Chemistry 12 - Dynamic Equilibrium Answer Key

1. A
2. B
3. A
4. B
5. A
6. C
7. C
8. C
9. D
10. C
11. D
12. C
13. D
14. C
15. A
16. C
17. C
18. B
19. B
20. C
21. B
22. D
23. B
24. B
25. B
26. A
27. B
28. C
29. C
30. See answer
31. B
32. C
33. B
34. D
35. C
36. D
37. C
38. D
39. A
40. C
41. D
42. B
43. D
44. A
45. A
46. C
47. See answer
48. a) see diagram
b) ↑$[Zn^{2+}]$
49. ↑Temp, ↓$[CH_4]$, ↑SA of C(s)
50. a) ↓ b/c H^+ reacts with solid, shift equilibrium left
b) see diagram
51. C
52. D
53. B
54. B
55. C
56. C
57. A
58. A
59. a) shift right, b/c few molecules; both rates increase due to Inc. [molecules]
b) Keq remains the same
60. C
61. A
62. D
63. D
64. D
65. C
66. A
67. C
68. D
69. D
70. A
71. C
72. B
73. B
74. A
75. B
76. A
77. A
78. D
79. C
80. D
81. D
82. D
83. C
84. B
85. B
86. C

87. A
88. D
89. D
90. B
91. D
92. a) Keq = 0.70
b) Keq = 0.65
c) ↓Temp = shift left = ↑$[N_2O_4]$
93. C
94. C
95. A
96. B
97. C
98. Keq = 0.0016
99. A
100. C
101. B
102. a) Keq = 0.00163
b) Reactants, Keq < 1
c) see answers
103. a) see diagram
b) Keq = 0.0023
104. Keq = 453
105. Keq = 64
106. Keq = 0.499
107. B
108. [HBr] = 0.025M
109. [NO] = 0.0139M
110. $[NH_3]$ = 0.60M
111. D
112. A
113. a) Keq(T) = 0.790, Equilibrium shifts left
b) [CO] = 0.103M, $[CO_2]$ = 0.0671M
c) ↑Temp
114. a) Keq(T) = 9 (shift right)
b) [HI] = 0.343M
115. C
116. Keq(T) = 1.0 (shift right)
117. D
118. D
119. C
120. A
121. D
122. B
123. C
124. B
125. D
126. A
127. C
128. D
129. D
130. Ignore
131. a) endothermic in order to react equilibrium
b) ↑Temp, ↑$[POCl_3]$, ↓$[PCl_3]$ or $[O_2]$
c) Keq = 2.97×10^{-5}
132. a) Keq = 17360
b) large Keq = Large [products]
c) see answer
133. a) no, Keq(T) = 0.39 = shift left
b) [CO] = 0.0488M
$[CO_2]$ = 0.0813M

Prescribed Learning Outcomes - Chemistry 12

Equilibrium Section

D: Dynamic Equilibrium (Introduction)

D1: Describe the reversible nature of most chemical reactions
D2: Identify the reversible pathways of a chemical reaction on the PE diagram
D3: Relate the changes in rates of the forward and reverse reactions to the changing concentrations of the reactants and products as equilibrium is established
D4: Describe the chemical equilibrium as a closed system at constant temperature:
- whose macroscopic properties are constant
- where the forward and reverse reaction rates are equal
- that can be achieved from either direction
- where the concentrations of reactants and products are constant

D5: Describe the dynamic nature of chemical equilibrium
D6: Infer that a system not at equilibrium will tend to move toward a position of equilibrium
D7: Determine entropy and enthalpy changes from a chemic equation (qualitatively)
D8: State that systems tend toward a position of minimum enthalpy and maximum randonmess (entropy)
D9: Predict the result when enthaply and entropy factors:
- both favour the products
- both favour the reactants
- oppose one another

E: Dynamic Equilibrium (Le Châtelier's Principle)

E1: Describe the term *shift* as it applies to equilibria
E2: Apply Le Châtelier's principle to the shifting of equilibrium involving the following:
- temperature change
- concentration change
- volume change of gaseous systems

E3: Explain the above shifts using the concepts of reaction kinetics

E4: Identify the effect of a catalyst on dynamic equilibrium
E5: Apply the concept of equilibrium to a commercial or industrial process

F: Dynamic Equlibrium (The Equilibrium Constant)

F1: Gather and interpret data on the concentration of reactants and products of a system at equlibrium
F2: Write the expression for the equilibrium constant when given the equation for either a homogeneous or heterogeneous equilibrium system
F3: relate the equilibrium position to the value of *Keq* and vice versa
F4: predict the effect (or lack of effect) on the value of *Keq* of changes in the following factors:
- temperature
- pressure
- concentration
- surface area
- catalyst

F5: Calculate the value of *Keq* given the equilibrium concentration of all species
F6: Calculate the value of *Keq* given the initial concentrations of all species and one equilibrium concentration
F7: Calculate the equilibrium concentrations of all species given the value of *Keq* and the initial concentrations
F8: Determine whether a system is at equilibrium, and if not, in which direction it will shift to reach equilibrium when given a set of concentrations for reactants and products

D1. Describe the reversible nature of most chemical reactions

D2. Identify the reversible pathways of a chemical reaction on the PE diagram

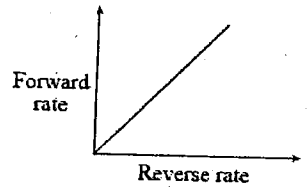
1. Which of the following is true for an endothermic reaction?
   A. forward E_a > reverse E_a
   B. reverse E_a > forward E_a
   C. forward E_a = reverse E_a
   D. forward E_a + reverse E_a = 0

2. Which of the following is true for an exothermic reaction?
   A. forward E_a > reverse E_a
   B. reverse E_a > forward E_a
   C. forward E_a = reverse E_a
   D. forward E_a + reverse E_a = 0

D3. Relate the changes in rates of the forward and reverse reactions to the changing concentrations of the reactants and products as equilibrium is established.

3. At different conditions, the relationship between the forward and reverse rates of reactions in an equilibrium system can be best represented by:

A.



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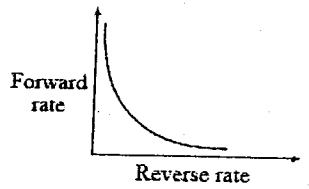
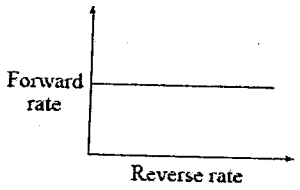
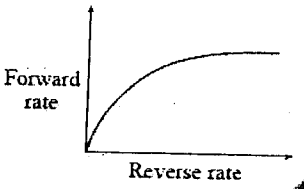


C.



D.



4. Consider the following:

$$2SO_{2\,(g)} + O_{2\,(g)} \leftrightarrows 2\,SO_{3\,(g)}$$

Initially, SO_3 is added to an empty flask. How do the rate of the reverse reaction and $[SO_3]$ change as the system proceeds to equilibrium?

	Reverse Rate	$[SO_3]$
A.	decreases	increases
B.	decreases	decreases
C.	increases	increases
D.	increases	decreases

5. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)}$$

How will the forward and reverse equilibrium reaction rates change when a catalyst is added to the system?

	Forward rate	Reverse rate
A.	increase	increase
B.	increase	decrease
C.	decrease	decrease
D.	decrease	increase

6. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)}$$

How will the forward and reverse equilibrium reaction rates change when H_2 is removed from the system?

	Forward rate	Reverse rate
A.	increase	increase
B.	increase	decrease
C.	decrease	decrease
D.	decrease	increase

7. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)}$$

How will the forward and reverse equilibrium reaction rates change when the temperature is lowered within the system?

	Forward rate	Reverse rate
A.	increase	increase
B.	increase	decrease
C.	decrease	decrease
D.	decrease	increase

8. Some Fe^{+3} and SCN^- were mixed and established the following equilibrium:

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

What happened to the forward rate and the $[Fe^{+3}]$ as equilibrium was established?

	forward rate	$[Fe^{+3}]$
A.	decreased	increased
B.	increased	increased
C.	decreased	decreased
D.	increased	decreased

D4. Describe the chemical equilibrium as a closed system at constant temperature:

- whose macroscopic properties are constant
- where the forward and reverse reaction rates are equal
- that can be achieved from either direction
- where the concentrations of reactants and products are constant

9. Which of the following applies to a chemical equilibrium:

I. Forward and reverse reaction rates are equal.
II. Equilibrium can be achieved in either direction.
III. Macroscopic properties are constant.

A. I only
B. I and II only
C. I and III only
D. I, II and III

10. Which of the following applies to a chemical equilibrium:

I. Forward reaction rate = reverse reaction rate
II. Equilibrium can be acheived in either direction.
III. Macroscopic properties are constant.
IV. [Reactant] = [Product]

A. I, II and IVonly
B. I and IV only
C. I , II and III only
D. II and III only

11. Which of the factors below is **not** a condition necessary for equilibrium?
A. a closed system
B. a constant temperature
C. equal forward and reverse reaction rates
D. equal concentrations of reactants and products

12. For the equilibrium system below:

$$Cu_{(s)} + 2\,Ag^{+1}_{(aq)} \leftrightarrows 2\,Ag_{(s)} + Cu^{+2}_{(aq)}$$

We would know the system is at equilibrium because

A. $[Cu^{+2}] = [Ag^{+1}]$
B. $[Cu^{+2}] = 2[Ag^{+1}]$
C. the mass of $Cu_{(s)}$ remains constant
D. the mass of the entire system remains constant

D5. Describe the dynamic nature of chemical equilibrium

D6. Infer that a system not at equilibrium will tend to more toward a position of equilibrium.

