1. What is the best definition of an effective collision?
   1) A collision between reactant particles with the proper heat of reaction and sufficient activation energy.
   2) A collision between reactant particles with the proper bond types and a sufficient amount of valence electrons.
   3) A collision between reactant particles with proper orientation and a sufficient amount of kinetic energy .
   4) A collision between reactant particles with a sufficient amount of activation energy.

2. As the temperature of a chemical reaction in the gas phase is increased, the rate of the reaction increases because
   1) fewer particle collisions occur
   2) the concentration of the reactants increases
   3) the required activation energy increases
   4) more effective particle collisions occur

3. After being ignited in a Bunsen burner flame, a piece of magnesium ribbon burns brightly, giving off heat and light. In this situation, the Bunsen burner flame provides
   1) activation energy
   2) heat of vaporization
   3) ionization energy
   4) heat of reaction

4. In most aqueous reactions as temperature increases, the effectiveness of collisions between reacting particles
   1) decreases
   2) increases
   3) remains the same

5. A solution that is at equilibrium must be
   1) unsaturated
   2) concentrated
   3) dilute
   4) saturated

6. Which balanced equation represents an endothermic reaction?
   1) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
   2) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$
   3) $N_2(g) + O_2(g) \rightarrow 2NO(g)$
   4) $C(s) + O_2(g) \rightarrow CO_2(g)$

7. Base your answer to the following question on the table below, which represents the production of 50 milliliters of CO_2 in the reaction of HCl with $NaHCO_3$. Five trials were performed under different conditions as shown. (The same mass of $NaHCO_3$ was used in each trial.)

Trial	Particle Size of $NaHCO_3$	Concentration of HCl	Temperature (°C) of HCl
A	small	1 M	20
B	large	1 M	20
C	large	1 M	40
D	small	2 M	40
E	large	2 M	40

Which two trials could be used to measure the effect of surface area?
   1) trials *A* and *B*
   2) trials *A* and *C*
   3) trials *A* and *D*
   4) trials *B* and *D*

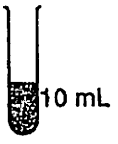
8. The entropy of a sample of H_2O increases as the sample changes from a
   1) liquid to a solid
   2) liquid to a gas
   3) gas to a solid
   4) gas to a liquid

9. For a given chemical reaction, the addition of a catalyst provides a different reaction pathway that
   1) decreases the reaction rate and has a higher activation energy
   2) increases the reaction rate and has a higher activation energy
   3) increases the reaction rate and has a lower activation energy
   4) decreases the reaction rate and has a lower activation energy

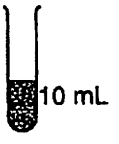
10. Which reaction releases the greatest amount of energy per 2 moles of product?
   1) $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
   2) $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
   3) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
   4) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

11. Each of four test tubes contains a different concentration of HCl(aq) at 25°C. A 1-gram cube of Zn is added to each test tube. In which test tube is the reaction occurring at the fastest rate?

1) 0.001 M HCl(aq)

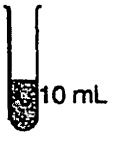


3) 1 M HCl(aq)



2) 0.1 M HCl(aq)

4) 0.01 M HCl(aq)



12. Given the balanced equation representing a reaction:

$$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

This reaction occurs more quickly when powdered iron is used instead of a single piece of iron of the same mass because the powdered iron
   1) acts as a better catalyst than the single piece of iron
   2) absorbs less energy than the single piece of iron
   3) has a greater surface area than the single piece of iron
   4) is more metallic than the single piece of iron

13. Given the balanced equation:

$$KNO_3(s) + 34.89\ kJ \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$$

Which statement best describes this process?
   1) It is exothermic and entropy decreases.
   2) It is exothermic and entropy increases.
   3) It is endothermic and entropy increases.
   4) It is endothermic and entropy decreases.

14. In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the
   1) activation energy
   2) heat of reaction
   3) entropy of the system
   4) heat of fusion

15. Given the balanced equation representing a phase change:

$$C_6H_4Cl_2(s) + \text{energy} \rightarrow C_6H_4Cl_2(g)$$

Which statement describes this change?

1) It is exothermic, and entropy decreases.
2) It is endothermic, and entropy decreases.
3) It is endothermic, and entropy increases.
4) It is exothermic, and entropy increases.

