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1. 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

2. Which event must *always* occur for a chemical reaction to take place?

   A) formation of a precipitate
   B) formation of a gas
   C) effective collisions between reacting particles
   D) addition of a catalyst to the reaction system

3. The energy needed to start a chemical reaction is called

   A) potential energy B) kinetic energy
   C) activation energy D) ionization energy

4. Given the reaction:

   $Mg + 2\ H_2O \rightarrow Mg(OH)_2 + H_2$

   At which temperature will the reaction occur at the greatest rate?

   A) 25ºC B) 50ºC
   C) 75ºC **D) 100ºC**

5. Which conditions will increase the rate of a chemical reaction?

   A) decreased temperature and decreased concentration of reactants
   B) decreased temperature and increased concentration of reactants
   C) increased temperature and decreased concentration of reactants
   D) increased temperature and increased concentration of reactants

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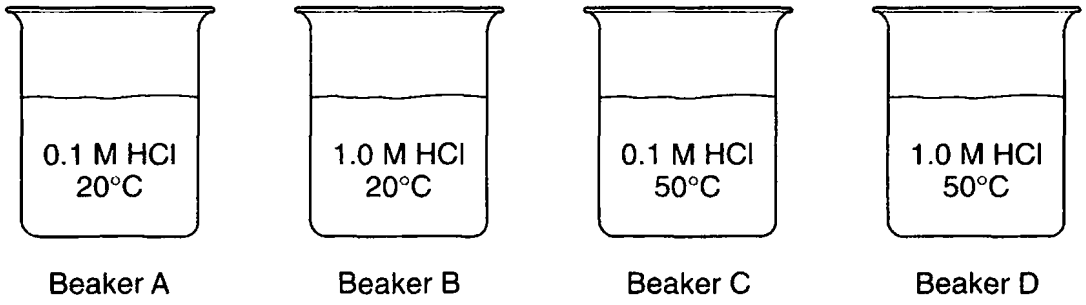
6. In each of the four beakers shown below, a 2.0-centimeter strip of magnesium ribbon reacts with 100 milliliters of HCl(aq) under the conditions shown.



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

A) A B) B C) C **D) D**

7. Beaker *A* contains a 1 gram piece of zinc and beaker *B* contains 1 gram of powdered zinc. If 100 milliliters of 0.1 M HCl is added to each of the beakers, how does the rate of reaction in beaker *A* compare to the rate of reaction in beaker *B*?

A) The rate in *A* is greater due to the smaller surface area of the zinc.
B) The rate in *A* is greater due to the larger surface area of the zinc.
C) The rate in *B* is greater due to the smaller surface area of the zinc.
D) The rate in *B* is greater due to the larger surface area of the zinc.

8. For a given reaction, adding a catalyst increases the rate of the reaction by

A) providing an alternate reaction pathway that has a higher activation energy
B) providing an alternate reaction pathway that has a lower activation energy
C) using the same reaction pathway and increasing the activation energy
D) using the same reaction pathway and decreasing the activation energy

9. Which balanced equation represents an endothermic reaction?

A) $C(s) + O_2(g) \rightarrow CO_2(g)$
B) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$
C) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
D) $N_2(g) + O_2(g) \rightarrow 2NO(g)$

10. The burning of wood is best described as an

A) endothermic chemical change
B) endothermic physical change
C) exothermic chemical change
D) exothermic physical change

11. Given the balanced equation representing a reaction at 101.3 kPa and 298 K:

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 91.8$ kJ

Which statement is true about this reaction?

A) It is exothermic and ΔH *equals –91.8 kJ.*
B) It is exothermic and ΔH *equals +91.8 kJ.*
C) It is endothermic and ΔH *equals –91.8 kJ.*
D) It is endothermic and ΔH *equals +91.8 kJ.*

12. Given the balanced equation:

$4Fe(s) + 3O_2(g) \rightarrow 2Fe2O_3(s) + 1640$ kJ

Which phrase best describes this reaction?

A) endothermic with $\Delta H = +1640$ kJ
B) endothermic with $\Delta H = -1640$ kJ
C) exothermic with $\Delta H = +1640$ kJ
D) exothermic with $\Delta H = -1640$ kJ

13. Given the reaction:

$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(\ell) + 571.6$ kJ

What is the approximate ΔH for the formation of 1 mole of $H_2O(\ell)$?

