

## Kinetics and Equilibrium

- \_\_\_ 1. In a chemical reaction the use of a catalyst results in a decrease in the (1) activation energy; (2) potential energy of the reactants; (3) heat of reaction; (4) amount of products.
- \_\_\_ 2. Given the reaction:  $\text{CO}_2(\text{s}) \rightleftharpoons \text{CO}_2(\text{g})$ . As the  $\text{CO}_2(\text{s})$  changes to  $\text{CO}_2(\text{g})$  the entropy of the system (1) decreases; (2) increases; (3) remains the same..
- \_\_\_ 3. Given the reaction at equilibrium:  $\text{X}(\text{g}) + \text{Y}(\text{g}) \rightleftharpoons 2\text{Z}(\text{g})$ . As the pressure on the system increases, the temperature remaining constant, the amount of  $\text{Z}(\text{g})$  (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 4. Given the reaction:  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) + 12.4\text{kcal} \rightleftharpoons 2\text{HI}(\text{g})$ . The equilibrium will shift to the right if there is an increase in (1) temperature; (2) pressure; (3) concentration of  $\text{HI}(\text{g})$ ; (4) volume of the reaction container.
- \_\_\_ 5. In a chemical reaction the difference between the potential energy of the products and the potential energy of the reactants is called (1) activation energy; (2) kinetic energy; (3) activated complex; (4) heat of reaction.
- \_\_\_ 6. Given the reaction:  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ . If the temperature remains constant, an increase in pressure will (1) have no effect on the equilibrium; (2) shift the equilibrium to the right; (3) shift the equilibrium to the left; (4) change the value of the equilibrium.
- \_\_\_ 7. As a system becomes less random its entropy (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 8. The net effect of a catalyst is to change the (1) potential energy of the reactants; (2) potential energy of the products; (3) heat of reaction; (4) rates of both the forward and reverse reactions.
- \_\_\_ 9. Given the reversible reaction  $\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons \text{C}(\text{g})$  at equilibrium. If the concentration of A is increased at constant temperature and pressure which will also increase? (1) the rate of the forward reactions; (2) the value of the equilibrium constant; (3) the activation energy; (4) the concentration of B.
- \_\_\_ 10. For the reaction  $\text{A} + \text{B} \rightarrow \text{C} + \text{heat}$ , the potential energy of the products compared to the potential energy of the reactants is (1) less and the reaction is exothermic; (2) less and the reaction is endothermic; (3) greater and the reaction is exothermic; (4) greater and the reaction is endothermic.
- \_\_\_ 11. A gas is most soluble in a liquid under conditions of (1) high temperature and high pressure; (2) high temperature and low pressure; (3) low temperature and high pressure; (4) low temperature and low pressure.
- \_\_\_ 12. Some compounds and their solubility product constants are shown below. Which compound is least soluble? (1)  $\text{AB } K_{\text{sp}} \rightleftharpoons 8 \times 10^{-5}$ ; (2)  $\text{AC } K_{\text{sp}} \rightleftharpoons 7 \times 10^{-6}$ ; (3)  $\text{XY } K_{\text{sp}} \rightleftharpoons 6 \times 10^{-7}$ ; (4)  $\text{XZ } K_{\text{sp}} \rightleftharpoons 5 \times 10^{-8}$ .
- \_\_\_ 13. An increase in temperature increases the rate of a chemical reaction because the (1) activation energy increases; (2) activation energy decreases; (3) number of

molecular collisions increases; (4) number of molecular collisions decreases.

- \_\_\_ 14. As 1 gram of  $\text{H}_2\text{O}(\text{s})$  changes to  $\text{H}_2\text{O}(\text{l})$ , the entropy of the system (1) increases; (2) decreases; (3) remains the same.
- \_\_\_ 15. The enthalpy of a reaction may also be called the (1) free energy; (2) heat of reaction; (3) entropy; (4) additivity.