16. Which equation represents an exothermic reaction at 298 K?

1) $C(s) + O_2(g) \rightarrow CO_2(g)$

2) $KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$

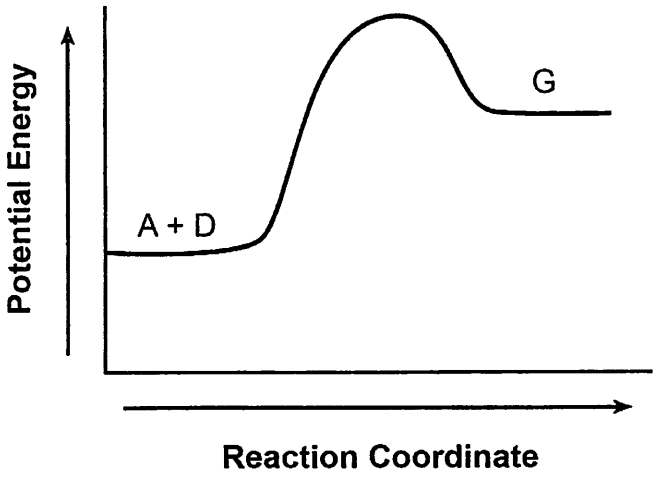
3) $NH_4Cl(s) \xrightarrow{H_2O} NH_4^+(aq) + Cl^-(aq)$

4) $N_2(g) + O_2(g) \rightarrow 2NO(g)$

17. In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is defined as the

1) ionization energy
2) activation energy
3) heat of vaporization
4) heat of reaction

18. Given the potential energy diagram and equation representing the reaction between substances *A* and *D*:



$A + D \longrightarrow G$

According to Table *I*, substance *G* could be

1) $CO_2(g)$
2) $H_2O(g)$
3) $HI(g)$
4) $C_2H_6(g)$

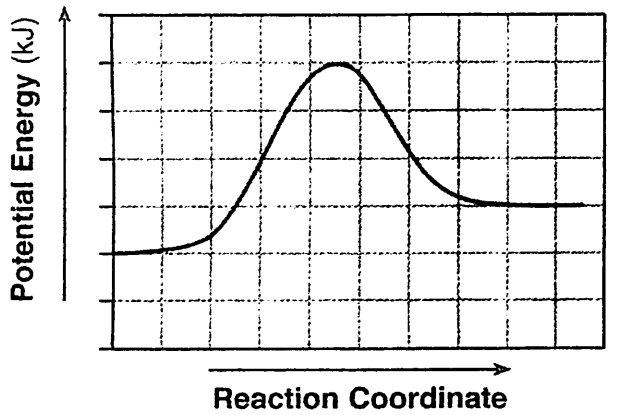
19. Which two factors must be equal when a chemical reaction reaches equilibrium?

1) the number of reactant particles and the number of product particles
2) the concentration of the reactants and the concentration of the products
3) the rate of the forward reaction and the rate of the reverse reaction
4) the mass of the reactants and the mass of the products

20. Which condition is necessary for a chemical reaction to occur spontaneously?

1) ΔG must be positive.
2) ΔS must be negative.
3) ΔG must be negative.
4) ΔS must be positive.

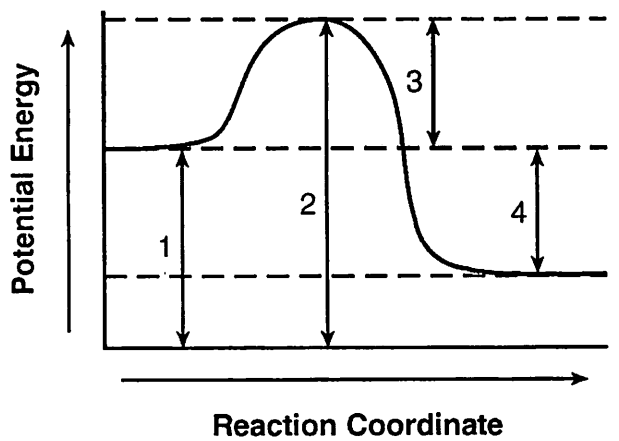
21. The potential energy diagram for a chemical reaction is shown below.



Each interval on the axis labeled "Potential Energy (kJ)" represents 40 kilojoules. What is the heat of reaction?

