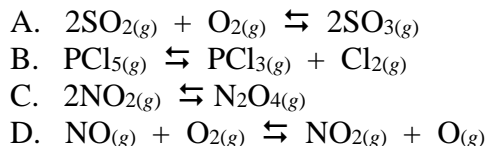


# Review Package: Equilibrium Theory

1. All of the following reactions are at equilibrium. The reaction which **does not** undergo an equilibrium shift when **only** the volume is changed is



2. Consider the following equilibrium system:



When the new equilibrium is established after adding some more  $\text{O}_2$ , which one of the following changes will have occurred?

- A.  $[\text{HF}]$  will have increased and  $[\text{OF}_2]$  will have decreased.  
B.  $[\text{O}_2]$  will have decreased and  $[\text{OF}_2]$  will have increased.  
C.  $[\text{HF}]$  will have decreased and  $[\text{OF}_2]$  will have increased.  
D.  $[\text{O}_2]$  and  $[\text{OF}_2]$  will remain unchanged.
3. Consider the following equilibrium system:



If the temperature of the system is increased,

- A.  $K_{\text{eq}}$  will decrease  
B.  $\Delta H$  will decrease  
C.  $K_{\text{eq}}$  will increase  
D.  $\Delta H$  will increase
4. Consider the following equilibrium system:

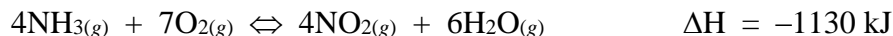


After a catalyst has been added to the system

- A.  $K_{\text{eq}}$  cannot now be determined  
B.  $K_{\text{eq}}$  increases  
C.  $K_{\text{eq}}$  remains the same as before  
D.  $K_{\text{eq}}$  decreases

## Review Package: Equilibrium Theory

11. Given the reaction



which of the following sets of conditions will give the greatest yield of  $\text{NO}_2$ ?

- A. Low pressure and low temperature
  - B. Low pressure and high temperature
  - C. High pressure and high temperature
  - D. High pressure and low temperature
12. What is the value of the equilibrium constant,  $K$ , for the reaction



if at equilibrium,  $[\text{A}] = 0.0300 \text{ M}$ ,  $[\text{B}] = 0.0400 \text{ M}$ , and  $[\text{C}] = 1.20 \text{ M}$ ?

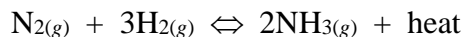
- A.  $8.33 \times 10^{-3}$
  - B.  $1.20 \times 10^3$
  - C.  $1.00 \times 10^4$
  - D.  $2.00 \times 10^4$
13. Which one of the sets of conditions below will give the greatest yield of  $\text{SO}_{3(g)}$  given the following equilibrium reaction?



- A. Low pressure and low temperature.
  - B. High pressure and low temperature.
  - C. Low pressure and high temperature.
  - D. High pressure and high temperature.
14. In which one of the following situations will an equilibrium constant change?
- A. When a catalyst is used.
  - B. When the temperature of the system is changed.
  - C. When the concentrations of the products are changed.
  - D. When the concentrations of the reactants are changed.
15. Which one of the following occurs when the pressure is increased in a chemical reaction involving gaseous reactants and products?
- A. Increasing the pressure has no effect on the equilibrium.
  - B. The equilibrium is always displaced to form more of the products.
  - C. The equilibrium is always displaced to form more of the reactants.
  - D. The equilibrium is displaced in the direction in which the number of moles of molecules decreases.

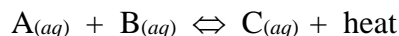
## Review Package: Equilibrium Theory

18. For the reaction



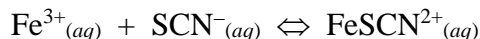
which one of the following changes will increase the yield of  $\text{NH}_{3(g)}$ ?

- A. Introduce a catalyst.
  - B. Increase the temperature.
  - C. Reduce the partial pressure of nitrogen.
  - D. Reduce the volume of the system at constant temperature.
19. For the equation



how will the equilibrium constant be affected by a temperature increase?

