Question #: 1

Which substance has the smallest standard molar entropy ($^\circ S$)?

A. He($g$)
B. H$_2$O($g$)
C. CH$_4$(g)
D. F$_2$(g)

Question #: 2

Phosgene, a chemical weapon used during World War I, is formed by the reaction of chloroform with oxygen:

\[ 2 \text{CHCl}_3(l) + \text{O}_2(g) \rightarrow 2 \text{COCl}_2(g) + 2 \text{HCl}(g) \quad \Delta H^o = -353 \text{ kJ} \]

The sign of the entropy change for the system, $\Delta S_{sys}$, is _1_ [positive, negative].
The sign of the entropy change for the surroundings, $\Delta S_{surr}$, is _2_ [positive, negative].
The sign of the entropy change for the universe, $\Delta S_{univ}$, is _3_ [positive, negative].
The reaction will be _4_ [spontaneous, nonspontaneous].

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

For this reaction at 298 K and constant pressure, \( \Delta S_{\text{surroundings}} = \) ______.

\[
3 \text{ CO}_2(g) + 4 \text{ H}_2\text{O}(g) \rightarrow \text{C}_3\text{H}_8(g) + 5 \text{ O}_2(g) \quad \Delta H^\circ = 2043 \text{ kJ}
\]

A. \( \Delta S_{\text{surroundings}} = 729 \text{ J/K} \)
B. \( \Delta S_{\text{surroundings}} = -729 \text{ J/K} \)
C. \( \Delta S_{\text{surroundings}} = 6,860 \text{ J/K} \)
D. \(\Delta S_{\text{surroundings}} = -6,860 \text{ J/K} \)

**Question #: 4**

Given the information below, what is \( \Delta S^\circ_{\text{rxn}} \) for

\[
2 \text{ C}_4\text{H}_{10}(l) + 13 \text{ O}_2(g) \rightarrow 8 \text{ CO}_2(g) + 10 \text{ H}_2\text{O}(l)
\]

<table>
<thead>
<tr>
<th>Compound</th>
<th>( S^\circ (\text{J/mol} \cdot \text{K}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{C}<em>4\text{H}</em>{10}(l)</td>
<td>310.</td>
</tr>
<tr>
<td>\text{O}_2(g)</td>
<td>205.</td>
</tr>
<tr>
<td>\text{CO}_2(g)</td>
<td>214.</td>
</tr>
<tr>
<td>\text{H}_2\text{O}(l)</td>
<td>70.0.</td>
</tr>
</tbody>
</table>

A. 799 J/mol•K
B. -873 J/mol•K
C. 363 kJ/mol•K
D. -799 J/mol•K

**Question #: 5**

Given

\[
\text{NaHCO}_3(s) + \text{HCl}(aq) \rightarrow \text{NaCl}(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g); \Delta H^\circ = 28.5 \text{ kJ} \cdot \text{mol}^{-1}; \Delta S^\circ = 230 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}
\]

above what Kelvin temperature will this reaction become spontaneous?

A. 24 K
B. 85 K
C. 106 K
D. 124 K
Question #: 6

Calculate the free energy change, $\Delta G^\circ_{\text{rxn}}$, for this reaction at 25.0 °C.

$2 \text{ Ca}(s) + \text{ O}_2(g) \rightarrow 2 \text{ CaO}(s)$; $\Delta H^\circ_{\text{rxn}} = -1270 \text{ kJ}$; $\Delta S^\circ_{\text{rxn}} = -365 \text{ J/K}$.

A. $-1.16 \times 10^3 \text{ kJ}$
B. $7.86 \times 10^3 \text{ kJ}$
C. $-1.38 \times 10^3 \text{ kJ}$
D. $1.08 \times 10^5 \text{ kJ}$

Question #: 7

What is $\Delta G^\circ_{\text{rxn}}$ for the reaction $3 \text{ C}(s) + 4 \text{ H}_2(g) \rightarrow \text{C}_3\text{H}_8(g)$ given the information below?

