Multiple Choice

Identify the choice that best completes the statement or answers the question.

1. A buffer solution is one which
   a. contains more than the expected amount of solute for a particular temperature and is therefore unstable.
   b. contains the maximum amount of solute possible for a particular temperature.
   c. changes color upon addition of strong base.
   d. contains an equal number of hydronium and hydroxide ions.
   e. resists changes in pH upon addition of acid or base.

2. In a buffer solution, if $[A^-] = [HA]$, which of the following must be true?
   a. $\text{pH} < \text{pK}_a$
   b. $\text{pH} = \text{pK}_a$
   c. $\text{pH} > \text{pK}_a$
   d. $\text{pH} < 7.00$
   e. $\text{pH} > 7.00$

3. A buffer solution is 0.500 M in ascorbic acid and 0.500 M in sodium ascorbate. Its pH is 4.10. After addition of 10 mL of 1 M NaOH to 1.00 L of this buffer, the most likely value of the pH is
   a. 4.08.
   b. 4.10.
   c. 4.12.
   d. 5.95.
   e. 10.15.

4. A buffer solution is 0.500 M in acetic acid and 0.500 M in sodium acetate. Its pH is 4.74. What is its pH after dilution by a factor of 2?
   a. 4.44
   b. 4.49
   c. 4.74
   d. 4.99
   e. 5.04

5. When 1.00 L of 0.45 M acetic acid ($\text{pK}_a = 4.74$) is mixed with the exact volume of 0.55 M NaOH required to convert the acid to its conjugate base, at the endpoint the solution will have a
   a. $\text{pH} < 7.00$
   b. $\text{pH} = 7.00$
   c. $\text{pH} > 7.00$
   d. $\text{pH} < \text{pK}_a$
   e. $\text{pH} = \text{pK}_a$
6. Which acid-base titration would yield a titration curve of the general form shown?

![Titration Curve Image]

a. H₂CO₃ titrated with NaOH  
b. NaOH titrated with H₃PO₄  
c. Na₃PO₄ titrated with HCl  
d. H₂SO₄ titrated with NaOH  
e. H₃PO₄ titrated with NaOH

7. The Kᵦₚ expression for silver phosphate, Ag₃PO₄ is

a. [Ag⁺][PO₄³⁻].  
b. [Ag⁺][PO₄³⁻]³.  
c. [Ag⁺]³[PO₄³⁻].  
d. 3[Ag⁺][PO₄³⁻].  
e. 3[Ag⁺]³[PO₄³⁻].

8. Silver phosphate is less soluble in Na₃PO₄ than in water. Why?
   a. A common ion displaces the solubility equilibrium towards the undissolved solute.  
   b. Some insoluble compounds are amphoteric.  
   c. The solubility of most salts increases as temperature increases.  
   d. The formation of complex ions displaces the solubility equilibrium to the right.  
   e. The solubility of many salts is affected by the pH of the solution.

9. Will a precipitate form when 10.0 mL of 0.500 M NaCl is added to 10.0 mL of 0.0500 M AgNO₃? The Kᵦₚ for AgCl is 1.8 × 10⁻¹⁰.
   a. Yes, because Q < Kᵦₚ  
   b. Yes, because Q = Kᵦₚ  
   c. Yes, because Q > Kᵦₚ  
   d. No, because Q < Kᵦₚ  
   e. No, because Q > Kᵦₚ

10. Five coins are tossed. Which combination of heads (H) and tails (T) is least likely?
   a. THTHT  
   b. TTTHT  
   c. HTTHT  
   d. HHTHT  
   e. THHTT

11. Which has the highest entropy?
   a. H₂O(g) at 150°C  
   b. H₂O(g) at 100°C  
   c. H₂O(l) at 100°C  
   d. H₂O(l) at 4°C (the temperature of maximum density)  
   e. H₂O(s) at −50°C
12. The boiling point of tin is 232°C. The heat of vaporization of tin at its boiling point is 247 kJ. The entropy of vaporization is
   a. 2045 J/K.
   b. 1065 J/K.
   c. 939 J/K.
   d. 489 J/K.
   e. 2.04 J/K.

