1. Which of the following has a **correct** van't Hoff factor indicated?

A. $Al_2(SO_4)_3$, $i = 5$

B. Na_2CO_3, $i = 6$

C. $CaBr_2$, $i = 2$

D. $C_6H_{12}O_6$, $i = 3$

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2. Calculate the vapor pressure of a solution containing 35.5 g of glycerin ($C_3H_8O_3$) in 155 g of water at 30.0 °C.

The vapor pressure of pure water at 30.0 °C is 31.8 torr. The molar mass of glycerin is 92.01 g/mol and the molar mass of water is 18.02 g/mol. Assume that glycerin is a nonvolatile nonelectrolyte.

A. 42.3 torr

B. 30.4 torr

C. 29.7 torr

D. 30.1 torr

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3. The osmotic pressure of a 150.0 mL solution of an unknown nonelectrolyte is 122 torr at 25 °C. Determine the molarity of the solution.

A. 4.87×10^{-3} M

B. 3.72 M

C. 6.56×10^{-3} M

D. 0.685 M

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4. Which solution would you expect to experience the **smallest** boiling point elevation?

A. 0.20 M $CaCl_2$

B. 0.20 M $NaNO_3$

C. 0.20 M K_2SO_4

D. 0.20 M Li_3PO_4

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5. The rate of a reaction is determined by monitoring the

A. distance traveled over time.

B. temperature change of the reaction over time.

C. change in activation energy over time.

D. change in concentration over time.

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6. Consider the reaction $H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$. During a 20.0 second period, the concentration of HCl increases from 0.100 M to 0.470 M. Determine the rate of the **reaction** during this time interval.

A. 0.110 M/s

B. 0.220 M/s

C. 4.40×10^{-3} M/s

D. 9.25×10^{-3} M/s

7. The decomposition of NOCl(g) is second order with respect to [NOCl] and proceeds as follows:

$$2\ NOCl(g) \rightarrow 2\ NO(g) + Cl_2(g) \quad T = 100\ °C$$

If the initial rate is 3.12×10^{-6} M/s when [NOCl] = 0.183 M, what will the initial rate be when the concentration of NOCl is decreased to 0.121 M?

A. 4.76×10^{-6} M/s

B. 1.42×10^{-5} M/s

C. 1.36×10^{-6} M/s

D. 5.01×10^{-7} M/s

8. Use the data in the table provided to determine the rate law of the reaction

$A\ (g) + 3\ B(g) \rightarrow C(g) + 3\ D(g)$

Experiment	[A], (M)	[B], (M)	Initial Rate (M/s)
1	0.100	0.100	0.028
2	0.200	0.100	0.113
3	0.200	0.200	0.221
4	0.400	0.400	1.79

A. Rate = $k[A][B]^3$

B. Rate = $k[A]^2[B]$

C. Rate = $k[A][B]^2$

D. Rate = $k[A][B]$

9. The thermal decomposition of phosphine, PH_3, into phosphorus and hydrogen is a first-order reaction:

$$4\ PH_3(g) \rightarrow P_4(g) + 6\ H_2(g) \qquad k = 1.98 \times 10^{-2}\ s^{-1} \text{ at T = 680 °C}$$

If the concentration of PH_3 is 0.462 M at the end of 65.0 seconds, what concentration of phosphine was originally present?

A. 1.67 M
C. 1.25 M
B. 0.260 M
D. 0.462 M

10. For a certain first-order reaction, the half-life is 1.55 s. What fraction of the reactant will remain after 7.25 seconds?

A. 0.0391
C. 0.182
B. 0.404
D. 0.0224

11. Which statement is **false**?

A. The rate of a reaction decreases with decreasing temperature.
B. As temperature decreases, fewer molecules have the minimum energy required to initiate a chemical reaction.
C. As the temperature decreases, the kinetic energy of the molecules decreases.
D. As temperature decreases, the rate constant of a reaction increases.

12. The rate constant for a reaction at 37.0 °C is 0.00434 s^{-1}. The rate constant for the same reaction at 97.0 °C is 0.316 s^{-1}. Determine the activation energy for the reaction.

A. 96.7 kJ/mol
C. 68.1 kJ/mol
B. 641 kJ/mol
D. 2.26 kJ/mol

13. Given the following mechanism, determine which species, if any, could be functioning as reaction intermediates and which species, if any, could be functioning as catalysts.

