1. Which phase change is exothermic?

   A) $NH_3(g) \rightarrow NH_3(l)$ B) $CO_2(s) \rightarrow CO_2(g)$
   C) $H_2O(s) \rightarrow H_2O(l)$ D) $H_2S(l) \rightarrow H_2S(g)$
   E) $HF(l) \rightarrow HF(g)$

2. When a substance dissolves in water, the temperature of the water decreases. This process is

   A) exothermic, with a release of energy
   B) endothermic, with a release of energy
   C) exothermic, with an absorption of energy
   D) endothermic, with an absorption of energy
   E) isothermic, with an increase in total energy

3. I. Heat is released with an endothermic reaction

   BECAUSE

   II. energy is released when bonds are formed.

   A) I is *TRUE*, II is *FALSE*
   B) I is *FALSE*, II is *TRUE*
   C) I and II are *BOTH FALSE*
   D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
   E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

4. I. An exothermic reaction always has a negative ΔG

   BECAUSE

   II. heat is released when the reaction occurs.

   A) I is *TRUE*, II is *FALSE*
   B) I is *FALSE*, II is *TRUE*
   C) I and II are *BOTH FALSE*
   D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
   E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

5. I. An endothermic reaction always has a positive ΔG

   BECAUSE

   II. heat is released when the reaction occurs.

   A) I is *TRUE*, II is *FALSE*
   B) I is *FALSE*, II is *TRUE*
   C) I and II are *BOTH FALSE*
   D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
   E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

6. I. A positive ΔS represents a decrease in potential energy

   BECAUSE

   II. ΔS represents the difference in the entropy of the products and the reactants.

   A) I is *TRUE*, II is *FALSE*
   B) I is *FALSE*, II is *TRUE*
   C) I and II are *BOTH FALSE*
   D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
   E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

7. I. A positive ΔS tells you that the reaction must be spontaneous

   BECAUSE

   II. entropy always increases when a reaction occurs.

   A) I is *TRUE*, II is *FALSE*
   B) I is *FALSE*, II is *TRUE*
   C) I and II are *BOTH FALSE*
   D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
   E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

8. I. A positive ΔH tells you that the reaction is exothermic

BECAUSE

II. with a positive ΔH, the products have more energy than the reactants.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

9. I. The activation energy of an exothermic reaction is always less than that of the reverse reaction

BECAUSE

II. the products have more energy than the reactants.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

10. I. When propane is burned in air, energy is absorbed

BECAUSE

II. the reaction is exothermic.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

11. Which will increase the concentration of gaseous carbon dioxide in the phase equilibrium reaction?

$$CO_2(s) \leftrightarrow CO_2(g)$$

A) Add dry ice, $CO_2(s)$
B) Increase the volume
C) Increase the pressure
D) Add an inert gas
E) Decrease the temperature

12. When a catalyst is added to a reaction at equilibrium, which of the following does not occur?

A) the activated complex of the reaction becomes more energetically favorable
B) the enthalpy of the reaction remains the same
C) the rate of the forward reaction increases
D) the rate of the reverse reaction increases
E) the equilibrium shifts to the side with greater entropy

13. Base your answer to the following question on the equation and the choices provided.

$$CN^-(aq) + H_2O(l) \leftrightarrow HCN(aq) + OH^-(aq)$$

(A) increases
(B) decreases
(C) remains the same
(D) increases, then decreases
(E) decreases, then increases

If a catalyst is added, the $[OH^-]$

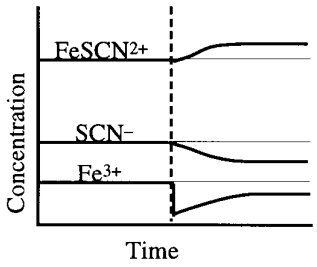
A) A B) B C) C D) D E) E

14. Base your answer to the following question on Given the system at equilibrium:

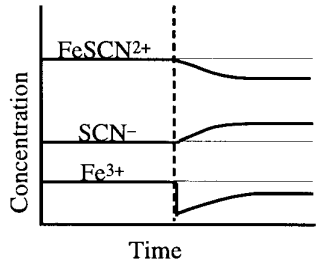
$$Fe^{3+}(aq) + SCN^{-}(aq) \leftrightarrow FeSCN^{2+}(aq)$$

What happens to the concentrations of the three ions when some Fe^{3+} ion is removed by precipitation from this aqueous solution, with the temperature remaining constant?

