1. The equilibrium constant \( K_c \) for the reaction
\[ \text{PCl}_3(g) + \text{Cl}_2(g) \rightleftharpoons \text{PCl}_5(g) \]
is 49 at 230°C. If 0.70 mol of \( \text{PCl}_3 \) is added to 0.70 mol of \( \text{Cl}_2 \) in a 1.00-L reaction vessel at 230°C, what is the concentration of \( \text{PCl}_3 \) when equilibrium has been established?
A. 0.049 \( M \) B. 0.11 \( M \) C. 0.30 \( M \) D. 0.59 \( M \) E. 0.83 \( M \)

2. The equilibrium constant, \( K_p \), for the reaction \( \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2\text{HI}(g) \) is 55.2 at 425°C. A rigid cylinder at that temperature contains 0.127 atm of hydrogen, 0.134 atm of iodine, and 1.055 atm of hydrogen iodide. Is the system at equilibrium?
A. Yes.
B. No, the forward reaction must proceed to establish equilibrium.
C. No, the reverse reaction must proceed to establish equilibrium.
D. Need to know the volume of the container before deciding.
E. Need to know the starting concentrations of all substances before deciding.

3. Write the mass-action expression, \( Q_c \), for the following chemical reaction.
\[ \text{MgO}(s) + \text{SO}_2(g) + \frac{1}{2}\text{O}_2(g) \rightleftharpoons \text{MgSO}_4(s) \]
A. \( \frac{[\text{MgO}][\text{SO}_2][\text{O}_2]^\frac{1}{2}}{[\text{MgSO}_4]} \) B. \( \frac{[\text{MgO}][\text{SO}_2][\text{O}_2]^\frac{1}{2}}{[\text{MgSO}_4]} \)
C. \( \frac{1}{[\text{SO}_2][\text{O}_2]^\frac{1}{2}} \) D. \( \frac{[\text{SO}_4][\text{O}_2]^\frac{1}{2}}{[\text{MgSO}_4]} \)
E. None of these choices is correct.

4. Butyric acid is responsible for the odor in rancid butter. A solution of 0.25 M butyric acid has a pH of 2.71. What is the \( K_a \) for the acid?
A. 0.36 B. \( 2.4 \times 10^{-2} \) C. \( 7.8 \times 10^{-3} \) D. \( 1.5 \times 10^{-5} \) E. None of these choices is correct.

5. The isomerization of cyclopropane to form propene

is a first-order reaction. At 760 K, 15% of a sample of cyclopropane changes to propene in 6.8 min. What is the half-life of cyclopropane at 760 K?
A. \( 3.4 \times 10^{-2} \) min B. 2.5 min C. 23 min D. 29 min E. 230 min

6. What is the pH of a 0.75 \( M \) HNO\(_3\) solution?
A. 0.12 B. 0.29 C. 0.63 D. 0.82 E. > 1.0
7. Consider this reaction: \(2\text{NH}_3(g) \rightarrow \text{N}_2(g) + 3\text{H}_2(g)\)

If the rate \(\Delta[\text{H}_2]/\Delta t\) is 0.030 mol L\(^{-1}\) s\(^{-1}\), then \(\Delta[\text{NH}_3]/\Delta t\) is:

A. -0.045 mol L\(^{-1}\) s\(^{-1}\)  
B. -0.030 mol L\(^{-1}\) s\(^{-1}\)  
C. -0.020 mol L\(^{-1}\) s\(^{-1}\)  
D. -0.010 mol L\(^{-1}\) s\(^{-1}\)  
E. None of these choices is correct.

8. The graphs below all refer to the same reaction. What is the order of this reaction?

A. zeroth order  
B. first order  
C. second order  
D. unable to predict

9. At high temperatures, carbon reacts with O\(_2\) to produce CO as follows:

\(\text{C(s)} + \text{O}_2(g) \rightleftharpoons \text{CO}(g)\). When 0.350 mol of O\(_2\) and excess carbon were placed in a 5.00-L container and heated, the equilibrium concentration of CO was found to be 0.060 \(M\). What is the equilibrium constant, \(K_c\), for this reaction?

A. 0.010  
B. 0.072  
C. 0.090  
D. 0.17  
E. 1.2

10. The radioactive isotope tritium decays with a first-order rate constant \(k\) of 0.056 year\(^{-1}\). What fraction of the tritium initially in a sample is still present 30 years later?

A. 0.19  
B. 0.60  
C. 0.15  
D. 2.8 \times 10^{-38}  
E. None of these choices is correct.

11. Select the pair of substances which is not a conjugate acid-base pair.

A. \(\text{H}_3\text{O}^+\), \(\text{H}_2\text{O}\)  
B. \(\text{HNO}_2\), \(\text{NO}_2^-\)  
C. \(\text{H}_2\text{SO}_4\), \(\text{HSO}_4^-\)  
D. \(\text{H}_2\text{S}\), \(\text{S}^{2-}\)  
E. \(\text{NH}_3\), \(\text{NH}_2^-\)

12. At 450\(^\circ\)C, tert-butyl alcohol decomposes into water and isobutene.

\((\text{CH}_3)_3\text{COH}(g) \rightleftharpoons (\text{CH}_3)_2\text{CCH}_2(g) + \text{H}_2\text{O}(g)\)

A reaction vessel contains these compounds at equilibrium. What will happen if the volume of the container is reduced by 50% at constant temperature?

A. The forward reaction will proceed to reestablish equilibrium.  
B. The reverse reaction will proceed to reestablish equilibrium.  
C. No change occurs.  
D. The equilibrium constant will increase.  
E. The equilibrium constant will decrease.