D7. Determine entropy and enthalpy changes from a chemical equation

13. Consider the following:

$$N_{2\,(g)} + 3H_{2\,(g)} \overset{?}{\leftrightarrows} 2NH_{3\,(g)} + \text{energy}$$

What positions do minimum enthalpy and maximum entropy tend towards?

	Minimum Enthalpy	Maximum Entropy
A.	reactants	products
B.	reactants	reactants
C.	products	products
D.	products	reactants

14. Consider the following:

$$2N_{2(g)} + O_{2(g)} + \text{Energy} \overset{?}{\leftrightarrows} 2\,N_2O_{(g)}$$

What positions to minimum enthalpy and maximum entropy tend towards?

	Minimum Enthalpy	Maximum Entropy
A.	products	products
B.	products	reactants
C.	reactants	reactants
D.	reactants	products

15. In which of the following will entropy and enthalpy factors favour the establishment of an equilibrium?

A. $CaCO_{3(s)} + 178\text{ kJ} \Rightarrow CaO_{(s)} + CO_{2(g)}$
B. $Mg_{(s)} + 2\,HCl_{(aq)} \Rightarrow MgCl_{2(aq)} + H_{2(g)} + 425\text{ kJ}$
C. $2C_{(s)} + 2H_{2(g)} \Rightarrow C_2H_{4(g)} \quad \Delta H = +52.3\text{ kJ}$
D. $2C_2H_{6(g)} + 7O_{2(g)} \Rightarrow 4CO_{2(g)} + 6H_2O_{(g)} \quad \Delta H = -1560\text{ kJ}$

16. In which of the following will entropy and enthalpy factors favour the reactants?

A. $CaCO_{3(s)} + 178\text{ kJ} \Rightarrow CaO_{(s)} + CO_{2(g)}$
B. $Mg_{(s)} + 2\,HCl_{(aq)} \Rightarrow MgCl_{2(aq)} + H_{2(g)} + 425\text{ kJ}$
C. $2C_{(s)} + 2H_{2(g)} \Rightarrow C_2H_{4(g)} \quad \Delta H = +52.3\text{ kJ}$
D. $2C_2H_{6(g)} + 7O_{2(g)} \Rightarrow 4CO_{2(g)} + 6H_2O_{(g)} \quad \Delta H = -1560\text{ kJ}$

D8. State that systems tend toward a position of minimum enthalpy and maximum entropy

17. In which of the following will the driving forces of minimum enthalpy and maximum entropy oppose one another?

A. $2C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} \quad \Delta H = -221\text{ kJ}$
B. $2N_{2(g)} + O_{2\,(g)} \rightarrow 2N_2O_{(g)} \quad \Delta H = +164\text{ kJ}$
C. $2CO_{(g)} + O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} \quad \Delta H = -566\text{ kJ}$
D. $4CO_{2\,(g)} + 6\,H_2O_{(g)} \rightarrow 2C_2H_{6\,(g)} + 7\,O_{2\,(g)} \quad \Delta H = +3122\text{ kJ}$

18. In order for a chemical reaction to go to completion, how must the entropy and enthalpy change?

	Entropy	Enthalpy
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

19. For the reacting system:

$$2\,Li_{(s)} + 2\,H_2O_{(l)} \rightarrow 2\,LiOH_{(aq)} + H_{2\,(g)} \quad \Delta H = -433\text{ kJ}$$

What will entropy and enthalpy factors favor?

	Entropy	Enthalpy
A.	products	reactants
B.	products	products
C.	reactants	products
D.	reactants	reactants

20. Which of the following reactions is accompanied by an increase in enthalpy?

A. $2NO_{(g)} + O_{2(g)} \leftrightarrows 2NO_{2(g)} + 113kJ$

B. $2H_{2(g)} + O_{2(g)} - 484\ kJ \leftrightarrows 2H_2O_{(g)}$

C. $2SO_{3(g)} \leftrightarrows 2SO_{2(g)} + O_{2(g)} \quad \Delta H = +197\ kJ$

D. $4HCl_{(g)} + O_{2(g)} \leftrightarrows 2H_2O_{(g)} + 2Cl_{2(g)} \quad \Delta H = -111.4\ kJ$

D9. Predict the result when enthalpy and entropy factors:

- both favour the products
- both favour the reactants
- oppose one another

21. Consider the following reaction:

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)} \quad \Delta H = -2202\ kJ$$

Which of the following applies to the forward reaction?

	Entropy	Enthalpy
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

22. Consider the following reaction:

$$PCl_{3(g)} + Cl_{2(g)} \rightarrow PCl_{5(g)} \quad \Delta H = +102\ kJ$$

Which of the following applies to the forward reaction?

	Entropy	Enthalpy
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

23. Consider the following reaction:

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow H_{2(g)} + Ca(OH)_{2(aq)} \quad \Delta H = -102\ kJ$$

Which of the following applies to the forward reaction?

	Entropy	Enthalpy
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

24. Two substances are mixed and no reaction occurs. With respect to enthalpy and entropy, which of the following could explain why no reaction occurs?

	Enthalpy	Entropy
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

25. Which of the following forward reaction changes would result in the most products?

	Entropy	Enthapy
A.	decreasing	decreasing
B.	increasing	decreasing
C.	decreasing	increasing
D.	increasing	increasing

26. In which of the following reactions do the tendencies for minimum enthalpy and maximum entropy both favour reactants?

A. $3O_{2(g)} \leftrightarrows 2O_{3(g)} \quad \Delta H = +285\ kJ$

B. $N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)} \quad \Delta H = -92\ kJ$

C. $2BrCl_{(g)} \leftrightarrows Br_{2(g)} + Cl_{2(g)} \quad \Delta H = -29.3\ kJ$

D. $CaCO_{3(s)} \leftrightarrows CaO_{(s)} + CO_{2(g)} \quad \Delta H = +175\ kJ$

27. Consider the following equation:

$$NH_4NO_{3(s)} \overset{?}{\leftrightarrows} N_2O_{(g)} + 2H_2O_{(g)} \quad \Delta H = -37\ kJ$$

Which of the following is true?

	Enthalpy	Entropy	Outcome
A.	favours reactants	favours reactants	reaction does not occur
B.	favours products	favours products	reaction goes to completion
C.	favours reactants	favours products	reaction reaches equilibrium
D.	favours products	favours reactants	reaction reaches equilibrium

28. Consider the following exothermic reaction:

$$C_3H_{8(g)} + 5O_{2(g)} \overset{?}{\leftrightarrows} 3CO_{2(g)} + 4H_2O_{(g)}$$

Explain, in terms of increasing or decreasing entropy and enthalpy, whether or not the reaction will reach equilibrium.

A. The reaction will reach equilibrium because the entropy and enthalpy are both decreasing.
B. The reaction will reach equilibrium because the entropy is increasing while the enthalpy is decreasing.
C. The reaction will go 100% because the entropy is increasing while the enthalpy is decreasing.
D. The reaction will reach equilibrium because the entropy and enthalpy are both increasing.

E1. Describe the term shift as it applies to equilibria

29. Consider the following system at equilibrium:

$$H_2O_{(g)} + CO_{(g)} \leftrightarrows CO_{2(g)} + H_{2(g)}$$

This equilibrium will shift right as the result of the addition of some extra H_2O. How will this shift affect the concentration of the other gases?

	[CO]	[CO_2]	[H_2]
A.	increases	decreases	decreases
B.	increases	increases	decreases
C.	decreases	increases	increases
D.	decreases	decreases	increases

30. Consider the following equilibrium:

$$2CrO_4^{-2}{}_{(aq)} + 2H^+{}_{(aq)} \leftrightarrows Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)}$$

yellow orange

a. Is the forward reaction endothermic or exothermic? Explain.

b. When OH^{-1} is added, the color of the solution turns from orange to yellow. Explain using LeChatelier's Principle.

31. Consider the following equilibrium system:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{(g)} \qquad \Delta H = -9.4\ kJ$$

In an experiment, the equilibrium concentrations of the chemical species were measured before and after a stress was added. The results are displayed:

Chemical species	[ ] before stress was applied	[ ] after stress was applied
H_2	0.050 M	0.070 M
I_2	0.050 M	0.070 M
HI	0.40 M	0.56 M

Which one of the following stresses would be consistent with the above data?