$ClO^-(aq) + H_2O(l) \rightleftharpoons HClO(aq) + OH^-(aq)$ Fast

$I^-(aq) + HClO(aq) \rightleftharpoons HIO(aq) + Cl^-(aq)$ Slow

$OH^-(aq) + HIO(aq) \rightleftharpoons H_2O(l) + IO^-(aq)$ Fast

$ClO^-(aq) + I^-(aq) \rightleftharpoons Cl^-(aq) + IO^-(aq)$ Overall

A. Intermediates: HClO, OH^-, HIO; Catalyst: H_2O
B. Intermediates: OH^-, HIO; Catalysts: H_2O, HClO
C. Intermediate: H_2O; Catalyst: HClO
D. Intermediates: ClO^-, I^-; Catalysts: Cl^-, IO^-

14. What is the intermediate *and* expected rate law for the **overall reaction** with the following two-step mechanism?

$NO_2(g) + Cl_2(g) \rightarrow ClNO_2(g) + Cl(g)$ Slow

$NO_2(g) + Cl(g) \rightarrow ClNO_2(g)$ Fast

A. Intermediate: $Cl(g)$; Rate = $k[NO_2]^2[Cl_2]$
B. Intermediate: $ClNO_2(g)$; Rate = $k[NO_2][Cl_2]$
C. Intermediate: $ClNO_2(g)$; Rate = $k[NO_2]^2[Cl_2]$
D. Intermediate: $Cl(g)$; Rate = $k[NO_2][Cl_2]$

15. The formation of ammonia, NH_3, is an energy-intensive process because breaking the N≡N bond in N_2 requires a great deal of energy for the reaction to proceed as written:

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

If a chemist were to add $Fe_3O_4(s)$ and observe an **increase** in the reaction rate, how would you characterize the function of the $Fe_3O_4(s)$ in this reaction?

A. $Fe_3O_4(s)$ is a heterogeneous reaction intermediate.

B. $Fe_3O_4(s)$ is a heterogeneous catalyst.

C. $Fe_3O_4(s)$ is a homogeneous reaction intermediate.

D. $Fe_3O_4(s)$ is a homogeneous catalyst.

16. Which statement is **true**?

A. Once equilibrium is established for a given reversible reaction, the reaction stops.

B. The time required to reach equilibrium is the same for all reactions.

C. When equilibrium is established for a reaction with a large equilibrium constant, the rate of the forward reaction is greater than the rate of the reverse reaction.

D. A reaction is at equilibrium when the rate of the forward reaction is equal to the rate of the reverse reaction.

17. What can be said about the direction of the following reaction?

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad K_c = 1.7 \times 10^8$$

A. The forward reaction is favored.

B. The reverse reaction is favored.

C. Neither direction is favored.

D. The favored direction cannot be deduced from the information given.

18. Determine the equilibrium constant, K_p, for this reaction at temperature, T,

$$2\ HCl\ (g) + I_2(g) \rightleftharpoons 2\ HI(g) + Cl_2(g)$$

Given the following equilibria at the same temperature:

$$2\ HCl(g) \rightleftharpoons H_2(g) + Cl_2(g) \qquad K_p = 2.0 \times 10^{-17}$$

$$2\ HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad K_p = 2.0$$

A. 4.0×10^{16}

B. 2.5×10^{16}

C. 1.0×10^{-17}

D. 9.9×10^{-18}

19. Consider the reaction:

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$$

At a certain temperature, $K_p = 2.70 \times 10^{-3}$. Solid NH_4HS is placed in a reaction chamber and allowed to come to equilibrium. Calculate the total pressure once the system comes to equilibrium.

A. 10.2 atm

B. 0.104 atm

C. 0.131 atm

D. 0.0612 atm

20. Ethanol can be produced according to the following equation:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad K_c = ?\ \text{at 600 K}$$

When the **initial** concentrations of C_2H_4 and H_2O are both 1.000 M, the **equilibrium** concentration of C_2H_5OH is 0.990 M. What is the value of K_c?

A. 8.17×10^3

B. 98.9

C. 9.90×10^3

D. 7.26×10^2

21. Silver sulfate dissolves in water according to the reaction:

$$Ag_2SO_4(s) \rightleftharpoons 2\ Ag^+(aq) + SO_4^{2-}(aq) \qquad K_c = 1.1 \times 10^{-5} \text{ at } 298\ K$$

A solution of Ag^+ ions and a solution of SO_4^{2-} ions are mixed such that a reaction quotient of 4.1×10^{-2} is obtained. Which statement is true?

