1. In the potential energy diagram, which letter represents the potential energy of the activated complex?
   A. A  B. B  C. C  D. D

2. The addition of a catalyst to a reaction will cause a change in the medicine.
   A. potential energy of the reactants
   B. potential energy of the products
   C. heat of reaction
   D. activation energy

3. In order for a chemical reaction to occur, there must always be medicine.
   A. an effective collision between reacting particles
   B. a bond that breaks in a reactant particle
   C. reacting particles with a high charge
   D. reacting particles with a high kinetic energy

4. Given the equation: \( I + I \rightarrow I_2 \). As the atoms of the iodine react to form molecules of iodine, the stability of the iodine
   A. decreases
   B. increases
   C. remains the same

5. Which arrow represents the activation energy for the forward reaction?
   A. A  B. B  C. C  D. D

6. The potential energy diagram of a chemical reaction is shown.
   Which arrow represents the part of the reaction most likely to be affected by the addition of a catalyst?
   A. A  B. B  C. C  D. D

7. A potential energy diagram of a chemical reaction is shown.
   What is the difference between the potential energy of the reactants and the potential energy of the products?
   A. 20. kcal  B. 40. kcal  C. 60. kcal  D. 80. kcal

8. What happens when two oxygen atoms combine to form a molecule of oxygen?
   A. Chemical bonds are broken and energy is absorbed.
   B. Chemical bonds are broken and energy is released.
   C. Chemical bonds are formed and energy is absorbed.
   D. Chemical bonds are formed and energy is released.
9. The accompanying diagram represents the energy changes that occur during the formation of a certain compound under standard conditions.

According to Reference Table G, the compound could be

A. \( \text{C}_2\text{H}_6\text{(g)} \)  B. \( \text{CO}_2\text{(g)} \)  C. \( \text{ICl}\text{(g)} \)  D. \( \text{SO}_2\text{(g)} \)

10. A potential energy diagram is shown.

Which letters represent the activation energy of the forward and reverse reactions, respectively?

A. A and C  B. A and D  C. B and C  D. B and D

11. According to Table I, which potential energy diagram best represents the reaction that forms \( \text{H}_2\text{O(l)} \) from its elements?

A.  
B.  
C.  
D.  

12. The potential energy diagram represents a reaction.

Which arrow represents the activation energy of the forward reaction?

A. A  B. B  C. C  D. D
13. On the set of axes below, sketch the potential energy diagram for an endothermic chemical reaction that shows the activation energy and the potential energy of the reactants and the potential energy of the products.

14. Base your answer(s) to the following question(s) on the information and potential energy diagram below.

Chemical cold packs are often used to reduce swelling after an athletic injury. The diagram represents the potential energy changes when a cold pack is activated.

Which lettered interval on the diagram represents the potential energy of the products?

15. Base your answer(s) to the following question(s) on the potential energy diagram and the equation below.

\[ 2C(s) + H_2(g) + 227.4 \text{kJ} \rightarrow C_2H_2(g) \]

The letter B represents which chemical formula or formulas in the equation?

16. Base your answer(s) to the following question(s) on the potential energy diagram below.

What is the activation energy for the forward reaction with the catalyst?
Chemical kinetics

17. Base your answer(s) to the following question(s) on the information below.

Propane is a fuel that is sold in rigid, pressurized cylinders. Most of the propane in a cylinder is liquid, with gas in the space above the liquid level. When propane is released from the cylinder, the propane leaves the cylinder as a gas. Propane gas is used as a fuel by mixing it with oxygen in the air and igniting the mixture, as represented by the balanced equation below.

\[ C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) + 2219.2 \text{ kJ} \]

A small amount of methanethiol, which has a distinct odor, is added to the propane to help consumers detect a propane leak. In methanethiol, the odor is caused by the thiol functional group (-SH). Methanethiol, CH₃SH, has a structure that is very similar to the structure of methanol.

On the diagram below, draw a potential energy diagram for this reaction.

