4. Equilibrium is reached in a chemical reaction when
   A. the reactants are completely consumed.
   B. the concentrations of all reactants and products become equal.
   C. the rates of the opposing reactions become equal.
   D. the forward and reverse reactions stop.
   Answer: C; Difficulty: easy; Reference: Section 16.3

2. According to Le Châtelier’s Principle, decreasing the temperature at which the following reaction takes place will
   \[ \text{N}_2\text{O}_4 + 58.6 \, \text{kJ} \rightleftharpoons 2\text{NO}_2(\text{g}) \]
   A. shift the equilibrium to the left.
   B. shift the equilibrium to the right.
   C. have no effect on the equilibrium.
   Answer: A; Difficulty: easy; Reference: Section 16.4

6. In which direction will the point of equilibrium shift when the pressure is increased in the following equilibrium?
   \[ \text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) \]
   A. Shift to the right
   B. Shift to the left
   C. No shift
   Answer: A; Difficulty: easy; Reference: Section 16.5

13. In which direction will the point of equilibrium shift when temperature is increased in the following equilibrium?
   \[ 2 \text{SO}_3(\text{g}) + 188 \, \text{kJ} \rightleftharpoons 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \]
   A. Shift to the right
   B. Shift to the left
   C. No shift
   Answer: A; Difficulty: easy; Reference: Section 16.7

15. In which direction will the point of equilibrium shift when a catalyst is added to the following equilibrium system?
   \[ 2 \text{C} (\text{s}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{CO} (\text{g}) + 110 \, \text{kJ} \]
   A. Shift to the right
   B. Shift to the left
C. No shift
*Answer: C; Difficulty: easy; Reference: Section 16.8*

35. Calculate the value of $K_{eq}$ for the following equilibrium when $[H_2] = 0.228 \text{ M}$, $[I_2] = 0.228 \text{ M}$, and $[HI] = 1.544 \text{ M}$.

$$H_2 (g) + I_2 (g) \rightleftharpoons 2 HI (g)$$

A. 29.7  
B. 0.0337  
C. 0.0219  
D. 45.9
*Answer: D; Difficulty: easy; Reference: Section 16.9*

23. Which acid ionization constant would indicate the strongest acid?
A. $3.5 \times 10^{-4}$  
B. $9.5 \times 10^{-8}$  
C. $1.5 \times 10^{-2}$  
D. $1.3 \times 10^{-13}$
*Answer: C; Difficulty: easy; Reference: Section 16.11*

5. A solution in which equilibrium is reached between dissolved and undissolved solute is
A. saturated.  
B. unsaturated.  
C. supersaturated.
*Answer: A; Difficulty: easy; Reference: Section 16.12*

21. Which species is oxidized in the following equation?

$$2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2 + \text{O}_2$$

A. H$_2$  
B. O$_2$  
C. H$^{+1}$  
D. O$^{-2}$
*Answer: D; Difficulty: easy; Reference: Section 17.1*

2. What is the oxidation number of manganese in MnO$_2$?
A. +2
B. -4  
C. +4  
D. 0  
Answer: C; Difficulty: easy; Reference: Section 17.1

32. Which occurs when a sodium atom is oxidized?  
   A. One electron is gained  
   B. One electron is lost  
   C. One proton is gained  
   D. One proton is lost  
Answer: B; Difficulty: easy; Reference: Section 17.1

33. Which occurs when an oxygen atom is reduced?  
   A. Two protons are gained  
   B. Two protons are lost  
   C. Two electrons are gained  
   D. Two electrons are lost  
Answer: C; Difficulty: easy; Reference: Section 17.1

13. The reducing agent is  
   A. the species that is reduced.  
   B. the species with a negative charge.  
   C. the species that loses electrons.  
   D. the species that gains electrons.  
Answer: C; Difficulty: easy; Reference: Section 17.2

48. In the following reaction, the chlorine atoms

\[ 2 \text{Na} + \text{Cl}_2 \rightarrow 2 \text{NaCl} \]

   A. gain electrons.  
   B. lose electrons.  
   C. gain protons.  
   D. lose protons.  
Answer: A; Difficulty: easy; Reference: Section 17.3

11. What always occurs at the cathode in an electrolytic cell?  
   A. Protons are gained  
   B. Protons are lost  
   C. Electrons are gained  
   D. Electrons are lost
18. In a voltaic cell
   A. a chemical reaction occurs spontaneously and releases energy as electricity.
   B. electricity causes a chemical reaction to occur.
   C. a physical change occurs spontaneously and releases energy as electricity.
   D. electricity causes a physical change to occur.
Answer: A; Difficulty: easy; Reference: Section 17.8