A. the addition of H_2
B. the addition of HI
C. a decrease in pressure
D. an increase in temperature

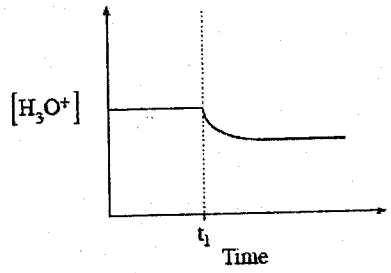
E2. Apply Le Chatelier's principle to the shifting of equilibrium involving the following:

- temperature change
- concentration change
- volume change of gaseous systems
- addition of catalysts or inhibitors

32. Consider the following equilibrium:

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + \text{heat}$$

A stress was applied at time t_1 and the data was plotted on the following graph:



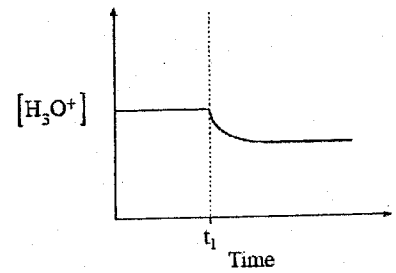
The stress that occured at time = t_1 is a result of

A. the addition of H_2O
B. decreasing the temperature
C. the addition of CH_3COO^{-1}
D. increasing the volume of the container

33. Consider the following equilibrium:

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + \text{heat}$$

A stress was applied at time t_1 and the data was plotted on the following graph:

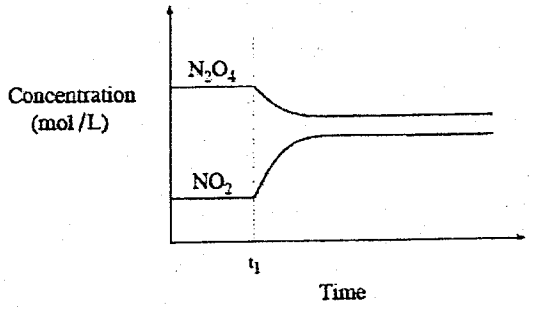


The stress that occured at time = t_1 is a result of

A. the addition of H_2O
B. increasing the temperature
C. the addition of H_3O^{+1}
D. adding an inhibitor

34. Consider the following equilibrium reaction:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$



At time t_1, heat is applied to the system. Which of the following best describes the equilibrium reaction and the change in K_{eq}?

	Forward reaction	K_{eq}
A.	exothermic	increases
B.	exothermic	decreases
C.	endothermic	decreases
D.	endothermic	increases

35. Consider the following equilibrium:

$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{\,(g)} + CO_{\,(g)}$$

Which two stresses will cause the equilibrium to shift to the left?

A. increase $[H_2]$ and increase [CO]
B. increase $[H_2]$ and decrease [CO]
C. decrease $[H_2]$ and increase [CO]
D. decrease $[H_2]$ and decrease [CO]

36. Consider the following:

$$2SO_{2(g)} + O_{2\,(g)} \leftrightarrows 2SO_{3(g)} + \text{energy}$$

Which of the following two stresses will each cause the system to shift to the right?

A. decrease temperature and decrease the $[O_2]$
B. increase temperature and increase $[SO_3]$
C. increase temperature and decrease $[SO_3]$
D. decrease temperature and increase $[SO_2]$

37. Consider the following equilibrium system:

$$2SO_{2(g)} + O_{2(g)} \leftrightarrows 2SO_{3(g)} \quad K_{eq} = 1.2 \times 10^4$$

If additional SO_2 is added the system, what happens to the equilibrium and the value of K_{eq}?

	Equilibrium	K_{eq}
A.	shifts left	decreases
B.	shifts right	increases
C.	shifts right	no change
D.	no change	no change

38. Consider the following equilibrium:

$$N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrows 2\,NH_{3\,(g)}$$

If some Ne gas is added at a constant volume then how will $[N_2]$, $[NH_3]$ and K_{eq} be affected?

	$[N_2]$	$[NH_3]$	K_{eq}
A.	increases	increases	decreases
B.	increase	decreases	does not change
C.	decreases	increases	does not change
D.	does not change	does not change	does not change

39. Consider the following equilibrium:

$$CO_{(g)} + 2\,H_{2(g)} \leftrightarrows CH_3OH_{(g)} \qquad \Delta H = -91kJ$$

Which of the factors below would increase the concentration of the CH_3OH at equilibrium?

A. an addition of CO
B. an increase in the volume
C. a decrease in pressure
D. an increase in temperature

40. Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)}$$

Which of the following factors will **not** alter the position of equilibrium?

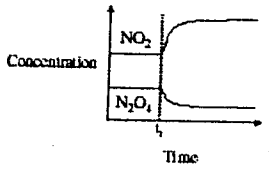
A. a pressure decrease
B. a temperature increase
C. addition of a catalyst
D. the addition of more $N_{2(g)}$

41. Consider the following equilibrium:

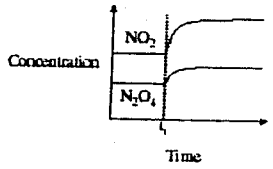
$$N_2O_{4(g)} + \text{energy} \leftrightarrows 2\,NO_{2(g)}$$

Which of the following graphs shows the result of adding a catalyst at time t_1?

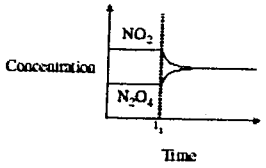
A.



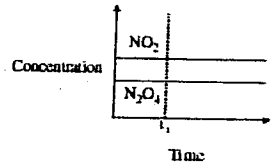
B.



C.

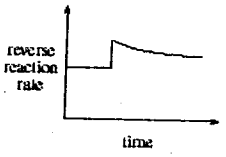


D.

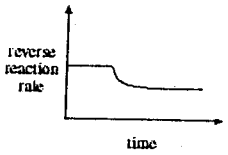


42. Temperature is gradually decreased then held constant in an exothermic equilibrium. Which of the following represents the change in the reverse reaction rate?

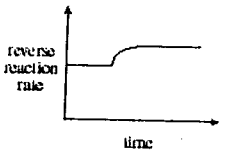
A.



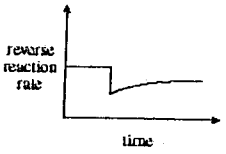
B.



C.



D.



43. When the temperature of an exothermic equilibrium is decreased, which of the following will happen?

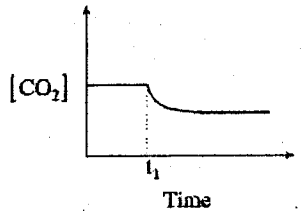
A. Equilibrium shifts left and [product] increases
B. Equilibrium shifts left and [product] decreases
C. Equilibrium shifts right and [reactant] increases
D. Equilibrium shifts right and [reactant] will decrease

44. Consider the following equilibrium:

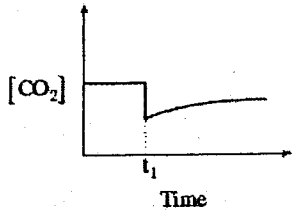
$$CaCO_{3\,(s)} \leftrightarrows CaO_{(s)} + CO_{2\,(g)} \qquad \Delta H = +175\ kJ$$

Which of the following diagrams best represents the change in the concentration of CO_2 as temperature is decreasesd at time t_1?

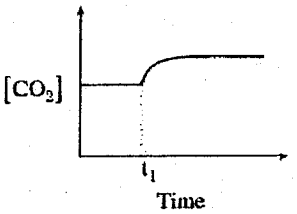
A.



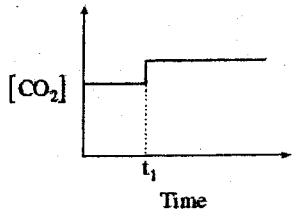
B.



C.



D.



45. Consider the following equilibrium:

$$energy + 2KClO_{3\,(s)} \leftrightarrows 2KCl_{(s)} + 3O_{2\,(g)}$$

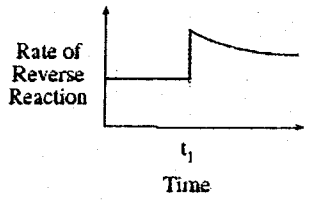
Which of the following will cause a shift to the left?

A. increasing pressure
B. grinding up the KCl
C. adding an inhibitor
D. increasing the temperature

46. Consider the following equilibrium:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)} + energy$$

The following diagram represents the rate of the reverse reaction:



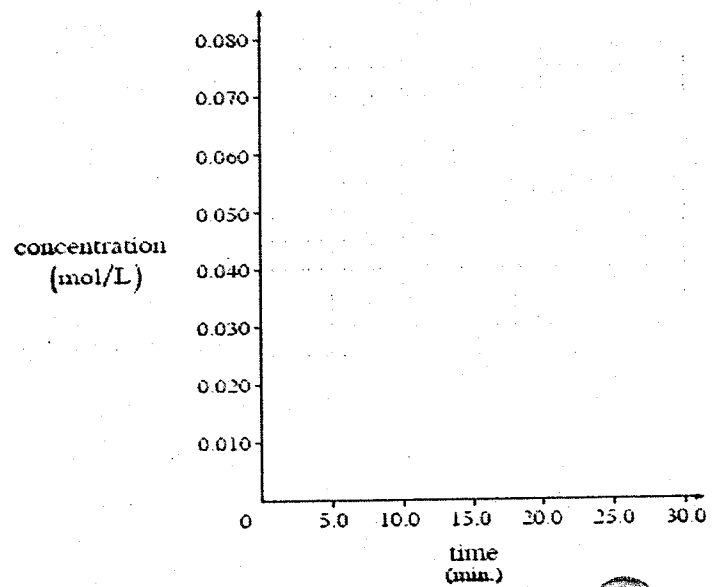
Which of the following stresses explains what happened at t_1?

A. $[H_2]$ increased
B. $[N_2]$ decreased
C. $[NH_3]$ increased
D. $[NH_3]$ decreased

47. Consider the following equilibrium:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{(g)}$$

A 2.0 L container is initally filled with 0.070 mol of H_2 and 0.060 mol of I_2.



47. See next page for rest of question

Equilibrium is reached after 15.0 minutes, at which time there are 0.060 mol of HI present.

a. Sketch the graph for $[H_2]$ $[I_2]$ and [HI] for the first 15 minutes.

