1. What is the concentration of hydroxide ions in a solution that contains of 0.100 M HCN(aq) and 0.200 M NaCN(aq)?

   - A. $2.4 \times 10^{-5}$ M
   - B. $1.1 \times 10^{-9}$ M
   - C. $2.5 \times 10^{-10}$ M
   - D. $4.1 \times 10^{-5}$ M

2. 10 ml of 0.1 M LiOH is added to each of the following solutions. Which of them will still be a buffer after addition of the base? I) 20 ml of 0.1 M HClO4 II) 20 ml of 0.1 M HClO2 III) 10 ml of 0.1 M HClO2 IV) 10 ml of 0.2 M HClO2 and 10 ml of 0.1 M HClO2 V) 10 ml of 0.1 M HClO2

   - A. II only
   - B. I and II
   - C. all of them
   - D. II and IV
   - E. IV and V

3. Which of the following species is the strongest base in water?

   - A. the conjugate base of HNO3
   - B. the conjugate base of a weak acid with $pK_a = 2.5$
   - C. a compound with $pK_b = 7.5$
   - D. a compound with $pK_b = 4.5$
   - E. the conjugate base of a weak acid with $pK_a = 11.5$

4. A solution of 0.5 M barium hydroxide dissociates completely in 100 ml of a 0.5 M formic acid and 0.4 M lithium formate. What is the volume of barium hydroxide that can be added before the buffer capacity is exceeded?

   - A. 20 ml
   - B. 40 ml
   - C. 100 ml
   - D. 50 ml
5. A buffer solution of volume 200.0 mL is 0.250 M Na₂HPO₄(aq) and 0.250 M KH₂PO₄(aq). The pH resulting from the addition of 50.0 mL of 0.100 M NaOH(aq) to the buffer solution will be

- A. 7.12
- B. 7.21
- C. 7.30
- D. 12.77

6. The titration curve for the titration of 0.100 M H₂SO₃(aq) with 0.100 M KOH(aq) is given below.

Estimate pKₐ₁ and pKₐ₂ of H₂SO₃.

7. What is the pH at the stoichiometric point for the titration of 0.100 M CH₃COOH(aq) with 0.100 M KOH(aq)? The value of Kₐ for acetic acid is 1.8 × 10⁻⁵.

- A. 5.28
- B. 8.72
- C. 7.00
- D. 9.26
- E. 8.89

8. What is the pH at the half-stoichiometric point for the titration of 0.22 M HNO₂(aq) with 0.10 M KOH(aq)? For HNO₂, Kₐ = 4.3 × 10⁻⁴.

- A. 2.31
- B. 7.00
9. Rocks with a variety of solubility product constants are thrown into water. Which of them will produce the fewest ions in solution?

- A. A rock of the form AB2 with a pK_sp = 10
- B. A rock of the form AB3 with a pK_sp = 10
- C. A rock of the form A2B3 with a pK_sp = 30
- D. A rock of the form AB2 with a pK_sp = 20
- E. A rock of the form AB with a pK_sp = 20

10. What is the solubility in moles/liter for lead (II) iodide at 25 °C given a K_sp value of 1.4 x 10^-8. Write using scientific notation and use 1 or 2 decimal places (even though this is strictly incorrect!)

11. The K_sp of AgCl is 1.6 x 10^-10. What is the solubility of AgCl in 0.0010 M CaCl_2? Give your answer using scientific notation and to 2 significant figures (i.e., one decimal place).

12. The solubility of all except which of the following compounds increases as the pH of the solution decreases?

- A. CaF_2
- B. Na_2CO_3
- C. PbSO_3
- D. KClO_4
- E. CuS

13. A 0.0010 M solution of a weak acid, HA, with K_a = 2 x 10^-10 produces [H_3O^+] < 10^-6 M. Which of the following equations can be used to determine [H_3O^+]?
D. \([H_3O^+] = [HA]_{\text{initial}}\)

E. \([H_3O^+] = (K_a[HA]_{\text{initial}})^\frac{1}{2}\)

14. In a solution that is labeled “0.10 M H₃PO₄(aq),” \([H_3O^+] = 0.024\) M. Match the species below with their concentrations.

- H₃PO₄: 6.2 × 10⁻⁸
- H₂PO₄⁻: 8.0 × 10⁻²
- HPO₄²⁻: 5.4 × 10⁻¹⁹
- PO₄³⁻: 2.4 × 10⁻²

15. Write the charge balance equation for a dilute aqueous solution of KOH.

A. \([\text{KOH}]_{\text{initial}} = [\text{K}^+]\)

B. \([\text{OH}^-] = [H_3O^+] + [\text{K}^+]\)

C. \([H_3O^+] = [\text{OH}^-]\)

D. \([\text{K}^+] = [\text{OH}^-] + [H_3O^+]\)

E. \([\text{OH}^-] = [\text{K}^+]\)

16. How many simultaneous equations need to be solved to determine the equilibrium concentrations of all species when NaHPO₄ and H₃PO₄ are added to solution? (Don't include the concentration of water in your considerations.)