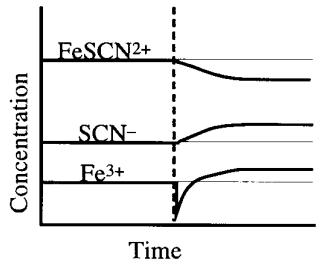
A)



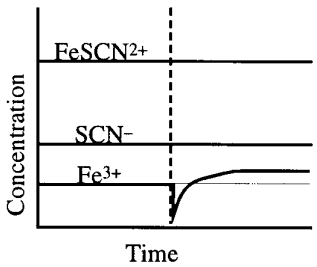
B)



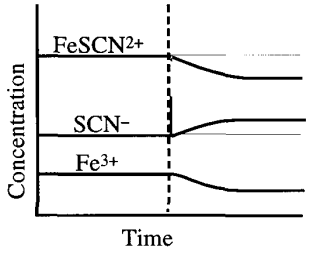
C)



D)



E)



15. Consider the system in equilibrium

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

What can be done to increase the quantity of $SO_3(g)$?

A) Introduce a catalyst
B) Increase the pressure on the system
C) Decrease the concentration of $O_2(g)$
D) Decrease the concentration of $SO_2(g)$
E) Increase the temperature of the system

Base your answers to questions **16** through **20** on the equation and the answers provided.

$$20\ HNO_3(aq) + 3\ P_4(s) + 8\ H_2O(l) + Heat \leftrightarrow 12\ H_3PO_4(aq) + 20\ NO(g)$$

(A) increases
(B) decreases
(C) remains the same
(D) increases, then decreases
(E) decreases, then increases

16. If some P_4 is added, the $[H_2O]$

A) A B) B C) C D) D E) E

17. If more HNO_3 is added, the $[H_3PO_4]$

A) A B) B C) C D) D E) E

18. If a little H_2O is added, the $[H_3PO_4]$

A) A B) B C) C D) D E) E

19. If the pressure is increased, the $[HNO_3]$

A) A B) B C) C D) D E) E

20. If temperature is decreased, the [NO]

A) A B) B C) C D) D E) E

Base your answers to questions **21** through **26** on the equation and the answers provided.

$$4\ NO(g) + 3\ O_2(g) \leftrightarrow 2\ N_2O_5(g) + Heat$$

(A) increases
(B) decreases
(C) remains the same
(D) increases, then decreases
(E) decreases, then increases

21. If some N_2O_5 is removed, the $[N_2O_5]$

A) A B) B C) C D) D E) E

22. If some NO is added, the $[O_2]$

A) A B) B C) C D) D E) E

23. If some O_2 is added, the $[O_2]$

A) A B) B C) C D) D E) E

24. If the pressure is decreased, the $[O_2]$

A) A B) B C) C D) D E) E

25. If temperature is decreased, the Keq

A) A B) B C) C D) D E) E

26. If temperature is increased, the $[N_2O_5]$

A) A B) B C) C D) D E) E

Base your answers to questions **27** through **30** on the equation and the choices provided.

$$CaCO_3(s) + Heat \leftrightarrow CaO(s) + CO_2(g)$$

(A) increases
(B) decreases
(C) remains the same
(D) increases, then decreases
(E) decreases, then increases

27. If the pressure is decreased, the $[CO_2]$

A) A B) B C) C D) D E) E

28. If the temperature is decreased, the Keq

A) A B) B C) C D) D E) E

29. If temperature is decreased, the $[CO_2]$

A) A B) B C) C D) D E) E

30. If temperature is increased, the [CaO]

A) A B) B C) C D) D E) E

31. What the equilibrium law expression for:

$$20\ HNO_3(aq) + 3\ P_4(s) + 8\ H_2O(\ell) + Heat \leftrightarrow 12\ H_3PO_4(aq) + 20\ NO(g)$$