1) -120kJ
2) -40kJ
3) +40kJ
4) +160kJ

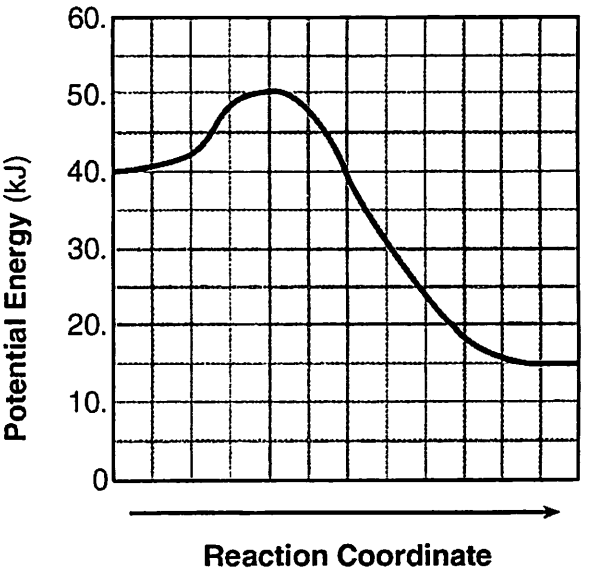
22. Given the potential energy diagram for a reaction:



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

1) 3
2) 1
3) 2
4) 4

23. Given the potential energy diagram for a chemical reaction:



Which statement correctly describes the energy changes that occur in the forward reaction?

1) The activation energy is 10. kJ and the reaction is endothermic.
2) The activation energy is 50. kJ and the reaction is endothermic.
3) The activation energy is 50. kJ and the reaction is exothermic.
4) The activation energy is 10. kJ and the reaction is exothermic.

24. Based on Reference Table G, which amount of a compound dissolved in 100 grams of water at the stated temperature represents a system at equilibrium?

1) 20 g $KClO_3$ at 80°C
2) 40 g KNO_3 at 25°C
3) 40 g KCl at 60°C
4) 60 g $NaNO_3$ at 40°C

25. Given the equation representing a system at equilibrium:

$$2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$$

At equilibrium, the concentration of

1) $SO_2(g)$ must equal the concentration of $SO_3(g)$
2) $O_2(g)$ must equal the concentration of $SO_2(g)$
3) $SO_2(g)$ must be constant
4) $O_2(g)$ must be decreasing

26. Given the equation representing a reaction:

$$N_2O_4(g) \leftrightarrow 2NO_2(g)$$

Which statement describes this reaction at equilibrium?

1) The concentration of $N_2O_4(g)$ must equal the concentration of $NO_2(g)$.
2) The rate of the reverse reaction is greater than the rate of the forward reaction.
3) The rate of the forward reaction is greater than the rate of the reverse reaction.
4) The concentration of $N_2O_4(g)$ and the concentration of $NO_2(g)$ must be constant.

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

$$H_2O(s) \leftrightarrow H_2O(\ell)$$

Which statement describes this equilibrium?

1) The mass of $H_2O(\ell)$ and the mass of $H_2O(s)$ each remain constant.
2) The $H_2O(s)$ melts faster than the $H_2O(\ell)$ freezes.
3) The $H_2O(\ell)$ freezes faster than the $H_2O(s)$ melts.
4) The mass of $H_2O(s)$ must equal the mass of $H_2O(\ell)$.

28. Given the equation representing a system at equilibrium:

$$H_2O(s) \leftrightarrow H_20(l)$$

At which temperature does this equilibrium exist at 101.3 kilopascals?

1) 32 K
2) 273°C
3) 0 K
4) 0°C

29. 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

1) removal of $N_2(g)$
2) an increase in pressure
3) a decrease in pressure
4) removal of $H_2(g)$

30. Given the reaction at equilibrium:

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

Which change will shift the equilibrium to the right?

1) increasing the pressure
2) increasing the temperature
3) decreasing the amount of $SO_2(g)$
4) decreasing the amount of $O_2(g)$

31. 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 $A_2B_3(g)$?

1) increasing the pressure
2) increasing the temperature
3) adding more $A(g)$
4) adding a catalyst

32. Given the reaction at equilibrium:

$$A(g) + B(g) \leftrightarrow C(g) + D(g)$$

The addition of a catalyst will

1) increase the rate of forward and reverse reactions equally
2) have no effect on the forward or reverse reactions
3) shift the equilibrium to the left
4) shift the equilibrium to the right

33. Given the equation representing a reaction at equilibrium:

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

What occurs when the concentration of $H_2(g)$ is increased?

1) The equilibrium shifts to the right, and the concentration of $N_2(g)$ increases
2) The equilibrium shifts to the left, and the concentration of $N_2(g)$ decreases.
3) The equilibrium shifts to the left, and the concentration of $N_2(g)$ increases.
4) The equilibrium shifts to the right, and the concentration of $N_2(g)$ decreases.

