1. An example of a nonelectrolyte is
   A) C₆H₁₂O₆(aq)    B) K₂SO₄(aq)
   C) NaCl(aq)        D) HCl(aq)

2. Which of the following aqueous solutions is the best conductor of electricity?
   A) 0.10 M CH₃OH    B) 1.0 M CH₃OH
   C) 0.10 M NaOH     D) 1.0 M NaOH

3. Which substance, when dissolved in water, forms a solution that conducts an electric current?
   A) C₂H₅OH          B) C₆H₁₂O₆
   C) C₁₂H₂₂O₁₁       D) CH₃COOH

4. Which compounds can be classified as electrolytes?
   A) alcohols         B) alkynes
   C) organic acids    D) saturated hydrocarbons

5. A substance is classified as an electrolyte because
   A) it has a high melting point
   B) it contains covalent bonds
   C) its aqueous solution conducts an electric current
   D) its aqueous solution has a pH value of 7

6. According to the Arrhenius theory, a substance that is classified as an acid will always yield
   A) H⁺(aq)          B) K⁺(aq)
   C) F⁻(aq)          D) I⁻(aq)

7. Unlike an acid, an aqueous solution of a base
   A) causes some indicators to change color
   B) conducts electricity
   C) contains more H⁺ ions than OH⁻ ions
   D) contains more OH⁻ ions than H⁺ ions

8. An Arrhenius base yields which ion as the only negative ion in an aqueous solution?
   A) hydride ion      B) hydrogen ion
   C) hydronium ion    D) hydroxide ion

9. The only positive ion found in H₂SO₄(aq) is the
   A) ammonium ion     B) hydronium ion
   C) hydroxide ion    D) sulfate ion

10. How are HNO₃(aq) and CH₃COOH(aq) similar?
    A) They are Arrhenius acids and they turn blue litmus red.
    B) They are Arrhenius acids and they turn red litmus blue.
    C) They are Arrhenius bases and they turn blue litmus red.
    D) They are Arrhenius bases and they turn red litmus blue.

11. Which pH change represents a hundredfold increase in the concentration of H₃O⁺?
    A) pH 5 to pH 7    B) pH 13 to pH 14
    C) pH 3 to pH 1    D) pH 4 to pH 3

12. Which of these pH numbers indicates the highest level of acidity?
    A) 5              B) 8              C) 10              D) 12

13. Given the following solutions:
    Solution A: pH of 10
    Solution B: pH of 7
    Solution C: pH of 5
    Which list has the solutions placed in order of increasing H⁺ concentration?
    A) A, B, C         B) B, A, C
    C) C, A, B        D) C, B, A

14. Which substance, if added to a saturated solution of NH₄OH, would cause the pH of the solution to increase?
    A) HCl             B) NH₄Cl
    C) LiOH            D) CH₃OH

15. As the pH of a solution is changed from 3 to 6, the concentration of hydronium ions
    A) increases by a factor of 3
    B) increases by a factor of 1000
    C) decreases by a factor of 3
    D) decreases by a factor of 1000

16. The ability of H₂SO₄(aq) to change blue litmus red is mainly due to the presence of
    A) SO₂ molecules    B) H₂O molecules
    C) H₃O⁺(aq) ions   D) SO₄²⁻(aq) ions
17. What color is phenolphthalein in a solution that has a pH of 9?
   A) blue  B) pink  C) white  D) colorless

18. In which solution will thymol blue indicator appear blue?
   A) 0.1 M CH₃COOH  B) 0.1 M KOH  C) 0.1 M HCl  D) 0.1 M H₂SO₄

19. An indicator was used to test a water solution with a pH of 12. Which indicator color would be observed?
   A) colorless with litmus  B) red with litmus  C) colorless with phenolphthalein  D) pink with phenolphthalein

20. In a solution, litmus is blue. The pH of the solution could be
   A) 10  B) 2  C) 3  D) 4

21. Given the reaction at equilibrium:
   \[ \text{HSO}_4^- + \text{NH}_3 \leftrightarrow \text{SO}_4^{2-} + \text{NH}_4^+ \]
   What are the two species that are acids?
   A) \text{NH}_3 \text{ and } \text{NH}_4^+  B) \text{NH}_3 \text{ and } \text{SO}_4^{2-}  C) \text{HSO}_4^- \text{ and } \text{SO}_4^{2-}  D) \text{HSO}_4^- \text{ and } \text{NH}_4^+

22. One acid-base theory defines a base as an
   A) \text{H}^+ \text{ donor}  B) \text{H}^+ \text{ acceptor}  C) \text{H} \text{ donor}  D) \text{H acceptor}

23. What are the bases that accept protons in the reaction?
   \[ \text{H}_2\text{S} + \text{H}_2\text{O} \leftrightarrow \text{H}_3\text{O}^+ + \text{HS}^- \]
   A) \text{H}_2\text{S} \text{ and } \text{H}_2\text{O}  B) \text{H}_2\text{S} \text{ and } \text{H}_3\text{O}^+  C) \text{HS}^- \text{ and } \text{H}_2\text{O}  D) \text{HS}^- \text{ and } \text{H}_3\text{O}^+