13. The substance \(\text{NH}_3\) is considered

A. a weak acid.  
B. a weak base.  
C. a strong acid.  
D. a strong base.  
E. a neutral compound.

14. When the reaction \(A \rightarrow B + C\) is studied, a plot of \(\ln[A]\) vs. time gives a straight line with a negative slope. What is the order of the reaction?

A. zero  
B. first  
C. second  
D. third  
E. More information is needed to determine the order.
15. What is the pH of a 0.0125 M NaOH solution?
A. 0.972  B. 1.903  C. 12.097  D. 13.028  E. None of these choices is correct.

16. The decomposition of hydrogen peroxide is a first-order process with a rate constant of $1.06 \times 10^{-3}$ min$^{-1}$. How long will it take for the concentration of H$_2$O$_2$ to drop from 0.0200 M to 0.0120 M?
A. < 1 min  B. 7.55 min  C. 481 min  D. 4550 min  E. 31,400 min

17. Based on the initial rate data below, what is the value of the rate constant?

\[
\text{2NOBr(g) \rightarrow 2NO(g) + Br}_2(g)\\
\begin{array}{c|c}
\text{[NOBr](mol L$^{-1}$)} & \text{Rate (mol L$^{-1}$s$^{-1}$)} \\
0.0450 & 1.62 \times 10^{-3} \\
0.0310 & 7.69 \times 10^{-4} \\
0.0095 & 7.22 \times 10^{-6} \\
\end{array}
\]
A. 0.0360 L mol$^{-1}$s$^{-1}$  B. 0.800 L mol$^{-1}$s$^{-1}$  C. 1.25 L mol$^{-1}$s$^{-1}$
D. 27.8 L mol$^{-1}$s$^{-1}$  E. 0.0360 s$^{-1}$

18. For the reaction A(g) + 2B(g) $\rightarrow$ 2C(g) + 2D(g), the following data were collected at constant temperature. Determine the correct rate law for this reaction.

\[
\begin{array}{c|c|c|c}
\text{Trial} & \text{Initial [A]} (\text{mol/L}) & \text{Initial [B]} (\text{mol/L}) & \text{Initial Rate} (\text{mol/(L min)}) \\
1 & 0.125 & 0.200 & 7.25 \\
2 & 0.375 & 0.200 & 21.75 \\
3 & 0.250 & 0.400 & 14.50 \\
4 & 0.375 & 0.400 & 21.75 \\
\end{array}
\]
A. Rate = $k[A][B]$  B. Rate = $k[A]^2[B]$  C. Rate = $k[A][B]^2$
D. Rate = $k[A]$  E. Rate = $k[A]^3$

19. What is the pH of a 0.050 M triethylamine, (C$_2$H$_5$)$_3$N, solution?

$K_b$ for triethylamine is $5.3 \times 10^{-4}$.
A. 11.69  B. 8.68  C. 5.32  D. 2.31  E. < 2.0

20. The reaction system POCl$_3(g) \rightleftharpoons$ POCl(g) + Cl$_2(g)$ is at equilibrium. Which of the following statements describes the behavior of the system if the partial pressure of chlorine is reduced by 50%?
A. POCl$_3$ will be consumed as equilibrium is established.
B. POCl will be consumed as equilibrium is established.
C. Chlorine will be consumed as equilibrium is established.
D. The partial pressure of POCl will decrease while the partial pressure of Cl$_2$ increases as equilibrium is established.
E. The volume will have to decrease before equilibrium can be reestablished.

21. If one starts with pure NO$_2(g)$ at a pressure of 0.500 atm, the total pressure inside the reaction vessel when 2NO$_2(g) \rightleftharpoons$ 2NO(g) + O$_2(g)$ reaches equilibrium is 0.674 atm. Calculate the equilibrium partial pressure of NO$_2$.
A. 0.152 atm  B. 0.174 atm  C. 0.200 atm  D. 0.326 atm  E. The total pressure cannot be calculated because $K_p$ is not given.
22. What is the [OH⁻] for a solution at 25°C that has pH = 4.29?
   A. 1.4 × 10⁻² M  B. 5.1 × 10⁻⁵ M  C. 1.9 × 10⁻¹⁰ M  D. 7.3 × 10⁻¹³ M  E. 9.71 M

23. Which one of the following pairs is not a conjugate acid-base pair?
   A. H₂O, OH⁻  B. H₂O₂, HO₂⁻  C. OH⁻, O²⁻  D. H₂PO₄⁻, HPO₄²⁻  E. HCl, H⁺

24. Formic acid, which is a component of insect venom, has a \( K_a = 1.8 \times 10^{-4} \). What is the \([H₃O^+]\) in a solution that is initially 0.10 M formic acid, HCOOH?
   A. 4.2 × 10⁻³ M  B. 8.4 × 10⁻³ M  C. 1.8 × 10⁻⁴ M  D. 1.8 × 10⁻⁵ M  E. 1.8 × 10⁻⁶ M

25. Which one of the following is a strong acid?
   A. H₂CO₃  B. H₂SO₃  C. H₂SO₄  D. H₃PO₄  E. CH₃COOH
1. (p. 755) B
2. (p. 750) C
3. (p. 746) C
4. (p. 800) D
5. D
6. (p. 792) A
7. (p. 690) C
8. A
9. (p. 752) C
10. (p. 702) A
11. (p. 779) D
12. (p. 764) B
13. (p. 788) B
14. (p. 701) B
15. (p. 792) C
16. (p. Sec. 16.4) C
17. (p. 697) B
18. (p. 697) D
19. (p. 807) A
20. (p. 761) A
21. A
22. (p. 792) C
23. (p. 779) E
24. (p. 801) A
25. (p. 788) C
## Exam One Summary

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