Circle the letter corresponding to the best answer for each of the following multiple choice questions. Each multiple choice question is worth 2 points.

For questions 1 – 4 consider the reaction below:

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

1. The rate of the reaction in terms of NO is given as:

   a. \( \frac{2\Delta[\text{NO}]}{\Delta t} \)
   b. \( -\frac{\Delta[\text{NO}]}{2\Delta t} \)
   c. \( \frac{\Delta[\text{NO}]}{2\Delta t} \)
   d. \( \frac{\Delta[\text{NO}]}{\Delta t} \)
   e. \( -\frac{\Delta[\text{NO}]}{\Delta t} \)

2. The rate of formation of \( \text{H}_2\text{O} \) is:

   a. one-half the rate of the reaction
   b. one-half the rate of formation of \( \text{N}_2 \) (g)
   c. equal to the rate of the reaction
   d. twice the rate of the reaction
   e. one-half the rate of destruction of NO

3. If the rate of the reaction under a particular set of conditions is 0.10 M/s, the rate of destruction of \( \text{H}_2 \) (g) is:

   a. 0.20 M/s    b. 0.10 M/s    c. 0.05 M/s    d. 0.40 M/s    e. 0.025 M/s

4. Which of the following changes would result in an increased rate of reaction?

   a. increase the concentration of only NO
   b. decrease the concentration of only \( \text{N}_2 \)
   c. increase the concentration of either NO or \( \text{H}_2 \)
   d. increase the concentration of only \( \text{H}_2 \)
   e. cannot tell from the information given
Consider the following set of initial rate data for questions 5-9.

The chemical reaction is:

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

<table>
<thead>
<tr>
<th>Experiment #</th>
<th>[ClO(_2)] (M)</th>
<th>[OH(^-)] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.030</td>
<td>0.010</td>
<td>2.07 \times 10^{-3}</td>
</tr>
<tr>
<td>2</td>
<td>0.010</td>
<td>0.010</td>
<td>2.3 \times 10^{-4}</td>
</tr>
<tr>
<td>3</td>
<td>0.030</td>
<td>0.030</td>
<td>6.21 \times 10^{-3}</td>
</tr>
</tbody>
</table>

5. What is the order of the reaction with respect to ClO\(_2\)?
   a. zeroth  b. first  c. second  d. third  e. fourth

6. What is the order of the reaction with respect to OH\(^-\)?
   a. zeroth  b. first  c. second  d. third  e. fourth

7. The rate law for the reaction is:
   a. Rate = k [ClO\(_2\)]^2[OH\(^-\)]
   b. Rate = k [ClO\(_2\)][OH\(^-\)]^2
   c. Rate = k [ClO\(_2\)]^3[OH\(^-\)]
   d. Rate = k [ClO\(_2\)]^2[OH\(^-\)]
   e. Rate = k [ClO\(_2\)][OH\(^-\)]

8. The value of the rate constant for the reaction is:
   a. 6.9 M\(^{-1}\)s\(^{-1}\)
   b. 230 M\(^{-2}\)s\(^{-1}\)
   c. 2.3 \times 10^4 M\(^{-3}\)s\(^{-1}\)
   d. 0.207 s\(^{-1}\)
   e. 0.069 s\(^{-1}\)

9. Under the conditions in Experiment #2, the rate of destruction of ClO\(_2\) is:
   a. 1.15 \times 10^4 Ms\(^{-1}\)
   b. 2.3 \times 10^4 Ms\(^{-1}\)
   c. 0.030 Ms\(^{-1}\)
   d. 4.6 \times 10^4 Ms\(^{-1}\)
   e. 9.2 \times 10^4 Ms\(^{-1}\)
10. Place an X in the all boxes below corresponding to true statements about a first-order reaction.

- [ ] the half-life depends on the initial concentration
- [ ] a plot of ln[A] vs. time will be linear
- [ ] a plot of 1/[A] vs. time will be linear
- [ ] the half-life does not depend on the initial concentration
- [ ] the rate of the reaction does not change with concentration

11. Which of the numbered boxes in the diagram represents the activation energy for the indicated reaction?

- a. 1
- b. 2
- c. 3
- d. 4

12. Which of the following equations is the equilibrium expression for the reaction:

\[ \text{C}_2\text{H}_4(\text{g}) + 2 \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g}) + \text{O}_2(\text{g}) \]

