1. Amphoteric hydroxides dissolve in both highly acidic and highly basic solutions.
   (a) true  (b) false

2. The magnitude of the ratio of $Q_{sp}/K_{sp}$ is used to predict whether an ionic solid will precipitate.
   (a) true  (b) false

3. The solubility of an ionic solid is decreased when a common ion is present in solution.
   (a) true  (b) false

4. Indicate the major chemical species present in a solution of 0.10M NH$_3$ and 0.10M NH$_4$Cl.
   (a) NH$_3$, NH$_4^+$
   (b) NH$_3$, NH$_4^+$, Cl$^-$
   (c) NH$_3$, NH$_4^+$, Cl$^-$, OH$^-$
   (d) NH$_3$, NH$_4^+$, Cl$^-$, OH$^-$, H$_2$O

5. What is the pH of a solution prepared by mixing 25.00mL of 0.10M CH$_3$COOH with 25.00mL of 0.050M NaCH$_3$CO$_2$? Assume that the volumes of solution are additive and that the $K_a$ for acetic acid is $1.8 \times 10^{-5}$.
   (a) 2.22  (b) 2.87  (c) 4.74  (d) 4.44

6. In general, the more atoms of a given type present in a molecule, the lesser the capacity to take up energy and thus the lower the entropy.
   (a) true  (b) false

7. Which of the following statements is not true?
   (a) $\Delta H - T\Delta S < 0$, then rxn is spontaneous as written
   (b) $\Delta H - T\Delta S > 0$, rxn is not spontaneous
   (c) $\Delta H - T\Delta S = 0$, rxn is at equilibrium
   (d) none of the above

8. Which of the following combinations of chemicals could be used to make a buffer solution?
   (a) HCl/NaOH  (b) NaOH/NH$_3$  (c) HCl/H$_3$PO$_4$  (d) HCl/NH$_3$

9. Which statement about buffers is true?
   (a) Buffers have a pH=7
   (b) Buffers consist of a strong acid and its conjugate base
   (c) A buffer does not change pH on addition of a strong acid or strong base
   (d) Buffers resist change in pH upon addition of small amounts of strong acid or strong base

10. What is $W$ in Boltzmann's formula, $S=k \ln W$?
    (a) a fraction indicating the probability of obtaining a result
    (b) a random number
    (c) the work times Avogadro's number
    (d) the number of ways of obtaining the state

11. The total entropy of a system and its surroundings always increases for a spontaneous process. This is a statement of
    (a) the law of constant composition  (b) the first law of thermodynamics
    (c) the third law of thermodynamics  (d) the second law of thermodynamics

12. TRIS [(HOCH$_2$)$_3$CNH$_2$] is one of the most common buffers used in biochemistry. A solution is prepared by adding enough TRIS and 12M HCl (aq) to give 1 liter of solution with [TRIS]=0.30 M and [TRISH$^+$]=0.60 M. What is the pH of this buffered system if the $pK_b$ is 5.92?
    (a) 8.08  (b) 5.92  (c) 6.22  (d) 7.78

13. Calculate the solubility of iodate if copper(II) iodate is dissolved in water and the value of $K_{sp} = 7.4 \times 10^{-8}$M$^3$ at 25°C.
    (a) 7.4 x 10$^{-3}$M  (b) 2.6 x 10$^{-3}$M  (c) 1.3x10$^{-3}$M  (d) 5.2x10$^{-3}$M

14. The emf of the following cell at 25°C is 0.475V. What is the pOH of the test solution?
Zn | Zn^{2+} (1 M) \parallel H^+(aq, test solution) | H_2(1 atm) | Pt
(a) 4.8 \quad (b) 9.6 \quad (c) 4.4 \quad (d) 9.2 \quad (e) 8.8

15. What is the percent dissociation of ascorbic acid if the solution has a pH = 5.50 and a pK_a = 4.10?
(a) 96% \quad (b) 10% \quad (c) 5% \quad (d) 1%