A) $K = \dfrac{[H_3PO_4][NO]}{[HNO_3][P_4][H_2O]}$

B) $K = \dfrac{[H_3PO_4]^{12}[NO]^{20}}{[HNO_3]^{20}[P_4]^3[H_2O]^8}$

C) $K = \dfrac{[2\ HNO_3]^{20}[P_4]^3[H_2O]^8}{[H_3PO_4]^{12}[2\ NO]^{20}}$

D) $K = \dfrac{[H_3PO_4]^{12}[NO]^{20}}{[HNO_3]^{20}}$

E) $K = \dfrac{[12\ H_3PO_4][20\ NO]^8}{[20\ HNO_3]^3[P_4]^{20}[H_2O]^{20}}$

32. What is the equilibrium law expression for:

$$4\ NO(g) + 3\ O_2(g) \leftrightarrow 2\ N_2O_5(g) + Heat$$

A) $K = \dfrac{[2\ N_2O_5]}{[4\ NO][3\ O_2]}$

B) $K = \dfrac{[2\ N_2O_5][Heat]}{[4\ NO][3\ O_2]}$

C) $K = \dfrac{[N_2O_5]^2}{[NO]^4[O_2]^3}$

D) $K = \dfrac{[N_2O_5]^2[Heat]}{[NO]^4[O_2]^3}$

E) $K = \dfrac{[3\ O_2][Heat]}{[NO]^4[2\ N_2O_5]}$

33. What is the equilibrium law expression for

$$N_2(g) + 3\ H_2(g) \leftrightarrow 2\ NH_3(g) + 22\ kcal$$

A) $K = \dfrac{[NH_3]}{[N_2][H_2]}$ B) $K = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$

C) $K = \dfrac{[2\ NH_3]}{[N_2][3\ H_2]}$ D) $K = \dfrac{[N_2][H_2]^3}{[NH_3]^2}$

E) $K = \dfrac{[N_2]^2}{[H_2][NH_3]^3}$

34. What is the equilibrium law expression for

$$CaCO_3(s) + Heat \leftrightarrow CaO(s) + CO_2(g)$$

A) $K = \dfrac{[CaCO_3]}{[CaO][CO_2]}$

B) $K = \dfrac{[CaO][CO_2]}{[CaCO_3]}$

C) $K = [CO_2]$

D) $K = \dfrac{1}{[CO_2]}$

E) $K = \dfrac{[CO_2]^2}{[CaO]}$

35. Which expression correctly represents the solubility product constant, K_{sp}, for manganese(II) oxalate, MnC_2O_4?

$$MnC_2O_4(s) \leftrightarrow Mn^{2+}(aq) + {C_2O_4}^{2-}(aq)$$

A) $K_{sp} = \dfrac{[Mn^{2+}][C_2O_4^{2-}]}{[MnC_2O_4]}$

B) $K_{sp} = \dfrac{[MnC_2O_4]}{[Mn^{2+}][C_2O_4^{2-}]}$

C) $K_{sp} = [Mn^{2+}][C_2O_4^{2-}]$

D) $K_{sp} = \dfrac{1}{[Mn^{2+}][C_2O_4^{2-}]}$

E) $K_{sp} = \dfrac{[C_2O_4^{2-}]}{[Mn^{2+}]}$

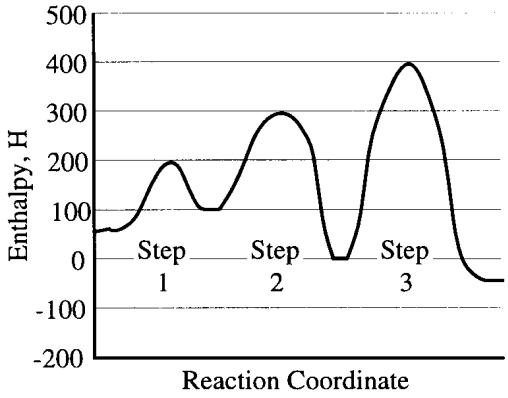
36. The activation energy of a reaction may be defined qualitatively as the

A) Energy supplied by the catalyst
B) Energy required by the reactant molecules to react
C) Heat content of the products minus that of the reactants
D) Energy supplied by the attractive forces between molecules
E) Heat content of the products plus the potential energy of the products

37. A catalyst increases the rate of reaction by

A) decreasing the heat of reaction.
B) decreasing the activation energy.
C) increasing the energy of the products.
D) increasing the value of the equilibrium constant.
E) increasing the potential energy of the reactants.

