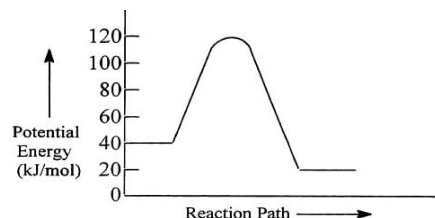


# Equilibrium and Reaction Rate

## Multiple Choice Questions

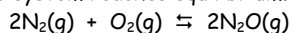
1. Activation energy could be considered as the minimum energy required to do which of these?
- change the orientation of the reactant molecules
  - increase the vibrational energy of the reactant molecules
  - make the reactant molecules collide
  - transform the reactants into an activated complex

2. What activation energy is required for the forward reaction shown on the diagram to the right?



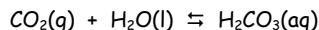
- 40 kJ/mol
  - 80 kJ/mol
  - 100 kJ/mol
  - 120 kJ/mol
3. Which factor causes an increase in the rate of most reactions when the temperature is increased?
- The reaction mechanism is changed.
  - The reactant particles have more energy.
  - The reactant particles collide less efficiently.
  - The reactant particles collide less frequently.
4. In general, what is the function of a catalyst?
- to alter the activation energy and the reaction rate
  - to alter the heat content of the reactants
  - to oxidize unwanted waste products
  - to permit the reaction products to be filtered easily

5. Which statement is true when this closed system reaches equilibrium?



- Pressure changes no longer occur.
- The forward reaction no longer occurs.
- The  $\text{N}_2(\text{g})$  has all been consumed.
- The  $\text{O}_2(\text{g})$  has all been consumed.

6. The following chemical equation represents a reaction that occurs when soft drinks are carbonated:



What occurs when this reaction is at equilibrium in a closed system?

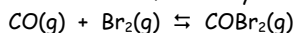
- The decomposition of  $\text{H}_2\text{CO}_3(\text{aq})$  begins.
  - The formation of  $\text{H}_2\text{CO}_3(\text{aq})$  stops.
  - The formation of  $\text{H}_2\text{CO}_3(\text{aq})$  stops, and the decomposition of  $\text{H}_2\text{CO}_3(\text{aq})$  begins.
  - The rates of formation and decomposition of  $\text{H}_2\text{CO}_3(\text{aq})$  are equal.
7. What is the result of an increase in the temperature of a system at equilibrium?
- The endothermic reaction is favoured, and the reaction rate decreases.
  - The endothermic reaction is favoured, and the reaction rate increases.
  - The exothermic reaction is favoured, and the reaction rate decreases.
  - The exothermic reaction is favoured, and the reaction rate increases.
8. According to Le Châtelier's principle, which chemical system shifts to the right when pressure is increased?
- $\text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g})$
  - $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$
  - $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
  - $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$

9. Which equation has this equilibrium constant expression?

$$K = \frac{[\text{Ni}^{2+}]}{[\text{Co}^{2+}]}$$

- $\text{Ni}(\text{s}) + \text{Co}^{2+}(\text{aq}) \rightleftharpoons \text{Ni}^{2+}(\text{aq}) + \text{Co}(\text{s})$
- $\text{Ni}^{2+}(\text{aq}) + \text{Co}(\text{s}) \rightleftharpoons \text{Ni}(\text{s}) + \text{Co}^{2+}(\text{aq})$
- $\text{Ni}^{2+}(\text{aq}) + \text{Co}^{2+}(\text{aq}) \rightleftharpoons \text{NiCo}^{4+}(\text{aq})$
- $\text{Ni}^{2+}(\text{aq}) + \text{Co}^{2+}(\text{aq}) \rightleftharpoons \text{NiCo}^{4+}(\text{s})$

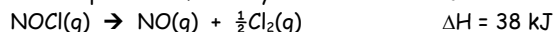
10. What is the numerical value of the equilibrium constant for the system:



If the equilibrium concentrations are  $[\text{CO}] = 1.0$ ,  $[\text{Br}_2] = 1.0$ , and  $[\text{COBr}_2] = 2.0$ ?