- a. \( K_e = \frac{[\text{C}_2\text{H}_4][\text{H}_2\text{O}]}{[\text{C}_2\text{H}_6][\text{O}_2]} \)
- b. \( K_e = \frac{[\text{C}_2\text{H}_6][\text{O}_2]}{[\text{C}_2\text{H}_4][\text{H}_2\text{O}]} \)
- c. \( K_e = [\text{C}_2\text{H}_4][\text{H}_2\text{O}] \)
- d. \( K_e = \frac{[\text{C}_2\text{H}_6]^2[\text{O}_2]}{[\text{C}_2\text{H}_4][\text{H}_2\text{O}]} \)
- e. \( K_e = \frac{[\text{C}_2\text{H}_6][\text{O}_2]}{[\text{C}_2\text{H}_4][\text{H}_2\text{O}]} \)
13. The equilibrium expression for the chemical reaction:
\[ 4 \text{HCl(aq)} + \text{O}_2(g) \rightleftharpoons 2\text{H}_2\text{O}(\ell) + 2\text{Cl}_2(g) \]

is:

a. \[ K_c = \frac{[\text{Cl}_2]^2}{[\text{HCl}]^4[\text{O}_2]} \]

b. \[ K_c = \frac{[\text{H}_2\text{O}]^2[\text{Cl}_2]^2}{[\text{HCl}]^4[\text{O}_2]} \]

c. \[ K_c = \frac{[\text{HCl}]^4[\text{O}_2]}{[\text{Cl}_2]^2} \]

d. \[ K_c = \frac{[\text{HCl}]^4[\text{O}_2]}{[\text{H}_2\text{O}]^2[\text{Cl}_2]^2} \]

e. \[ K_c = \frac{[\text{HCl}]^4[\text{O}_2]}{[\text{Cl}_2]^2} \]

14. At a particular temperature the equilibrium constant for the following reaction is \(5.8 \times 10^{-2}\).
\[ \text{PCl}_3(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g) \]

What is the value of the equilibrium constant for the reaction:
\[ 2 \text{PCl}_3(g) + 2\text{Cl}_2(g) \rightleftharpoons 2\text{PCl}_5(g) \]

a. \(5.8 \times 10^{-2}\)  b. 17.2  c. 297  d. \(3.36 \times 10^{-3}\)  e. 0.241

15. The equilibrium constant, \(K_p\), is \(8.9 \times 10^{-5}\) for the reaction:
\[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) \]

Which of the following combinations of pressures represents a system that is at equilibrium?

a. \(P_{\text{N}_2} = 0.050\ \text{atm}, P_{\text{H}_2} = 0.24\ \text{atm}, P_{\text{NH}_3} = 0.0035\ \text{atm}\)

b. \(P_{\text{N}_2} = 11\ \text{atm}, P_{\text{H}_2} = 0.24\ \text{atm}, P_{\text{NH}_3} = 0.0045\ \text{atm}\)

c. \(P_{\text{N}_2} = 0.35\ \text{atm}, P_{\text{H}_2} = 9.0\ \text{atm}, P_{\text{NH}_3} = 3.5\ \text{atm}\)

d. \(P_{\text{N}_2} = 18\ \text{atm}, P_{\text{H}_2} = 0.25\ \text{atm}, P_{\text{NH}_3} = 0.0050\ \text{atm}\)

e. \(P_{\text{N}_2} = 0.050\ \text{atm}, P_{\text{H}_2} = 0.0050\ \text{atm}, P_{\text{NH}_3} = 1.5\ \text{atm}\)
Problems. Show your work to receive full credit.

16. (10 points) Show your work.
A first order reaction has the form $A \rightarrow B$ with a rate constant of $1.45 \times 10^{-3}$ s$^{-1}$.

a. If the initial concentration of $A$ is 0.250 M, how long would it take for the concentration of $A$ to drop to 0.100 M?

b. What is the half-life of the reaction?

c. What concentration of $A$ is left after a period of 4.0 minutes?

d. If the third-life is defined to be the period of time required for the concentration of $A$ to be one-third of its initial value, what is the third-life of this reaction?
17. (10 points) Show your work.
A second-order reaction has the form $A \rightarrow B$.

a. If it takes 1500 s for the concentration of $A$ to drop from 0.500 M to 0.280 M, what is the rate constant for the reaction? Include the units.

b. What is the half-life for the reaction if the initial concentration of $A$ is 0.500 M?

c. How long would it take for the concentration of $A$ to drop from 0.500 M to 0.150 M?

d. What is the concentration of $A$ after 1000 s starting from the 0.500 M concentration?
18. (10 points) Show your work.
   a. A particular reaction has a preexponential factor, \( A \), of \( 4.5 \times 10^{11} \text{ Ms}^{-1} \) and an activation energy of 45 kJ/mol. What is the value of this reaction’s rate constant at a temperature of 125 °C?

\[ k = A e^{-E_a/RT} \]

\[ R = 8.314 \text{ J} / \text{ mol} \cdot \text{K} \]

b. At what temperature would the reaction have a rate constant of \( 1 \times 10^4 \text{ Ms}^{-1} \)?
NAME ___________________________

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