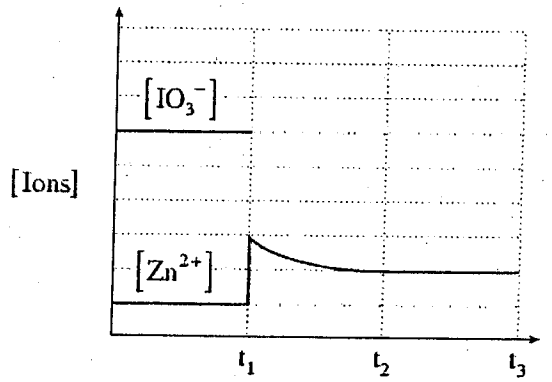
b. Calculate the K_{eq} for this equilibrium at 15 minutes.

c. At 15 minutes, the volume of the container is decreased from 2.0 to 1.0 L. Sketch what the graph would look like from 15.0 minutes until 30.0 minutes with this shock and the new equilibrium that will occur.

d. How will the K_{eq} change with this stress at 15.0 minutes?

48. Consider the following equilibrium and accompanying graph:

$$Zn(IO_3)_{2(s)} \rightleftarrows Zn^{2+}_{(aq)} + 2IO_3^-{}_{(aq)}$$



a. Identify the stress that occured at time t_1.

b. Complete the above graph from t_1 to t_3 for the $[IO_3^-]$

49. Consider the following equilibrium system:

$$C_{(s)} + 2H_{2(g)} \leftrightarrows CH_{4(g)} \quad \Delta H = -75 \text{ kJ}$$

State three different ways to make more $C_{(s)}$ react.

i) _____

ii) _____

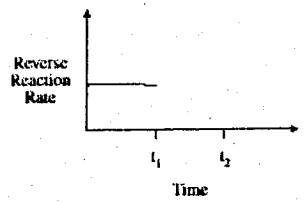
iii) _____

50. Consider the following equilibrium:

$$Al(H_2O)_4(OH)_4^{+}{}_{(aq)} \leftrightarrows Al(H_2O)_3(OH)_{3\,(s)} + H^{+}{}_{(aq)}$$

a. Some $HCl_{(aq)}$ is added to the equilibrium. What happens to the amount of solid $Al(H_2O)_3(OH)_3$? Explain.

b. The HCl is added at time t_1 and equililibrium is re-established at time t_2. On the axis below, sketch what happens to the reverse reaction rate.



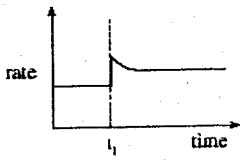
E3. Explain the above shifts using the concepts of reaction kinetics

51. Consider the following equilibrium:

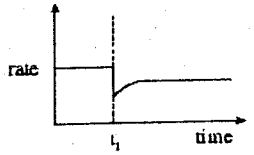
$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{(g)} + CO_{(g)}$$

Which of the following graphs best represents the forward rate of reaction when H_2O is added to the above equilibrium at time = t_1?

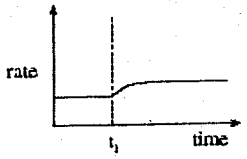
A.



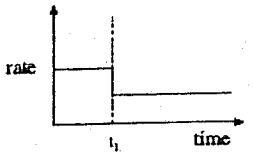
B.



C.



D.

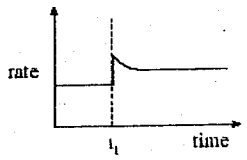


52. Consider the following equilibrium:

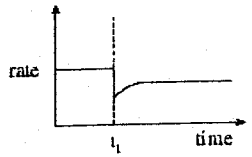
$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{(g)} + CO_{(g)}$$

Which of the following graphs best represents the forward reaction rate when the volume of the container is increased at time = t_1?

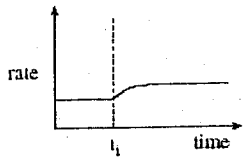
A.



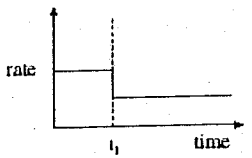
B.



C.



D.

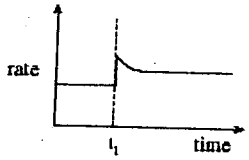


53. Consider the following equilibrium:

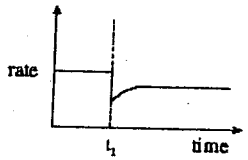
$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{\,(g)} + CO_{\,(g)}$$

Which of the following graphs best represents the reverse reaction rate when some H_2O is removed from the above equilibrium at time = t_1?

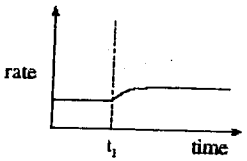
A.



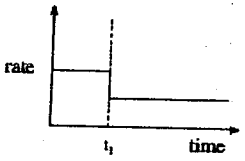
B.



C.



D.

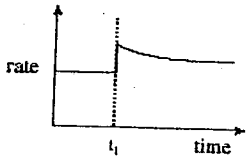


54. Consider the following:

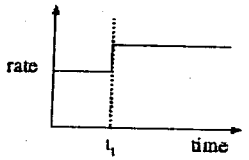
$$2SO_{2(g)} + O_{2\,(g)} \leftrightarrows 2SO_{3(g)} + \text{energy}$$

Which of the following graphs would show the **forward** reaction rate when a catalyst is added to the equilibrium at time = t_1?

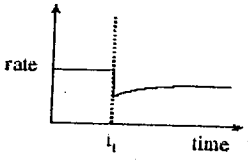
A.



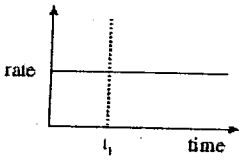
B.



C.



D.

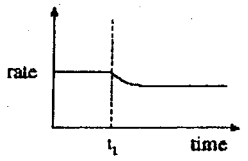


55. Consider the following equilibrium:

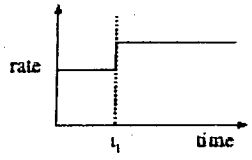
$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{\,(g)} + \text{energy}$$

Which of the following shows the **reverse** rate of reaction when some HBr (g) is removed at time = t_1?

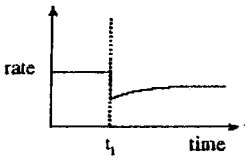
A.



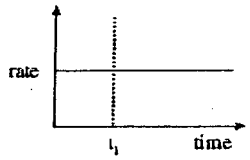
B.



C.



D.

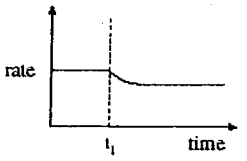


56. Consider the following equilibrium:

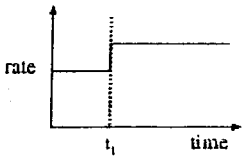
$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{\,(g)} + \text{energy}$$

Which of the following shows the forward reaction rate when the volume of the container is increased at time = t_1?

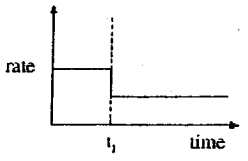
A.



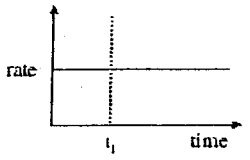
B.



C.



D.



57. Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \leftrightarrows PCl_{5(g)}$$

If the volume of the system is decreased, how will the reaction rates in the new equilibrium compare with the rates of the original equilibrium?

	Forward Rate	Reverse Rate
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

58. Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \leftrightarrows PCl_{5(g)}$$

If the temperature of the system is increased, how will the reaction rates in the new equilibrium compare with the rates of the original equilibrium?

	Forward Rate	Reverse Rate
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

59. Consider the following equilibrium:

$$2NF_{2\,(g)} \leftrightarrows N_2F_{4\,(g)}$$

The volume is decreased, with temperature constant.

a. Describe the shifts in setting up a new equilibrium, and relate to reaction rates.

b. Will the K_{eq} increase, decrease or stay the same because of this shock? Explain your answer.

E4. Identify the effect of a catalyst on dynamic equilibrium

60. What is the effect of adding a catalyst to an equilibrium system?

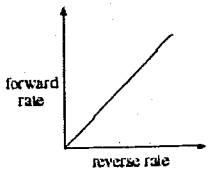
A. The value of E_a increases
B. The value K_{eq} increases
C. Forward and reverse reaction rates increase
D. Product concentrations increase

61. Consider the following reaction:

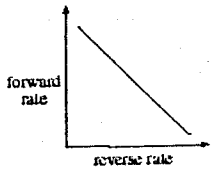
$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)}$$

Which of the following diagrams represents what happens to the forward and reverse reaction rates when the catalyst Fe_3O_4 is added?

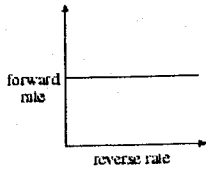
A.



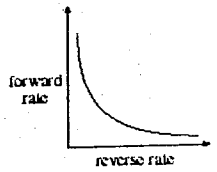
B.



C.



D.



62. The following equation represents the catalyzed decomposition of O_3 (ozone):

$$O_{(g)} + Cl_{(g)} + O_{3\,(g)} \leftrightarrows 2O_{2\,(g)} + Cl_{(g)}$$

Which of the following statements is true?

