1. Consider the following reaction: \[ 2\text{NH}_3(g) \rightleftharpoons \text{N}_2(g) + 3\text{H}_2(g) \]
   A flask is initially filled with \( \text{NH}_3 \). As the system approaches equilibrium, the rate of the forward reaction
   
   A. increases as the rate of the reverse reaction decreases
   B. decreases as the rate of the reverse reaction increases
   C. increases as the rate of the reverse reaction increases
   D. decreases as the rate of the reverse reaction decreases

2. Consider the following reaction:
   \[ \text{Na}_2\text{CO}_3(s) + 2\text{HCl}(aq) \rightarrow 2\text{NaCl}(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l) \]
   \( \Delta H = -153 \text{ KJ} \)
   In this reaction
   
   A. minimum enthalpy and maximum entropy both favour the products
   B. minimum enthalpy and maximum entropy both favour the reactants
   C. minimum enthalpy favours products and maximum entropy reactants
   D. minimum enthalpy favours reactants and maximum entropy products

3. In all systems at equilibrium, the
   
   A. concentration of reactants is less than the concentration of the products
   B. concentration of reactants and the concentration of the products are equal
   C. concentration of reactants is greater than the concentration of the products
   D. concentration of reactants and the products are constant

4. Chemical systems tend to move toward positions of
   
   A. minimum enthalpy and maximum entropy.
   B. maximum enthalpy and minimum entropy.
   C. minimum enthalpy and minimum entropy.
   D. maximum enthalpy and maximum entropy.

5. An equilibrium system shifts left when the
   
   A. rate of the forward reaction is equal to the rate of the reverse reaction.
   B. rate of the forward reaction is less than the rate of the reverse reaction.
   C. rate of the forward reaction is greater than the rate of the reverse reaction.
   D. rate of the forward reaction and the reverse reaction are constant.

6. A 1.00 L flask contains a gaseous equilibrium system. The addition of reactants to this flask results in a
   
   A. shift left and a decrease in the concentration of the products.
   B. shift left and an increase in the concentration of the products.
   C. shift right and a decrease in the concentration of the products.
   D. shift right and a increase in the concentration of the products.

7. Consider the following equilibrium: \[ \text{CH}_4(g) + \text{H}_2\text{O}(g) + \text{heat} \rightleftharpoons \text{CO}_2(g) + 3\text{H}_2(g) \]
   In which of the following will both stresses shift the equilibrium to the right?
   
   A. a decrease in temperature and a decrease in volume
   B. a increase in temperature and a decrease in volume
   C. a decrease in temperature and a increase in volume
   D. a increase in temperature and a increase in volume
8. Consider the following equilibrium: \(2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g) \quad \Delta H = -198 \text{ kJ}\)

There will be no shift in this equilibrium when

A. more \(\text{O}_2\) is added.
B. a catalyst is added.
C. the volume is increased.
D. the temperature is increased.

Consider the following equilibrium: \(2\text{Fe}_3 + 3\text{H}_2\text{O}_3 = \text{Fe}_2\text{O}_3 + 3\text{H}_2\text{(g)}\)

9. The equilibrium expression is

A. \(\text{Keq} = [\text{Fe}_2\text{O}_3][\text{H}_2]^3\)

1. \([\text{Fe}]^2[\text{H}_2\text{O}]^3\]

B. \(\text{Keq} = [\text{Fe}_2\text{O}_3][3\text{H}_2]\)

1. \([2\text{Fe}][3\text{H}_2\text{O}]\)

C. \(\text{Keq} = [\text{H}_2]^3\)

2. \([\text{H}_2\text{O}]^3\]

D. \(\text{Keq} = [\text{H}_2]^3\)

10. Consider the following equilibrium: \(\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \quad \text{Keq} = 0.133\)