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Reaction Equation</th>
<th>$\Delta G^\circ_{\text{rxn}}$ (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$3 \text{ CO}_2(g) + 4 \text{ H}_2\text{O}(g) \rightarrow \text{C}_3\text{H}_8(g) + 5 \text{ O}_2(g)$</td>
<td>2074</td>
</tr>
<tr>
<td>B</td>
<td>$\text{CO}_2(g) \rightarrow \text{C}(s) + \text{ O}_2(g)$</td>
<td>394</td>
</tr>
<tr>
<td>C</td>
<td>$2 \text{ H}_2(g) + \text{ O}_2(g) \rightarrow 2 \text{ H}_2\text{O}(g)$</td>
<td>$-457$</td>
</tr>
</tbody>
</table>

A. $-22 \text{ kJ}$
B. $2625 \text{ kJ}$
C. $-1805 \text{ kJ}$
D. $52 \text{ kJ}$
Question #: 8

Which **two** statements about \( \Delta H_{\text{solution}} \) are true?

\[ \Delta H_{\text{solution}} = \Delta H_{\text{mix}} + \Delta H_{\text{solute}} + \Delta H_{\text{solvent}} \]

A. \( \Delta H_{\text{solution}} \) will be endothermic when \( \Delta H_{\text{solute}} + \Delta H_{\text{solvent}} > \Delta H_{\text{mix}} \).
B. \( \Delta H_{\text{solution}} \) will always be exothermic when \( \Delta H_{\text{solute}} + \Delta H_{\text{solvent}} = \Delta H_{\text{mix}} \).
C. \( \Delta H_{\text{solution}} \) will be exothermic when the solute-solvent intermolecular forces are stronger than the sum of the solute-solute and solvent-solvent intermolecular forces.
D. Solutions only form when \( \Delta H_{\text{solution}} \) is exothermic.

---

Question #: 9

Using the solubility curves shown below, describe the solubility of the following salts in 100.0 g of water, each at 20.0 °C. Respond with **saturated**, **unsaturated**, or **supersaturated**.

1. 20.0 grams of KCl
2. 30.0 grams of KNO₃

![Solubility Curves Graph](image-url)
Question #: 10

An aqueous solution is saturated in both CO_2(g) and KCl(aq) at 25 ºC. If the solution is cooled to 0 ºC, which process is most likely to occur?

A. Some CO_2 vaporizes but no KCl precipitates.
B. No CO_2 vaporizes but some KCl precipitates.
C. Some CO_2 vaporizes and some KCl precipitates.
D. All the CO_2 vaporizes and all the KCl precipitates.

Question #: 11

What is the concentration of NH_3 when the partial pressure of ammonia, P_{NH_3}, is 0.25 atm above the solution at 25 ºC? An 8.7 M NH_3 solution results when the pressure of P_{NH_3} is 0.15 atm at 25 ºC?

A. 7.6 M
B. 12 M
C. 18 M
D. 15 M

Question #: 12

The vapor pressure of pure benzene, C_6H_6 (78.1 g/mol), is 400. mmHg at 60.1 ºC. What is the vapor pressure at 60.1 ºC of a solution prepared by dissolving 49.2 g of camphor, C_{10}H_{16}O (152.2 g/mol), in 197 g of benzene? Camphor is a nonvolatile, nonionizing solute.

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

1. ___________
Question #: 13

What is the boiling point of a solution of 106 g potassium phosphate (K₃PO₄, 212 g/mol) in 2.50 × 10² g H₂O?

\( K_b(H_2O) = 0.512 \, ^\circ C/m \) and \( T_b = 100.0 \, ^\circ C \) for the boiling point of pure water. Use ideal van't Hoff factors, if needed.

A. 102°C  
B. 104°C  
C. 106°C  
D. 108°C

---

Question #: 14

An osmotic cell with a semipermeable membrane is set up with pure water in chamber A and 1.50 M KCl in chamber B. What happens as the cell reaches equilibrium?

A. The volumes in chamber A and chamber B remain equal.  
B. H₂O from chamber A flows into chamber B, increasing the volume in chamber B.  
C. KCl from chamber B flows into chamber A, increasing the volume in chamber A.  
D. H₂O from chamber B flows into chamber A, increasing the volume in chamber A.
Question #: 15

The ideal van't Hoff factor for (NH₄)₃PO₄ is 1. Report your answer as a whole number. Do NOT include units in your answer.

1. ________

Question #: 16

Assuming an ideal van't Hoff factor, what mass of NaCl (58.4 g/mol) needs to be added to 1.00 kg of water to lower the freezing point of water by 3.00 ºC? \( K_f \) for water is 1.86 ºC/m.