A) –285.8 kJ B) +285.8 kJ
C) –571.6 kJ D) +571.6 kJ

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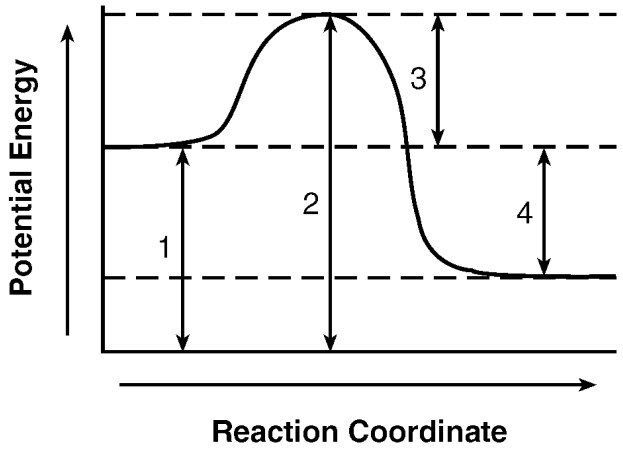
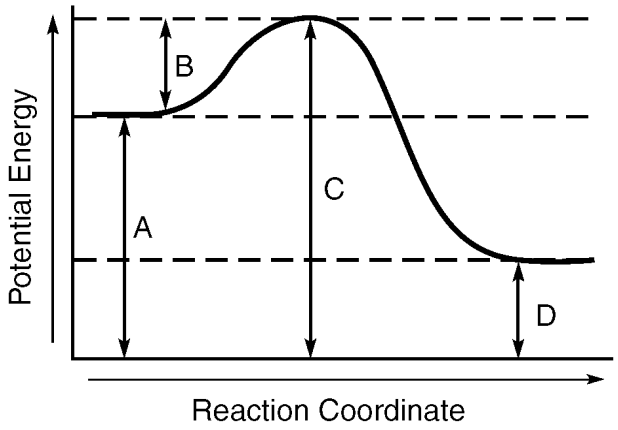
14. Given the potential energy diagram for a reaction:



Which interval on this diagram represents the difference between the potential energy of the products and the potential energy of the reactants?

A) 1 B) 2 C) 3 **D) 4**

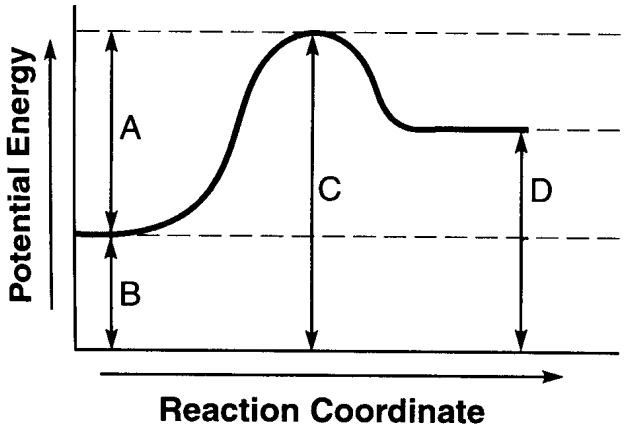
15. The potential energy diagram below represents a reaction.



Which arrow represents the activation energy of the forward reaction?

A) *A* **B) *B*** C) *C* D) *D*

16. Given the potential energy diagram of a chemical reaction:



Which arrow represents the potential energy of the reactants?

A) *A* **B) *B*** C) *C* D) *D*

17. The activation energy required for a chemical reaction can be *decreased* by

A) increasing the surface area of the reactant
B) increasing the temperature of the reactant
C) adding a catalyst to the reaction
D) adding more reactant

18. Given the equation representing a phase change at equilibrium:

$$C_2H_5OH(\ell) \leftrightarrow C_2H_5OH(g)$$

Which statement is true?

A) The forward process proceeds faster than the reverse process.
B) The reverse process proceeds faster than the forward process.
C) The forward and reverse processes proceed at the same rate.
D) The forward and reverse processes both stop.