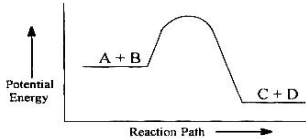
- 0.50
  - 1.0
  - 2.0
  - 4.0
11. For the reaction,  $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$ , which value of the equilibrium constant indicates the largest concentration of  $\text{NO}_2$ ?
- $1.8 \times 10^{-2}$
  - $1.5 \times 10^{-1}$
  - 0.41
  - 0.87

12. The activation energy for the decomposition of nitrosyl chloride is 100 kJ.

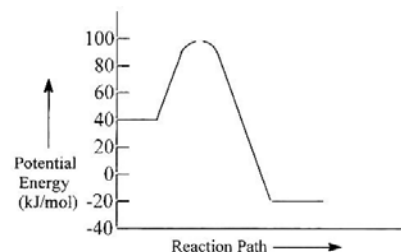


What is the activation energy for the reverse reaction?

- 38 kJ
  - 62 kJ
  - 100 kJ
  - 138 kJ
13. Which phrase could be a definition of the activation energy of a reaction?
- the energy gained by reactant molecules to undergo a reaction
  - the energy supplied by the attractive forces between molecules
  - the energy supplied by a catalyst
  - the heat content of the products minus that of the reactants

- \_\_\_\_\_ 14. Which factors affect the initial rate of a reaction?
- the nature of the reactants
  - the concentration of the reactants
  - the size of solid reactant particles
- A. 1 and 2 only      B. 1 and 3 only      C. 2 and 3 only      D. 1, 2, and 3
- \_\_\_\_\_ 15. What is the detailed sequence of steps that leads to the net overall reaction called?
- A. reaction coordinate      C. reaction potential  
B. reaction mechanism      D. reaction rate law
- \_\_\_\_\_ 16. Which examples illustrate a state of dynamic equilibrium at constant temperature?
- a stoppered flask half full of water
  - an open pan of boiling water
  - a stoppered flask of a saturated sodium carbonate solution
- A. 1 and 2 only      B. 1 and 3 only      C. 2 and 3 only      D. 1, 2, and 3
- \_\_\_\_\_ 17. Which change would favour the net reverse reaction for the system,
- $$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) + \text{heat}$$
- A. a decrease in the concentration of ammonia      C. a decrease in the temperature  
B. a decrease in the concentration of nitrogen      D. a decrease in the volume
- \_\_\_\_\_ 18. Consider the equilibrium:  $\text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$        $\Delta H = +67 \text{ kJ}$   
How could the amount of  $\text{SO}_2$  be increased?
- A. adding  $\text{Cl}_2$  to the system      C. increasing the temperature  
B. decreasing the volume of the reaction vessel      D. removing  $\text{SO}_2\text{Cl}_2$
- \_\_\_\_\_ 19. Which change will increase the amount of  $\text{SO}_3$ ?       $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) + \text{heat}$
- A. Decrease the concentration of  $\text{O}_2(\text{g})$ .      C. Increase the temperature of the system.  
B. Increase the pressure on the system.      D. Introduce a catalyst.
- \_\_\_\_\_ 20. When a catalyst is used in a chemical reaction that reaches equilibrium, what does it change?
