35. For each of the following aqueous reactions, identify the acid, the base, the conjugate base, and the conjugate acid.

a. \( \text{H}_2\text{O} + \text{H}_2\text{CO}_3 \iff \text{H}_3\text{O}^+ + \text{HCO}_3^- \)

b. \( \text{C}_5\text{H}_5\text{NH}^+ + \text{H}_2\text{O} \iff \text{C}_5\text{H}_5\text{N} + \text{H}_3\text{O}^+ \)

c. \( \text{HCO}_3^- + \text{C}_5\text{H}_5\text{NH}^+ \iff \text{H}_2\text{CO}_3 + \text{C}_5\text{H}_5\text{N} \)
Write the formula and name of the conjugate base for each of the following acids:

a. HCN(aq)

b. NH$_4^+$ (aq)

c. H$_2$CO$_3$ (aq)

d. HSO$_4^-$ (aq)

e. HClO$_2$ (aq)

Write the formula and name of the conjugate acid for each of the following bases:

a. CO$_3^{2-}$ (aq)

b. SH (aq)

c. H$_2$PO$_3^-$ (aq)

d. Br$^-$ (aq)

e. NO$_2^-$ (aq)
33. Write balanced equations that describe the following reactions.
   a. the dissociation of perchloric acid in water
   b. the dissociation of propanoic acid (CH₃CH₂CO₂H) in water
   c. the dissociation of ammonium ion in water
19. Anions containing hydrogen (for example, \( \text{HCO}_3^- \) and \( \text{H}_2\text{PO}_4^- \)) usually show amphoteric behavior. Write equations illustrating the amphotericism of these two anions.
39. Use Table 14.2 to order the following from the strongest to the weakest acid.

\[ \text{HClO}_2, \quad \text{H}_2\text{O}, \quad \text{NH}_4^+, \quad \text{HClO}_4 \]
41. You may need Table 14.2 to answer the following questions.
   a. Which is the stronger acid, HCl or H$_2$O?
   b. Which is the stronger acid, H$_2$O or HNO$_2$?
   c. Which is the stronger acid, HCN or HOC$_6$H$_5$?
42. You may need Table 14.2 to answer the following questions.
   a. Which is the stronger base, Cl\(^-\) or H\(_2\)O?
   b. Which is the stronger base, H\(_2\)O or NO\(_2\)\(^-\)?
   c. Which is the stronger base, CN\(^-\) or OC\(_6\)H\(_5\)\(^-\)?
43. Calculate the $[\text{OH}^-]$ of each of the following solutions at 25°C. Identify each solution as neutral, acidic, or basic.

a. $[\text{H}^+] = 1.0 \times 10^{-7} \text{ M}$

b. $[\text{H}^+] = 8.3 \times 10^{-16} \text{ M}$

c. $[\text{H}^+] = 12 \text{ M}$

d. $[\text{H}^+] = 5.4 \times 10^{-5} \text{ M}$
45. Values of $K_w$ as a function of temperature are as follows:

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>$K_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$1.14 \times 10^{-15}$</td>
</tr>
<tr>
<td>25</td>
<td>$1.00 \times 10^{-14}$</td>
</tr>
<tr>
<td>35</td>
<td>$2.09 \times 10^{-14}$</td>
</tr>
<tr>
<td>40</td>
<td>$2.92 \times 10^{-14}$</td>
</tr>
<tr>
<td>50</td>
<td>$5.47 \times 10^{-14}$</td>
</tr>
</tbody>
</table>

a. Is the autoionization of water exothermic or endothermic?

b. Calculate $[\text{H}^+]$ and $[\text{OH}^-]$ in a neutral solution at 50.°C.
47. Calculate the pH and pOH of the solutions in Exercise 43

43. Calculate the $[\text{OH}^-]$ of each of the following solutions at 25°C. Identify each solution as neutral, acidic, or basic.

   a. $[\text{H}^+] = 1.0 \times 10^{-7} \ M$
   
   b. $[\text{H}^+] = 8.3 \times 10^{-16} \ M$

   c. $[\text{H}^+] = 12 \ M$

   d. $[\text{H}^+] = 5.4 \times 10^{-5} \ M$
51. The pH of a sample of gastric juice in a person’s stomach is 2.1. Calculate the pOH, [H\(^+\)], and [OH\(^-\)] for this sample. Is gastric juice acidic or basic?
49. Fill in the missing information in the following table.