\( \text{1 g NaCl} \)

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

1. ________

Question #: 17

A 6.00 g sample of an unknown nonelectrolyte is dissolved in 24.0 g of carbon tetrachloride, CC\(_4\), to make a solution that boils at 85.35 ºC. The \( K_b \) value for C\( \text{Cl}_4 \) is 5.03 ºC/m and the boiling point of pure C\( \text{Cl}_4 \) is 76.80 ºC. What is the molar mass of the unknown compound?

A. 40.7 g/mol  
B. 118 g/mol  
C. 122 g/mol  
D. 147 g/mol

Question #: 18

NO\(_2\)\((g)\) reacts with water to form nitric acid, HNO\(_3\).

\[ 3 \text{NO}_2(g) + \text{H}_2\text{O}(l) \rightarrow 2 \text{HNO}_3(aq) + \text{NO}(g) \]

What is the rate at which HNO\(_3\) is being formed when NO\(_2\) is reacting at 0.90 M/s? Report your answer with two significant figures. Do NOT include units with your answer.

\( \text{1 M/s} \)

1. ________
Question #: 19

Given the following reaction and data, what is the rate law for the reaction?
I\(^-\)(aq) + OCl\(^-\)(aq) → Cl\(^-\)(aq) + OI\(^-\)(aq)

<table>
<thead>
<tr>
<th>[I(^-)] (M)</th>
<th>[OCl(^-)] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0010</td>
<td>0.0010</td>
<td>5.75 × 10(^{-5})</td>
</tr>
<tr>
<td>0.0010</td>
<td>0.0020</td>
<td>2.30 × 10(^{-4})</td>
</tr>
<tr>
<td>0.0020</td>
<td>0.0010</td>
<td>1.15 × 10(^{-4})</td>
</tr>
</tbody>
</table>

A. rate = \(k[I^-][OCl^-]^2\)
B. rate = \(k[I^-][OCl^-]\)
C. rate = \(k[I^-]^2[OCl^-]\)
D. rate = \(k[OCl^-]^2\)

Question #: 20

The gas phase reaction  \(\text{NO}_2(g) + \text{CO}(g) → \text{NO}(g) + \text{CO}_2(g)\)  is found to be second-order in \(\text{NO}_2\) and zero-order in \(\text{CO}\) at temperatures less than 500 K. What is the effect on the rate if the concentration of \(\text{NO}_2\) is tripled and the concentration of \(\text{CO}\) is doubled?

A. The rate increases by a factor of 6.
B. The rate increases by a factor of 18.
C. The rate increases by a factor of 9.
D. The rate increases by a factor of 3.
Question #: 21

For the reaction A $\rightarrow$ B, fill in the blanks with zero, first, or second for the kinetic data graphed below.

A reaction is _1_ -order when a plot of ln [A] versus time is linear.

A reaction is _2_ -order when the plot of 1/[A] versus time is linear.

A reaction is _3_ -order when a plot of [A] versus time is linear.

1. _________
2. _________
3. _________

Question #: 22

Using the given data, determine the rate constant, $k$, of the reaction

$$2 \text{ClO}_2(aq) + 2 \text{OH}^-(aq) \rightarrow \text{ClO}_3^-(aq) + \text{ClO}_2^-(aq) + \text{H}_2\text{O}(l)$$

where rate = $k[\text{OH}^-]$.

<table>
<thead>
<tr>
<th>Trial</th>
<th>[ClO$_2$] (M)</th>
<th>[OH$^-$] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.060</td>
<td>0.030</td>
<td>0.0248</td>
</tr>
<tr>
<td>2</td>
<td>0.020</td>
<td>0.030</td>
<td>0.0249</td>
</tr>
<tr>
<td>3</td>
<td>0.020</td>
<td>0.090</td>
<td>0.0746</td>
</tr>
</tbody>
</table>

A. 7.6 $\times 10^3$ s$^{-1}$
B. 14 s$^{-1}$
C. 7.4 $\times 10^{-4}$ s$^{-1}$
D. 0.83 s$^{-1}$
Question #: 23

Radioactive technetium-99 (Tc-99) decays following first order kinetics with $k = 0.116 \text{ h}^{-1}$. How much Tc-99 remains after 2.2 hours in a solution initially 0.500 M in Tc-99?