A. The catalyst O speeds up only the forward rate.
B. The catalyst Cl speeds up only the forward rate.
C. The catalyst O speeds up both the forward and reverse rates.
D. The catalyst Cl speeds up both the forward and reverse rates.

E5. Apply the concept of equilibrium to a commercial or industrial process

63. Consider the following reaction for the Haber Process for ammonia production:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2\,NH_{3\,(g)} \qquad \triangle H = -92\ kJ$$

The system is normally maintained at a temperature of approximately 500° C. Why is the temperature of 100°C not used?

A. The forward reaction would change from exothermic to endothermic and equilibrium would be lost.
B. The equilibrium would shift to the left, reducing % yield.
C. The equilibrium would shift to the right, reducing % yield.
D. Too few collisions would decrease the number of successful collisions thus reducing the % yield.

64. The Haber Process is used to produce ammonia commercially according to the following equilibrium:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)} \qquad \triangle H = -92\ kJ$$

Which of the following conditions will produce the highest yield of ammonia?

A. increase temperature and increase pressure
B. increase temperature and decrease pressure
C. decrease temperature and decrease pressure
D. decrease temperature and increase pressure

65. Limestone is decomposed to make quicklime (CaO) according to the following equilibrium:

$$CaCO_{3\,(s)} + 175\ kJ \leftrightarrows CaO_{(s)} + CO_{2\,(g)}$$

Which of the following conditions would produce the greatest yield of CaO?

	Temperature	Pressure
A.	low	low
B.	low	high
C.	high	low
D.	high	high

F1. Gather and interpret data on the concentration of reactants and products of a system at equilibrium

66. Consider the following equilibrium:

$$2SO_{2(g)} + O_{2\,(g)} \leftrightarrows 2SO_{3(g)} + \text{energy}$$

Initially, some SO_3 is placed into a 3.0 L container. At equilibrium there is 0.030 mol SO_2 present. What is the $[O_2]$ at equilibrium?

A. 0.0050 mol/L
B. 0.010 mol/L
C. 0.015 mol/L
D. 0.030 mol/L

67. Consider the following equilibrium:

$$Cl_{2(g)} + 2NO_{(g)} \leftrightarrows 2NOCl_{(g)} \qquad K_{eq} = 5.0$$

At equilibrium $[Cl_2] = 1.0$ M and $[NO] = 2.0$ M. What is the [NOCl] at equilibrium?

A. 0.80 M B. 0.89 M C. 4.5 M D. 10 M

68. Consider the following equilibrium:

$$2NH_{3\,(g)} \leftrightarrows N_{2\,(g)} + 3H_{2\,(g)}$$

Initially, some NH_3 is placed into a 1.0 L container and allowed to reach equilibrium. At equilibrium there is 0.030 mol N_2 present. What is the $[H_2]$ at this equilibrium?

A. 0.010 mol/L B. 0.030 mol/L C. 0.060 mol/L D. 0.090 mol/L

69. Consider the following:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2\,HI_{(g)}$$

Initially, some HI is placed into a 1.0 L container. At equilibrium there is 0.010 mol H_2, 0.010 mol of I_2 and 0.070 mol of HI present. How many moles of HI were initially placed into the container?

A. 0.060 mol B. 0.070 mol C. 0.080 mol D. 0.090 mol

70. Consider the following equilibrium and the table of experimental data:

$$N_2O_{4(g)} \leftrightarrows 2NO_{2(g)}$$

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

	Initial		Equilibrium	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
Trial 1	0.0400	0.0000	0.0337	0.0125
Trial 2	0.0200	0.0600	0.0429	0.0141

Which of the following represents the K_{eq} value?

A. 4.64×10^{-3} B. 3.71×10^{-1} C. 7.42×10^{-1} D. 2.16×10^{2}

71. Consider the following equilibrium:

$$Cr_2O_7^{-2}{}_{(aq)} + 2OH^-{}_{(aq)} \leftrightarrows 2CrO_4^{-2}{}_{(aq)} + H_2O_{(l)} \quad K_{eq} = 4.14$$

The concentration of ions at equilibrium was measured at a specific temperature and found to be $[Cr_2O_7^{-2}] = 0.100$ M and $[OH^-] = 0.020$ M. What is the equilibrium $[CrO_4^{-2}]$?

A. 1.7×10^{-4} M B. 3.1×10^{-3} M C. 1.3×10^{-2} M D. 2.0×10^{-1} M

F2. Write the expression for the equilibrium constant when given the equation for either a homogeneous or heterogeneous equilibrium system

72. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2\,HI_{(g)} \quad K_{eq} = 50.0$$

What is the value for K_{eq} for the same reaction rewritten as

$$2\,HI_{(g)} \leftrightarrows H_{2(g)} + I_{2(g)}$$

A. -50.0 B. 0.0200 C. 25.0 D. 50.0

73. Consider the following equilibrium:

$$2\,CrO_4^{-2}{}_{(aq)} + 2\,H^+{}_{(aq)} \leftrightarrows Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)}$$

What is the K_{eq} expression?

A. $\dfrac{[CrO_4^{2-}]^2[H^+]^2}{[Cr_2O_7^{2-}]}$

B. $\dfrac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$

C. $\dfrac{[Cr_2O_7^{2-}]}{[2CrO_4^{2-}][2H^+]}$

D. $\dfrac{[Cr_2O_7^{2-}][H_2O]}{[CrO_4^{2-}]^2[H^+]^2}$

74. Consider the following equilibrium:

$$Fe_2O_{3(s)} + 3CO_{(g)} \leftrightarrows 2\,Fe_{(s)} + 3\,CO_{2(g)}$$

Identify the equilibrium constant expression.

A. $K_{eq} = \dfrac{[CO_2]^3}{[CO]^3}$

B. $K_{eq} = \dfrac{[3CO_2]}{[3CO]}$

C. $K_{eq} = \dfrac{[3CO_2]^3[2Fe]^2}{[3CO]^3[Fe_2O_3]}$

D. $K_{eq} = \dfrac{[CO]^3[Fe_2O_3]}{[CO_2]^3[Fe]^2}$

75. Consider the following equilibrium:

$$CaCO_{3(s)} + 2HF_{(g)} \leftrightarrows CaF_{2(s)} + H_2O_{(g)} + CO_{2(g)}$$

Which of the following represents the equilibrium $[H_2O]$?

A. $[H_2O] = \dfrac{[HF]^2}{K_{eq}[CO_2]}$

B. $[H_2O] = \dfrac{K_{eq}[HF]^2}{[CO_2]}$

C. $[H_2O] = \dfrac{[HF]^2[CaCO_3]}{K_{eq}[CO_2]CaF_2}$

D. $[H_2O] = \dfrac{K_{eq}[HF]^2[CaCO_3]}{[CO_2]CaF_2}$

F3. Relate the equilibrium position to the vaue of K_{eq} and vice versa

76. A container is initially filled with pure SO_3. After a period of time, the following equilibrium is established:

$$2\,SO_{2(g)} + O_{2(g)} \leftrightarrows 2\,SO_{3(g)} \quad K_{eq} = 7.0 \times 10^{25}$$

What does this equilibrium mixture contain?

A. mostly products B. mostly reactants

C. 3/5 reactants and 2/5 products D. equal amounts of reactants and products

77. Which of the following reactions will proceed furthest toward completion?

A. $Si_{(s)} + O_{2(g)} \leftrightarrows SiO_{2(s)}$ $K_{eq} = 2.0 \times 10^{142}$

B. $2HBr_{(g)} \leftrightarrows H_{2(g)} + Br_{2(g)}$ $K_{eq} = 7.0 \times 10^{-20}$

C. $2H_2O_{(g)} \leftrightarrows 2H_{2(g)} + O_{2(g)}$ $K_{eq} = 7.3 \times 10^{-18}$

D. $C_2H_{4(g)} + H_{2(g)} \leftrightarrows C_2H_{6(g)}$ $K_{eq} = 9.0 \times 10^{19}$

78. In which of the following equilibria does the concentration of reactants equal the concentration of products?

A. $N_2O_{4(g)} \leftrightarrows 2NO_{2(g)}$ $K_{eq} = 0.71$

B. $H^+{}_{(aq)} + OH^-{}_{(aq)} \leftrightarrows H_2O_{(l)}$ $K_{eq} = 1.0 \times 10^{14}$

C. $CO_{2(g)} + H_{2(g)} \leftrightarrows CO_{(g)} + H_2O_{(g)}$ $K_{eq} = 0.279$

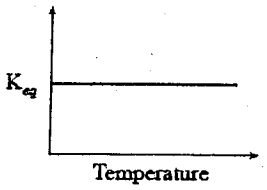
D. $H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)}$ $K_{eq} = 1.00$

F4. Predict the effect (or lack of effect) on the value of K_{eq} of changes in the following factors:

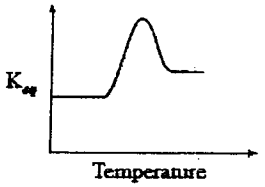
- temperature
- pressure
- concentration
- surface area
- catalyst

79. Which of the following best describes the relationship between K_{eq} and temperature for an endothermic forward reaction?

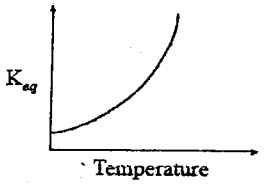
A.



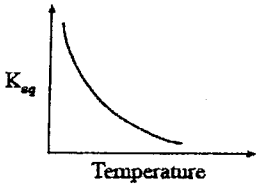
B.