- A. the amount of products obtained at equilibrium  
B. the concentration of the products at equilibrium  
C. the equilibrium constant at a given temperature  
D. the rate of attaining equilibrium
- \_\_\_\_\_ 21. What affects the numerical value of the equilibrium constant for a reversible reaction at equilibrium?
- A. adding a catalyst      C. changing the pressure  
B. changing reactant concentrations      D. changing the temperature
- \_\_\_\_\_ 22. What is the numerical value of the equilibrium constant for the system:
- $$2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}_2(\text{g})$$
- if the equilibrium concentrations are  $[\text{CO}] = 2.0$ ,  $[\text{O}_2] = 1.0$ , and  $[\text{CO}_2] = 16$ ?
- A. 8.0      B. 32      C. 64      D. 128
- \_\_\_\_\_ 23. For the system described by the potential energy diagram on the right, which statement is correct?
- 
- A. A and B are less stable than C and D.  
B. Activation energy for the forward reaction is greater than for the reverse reaction.  
C. The effect of a temperature change is greater for the forward reaction than for the reverse reaction.  
D. The forward reaction is endothermic.
- \_\_\_\_\_ 24. What is the main reason for the increase in reaction rate with increasing temperature?
- A. Activation energy increases rapidly with temperature.  
B. Heat acts as a catalyst.  
C. The fraction of high energy molecules increases exponentially.  
D. There is a dramatic increase in the number of collisions.
- \_\_\_\_\_ 26. What is usually true concerning the activation energy of a reaction?
- A. It is decreased by the addition of a catalyst.  
B. It is decreased by increasing the temperature of the system.  
C. It is equal to the  $\Delta H$  of the reaction.  
D. It is equal to the sum of the energies of the reactants and products.
- \_\_\_\_\_ 27. In which reaction does a decrease in the volume of the reaction vessel at constant temperature favour formation of the products?
- A.  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{O}(\text{g})$       C.  $\text{NO}_2(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{NO}(\text{g}) + \text{CO}_2(\text{g})$   
B.  $\text{MgCO}_3(\text{s}) \rightleftharpoons \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$       D.  $2\text{O}_3(\text{g}) \rightleftharpoons 3\text{O}_2(\text{g})$
- \_\_\_\_\_ 28. Which of the following equilibria would be affected by pressure changes at constant temperature?
- $\text{FeO}(\text{s}) + \text{CO}(\text{g}) \rightleftharpoons \text{Fe}(\text{s}) + \text{CO}_2(\text{g})$
  - $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
  - $2\text{Mg}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{MgO}(\text{s}) + \text{C}(\text{s})$
- A. 1 and 2 only      B. 1 and 3 only      C. 2 and 3 only      D. 1, 2, and 3