- A. The equilibrium constant increases.
  - B. The equilibrium constant decreases.
  - C. The equilibrium constant is unchanged.
  - D. There are insufficient data to make a prediction.
21. Consider the following system:

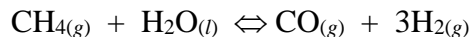


A solution of  $\text{Fe}(\text{NO}_3)_3$  is added to a solution of  $\text{KSCN}$ . As equilibrium is being established, the

- A.  $[\text{Fe}^{3+}]$  increases and the  $[\text{FeSCN}^{2+}]$  increases.
  - B.  $[\text{Fe}^{3+}]$  decreases and the  $[\text{FeSCN}^{2+}]$  increases.
  - C.  $[\text{Fe}^{3+}]$  increases and the  $[\text{FeSCN}^{2+}]$  decreases.
  - D.  $[\text{Fe}^{3+}]$  decreases and the  $[\text{FeSCN}^{2+}]$  decreases.
22. A system has reached equilibrium when
- A. maximum entropy has been achieved.
  - B. minimum enthalpy has been achieved.
  - C. the rate of forward and reverse reactions is zero.
  - D. the concentration of reactants and products has stopped changing.
23. Entropy is a measure of
- A. disorder.
  - B. kinetic energy.
  - C. potential energy.
  - D. change in potential energy.

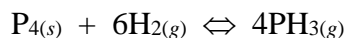
## Review Package: Equilibrium Theory

24. Consider the following system at equilibrium:



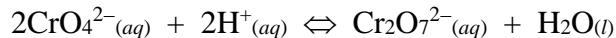
Which of the following chemicals, when added to the above equilibrium, would result in a decrease in  $[\text{H}_2(g)]$ ?

- A.  $\text{H}_2$
  - B.  $\text{CO}$
  - C.  $\text{CH}_4$
  - D.  $\text{H}_2\text{O}$
29. An equilibrium system is described as 'dynamic' because at equilibrium
- A. forward and reverse reactions continue.
  - B. pressure and temperature do not change.
  - C. maximum randomness has been achieved.
  - D. concentrations of all chemical species remain constant.
30. In which of the following systems would the tendencies toward minimum enthalpy and maximum entropy be in opposition to each other?
- A.  $\text{H}_2\text{O}(l) + \text{heat} \rightarrow \text{H}_2\text{O}(g)$
  - B.  $\text{NaOH}(s) \rightarrow \text{NaOH}(aq) + \text{heat}$
  - C.  $\frac{1}{2}\text{N}_2(g) + \text{O}_2(g) + \text{heat} \rightarrow \text{NO}_2(g)$
  - D.  $\text{Na}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq) + \frac{1}{2}\text{H}_2(g) + \text{heat}$
31. Consider the following system:



Which of the following changes would cause the above system to shift right?

- A. Add more  $\text{P}_4$ .
  - B. Add a catalyst.
  - C. Increase pressure.
  - D. Increase surface area.
32. Given the following system:



Which of the following chemicals, when added to the above system at equilibrium, would result in a decrease in  $[\text{CrO}_4^{2-}]$ ?

- A.  $\text{NaOH}$
- B.  $\text{HNO}_3$
- C.  $\text{Na}_2\text{CrO}_4$
- D.  $\text{Na}_2\text{Cr}_2\text{O}_7$

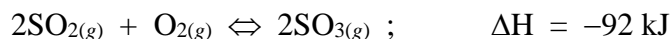
## Review Package: Equilibrium Theory

37. Equilibrium is considered to be a “dynamic” process because
- A. it occurs in a closed system.
  - B. equilibrium can be achieved from either direction.
  - C. the forward and reverse reactions continue to occur.
  - D. the concentrations of reactants and products are constant.
38. In which of the following reactions will entropy favour the reactants while enthalpy favours the products?
- A.  $\text{Cl}_{2(g)} \rightleftharpoons \text{Cl}_{2(aq)} + 25 \text{ kJ}$
  - B.  $\text{P}_{4(s)} + 6\text{H}_{2(g)} + 37 \text{ kJ} \rightleftharpoons 4\text{PH}_{3(g)}$
  - C.  $\text{PCl}_{5(g)} \rightleftharpoons \text{PCl}_{3(g)} + \text{Cl}_{2(g)} ; \Delta H = +92.5 \text{ kJ}$
  - D.  $\text{NO}_{2(g)} \rightleftharpoons \frac{1}{2} \text{N}_{2(g)} + \text{O}_{2(g)} ; \Delta H = -33.8 \text{ kJ}$
39. Methanol,  $\text{CH}_3\text{OH}$ , can be manufactured using the following equilibrium:

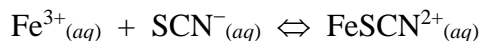


The equilibrium will shift to the right when

- A. a catalyst is added.
  - B. the  $[\text{CO}]$  is increased.
  - C. the  $[\text{CH}_3\text{OH}]$  is increased.
  - D. the temperature is increased.
40. To increase the yield of product in the following equilibrium:



- A. increase the pressure and temperature.
  - B. decrease the pressure and temperature.
  - C. increase the pressure and decrease the temperature.
  - D. decrease the pressure and increase the temperature.
45. Consider the following reversible reaction:



A solution of  $\text{Fe}(\text{NO}_3)_3$  is added to a solution of  $\text{KSCN}$ . Which one of the following statements describes the changes in forward and reverse reaction rates as the reaction moves towards equilibrium?