C.

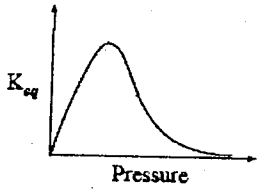


D.

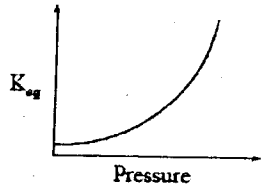


80. The relationship between K_{eq} and the pressure of a gaseous equilibrium at constant temperature can be best described by:

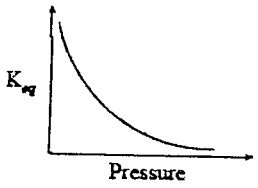
A.



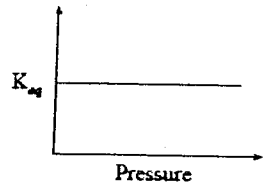
B.



C.

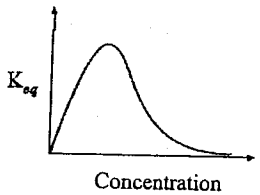


D.

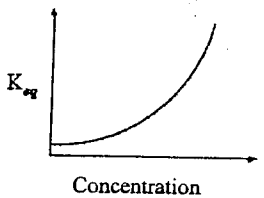


81. The relationship between K_{eq} and the concentrations of reactants in the same equilibrium system at constant temperature can best be described by

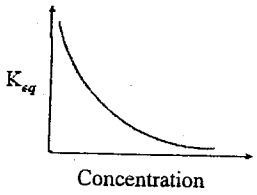
A.



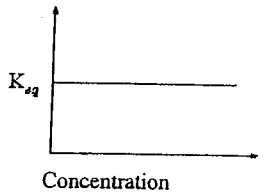
B.



C.



D.



82. What will cause the K_{eq} for an exothermic reaction to increase?

A. increasing [reactant]
B. decreasing [product]
C. increasing temperature
D. decreasing temperature

83. What will cause the value of K_{eq} for an endothermic reaction to increase?

A. increase [products]
B. decrease [products]
C. increase the temperature
D. decrease the temperature

84. What will cause the value of K_{eq} for an exothermic reaction to decrease?

A. increasing the pressure
B. increasing the temperature
C. decreasing the pressure
D. decreasing the temperature

85. Consider the following equilibrium:

$$N_2O_{4(g)} + \text{energy} \leftrightarrows 2\,NO_{2(g)}$$

How are K_{eq} and $[N_2O_4]$ affected by the addition of Ne (an inert gas) into the container at constant volume?

	K_{eq}	$[N_2O_4]$
A.	no change	no change
B.	no change	increases
C.	increases	decreases
D.	decreases	increases

86. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \leftrightarrows 2NOCl_{(g)} \qquad \Delta H = -77kJ$$

In which direction will the equilibrium shift and what happens to the value of K_{eq} when the volume of the system is increased?

	Shift	K_{eq}
A.	right	increases
B.	right	stays constant
C.	left	stays constant
D.	left	decreases

87. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \leftrightarrows 2NOCl_{(g)} \qquad \Delta H = -77kJ$$

In which direction will the equilibrium shift and what happens to the value of K_{eq} when the temperature of the system is decreased?

	Shift	K_{eq}
A.	right	increases
B.	right	stays constant
C.	left	stays constant
D.	left	decreases

88. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \leftrightarrows 2NOCl_{(g)}$$

In which direction will the equilibrium shift and what happens to the value of K_{eq} when the temperature of the system is increased?

	Shift	K_{eq}
A.	right	increases
B.	right	stays constant
C.	left	stays constant
D.	left	decreases

89. The following equilibrium is established in a 1.0 L container:

$$\text{heat} + CH_{4\,(g)} + 2H_2S_{\,(g)} \leftrightarrows CS_{2\,(g)} + 4H_{2\,(g)}$$

If some CH_4 is added to the system, what happens to the net concentration of CH_4 and the value of K_{eq}?

	$[CH_4]$	K_{eq}
A.	decreased	increased
B.	increased	increased
C.	decreased	remains constant
D.	increased	remains constant

90. The following equilibrium is established in a 1.0 L container:

$$\text{heat} + CH_{4\,(g)} + 2H_2S_{\,(g)} \leftrightarrows CS_{2\,(g)} + 4H_{2\,(g)}$$

If some heat is removed from the system, what happens to the net concentration of CH_4 and the value of K_{eq}?

	$[CH_4]$	K_{eq}
A.	decreased	increased
B.	increased	decreased
C.	decreased	remains constant
D.	increased	remains constant

91. The following equilibrium is established in a 1.0 L container:

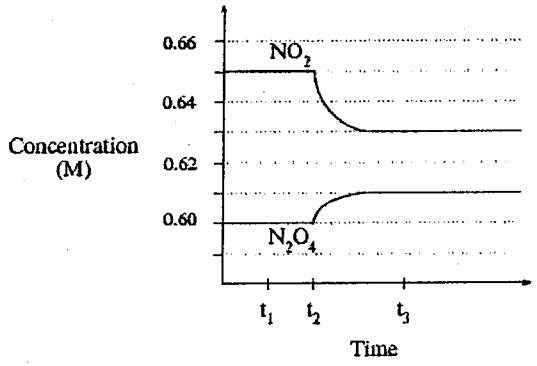
$$\text{heat} + CH_{4\,(g)} + 2H_2S_{\,(g)} \leftrightarrows CS_{2\,(g)} + 4H_{2\,(g)}$$

If the volume of the container is reduced to 0.50 L, what happens to the net concentration of CH_4 and the value of K_{eq}?

	$[CH_4]$	K_{eq}
A.	decreased	increased
B.	increased	decreased
C.	decreased	remains constant
D.	increased	remains constant

92. Consider the following diagram for the equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad \Delta H = +59\ kJ$$



a. Calculate the value of K_{eq} at t_1.

b. Calculate the value of K_{eq} at t_3.

92.

c. What stress was applied at time t_2? Explain.

Stress: _____

Explanation:

F5. Calculate the value of K_{eq} given the equilibrium concentration of all species

93. Consider the following equilibrium:

$$PCl_{5\,(g)} \leftrightarrows PCl_{3\,(g)} + Cl_{2\,(g)} \qquad Keq = 9.0 \times 10^{-2}$$

In a 1.0 L container an equilibrium mixture contains 6.0×10^{-3} mol PCl_5 and 1.0×10^{-2} mol PCl_3. How many moles of Cl_2 are also present at equilibrium?

A. 5.4×10^{-6} B. 6.7×10^{-4} C. 5.4×10^{-2} D. 1.5×10^{-1}

94. Consider the following equilibrium:

$$PCl_{5\,(g)} \leftrightarrows PCl_{3\,(g)} + Cl_{2\,(g)} \qquad Keq = 9.0 \times 10^{-3}$$

In a 1.0 L container an equilibrium mixture contains 2.5×10^{-3} mol PCl_5, 1.0×10^{-2} mol PCl_3 and 1.0×10^{-2} mol of Cl_2. How does the equilibrium shift and why?

A. $K_{eq} > K_{trial}$ and equilibrium shifts left B. $K_{eq} > K_{trial}$ and equilibrium shifts right
C. $K_{eq} < K_{trial}$ and equilibrium shifts left D. $K_{eq} < K_{trial}$ and equilibrium shifts right

95. Consider the following:

$$N_2O_{4\,(g)} \leftrightarrows 2\,NO_{2\,(g)}$$

An equilibrium mixture contains 4.0×10^{-2} mol of N_2O_4 and 1.5×10^{-2} mol of NO_2 in a 1.0 L flask. What is the K_{eq}?

A. 5.6×10^{-3} B. 3.8×10^{-1} C. 7.5×10^{-1} D. 1.8×10^{2}

96. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \leftrightarrows CH_3OH_{(g)}$$

At equilibrium it was found that [CO] = 0.105 mol/L, [H_2] = 0.250 mol/L and [CH_3OH] = 0.00261mol/L. Which of the following is the equilibrium constant value?

A. 9.94×10^{-2} B. 0.398 C. 2.51 D. 10.0

97. Consider the following equilibrium:

$$CH_{4\,(g)} + H_2O_{(g)} \leftrightarrows CO_{(g)} + 3H_{2\,(g)} \qquad K_{eq} = 5.67$$

An equilibrium mixture of this system was found to contain the following concentrations: [CH_4] = 0.59 M, [H_2O] = 0.63 M, [CO] = 0.25 M. What was the equilibrium [H_2] ?

A. 0.26 M B. 0.64 M C. 2.0 M D. 8.4 M

98. Consider the following equilibrium:

$$C_{(s)} + H_2O_{(l)} \leftrightarrows CO_{(g)} + H_{2\,(g)}$$

At equilibrium, 4.0×10^{-2} mol H_2, 4.0×10^{-2} mol CO, 1.0×10^{-2} mol H_2O and 1.0×10^{-2} mol C were present in a 1.0 L container. What is the value of K_{eq}?

99. Consider the following equlibrium:

$$CH_{4\,(g)} + H_2O_{(l)} \leftrightarrows CO_{(g)} + 3H_{2\,(g)}$$

At equilibrium, 1.2 mol CH_4, 1.2 mol H_2O, 0.080 mol CO and 0.040 mol H_2 are present in a 1.0 L container. What is the value of K_{eq}?

