Multiple Choice Section: This study guide is a compilation of questions from provincial exams since April 1994. I urge you to become intimately familiar with question types. You will notice that questions from one year to another are very similar in their composition. Identification of question types will allow you to be more efficient in answering these questions on the provincial examination. My recommendations for using this study guide are as follows:

1. **DO ALL THE QUESTIONS** in this booklet. These are actual Provincial Exam questions! Your own provincial exam and unit test will include questions similar to the ones in this booklet!

2. **RESIST THE URGE TO LOOK AT THE ANSWER KEY** until you have given all the questions in the section your best effort. Don’t do one question, then look at the key, then do another and look at the key, and so on. Each time you look at one answer in the study guide, your eye will notice other answers around them, and this will reduce the effectiveness of those questions in helping you to learn.

3. **LEARN FROM YOUR MISTAKES!** If you get a question wrong, **figure out why**! If you are having difficulty, **talk to your study partner**, or maybe **phone someone in your Peer Tutoring group**. Get together with group members or other students from class and work on these questions together. Explain how you got your answers to tough questions to others. In explaining yourself to someone else, you will learn the material better yourself (try it!) Ask your teacher to explain the questions to you during tutorial or after school. **Your goal should be to get 100% on any Chemistry 12 multiple choice test**--learning from your mistakes in this booklet will really help you in your efforts to meet this goal!

4. **This is REALLY CRUCIAL: DO NOT** mark the answer anywhere on the questions themselves. For example, do not circle any of options A B C or D-instead use a different sheet of paper to place your answers on. By avoiding this urge, you can re-use this study guide effectively again, when preparing for your final exam. In the box to the left, put an asterisk or small note to yourself to indicate that you got the question wrong and need to come back to it. If you got the question correct initially, a check mark might be assurance that you understand this type of question and therefore can concentrate on other questions that present a challenge to you.

5. **Check Off the STATUS box on the PRESCRIBED LEARNING OUTCOMES sheet.** I have tried to organize the questions in the identical sequence to which they appear on your Acid Base Prescribed Learning Outcome sheet. By doing this, you can be confident that you know everything you need to know for both the UNIT EXAM and PROVINCIAL EXAM!

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**PROPERTIES AND DEFINITIONS**

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<tr>
<th>J01</th>
<th>1. A test that could be safely used to distinguish a strong base from a weak base is</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. taste.</td>
</tr>
<tr>
<td></td>
<td>B. touch.</td>
</tr>
<tr>
<td></td>
<td>C. litmus paper.</td>
</tr>
<tr>
<td></td>
<td>D. electrical conductivity.</td>
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</table>

<table>
<thead>
<tr>
<th>J01</th>
<th>2. To distinguish between a strong acid and a strong base, an experimenter could use</th>
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<tbody>
<tr>
<td></td>
<td>A. odour.</td>
</tr>
<tr>
<td></td>
<td>B. magnesium.</td>
</tr>
<tr>
<td></td>
<td>C. a conductivity test.</td>
</tr>
<tr>
<td></td>
<td>D. the common ion test.</td>
</tr>
</tbody>
</table>

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### J02 3. Which of the following is a property of a base?

A. a sour taste  
B. turns litmus red  
C. the ability to neutralize CH₃COOH  
D. the ability to react with Zn to produce \( \text{H}_2(g) \)

### J02 4. Which of the following properties are common to **both** strong acids and bases?

- I. Taste bitter.  
- II. Conduct an electric current.  
- III. Cause neutral litmus to change colour.

A. I and II only  
B. I and III only  
C. II and III only  
D. I, II and III

### J02 5. A basic solution

A. tastes sour.  
B. feels slippery.  
C. does not conduct electricity.  
D. reacts with metals to release oxygen gas.

### J02 6. Which of the following is a general property common to both acidic and basic solutions?

A. tastes sour  
B. feels slippery  
C. reacts with metals  
D. conducts electricity

### J02 7. Which of the following is a general property of bases?

A. taste sour  
B. turn litmus red  
C. conduct electric current in solution  
D. concentration of \( \text{H}_3\text{O}^+ \) is greater than concentration of \( \text{OH}^- \)