- \_\_\_ 16. The equilibrium constant value for a sample of water at 1 atmosphere and 298 °K will be most likely to change when there is an increase in the (1) concentration of  $\text{H}^+$  ions; (2) concentration of  $\text{OH}^-$  ions; (3) pressure; (4) temperature.
- \_\_\_ 17. Which change may occur in a reaction system when a catalyst is added? (1) The equilibrium point is reached more rapidly; (2) The potential energy of the reactants increases; (3) The potential energy of the products decreases; (4) The heat of reaction becomes smaller.
- \_\_\_ 18. As the concentration of a reactant in a chemical reaction increases the rate of the reaction generally (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 19. Given the reaction:  $2\text{AB}(\text{g}) + \text{heat} \rightleftharpoons \text{A}_2(\text{g}) + \text{B}_2(\text{g})$ . The equilibrium of the above reaction at equilibrium will shift to the right when the (1) temperature increases; (2) temperature decreases; (3) pressure increases; (4) pressure decreases.
- \_\_\_ 20. Heat of reaction,  $\Delta H$ , is equal to (1)  $H(\text{products}) + H(\text{reactants})$ ; (2)  $H(\text{products}) - H(\text{reactants})$ ; (3)  $H(\text{products}) \times H(\text{reactants})$ ; (4)  $H(\text{products}) / H(\text{reactants})$ .
- \_\_\_ 21. Given the reaction:  $\text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + 57.8 \text{ kcal}$ . If the activation energy for the forward reaction is 40.0 kilocalories per mole, the activation energy for the reverse reaction, in kilocalories per mole, will be (1) 17.8; (2) 30.0; (3) 60.0; (4) 97.8.
- \_\_\_ 22. Which saturated solution would have the highest sulfide ion concentration at 18 degrees Celsius? (1)  $\text{CdS} (\text{Ksp}) \rightleftharpoons 3.6 \times 10^{-29}$ ; (2)  $\text{CoS} (\text{Ksp}) \rightleftharpoons 3.0 \times 10^{-26}$ ; (3)  $\text{PbS} (\text{Ksp}) \rightleftharpoons 3.4 \times 10^{-29}$ ; (4)  $\text{FeS} (\text{Ksp}) \rightleftharpoons 3.7 \times 10^{-19}$ .
- \_\_\_ 23. When a catalyst is added to a reaction at equilibrium the rate of the forward reaction (1) decreases and the rate of the reverse reaction decreases; (2) decreases and the rate of the reverse reaction increases; (3) increases and the rate of the reverse reaction decreases; (4) increases and the rate of the reverse reaction increases.
- \_\_\_ 24. Equilibrium is reached in all reversible chemical reactions when the (1) forward reaction stops; (2) reverse reaction stops; (3) concentrations of the reactants and the products become equal; (4) rates of the opposing reactions become equal.
- \_\_\_ 25. Given the reaction  $\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons \text{AB}(\text{g})$ . As the pressure increases at a constant temperature the rate of the forward reaction will (1) decrease; (2) increase; (3) remain the same.
- \_\_\_ 26. Given the equilibrium reaction:  $\text{A} + \text{B} \rightleftharpoons \text{C} + \text{D} + \text{heat}$ . What change in the reaction system will change the value of the equilibrium constant? (1) an increase in the concentration of A and B; (2) an increase in the concentration of C and D; (3) an increase in temperature; (4) an increase in pressure.

- \_\_\_ 27. Which phrase best describes the following reaction:  $C(s) + 1/2O_2(g) \rightarrow CO(g) + 26.4 \text{ kcal}$ ? (1) exothermic with an increase in entropy; (2) exothermic with a decrease in entropy; (3) endothermic with an increase in entropy; (4) endothermic with a decrease in entropy.