Base your answers to questions **38** and **39** on the graph below showing the energy during a catalyzed reaction.



38. The heat of reaction for Step #3 is:

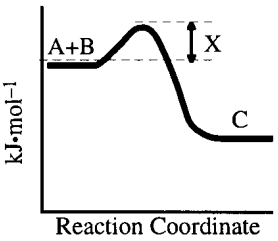
A) –450 B) –50 C) +50 D) +100 E) +400

39. The heat of reaction for the overall reaction is:

A) –100 B) –50 C) +50 D) +100 E) +400

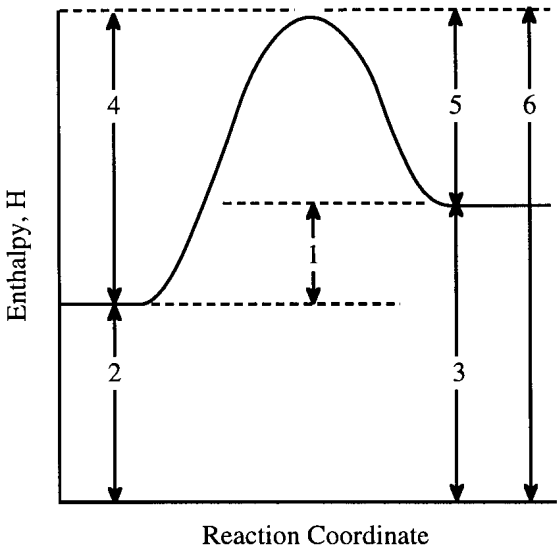
40. Which reaction characteristic is shown by the potential energy diagram?

$$A + B \rightarrow C$$



A) slow
B) rapid
C) equilibrium
D) exothermic
E) endothermic

Base your answers to questions **41** through **44** on the diagram shown below.



41. The reaction diagrammed has a ΔH which is

A) negative and exothermic
B) positive and exothermic
C) positive and endothermic
D) negative and endothermic
E) Unable to be determined from the information given

42. The *least* stable species in this diagram is the

A) reactants
B) products
C) exothermic reaction
D) endothermic reaction
E) activated complex

43. The products have a total energy represented by number

A) 6 B) 2 C) 3 D) 4 E) 5

44. Which represents the energy of the activated complex?

A) 6 B) 2 C) 3 D) 4 E) 5

---

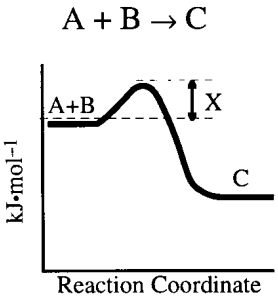
45. Which best describes the role of catalysts in chemical reactions? Catalysts

A) are consumed as they speed up the reaction rate
B) do not take part in the reaction; they only speed up the rate
C) main function is to provide a surface for the reaction to occur
D) are both consumed and regenerated while speeding up the reaction rate
E) increase the activation energy of the reaction

46. A catalyst increases the rate of reaction by

A) decreasing the heat of reaction
B) decreasing the activation energy
C) increasing the energy of the products
D) increasing the value of the equilibrium constant
E) increasing the number of collisions

47. How is the interval "X" changed in the potential energy diagram?



A) Change the volume
B) Introduce a catalyst
C) Increase the pressure
D) Decrease the temperature
E) Add more of substance A

48. Given the reaction $H_2(g) + I_2(g) + \text{heat} \leftrightarrow 2\ HI(g)$, what effect will increasing the pressure have?

A) increase the $[H_2]$ B) increase the $[I_2]$
C) increase the [HI] D) decrease the [HI]
E) none of the above

49. When a reactant is added to a reaction at equilibrium, the equilibrium shifts towards the product side. Which of the following best describes this phenomenon?

A) Graham's law
B) the second law of thermodynamics
C) Gibb's free energy
D) collision theory of reaction rates
E) Boyle's law

50. Why does increased concentration increase reaction rate?

A) Increased activation energy
B) Increased number of collisions
C) Increased average kinetic energy
D) Increased energy for effective collisions
E) Increased energy of reactants

51. Consider the reaction between $BaCO_3$ and an acid.

$$BaCO_3(s) + 2\ H^+(aq) \rightarrow Ba^{2+}(aq) + H_2O(l) + CO_2(g) + \text{Heat}$$

Which will increase the rate of evolution of carbon dioxide?