16. What is the characteristic pH-titrant curve for the titration of a strong acid by a strong base?

\[
\begin{align*}
\text{pH} & \quad \text{titrant (A)} \\
\text{titrant (B)} & \quad \text{titrant (C)} \\
\text{titrant (D)} & \quad
\end{align*}
\]

17. Formic acid (HCOOH, K_a = 1.8 \times 10^{-4}) is the principal component in the venom of stinging ants. What is the molarity of the formic acid solution if 25.00 mL of aqueous formic acid required 29.80 mL of 0.0567 M NaOH to reach the equivalence point?
(a) 0.0676 M \quad (b) 0.0567 M \quad (c) 0.0476 M \quad (d) 0.0134 M

18. Which of the following metal hydroxides are amphoteric?
(a) Al(OH)_3, Zn(OH)_2, Cr(OH)_3, Sn(OH)_2
(b) Cu(OH)_2, Mn(OH)_2, Fe(OH)_2, Fe(OH)_3
(c) Be(OH)_2, Ca(OH)_2, Ba(OH)_2, Sr(OH)_2
(d) LiOH, NaOH, KOH, RbOH

19. Which of the following gas molecules has the greatest standard molar entropy at 25°C?
(a) H−C≡C−H \quad (b) H_2C=CH_2 \quad (c) H_3C−CH_3 \quad (d) all have the same entropy

20. What is the relationship between \Delta G, Q_p, and K_p for a reaction involving gases?
(a) \Delta G = Q_p/K_p \quad (b) \Delta G = K_p/Q_p \quad (c) \Delta G = RT \ln(Q_p/K_p) \quad (d) \Delta G = RT \ln(K_p/Q_p)

21. Consider the reaction: N_2(g) + F_2(g) \rightarrow NF_3(g) \quad \Delta H^\circ = -249 kJ and \Delta S^\circ = -278 J/K at 25°C. Calculate \Delta G^\circ and state whether the equilibrium composition should favor reactants or products at standard conditions.

(a) \Delta G^\circ = -332 kJ; the equilibrium composition should favor products
(b) \Delta G^\circ = -332 kJ; the equilibrium composition should favor reactants
(c) \Delta G^\circ = -166 kJ; the equilibrium composition should favor products
(d) \Delta G^\circ = -166 kJ; the equilibrium composition should favor reactants

22. For a cell reaction based on the following half-reactions, how many moles of lead are oxidized by one mole of Cr_2O_7^{2−}\rightarrow

Cr_2O_7^{2−}(aq) + 14 H^+(aq) + 6e^− \rightarrow 2 Cr^{3+}(aq) + 7 H_2O(l)
Pb(s) \rightarrow Pb^{2+}(aq) + 2e^−

(a) 1 \quad (b) 2 \quad (c) 3 \quad (d) 6

23. The iron content of foods can be determined by dissolving them in acid (forming Fe^{3+}), reducing the iron(III) to iron(II), and titrating with cerium(IV). Fe^{3+} (aq) + Ce^{4+} (aq) \rightarrow Fe^{2+} (aq) + Ce^{3+} (aq). Identify the two half-reactions in the above reaction.

Oxidation half-reaction \quad \text{reduction half-reaction}

(a) Fe^{3+} (aq) + e^− \rightarrow Fe^{2+} (aq) \quad Ce^{4+} (aq) \rightarrow Ce^{3+} (aq) + e^−
(b) Ce^{4+} (aq) + e^− \rightarrow Ce^{3+} (aq) \quad Fe^{3+} (aq) \rightarrow Fe^{2+} (aq) + e^−
(c) Fe^{2+} (aq) \rightarrow Fe^{3+} (aq) + e^− \quad Ce^{4+} (aq) + e^− \rightarrow Ce^{3+} (aq)
(d) Ce^{4+} (aq) \rightarrow Ce^{3+} (aq) + e^− \quad Fe^{3+} (aq) + e^− \rightarrow Fe^{2+} (aq)

24. For the galvanic cell Pt(s)/Sn^{2+}(aq), Sn^{4+}(aq)|| Pb^{2+}(aq) \rightarrow Pb(s), what is the function of the Pt(s)?

