your answer to two significant figures and do not use scientific notation.

\[
K_c = 1.64
\]

Question #: 18

Consider the equilibrium decomposition of ammonium hydrosulfide below.

\[
NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)
\]

At a certain temperature, \( K_c = 8.5 \times 10^{-3} \). At this temperature, there are concentrations of \([NH_3] = [H_2S] = 0.097 \text{ M} \) above a sample of solid \( NH_4HS \).

Which of the following statements is correct?

A. The system is at equilibrium.
B. More \( NH_4HS(s) \) will decompose in order to reach equilibrium.
C. More \( NH_4HS(s) \) will form in order to reach equilibrium.
D. The answer cannot be determined from the information given.

 Question #: 19
What is the equilibrium concentration of N₂ if [NH₃] = 0.015 M and [H₂] = 0.92 M at equilibrium for the reaction below?

\[ \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \quad K_c = 3.7 \times 10^{-3} \]

A. 2.8 \times 10^{-4} M  
B. 0.17 M  
✓C. 7.8 \times 10^{-2} M  
D. 6.5 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 Cl₂ when 1.0 mole of NOCl is injected into a 5.0 L reaction vessel?

A. 6.5 \times 10^{-5} M  
✓B. 1.7 \times 10^{-2} M  
C. 2.8 \times 10^{-4} M  
D. 4.2 \times 10^{-2} M

---

**Question #: 21**

Consider the reaction below at equilibrium at a fixed temperature.

\[ \text{XeF}_4(g) \rightleftharpoons \text{Xe}(g) + 2 \text{F}_2(g) \]

Select two of the following disturbances that will cause the reaction to shift to the left (towards reactants) in order to reestablish equilibrium.

✓A. decrease in volume
B. increase in volume
✓ C. increase in the number of moles of F₂
D. decrease in the number of moles of Xe
E. pressure increase by addition of an inert gas

Question #: 22

Reaction 1: PH₃(g) + HI(g) → PH₄I(s)
Reaction 2: NaOH(aq) + H₂S(aq) → NaSH(aq) + H₂O(l)

Reaction 1 is best described by the ___ theory; ___ is the base and ___ is the acid.
Reaction 2 is best described by the ___ theory; ___ is the base and ___ is the acid.

✓ A. Brønsted-Lowry; PH₃; HI
   Arrhenius; NaOH; H₂S
B. Arrhenius; PH₃; HI
   Brønsted-Lowry; NaOH; H₂S
C. Brønsted-Lowry; HI; PH₃
   Arrhenius; NaOH; H₂S
D. Arrhenius theory; PH₃; HI
   Brønsted-Lowry; H₂S; NaOH

Question #: 23

Match the acids on the left with the descriptions on the right by entering the letter A, B, C or D for each acid.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H₂SO₄</td>
<td>A. monoprotic strong acid</td>
</tr>
<tr>
<td>2</td>
<td>HF</td>
<td>B. diprotic strong acid</td>
</tr>
<tr>
<td>3</td>
<td>HBr</td>
<td>C. diprotic weak acid</td>
</tr>
<tr>
<td>4</td>
<td>H₂CO₃</td>
<td>D. monoprotic weak acid</td>
</tr>
</tbody>
</table>

1. B|b|B.|diprotic strong acid|
2. D|d|D.|monoprotic weak acid|
3. A|a|A.|monoprotic strong acid|
4. C|c|C.|diprotic weak acid|

**Question #: 24**

For the acids listed in the table below, **1** is the **strongest acid** and **2** is the **strongest conjugate base**. Write the names of the **acids** or **conjugate base ions** as they appear in the table. Partial credit will **not** be awarded if an acid is written in place of the conjugate base for your answer, or vice versa. You **must** correctly identify the acid or the base.

<table>
<thead>
<tr>
<th>Acid / Conjugate Base</th>
<th>$K_a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>phenol / phenolate ion</td>
<td>$1.3 \times 10^{-10}$</td>
</tr>
<tr>
<td>formic acid / formate ion</td>
<td>$1.8 \times 10^{-4}$</td>
</tr>
<tr>
<td>nitrous acid / nitrite ion</td>
<td>$4.6 \times 10^{-4}$</td>
</tr>
<tr>
<td>benzoic acid / benzoate ion</td>
<td>$6.5 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

1. nitrous acid|nitrousacid|nitrous|
2. phenolate ion

**Question #: 25**

$[H^+] = \underline{1} \ M$ in pure water at 30 °C.
At 30 °C, $K_w = 1.5 \times 10^{-14}$.
Report your answer with one digit to the right of the decimal in scientific notation with the format 2.2E2 or 2.2E-2.

1. $1.2E-7$