19. Which statement must be true when solution equilibrium occurs?

A) The solution is at STP.
B) The solution is supersaturated.
C) The concentration of the solution remains constant.
D) The masses of the dissolved solute and the undissolved solute are equal.

20. A solution that is at equilibrium must be

A) concentrated B) dilute
C) saturated D) unsaturated

21. Which balanced equation represents a phase equilibrium?

A) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
B) $2NO_2(g) \rightleftharpoons N_2O_4(g)$ **C)** $Cl_2(g) \rightleftharpoons Cl_2(\ell)$
D) $3O_2(g) \rightleftharpoons 2O_3(g)$

22. Ammonia is produced commercially by the Haber reaction:

$N_2(g) + 3\ H_2(g) \leftrightarrow 2\ NH_3(g) + \text{heat}$

The formation of ammonia is favored by

A) an increase in pressure
B) a decrease in pressure
C) removal of $N_2(g)$
D) removal of $H_2(g)$

23. Given the reaction at equilibrium:

$2\ SO_2(g) + O_2(g) \leftrightarrow 2\ SO_3(g) + \text{heat}$

The concentration of $SO_3(g)$ may be increased by

A) decreasing the concentration of $SO_2(g)$
B) decreasing the concentration of $O_2(g)$
C) increasing the pressure
D) increasing the temperature

24. Given the reaction at equilibrium:

$2\ A(g) + 3\ B(g) \leftrightarrow A_2B_3(g) + \text{heat}$

Which change will not affect the equilibrium concentrations of $A(g)$, $B(g)$, and $A_2B_3(g)$?

A) adding more $A(g)$
B) adding a catalyst
C) increasing the temperature
D) increasing the pressure

25. Given the reaction at equilibrium:

$A(g) + B(g) \leftrightarrow C(g) + D(g)$
The addition of a catalyst will

A) shift the equilibrium to the right
B) shift the equilibrium to the left
C) increase the rate of forward and reverse reactions equally
D) have no effect on the forward or reverse reactions

26. Given the system at equilibrium:
$2\ POCl_3(g) + \text{energy} \rightleftharpoons 2\ PCl_3(g) + O_2(g)$
Which changes occur when $O_2(g)$ is added to this system?

A) The equilibrium shifts to the right and the concentration of $PCl_3(g)$ increases.
B) The equilibrium shifts to the right and the concentration of $PCl_3(g)$ decreases.
C) The equilibrium shifts to the left and the concentration of $PCl_3(g)$ increases.
D) The equilibrium shifts to the left and the concentration of $PCl_3(g)$ decreases.

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27. Given the reaction at equilibrium:

$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 91.8kJ$
What occurs when the concentration of $H_2(g)$ is increased?

A) The rate of the forward reaction increases and the concentration of $N_2(g)$ decreases.
B) The rate of the forward reaction decreases and the concentration of $N_2(g)$ increases.
C) The rate of the forward reaction and the concentration of $N_2(g)$ both increase.
D) The rate of the forward reaction and the concentration of $N_2(g)$ both decrease.

28. Given the system at equilibrium:

$N_2O_4(g) + 58.1\ kJ \leftrightarrow 2\ NO_2(g)$
What will be the result of an increase in temperature at constant pressure?

A) The equilibrium will shift to the left, and the concentration of $NO_2(g)$ will decrease.
B) The equilibrium will shift to the left, and the concentration of $NO_2(g)$ will increase.
C) The equilibrium will shift to the right, and the concentration of $NO_2(g)$ will decrease.
D) The equilibrium will shift to the right, and the concentration of $NO_2(g)$ will increase.

29. Given the equilibrium reaction in a closed system:

$H_2(g) + I_2(g) + heat \leftrightarrow 2\ HI(g)$
What will be the result of an increase in temperature?

A) The equilibrium will shift to the left and $[H_2]$ will increase.
B) The equilibrium will shift to the left and $[H_2]$ will decrease.
C) The equilibrium will shift to the right and [HI] will increase.
D) The equilibrium will shift to the right and [HI] will decrease.