A. 0.187 M  
B. 0.297 M  
C. 0.387 M  
D. 0.407 M

Question #: 24

The decomposition below is second order in NO$_2$. How long will it take for the concentration of NO$_2$ to decrease from 4.00 M to 1.00 M?

$$\text{NO}_2(g) \rightarrow \text{NO}(g) + \frac{1}{2} \text{O}_2(g) \quad k = 3.4 \text{ M}^{-1}\cdot\text{min}^{-1}$$

A. 0.88 min  
B. 1.4 min  
C. 0.22 min  
D. 0.074 min

Question #: 25

When heated to 499 °C, cyclopropane rearranges (isomerizes) and forms propene with a rate constant of $3.57 \times 10^{-2} \text{ min}^{-1}$. What is the half-life of this reaction, in minutes? Report your answer to three significant figures. Do NOT include units in your answer.

___ minutes

1. __________
Question #: 26

The activation energy for a certain reaction is 255 kJ and the $\Delta H_{\text{rxn}}$ is 121 kJ. What is the activation energy of the reverse reaction?

A. $-255$ kJ  
B. 376 kJ  
C. 134 kJ  
D. $-121$ kJ

Question #: 27

A certain reaction has an activation energy of 254 kJ/mol. At what temperature will the reaction will proceed four times faster than it does at 298 K?

A. 294 K  
B. 73.9 K  
C. 302 K  
D. 1190 K

Question #: 28

In the diagram below, the 1 of the reaction is greater than the 2 needed to reach the 3 before proceeding to products. Fill in the blanks with activation energy, enthalpy, or transition state.

1. 
2. 
3. 

[Diagram of a reaction with potential energy and reaction progress axes]
Question #: 29

Which **two** statements about catalysts are **false**?

A. A catalyst is a substance that lowers the activation energy of a chemical reaction.
B. A catalyst is always an enzyme.
C. A catalyst speeds up the rate of a reaction.
D. A catalyst is consumed during the chemical reaction.

Question #: 30

The overall reaction $2O_3(g) \rightarrow 3O_2(g)$ can occur by the following mechanism:

\[
\begin{align*}
\text{NO}(g) + O_3(g) & \rightarrow \text{NO}_2(g) + O_2(g) \\
O_3(g) & \rightarrow O_2(g) + O(g) \\
\text{NO}_2(g) + O(g) & \rightarrow \text{NO}(g) + O_2(g)
\end{align*}
\]

Select the **TWO** **intermediates** in this mechanism.

$\text{NO}(g) + O_3(g) \rightarrow \text{NO}_2(g) + O_2(g)$

A. NO$(g)$
B. O$_3$(g)
C. NO$_2$(g)
D. O$_2$(g)
E. O$(g)$
Which substance has the smallest standard molar entropy ($\Delta S$)?

A. He($g$)  
B. H$_2$O($g$)  
C. CH$_4$($g$)  
D. F$_2$($g$)

Phosgene, a chemical weapon used during World War I, is formed by the reaction of chloroform with oxygen:
\[ 2 \text{CHCl}_3(l) + \text{O}_2(g) \rightarrow 2 \text{COCl}_2(g) + 2 \text{HCl}(g) \quad \Delta H^\circ = -353 \text{ kJ} \]

The sign of the entropy change for the system, \( \Delta S_{\text{sys}} \), is 1 [positive, negative].

The sign of the entropy change for the surroundings, \( \Delta S_{\text{surr}} \), is 2 [positive, negative].

The sign of the entropy change for the universe, \( \Delta S_{\text{univ}} \), is 3 [positive, negative].

The reaction will be 4 [spontaneous, nonspontaneous].

