1. Consider the following reaction mechanism:
   step 1: \( M + X \rightarrow MX \)
   step 2: \( MX + A \rightarrow D + X \)
   The chemical species MX is a(n)
   A. catalyst
   B. inhibitor
   C. final product
   D. reaction intermediate

2. Consider the following reaction: \( 2\text{N}_2\text{O}_5(g) \rightarrow 4\text{NO}_2(g) + \text{O}_2(g) \)
   At a certain temperature the rate of decomposition of \( 2\text{N}_2\text{O}_5(g) \) is \( 2.5 \times 10^{-6} \) mol/s. The rate of formation of \( \text{NO}_2 \) is
   A. \( 1.0 \times 10^{-5} \) mol/s
   B. \( 1.3 \times 10^{-6} \) mol/s
   C. \( 2.5 \times 10^{-6} \) mol/s
   D. \( 5.0 \times 10^{-6} \) mol/s

3. Which of the following factors affect the rates of both homogeneous and heterogeneous reactions.
   I nature of the reactants
   II presence of a catalyst
   III temperature of system
   IV concentration of reactants
   A. I and IV only
   B. II and III only
   C. II, III, and IV only
   D. I, II, III, and IV

4. Which of the following equations represents an endothermic reaction?
   A. \( \text{N}_2\text{O}_4(g) + 59 \text{ kJ} \rightarrow 2\text{NO}_2(g) \)
   B. \( 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(l) + 572 \text{ kJ} \)
   C. \( 2\text{BrCl}(g) -29.3 \text{ kJ} \rightarrow \text{Br}_2(g) + \text{Cl}_2(g) \)
   D. \( 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(l) \quad \Delta H = -572 \text{ kJ} \)

5. Consider the potential energy diagram. The activation energy for the reverse reaction is
   A. \( 30 \) kJ
   B. \( 140 \) kJ
   C. \( 170 \) kJ
   D. \( 200 \) kJ
6. Consider the following mechanism:

\[
\text{Step 1: } \text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2
\]

\[
\text{Step 2: } \text{O} + \text{ClO} \rightarrow \text{Cl} + \text{O}_2
\]

The reaction intermediate is

A. Cl  
B. O\(_2\)  
C. O\(_3\)  
D. ClO

7. In a reaction mechanism, the rate determining step is the

A. fastest and has the lowest activation energy.  
B. fastest and has the highest activation energy.  
C. slowest and has the lowest activation energy.  
D. slowest and has the highest activation energy.

8. A catalyst increases the rate of a reaction by

A. increasing the concentration of reactant(s).  
B. decreasing the concentration of the reactant(s).  
C. increasing the activation energy of the overall reaction.  
D. decreasing the activation energy of the overall reaction.

9. Which of the following properties could be used to measure the rate of the following reaction in an open container. \(\text{Zn}(s) + 2\text{HCl}(aq) \rightarrow \text{ZnCl}_2(aq) + \text{H}_2(g)\)

A. mass of Zn  
B. solubility of HCl  
C. concentration of Cl\(^-\)  
D. colour of the solution

10. Consider the following potential energy diagram:

The above diagram represents an

A. exothermic reaction involving one step.  
B. exothermic reaction involving two steps.  
C. endothermic reaction involving one step.  
D. endothermic reaction involving two steps.
11. Which of the following are necessary for successful collisions to occur?

I. Favourable geometry  
II. Sufficient energy  
III. Large ΔH

A. I only  
B. I and II only  
C. II and III only  
D. I, II, and III

12. Consider the following reaction:  

\[ 2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \]

When 1.0 g of KI is added to the H\(_2\)O\(_2\), bubbles of O\(_2\) are produced at an increased rate. The KI is a

A. product  
B. catalyst  
C. reactant  
D. intermediate

13. Consider the following

I. Frequency of successful collision  
II. Volume of the reaction vessel  
III. Pressure of the system  
IV. Mass of the system

To increase the rate of a chemical reaction there must be an increase in

A. I only  
B. I and III only  
C. I, III and IV only  
D. I, II, III, and IV

14. Consider the following reaction mechanism:

Step 1: \( \text{ICl} + \text{H}_2 \rightarrow \text{HI} + \text{HCl} \) slow
Step 2: \( \text{ICl} + \text{HI} \rightarrow \text{HCl} + \text{I}_2 \) fast