At equilibrium, the \([\text{N}_2\text{O}_4]\) is equal to

A. \(0.133\)

B. \([\text{NO}_2]\)

C. \(0.133\)

D. \([\text{NO}_2]^2\)

11. Which of the following equilibrium systems most favours the products?

A. \(\text{Cl}_2(g) \rightleftharpoons 2\text{Cl}(g) \quad \text{Keq} = 6.4 \times 10^{-39}\)

B. \(\text{Cl}_2(g) + 2\text{NO}_2(g) \rightleftharpoons 2\text{NOCl}(g) \quad \text{Keq} = 3.7 \times 10^8\)

C. \(\text{Cl}_2(g) + 2\text{NO}_2(g) \rightleftharpoons 2\text{NO}_2\text{Cl}(g) \quad \text{Keq} = 1.8\)

D. \(2\text{HCl}(g) \rightleftharpoons \text{H}_2(g) + \text{Cl}_2(g) \quad \text{Keq} = 2.0 \times 10^{-7}\)

12. Consider the following equilibrium: \(4\text{KO}_2(s) + 2\text{H}_2\text{O}(g) \rightleftharpoons 4\text{KOH}(s) + 3\text{O}_2(g)\)

The equilibrium expression is

A. \(\text{Keq} = [\text{KOH}]^4[\text{O}_2]^3\)

1. \([\text{KO}_2]^2[\text{H}_2\text{O}]^2\]

B. \(\text{Keq} = [\text{O}_2]^3\)

1. \([\text{H}_2\text{O}]^2\)

C. \(\text{Keq} = [\text{KOH}]^4[\text{H}_2\text{O}]^2\)

2. \([\text{KO}_2]^2[\text{O}_2]^3\]

D. \(\text{Keq} = [\text{H}_2\text{O}]^2\)

\([\text{O}_2]^3\)

13. Consider the following equilibrium: \(\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}_2(g) \quad \Delta H = +181 \text{ kJ}\)

When the temperature is decreased, the equilibrium:

A. shifts left and the Keq value increases
B. shifts left and the Keq value decreases
C. shifts right and the Keq value increases
D. shifts right and the Keq value decreases
14. Consider the following equilibrium: \( \text{CaCO}_3(s) + 556 \text{ kJ} \rightleftharpoons \text{CaO} + \text{CO}_2(g) \)

The value of the equilibrium constant will increase when

A. CO\(_2\) is added.
B. CO\(_2\) is removed.
C. the temperature is increased.
D. the temperature is decreased.

15. Consider the following equilibrium: \( \text{C(s)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO(g)} + \text{H}_2(g) \)

The contents of a 1.00 L container at equilibrium were analyzed and found to contain 0.20 mole C, 0.20 mole H\(_2\)O, 0.60 mole CO, and 0.60 mole H\(_2\). The equilibrium constant is

A. 0.11
B. 0.56
C. 1.8
D. 0.0

16. Consider the following equilibrium: \( \text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \) \( \text{Keq} = 4.61 \times 10^{-3} \)

A 1.00 L container at equilibrium was analyzed and found to contain 0.0200 mole NO\(_2\). At equilibrium, the concentration of N\(_2\)O\(_4\) is

A. 0.0868 M
B. 0.230 M
C. 4.34 M
D. 11.5 M

17. Consider the following equilibrium: \( \text{H}_2\text{O(g)} + \text{CO(g)} \rightleftharpoons \text{H}_2(g) + \text{CO}_2(g) \)

A closed container is initially filled with H\(_2\)O and CO. As the reaction proceeds to equilibrium the

A. [CO] and [CO\(_2\)] both increase
B. [CO] and [CO\(_2\)] both decrease
C. [CO] increases and [CO\(_2\)] decreases
D. [CO] decreases and [CO\(_2\)] increases

18. Consider the equilibrium: \( \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2\text{HI(g)} \) The pressure of the system is increased by reducing the volume. When comparing the new equilibrium with the original equilibrium,

A. all concentrations remain constant
B. the concentrations of all species have increased
C. reactant concentrations have increased while products decreased
D. reactant concentrations have decreased while products increased

19. Consider the following equilibrium: \( \text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \) A 1.00 L container is initially filled with 0.200 moles of N\(_2\)O\(_4\). At equilibrium, 0.160 moles NO\(_2\) are present. What is the equilibrium concentration of N\(_2\)O\(_4\)?