![Potential Energy Diagram](image.png)

18. Base your answer(s) to the following question(s) on the reaction represented by the balanced equation below.

\[ 2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + 571.6 \text{ kJ} \]

On the axes below, draw a potential energy diagram for the reaction represented by this equation.

![Potential Energy Diagram](image.png)

19. Given the reaction at equilibrium:

\[ A(g) + B(g) \rightleftharpoons C(g) + D(g) \]

The equilibrium will shift to the right when the

A. pressure is decreased
B. temperature is increased
C. concentration of A(g) is decreased
D. concentration of C(g) is increased

20. Given the reaction:

\[ _____K_2Cr_2O_7 + _____HCl \rightarrow _____KCl + _____CrCl_3 + _____Cl_2 + _____H_2O \]

When the reaction is completely balanced using *smallest* whole numbers, the coefficient of Cl₂ will be

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

21. Given the reaction at equilibrium:

\[ NaCl(s) = Na^+(aq) + Cl^-(aq) \]

The addition of KCl to this system will cause a shift in the equilibrium to the

A. left, and the concentration of Na⁺(aq) ions will increase
B. right, and the concentration of Na⁺(aq) ions will increase
C. left, and the concentration of Na⁺(aq) ions will decrease
D. right, and the concentration of Na⁺(aq) ions will decrease

22. The diagram here shows a bottle containing NH₃(g) dissolved in water. How can the equilibrium NH₃(g) ⇌ NH₃(aq) be reached?

A. Add more water.
B. Add more NH₃(g).
C. Cool the contents.
D. Stopper the bottle.
23. Given the reaction at STP and at equilibrium:
\[ \text{H}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2\text{HCl}(g) \]
Which change will result in an increase in the concentration of \text{Cl}_2(g)?

A. decreasing the pressure of the system  
B. decreasing the concentration of HCl(g)  
C. increasing the concentration of H\text{_2}(g)  
D. increasing the concentration of HCl(g)

24. The reaction A(g) + B(g) \rightleftharpoons C(g) is occurring in the apparatus shown. The rate of reaction can be decreased by increasing the

A. pressure on the reactants  
B. temperature of the reactants  
C. concentration of reactant A(g)  
D. volume of the reaction chamber

25. If the pressure on gaseous reactants is increased, the rate of reaction is increased because there is an increase in the

A. activation energy  
B. volume  
C. concentration  
D. heat of reaction

26. Under which conditions will the rate of a chemical reaction always decrease?

A. The concentration of the reactants decreases, and the temperature decreases.  
B. The concentration of the reactants decreases, and the temperature increases.  
C. The concentration of the reactants increases, and the temperature decreases.  
D. The concentration of the reactants increases, and the temperature increases.

27. As the concentration of reacting particles increases, the rate of reaction generally

A. decreases  
B. increases  
C. remains the same

28. Increasing the temperature increases the rate of a reaction by

A. lowering the activation energy  
B. increasing the activation energy  
C. lowering the frequency of effective collisions between reacting molecules  
D. increasing the frequency of effective collisions between reacting molecules

29. Given the reaction at 25°C:
\[ \text{Zn}(s) + 2\text{HCl}(aq) \rightarrow \text{ZnCl}_2(aq) + \text{H}_2(g) \]
The rate of this reaction can be increased by using 5.0 grams of powdered zinc instead of a 5.0-gram strip of zinc because the powdered zinc has

A. lower kinetic energy  
B. lower concentration  
C. more surface area  
D. more zinc atoms
Chemical kinetics

30. In each of the four beakers shown below, a 2.0-centimeter strip of magnesium ribbon reacts with 100 milliliters of HCl(aq) under the conditions shown. [Beaker A] 0.1 M HCl 20°C [Beaker B] 1.0 M HCl 20°C [Beaker C] 0.1 M HCl 50°C [Beaker D] 1.0 M HCl 50°C

In which beaker will the reaction occur at the fastest rate?