The species HCl is a

A. product  
B. catalyst  
C. reactant  
D. reaction intermediate
15. Consider the following potential energy diagram:

![Potential Energy Diagram]

The activation energy in the forward direction is

A. 25 kJ  
B. 50 kJ  
C. 75 kJ  
D. 125 kJ

16. Consider the following reactions:

I. \( \text{N}_2 + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g}) \)
II. \( \text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{MgO}(\text{s}) \)
III. \( \text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) \)

Increasing the surface area will increase the reaction rate in

A. II only  
B. I and III only  
C. II and III only  
D. I, II, and III

17. Consider the following reaction mechanism:

Step 1: \( \text{V}^{3+} + \text{Cu}^{2+} \rightarrow \text{V}^{4+} + \text{Cu}^{+} \)
Step 2: \( \text{Cu}^{+} + \text{Fe}^{3+} \rightarrow \text{Cu}^{2+} + \text{Fe}^{2+} \) slow

The reaction intermediate is

A. \( \text{Cu}^{+} \)  
B. \( \text{Cu}^{2+} \)  
C. \( \text{V}^{3+} \)  
D. \( \text{Fe}^{3+} \)

18. The rate of a chemical reaction can be expressed in

A. grams per mole  
B. energy consumed per mole  
C. volume of gas per unit time  
D. mole formed per litre of solution
19. Consider the following reaction:

\[ 2\text{MnO}_4^{-}(aq) + 5\text{C}_2\text{O}_4^{2-}(aq) + 16\text{H}^+(aq) \rightarrow 2\text{Mn}^{2+}(aq) + 10\text{CO}_2(g) + 8\text{H}_2\text{O}(l) \]

The rate of decomposition of the oxalate ion is increased by

A. adding NaOH.
B. removing CO$_2$
C. adding a catalyst
D. decreasing the pressure

20. The minimum amount of energy needed to start a reaction is called the

A. activation energy.
B. energy of reaction.
C. entropy of reaction
D. reaction mechanism energy

21. An 8.00g piece of magnesium was placed into 6.0 M HCl. After 25 s, 3.50 g of unreacted magnesium remained. The average rate at which magnesium was consumed is

A. 0.14 g/s
B. 0.18 g/s
C. 0.32 g/s
D. 4.50 g/s

22. In general rates double when the temperature is increased by 10 °C. The temperature of a reaction is increased by 40 °C. The rate will increase by a factor of

A. 2
B. 4
C. 8
D. 16

23. Consider the following factors
I. reactant particles collide
II. sufficient kinetic energy is present
III. a favourable geometry exists
IV. catalysts are present
Which combination of the above factors is required for all successful collisions?

A. I only
B. II and III only
C. I, II and III only
D. I, II, III, and IV

24. Consider the following reaction at constant temperature in an open system:

\[ \text{MgCO}_3(s) + 2\text{HCl}(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) + \text{MgCl}_2(aq) \]

Which of the following properties could be used to determine the reaction rate.

A. mass of the system
B. pressure of the gas
C. concentration of H$_2$O
D. concentration of MgCO$_3$

25. Which combination of factors will affect the rate of the following reaction?

\[ \text{MgCO}_3(s) + 2\text{HCl}(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) + \text{MgCl}_2(aq) \]

A. temperature and surface area only
B. temperature and concentration only
C. concentration and surface area only
D. temperature, concentration, and surface area only
26. As reactant molecules approach each other

A. heat is released
B. a reaction intermediate forms
C. kinetic energy changes into potential energy
D. potential energy changes into kinetic energy

Consider the following potential energy diagram for the next three five questions.

![Potential Energy Diagram](image)

27. The interval representing $\Delta H$ for the reverse reaction is

A. 1
B. 2
C. 3
D. 4

28. The interval representing $\Delta H$ for the forward reaction is

A. 1
B. 2
C. 3
D. 4

29. The interval representing $E_a$ for the reverse reaction is

A. 1
B. 2
C. 3
D. 4

30. The interval representing $E_a$ for the forward reaction is

A. 1
B. 2
C. 3
D. 4

31. The interval representing the energy of the activated complex is

A. 1
B. 2
C. 3
D. 4
32. When a catalyst is added to a reaction, ΔH will
   A. increase slowly
   B. remain constant
   C. decrease slowly
   D. increase rapidly due to the alternate pathway