(a) Pt is the anode and is a reactant in the overall cell reaction
(b) Pt is the cathode and is a product in the overall cell reaction
(c) Pt is the anode and does not appear in the overall cell reaction
(d) Pt is the cathode and does not appear in the overall cell reaction
25. What is the relation between $\Delta G^\circ$ and $E^\circ$ for the cell reaction below?

$$\text{Ni}^{2+}(aq) + \text{Cd}(s) \rightarrow \text{Cd}^{2+}(aq) + \text{Ni}(s)$$

(a) $\Delta G^\circ = FE^\circ$  
(b) $\Delta G^\circ = 2 FE^\circ$  
(c) $\Delta G^\circ = -FE^\circ$  
(d) $\Delta G^\circ = -2FE^\circ$

26. Given $P_{H_2} = 0.100 \text{ atm}$, $[\text{Cd}^{2+}] = 0.200 \text{ M}$, and $[H^+] = 1.00 \times 10^{-5} \text{ M}$, calculate $E$ at $25^\circ \text{ C}$ for a cell based on the reaction: $\text{Cd}(s) + 2H^+(aq) \rightarrow H_2(g) + \text{Cd}^{2+}(aq)$. $E^\circ = +0.40 \text{ V}$.

(a) $-0.15 \text{ V}$  
(b) $-0.30 \text{ V}$  
(c) $+0.30 \text{ V}$  
(d) $+0.15 \text{ V}$

27. How long must a 50.0 A current be passed through an electrolytic cell for refining copper to produce 3.00 moles of copper?

(a) 1.50 hours  
(b) 1.61 hours  
(c) 2.50 hours  
(d) 3.22 hours

Key equations

- $K.E. = \frac{mv^2}{2}$
- $m_e = 9.11 \times 10^{-31} \text{ kg}$
- $m_p = 1.673 \times 10^{-27} \text{ kg}$
- $m_n = 1.675 \times 10^{-27} \text{ kg}$
- $J = N_e m$
- $F = 96,500 \text{ C}$
- $N = m_e k_g$•$^2$
- $R = 0.0821 \text{ atm} \cdot \text{mol} \cdot \text{K}^{-1}$
- $1 \text{ atm} = 101 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
- $g = 9.807 \text{ m/s}^2$
- $w = -P \Delta V$
- $\Delta H = q + w$
- $\Delta H^\circ_{\text{run}} = \Sigma \Delta H^\circ(\text{products}) - \Sigma \Delta H^\circ(\text{reactants})$
- $\Delta H = n_c \Delta T$
- $q = m_s \Delta T$
- $1 \text{ Ci} = 3.700 \times 10^{10} \text{ dps}$
- $t_{1/2} = 5730 \text{ years}$ for $^{14}C$
- $x_e = \left( \frac{\eta_e}{\eta_{\text{total}}} \right) = \left( \frac{P_e}{P_{\text{total}}} \right)$

$$\log \left( \frac{P_e}{P_i} \right) = \left( \frac{\Delta H^\circ_{\text{run}}}{2.303R} \right) \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\ln \left( \frac{K_{e2}}{K_{i2}} \right) = \left( \frac{\Delta H^\circ_{\text{run}}}{R} \right) \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$S = k_0 P$$

$$P_1 = P_2 \cdot X_A$$

$$\Delta P = P_2 \cdot X_B$$

$$\Delta T = K_{\text{Gibbs}}$$

$$\pi = \text{MRT}$$

$$\ln [A]_0 = -k t$$

$$\log [A]_0 = -k t / 2.303$$

$$\log \left( \frac{k_2}{k_1} \right) = \frac{E_2}{2.303R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$