A. 4.3×10^{-6} B. 3.6×10^{-6} C. 2.7×10^{-3} D. 2.3×10^{5}

F6. Calculate the value of K_{eq} given the initial concentrations of all species and one equilibrium concentration

100. Consider the following equilibrium:

$$2N_2O_{(g)} \leftrightarrows 2\,N_{2\,(g)} + O_{2\,(g)}$$

Initially, 0.800 mol N_2O is placed in a 1.0 L container. At equilibrium, the [N_2] is found to be 0.780 M. What is the value of K_{eq}?

A. 1.7×10^{-3} B. 1.5×10^{1} C. 5.9×10^{2} D. 1.2×10^{3}

101. Consider the following equilibrium:

$$2NO_{(g)} + 2H_{2\,(g)} \leftrightarrows N_{2\,(g)} + 2H_2O_{(g)}$$

Initially, 0.100 mol NO, 0.0500 mol H_2 and 0.100 mol H_2O are placed in a 1.0 L container. At equilibrium, [H_2O] = 0.138 M. What is the value of K_{eq}?

A. 3.5 B. 6.5×10^{2} C. 1.5×10^{-3} D. 1.3×10^{3}

102. Consider the following equlibrium:

$$CO_{2\,(g)} + 2H_2O_{(l)} \leftrightarrows CH_{4\,(g)} + 2O_{2\,(g)}$$

Initally, 0.450 moles of CO_2, 0.480 moles of H_2O, 0.250 moles of CH_4 and 0.500 moles of O_2 are placed in a 5.00 L container and allowed to reach equilibrium.

a. When equilibrium is reached, the $[O_2]$ is 0.0700 M. Calculate the K_{eq} of the equilibrium.

b. Are reactants or products favored? _____ Explain your answer.

c. How would the following stresses affect the equilibrium? Complete the table below using the arrows indicated.

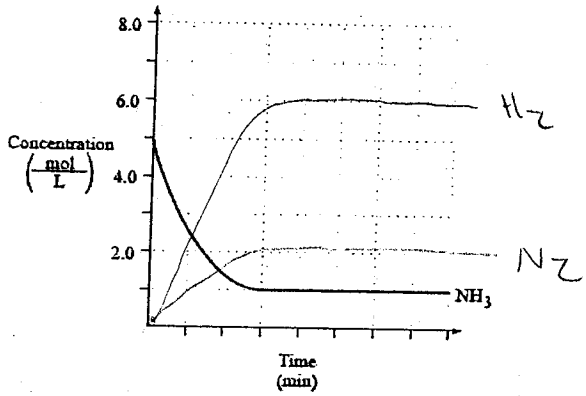
shift left (from shock) ← increased rate of forward reaction after equilibrium reestablished ↑
shift right (from shock) → decreased rate of forward reaction after equlibrium reestablished ↓
no shift - no change in rate -

Stress (shock) introduced	Equilibrium shift	$[CO_2]$ (after shifting)	Forward reaction rate (after equilibrium is back)
Decrease pressure			
add $CH_{4\,(g)}$			
increase temperature			
add catalyst			
increase volume of container			
remove some $CO_{2\,(g)}$			

103. Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{energy}$$

A 1.00 L container is filled with 5.0 mol NH_3 and the system proceeds to equilibrium as indicated by the graph.



a. Draw and label the graph for N_2 and H_2.

b. Calculate the K_{eq} for $N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3\,(g)}$

104. Consider the following equilibrium:

$$3I_{2\,(g)} + 3\,F_{2(g)} \leftrightarrows 2IF_{2\,(g)} + I_4F_{2\,(g)}$$

Initially 2.00×10^{-1} mol of I_2 and 3.00×10^{-1} mol of F_2 and 1.00×10^{-1} mol of I_4F_2 are put into a 10.00 L flask. At equilibrium $[IF_2]$ is 2.00×10^{-3} M Calculate the value of K_{eq}.

105. Consider the following:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{\,(g)}$$

Initally, 0.200 mol of H_2 and 0.200 mol I_2 are added to an empty 2.00 L container. At equilibrium $[I_2]$ is 0.020 mol/L. Calculate the value of K_{eq}.

106. Consider the following equilibrium:

$$SO_{3\,(g)} + NO_{\,(g)} \leftrightarrows NO_{2\,(g)} + SO_{2\,(g)}$$

In an experiment, 0.100 moles of SO_3 and 0.100 moles of NO are placed in a 1.00 L container. When equilibrium is achieved, $[NO_2] = 0.0414$ mol/L. Calculate the K_{eq} value.

F7. Calculate the equilibrium concentrations of all species given the value of K_{eq} and the initial concentrations

107. Consider the following equilibrium:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{\,(g)} \qquad K_{eq} = 49.5 \text{ at } 440^{o}\text{ C}$$

If 5.0 M HI is initally placed into a container at 440° C, what will be the equilibrium [HI]?

A. 0.33 M B. 3.9 M C. 4.4 M D. 4.8 M

108. Consider the following:

$$H_{2\,(g)} + Br_{2\,(g)} \leftrightarrows 2\,HBr_{(g)} \qquad K_{eq} = 12.0$$

Initially, 0.080 mol H_2 and 0.080 mol of Br_2 are placed into a 4.00 L container. What is the [HBr] at equilibrium?

109. Consider the following equilibrium:

$$N_{2\,(g)} + O_{2\,(g)} \leftrightarrows 2NO_{(g)} \qquad K_{eq} = 0.0095$$

Initially, 0.15 mol N_2 and 0.15 mol O_2 were placed in a 1.0 L container. Calculate the concentration of all species at equilibrium.

110. Consider the following equilibrium:

$$NH_2COONH_{4\,(s)} \leftrightarrows CO_{2\,(g)} + 2NH_{3\,(g)} \qquad K_{eq} = 0.108$$

Initially, 2.00 moles of NH_2COONH_4 are placed in a 500.0 mL container. Calculate $[NH_3]$ at equilibrium.

F8. Determine whether a system is at equilibrium, and if not, in which direction it will shift to reach equilibrium when given a set of concentrations for reactants and products

111. Consider the following equilibrium:

$$2NOCl_{(g)} \leftrightarrows 2NO_{(g)} + Cl_{2(g)}$$

A flask is filled with NOCl, NO and Cl_2. Initially, there was a total of 5.0 moles of gases present. When equilibrium is reached, there is a total of 6.0 moles of gases present. Which of the following explains this observation?

A. The reaction shifted left because $K_{trial} > K_{eq}$.
B. The reaction shifted right because $K_{trial} > K_{eq}$.
C. The reaction shifted left because $K_{trial} < K_{eq}$.
D. The reaction shifted right because $K_{trial} < K_{eq}$.

112. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \leftrightarrows CH_3OH_{(g)}$$

Some CO, H_2 and CH_3OH were placed in a 1.0 L container. When equilibrium was established, the [CO] had increased. Which of the following is true?

A. Trial $K_{eq} > K_{eq}$ so reaction shifted left to reach equilibrium.
B. Trial $K_{eq} < K_{eq}$ so reaction shifted left to reach equilibrium.
C. Trial $K_{eq} > K_{eq}$ so reaction shifted right to reach equilibrium.
D. Trial $K_{eq} < K_{eq}$ so reaction shifted right to reach equilibrium.

113. Consider the following equilibrium:

$$CO_{(g)} + H_2O_{(g)} + \text{energy} \leftrightarrows CO_{2(g)} + H_{2(g)} \qquad K_{eq} = 0.425$$

Initially there are 0.180 mol of CO, 0.180 mol of H_2O, 0.160 mol of CO_2 and 0.160 mol of H_2 in a 2.00 L container.

a. Is the container of gases at equilibrium? If not, which way will the equilibrium shift to reach equilibrium?

b. Calculate the [CO] and [CO_2] when equilibrium is reached.

c. What could be done to the equilibrium to increase the K_{eq}?

114. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2\,HI_{(g)} \qquad K_{eq} = 144$$

Initially 0.480 mol of HI, 0.160 mol of H_2 and 0.160 mol of I_2 are placed in a 2.00 L container and allowed to reach equilibrium.

a. Which way will the equilibrium shift in order to reach equilibrium?

b. What will be the [HI] at equilibrium?

115. Consider the following equilibrium:

$$N_2O_{4(g)} \leftrightarrows 2\,NO_2 \qquad K_{eq} = 9.5 \times 10^{-3}$$

Initially, 0.060 mol N_2O_4 and 0.020 mol NO_2 are placed in a 2.00 L container.
Determine the direction in which the reaction will proceed in order to reach equilibrium.

A. It will shift to the right because $K_{trial} > K_{eq}$.
B. It will shift to the left because $K_{trial} > K_{eq}$.
C. It will shift to the right because $K_{trial} < K_{eq}$.
D. It will shift to the left because $K_{trial} < K_{eq}$.

116. Given the following reaction:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)} \qquad K_{eq} = 64$$

Equal moles of H_2, I_2 and HI are placed in a 1.0 L container. Use calculations to determine the direction the reaction will proceed in order to reach equilibrium.

117. Consider the following equilibrium:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{(g)} \qquad K_{eq} = 49.5 \text{ at } 440^{o}\,C$$

If 0.120 M H_2, 0.120 M I_2 and 0.844 M HI are initially placed into a container at 440° C, which of the following is true as equilibrium is approached?
A. $[I_2]$ decreases significantly
B. [HI] decreases significantly
C. $[H_2]$ decreases significantly
D. $[H_2]$ remains the same.