33. Consider the following reaction: \( \text{Zn}(s) + 2\text{HCl}(aq) \rightarrow \text{H}_2(g) + \text{ZnCl}_2(aq) \)
   Data for the reaction is shown below:

<table>
<thead>
<tr>
<th>Time</th>
<th>Mass of Zn (g)</th>
<th>Volume of H₂ (mL)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.65</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>4.50</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>4.35</td>
<td>100</td>
<td>22</td>
</tr>
</tbody>
</table>

   The rate of the reaction can be measured in units of
   A. g/min
   B. g/mL
   C. min/mL
   D. g/(mL)(°C)

34. When a lit match is touched to the wick of a candle, the candle begins to burn. When the match is removed, the candle continues to burn, the match,
   A. behaves as a catalyst
   B. supplies the activation energy
   C. is part of the rate determining step
   D. lowers the activation energy barrier

35. Consider the following reaction: \( 2\text{NO}_2(g) + \text{O}_2(g) \rightarrow 2\text{NO}_2(g) + 112 \text{kJ} \)
   ΔH for the above reaction is:
   A. positive and the reaction is exothermic
   B. negative and the reaction is exothermic
   C. positive and the reaction is endothermic
   D. negative and the reaction is endothermic

36. Consider the following reaction: \( 2\text{S}(s) + 3\text{O}_2(g) \rightarrow 2\text{SO}_2(g) + \text{heat} \)
   The rate of this reaction could be increased by
   A. decreasing the temperature
   B. adding a catalyst
   C. increasing the concentration of S
   D. decreasing the surface area of the S
37. Consider the following reaction: \( \frac{1}{2} \text{H}_2 + \frac{1}{2} \text{I}_2 \rightarrow \text{HI} \quad \Delta H = +28 \text{ kJ} \)
The activation energy for the formation of HI is 167 kJ. The activation energy for the decomposition of HI is

A. 28 kJ  
B. 139 kJ  
C. 167 kJ  
D. 195 kJ

38. Some reactants are more reactive than others because of their activation energy \( E_a \). What graph shows the relationship between \( E_a \) and rate.

A.  

B.  

C.  

D.  

39. The activated complex is a chemical species that is

A. stable and has low PE.  
B. stable and has high PE.  
C. unstable and has low PE.  
D. unstable and has high PE.

40. As an activated complex changes into products,

A. potential energy changes into kinetic energy.  
B. kinetic energy changes into potential energy.  
C. kinetic energy changes into activation energy.  
D. potential energy changes into activation energy.
Long Answer – Written response Questions

1. On the potential energy diagram above, clearly label the activation energy, heat of the reaction (ΔH), and the energy of the activated complex.

2. Is the above reaction endothermic or exothermic in the forward direction?

3. On the graph below, draw the potential energy diagram for an exothermic reaction and label the activation energy.

4. Nitric oxide (NO) is involved in the decomposition of ozone by the following mechanism:
   \[
   \text{Step 1: } O_3 + \text{ sunlight } \rightarrow O_2 + O \\
   \text{Step 2: } O_3 + NO \rightarrow NO_2 + O_2 \\
   \text{Step 3: } NO_2 + O \rightarrow NO + O_2
   \]
   a) Write the net equation for the decomposition reaction
   b) Identify a catalyst
   c) Identify a reaction intermediate
d) What is the function of sunlight in this reaction?

5. Consider the following reaction: \( 2\text{NO} + 2\text{H}_2 \rightarrow 2\text{H}_2\text{O} + \text{N}_2 \)

a) Explain why the reaction is likely to involve more than one step.

b) A proposed mechanism for the above reaction is:

   Step 1: \( \text{NO} + \text{H}_2 \rightarrow \text{N} + \text{H}_2\text{O} \)
   Step 2: ?
   Step 3: \( \text{N}_2\text{O} + \text{H}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O} \)

   Write the equation for step 2.

6. Define the term activation energy.

7. The combustion of coal, \( \text{C} \), produces carbon dioxide and water according to the following equation: \( \text{C}(s) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + 394 \text{ kJ} \)

   a) What is \( \Delta H \) for this reaction?
   
   b) Using the collision theory, explain why a lump of coal does not react with oxygen at room temperature and pressure.
   
   c) Many coalmine disasters have resulted when a spark ignites coal dust in the air. Explain using the collision theory.