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>pOH</th>
<th>[H⁺]</th>
<th>[OH⁻]</th>
<th>Acidic, Basic, or Neutral?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution a</td>
<td>6.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution b</td>
<td></td>
<td></td>
<td></td>
<td>$8.4 \times 10^{-14} \text{ } M$</td>
<td></td>
</tr>
<tr>
<td>Solution c</td>
<td></td>
<td>3.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution d</td>
<td></td>
<td></td>
<td>$1.0 \times 10^{-7} \text{ } M$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What are the major species present in 1.0 M solutions of the following:

a. hydrosulfuric acid  
b. perchloric acid  
c. permanganic acid  
d. hydroiodic acid  
e. sodium chloride
55. Calculate the pH of each of the following solutions of a strong acid in water.
   a. $0.10 \, M \, HCl$
   b. $5.0 \, M \, HCl$
   c. $1.0 \times 10^{-11} \, M \, HCl$
57. Calculate the concentration of an aqueous HI solution that has pH = 2.50. HI is a strong acid.
59. How would you prepare 1600 mL of a pH = 1.50 solution using concentrated (12 M) HCl?
63. Calculate the concentration of all species present and the pH of a 0.020 \( M \) HF solution.
67. Monochloroacetic acid, $\text{HC}_2\text{H}_2\text{ClO}_2$, is a skin irritant that is used in "chemical peels" intended to remove the top layer of dead skin from the face and ultimately improve the complexion. The value of $K_a$ for monochloroacetic acid is $1.35 \times 10^{-3}$. Calculate the pH of a 0.10 $M$ solution of monochloroacetic acid.
69. Calculate the pH of a solution that contains 1.0 M HF and 1.0 M HOC₆H₅. Also calculate the concentration of OC₆H₅⁻ in this solution at equilibrium.
71. Calculate the percent dissociation of the acid in each of the following solutions.

a. 0.50 M acetic acid
b. 0.050 M acetic acid
c. 0.0050 M acetic acid
d. Use Le Châtelier’s principle to explain why percent dissociation increases as the concentration of a weak acid decreases.
e. Even though the percent dissociation increases from solutions a to c, the [H\(^+\)] decreases. Explain.
Percent dissociation can be used to calculate $K_a$!
73. A 0.15 M solution of a weak acid is 3.0% dissociated. Calculate $K_a$. 
75. The pH of a $1.00 \times 10^{-2} \, M$ solution of cyanic acid (HOCN) is 2.77 at 25°C. Calculate $K_a$ for HOCN from this result.
77. A solution of formic acid (HCOOH, \( K_a = 1.8 \times 10^{-4} \)) has a pH of 2.70. Calculate the initial concentration of formic acid in this solution.
83. Use Table 14.3 to help order the following bases from strongest to weakest.

\[ \text{NO}_3^- , \quad \text{H}_2\text{O} , \quad \text{NH}_3 , \quad \text{C}_5\text{H}_5\text{N} \]
85. Use Table 14.3 to help answer the following questions.
   a. Which is the stronger base, ClO₄⁻ or C₆H₅NH₂?
   b. Which is the stronger base, H₂O or C₆H₅NH₂?
   c. Which is the stronger base, OH⁻ or C₆H₅NH₂?
   d. Which is the stronger base, C₆H₅NH₂ or CH₃NH₂?
What are the major species present in 0.015 M solutions of each of the following bases?

a. KOH  b. Ba(OH)$_2$
87. Calculate the pH of the following solutions.

a. 0.10 \text{ M} \text{ NaOH}

b. 1.0 \times 10^{-10} \text{ M} \text{ NaOH}

c. 2.0 \text{ M} \text{ NaOH}
91. What mass of KOH is necessary to prepare 800.0 mL of a solution having a pH = 11.56?
97. Calculate the pH of a 0.20 \( M \) \( \text{C}_2\text{H}_5\text{NH}_2 \) solution \( (K_b = 5.6 \times 10^{-4}) \).
99. What is the percent ionization in each of the following solutions?
   a. 0.10 \( M \) NH\(_3\)  
   b. 0.010 \( M \) NH\(_3\)  
   c. 0.10 \( M \) CH\(_3\)NH\(_2\)
The pH of a 0.016 M aqueous solution of \( p \)-toluidine (\( \text{CH}_3\text{C}_6\text{H}_4\text{NH}_2 \)) is 8.60. Calculate \( K_b \).
103. Write out the stepwise $K_a$ reactions for the diprotic acid $\text{H}_2\text{SO}_3$. 
107. Calculate the pH and \([S^{2-}]\) in a 0.10 \(M\) \(H_2S\) solution. Assume \(K_{a_1} = 1.0 \times 10^{-7}\); \(K_{a_2} = 1.0 \times 10^{-19}\).
Calculate the pH of a 5.0 M $\text{H}_3\text{PO}_4$ solution and the equilibrium concentrations of the species $\text{H}_3\text{PO}_4$, $\text{H}_2\text{PO}_4^-$, $\text{HPO}_4^{2-}$, and $\text{PO}_4^{3-}$.
109. Calculate the pH of a 2.0 \( M \) \( \text{H}_2\text{SO}_4 \) solution.
110. Calculate the pH of a $5.0 \times 10^{-3} \, M$ solution of $\text{H}_2\text{SO}_4$. 
Calculate the pH of a 0.30 \( M \) NaF solution. The \( K_a \) value for HF is \( 7.2 \times 10^{-4} \).
Calculate the pH of a 0.10 $M$ NH$_4$Cl solution. The $K_b$ value for NH$_3$ is $1.8 \times 10^{-5}$. 
111. Arrange the following 0.10 M solutions in order of most acidic to most basic.