2. The instrument used to measure ionizing radiation is a
   A. radioactive counter.
   B. Curie counter.
   C. Roentgen counter.
   D. Geiger counter.
Answer: D; Difficulty: easy; Reference: Section 18.7

9. Gamma radiation has
   A. a mass of 4 amu.
   B. a charge of +2.
   C. a charge of -1.
   D. neither mass nor charge.
Answer: D; Difficulty: easy; Reference: Section 18.3

10. An alpha particle has
    A. a mass of 2 amu.
    B. a mass of 4 amu.
    C. a charge of -1.
    D. neither mass nor charge.
Answer: B; Difficulty: easy; Reference: Section 18.3

11. A beta particle has
    A. a mass of 4 amu.
    B. a charge of +4.
    C. a charge of -1.
    D. neither mass nor charge.
Answer: C; Difficulty: easy; Reference: Section 18.3

25. In which type of reaction does a heavy nucleus absorb a neutron, split to form two or more intermediate sized fragments, and release at least two neutrons?
   A. Alpha decay
   B. Beta decay
   C. Fission
D. Fusion  
*Answer: C; Difficulty: easy; Reference: Section 18.8*

26. In which type of reaction do the nuclei of two light elements unite to form a heavier nucleus?  
  A. Fission  
  B. Fusion  
  C. Alpha decay  
  D. Beta decay  
*Answer: B; Difficulty: easy; Reference: Section 18.11*

27. Which form of nuclear emission requires the greatest amount of shielding to provide protection from radiation injury?  
  A. Alpha  
  B. Beta  
  C. Gamma  
*Answer: C; Difficulty: easy; Reference: Section 18.14*

28. Which form of nuclear emission requires the least amount of shielding to provide protection from radiation injury?  
  A. Alpha  
  B. Beta  
  C. Gamma  
*Answer: A; Difficulty: easy; Reference: Section 18.14*

32. How many neutrons are in the nucleus of cobalt-60?  
  A. 29  
  B. 31  
  C. 27  
  D. 33  
*Answer: D; Difficulty: easy; Reference: Section 18.1*

33. What type of emission causes C-14 to decay to N-14?  
  A. Alpha  
  B. Beta  
  C. Positron  
  D. Gamma  
*Answer: B; Difficulty: medium; Reference: Section 18.3*

41. When Kr-85 emits gamma radiation, the remaining nucleus is  
  A. Rb-85  
  B. Se-81  

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C. Kr-85
D. Rb-84

Answer: C; Difficulty: easy; Reference: Section 18.5
96. The ionization constant, $K_a$, for an acetic acid solution is $1.8 \times 10^{-5}$. For a 0.45 M solution of acetic acid calculate the following:

A. $[H^+]$

B. pH

Answer: A. $[H^+] = 2.8 \times 10^{-3}$ M; B. $pH = 2.6$; Difficulty: medium; Reference: Section 16.11

100. The $K_{sp}$ value for barium sulfate is $1.5 \times 10^{-9}$. Calculate the solubility of barium sulfate in grams per liter.

Answer: Solubility is $9.0 \times 10^{-3}$ g/L; Difficulty: easy; Reference: Section 16.12

99. Use the activity series at the right to predict whether each of the following reactions will occur spontaneously.

<table>
<thead>
<tr>
<th>More active</th>
<th>K</th>
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<tbody>
<tr>
<td>Ba</td>
<td>Ca</td>
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<tr>
<td>Na</td>
<td>Mg</td>
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<tr>
<td>Al</td>
<td>Zn</td>
</tr>
<tr>
<td>Cr</td>
<td>Fe</td>
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</tbody>
</table>

A. Fe + Ca(NO$_3$)$_2$

B. Mg + Zn(NO$_3$)$_2$

C. K + Zn(NO$_3$)$_2$

D. Cr + NaNO$_3$

E. Mg + Ca(NO$_3$)$_2$

F. Ba + Al(NO$_3$)$_3$

Answer: A. No reaction; B. Spontaneous reaction; C. Spontaneous reaction; D. No reaction; E. No reaction; F. Spontaneous reaction; Difficulty: easy; Reference: Section 17.5

102. Define the term “half-life”. Why are half-lives important when using radioactive tracers for medical purposes?

Answer: The half-life refers to the amount of time it takes for the concentration of a species to
drop to half of its initial value. Half-lives for radioactive tracers used for medical purposes must be quite short to minimize the exposure of the patient to potentially damaging effects of the radiation emitted by the tracer.; Difficulty: easy; Reference: Section 18.14