A. The reaction is at equilibrium.

B. The reaction is not at equilibrium and will shift to the right to reach equilibrium.

C. The reaction is not at equilibrium and will shift to the left to reach equilibrium.

D. The reaction is not at equilibrium and cannot reach equilibrium under these conditions.

22. For the following reaction, at 298 K, $K_p = 6.7$

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$$

At equilibrium, the partial pressure of N_2O_4 is 0.127 atm. Determine the partial pressure of NO_2 at equilibrium.

A. 0.017 atm

B. 0.14 atm

C. 7.7 atm

D. 0.25 atm

23. Consider the reaction

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad K_p = 3.11 \text{ at } 1000\ K$$

A 5.0-L reaction vessel is charged with 380 torr of $COCl_2$. Calculate the equilibrium partial pressure of Cl_2 in the container.

A. 12.2 torr

B. 312 torr

C. 450 torr

D. 206 torr

24. The following reaction is initially at equilibrium:

$$SnO_2(s) + H_2(g) \rightleftharpoons Sn(s) + H_2O(g)$$

Which change will shift the equilibrium in favor of forming more **H_2**?

A. Add $H_2O(g)$.
C. Remove $H_2O(g)$.
B. Add $Sn(s)$.
D. Remove $SnO_2(s)$.

25. For each of the following systems at equilibrium, the volume of the container is **increased**. Which reaction will shift to the **right** in order to reestablish equilibrium?

A. $CO(g) + H_2(g) \rightleftharpoons C(s) + H_2O(g)$
C. $2\ BrNO(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$
B. $C(s) + 2\ H_2(g) \rightleftharpoons CH_4(g)$
D. $H_2(g) + Cl_2(g) \rightleftharpoons 2\ HCl(g)$

26. Consider the endothermic reaction:

$$C_2H_4Cl_2(g) \rightleftharpoons C_2H_4(g) + Cl_2(g).$$

Which one of the following statements is **true**?

A. As the temperature increases, the reaction shifts to the right and the magnitude of the equilibrium constant increases.
B. As the temperature increases, the reaction shifts to the right and the magnitude of the equilibrium constant decreases.
C. As the temperature increases, the reaction shifts to the left and the magnitude of the equilibrium constant increases.
D. As the temperature increases, the reaction shifts to the left and the magnitude of the equilibrium constant decreases.

27. Select the **reactants** from each balanced chemical equation below that function as Brønsted-Lowry **bases**.

(1) $H_2PO_4^-(aq) + NH_3(aq) \rightarrow HPO_4^{2-}(aq) + NH_4^+(aq)$

(2) $HCOOH(aq) + CN^-(aq) \rightarrow HCOO^-(aq) + HCN(aq)$

A. (1) $H_2PO_4^-$; (2) HCOOH
C. (1) NH_3; (2) HCOOH
B. (1) $H_2PO_4^-$; (2) CN^-
D. (1) NH_3; (2) CN^-

28. The K_a values for four acids are given below. Which acid is the **weakest** acid?

A. HCN: $K_a = 4.9 \times 10^{-10}$

B. HC_6H_5O: $K_a = 1.3 \times 10^{-10}$

C. HNO_2: $K_a = 4.6 \times 10^{-4}$

D. $HCHO_2$: $K_a = 1.8 \times 10^{-4}$

29. Which statement is **false** for an aqueous acid solution at 25 °C?

A. $[H^+] > 1.0 \times 10^{-7}$ M

B. $[OH^-] < 1.0 \times 10^{-7}$ M

C. pOH < 7

D. pH < 7

30. Calculate $[OH^-]$ at 25 °C for a solution with $[H_3O^+] = 7.48 \times 10^{-6}$ M and indicate whether the solution is acidic, basic, or neutral.

A. $[OH^-] = 1.34 \times 10^{-9}$ M, acidic

B. $[OH^-] = 1.64 \times 10^{-5}$ M, acidic

C. $[OH^-] = 1.26 \times 10^{-3}$ M, basic

D. $[OH^-] = 1.17 \times 10^{-9}$ M, neutral

Answer Key:

1. A
2. B
3. C
4. B
5. D
6. D
7. C
8. B
9. A
10. A
11. D
12. C
13. A
14. D
15. B
16. D
17. A
18. C
19. B
20. C
21. C
22. B
23. D
24. A
25. C
26. A
27. D
28. B
29. C
30. A