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

31. Base your answer(s) to the following question(s) on the information and table below.

A student conducts an experiment to determine how the temperature of water affects the rate at which an antacid tablet dissolves in the water. The student has three antacid tablets of the same size and composition. The student drops one tablet into each of three beakers containing 200 milliliters of water at different temperatures and measures the time it takes for each tablet to completely dissolve. The results are shown in the table below.

**Dissolving Data for Three Antacid Tablets**

<table>
<thead>
<tr>
<th>Beaker</th>
<th>Original Temperature of Water (°C)</th>
<th>Time for Tablet to Dissolve (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.</td>
<td>40.</td>
</tr>
<tr>
<td>2</td>
<td>30.</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>40.</td>
<td>10.</td>
</tr>
</tbody>
</table>

Explain, in terms of collision theory, how water temperature influences the rate of dissolving.

32. What change, other than temperature, would affect the rate of dissolving?

33. Base your answer(s) to the following question(s) on the information below.

An investigation was conducted to study the effect of the concentration of a reactant on the total time needed to complete a chemical reaction. Four trials of the same reaction were performed. In each trial the initial concentration of the reactant was different. The time needed for the chemical reaction to be completed was measured. The data for each of the four trials are shown in the table below.

**Reactant Concentration and Reaction Time**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Initial Concentration (M)</th>
<th>Reaction Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.020</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>0.015</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>0.010</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>0.005</td>
<td>58</td>
</tr>
</tbody>
</table>

State the effect of the concentration of the reactant on the rate of the chemical reaction.
34. Given the balanced equation representing a reaction:
\[ \text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{H}_2(\text{g}) + \text{ZnCl}_2(\text{aq}) \]
Which set of reaction conditions produces \( \text{H}_2(\text{g}) \) at the fastest rate?
A. a 1.0 g lump of \( \text{Zn(s)} \) in 50. mL of 0.5 M \( \text{HCl(aq)} \) at 20.\(^\circ\)C
B. a 1.0 g lump of \( \text{Zn(s)} \) in 50. mL of 0.5 M \( \text{HCl(aq)} \) at 30.\(^\circ\)C
C. 1.0 g of powdered \( \text{Zn(s)} \) in 50. mL of 1.0 M \( \text{HCl(aq)} \) at 20.\(^\circ\)C
D. 1.0 g of powdered \( \text{Zn(s)} \) in 50. mL of 1.0 M \( \text{HCl(aq)} \) at 30.\(^\circ\)C

35. The amount of energy required to remove the most loosely bound electron from an atom in the gaseous phase is called
A. kinetic energy
B. potential energy
C. ionization energy
D. electron affinity

36. Which compound is a nonelectrolyte?
A. \( \text{KOH} \)
B. \( \text{HNO}_3 \)
C. \( \text{CaCl}_2 \)
D. \( \text{C}_{12}\text{H}_{22}\text{O}_{11} \)

37. Which will occur if a catalyst is added to a reaction mixture?
A. The activation energy will be changed.
B. Only the rate of the forward reaction will be increased.
C. Only the rate of the reverse reaction will be increased.
D. The energy change (\( \Delta H \)) of the reaction will be decreased.

38. A catalyst can increase the rate of reaction by
A. decreasing the activation energy
B. increasing the activation energy
C. decreasing the potential energy of the products
D. increasing the potential energy of the products

39. Given the reaction at equilibrium:
\[ 2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3 + \text{heat} \]
Which effect does a platinum catalyst have on the rates of reaction?
A. It increases the rate of forward reaction, only.
B. It decreases the rate of reverse reaction, only.
C. It changes the rates of the forward and the reverse reactions unequally.
D. It changes the rates of the forward and the reverse reactions equally.

40. As a catalyst is added to a system in equilibrium, the amount of products formed
A. decreases
B. increases
C. remains the same

41. Base your answer(s) to the following question(s) on the potential energy diagram below, which represents the reaction \( A + B \rightarrow C \) + energy.