- \_\_\_ 28. A chemical reaction is most likely to occur spontaneously if the (1) free energy change ( $\Delta G$ ) is negative; (2) entropy change ( $\Delta S$ ) is negative; (3) activation energy ( $E_a$ ) is positive; (4) heat of reaction ( $\Delta H$ ) is positive.
- \_\_\_ 29. A change in which factor is most likely to change the value of an equilibrium constant? (1) pressure; (2) catalyst; (3) concentration; (4) temperature.
- \_\_\_ 30. In which reaction would an increase in pressure produce an increase in the amount of product if temperature remains a constant? (1)  $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ ; (2)  $2HgO(s) \rightleftharpoons 2Hg(l) + O_2(g)$ ; (3)  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ ; (4)  $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ .
- \_\_\_ 31. As a lump of sugar dissolves in a beaker of water the entropy of the sugar and water system (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 32. The energy stored in chemical bonds is mostly (1) kinetic; (2) heat; (3) potential; (4) electrical.
- \_\_\_ 33. In a system at equilibrium the free energy change is (1) always zero; (2) always a positive value; (3) always a negative value; (4) either a positive or negative value.
- \_\_\_ 34. Endothermic reactions can occur spontaneously when the entropy of the system (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 35. Given the process:  $N_2 + 2O_2 + 16.2 \text{ kcal} \rightleftharpoons 2NO_2$  As nitrogen reacts with oxygen in the equation, the heat of formation for nitrogen dioxide is (1) -8.1 Kcal/mole; (2) -16.2 kcal/mole; (3) +8.1 kcal/mole; (4) +16.2 kcal/mole.
- \_\_\_ 36. The activation energy of a system may be lowered by (1) increasing the concentration of the reactants; (2) increasing the pressure; (3) decreasing the pressure; (4) adding a catalyst.
- \_\_\_ 37. A chemical reaction must be spontaneous if it results in an energy (1) gain and an entropy increase; (2) gain and an entropy decrease; (3) loss and an entropy increase; (4) loss and an entropy decrease.
- \_\_\_ 38. As the temperature of ethyl alcohol decreases its vapor pressure (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 39. As the rate of a given reaction increases due to an increase in the concentration of the reactants the activation energy for that reaction (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 40.  $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ . Consider this reaction at equilibrium. As chloride ions are added to this system and the temperature is kept constant, the value of the equilibrium constant (1) decreases; (2) increases; (3) remains the same.

- \_\_\_ 41. A catalyst can increase the rate of a chemical reaction by (1) increasing the value of the equilibrium constant; (2) increasing the energy of the products; (3) decreasing the energy of the products; (4) decreasing the required activation energy.
- \_\_\_ 42. For a chemical system at equilibrium a rise in temperature will (1) favor the endothermic reaction; (2) favor the exothermic reaction; (3) decrease the rates of the reactions; (4) have no effect upon the equilibrium.
- \_\_\_ 43. The equilibrium constant for a given system changes when (1) the temperature of the system is changed; (2) the pressure of the system is changed; (3) the concentration of one or more of the reactants is changed; (4) a catalyst is added.
- \_\_\_ 44. An increase in the rate of all chemical reactions results from (1) an increase in pressure; (2) a decrease in pressure; (3) an increase in temperature; (4) a decrease in temperature.
- \_\_\_ 45. When solid ammonium chloride is dissolved in a beaker of water the temperature of the mixture decreases. The reaction occurring in the beaker is (1) exothermic and spontaneous; (2) exothermic and not spontaneous; (3) endothermic and spontaneous; (4) endothermic and not spontaneous.
- \_\_\_ 46. As the activation energy of a reaction decreases because of the addition of a catalyst the heat of reaction (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 47. As iodine molecules change from the solid phase to the vapor phase the entropy of the system (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 48. A 1 gram sample of a substance has the greatest entropy when it is in the (1) solid state; (2) liquid state; (3) crystalline state; (4) gaseous state.