8. State two reasons why some collisions may not result in a chemical reaction.
9. A student wishes to monitor the rate of the following reaction:

\[ \text{CaCO}_3(s) + 2\text{HCl(aq)} \rightarrow \text{CaCl}_2(aq) + \text{CO}_2(g) + \text{H}_2\text{O(l)} \]

Identify two different properties that could be used to monitor the rate of the reaction. Describe and explain the changes that would occur.

Property 1

Change and explanation

Property 2

Change and explanation

10. An experiment is done to determine the rate of the following reaction:

\[ 2\text{Al(s)} + 6\text{HCl(aq)} \rightarrow 3\text{H}_2(g) + 2\text{AlCl}_3(aq) \]

The following data are collected

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Mass of Flask + Contents (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>270.230</td>
</tr>
<tr>
<td>30.0</td>
<td>270.200</td>
</tr>
<tr>
<td>60.0</td>
<td>270.170</td>
</tr>
</tbody>
</table>

Calculate the rate of consumption of Al in mol/min.
Chem 12  Practice Test 1  Answers

1. Consider the following reaction mechanism:
   step 1:  M + X → MX
   step 2:  MX + A → D + X

   The chemical species MX is a(n)
   A. catalyst
   B. inhibitor
   C. final product
   D. reaction intermediate

2. Consider the following reaction:  \(2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)\)

   At a certain temperature the rate of decomposition of \(2N_2O_5(g)\) is \(2.5 \times 10^{-6}\) mol/s. The rate of formation of \(NO_2\) is
   A. \(1.0 \times 10^{-5}\) mol/s
   B. \(1.3 \times 10^{-6}\) mol/s
   C. \(2.5 \times 10^{-6}\) mol/s
   D. \(5.0 \times 10^{-6}\) mol/s

3. Which of the following factors affect the rates of both homogeneous and heterogeneous reactions.
   I. nature of the reactants
   II. presence of a catalyst
   III. temperature of system
   IV. concentration of reactants

   A. I and IV only
   B. II and III only
   C. II, III, and IV only
   D. I, II, III, and IV

4. Which of the following equations represents an endothermic reaction?
   A. \(N_2O_4(g) + 59\text{ kJ} \rightarrow 2NO_2(g)\)
   B. \(2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + 572\text{ kJ}\)
   C. \(2BrCl(g) -29.3\text{ kJ} \rightarrow Br_2(g) + Cl_2(g)\)
   D. \(2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \quad \Delta H = -572\text{ kJ}\)
5. Consider the potential energy diagram. The activation energy for the reverse reaction is

A. 30 kJ
B. **140 kJ**
C. 170 kJ
D. 200 kJ

6. Consider the following mechanism:

\[
\text{Step 1: } \text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2 \\
\text{Step 2: } \text{O} + \text{ClO} \rightarrow \text{Cl} + \text{O}_2
\]

The reaction intermediate is

A. Cl
B. O$_2$
C. O$_3$
D. ClO

7. In a reaction mechanism, the rate determining step is the

A. fastest and has the lowest activation energy.
B. fastest and has the highest activation energy.
C. slowest and has the lowest activation energy.
D. **slowest and has the highest activation energy.**

8. A catalyst increases the rate of a reaction by

A. increasing the concentration of reactant(s).
B. decreasing the concentration of the reactant(s).
C. increasing the activation energy of the overall reaction.
D. **decreasing the activation energy of the overall reaction.**

9. Which of the following properties could be used to measure the rate of the following reaction in an open container. \( \text{Zn(s)} + 2\text{HCl}_{(aq)} \rightarrow \text{ZnCl}_2_{(aq)} + \text{H}_2(g) \)

A. **mass of Zn**
B. solubility of HCl
C. concentration of Cl$^-$
D. colour of the solution
10. Consider the following potential energy diagram:

The above diagram represents an

A. exothermic reaction involving one step.
B. **exothermic reaction involving two steps.**
C. endothermic reaction involving one step.
D. endothermic reaction involving two steps.