13. Which has the lowest entropy at a given temperature?
   a. H₂(g)
   b. O₂(g)
   c. H₂O(g)
   d. H₂O(l)
   e. H₂O(s)

14. Calculate the value of \( \Delta S^\circ \) for the reaction shown:
   \[ \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \]
   At 25°C the values of entropy in J K\(^{-1}\) mol\(^{-1}\) are nitrogen, 191.61; hydrogen, 130.68; and ammonia, 192.77.
   a. −198.11 J/K
   b. −259.03 J/K
   c. −390.88 J/K
   d. −393.20 J/K
   e. −969.19 J/K

15. If a reaction is product-favored at any temperature, then \( \Delta H^\circ \) is _____ and \( \Delta S^\circ \) is _____.
   a. positive; positive
   b. positive; negative
   c. zero; positive
   d. negative; positive
   e. negative; negative

16. At constant \( T \) and \( P \), in which of the following situations will the reaction be product-favored at low temperature but not at high temperature
   a. \( \Delta H > 0 \) and \( \Delta S < 0 \)
   b. \( \Delta H > 0 \) and \( \Delta S > 0 \)
   c. \( \Delta H < 0 \) and \( \Delta S < 0 \)
   d. \( \Delta H < 0 \) and \( \Delta S > 0 \)
   e. none of these choices

17. Use the data given to calculate the value of \( \Delta G^\circ_{\text{rxn}} \) for the reaction at 25°C
   \[ \text{AgCl}(s) \rightleftharpoons \text{Ag}^+(aq) + \text{Cl}^- (aq) \]

<table>
<thead>
<tr>
<th>S(^\circ) (J K(^{-1}) mol(^{-1}))</th>
<th>Ag(^{+})(aq)</th>
<th>Cl(^{-}) (aq)</th>
<th>AgCl(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.68</td>
<td>56.4</td>
<td>96.2</td>
<td></td>
</tr>
<tr>
<td>( \Delta H^\circ_{\text{f}} ) (kJ/mol)</td>
<td>105.58</td>
<td>−167.2</td>
<td>−127.07</td>
</tr>
</tbody>
</table>

   a. −75.2 kJ
   b. −55.7 kJ
   c. +32.5 kJ
   d. +55.7 kJ
   e. +75.2 kJ
18. A certain reaction has $\Delta H^{\circ}_{\text{rxn}} = +177.8$ kJ, and $\Delta S^{\circ}_{\text{rxn}} = +160.5$ J/K. Above what temperature does it become product-favored?
   a. 384°C  
   b. 630°C  
   c. 835°C  
   d. 1108°C  
   e. 1381°C

19. If a chemical reaction is at equilibrium, it must be true that
   a. $\Delta G^{\circ} = 1$.  
   b. $\Delta G > 1$.  
   c. $\Delta G < 1$.  
   d. $\Delta G = 1$.  
   e. $\Delta G = 0$.

20. In the reaction shown below, _____ is the oxidizing agent and _____ the reducing agent.
   $$\text{Zn(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{ZnSO}_4(\text{aq})$$
   a. $\text{Zn}^{2+}$; $\text{H}_2$  
   b. $\text{Zn}$; $\text{H}^+$  
   c. $\text{H}_2$; $\text{Zn}^{2+}$  
   d. $\text{H}^+$; $\text{Zn}^{2+}$  
   e. $\text{H}^+$; $\text{Zn}$

21. Of the following, select the material containing the element with the highest oxidation number and determine how many electrons are required to reduce that element to an oxidation number of zero?
   FeCl$_3$  SnH$_4$  NaClO$_4$  CrO$_3$  H$_2$O$_2$
   a. 8  
   b. 7  
   c. 6  
   d. 4  
   e. 3

22. In the anode compartment of an electrochemical cell, the electrode is being _____, and _____ are flowing in from the salt bridge.
   a. oxidized; anions  
   b. oxidized; cations  
   c. oxidized; electrons  
   d. reduced; cations  
   e. reduced; anions
23. Consider an electrochemical cell as shown, with Zn in ZnCl$_2$(aq) and Cu in Cu(NO$_3$)$_2$(aq), and a salt bridge containing KNO$_3$(aq). The overall chemical reaction is:

\[ \text{Zn(s)} + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu(s)} \]

Which statement is correct?

a. One mole of electrons is transferred in this reaction.
b. Copper is oxidized at the anode.
c. Electrons travel from the Zn to the Cu.
d. This is an example of a concentration cell.
e. Zinc is reduced at the cathode.