30. In terms of energy and entropy, systems in nature tend to undergo changes toward

A) higher energy and higher entropy
B) higher energy and lower entropy
C) lower energy and higher entropy
D) lower energy and lower entropy

31. Which chemical reaction will always be spontaneous?

A) an exothermic reaction in which entropy decreases
B) an exothermic reaction in which entropy increases
C) an endothermic reaction in which entropy decreases
D) an endothermic reaction in which entropy increases

32. Which reaction has the greatest increase in entropy?

A) $2\ H_2O(\ell) \rightarrow 2\ H_2(g) + O_2(g)$
B) $2\ H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$
C) $H_2O(g) \rightarrow H_2O(\ell)$
D) $H_2O(\ell) \rightarrow H_2O(s)$

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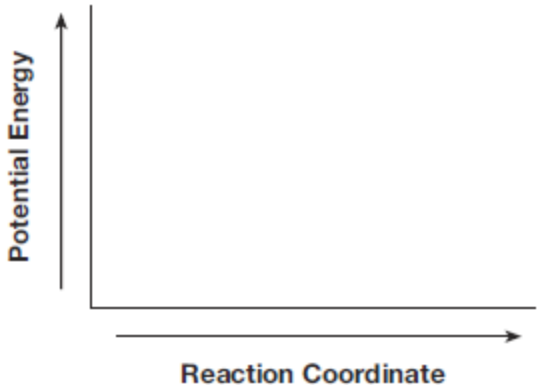
Base your answers to questions **33** and **34** on the information below and on your knowledge of chemistry.

Carbon monoxide, CO(g), is a toxic gas found in automobile exhaust. The concentration of CO(g) can be decreased by using a catalyst in the reaction between CO(g) and O_2(g). This reaction is represented by the balanced equation below.

$2CO(g) + O_2 \xrightarrow{catalyst} 2CO_2(g) + \text{energy}$

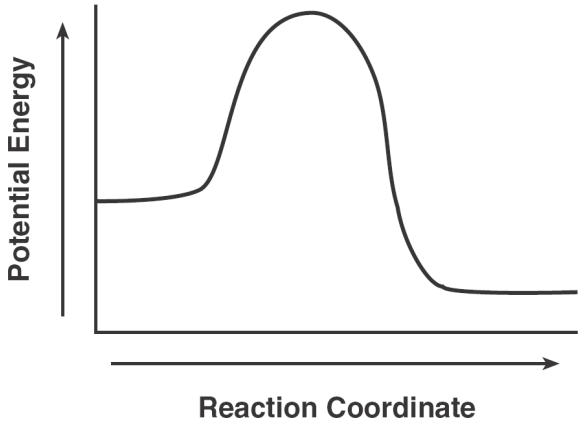
33. On the labeled axes below, draw the potential energy curve for the reaction represented by this equation.



34. Explain, in terms of collision theory, why an increase in temperature increases the rate of the reaction.

35. Explain, in terms of collision theory, why the rate of a chemical reaction increases with an increase in temperature.

36. A potential energy diagram for a chemical reaction is shown below. On this diagram, draw a curve to show how the potential energy diagram will change when a catalyst is added to the reaction.



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37. Base your answer to the following question on the information below.
Given the reaction at equilibrium:

$2NO_2(g) \leftrightarrow N_2O_4(g) + 55.3\ kJ$

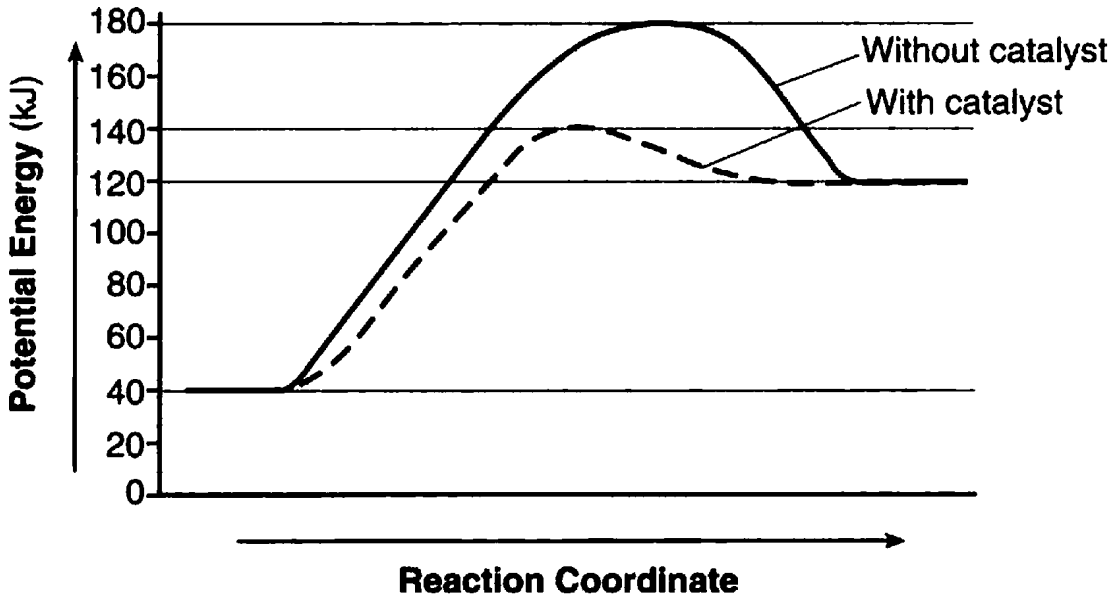
Explain, in terms of Le Chatelier's principle, why the equilibrium shifts to the right to relieve the stress when the pressure on the system is increased at constant temperature.

38. Base your answer to the following question on the information and balanced equation below.

Given the equation for a reaction at equilibrium:
$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) + \text{energy}$

Explain, in terms of collisions between molecules, why increasing the concentration of $O_2(g)$ produces a *decrease* in the concentration of $SO_2(g)$.

39. Base your answer to the following question 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.

40. Base your answer to the following question on the information below.

Given the equilibrium equation at 298 K:

$KNO_3(s) + 34.89\ kJ \leftrightarrow K^+(aq) + NO_3^-(aq)$

The equation indicates that KNO_3 has formed a saturated solution. Explain, in terms of equilibrium, why the solution is saturated.

Answer Key
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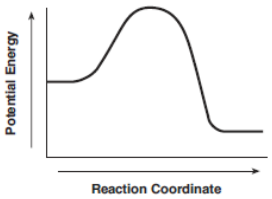
1. **D**
2. **C**
3. **C**
4. **D**
5. **D**
6. **D**
7. **D**
8. **B**
9. **D**
10. **C**
11. **A**
12. **D**
13. **A**
14. **D**
15. **B**
16. **B**
17. **C**
18. **C**
19. **C**
20. **C**
21. **C**
22. **A**
23. **C**
24. **B**
25. **C**
26. **D**
27. **A**
28. **D**
29. **C**
30. **C**
31. **B**
32. **A**

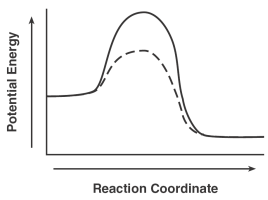
33.



34. – The rate of the chemical reaction increases because the reactant molecules move faster and collide with more kinetic energy. – Increasing the temperature causes more frequent collisions. – As molecules acquire more kinetic energy, the probability of effective collisions increases. – More reactant molecules collide with sufficient energy.

35. As temperature increases, the rate of a chemical reaction increases because the reactant particles move faster and collide more often.

36.



37. *Examples*: – Equilibrium shifts towards the fewer number of moles of gas – The reaction shifts to the side that would result in a reduction of pressure – fewer moles of gas, less pressure

38. Examples: – A higher concentration of $O_2(g)$ causes more collisions and reactions with SO_2 (g) molecules, decreasing $SO_2(g)$ concentration. – More collisions between reactants shift the reaction to the right.

39. Acceptable responses include, but are not limited to:
A catalyst provides an alternate reaction pathway that has a lower activation energy than an uncatalyzed reaction.

A catalyst speeds up the reaction, lower activation energy

40. The rate of dissolving KNO_3 is equal to the rate of recrystallizing KNO_3 *or* The KNO_3 is going into the solution at the same rate it precipitates out of the solution