29. Consider the reaction:  $S_2Cl_2(l) + CCl_4(l) \rightleftharpoons CS_2(g) + 3Cl_2(g)$   $\Delta H = 84.3 \text{ kJ}$   
 If the reactants and products are at equilibrium in a closed vessel, how can the number of moles of  $CS_2$  be decreased?  
 A. adding some  $S_2Cl_2$  to the system  
 B. decreasing the size of the reaction vessel  
 C. increasing the temperature of the reaction system  
 D. removing some  $Cl_2$  from the system
30. For the equilibrium,  $2NO(g) + 2CO(g) \rightleftharpoons N_2(g) + 2CO_2(g) + \text{heat}$ ,  
 what conditions favour maximum conversion of the reactants to products?  
 A. high temperature and high pressure  
 B. high temperature and low pressure  
 C. low temperature and high pressure  
 D. low temperature and low pressure
31. In a chemical reaction at constant temperature, what does the addition of a catalyst do?  
 A. affects the equilibrium constant  
 B. decreases the energy released in the chemical reaction  
 C. increases the concentration of the products at equilibrium  
 D. provides an alternate reaction pathway with a different activation energy
32. The equilibrium constant at 1300 K for the reaction  $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$  is  $1.6 \times 10^5$ . What is the value of K for the reverse reaction?  
 A.  $-1.6 \times 10^5$   
 B.  $6.3 \times 10^{-6}$   
 C.  $1.6 \times 10^{-5}$   
 D.  $6.3 \times 10^{-5}$
33. Analysis of a sample of HCl gas showed that when equilibrium was reached at a certain temperature, one half of the HCl molecules had dissociated into  $H_2$  and  $Cl_2$  molecules:  
 $2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$   
 What is numerical value of the equilibrium constant at this temperature?  
 A. 0.25  
 B. 0.50  
 C. 1.0  
 D. 2.0
34. What activation energy is required for the forward reaction shown on the diagram to the right?  
 A. 40 kJ/mol  
 B. 60 kJ/mol  
 C. 100 kJ/mol  
 D. 120 kJ/mol
35. Why does increasing the concentrations of the reactants in a chemical reaction increase the rate of the reaction?  
 A. The activation energy of the reaction decreases.  
 B. The average kinetic energy of the reactants increases.  
 C. The collisions become more effective.  
 D. The frequency of collisions increases.
36. How does a catalyst speed up a chemical reaction?  
 A. decreases the heat of reaction  
 B. increases the heat of reaction  
 C. lowers the activation energy  
 D. raises the activation energy
37. A student prepares a sodium chloride solution by placing 100 g of solid sodium chloride in a flask, adding 200 mL of distilled water, placing a stopper in the flask and then shaking the flask vigorously. Which is an observable property that indicates the system is at equilibrium?  
 A. The amount of undissolved sodium chloride gradually decreases.  
 B. The amount of undissolved sodium chloride remains constant.  
 C. The rate of dissolving equals the rate of crystallizing.  
 D. The rate of precipitation equals the rate of crystallizing.
38. "If a system is subjected to stress, the system acts to relieve the effects of the stress" Who proposed this idea?  
 A. Arrhenius  
 B. Brønsted and Lowry  
 C. Le Châtelier  
 D. Lewis
39. Which change will increase the equilibrium concentration of  $SO_3$ ?  
 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + \text{heat}$   
 A. Decrease the concentration of  $O_2(g)$ .  
 B. Increase the pressure on the system.  
 C. Increase the temperature of the system.  
 D. Introduce a catalyst.
40. What is the result of increasing the concentration of  $CH_3COOH$  in this equilibrium system?  
 $CH_3COOC_2H_5(aq) + H_2O(l) \rightleftharpoons C_2H_5OH(aq) + CH_3COOH(aq)$   
 A. a change in the equilibrium constant  
 B. a decreased concentration of  $CH_3COOC_2H_5$   
 C. a decreased concentration of  $H_2O$   
 D. a decreased concentration of  $C_2H_5OH$
41. Which expression represents the equilibrium constant for this equation?  
 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$   
 A.  $\frac{[NO][O_2]}{[NO_2]}$   
 B.  $\frac{[NO]^2 + [O_2]}{[NO_2]^2}$   
 C.  $\frac{[NO_2]}{[NO][O_2]}$   
 D.  $\frac{[NO_2]^2}{[NO]^2[O_2]}$