24. Two batteries have the same design, but are different sizes. The larger one will

a. have a higher voltage.
b. deliver the same current for a longer time.
c. deliver a higher quantity of charge.
d. display properties b and c.
e. display properties a, b, and c.

Exhibit 19-1

Use this list of half-reactions to answer the following question(s).

- MnO$_4^-$ (aq) + 8H$^+$ (aq) + 5e$^-$ → Mn$^{2+}$(aq) + 4H$_2$O(l)  \quad +1.51$ V
- Cr$_2$O$_7^{2-}$(aq) + 6e$^-$ → 2Cr$^{3+}$(aq) + 7H$_2$O(l)  \quad +1.33$ V
- Pt$^{2+}$(aq) + 2e$^-$ → Pt(s)  \quad +1.20$ V
- Cu$^{2+}$(aq) + 2e$^-$ → Cu(s)  \quad +0.34$ V
- Pb$^{2+}$(aq) + 2e$^-$ → Pb(s)  \quad -0.13$ V
- Al$^{3+}$(aq) + 3e$^-$ → Al(s)  \quad -1.66$ V

25. Refer to Exhibit 19-1. The potential for the product-favored reaction involving aluminum and copper metals, Al$^{3+}$(aq), and Cu$^{2+}$(aq) is

a. 2.17 V.
b. 2.00 V.
c. 1.79 V.
d. 1.32 V.
e. 1.15 V.

26. Refer to Exhibit 19-1. The strongest reducing agent in the table is

a. Al(s).
b. Al$^{3+}$(aq).
c. H$^+$(aq).
d. MnO$_4^-$ (aq).
e. Mn$^{2+}$(aq).
27. Consider the cell reaction
   \[ \text{Sn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Cu(s)}. \]
   The value of \( E^{\circ}_{\text{cell}} \) is 0.447 V at 25°C. Calculate the value of \( \Delta G^{\circ} \) and \( K \) for this cell.
   a. \(-86.3 \text{ kJ}; 1.34 \times 10^{15}\)
   b. \(-43.1 \text{ kJ}; 1.37 \times 10^{43}\)
   c. \(43.1 \text{ kJ}; 3.55 \times 10^{7}\)
   d. \(86.3 \text{ kJ}; 7.92 \times 10^{-16}\)
   e. \(86.3 \text{ kJ}; 2.00 \times 10^{86}\)

28. A concentration cell is a cell in which
   a. the voltage is generated because of a difference in concentrations
   b. the concentrations of all cell components are all 1.00 M
   c. the concentrations of all cell components remain constant throughout the life of the cell
   d. the cell voltage never varies by more than \( 1.00 \times 10^{-14} \) V
   e. none of these choices are correct

29. The value of \( E_{\text{cell}}^{\circ} \) for the cell shown below is + 1.41 V.
   \[ \text{Al}(s) \mid \text{Al}^{3+}(\text{aq}) \parallel \text{Ni}^{2+}(\text{aq}) \mid \text{Ni}(s) \]
   What is the value of \( E_{\text{cell}} \) at 25°C if the concentration of \( \text{Al}^{3+}(\text{aq}) \) is 0.050 M, and of \( \text{Ni}^{2+}(\text{aq}), 2.0 \text{ M}\)?
   a. +1.34 V
   b. +1.38 V
   c. +1.41 V
   d. +1.44 V
   e. +1.48 V

30. A secondary cell is one which _____; this is possible because _____.
   a. is driven by a primary cell; the cell reactions are coupled
   b. is disposable without harming the environment; no mercury is used
   c. is rechargeable; the cell reaction is completely reversible
   d. has double the lifetime of a primary cell; two primary cells are placed in parallel
   e. has double the voltage of a primary cell; two primary cells are placed in series

31. Alpha particles are best described as
   a. neutral particles that weigh approximately one atomic mass unit.
   b. positive particles that are identical to the nucleus of an atom of \( ^4\text{He} \).
   c. electrons ejected at high speeds from a radioactive nucleus.
   d. high-speed particles similar in size to an electron, but oppositely charged.
   e. a form of electromagnetic radiation.