- \_\_\_ 49. When a piece of magnesium is placed in a sample of hydrochloric acid 0.048 grams of magnesium reacts in 20 seconds. The average rate of the reaction is (1) .001 mole/sec; (2) .0001 mole/sec; (3) .01 mole/sec; (4) 1.0 mole/sec.
- \_\_\_ 50. In a reversible reaction the difference between the activation energy of the forward reaction and the activation energy of the reverse reaction is equal to the (1) activation complex; (2) heat of reaction; (3) potential energy of reactants; (4) potential energy of products.
- \_\_\_ 51. If the concentration of one of the reactants in a chemical reaction is increased the rate of the reaction usually (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 52. As a catalyst is added to a system at equilibrium the value of the equilibrium constant (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 53. As a result of dissolving a salt in water a student found that the temperature of the water increased. From this observation alone the student should conclude that the dissolving of the salt (1) produced an acid solution; (2) produced a basic solution; (3) was endothermic; (4) was exothermic.
- \_\_\_ 54. If the pressure on a gaseous system is increased the rate of reaction increases because (1) the activation energy is increased; (2) the temperature is decreased; (3) the concentration is increased; (4) the volume is increased.

- \_\_\_ 55. A chemical reaction in which the product appears quickly has a (1) slow reaction rate; (2) rate determining step with a low threshold energy; (3) high activation energy; (4) complex reaction.
- \_\_\_ 56. In order for reactions to occur (1) the reactants must be gases; (2) chemical bonds must break; (3) the temperature must be high; (4) collisions must occur between molecules.
- \_\_\_ 57. The rate of a reaction may be increased by (1) an increase in concentration; (2) a catalyst; (3) an increase in temperature; (4) all of the above..
- \_\_\_ 58. Which of the following chemicals would not be included in an equilibrium expression? (1) water(l); (2) NaCl(aq); (3) water (g); (4) oxygen(g).
- \_\_\_ 59. A decrease in the rate of reaction in a gaseous system may be caused by an increase in (1) temperature; (2) concentrations; (3) pressure; (4) volume.
- \_\_\_ 60. Given the process:  $A(s) + B(s) \rightleftharpoons C(g) + D(g) + \text{heat}$ . The entropy of the system (1) increases and the reaction is exothermic; (2) increases and the reaction is endothermic; (3) decreases and the reaction is exothermic; (4) decreases and the reaction is endothermic.
- \_\_\_ 61. Given the reaction:  $A + B \rightleftharpoons AB + 30 \text{ kcal}$ . If an activation energy of 10 kcal is required, the activation of the reverse reaction is (1) 5 kcal; (2) 40 kcal; (3) 20 kcal; (4) 30 kcal.
- \_\_\_ 62. When two atoms form a bond their potential energy (1) decreases; (2) increases; (3) remains the same; (4) varies.
- \_\_\_ 63. The value of the equilibrium constant for a reaction will change when (1) a catalyst is added; (2) the pressure is changed; (3) the concentrations of the reactants are changed; (4) the temperature is changed.
- \_\_\_ 64. Given the reaction:  $N_2(g) + O_2(g) \rightleftharpoons 2NO(g) + 43.2 \text{ kcal}$ . In the above reaction as the pressure is increased the number of moles of NO produced will (1) decrease; (2) increase; (3) remain the same; (4) vary randomly.
- \_\_\_ 65. When a catalyst is added to a system in equilibrium the equilibrium concentration of the reactants (1) decreases; (2) increases; (3) remains the same; (4) varies up and down.
- \_\_\_ 66. As carbon dioxide molecules in the solid phase change into the gaseous phase the entropy (1) decreases; (2) increases; (3) remains the same; (4) varies.
- \_\_\_ 67. Which change is accompanied by a decrease in entropy? (1)  $H_2O(l) \rightleftharpoons H_2O(s)$ ; (2)  $H_2O(s) \rightleftharpoons H_2O(g)$ ; (3)  $H_2O(l) \rightleftharpoons H_2O(g)$ ; (4)  $H_2O(s) \rightleftharpoons H_2O(l)$ .