11. Which of the following are necessary for successful collisions to occur?

I. Favourable geometry
II. Sufficient energy
III. Large ΔH

A. I only
B. **I and II only**
C. II and III only
D. I, II, and III

12. Consider the following reaction: \(2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})\)

When 1.0 g of KI is added to the \(\text{H}_2\text{O}_2\), bubbles of \(\text{O}_2\) are produced at an increased rate. The KI is a

A. product
B. **catalyst**
C. reactant
D. intermediate
13. Consider the following

I. Frequency of successful collision
II. Volume of the reaction vessel
III. Pressure of the system
IV. Mass of the system

To increase the rate of a chemical reaction there must be an increase in

A. I only
B. I and III only
C. I, III and IV only
D. I, II, III, and IV

14. Consider the following reaction mechanism:
Step 1: ICl + H₂ → HI + HCl  slow
Step 2: ICl + HI → HCl + I₂  fast

The species HCl is a

A. product
B. catalyst
C. reactant
D. reaction intermediate

15. Consider the following potential energy diagram:

![Potential Energy Diagram]

Progress of the reaction

The activation energy in the forward direction is

A. 25 kJ
B. 50 kJ
C. 100 kJ
D. 125 kJ
16. Consider the following reactions:
   I. \( \text{N}_2 + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g}) \)
   II. \( \text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{MgO}(\text{s}) \)
   III. \( \text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) \)

Increasing the surface area will increase the reaction rate in
   A. II only
   B. I and III only
   C. II and III only
   D. I, II, and III

17. Consider the following reaction mechanism: Step 1: \( \text{V}^{3+} + \text{Cu}^{2+} \rightarrow \text{V}^{4+} + \text{Cu}^{+} \) slow
   Step 2: \( \text{Cu}^{+} + \text{Fe}^{3+} \rightarrow \text{Cu}^{2+} + \text{Fe}^{2+} \) slow

The reaction intermediate is
   A. \( \text{Cu}^{+} \)
   B. \( \text{Cu}^{2+} \)
   C. \( \text{V}^{3+} \)
   D. \( \text{Fe}^{3+} \)

18. The rate of a chemical reaction can be expressed in
   A. grams per mole
   B. energy consumed per mole
   C. volume of gas per unit time
   D. mole formed per litre of solution

19. Consider the following reaction:
   \( 2\text{MnO}_4^{-}(\text{aq}) + 5\text{C}_2\text{O}_4^{2-}(\text{aq}) + 16\text{H}^+(\text{aq}) \rightarrow 2\text{Mn}^{2+}(\text{aq}) + 10\text{CO}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l}) \)

The rate of decomposition of the oxalate ion is increased by
   A. adding NaOH.
   B. removing CO\(_2\)
   C. adding a catalyst
   D. decreasing the pressure

20. The minimum amount of energy needed to start a reaction is called the
   A. activation energy.
   B. energy of reaction.
   C. entropy of reaction
   D. reaction mechanism energy
21. An 8.00g piece of magnesium was placed into 6.0 M HCl. After 25 s, 3.50 g of unreacted magnesium remained. The average rate at which magnesium was consumed is

A. 0.14 g/s  
B. **0.18 g/s**  
C. 0.32 g/s  
D. 4.50 g/s

22. In general rates double when the temperature is increased by 10 °C. The temperature of a reaction is increased by 40 °C. The rate will increase by a factor of

A. 2  
B. 4  
C. 8  
D. **16**

23. Consider the following factors
I. reactant particles collide  
II. sufficient kinetic energy is present  
III. a favourable geometry exists  
IV. catalysts are present
Which combination of the above factors is required for all successful collisions?

A. I only  
B. II and III only  
C. **I, II and III only**  
D. I, II, III, and IV

24. Consider the following reaction at constant temperature in an open system:

\[
\text{MgCO}_3(s) + 2\text{HCl(aq)} \rightarrow \text{CO}_2(g) + \text{H}_2\text{O(l)} + \text{MgCl}_2(aq)
\]
Which of the following properties could be used to determine the reaction rate.

A. **mass of the system**  
B. pressure of the gas  
C. concentration of H\textsubscript{2}O  
D. concentration of MgCO\textsubscript{3}

25. Which combination of factors will affect the rate of the following reaction?

\[
\text{MgCO}_3(s) + 2\text{HCl(aq)} \rightarrow \text{CO}_2(g) + \text{H}_2\text{O(l)} + \text{MgCl}_2(aq)
\]
A. temperature and surface area only  
B. temperature and concentration only  
C. concentration and surface area only  
D. **temperature, concentration, and surface area only**
26. As reactant molecules approach each other
   A. heat is released
   B. a reaction intermediate forms
   C. kinetic energy changes into potential energy
   D. potential energy changes into kinetic energy

Consider the following potential energy diagram for the next three five questions.