Question #: 3

For this reaction at 298 K and constant pressure, \( \Delta S_{\text{surroundings}} = \ldots \).

\[ 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(g) \rightarrow \text{C}_3\text{H}_8(g) + 5 \text{O}_2(g) \quad \Delta H^\circ = 2043 \text{ kJ} \]

A. \( \Delta S_{\text{surroundings}} = 729 \text{ J/K} \)

B. \( \Delta S_{\text{surroundings}} = -729 \text{ J/K} \)

C. \( \Delta S_{\text{surroundings}} = 6,860 \text{ J/K} \)

D. \( \Delta S_{\text{surroundings}} = -6,860 \text{ J/K} \)

Question #: 4

Given the information below, what is \( \Delta S_{\text{rxn}}^\circ \) for

\[ 2 \text{C}_4\text{H}_{10}(l) + 13 \text{O}_2(g) \rightarrow 8 \text{CO}_2(g) + 10 \text{H}_2\text{O}(l) \]

<table>
<thead>
<tr>
<th>Compound</th>
<th>( S^\circ ) (J/mol( \cdot )K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{C}<em>4\text{H}</em>{10}(l) )</td>
<td>310.</td>
</tr>
<tr>
<td>( \text{O}_2(g) )</td>
<td>205</td>
</tr>
<tr>
<td>( \text{CO}_2(g) )</td>
<td>214</td>
</tr>
<tr>
<td>( \text{H}_2\text{O}(l) )</td>
<td>70.0</td>
</tr>
</tbody>
</table>
Question #: 5

Given

\[ \text{NaHCO}_3(s) + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2(g); \Delta H^\circ = 28.5 \text{ kJ\cdot mol}^{-1}; \Delta S^\circ = 230 \text{ J\cdot mol}^{-1}\cdot\text{K}^{-1} \]

above what Kelvin temperature will this reaction become spontaneous?

A. 24 K
B. 85 K
C. 106 K
D. 124 K

Question #: 6

Calculate the free energy change, \( \Delta G^\circ_{\text{rxn}} \), for this reaction at 25.0 °C.

\[ 2 \text{ Ca(s)} + \text{O}_2(g) \rightarrow 2 \text{ CaO(s)}; \Delta H^\circ_{\text{rxn}} = -1270 \text{ kJ}; \Delta S^\circ_{\text{rxn}} = -365 \text{ J/K} \]

A. \(-1.16 \times 10^3 \text{ kJ}\)
B. \(7.86 \times 10^3 \text{ kJ}\)
C. \(-1.38 \times 10^3 \text{ kJ}\)
D. \(1.08 \times 10^5 \text{ kJ}\)

Question #: 7

What is \( \Delta G^\circ_{\text{rxn}} \) for the reaction \( 3 \text{ C(s)} + 4 \text{ H}_2(g) \rightarrow \text{C}_3\text{H}_8(g) \) given the information below?

<table>
<thead>
<tr>
<th>Reaction A: ( 3 \text{ CO}_2(g) + 4 \text{ H}_2\text{O}(g) \rightarrow \text{C}_3\text{H}_8(g) + 5 \text{ O}_2(g) )</th>
<th>( G^\circ_{\text{rxn}} ) (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2074</td>
<td></td>
</tr>
</tbody>
</table>
Question #: 8

Which two statements about $\Delta H_{\text{solution}}$ are true?

$\Delta H_{\text{solution}} = \Delta H_{\text{mix}} + \Delta H_{\text{solute}} + \Delta H_{\text{solvent}}$

A. $\Delta H_{\text{solution}}$ will be endothermic when $\Delta H_{\text{solute}} + \Delta H_{\text{solvent}} > \Delta H_{\text{mix}}$.

B. $\Delta H_{\text{solution}}$ will always be exothermic when $\Delta H_{\text{solute}} + \Delta H_{\text{solvent}} = \Delta H_{\text{mix}}$.

C. $\Delta H_{\text{solution}}$ will be exothermic when the solute-solvent intermolecular forces are stronger than the sum of the solute-solute and solvent-solvent intermolecular forces.

D. Solutions only form when $\Delta H_{\text{solution}}$ is exothermic.

Question #: 9

Using the solubility curves shown below, describe the solubility of the following salts in 100.0 g of water, each at 20.0 °C.

Respond with saturated, unsaturated, or supersaturated.

1. 20.0 grams of KCl
2. 30.0 grams of KNO₃
1. **unsaturated**  
2. **saturated**

**Question #**: 10

An aqueous solution is saturated in both CO₂\((g)\) and KCl\((aq)\) at 25 °C. If the solution is cooled to 0 °C, which process is most likely to occur?

- A. Some CO₂ vaporizes but no KCl precipitates.
- ✓ B. No CO₂ vaporizes but some KCl precipitates.
- C. Some CO₂ vaporizes and some KCl precipitates.
- D. All the CO₂ vaporizes and all the KCl precipitates.