- \_\_\_\_\_ 42. A mixture of gases is placed in a one litre container, and the gases react according to the equation:  

$$4A(g) + 3B(g) \rightleftharpoons 2C(g)$$
 At equilibrium, 2.0 mol of A, 3.0 mol of B, and 4.0 mol of C are present in the container. What is the value of the equilibrium constant?  
 A. 0.037                      B. 0.37                      C. 0.67                      D. 0.80
- \_\_\_\_\_ 43. At a certain temperature, the equilibrium constant of this reaction equals 8.81:  

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$
 If the concentration of  $NO_2$  is 0.200 mol/L, what is the concentration of  $N_2O_4$ ?  
 A.  $1.76 \times 10^{-1}$  mol/L    B.  $2.27 \times 10^{-2}$  mol/L    C.  $3.52 \times 10^{-1}$  mol/L    D.  $4.53 \times 10^{-3}$  mol/L
- \_\_\_\_\_ 44. For the reaction,  $2NO_2(g) \rightleftharpoons N_2O_4(g)$ , which value of the equilibrium constant indicates the greatest conversion to products?  
 A.  $1.5 \times 10^{-1}$               B.  $1.8 \times 10^{-2}$               C.  $4.1 \times 10^{-1}$               D.  $8.7 \times 10^{-1}$
- \_\_\_\_\_ 45. What happens as the temperature of a gas increases?  
 A. Every gas molecule now moves faster than any molecule did before.  
 B. None of the gas molecules experiences a change in velocity.  
 C. The average molecular velocity increases.  
 D. When gas molecules collide, they lose energy.
- \_\_\_\_\_ 46. If the activation energy for an exothermic reaction is 50 kJ/mol, what is the activation energy for the reverse reaction?  
 A. < 50 kJ/mol              B. 50 kJ/mol                      C. > 50 kJ/mol                      D. 100 kJ/mol
- \_\_\_\_\_ 47. Which conditions will cause a reaction to occur at the fastest rate?  
 A. high concentration of reactants and high temperature  
 B. high concentration of reactants and low temperature  
 C. low concentration of reactants and high temperature  
 D. low concentration of reactants and low temperature
- \_\_\_\_\_ 48. What is true about a chemical system at equilibrium?  
 A. complete conversion of reactants into products    C. equal quantities of reactants and products  
 B. constant quantities of reactants and products    D. only reactants present
- \_\_\_\_\_ 49. Which system would most likely be at equilibrium?  
 A. beaker of alcohol sitting on a counter at room temperature  
 B. kettle of water boiling at a constant rate  
 C. natural gas burning in a home furnace  
 D. unopened can of soda pop sitting on a grocery shelf
- \_\_\_\_\_ 50. Ammonia reacts with aqueous silver ions to form a complex ion.  

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \quad K = 1.7 \times 10^7 \text{ at } 25^\circ C$$
 What will be the final result of adding more ammonia to this system without changing the temperature?  
 A. The concentration of  $Ag^+(aq)$  will increase.  
 B. The concentration of  $Ag(NH_3)_2^+(aq)$  will decrease.  
 C. The concentration of  $NH_3(aq)$  will decrease.  
 D. The equilibrium constant will remain the same.
- \_\_\_\_\_ 51. Which would increase the equilibrium concentration of  $Cl_2O(g)$ ?  

$$2Cl_2(g) + O_2(g) \rightleftharpoons 2Cl_2O(g) \quad \Delta H = +103 \text{ kJ}$$
 A. adding a suitable catalyst                      C. decreasing the temperature  
 B. decreasing the concentration of  $Cl_2(g)$                       D. increasing the concentration of  $O_2(g)$
- \_\_\_\_\_ 52. What is the equilibrium constant expression for this equation?  

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g)$$
 A.  $\frac{[CO][C]}{[CO_2]}$                       B.  $\frac{[CO]^2}{[CO_2][C]}$                       C.  $\frac{[CO]}{[CO_2]}$                       D.  $\frac{[CO]^2}{[CO_2]}$
- \_\_\_\_\_ 53. At equilibrium in this gaseous system  $2A + B \rightleftharpoons 2C + D$   
 $[A] = 2.00$ ,  $[B] = 1.20$ ,  $[C] = 3.00$ , and  $[D] = 0.600$ . What is the numerical value of the equilibrium constant?  
 A. 4.32                      B. 1.33                      C. 1.13                      D. 0.889
- \_\_\_\_\_ 54. At a certain temperature, the equilibrium constant of this reaction equals 0.018:  

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$
 If the concentration of HI is  $1.6 \times 10^{-2}$  mol/L and the concentration of  $H_2$  is  $2.9 \times 10^{-3}$  mol/L, what is the concentration of  $I_2$ ?  
 A.  $1.6 \times 10^{-3}$  mol/L    B.  $1.8 \times 10^{-2}$  mol/L    C.  $9.9 \times 10^{-2}$  mol/L    D.  $1.0 \times 10^1$  mol/L
- \_\_\_\_\_ 55. For the reaction,  $2NO_2(g) \rightleftharpoons N_2O_4(g)$ , which value of the equilibrium constant indicates the largest concentration of  $N_2O_4$ ?  
 A. 0.87                      B. 0.41                      C. 0.15                      D. 0.018