27. The interval representing $\Delta H$ for the reverse reaction is
   A. 1
   B. 2
   C. 3
   D. 4

28. The interval representing $\Delta H$ for the forward reaction is
   A. 1
   B. 2
   C. 3
   D. 4

29. The interval representing $E_a$ for the reverse reaction is
   A. 1
   B. 2
   C. 3
   D. 4
30. The interval representing $E_a$ for the forward reaction is

A. 1  
B. 2  
C. 3  
D. 4

31. The interval representing the energy of the activated complex is  

A. 1  
B. 2  
C. 3  
D. 4

32. When a catalyst is added to a reaction, $\Delta H$ will  

A. increase slowly  
B. remain constant  
C. decrease slowly  
D. increase rapidly due to the alternate pathway

33. Consider the following reaction:  

$$Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$$

Data for the reaction is shown below:

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Mass of Zn (g)</th>
<th>Volume of H$_2$ (mL)</th>
<th>Temperature (${^\circ}$C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.65</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>4.50</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>4.35</td>
<td>100</td>
<td>22</td>
</tr>
</tbody>
</table>

The rate of the reaction can be measured in units of:

A. g/min  
B. g/mL  
C. min/mL  
D. g/(mL)$({^\circ}$C)

34. When a lit match is touched to the wick of a candle, the candle begins to burn. When the match is removed, the candle continues to burn, the match,

A. behaves as a catalyst  
B. supplies the activation energy  
C. is part of the rate determining step  
D. lowers the activation energy barrier

35. Consider the following reaction:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g) + 112 \text{ kJ}$$

$\Delta H$ for the above reaction is:
A. positive and the reaction is exothermic  
**B. negative and the reaction is exothermic**  
C. positive and the reaction is endothermic  
D. negative and the reaction is endothermic

36. Consider the following reaction: \( 2S(s) + 3O_2(g) \rightarrow 2SO_2(g) + \text{heat} \)  
The rate of this reaction could be increased by  
A. decreasing the temperature  
**B. adding a catalyst**  
C. increasing the concentration of S  
D. decreasing the surface area of the S

37. Consider the following reaction: \( \frac{1}{2}H_2 + \frac{1}{2}I_2 \rightarrow HI \quad \Delta H = +28 \text{ kJ} \)  
The activation energy for the formation of HI is 167 kJ. The activation energy for the decomposition of HI is  
A. 28 kJ  
**B. 139 kJ**  
C. 167 kJ  
D. 195 kJ

38. Some reactants are more reactive than others because of their activation energy \( E_a \). What graph shows the relationship between \( E_a \) and rate.

A.  
B.  
C.  
**D.**

39. The activated complex is a chemical species that is  
A. stable and has low PE.  
B. stable and has high PE.  
C. unstable and has low PE.  
**D. unstable and has high PE.**
40. As an activated complex changes into products,

A. **potential energy changes into kinetic energy.**
B. kinetic energy changes into potential energy.
C. kinetic energy changes into activation energy.
D. potential energy changes into activation energy.

Chemistry 12 1999 Subjective

1. On the potential energy diagram above, clearly label the activation energy, heat of the reaction ($\Delta H$), and the energy of the activated complex. (3 marks)

2. Is the above reaction endothermic or exothermic in the forward direction? (1 mark)

3. On the graph below, draw the potential energy diagram for an exothermic reaction and label the activation energy. (2 marks)

4. Nitric oxide (NO) is involved in the decomposition of ozone by the following mechanism:
   
   Step 1: $O_3 + \text{sunlight} \rightarrow O_2 + O$
   
   Step 2: $O_3 + NO \rightarrow NO_2 + O$
   
   Step 3: $NO_2 + O \rightarrow NO + O_2$

   a) Write the net equation for the decomposition reaction

   $$2O_3 + \text{sunlight} \rightarrow 3O_2$$

   b) Identify a catalyst
NO

c) Identify a reaction intermediate

NO$_2$ and O

d) What is the function of sunlight in this reaction? (4 marks)

Provides the activation energy

5. Consider the following reaction: 2NO + 2H$_2$ → 2H$_2$O + N$_2$

a) Explain why the reaction is likely to involve more than one step.