### J04 8. An **Arrhenius** acid is a substance that

A. accepts a proton.  
B. donates a proton.  
C. produces \( \text{H}^+ \) in solution.  
D. produces \( \text{OH}^- \) in solution.
<table>
<thead>
<tr>
<th>Question</th>
<th>Statement</th>
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<tbody>
<tr>
<td>J04 9.</td>
<td>An Arrhenius base is defined as a substance which</td>
</tr>
<tr>
<td></td>
<td>A. donates protons.</td>
</tr>
<tr>
<td></td>
<td>B. donates electrons.</td>
</tr>
<tr>
<td></td>
<td>C. produces H⁺ in solution.</td>
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<tr>
<td></td>
<td>D. produces OH⁻ in solution.</td>
</tr>
<tr>
<td>J05 10.</td>
<td>Caustic soda, NaOH, is found in</td>
</tr>
<tr>
<td></td>
<td>A. fertilizers.</td>
</tr>
<tr>
<td></td>
<td>B. beverages.</td>
</tr>
<tr>
<td></td>
<td>C. toothpaste.</td>
</tr>
<tr>
<td></td>
<td>D. oven cleaners.</td>
</tr>
<tr>
<td>J05 11.</td>
<td>The acid used in the lead-acid storage battery is</td>
</tr>
<tr>
<td></td>
<td>A. HCl</td>
</tr>
<tr>
<td></td>
<td>B. HNO₃</td>
</tr>
<tr>
<td></td>
<td>C. H₂SO₄</td>
</tr>
<tr>
<td></td>
<td>D. CH₃COOH</td>
</tr>
<tr>
<td>J05 12.</td>
<td>Drano®, a commercial product used to clean drains, contains small bits of aluminum metal and</td>
</tr>
<tr>
<td></td>
<td>A. ammonia.</td>
</tr>
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<td></td>
<td>B. acetic acid.</td>
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<tr>
<td></td>
<td>C. hydrochloric acid.</td>
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<tr>
<td></td>
<td>D. sodium hydroxide.</td>
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<tr>
<td>J07 13.</td>
<td>Identify the two substances that act as Bronsted-Lowry bases in the equation</td>
</tr>
<tr>
<td></td>
<td>( \text{HS}^- + \text{SO}_4^{2-} \rightleftharpoons \text{S}^{2-} + \text{HSO}_4^- )</td>
</tr>
<tr>
<td></td>
<td>A. HS⁻ and S²⁻</td>
</tr>
<tr>
<td></td>
<td>B. SO₄²⁻ and S²⁻</td>
</tr>
<tr>
<td></td>
<td>C. HS⁻ and HSO₄⁻</td>
</tr>
<tr>
<td></td>
<td>D. SO₄²⁻ and HSO₄⁻</td>
</tr>
<tr>
<td>J07 14.</td>
<td>In the equilibrium system:</td>
</tr>
<tr>
<td></td>
<td>( \text{H}_2\text{BO}_3^{-}(\text{aq}) + \text{HCO}_3^{-}(\text{aq}) \rightleftharpoons \text{H}_2\text{CO}_3^{-}(\text{aq}) + \text{HBO}_3^{2-}(\text{aq}) )</td>
</tr>
<tr>
<td></td>
<td>The two species acting as Brönsted-Lowry acids are</td>
</tr>
<tr>
<td></td>
<td>A. HCO₃⁻ and H₂CO₃</td>
</tr>
<tr>
<td></td>
<td>B. H₂BO₄⁻ and H₂CO₃</td>
</tr>
<tr>
<td></td>
<td>C. HCO₃⁻ and HBO₃²⁻</td>
</tr>
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<td></td>
<td>D. H₂BO₄⁻ and HBO₃²⁻</td>
</tr>
</tbody>
</table>
Consider the following equilibria:

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<table>
<thead>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>$\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-$</td>
</tr>
<tr>
<td>II</td>
<td>$\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NH}_3$</td>
</tr>
<tr>
<td>III</td>
<td>$\text{HSO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{O} + \text{H}_2\text{SO}_3$</td>
</tr>
</tbody>
</table>

Water acts as a Brønsted-Lowry base in

A. III only.
B. I and II only.
C. II and III only.
D. I, II and III.

Consider the following acid-base reaction:

$$\text{HSO}_3^- + \text{HF} \rightleftharpoons \text{H}_2\text{SO}_3 + \text{F}^-$$

The order of Brønsted-Lowry acids and bases in this equation is

A. acid + base $\rightleftharpoons$ acid + base
B. acid + base $\rightleftharpoons$ base + acid
C. base + acid $\rightleftharpoons$ base + acid
D. base + acid $\rightleftharpoons$ acid + base

Consider the following equilibrium:

$$\text{CH}_3\text{COOH}_{(aq)} + \text{NH}_3_{(aq)} \rightleftharpoons \text{CH}_3\text{COO}^-_{(aq)} + \text{NH}_4^+_{(aq)}$$

The sequence of Brønsted-Lowry acids and bases in the above equilibrium is

A. acid, base, base, acid.
B. acid, base, acid, base.
C. base, acid, base, acid.
D. base, acid, acid, base.

Consider the following equilibrium:

$$\text{H}_2\text{SO}_3 + \text{NO}_2^- \rightleftharpoons \text{HSO}_3^- + \text{HNO}_2$$