32. Beta particles are best described as _____, ejected at high speeds from a radioactive nucleus.
   a. protons
   b. particles similar in size to an electron, but oppositely charged
   c. electrons
   d. neutral particles weighing approximately one atomic mass unit
   e. positive particles identical to the nucleus of an atom of \( ^4\text{He} \)

33. If polonium-210 emits an alpha particle, the other product will be
   a. lead-206.
   b. mercury-204.
   c. mercury-206.
   d. polonium-208.
   e. radon-206.
34. All elements in the Periodic Table beyond _____ have only radioactive isotopes; these mostly decay by _____ emission.
   a. Bi; alpha
   b. Po; beta
   c. Ra; alpha
   d. U; beta
   e. Pu; gamma

35. If pure polonium-210 (k = 5.02 × 10^{-3} \text{ day}^{-1}) were used in a crime, based on radioactive disintegration alone, how long would it take for half the original isotope to disappear?
   a. 1.44 × 10^3 \text{ minutes}
   b. 69.3 \text{ hours}
   c. 138 \text{ days}
   d. 2.9 \text{ years}
   e. 210 \text{ years}
MULTIPLE CHOICE

1. ANS: E  PTS: 1  TOP: 17.1 Buffer Solutions
2. ANS: B  PTS: 1  TOP: 17.1 Buffer Solutions
3. ANS: C  PTS: 1  TOP: 17.1 Buffer Solutions
4. ANS: C  PTS: 1  TOP: 17.1 Buffer Solutions
5. ANS: C  PTS: 1  TOP: 17.2 Acid-Base Titrations
6. ANS: E  PTS: 1  TOP: 17.2 Acid-Base Titrations
7. ANS: C  PTS: 1  TOP: 17.4 Solubility Equilibria and the Solubility Product Constant, Ksp
8. ANS: A  PTS: 1  TOP: 17.5 Factors Affecting Solubility
9. ANS: C  PTS: 1  TOP: 17.6 Precipitation: Will it Occur?
10. ANS: B  PTS: 1  TOP: 18.2 Chemical Reactions and Dispersal of Energy
14. ANS: A  PTS: 1  TOP: 18.4 Calculating Entropy Changes
15. ANS: D  PTS: 1  TOP: 18.5 Entropy and the Second Law of Thermodynamics
16. ANS: C  PTS: 1  TOP: 18.5 Entropy and the Second Law of Thermodynamics
17. ANS: D  PTS: 1  TOP: 18.6 Gibbs Free Energy
18. ANS: C  PTS: 1  TOP: 18.6 Gibbs Free Energy
19. ANS: E  PTS: 1  TOP: 18.7 Gibbs Free Energy Changes and Equilibrium Constants
20. ANS: E  PTS: 1  TOP: 19.1 Redox Reactions
21. ANS: B  PTS: 1  TOP: 19.2 Using Half-Reactions to Understand Redox Reactions
22. ANS: A  PTS: 1  TOP: 19.3 Electrochemical Cells
23. ANS: C  PTS: 1  TOP: 19.3 Electrochemical Cells
24. ANS: D  PTS: 1  TOP: 19.4 Electrochemical Cells and Voltage
25. ANS: B  PTS: 1  TOP: 19.5 Using Standard Cell Potentials
26. ANS: A  PTS: 1  TOP: 19.5 Using Standard Cell Potentials
28. ANS: A  PTS: 1  TOP: 19.7 Effect of Concentration on Cell Potential
29. ANS: D  PTS: 1  TOP: 19.7 Effect of Concentration on Cell Potential
30. ANS: C  PTS: 1  TOP: 19.9 Common Batteries
31. ANS: B  PTS: 1  TOP: 20.1 The Nature of Radioactivity
32. ANS: C  PTS: 1  TOP: 20.1 The Nature of Radioactivity
33. ANS: A  PTS: 1  TOP: 20.2 Nuclear Reactions
34. ANS: A  PTS: 1  TOP: 20.3 Stability of Atomic Nuclei
35. ANS: C  PTS: 1  TOP: 20.4 Rates of Disintegration Reactions