**Question #**: 11

What is the concentration of NH₃ when the partial pressure of ammonia, \(P_{\text{NH}_3}\), is 0.25 atm above the solution at 25 °C? An 8.7 M NH₃ solution results when the pressure of \(P_{\text{NH}_3}\) is 0.15
The vapor pressure of pure benzene, C₆H₆ (78.1 g/mol), is 400. mmHg at 60.1 °C. What is the vapor pressure at 60.1 °C of a solution prepared by dissolving 49.2 g of camphor, C₁₀H₁₆O (152.2 g/mol), in 197 g of benzene? Camphor is a nonvolatile, nonionizing solute.

1 mmHg

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

1. 354

What is the boiling point of a solution of 106 g potassium phosphate (K₃PO₄, 212 g/mol) in 2.50 × 10² g H₂O?

K_b(H₂O) = 0.512 °C/m and T_b = 100.0 °C for the boiling point of pure water. Use ideal van't Hoff factors, if needed.

A. 102°C
✓B. 104°C
C. 106°C
D. 108°C

An osmotic cell with a semipermeable membrane is set up with pure water in chamber A and 1.50 M KCl in chamber B. What happens as the cell reaches equilibrium?
A. The volumes in chamber A and chamber B remain equal.
× B. H₂O from chamber A flows into chamber B, increasing the volume in chamber B.
C. KCl from chamber B flows into chamber A, increasing the volume in chamber A.
D. H₂O from chamber B flows into chamber A, increasing the volume in chamber A.

Question #: 15

The ideal van't Hoff factor for (NH₄)₃PO₄ is $\frac{4}{3} \frac{4}{4}$ is 1.
Report your answer as a whole number. Do NOT include units in your answer.

1. 4[four]

Question #: 16
Assuming an ideal van't Hoff factor, what **mass** of NaCl \((58.4 \text{ g/mol})\) needs to be added to \(1.00 \text{ kg}\) of water to lower the freezing point of water by \(3.00 \degree \text{C}\)? \(K_f\) for water is \(1.86 \degree \text{C/m}\).

\[1 \text{ g NaCl}\]

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

1. \(47.1\)

---

**Question #**: 17

A \(6.00 \text{ g}\) sample of an unknown nonelectrolyte is dissolved in \(24.0 \text{ g}\) of carbon tetrachloride, CCl\(_4\), to make a solution that boils at \(85.35 \degree \text{C}\). The \(K_b\) value for CCl\(_4\) is \(5.03 \degree \text{C/m}\) and the boiling point of pure CCl\(_4\) is \(76.80 \degree \text{C}\). What is the molar mass of the unknown compound?

A. \(40.7 \text{ g/mol}\)  
B. \(118 \text{ g/mol}\)  
C. \(122 \text{ g/mol}\)  
D. \(147 \text{ g/mol}\)

✓ D. \(147 \text{ g/mol}\)

---

**Question #**: 18

\(\text{NO}_2(g)\) reacts with water to form nitric acid, HNO\(_3\).  
\[3 \text{ NO}_2(g) + \text{H}_2\text{O} (l) \rightarrow 2 \text{ HNO}_3(aq) + \text{NO}(g)\]

What is the rate at which HNO\(_3\) is being formed when NO\(_2\) is reacting at \(0.90 \text{ M/s}\)?

Report your answer with **two** significant figures. Do **NOT** include units with your answer.

\[1 \text{ M/s}\]

1. \(0.60\)

---

**Question #**: 19

Given the following reaction and data, what is the rate law for the reaction?

\[\text{I}^- (aq) + \text{OCl}^- (aq) \rightarrow \text{Cl}^- (aq) + \text{OI}^- (aq)\]
The gas phase reaction \( \text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g) \) is found to be second-order in \( \text{NO}_2 \) and zero-order in \( \text{CO} \) at temperatures less than 500 K. What is the effect on the rate if the concentration of \( \text{NO}_2 \) is tripled and the concentration of \( \text{CO} \) is doubled?

- A. The rate increases by a factor of 6.
- B. The rate increases by a factor of 18.
- ✓ C. The rate increases by a factor of 9.
- D. The rate increases by a factor of 3.