KOH, KNO₃, KCN, NH₄Cl, HCl
157. The equilibrium constant $K_a$ for the reaction

$$\text{Fe(H}_2\text{O)}_6^{3+}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{Fe(H}_2\text{O)}_5(\text{OH})^{2+}(aq) + \text{H}_3\text{O}^+(aq)$$

is $6.0 \times 10^{-3}$.

a. Calculate the pH of a 0.10 M solution of Fe(H$_2$O)$_6^{3+}$.

b. Will a 1.0 M solution of iron(II) nitrate have a higher or lower pH than a 1.0 M solution of iron(III) nitrate? Explain.
Predict whether an aqueous solutions of the following salts will be acidic, basic or neutral:

\[\text{NH}_4\text{C}_2\text{H}_3\text{O}_2\]
\[K_a \text{ for } \text{NH}_4^+ = 5.6 \times 10^{-10}, K_b \text{ for } \text{C}_2\text{H}_3\text{O}_2^- = 5.6 \times 10^{-10}\]

\[\text{NH}_4\text{CN}\]
\[K_a \text{ for } \text{NH}_4^+ = 5.6 \times 10^{-10}, K_a \text{ for } \text{HCN} = 6.3 \times 10^{-10}\]

\[\text{Al}_2(\text{SO}_4)_3\]
\[K_a \text{ for } \text{Al(H}_2\text{O})_6^{3+} = 1.4 \times 10^{-5}, K_{a2} \text{ for } \text{H}_2\text{SO}_4 = 1.2 \times 10^{-2}\]
125. Are solutions of the following salts acidic, basic, or neutral? For those that are not neutral, write balanced chemical equations for the reactions causing the solution to be acidic or basic. The relevant $K_a$ and $K_b$ values are found in Tables 14.2 and 14.3.

a. NaNO$_3$  

b. NaNO$_2$  

c. C$_5$H$_5$NHClO$_4$  

d. NH$_4$NO$_2$  

e. KOCl  

f. NH$_4$OCl
127. Place the species in each of the following groups in order of increasing acid strength. Explain the order you chose for each group.

a. HIO$_3$, HBrO$_3$    c. HOCl, HOI
b. HNO$_2$, HNO$_3$    d. H$_3$PO$_4$, H$_3$PO$_3$
129. Place the species in each of the following groups in order of increasing acid strength.

a. H₂O, H₂S, H₂Se (bond energies: H—O, 467 kJ/mol; H—S, 363 kJ/mol; H—Se, 276 kJ/mol)
b. CH₃CO₂H, FCH₂CO₂H, F₂CHCO₂H, F₃CCO₂H
c. NH₄⁺, HONH₃⁺
d. NH₄⁺, PH₄⁺ (bond energies: N—H, 391 kJ/mol; P—H, 322 kJ/mol)

Give reasons for the orders you chose.
131. Will the following oxides give acidic, basic, or neutral solutions when dissolved in water? Write reactions to justify your answers.

a. CaO  

b. SO₂  

c. Cl₂O
133. Identify the Lewis acid and the Lewis base in each of the following reactions.

a. \( \text{B(OH)}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{B(OH)}_4^-(aq) + \text{H}^+(aq) \)

b. \( \text{Ag}^+(aq) + 2\text{NH}_3(aq) \rightleftharpoons \text{Ag(NH}_3)_2^+(aq) \)

c. \( \text{BF}_3(g) + \text{F}^-(aq) \rightleftharpoons \text{BF}_4^-(aq) \)
135. Aluminum hydroxide is an amphoteric substance. It can act as either a Brønsted–Lowry base or a Lewis acid. Write a reaction showing \( \text{Al(OH)}_3 \) acting as a base toward \( \text{H}^+ \) and as an acid toward \( \text{OH}^- \).
137. Would you expect Fe$^{3+}$ or Fe$^{2+}$ to be the stronger Lewis acid? Explain.
151. A solution is tested for pH and conductivity as pictured below:

The solution contains one of the following substances: HCl, NaOH, NH₄Cl, HCN, NH₃, HF, or NaCN. If the solute concentration is about 1.0 M, what is the identity of the solute?