34. Given the equation representing a system at equilibrium:

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

Which changes occur when the temperature of this system is *decreased*?

1) The concentration of $H_2(g)$ increases and the concentration of $N_2(g)$ increases.
2) The concentration of $H_2(g)$ decreases and the concentration of $NH_3(g)$ increases.
3) The concentration of $H_2(g)$ decreases and the concentration of $N_2(g)$ increases.
4) The concentration of $H_2(g)$ decreases and the concentration of $NH_3(g)$ decreases.

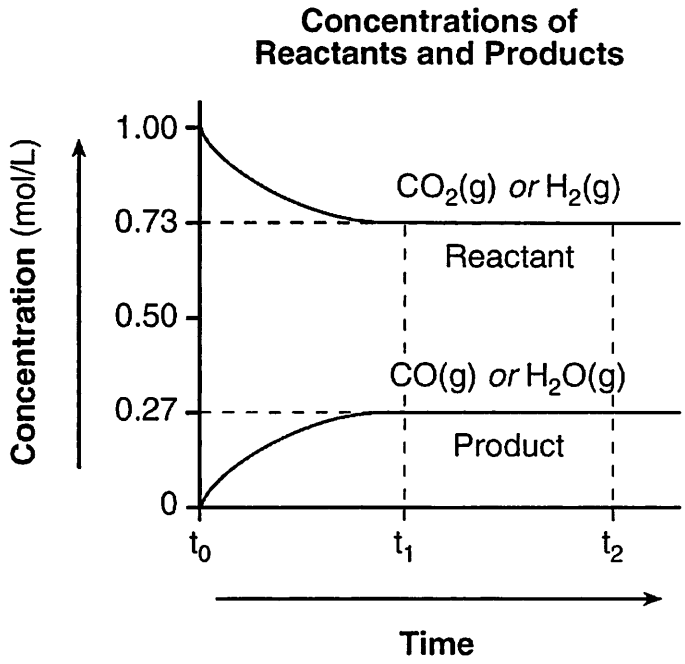
35. Given the balanced equation representing a reaction:

$$2HCl(aq) + Na_2S_2O_3(aq) \rightarrow S(s) + H_2SO_3(aq) + 2NaCl(aq)$$

Decreasing the concentration of $Na_2S_2O_3(aq)$ decreases the rate of reaction because the
1) frequency of effective collisions decreases
2) activation energy increases
3) activation energy decreases
4) frequency of effective collisions increases

Base your answers to questions **36** and **37** on the information below.

At 550°C, 1.00 mole of $CO_2(g)$ and 1.00 mole of $H_2(g)$ are placed in a 1.00-liter reaction vessel. The substances react to form $CO(g)$ and $H_2O(g)$. Changes in the concentrations of the reactants and the concentrations of the products are shown in the graph below.

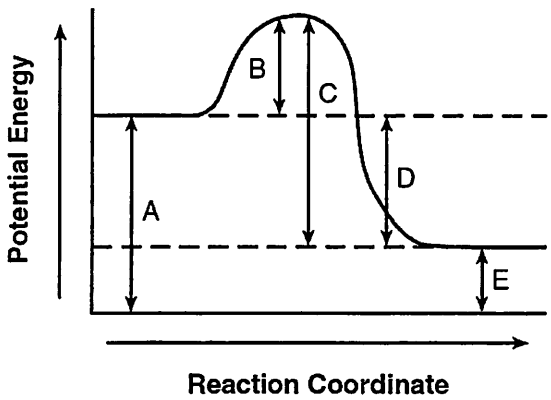


36. What can be concluded from the graph about the concentrations of the reactants and the concentrations of the products between time t_1 and time t_2?

37. Determine the change in the concentration of $CO_2(g)$ between time t_0 and time t_1.

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

The chemical reaction between methane and oxygen is represented by the potential energy diagram and balanced equation below.



$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell) + 890.4\ kJ$$

Explain, in terms of collision theory, why a lower concentration of oxygen gas *decreases* the rate of this reaction.

39. Base your answer to the following question on the information below.
The balanced equation below represents the decomposition of potassium chlorate.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

State why the entropy of the reactant is less than the entropy of the products.

40. Given the equation representing a reaction at equilibrium:

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

Explain, in terms of collision theory, why the rate of the forward reaction *decreases* when the concentration of $N_2(g)$ is decreased.