For the reaction \( \text{A} \rightarrow \text{B} \), fill in the blanks with \textbf{zero}, \textbf{first}, or \textbf{second} for the kinetic data graphed below.
Using the given data, determine the rate constant, $k$, of the reaction

$$2 \text{ClO}_2(aq) + 2 \text{OH}^-(aq) \rightarrow \text{ClO}_3^-(aq) + \text{ClO}_2^-(aq) + \text{H}_2\text{O}(l)$$

where rate = $k[\text{OH}^-]$.

<table>
<thead>
<tr>
<th>Trial</th>
<th>$[\text{ClO}_2]$ (M)</th>
<th>$[\text{OH}^-]$ (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.060</td>
<td>0.030</td>
<td>0.0248</td>
</tr>
<tr>
<td>2</td>
<td>0.020</td>
<td>0.030</td>
<td>0.0249</td>
</tr>
<tr>
<td>3</td>
<td>0.020</td>
<td>0.090</td>
<td>0.0746</td>
</tr>
</tbody>
</table>

A. $7.6 \times 10^3$ s$^{-1}$  
B. 14 s$^{-1}$  
C. $7.4 \times 10^{-4}$ s$^{-1}$  
✓D. $0.83$ s$^{-1}$
Question #: 23

Radioactive technetium-99 (Tc-99) decays following first order kinetics with \( k = 0.116 \text{ h}^{-1} \). How much Tc-99 remains after 2.2 hours in a solution initially 0.500 M in Tc-99?

A. 0.187 M  
B. 0.297 M  
✓ C. 0.387 M  
D. 0.407 M

Question #: 24

The decomposition below is second order in NO\(_2\). How long will it take for the concentration of NO\(_2\) to decrease from 4.00 M to 1.00 M ?

\[
\text{NO}_2(g) \rightarrow \text{NO}(g) + \frac{1}{2} \text{O}_2(g) \quad k = 3.4 \text{ M}^{-1} \cdot \text{min}^{-1}
\]

A. 0.88 min  
B. 1.4 min  
✓ C. 0.22 min  
D. 0.074 min

Question #: 25

When heated to 499 °C, cyclopropane rearranges (isomerizes) and forms propene with a rate constant of \( 3.57 \times 10^{-2} \text{ min}^{-1} \). What is the half-life of this reaction, in minutes?

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

1. 19.4

Question #: 26
The activation energy for a certain reaction is 255 kJ and the $\Delta H_{rxn}$ is 121 kJ. What is the activation energy of the reverse reaction?

A. $-255$ kJ  
B. 376 kJ  
C. 134 kJ  
D. $-121$ kJ

**Question #: 27**

A certain reaction has an activation energy of 254 kJ/mol. At what temperature will the reaction proceed four times faster than it does at 298 K?

A. 294 K  
B. 73.9 K  
C. 302 K  
D. 1190 K

**Question #: 28**

In the diagram below, the ___1___ of the reaction is greater than the ___2___ needed to reach the ___3___ before proceeding to products. Fill in the blanks with **activation energy**, **enthalpy**, or **transition state**.

[Diagram of potential energy diagram with labeled points 1, 2, and 3]
Question #: 29

Which two statements about catalysts are false?

A. A catalyst is a substance that lowers the activation energy of a chemical reaction. ✓
B. A catalyst is always an enzyme.
C. A catalyst speeds up the rate of a reaction. ✓
D. A catalyst is consumed during the chemical reaction.

Question #: 30

The overall reaction \(2\text{O}_3(g) \rightarrow 3\text{O}_2(g)\) can occur by the following mechanism:

\[
\text{NO}(g) + \text{O}_3(g) \rightarrow \text{NO}_2(g) + \text{O}_2(g) \\
\text{O}_3(g) \rightarrow \text{O}_2(g) + \text{O}(g) \\
\text{NO}_2(g) + \text{O}(g) \rightarrow \text{NO}(g) + \text{O}_2(g)
\]

Select the two intermediates in this mechanism.

\(\text{NO}(g)\) + \(\text{O}_3(g)\) \(\rightarrow\) \(\text{NO}_2(g)\) + \(\text{O}_2(g)\)

A. \(\text{NO}(g)\)
B. \(\text{O}_3(g)\)
C. \(\text{NO}_2(g)\)
D. \(\text{O}_2(g)\)
E. \(\text{O}(g)\)

✓