A. 4

B. 5

C. 6

D. 7

E. 8

17. For a solution labeled “0.10 M H₃PO₄(aq),”

A. \([H_2PO_4^-]\) is greater than 0.10 M.

B. \([\text{H}^+] = 0.30\) M.

C. \([\text{PO}_4^{3-}] = 0.10\) M.
D. $[H^+] = 0.10$ M.
E. $[H^+]$ is less than 0.10 M.

18. Estimate the pH of 0.10 M Na$_2$HPO$_4$(aq) given $pK_{a1} = 2.12$, $pK_{a2} = 7.21$, and $pK_{a3} = 12.68$ for phosphoric acid.
A. 12.68
B. 9.94
C. 7.40
D. 4.67
E. 2.12

19. Estimate the pH of $10^{-7}$ M KOH(aq).
A. 6.9
B. 9
C. 13
D. 7.2
E. 7.0

20. For a solution labeled “0.10 M H$_2$SO$_4$(aq),”
A. $[HSO_4^-]$ is greater than 0.10 M.
B. the pH is less than 1.0.
C. $[SO_4^{2-}] = 0.10$ M.
D. the pH equals 1.0.
E. the pH is greater than 1.0.

21. What is the sum of the coefficients when the following redox couple is balanced in acidic solution? MnO$_4^-$ + 2I$^- \rightarrow$ Mn$^{2+}$ + I$_2$
A. 12
B. 14
C. 38
22. What is the sum of the coefficients when the following redox couple is balanced in basic solution? \( \text{MnO}_4^- + \text{Ag} \rightarrow \text{MnO}_2 + \text{Ag}^+ \)

A. 4  
B. 12  
C. 14  
D. 4  
E. 3

23. If the standard potentials for the couples \( \text{Cu}^{2+}/\text{Cu}, \text{Ag}^+/\text{Ag}, \) and \( \text{Fe}^{2+}/\text{Fe} \) are +0.34, +0.80, and –0.44 V, respectively, which is the strongest reducing agent?

A. \( \text{Fe} \)  
B. \( \text{Ag} \)  
C. \( \text{Ag}^+ \)  
D. \( \text{Cu} \)  
E. \( \text{Fe}^{2+} \)

24. What is the proper cell diagram for the reaction

\[
2\text{AgCl(s)} + \text{H}_2(g) \rightarrow 2\text{Ag(s)} + 2\text{H}^+(aq) + 2\text{Cl}^-(aq)
\]

A. \( \text{Pt}|\text{Cl}^-(aq)|\text{H}^+(aq) \parallel \text{H}_2(g)|\text{AgCl(s)}|\text{Ag(s)} \)
B. \( \text{Pt}|\text{H}_2(g)|\text{H}^+(aq) \parallel \text{Cl}^-(aq)|\text{AgCl(s)}|\text{Ag(s)} \)
C. \( \text{Ag(s)}|\text{AgCl(s)}|\text{Cl}^-(aq) \parallel \text{H}^+(aq)|\text{H}_2(g)|\text{Pt} \)
D. \( \text{Pt}|\text{H}_2(g)|\text{H}^+(aq) \parallel \text{Cl}^-(aq)|\text{Ag(s)}|\text{Pt} \)
E. \( \text{Ag(s)}|\text{AgCl(s)}|\text{H}^+(aq) \parallel \text{Cl}^-(aq)|\text{H}_2(g)|\text{Pt} \)

25. In a working electrochemical cell (+ cell voltage), the electrons flow from the anode through the external circuit to the cathode. True or false?
26. The standard potential of the Cu^{2+}/Cu electrode is +0.34 V and the standard potential of the cell

\[ \text{Pb(s)} | \text{Pb}^{2+} (aq) \rightleftharpoons \text{Cu}^{2+} (aq) | \text{Cu(s)} \]

is +0.47 V. What is the standard potential of the Pb^{2+}/Pb electrode?

A. –0.26 V  
B. +0.81 V  
C. –0.81 V  
D. –0.13 V  
E. +0.13 V

27. The standard potential of the cell

\[ \text{Pb(s)} | \text{PbSO}_4(s) | \text{SO}_4^{2-}(aq) | \text{Pb}^{2+}(aq) | \text{Pb(s)} \]

is +0.23 V at 25°C. Calculate the equilibrium constant for the reaction of 1 M Pb^{2+}(aq) with 1M SO_4^{2-}(aq).

A. \(3.7 \times 10^{16}\)  
B. \(8.0 \times 10^{17}\)  
C. \(6.0 \times 10^{7}\)  
D. \(1.7 \times 10^{-8}\)  
E. \(7.7 \times 10^{3}\)

28. In an electrolytic cell, a current is passed through a solution of a chloride of iron, producing Fe(s) and Cl_2(g) according to the reaction:

\[ \text{FeCl}_2(l) \rightarrow \text{Fe(s)} + \text{Cl}_2(g) \]

The current that would produce chlorine gas at a rate of 3.00 grams per hour is:

A. 1.126 A  
B. 2.25 A  
C. 1.51 A  
D. 4.53 A

Answer: B

29. Consider the following cell:

\[ \text{Pt} | \text{H}_2(g, 1 \text{ atm}) | \text{H}^+(aq, ? \text{ M}) \rightleftharpoons \text{Ag}^+(aq, 1.0 \text{ M}) | \text{Ag(s)} \]
If the voltage of this cell is 1.04 V at 25°C and the standard potential of the Ag⁺/Ag couple is +0.80 V, calculate the hydrogen ion concentration in the anode compartment.

- **A.** $4.6 \times 10^{-10}$ M
- **B.** $8.8 \times 10^{-5}$ M
- **C.** $9.4 \times 10^{-3}$ M
- **D.** 1.0 M
- **E.** $3.7 \times 10^{-8}$ M

30. When a cell of a lead storage battery is being charged, it is:

- **A.** A galvanic cell
- **B.** A Daniell cell
- **C.** An electrolytic cell
- **D.** A dry cell