A. 0.040 M
B. 0.080 M
C. 0.120 M
D. 0.160 M
20. Equilibrium is dynamic process because the

A. macroscopic properties are not changing  
B. mass of the reactants equals the mass of the products  
C. forward and reverse reactions continue to occur  
D. concentrations of reactants and products are constant

21. Consider the following equilibrium: \( \text{C}_\text{s} + 2\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) \) The addition of \( \text{H}_2 \) will cause the equilibrium to shift to the

A. left and [\( \text{CH}_4 \)] will increase  
B. left and [\( \text{CH}_4 \)] will decrease  
C. right and [\( \text{CH}_4 \)] will increase  
D. right and [\( \text{CH}_4 \)] will decrease

22. Given the following system: \( 2\text{CrO}_4^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightleftharpoons \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(l) \)

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

A. NaOH  
B. HNO₃  
C. \( \text{Na}_2\text{CrO}_4 \)  
D. \( \text{Na}_2\text{Cr}_2\text{O}_7 \)

23. Addition of a catalyst to an equilibrium system

A. increases the value of the Keq.  
B. increases the yield of the products.  
C. has no effect on the rates of the reaction.  
D. increases the rate of formation of both reactants and products.

24. Consider the following reaction: \( 2\text{B}(\text{s}) + 3\text{F}_2(\text{g}) \rightleftharpoons 2\text{BF}_3(\text{g}) \) The equilibrium expression is

A. \( \text{Keq} = \frac{[\text{BF}_3]^2}{[\text{F}_2]^3} \)  
B. \( \text{Keq} = \frac{[\text{F}_2]^3}{[\text{BF}_3]} \)  
C. \( \text{Keq} = \frac{[\text{BF}_3]^2}{[\text{F}_2]^3} \)  
D. \( \text{Keq} = \frac{[\text{BF}_3]^2}{[\text{B}][\text{F}_2]^3} \)

Consider the following equilibrium: \( 2\text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + \text{O}_2(\text{g}) \) \( \text{Keq} = 2.01 \times 10^{30} \)

25. The value of the equilibrium constant indicates that the

A. \( [\text{NO}]^2 < [\text{N}_2][\text{O}_2] \)  
B. \( [\text{NO}]^2 > [\text{N}_2][\text{O}_2] \)  
C. \( [\text{NO}] = [\text{N}_2][\text{O}_2] \)  
D. \( [\text{NO}] > [\text{N}_2][\text{O}_2] \)
26. Consider the equilibrium: \( \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2\text{HI}(g) \)
At equilibrium the \([\text{H}_2] = 0.020\ \text{M}, [\text{I}_2] = 0.020\ \text{M}, \) and \([\text{HI}] = 0.160\ \text{M}. \) The value of the equilibrium constant is:

A. \(2.5 \times 10^{-3}\)
B. \(1.6 \times 10^{-2}\)
C. \(6.4 \times 10^1\)
D. \(4.0 \times 10^2\)

Consider the following equilibrium: \( \text{H}_2\text{O}(g) + \text{Cl}_2\text{O}(g) \rightleftharpoons 2\text{HOCl}(g) \) \( \text{K}_{eq} = 9.0 \times 10^{-2} \)

27. A 1.0 L flask contains a mixture of \(1.8 \times 10^{-1}\) mole \(\text{H}_2\text{O}, 4.0 \times 10^{-4}\) mole \(\text{Cl}_2\text{O},\) and \(8.0 \times 10^{-2}\) mole \(\text{HOCl}.\) To establish equilibrium, the system will proceed to the

A. left because the trial \(\text{K}_{eq} > \text{K}_{eq}\)
B. left because the trial \(\text{K}_{eq} < \text{K}_{eq}\)
C. right because the trial \(\text{K}_{eq} > \text{K}_{eq}\)
D. right because the trial \(\text{K}_{eq} < \text{K}_{eq}\)