- \_\_\_ 68. For the reaction  $A(g) + B(g) \rightleftharpoons AB(g)$ , 1.0 mole of A and 1.0 mole of B are placed in a 1.0 liter container. At equilibrium the concentration of AB is 0.20 Molar. What is the K for this reaction at constant temperature? (1) 0.64; (2) 0.25; (3) 0.20; (4) 0.31.
- \_\_\_ 69. A chemical reaction must be spontaneous if it results in an energy (1) gain and an

entropy increase; (2) gain and an entropy decrease; (3) loss and an entropy increase; (4) loss and an entropy decrease.

- \_\_\_ 70. Given the reaction:  $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ . When calcium carbonate decomposes according to the above equation the entropy of the system (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 71. As sodium hydroxide is added to a solution of sulfuric acid the hydrogen ion concentration of the solution (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 72. Given  $\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons \text{AB}(\text{g}) + \text{heat}$  with an equilibrium constant (K) at 25 degrees Celsius of 0.50. If a catalyst is added to the above system at equilibrium with temperature and pressure remaining constant the concentration of A would (1) decrease; (2) increase; (3) remain the same.
- \_\_\_ 73. Given  $\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons \text{AB}(\text{g}) + \text{heat}$  with an equilibrium constant (K) at 25 degrees Celsius of 0.50. When chemical equilibrium is reached in the above system, the concentration of AB, compared to the concentration of A times the concentration of B, is (1) less; (2) greater; (3) the same.
- \_\_\_ 74. Given  $\text{A}(\text{g}) + \text{B}(\text{g}) \rightleftharpoons \text{AB}(\text{g}) + \text{heat}$  with an equilibrium constant (K) at 25 degrees Celsius of 0.50. As the concentration of B is increased at constant temperature in the above system the value of K will (1) decrease; (2) increase; (3) remain the same.
- \_\_\_ 75. Carbon dioxide is most soluble in water under conditions of (1) high pressure and high temperature; (2) high pressure and low temperature; (3) low pressure and low temperature; (4) low pressure and high temperature.
- \_\_\_ 76. Given the reaction  $\text{A} + \text{B} \rightleftharpoons \text{AB} + 50 \text{ kcal}$ . If an activation energy of 5 kcal. is required the activation energy of the reverse reaction is (1) 5 kcal.; (2) 45 kcal.; (3) 50 kcal.; (4) 55 kcal..
- \_\_\_ 77. When solid KI dissolves in water, heat is absorbed. This process may be described as (1) exothermic, resulting in an entropy increase; (2) exothermic, resulting in an entropy decrease; (3) endothermic, resulting in an entropy increase; (4) endothermic, resulting in an entropy decrease.
- \_\_\_ 78. The effect of an increase in temperature on the rates of chemical reactions is to increase the rate of (1) endothermic reactions only; (2) exothermic reactions only; (3) both endothermic and exothermic reactions; (4) neither endothermic nor exothermic reactions.
- \_\_\_ 79. A sample of water and a sample of ethanol are both boiling in open containers at standard pressure. The two liquids have (1) the same vapor pressure and the same temperature; (2) the same vapor pressure but different temperatures; (3) different vapor pressures but the same temperature; (4) different vapor pressures and different temperatures.
- \_\_\_ 80. If a reaction has a positive heat of reaction and a negative entropy the reaction will (1) occur only at high temperatures; (2) occur only at low temperatures; (3) occur at all temperatures; (4) never occur..
- \_\_\_ 81. If a reaction has a negative heat of reaction and a negative entropy the reaction will

(1) occur at high temperatures; (2) occur at low temperatures; (3) occur at all temperatures; (4) never occur..