A) Adding water to the system
B) Decreasing the temperature
C) Using finely powdered $BaCO_3$
D) Increasing the barium ion concentration, $[Ba^{2+}]$
E) Using $H_2(g)$ instead of $H^+(aq)$

52. Consider the two reactions:

(I) $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$
(II) $4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$

Which statement best describes the relative rates of the two reactions?

A) I is faster than II
B) II is faster than I
C) I and II are both fast
D) I and II are both slow
E) I and II are exactly the same

53. Consider the two reactions:

(I) $4\ Al(s) + 3\ O_2(g) \rightarrow 2\ Al_2O_3(s)$
(II) $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

Which statement best describes the relative rates of the two reactions?

A) I is faster than II
B) II is faster than I
C) I and II are both fast
D) I and II are both slow
E) I and II are exactly the same

54. Increasing the temperature increases the reaction rate. This is best explained by a(n)

A) new reaction path.
B) higher activation energy.
C) increased concentration of reactants.
D) increased number of effective collisions.
E) increase in the potential energy of the reactants.

Base your answers to questions **55** through **57** on the rate law given below for the reaction $A + B + C \rightarrow D$.

$$\text{Rate} = k[A]^2[B][C]$$

55. If the concentration of B is decreased, what will happen?

A) Both [A] and [C] will increase.
B) Both [A] and [C] will decrease.
C) [A] will decrease and [C] will increase.
D) [A] will increase and [C] will decrease.
E) Both [A] and [C] will stay the same.

56. If the concentration of C is doubled what will happen?

A) The rate of the reaction increases
B) The rate of the reaction decreases
C) The value of the equilbrium constant increases
D) The value of the equilibrium constant decreases
E) Neither the equilibrium constant nor the rate would change.

57. If [A] is doubled and [B] tripled, by what factor would the rate change?

A) 2 B) 3 C) 6 D) 12 E) 18

58. Which is the value for the enthalpy change, ΔH, for this reaction in kJ?

$$CuS(s) + 2\ O_2(g) \rightarrow CuSO_4(g) + 721\ \text{kJ}$$

A) 0.00 B) –721 C) +721 D) +770 E) –770

59. Which is true for *exothermic* reactions?

A) Increasing enthalpy, increased stability, increased energy.
B) Increasing enthalpy, decreased stability, increased energy.
C) Decreasing enthalpy, increased stability, decreased energy.
D) Decreasing enthalpy, decreased stability, decreased energy.
E) Decreasing enthalpy, increased stability, increased energy.

60. The heats of formation of $O_2(g)$, $P_4(s)$ and Na(s) are all

A) zero B) large
C) small D) given in the table
E) unknown

61. What is the enthalpy change, ΔH, of the following reaction in kJ?

$$SO_2(g) + \tfrac{1}{2}\, O_2(g) \rightarrow SO_3(g) + 98.49 \text{ kJ}$$

A) 0.00 kJ
B) –98.49 kJ
C) –49.25 kJ
D) +49.25 kJ
E) +98.49 kJ

62. Bond breaking is

A) exothermic and absorbs energy
B) exothermic and evolves energy
C) endothermic and absorbs energy
D) endothermic and evolves energy
E) either endothermic or exothermic

63. Consider the reaction:

$$H_2 + Cl_2 \rightarrow 2\ HCl + \text{Energy}$$

The equation indicates that the reaction described is

A) very slow
B) impossible
C) exothermic
D) endothermic
E) very fast

64. Consider the equation:

$$2\ Al(s) + Fe_2O_3\ (s) \rightarrow 2\ Fe(s) + Al_2O_3\ (s) + 400\ kJ$$

How many grams of aluminum react to produce 40 kJ of heat?