F9 Review

118. Consider the following:

$$2HBr_{(g)} \leftrightarrows H_{2(g)} + Br_{2(g)}$$

Initially, HBr is added to an empty flask. How do the rate of the reverse reaction and the [HBr] change as the system proceeds to equilibrium?

	Reverse Rate	[HBr]
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

119. Two experiments were performed involving the following equilibrium. The temperature was the same in both experiments.

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{\,(g)}$$

In experiment A, 1.0 M H_2 and 1.0 M I_2 were initially added to a flask and equilibrium was established. In experiment B, 2.0 M HI was initially added to a second flask and equilibrium was established. Which of the following statements is always true about the equilibrium concentrations?

A. $[H_2] = [HI]$ in experiment A
B. $[HI] = 2[H_2]$ in experiment A
C. $[HI]$ in experiment A = $[HI]$ in experiment B.
D. $[HI]$ in experiment A = $1/2\,[I_2]$ in experiment B.

120. In which of the following equations does entropy most favour reactants?

A. $^1/_2N_{2\,(g)} + O_{2\,(g)} \leftrightarrows NO_{2\,(g)}$
B. $4PH_{3\,(g)} \leftrightarrows P_{4\,(g)} + 6\,H_{2\,(g)}$
C. $NH_4Cl_{\,(s)} \leftrightarrows NH_4^{+}{}_{(aq)} + Cl^{-}{}_{(aq)}$
D. $SnO_{2\,(s)} + 2H_{2\,(g)} \leftrightarrows Sn_{\,(s)} + 2H_2O_{\,(g)}$

121. When the temperature of an endothermic equilibrium is increased, which of the following will happen?

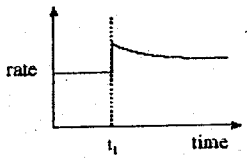
A. Equilibrium shifts left and [product] increases
B. Equilibrium shifts left and [product] decreases
C. Equilibrium shifts right and [reactant] increases
D. Equilibrium shifts right and [reactant] will decrease

122. Consider the following equilibrium:

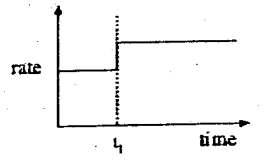
$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{\,(g)} + \text{energy}$$

Which of the following shows the **reverse** rate of reaction when the volume is decreased at time = t_1?

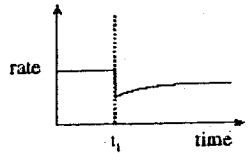
A.



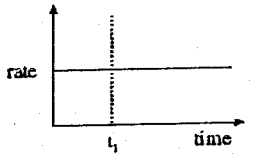
B.



C.



D.

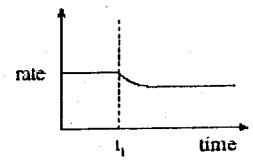


123. Consider the following equilibrium:

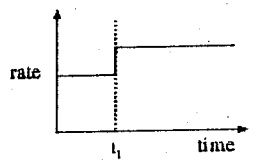
$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{\,(g)} + \text{energy}$$

Which of the following shows the forward reaction rate when the temperature is decreased at time = t_1?

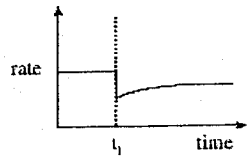
A.



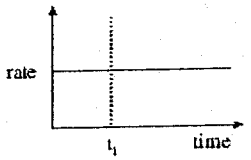
B.



C.



D.



124. Consider the following reaction for the Haber Process for ammonia production:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2\,NH_{3\,(g)} \qquad \Delta H = -92\ kJ$$

The system is normally maintained at a temperature of approximately 500° C. Why is the temperature of 1000°C not used?

A. The forward reaction would change from exothermic to endothermic and equilibrium would be lost.
B. The equilibrium would shift to the left, reducing % yield.
C. The equilibrium would shift to the right, reducing % yield.
D. Too many collisions would decrease the number of successful collisions thus reducing the % yield.

125. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)} \qquad \Delta H = -71.9\ kJ$$

Which of the following would allow you to conclude that the system has reached equilibrium?

A. The gas pressure remains constant
B. $[H_{2(g)}] = 2[HI_{(g)}]$
C. $[H_{2(g)}] = [I_{2(g)}]$
D. The temperature remains constant

126. Which reaction has the following equlibrium expression?

$$K_{eq} = \frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7}$$

A. $4\,NH_{3\,(g)} + 7O_{2\,(g)} \leftrightarrows 4\,NO_{2\,(g)} + 6\,H_2O_{\,(g)}$
B. $4\,NH_{3\,(g)} + 7O_{2\,(g)} \leftrightarrows 4\,NO_{2\,(g)} + 6\,H_2O_{\,(l)}$
C. $4\,NO_{2\,(g)} + 6\,H_2O_{\,(l)} \leftrightarrows 4\,NH_{3\,(g)} + 7O_{2\,(g)}$
D. $4\,NO_{2\,(g)} + 6\,H_2O_{\,(g)} \leftrightarrows 4\,NH_{3\,(g)} + 7O_{2\,(g)}$

127. Consider the following equilbrium:

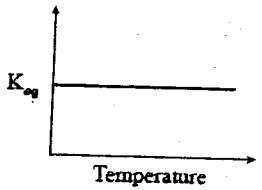
$$CO_{2(g)} + 2H_2O_{(g)} \leftrightarrows CH_{4(g)} + O_{2(g)}$$

Which of the options below indicates that the reactants are favoured?

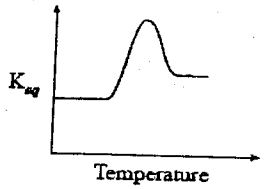
A. K_{eq} is zero
B. K_{eq} is very large
C. K_{eq} is slightly less than 1
D. K_{eq} is slightly greater than 1

128. Which of the following best describes the relationship between K_{eq} and temperature for an exothermic forward reaction?

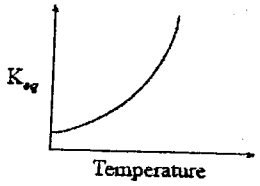
A.



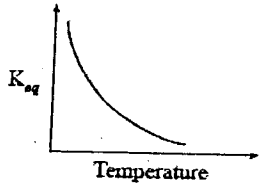
B.



C.



D.



129. What will cause the value of K_{eq} for an exothermic reaction to increase?

A. decrease the volume
B. increase the volume
C. increase the temperature
D. decrease the temperature

130. Consider the following equilibrium:

$$2CrO_4^{-2}{}_{(aq)} + 2H^+{}_{(aq)} \leftrightarrows Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)}$$

A solution of $Ba(NO_3)_2$ is added, and a precipitate of $BaCrO_4$ forms. What could you add to the solution to dissolve the precipitate, and predict the equilibrium shift and change to K_{eq}.

Add	Equilibrium shift	K_{eq}
A. $Cr_2O_7^{-2}$	left	decreases
B. CrO_4^{-2}	right	increases
C. H_2O	left	remains constant
D. H^+	right	remains constant

131. Consider the following equilibrium:

$2POCl_{3\,(g)} \rightleftarrows 2PCl_{3\,(g)} + O_{2\,(g)}$

3.00 moles of $POCl_3$ were put into a 2.00 L container and allowed to reach equilibrium. At equilibrium $[O_2] = 0.0250$ M.

a. Use the concepts of entropy and enthalpy to predict whether or not the forward reaction will be endothermic or exothermic.

b. List three ways that you could shift the equilibrium to the product side.

(1)

(2)

(3)

c. Calculate the K_{eq} for the above container when equilibrium is reached.

132. Consider the following equlibrium:

$2CrO_4^{-2}{}_{(aq)} + 2H^+{}_{(aq)} \rightleftarrows Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)}$

Initally, 0.450 moles of $Cr_2O_7^{-2}$, 0.480 moles of H_2O, 0.250 moles of CrO_4^{-2} and 0.500 moles of H^+ are placed in a 5.00 L container and allowed to reach equilibrium.

a. When equilibrium is reached, the $[Cr_2O_7^{-2}]$ is 0.100 M. Calculate the K_{eq} of the equilibrium.

b. Are reactants or products favored? _____ Explain your answer.

c. How would the following stresses affect the equilibrium? Complete the table below using the arrows indicated.

shift left (from shock) ← increased rate of forward reaction after equilibrium reestablished ↑
shift right (from shock) → decreased rate of forward reaction after equlibrium reestablished ↓
no shift - no change in rate

Stress (shock) introduced	Equilibrium shift	$[Cr_2O_7^{-2}]$ (after shifting)	Forward reaction rate (after equilibrium is back)
Decrease pressure			
add $CrO_4^{-2}{}_{(aq)}$			
increase temperature			
add inhibitor			
increase volume of container			
remove some $Cr_2O_7^{-2}{}_{(aq)}$			

133. Consider the following equilibrium:

$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{\,(g)} + CO_{\,(g)} \qquad K_{eq} = 0.36$$

Initially, 0.240 moles and CO_2, 0.240 moles of H_2, 0.150 moles of H_2O and 0.150 moles of CO are placed in a 3.00 L container.

a. Is the container at equilibrium? _____
If not, which way will the equilibrium shift in order to reach equilibrium.
Support your answer with calculations.

b. Calculate the [CO] and [CO_2] at equilibrium.