- A. Forward and reverse rates increase.
- B. Forward and reverse rates decrease.
- C. Forward rate increases and reverse rate decreases.
- D. Forward rate decreases and reverse rate increases.

## Review Package: Equilibrium Theory

46. A system at equilibrium is said to be dynamic because at equilibrium the

- A. temperature does not change.
- B. macroscopic properties are constant.
- C. forward and reverse reactions continue to occur.
- D. concentrations of reactants and products are constant.

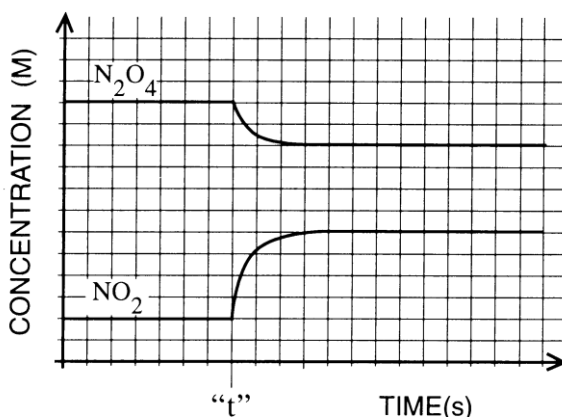
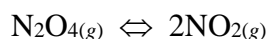
47. Consider the following equilibrium system:



Which one of the following changes would cause the above system to shift left?

- A. Add more CaO.
- B. Remove CaCO<sub>3</sub>.
- C. Decrease volume.
- D. Increase surface area of CaO.

48. Consider the following concentration versus time graph for the equilibrium:



At time = "t", which one of the following stresses occurred?

- A. Catalyst was added.
- B. Pressure was changed.
- C. Temperature was changed.
- D. concentration of NO<sub>2</sub> was changed.

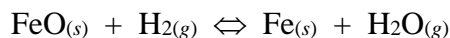
## Review Package: Equilibrium Theory

49. Consider the following equilibrium constant expression

$$K_{eq} = [\text{CO}_2]$$

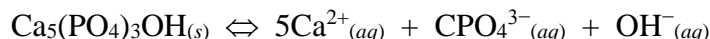
Which one of the following equilibrium systems does the above expression represent?

- A.  $\text{CO}_{2(g)} \rightleftharpoons \text{CO}_{2(s)}$   
B.  $\text{PbO}_{(s)} + \text{CO}_{2(g)} \rightleftharpoons \text{PbCO}_{3(s)}$   
C.  $\text{CaCO}_{3(s)} \rightleftharpoons \text{CaO}_{(s)} + \text{CO}_{2(g)}$   
D.  $\text{H}_2\text{CO}_{3(aq)} \rightleftharpoons \text{H}_2\text{O}_{(l)} + \text{CO}_{2(aq)}$
53. Macroscopic properties become constant in an equilibrium system when
- A. all reactions have stopped.  
B. the reactants are completely used up.  
C. maximum enthalpy has been reached.  
D. forward and reverse reaction rates are equal.
54. In which of the following systems would the tendencies toward minimum enthalpy and maximum entropy be in opposition to each other?
- A.  $\text{Br}_{2(l)} + \text{heat} \rightarrow \text{Br}_{2(g)}$   
B.  $\text{NaOH}_{(s)} \rightarrow \text{Na}^+_{(aq)} + \text{OH}^-_{(aq)} + \text{heat}$   
C.  $2\text{C}_{(g)} + 2\text{H}_{2(g)} \rightarrow \text{C}_2\text{H}_{4(g)}$   $\Delta H$  is positive  
D.  $\text{K}_{(s)} + \text{H}_2\text{O}_{(l)} \rightarrow \text{K}^-_{(aq)} + \text{OH}^-_{(aq)} + \frac{1}{2}\text{H}_{2(g)}$   $\Delta H$  is negative
55. Consider the following equilibrium system:



Which one of the following statements describes the effect that a decrease in volume would have on the position of equilibrium and  $[\text{H}_2]$  in the above system?