28. Consider the following equilibrium: \( \text{SO}_2(g) + \text{NO}_2(g) \rightleftharpoons \text{SO}_3(g) + \text{NO} + \text{energy} \)
The equilibrium does not shift with a change in

A. volume
B. temperature
C. concentration of products
D. concentration of reactions

29. Consider the following equilibrium: \( \text{SO}_2\text{Cl}_2(g) + \text{energy} \rightleftharpoons \text{SO}_2(g) + \text{Cl}_2(g) \)
When the temperature is decreased, the equilibrium shifts

A. left and the \([\text{SO}_2\text{Cl}_2]\) increases
B. left and the \([\text{SO}_2\text{Cl}_2]\) decreases
C. right and the \([\text{SO}_2\text{Cl}_2]\) increases
D. right and the \([\text{SO}_2\text{Cl}_2]\) decreases

30. Consider the following equilibrium: \( \text{NH}_3(g) + \text{HCl}(g) \rightleftharpoons \text{NH}_4\text{Cl}(s) + \text{energy} \)
Which of the following will result in a decrease in the mass of \(\text{NH}_4\text{Cl}\)?

A. adding \(\text{NH}_3\)
B. removing \(\text{HCl}\)
C. decreasing the volume
D. decreasing the temperature

31. Consider the following equilibrium: \( \text{PCl}_3(g) + \text{Cl}_2(g) \rightleftharpoons \text{PCl}_5(g) \)
When 0.40 moles of \(\text{PCl}_3\) and 0.40 moles of \(\text{Cl}_2\) are placed in a 1.00 L container and allowed to reach equilibrium, 0.244 mole of \(\text{PCl}_5\) are present. From this information, the value of the \(\text{K}_{eq}\) is

A. 0.10
B. 0.30
C. 3.3
D. 10
32. Consider the following reaction: \( C(s) + 2H_2(g) \rightarrow CH_4(g) \quad \Delta H = -74.8 \text{ kJ} \)
Which of the following will cause an increase in the value of the Keq?

A. increasing \([H_2]\)
B. decreasing the volume
C. finely powdering the \(C(s)\)
D. decreasing the temperature

33. Consider the following equilibrium: \( H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \)
At equilibrium \([H_2] = 0.00220 \text{ M}, [I_2] = 0.00220 \text{ M}, \) and \([HI] = 0.0156 \text{ M} \). The value of the Keq is

A. \(3.10 \times 10^{-4}\)
B. \(1.99 \times 10^{-2}\)
C. \(5.03 \times 10^{1}\)
D. \(3.22 \times 10^{3}\)

34. Consider the rate diagram for the following reaction:
\( H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \)
Which of the following occurs at \(t_1\)?

A. addition of \(H_2\)
B. addition of \(HI\)
C. addition of a catalyst
D. a decrease in volume

35. Chemical equilibrium is said to be dynamic because

A. the reaction proceeds quickly
B. the mass of the reactants is decreasing
C. the macroscopic properties are constant
D. both forward and reverse rates are occurring

36. Given the following system: \( 2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l) \)
Which of the following chemicals, when added to the above system at equilibrium, would result in a decrease in \([Cr_2O_7^{2-}]\)?

A. \(NaOH\)
B. \(HNO_3\)
C. \(Na_2CrO_4\)
D. \(Na_2Cr_2O_7\)

37. Consider the following equilibrium: \( 2O_3(g) \rightleftharpoons 3O_2(g) \quad Keq = 65 \)
Initially 0.10 mole of \(O_3\) and 0.10 mole of \(O_2\) are placed in a 1.0 L container, Which of the following describes the changes in concentrations as the reaction proceeds towards equilibrium?

\[
\begin{array}{c|c|c}
[O_3] & [O_2] \\
\hline
A. & decreases & decreases \\
B. & decreases & increases \\
C. & increases & decreases \\
D. & increases & increases \\
\end{array}
\]
38. Consider the following equilibrium:
\[ \text{CH}_3\text{COOH}_{(aq)} \rightleftharpoons \text{CH}_3\text{COO}^-_{(aq)} + \text{H}^+_{(aq)} + \text{heat} \]
A stress was applied at time \( t_1 \) and the data plotted on the following graph:

The stress imposed at time \( t_1 \) is the result of:

A. the addition of HCl
B. decreasing the temperature
C. the addition of NaCH_3COO
D. increasing the volume of the container

39. Consider the following potential energy diagram for an equilibrium system:

When the temperature of the system is increased, the equilibrium shifts to the:

A. left and the Keq increases
B. left and the Keq decreases
C. right and the Keq increases
D. right and the Keq decreases

40. Addition of a catalyst to an equilibrium system:

A. increases the value of the Keq
B. increases the yield of the product
C. has no effect on the rates of the reaction
D. increases the rates of formation of both reactants and products
41. Ammonia, NH₃, is produced by the following reaction:

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) + \text{energy} \]

Which of the following would result in the highest concentration of ammonia at equilibrium?

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

42. Consider the following equilibrium:

\[ 2\text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g) \quad K_{eq} = 1.15 \]

The equilibrium concentration of NO₂ is 0.05 mol/L. Calculate the equilibrium concentration of N₂O₄(g).

A. 0.22 mol/L  
B. 0.29 mol/L  
C. 0.43 mol/L  
D. 0.58 mol/L

43. Consider the following equilibrium:

\[ \text{H}_2(g) + \text{I}_2 \rightleftharpoons 2\text{HI}(g) \quad K_{eq} = 50.0 \]

What is the value \( K_{eq} \) for the reaction rewritten as:

\[ 2\text{HI}(g) \rightleftharpoons \text{H}_2(g) + \text{I}_2(g) \quad K_{eq} = ? \]

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

44. Consider the following equilibrium:

\[ 4\text{NH}_3(g) + 5\text{O}_2(g) \rightleftharpoons 4\text{NO}(g) + 6\text{H}_2\text{O}(g) + \text{energy} \]

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

A. adding H₂O(g)  
B. removing some NO(g)  
C. increasing the volume  
D. decreasing the temperature

45. Consider the following equilibrium: 2NOBr(g) \( \rightleftharpoons 2\text{NO}(g) + \text{Br}_2(g) \) \( K_{eq} = 0.064 \)

At equilibrium, a 1.00 L flask contains 0.030 mole NOBr and 0.030 mole NO. How many moles of Br₂ are present?

A. 0.0019  
B. 0.064  
C. 0.030  
D. 0.47
46. Which of the following does not apply to all chemical equilibrium systems?

A. They are closed.
B. The macroscopic properties are constant
C. Forward and reverse rates are equal
D. There are equal concentrations of reactants and products

47. Methanol, CH₃OH, can be produced by the following:

\[ \text{CO}(g) + 2\text{H}_2(g) \rightleftharpoons \text{CH}_3\text{OH}(g) + \text{energy} \]

The conditions necessary to maximize the equilibrium yield of CH₃OH are

A. low temperature and low pressure
B. high temperature and low pressure
C. low temperature and high pressure
D. high temperature and high pressure

48. Consider the following equilibrium: 2NO(g) + O₂(g) ⇌ 2NO₂(g) + energy
When the volume of the container is increased, the equilibrium shifts to the

A. left and the Keq decreases
B. right and the Keq increases
C. left and the Keq remains constant
D. right and the Keq remains constant

49. Consider the following reaction:

\[ \text{C}_3\text{H}_8(g) + 5\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(g) \quad \Delta H = -2202 \text{ kJ} \]

Which of the following applies to the forward reaction?

<table>
<thead>
<tr>
<th>Entropy</th>
<th>Enthalpy</th>
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<tbody>
<tr>
<td>A.</td>
<td>increases increases</td>
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<tr>
<td>B.</td>
<td>increases decreases</td>
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<tr>
<td>C.</td>
<td>decreases increases</td>
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<tr>
<td>D.</td>
<td>decreases decreases</td>
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