- \_\_\_ 82. Given the reaction  $A(g) + B(g) \rightleftharpoons AB(g)$  at a constant temperature. If the equilibrium constant (K)  $\rightleftharpoons 10$  then (1) products are favored; (2) reactants are favored; (3) the reaction is at equilibrium; (4) the reaction is impossible.
- \_\_\_ 83. Which saturated salt solution is more concentrated? (1)  $AgC_2H_3O_2(aq)$ ; (2)  $Ag_2CO_3(aq)$ ; (3)  $Ag_2S(aq)$ ; (4)  $AgCl(aq)$ .
- \_\_\_ 84. Which change takes place when a catalyst is added to a reaction of equilibrium? (1) The point of equilibrium is shifted to the right; (2) The point of equilibrium is shifted to the left; (3) The rates of the forward and reverse reactions are increased; (4) The rates of the forward and reverse reaction increase equally.
- \_\_\_ 85. As the number of effective collisions between reacting particles increases the rate of the reaction (1) decreases; (2) The point of equilibrium is shifted to the left.; (3) remains the same.
- \_\_\_ 86. Given the reaction at equilibrium;  $A(g) + B(g) \rightleftharpoons C(g) + D(g) + \text{heat}$  As additional A(g) is added to the system at constant temperature the concentration of B(g) (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 87. Which compound forms spontaneously from its elements? (1) ethyne; (2) ammonia; (3) hydrogen iodide; (4) nitrogen (IV) oxide.
- \_\_\_ 88. A nonreversible chemical reaction is exothermic and occurs with an increase in entropy. The DG for this reaction (1) must be negative; (2) must be positive; (3) could be negative or positive; (4) could be zero.
- \_\_\_ 89. As a solid is dissolving in water the temperature of the water increases. The dissolving of this solid is (1) exothermic and spontaneous; (2) endothermic and spontaneous; (3) exothermic and not spontaneous; (4) endothermic and not spontaneous.
- \_\_\_ 90. Which of the following compounds is least soluble at 298 °K? (1)  $PbCl_2$ ; (2)  $PbI_2$ ; (3)  $AgCl$ ; (4)  $AgI$ .
- \_\_\_ 91. Given the reaction at equilibrium;  $AgCl(s) \rightleftharpoons Ag^{1+}(aq) + Cl^{1-}(aq)$  The addition of chloride ions will shift the equilibrium to the (1) right, decreasing the solubility of  $AgCl(s)$ ; (2) right, increasing the solubility of  $AgCl(s)$ ; (3) left, decreasing the solubility of  $AgCl(s)$ ; (4) left, increasing the solubility of  $AgCl(s)$ .
- \_\_\_ 92. A solution in which an equilibrium exists between dissolved and undissolved solute must be (1) saturated; (2) unsaturated; (3) dilute; (4) concentrated.
- \_\_\_ 93. Given the equilibrium;  $A + B \rightleftharpoons C$  The greatest concentration of C would be produced if the equilibrium constant of the reaction is equal to (1)  $1 \times 10^3$ ; (2)  $1 \times 10^9$ ; (3)  $1 \times 10^{-3}$ ; (4)  $1 \times 10^{-9}$ .
- \_\_\_ 94. In a chemical reaction, the products have a lower potential energy than the reactants. This reaction must have a negative (1) DG; (2) DS; (3) DH; (4) DX.
- \_\_\_ 95. The heat of formation of  $H_2O(g)$  is (1)  $-57.8 \text{ kcal/mole}$ ; (2)  $+68.3 \text{ kcal/mole}$ ;

(3) -54.6 kcal/mole; (4) +56.7 kcal/mole.

- \_\_\_ 96. As the surface area of the Zn(s) used in the reaction  $\text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$  is increased the rate of the reaction will (1) decrease; (2) increase; (3) remain the same.
- \_\_\_ 97. Given the equilibrium reaction:  $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)} + \text{heat}$ . When the pressure on the system is increased, the concentration of the  $\text{SO}_3$  will (1) decrease; (2) increase; (3) remain the same.