24. In the reaction:
   \[ \text{NH}_2^- + \text{HOH} \leftrightarrow \text{NH}_3 + \text{OH}^- \]
   The two acids are
   A) \text{HOH and } \text{NH}_2^-  B) \text{HOH and } \text{NH}_3  C) \text{OH}^- \text{ and } \text{HOH}  D) \text{OH}^- \text{ and } \text{NH}_3

25. Base your answer to the following question on Given the balanced equation representing a reaction:
   \[ \text{NH}_3(g) + \text{H}_2\text{O}(\ell) \rightarrow \text{NH}_4^+(aq) + \text{OH}^-(aq) \]
   According to one acid-base theory, the \text{NH}_3(g) molecules act as
   A) an acid because they accept \text{H}^+ \text{ ions}  B) an acid because they donate \text{H}^+ \text{ ions}  C) a base because they accept \text{H}^+ \text{ ions}  D) a base because they donate \text{H}^+ \text{ ions}

26. Which species is amphoteric (amphiprotic)?
   A) \text{H}_2  B) \text{H}_2\text{SO}_4  C) \text{HSO}_4^-  D) \text{SO}_4^{2-}

27. The formula for the calcium salt of sulfuric acid is
   A) \text{CaS}  B) \text{Ca}_2\text{S}  C) \text{CaSO}_4  D) \text{Ca}_2\text{SO}_4

28. Which compound could serve as a reactant in a neutralization reaction?
   A) \text{NaCl}  B) \text{KOH}  C) \text{CH}_3\text{OH}  D) \text{CH}_3\text{CHO}

29. Equal volumes of 0.1 M NaOH and 0.1 M HCl are thoroughly mixed. The resulting solution has a pH closest to
   A) weak acid and a weak base  B) weak acid and a strong base  C) strong acid and a weak base  D) strong acid and a strong base

30. Potassium chloride, KCl, is a salt derived from the neutralization of a
   A) substitution  B) saponification  C) ionization  D) neutralization

31. Which reaction occurs when hydrogen ions react with hydroxide ions to form water?
   A) substitution  B) saponification  C) ionization  D) neutralization

32. The acid and base in each of the following reactions completely neutralize each other. In which reaction is the final solution acidic?
   A) \text{HCl(aq)} + \text{KOH(aq)} \rightarrow \text{KCl(aq)} + \text{H}_2\text{O}  B) \text{H}_2\text{SO}_4(aq) + 2 \text{KOH(aq)} \rightarrow \text{K}_2\text{SO}_4(aq) + 2 \text{H}_2\text{O}  C) \text{H}_2\text{S(aq)} + 2 \text{NaOH(aq)} \rightarrow \text{Na}_2\text{S(aq)} + 2 \text{H}_2\text{O}  D) \text{HNO}_3(aq) + \text{NH}_4\text{OH(aq)} \rightarrow \text{NH}_4\text{NO}_3(aq) + \text{H}_2\text{O}
33. An aqueous solution of NaC₂H₃O₂ is basic. The salt NaC₂H₃O₂ can be derived from the reaction of a
   A) strong acid with a weak base
   B) strong acid with a strong base
   C) weak acid with a weak base
   D) weak acid with a strong base

34. Given the reaction:
   \[ \text{HC}_2\text{H}_3\text{O}_2(aq) + \text{KOH}(aq) \rightarrow \text{KC}_2\text{H}_3\text{O}_2(aq) + \text{H}_2\text{O}(l) \]

   The products of this reaction form a salt solution that is
   A) acidic and turns litmus blue
   B) acidic and turns litmus red
   C) basic and turns litmus blue
   D) basic and turns litmus red

35. Which volume of 0.10 M NaOH(aq) exactly neutralizes 15.0 milliliters of 0.20 M HNO₃(aq)?
   A) 1.5 mL   B) 7.5 mL
   C) 3.0 mL   D) 30. mL

36. What volume of 0.500 M HNO₃(aq) must completely react to neutralize 100.0 milliliters of 0.100 M
   KOH(aq)?
   A) 10.0 mL   B) 20.0 mL
   C) 50.0 mL   D) 500. mL

37. A student neutralized 16.4 milliliters of HCl by adding 12.7 milliliters of 0.620 M KOH. What was the
   molarity of the HCl acid?
   A) 0.168 M   B) 0.480 M
   C) 0.620 M   D) 0.801 M

38. During which process can 10.0 milliliters of a 0.05 M HCl(aq) solution be used to determine the unknown
   concentration of a given volume of NaOH(aq) solution?
   A) evaporation   B) distillation
   C) filtration   D) titration

39. Which process uses a volume of solution of known concentration to determine the concentration of another
   solution?
   A) distillation   B) substitution
   C) transmutation   D) titration

40. The table below shows the color of an indicator in specific pH ranges.

<table>
<thead>
<tr>
<th>Color</th>
<th>pH Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>1–4</td>
</tr>
<tr>
<td>Orange</td>
<td>5–6</td>
</tr>
<tr>
<td>Green</td>
<td>6–7</td>
</tr>
<tr>
<td>Blue</td>
<td>8–10</td>
</tr>
<tr>
<td>Violet</td>
<td>11–14</td>
</tr>
</tbody>
</table>