- A. No shift,  $[\text{H}_2]$  increases.  
B. Shift right,  $[\text{H}_2]$  increases.  
C. Shift right,  $[\text{H}_2]$  decreases.  
D. No shift,  $[\text{H}_2]$  remains constant.
56. Tooth enamel,  $\text{Ca}_5(\text{PO}_4)_3\text{OH}_{(s)}$  establishes the following equilibrium:



Which one of the following, when added to the above equilibrium system, would result in a shift to the right?

- A.  $\text{H}^+_{(aq)}$   
B.  $\text{OH}^-_{(aq)}$   
C.  $\text{Ca}^{2+}_{(aq)}$   
D.  $\text{Ca}_5(\text{PO}_4)_3\text{OH}_{(s)}$

# Review Package: Equilibrium Theory

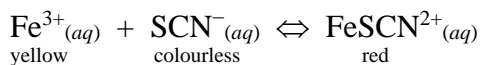
## WRITTEN RESPONSE

For the remainder of the questions, marks will be awarded as shown. Your steps and assumptions leading to a solution must be shown. In questions involving calculations, full marks will not be given for providing only an answer. Students will be expected to communicate the knowledge and understanding of chemical principles in a clear and logical manner.

6. For a given reaction, what effect does a catalyst have on the following :  
a) time required for the reaction to achieve equilibrium **(1 mark)**  
b) position of the equilibrium. **(1 mark)**
8. Give one advantage and one disadvantage in using a low temperature for the production of ammonia by the following equilibrium reaction :  
 $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) \quad \Delta\text{H} = -92 \text{ kJ}$  **(2 marks)**
11.  $2 \text{CrO}_4^{2-}(\text{aq}) + 2 \text{H}^+(\text{aq}) \rightleftharpoons \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
yellow orange

Some NaOH (s) is added to a yellow-orange solution containing this equilibrium. How is the equilibrium affected by this addition, and what colour change, if any, will be observed ? **(2 marks)**

14. List two distinct characteristics of a system at equilibrium. **(2 marks)**
16. Define the term 'closed system'. **(1 mark)**
18. State Le Chatelier's Principle. **(2 marks)**
20. Consider the following equilibrium system:



In an experiment, a student places the above equilibrium system into a cold water bath and notes that the intensity of the red colour increases. The student then concludes that the equilibrium is exothermic.

- a) Do you agree or disagree? **(½ mark)**  
b) Explain. **(1 ½ marks)**



# Review Package: Equilibrium Theory

## ANSWER KEY

### MULTIPLE CHOICE

- |     |   |     |   |     |   |     |   |
|-----|---|-----|---|-----|---|-----|---|
| 1.  | D | 15. | D | 30. | A | 46. | C |
| 2.  | C | 18. | D | 31. | C | 47. | C |
| 3.  | C | 19. | B | 32. | B | 48. | C |
| 4.  | C | 21. | B | 37. | C | 49. | C |
| 11. | D | 22. | D | 38. | A | 53. | D |
| 12. | B | 23. | A | 39. | B | 54. | A |
| 13. | B | 24. | B | 40. | C | 55. | A |
| 14. | B | 29. | A | 45. | D | 56. | A |

### WRITTEN RESPONSE

6. a) time will be shorter  
b) no effect on the position of the equilibrium.
8. advantage : products are favoured  
disadvantage : slower reaction rate
11. a) equilibrium shifts left due to reaction of  $\text{OH}^-$  with  $\text{H}^+$   
b) solution turns yellow
14. **(1 mark for any 2 of the following points)**  
**(Note: accept conditions or characteristics)**
- forward and reverse reaction rate equal
  - concentrations constant
  - closed system
  - reversible reaction
  - constant temperature
  - system at equilibrium stays at equilibrium unless stressed.
  - if stressed, system spontaneously moves to re-establish  $\text{eq}^m$
16. A system which matter may not leave or enter.
18. A generalization stating that when conditions are changed**(1 mark)**,  
a system in equilibrium **(1/2 mark)**  
will adjust to produce a new equilibrium.**(1/2 mark)**
20. a) agree  
b) cold water bath caused shift in forward direction **(1/2 mark)**  
when temp. is decreased, equilibrium shifts in exothermic direction **(1 mark)**