The Brønsted-Lowry acids and bases are, respectively,

A. acid, base, base, acid.
B. acid, base, acid, base.
C. base, acid, base, acid.
D. base, acid, acid, base.
Consider the following equilibrium:

\[ \text{H}_2\text{SO}_3^{(aq)} + \text{NO}_2^- (aq) \rightleftharpoons \text{HSO}_3^- (aq) + \text{HNO}_2(aq) \]

The \( \text{NO}_2^- \) is acting as a

A. Brønsted-Lowry acid by donating a proton.
B. Brønsted-Lowry base by donating a proton.
C. Brønsted-Lowry acid by accepting a proton.
D. Brønsted-Lowry base by accepting a proton.

Consider the following equilibrium:

\[ \text{HS}^- + \text{H}_3\text{PO}_4 \rightleftharpoons \text{H}_2\text{S} + \text{H}_2\text{PO}_4^- \]

The order of Brønsted-Lowry acids and bases is

A. acid, base, acid, base.
B. acid, base, base, acid.
C. base, acid, acid, base.
D. base, acid, base, acid.

The hydronium ion, \( \text{H}_3\text{O}^+ \) is a water molecule that has

A. lost a proton.
B. gained a proton.
C. gained a neutron.
D. gained an electron.

A base is converted to its conjugate acid by

A. adding a proton.
B. adding an electron.
C. removing a proton.
D. removing an electron.

The conjugate acid of \( \text{H}_2\text{C}_6\text{H}_5\text{O}_7^- \) is

A. \( \text{C}_6\text{H}_5\text{O}_7^- \)
B. \( \text{HC}_6\text{H}_5\text{O}_7^- \)
C. \( \text{H}_2\text{C}_6\text{H}_5\text{O}_7 \)
D. \( \text{H}_3\text{C}_6\text{H}_5\text{O}_7 \)
The conjugate acid of \( \text{OH}^- \) is
A. \( \text{H}^+ \)
B. \( \text{O}^{2-} \)
C. \( \text{H}_2\text{O} \)
D. \( \text{H}_3\text{O}^+ \)

The conjugate base of \( \text{H}_2\text{BO}_3^- \) is
A. \( \text{BO}_3^{3-} \)
B. \( \text{H}_3\text{BO}_3 \)
C. \( \text{HBO}_3^{2-} \)
D. \( \text{H}_4\text{BO}_3^- \)

Which of the following is a conjugate acid-base pair?
A. \( \text{H}_3\text{PO}_4 \) and \( \text{PO}_4^{3-} \)
B. \( \text{H}_2\text{PO}_4^- \) and \( \text{PO}_4^{3-} \)
C. \( \text{H}_3\text{PO}_4 \) and \( \text{HPO}_4^{2-} \)
D. \( \text{H}_2\text{PO}_4^- \) and \( \text{HPO}_4^{2-} \)

The conjugate acid of \( \text{H}_2\text{PO}_4^- \) is
A. \( \text{PO}_4^{3-} \)
B. \( \text{H}_3\text{PO}_4 \)
C. \( \text{HPO}_4^{2-} \)
D. \( \text{H}_3\text{PO}_4^- \)

The conjugate acid of \( \text{C}_6\text{H}_5\text{O}^- \) is
A. \( \text{C}_6\text{H}_4\text{O}^- \)
B. \( \text{C}_6\text{H}_5\text{OH} \)
C. \( \text{C}_6\text{H}_4\text{O}^{2-} \)
D. \( \text{C}_6\text{H}_5\text{OH}^+ \)
STRONG/WEAK ACIDS AND BASES

K01 29. Which of the following 0.10 M solutions will have the greatest electrical conductivity?
   A. HF
   B. NH₃
   C. NaOH
   D. C₆H₅COOH

K01 30. The 0.10 M solution with the greatest electrical conductivity is
   A. H₂S
   B. H₂SO₄
   C. H₂SO₃
   D. H₂CO₃

K01 31. Which of the following solutions will have the greatest electrical conductivity?
   A. 1.0 M HCl
   B. 1.0 M HNO₂
   C. 1.0 M H₃BO₃
   D. 1.0 M HCOOH

K01 32. Which of the following 1.0 M solutions will have the greatest electrical conductivity?
   A. HI
   B. H₂S
   C. HCN
   D. H₃PO₄

K05 33. The equation representing the reaction of ethanoic acid with water is
   A. CH₃COO⁻ + H₂O ⇌ CH₃COOH + OH⁻
   B. CH₃COO⁻ + H₂O ⇌ CH₃COO⁻ + H₂O⁻
   C. CH₃COOH + H₂O ⇌ CH₃COOH₂⁺ + OH⁻
   D. CH₃COOH + H₂O ⇌ CH₃COOH + OH⁻