A) 2.7 g B) 5.4 g C) 9.0 g D) 27 g E) 54 g

65. Which change is accompanied by an increase in entropy?

A) $H_2O(l) \rightarrow H_2O(s)$
B) $H_2O(g) \rightarrow H_2O(s)$
C) $H_2O(l) \rightarrow H_2O(g)$
D) $H_2O(g) \rightarrow H_2O(l)$
E) $H_2O(aq) \rightarrow H_2O(s)$

66. In the reaction

$$A(s) + B(s) \rightarrow C(g) + D(g) + \text{heat}$$

the entropy of the system

A) increases and the reaction is exothermic.
B) decreases and the reaction is exothermic.
C) increases and the reaction is endothermic.
D) decreases and the reaction is endothermic.
E) either increases or decreases depending on the temperature.

67. Calcium carbonate, $CaCO_3$, decomposes according to the reaction

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)\ .$$

The entropy change, $\Delta S°$, of this system:

A) always decreases
B) always increases
C) remains the same
D) increases at high temperatures only
E) decreases at high temperatures only

68. Endothermic reactions can occur spontaneously when the free energy, ΔG, of the system:

A) decreases
B) increases
C) remains the same
D) either increases or decreases
E) it cannot be determined from the information given

69. In a system at equilibrium, the free energy change, $\Delta G°$, is

A) always zero
B) always a positive value
C) always a negative value
D) either a negative or a positive value
E) dependent on the states of the reactants

70. Free energy is a measure of

A) chaos
B) kinetic energy
C) heat flow
D) potential energy
E) net driving force

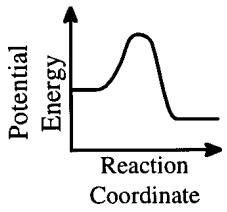
71. When the temperature change of a system is low, the reaction generally proceeds as predicted by the enthalpy change (ΔH) because

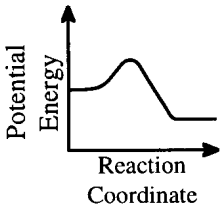
A) ΔS is negative
B) the product $T\Delta S$ is equal to ΔH
C) the product $T\Delta S$ is small compared to ΔH
D) the product $T\Delta S$ is large compared to ΔH
E) ΔS is positive

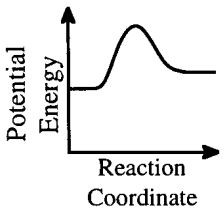
72. When solid ammonium chloride, NH_4Cl, is dissolved in a beaker of water, the temperature of the water *decreases*. The reaction occurring in the beaker

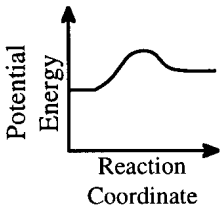
A) is exothermic and spontaneous
B) is endothermic and spontaneous
C) is exothermic and nonspontaneous
D) is endothermic and nonspontaneous
E) could be either exothermic or endothermic

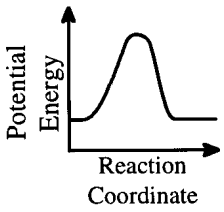
73. Four reactions are represented by the reaction diagrams shown at the same scale. Which exothermic reaction occurs most spontaneously?

A)


B)


C)


D)


E)


74. I. Increasing the temperature increases the rate of a chemical reaction

BECAUSE

II. the activation energy is lowered.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

75. I. When the pressure on a reaction at equilibrium is increased, the equilibrium will always shift to the products

BECAUSE

II. the available volume decreases.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

76. I. Exothermic reactions are always spontaneous

BECAUSE

II. spontaneous reactions have a negative ΔG.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

77. I. Increasing the pressure on gaseous reactants will increase the rate of a reaction

BECAUSE

II. the equilibrium shifts to the smaller gas volume.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

78. I. A positive ΔG signifies an endothermic reaction

BECAUSE

II. the reaction is not spontaneous..

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

79. I. Powdered aluminum reacts at a slower rate than aluminum strips

BECAUSE

II. powdered aluminum has a decreased surface area.

A) I is *TRUE*, II is *FALSE*
B) I is *FALSE*, II is *TRUE*
C) I and II are *BOTH FALSE*
D) I and II are *BOTH TRUE* but II *IS NOT* a correct explanation of I
E) I and II are *BOTH TRUE* and II *IS* a correct explanation of I

80. In the reaction:

$$A(g) + B(g) + \text{heat} \rightarrow C(s) + D(l)$$

the entropy change, ΔS, of the system:

A) decreases under any conditions
B) increases under any conditions
C) remains the same
D) decreases at high pressures only
E) increases at high temperatures only