Reactions that have more than three reactant particles likely have mechanisms.

b) A proposed mechanism for the above reaction is: Step 1: NO + H$_2$ → N + H$_2$O
Step 2: ?
Step 3: N$_2$O + H$_2$ → N$_2$ + H$_2$O

Write the equation for step 2.

NO + N → N$_2$O

6. Define the term activation energy.

The minimum energy required for a successful collision

7. The combustion of coal, C, produces carbon dioxide and water according to the following equation:
C$_{\text{s}}$ + O$_2$$_{(g)}$ → CO$_2$$_{(g)}$ + 394 kJ

a) What is $\Delta$H for this reaction? (1 mark)

$\Delta$H + -394 kJ

b) Using the collision theory, explain why a lump of coal does not react with oxygen at room temperature and pressure. (1 mark)

The Ea is too high for the room temperature collisions to be successful.

c) Many coalmine disasters have resulted when a spark ignites coal dust in the air. Explain using the collision theory. (2 marks)

The spark provides the Ea, the reaction is exothermic and has a high surface area and an explosion results.

8. State two reasons why some collisions may not result in a chemical reaction. (2 marks)
9. A student wishes to monitor the rate of the following reaction:
   \[ \text{CaCO}_3(s) + 2\text{HCl(aq)} \rightarrow \text{CaCl}_2(aq) + \text{CO}_2(g) + \text{H}_2\text{O(l)} \]
Identify two different properties that could be used to monitor the rate of the reaction. Describe and explain the changes that would occur. **Any two of the following.**

- **Property 1**
  - **Mass of CaCO\(_3\)**
  - **Change and explanation** Decreases as reactants are converted into products

- **Property 2**
  - **Concentration of HCl**
  - **Change and explanation** Decreases as reactants are converted into products

- **Property 3**
  - **Concentration of CaCl\(_2\)**
  - **Change and explanation** Increases as reactants are converted into products

- **Property 4**
  - **Volume of CO\(_2\) gas**
  - **Change and explanation** Increases as reactants are converted into products

- **Property 5**
  - **Mass of open system**
  - **Change and explanation** Decreases as gas escapes

- **Property 6**
  - **Pressure of a closed system**
  - **Change and explanation** Increases as gas is produced

10. An experiment is done to determine the rate of the following reaction:
    \[ 2\text{Al(s)} + 6\text{HCl(aq)} \rightarrow 3\text{H}_2(g) + 2\text{AlCl}_3(aq) \]

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Mass of Flask + Contents (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>270.230</td>
</tr>
<tr>
<td>30.0</td>
<td>270.200</td>
</tr>
<tr>
<td>60.0</td>
<td>270.170</td>
</tr>
<tr>
<td><strong>60.0 s</strong></td>
<td><strong>0.060 g H(_2)</strong></td>
</tr>
</tbody>
</table>
Calculate the rate of consumption of Al in mol/min.  

\[
\begin{align*}
\text{0.060 g H}_2 & \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{1 \text{ mole H}_2}{2.0 \text{ g}} \times \frac{2 \text{ mol Al}}{3 \text{ mol H}_2} \\
\text{60.0 s} & \times \frac{1 \text{ min}}{60 \text{ s}} \\
& = 0.020 \text{ mol Al/min}
\end{align*}
\]

1.00 g of Al is placed in a beaker and allowed to react for 12.00 minutes with 2.00 M HCl. If the rate of consumption of HCl is 0.250 g/min, calculate the amount of Al remaining.

\[
\begin{align*}
\text{12.00 min} & \times \frac{0.250 \text{ g HCl}}{1 \text{ min}} \times \frac{1 \text{ mol}}{36.5 \text{ g}} \times \frac{2 \text{ mol Al}}{6 \text{ mol HCl}} \times \frac{27.0 \text{ g}}{1 \text{ mole}} \\
& = 0.740 \text{ g}
\end{align*}
\]

\[
\begin{align*}
\text{1.00 g} & - \frac{0.740 \text{ g}}{1 \text{ mole}} \\
\text{= 0.26 g} & \quad \text{Note the loss of one sig fig.}
\end{align*}
\]