Which numbered interval will change with the addition of a catalyst to the system?
A. 1
B. 2
C. 3
D. 4
42. Base your answer(s) to the following question(s) on the information and diagram below, which represent the changes in potential energy that occur during the given reaction.

Given the reaction: \( A + B \rightarrow C \)

On the diagram provided below, draw a dashed line to indicate a potential energy curve for the reaction if a catalyst is added.

43. Base your answer(s) to the following question(s) on the potential energy diagram below.

Explain, in terms of the function of a catalyst, why the curves on the potential energy diagram for the catalyzed and uncatalyzed reactions are different.

44. Base your answer(s) to the following question(s) on the information below.

The catalytic converter in an automobile changes harmful gases produced during fuel combustion to less harmful exhaust gases. In the catalytic converter, nitrogen dioxide reacts with carbon monoxide to produce nitrogen and carbon dioxide. In addition, some carbon monoxide reacts with oxygen, producing carbon dioxide in the converter. These reactions are represented by the balanced equations below.

Reaction 1: \( 2\text{NO}_2(g) + 4\text{CO}(g) \rightarrow \text{N}_2(g) + 4\text{CO}_2(g) + 1198.4 \text{ kJ} \)

Reaction 2: \( 2\text{CO}(g) + \text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 566.0 \text{ kJ} \)

The potential energy diagram below represents reaction 1 without a catalyst. On the same diagram, draw a dashed line to indicate how potential energy changes when the reaction is catalyzed in the converter.

45. Which factors must be equal in a reversible chemical reaction at equilibrium?

A. the concentration of the reactants and products
B. the potential energies of the reactants and products
C. the activation energies of the forward and reverse reactions
D. the rates of reaction of the forward and reverse reactions
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Answer: B</td>
<td>16.</td>
<td>Answer: 100kJ</td>
</tr>
<tr>
<td>2.</td>
<td>Answer: D</td>
<td>17.</td>
<td>Answer:</td>
</tr>
<tr>
<td>3.</td>
<td>Answer: A</td>
<td>18.</td>
<td>Answer:</td>
</tr>
<tr>
<td>4.</td>
<td>Answer: B</td>
<td>19.</td>
<td>Answer: B</td>
</tr>
<tr>
<td>5.</td>
<td>Answer: A</td>
<td>20.</td>
<td>Answer: C</td>
</tr>
<tr>
<td>7.</td>
<td>Answer: A</td>
<td>22.</td>
<td>Answer: D</td>
</tr>
<tr>
<td>8.</td>
<td>Answer: D</td>
<td>23.</td>
<td>Answer: D</td>
</tr>
<tr>
<td>10.</td>
<td>Answer: C</td>
<td>25.</td>
<td>Answer: C</td>
</tr>
<tr>
<td>11.</td>
<td>Answer: A</td>
<td>26.</td>
<td>Answer: A</td>
</tr>
<tr>
<td>12.</td>
<td>Answer: B</td>
<td>27.</td>
<td>Answer: B</td>
</tr>
</tbody>
</table>

### Chemical Kinetics

#### 14.
Answer: $D$

#### 15.
Answer: $C_2H_2$
Answer: $C_2H_2(g)$

#### 16.
Answer: $100kJ$

#### Diagrams

- [Diagram of Reaction Coordinate]
- [Diagram of Potential Energy vs. Reaction Coordinate]
28. Answer: D
29. Answer: C
30. Answer: D
31. Answer: At higher temperatures the water molecules collide more often and more effectively with the tablet, so the tablet dissolves faster.
32. Answer: crushing the tablet or stirring/shaking/agitating
33. Answer: Acceptable responses include, but are not limited to:
   —As concentration of the reactant decreases, the rate of the reaction decreases.
   —As concentration increases, the rate of reaction increases.
34. Answer: D
35. Answer: C
36. Answer: D
37. Answer: A
38. Answer: A
39. Answer: D
40. Answer: C
41. Answer: B
42. Answer: A catalyst speeds up the reaction by lowering the required activation energy.
43. Answer: D