- \_\_\_ 98. Which substance will form spontaneously from its elements in their standard states at 1 atmosphere and 298 °K? (1) ethene; (2) ethyne; (3) hydrogen iodide; (4) hydrogen fluoride.
- \_\_\_ 99. Which of the following compounds would most likely have the smallest  $K_{sp}$ ? (1) barium carbonate; (2) calcium sulfate; (3) magnesium nitrate; (4) silver acetate.
- \_\_\_ 100. Which substance, if added to a saturated solution of ammonia (ammonium hydroxide) would cause the pH of the solution to increase? (1) HCl; (2)  $\text{NH}_4\text{Cl}$ ; (3) LiOH; (4)  $\text{CH}_3\text{OH}$ .
- \_\_\_ 101. Given the reaction at equilibrium and 298 K:  $\text{CH}_3\text{COOH(aq)} \rightleftharpoons \text{H}^+\text{(aq)} + \text{CH}_3\text{COO}^-\text{(aq)}$ . The equilibrium constant,  $K_a$ , for the reaction will change if there is an increase in the (1) pressure; (2) temperature; (3) concentration of  $\text{H}^+\text{(aq)}$  ions; (4) concentration of  $\text{CH}_3\text{COO}^-\text{(aq)}$  ions.
- \_\_\_ 102. As products are formed in the reaction:  $\text{NH}_4\text{Cl(s)} + 3.5 \text{ Kcal} \rightarrow \text{NH}_4^+\text{(aq)} + \text{Cl}^-\text{(aq)}$ . The entropy of the system (1) decreases and the heat is absorbed; (2) decreases and the heat is released; (3) increases and heat is absorbed; (4) increases and heat is released.
- \_\_\_ 103. Given the reaction at equilibrium;  $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)} + \text{heat}$  Which change would shift the equilibrium to the right? (1) increase the temperature; (2) increase the pressure; (3) decrease the  $[\text{N}_2]$ ; (4) decrease the  $[\text{H}_2]$ .
- \_\_\_ 104. The effect of a catalyst on a chemical reaction is to change the (1) activation energy; (2) heat of reaction; (3) potential energy of the products; (4) potential energy of the reactants.
- \_\_\_ 105. The greatest amount of energy would be given up by the complete oxidation of 1 mole of (1)  $\text{CH}_4\text{(g)}$ ; (2)  $\text{C}_3\text{H}_8\text{(g)}$ ; (3)  $\text{CH}_3\text{OH(l)}$ ; (4)  $\text{C}_6\text{H}_{12}\text{O}_6\text{(s)}$ .
- \_\_\_ 106. Consider the reaction:  $\text{H}_2\text{O(l)} + \text{energy} \rightarrow \text{H}_2\text{(g)} + 1/2 \text{O}_2\text{(g)}$ . Which phrase best describes this reaction? (1) exothermic, releasing energy; (2) exothermic, absorbing energy; (3) endothermic, releasing energy; (4) endothermic, absorbing energy.
- \_\_\_ 107. In a gaseous system, temperature remaining constant, an increase in pressure will (1) increase the activation energy; (2) decrease the activation energy; (3) increase the reaction rate; (4) decrease the reaction rate.
- \_\_\_ 108. Given the equilibrium;  $\text{AgCl(s)} \rightleftharpoons \text{Ag}^+\text{(aq)} + \text{Cl}^-\text{(aq)}$  The equilibrium constant will change if there is an increase in the (1) concentration of  $\text{Ag}^+\text{(aq)}$  ions; (2) concentration of  $\text{Cl}^-\text{(aq)}$  ions; (3) pressure; (4) temperature.

- \_\_\_ 109. Given the reaction at equilibrium;  $\text{BaSO}_4(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$  As the concentration of the  $\text{SO}_4^{2-}$  increases at constant temperature the concentration of  $\text{Ba}^{2+}$  ions (1) decreases; (2) increases; (3) remains the same.