   If this indicator is used when titrating an unknown strong base by adding a strong acid, the color of the
   indicator will change from
   A) blue to green   B) green to blue
   C) orange to green   D) green to orange

41. When the salt NaHCO₃ is dissolved in water, the solution becomes
   A) basic due to the production of H₃O⁺ ions
   B) acidic due to the production of H₃O⁺ ions
   C) basic due to the production of OH⁻ ions
   D) acidic due to the production of OH⁻ ions

42. Which aqueous solution has a pH greater than 7?
   A) NaCl   B) NaNO₃
   C) Na₂SO₄   D) Na₂CO₃
43. Base your answer to the following question on the information below.

Vitamin C, also known as ascorbic acid, is water soluble and cannot be produced by the human body. Each day, a person's diet should include a source of vitamin C, such as orange juice. Ascorbic acid has a molecular formula of C₆H₈O₆ and a gram-formula mass of 176 grams per mole.

What is the color of the indicator thymol blue after it is added to an aqueous solution of vitamin C?

44. Base your answer to the following question on the information below.

A 20.0-milliliter sample of HCl(aq) is completely neutralized by 32.0 milliliters of 0.50 M KOH(aq).

According to the data, to what number of significant figures should the calculated molarity of the HCl(aq) be expressed?

Base your answers to questions 45 and 46 on the information below.

In one trial of an investigation, 50.0 milliliters of HCl(aq) of an unknown concentration is titrated with 0.10 M NaOH(aq). During the titration, the total volume of NaOH(aq) added and the corresponding pH value of the reaction mixture are measured and recorded in the table below.

<table>
<thead>
<tr>
<th>Total Volume of NaOH(aq) Added (mL)</th>
<th>pH Value of Reaction Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>1.6</td>
</tr>
<tr>
<td>20.0</td>
<td>2.2</td>
</tr>
<tr>
<td>24.0</td>
<td>2.9</td>
</tr>
<tr>
<td>24.9</td>
<td>3.9</td>
</tr>
<tr>
<td>25.1</td>
<td>10.1</td>
</tr>
<tr>
<td>26.0</td>
<td>11.1</td>
</tr>
<tr>
<td>30.0</td>
<td>11.8</td>
</tr>
</tbody>
</table>

45. In another trial, 40.0 milliliters of HCl(aq) is completely neutralized by 20.0 milliliters of this 0.10 M NaOH(aq). Calculate the molarity of the titrated acid in this trial. Your response must include both a numerical setup and the calculated result.

46. Write a balanced equation that represents this neutralization reaction.
Acid rain lowers the pH in ponds and lakes and over time can cause the death of some aquatic life. Acid rain is caused in large part by the burning of fossil fuels in power plants and by gasoline-powered vehicles. The acids commonly associated with acid rain are sulfurous acid, sulfuric acid, and nitric acid.

In general, fish can tolerate a pH range between 5 and 9. However, even small changes in pH can significantly affect the solubility and toxicity of common pollutants. Increased concentrations of these pollutants can adversely affect the behavior and normal life processes of fish and cause deformity, lower egg production, and less egg hatching.

47. Sulfur dioxide, SO\textsubscript{2}, is one of the gases that reacts with water to produce acid rain. According to Reference Table \textit{G}, describe how the solubility of sulfur dioxide in water is affected by an increase in water temperature.

48. Using information in the passage, describe \textit{one} effect of acid rain on future generations of fish species in ponds and lakes.

Base your answers to questions 49 through 51 on the information below.

A student was studying the pH differences in samples from two Adirondack streams. The student measured a pH of 4 in stream \textit{A} and a pH of 6 in stream \textit{B}.

49. Identify \textit{one} compound that could be used to neutralize the sample from stream \textit{A}.

50. Compare the hydronium ion concentration in stream \textit{A} to the hydronium ion concentration in stream \textit{B}.

51. What is the color of bromthymol blue in the sample from stream \textit{A}?
1. A
2. D
3. D
4. C
5. C
6. A
7. D
8. D
9. B
10. A
11. C
12. A
13. A
14. C
15. D
16. C
17. B
18. B
19. D
20. A
21. D
22. B
23. C
24. B
25. C
26. C
27. C
28. B
29. B
30. D
31. D
32. D
33. D
34. C
35. D
36. B
37. B
38. D
39. D
40. A
41. C
42. D
43. yellow
44. 2 or two.
45. A correct numerical set up is shown. A result of 0.050 M or a response consistent with the student's numerical setup is shown.
46. • NaOH(aq) + HCl(aq) → NaCl(aq) + H₂O(ℓ)
47. Examples: – As the water temperature increases, the solubility of sulfur dioxide decreases. – The solubility of SO₂ decreases.
48. Examples: – There will be a decrease in the number of fish eggs that hatch. – Fewer eggs produced – more deformities
49. •sodium hydroxide
  •lime  •NH₃  •any base
50. •Stream A has more hydronium ions. • Stream B has a lower concentration. •A is higher • 100 times higher
51. yellow.