- \_\_\_ 110. Why does the reaction  $2\text{K}(\text{s}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{KCl}(\text{s})$  occur spontaneously? (1) DS is positive; (2) DS is negative; (3) DG is positive; (4) DG is negative.
- \_\_\_ 111. A saturated solution of which salt would be most dilute? (1) AgCl; (2)  $\text{BaSO}_4$ ; (3) ZnS; (4)  $\text{PbCrO}_4$ .
- \_\_\_ 112. For a chemical reaction, the free energy change, DG, is equal to (1)  $\text{DH} + \text{T DS}$ ; (2)  $\text{DH} - \text{T DS}$ ; (3)  $\text{T DH} + \text{DS}$ ; (4)  $\text{T DS} - \text{DH}$ .
- \_\_\_ 113. Given the reaction at equilibrium;  $\text{Mg}(\text{OH})_2(\text{s}) \rightleftharpoons \text{Mg}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq})$  What is the correct expression for the solubility product constant for this reaction? (1)  $K_{\text{sp}} \rightleftharpoons [\text{Mg}^{2+}][2\text{OH}^{-}]$ ; (2)  $K_{\text{sp}} \rightleftharpoons [\text{Mg}^{2+}] + [\text{OH}^{-}]$ ; (3)  $K_{\text{sp}} \rightleftharpoons [\text{Mg}^{2+}][\text{OH}^{-}]_2$ ; (4)  $K_{\text{sp}} \rightleftharpoons [\text{Mg}^{2+}] + [\text{OH}^{-}]_2$ .
- \_\_\_ 114. In a chemical reaction the difference in potential energy between the products and the reactants is equal to (1) DS; (2) DG; (3) DH; (4) DT.
- \_\_\_ 115. Given the system at chemical equilibrium;  $2\text{O}_3(\text{g}) \rightleftharpoons 3\text{O}_2(\text{g})$  ( $K = 2.5 \times 10^{12}$ ) The concentration of  $\text{O}_3$  and  $\text{O}_2$  must be (1) constant; (2) equal; (3) increasing; (4) decreasing.
- \_\_\_ 116. As additional solid KCl is added to a saturated solution of KCl, the conductivity of the solution (1) decreases; (2) equal; (3) remains the same.
- \_\_\_ 117. Given the reaction at equilibrium;  $\text{A}(\text{g}) + \text{B}(\text{g}) + \text{heat} \rightleftharpoons \text{AB}(\text{g})$  As the pressure increases at constant temperature the value of the equilibrium constant (1) decreases; (2) equal; (3) remains the same.
- \_\_\_ 118. As 1 gram of water changes to 1 gram of ice the entropy of the system (1) decreases; (2) equal; (3) remains the same.
- \_\_\_ 119. Which statement is true if the free energy (DG) of a reaction is zero? (1) The rate of the forward reaction is zero.; (2) The rate of the reverse reaction is zero.; (3) The reaction is approaching equilibrium.; (4) The reaction is at equilibrium..
- \_\_\_ 120. Which compound is more soluble than  $\text{BaSO}_4$  at 1 atmosphere and 298 °K? (1) AgBr; (2)  $\text{PbCl}_2$ ; (3) AgI; (4) ZnS.
- \_\_\_ 121. A chemical reaction will always occur spontaneously if the reaction has a (1) negative DG; (2) positive DG; (3) negative DH; (4) positive DH.
- \_\_\_ 122. The free energy change, DG, must be negative when (1) DH is positive and DS is positive; (2) DH is positive and DS is negative; (3) DH is negative and DS is positive; (4) DH is negative and DS is negative.
- \_\_\_ 123. The Haber process is used to produce (1) sulfur dioxide; (2) ammonia; (3) sulfuric acid; (4) sodium chloride.