K06 34. How many acids from the list below are known to be weak acids?
   HCl,  HF,  H₂SO₃,  H₂SO₄,  HNO₃,  HNO₂ :
   A. 2
   B. 3
   C. 4
   D. 5
<table>
<thead>
<tr>
<th>Question</th>
<th>Statement</th>
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<tbody>
<tr>
<td>K06 35.</td>
<td>Which of the following is the strongest acid?</td>
</tr>
<tr>
<td>A.</td>
<td>acetic acid</td>
</tr>
<tr>
<td>B.</td>
<td>oxalic acid</td>
</tr>
<tr>
<td>C.</td>
<td>benzoic acid</td>
</tr>
<tr>
<td>D.</td>
<td>carbonic acid</td>
</tr>
<tr>
<td>K06 36.</td>
<td>In the following Brønsted-Lowry acid-base equation: $\text{NH}_4^+ + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_3(aq) + \text{H}_3\text{O}^+$</td>
</tr>
<tr>
<td>The stronger base is</td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>$\text{NH}_4^+$</td>
</tr>
<tr>
<td>B.</td>
<td>$\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>C.</td>
<td>$\text{NH}_3$</td>
</tr>
<tr>
<td>D.</td>
<td>$\text{H}_3\text{O}^+$</td>
</tr>
<tr>
<td>K06 37.</td>
<td>Consider the following equilibrium: $\text{HS}^- + \text{H}_2\text{C}_2\text{O}_4 \rightleftharpoons \text{HC}_2\text{O}_4^- + \text{H}_2\text{S}$</td>
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<tr>
<td>The stronger acid is</td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>$\text{HS}^-$</td>
</tr>
<tr>
<td>B.</td>
<td>$\text{H}_2\text{C}_2\text{O}_4$</td>
</tr>
<tr>
<td>C.</td>
<td>$\text{HC}_2\text{O}_4^-$</td>
</tr>
<tr>
<td>D.</td>
<td>$\text{H}_2\text{S}$</td>
</tr>
<tr>
<td>K06 38.</td>
<td>Which of the following is the weakest acid?</td>
</tr>
<tr>
<td>A.</td>
<td>$\text{HCOOH}$</td>
</tr>
<tr>
<td>B.</td>
<td>$\text{C}_6\text{H}_5\text{OH}$</td>
</tr>
<tr>
<td>C.</td>
<td>$\text{H}_3\text{C}_6\text{H}_4\text{O}_7$</td>
</tr>
<tr>
<td>D.</td>
<td>$\text{CH}_3\text{COOH}$</td>
</tr>
<tr>
<td>K06 39.</td>
<td>Which of the following is the weakest acid?</td>
</tr>
<tr>
<td>A.</td>
<td>$\text{HIO}_3$</td>
</tr>
<tr>
<td>B.</td>
<td>$\text{HCN}$</td>
</tr>
<tr>
<td>C.</td>
<td>$\text{HNO}_2$</td>
</tr>
<tr>
<td>D.</td>
<td>$\text{C}_6\text{H}_5\text{COOH}$</td>
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<tr>
<td>K06 40.</td>
<td>The 1.0 M acidic solution with the highest pH value is</td>
</tr>
<tr>
<td>A.</td>
<td>$\text{H}_2\text{S}$</td>
</tr>
<tr>
<td>B.</td>
<td>$\text{HNO}_2$</td>
</tr>
<tr>
<td>C.</td>
<td>$\text{HNO}_3$</td>
</tr>
<tr>
<td>D.</td>
<td>$\text{H}_3\text{BO}_3$</td>
</tr>
</tbody>
</table>
### K07 41. Which of the following is the strongest base in water?

A. OH<sup>-</sup>  
B. H<sub>2</sub>O  
C. NH<sub>3</sub>  
D. HO<sub>2</sub>⁻

### K08 42. Consider the following equilibrium system:

\[
\text{OCl}^-_{\text{(aq)}} + \text{HC}_2\text{H}_3\text{O}_2_{\text{(aq)}} \rightleftharpoons \text{HOCl}_{\text{(aq)}} + \text{C}_2\text{H}_3\text{O}_2^-_{\text{(aq)}} \quad K_{\text{eq}} = 2.1 \times 10^3
\]

At equilibrium,

A. products are favoured and HOCl is the stronger acid.  
B. reactants are favoured and HOCl is the stronger acid.  
C. products are favoured and HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> is the stronger acid.  
D. reactants are favoured and HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> is the stronger acid.

### K09 43. The 1.0 M acid solution with the largest \([H_3O^+]\) is

A. HNO<sub>2</sub>  
B. H<sub>2</sub>SO<sub>3</sub>  
C. H<sub>2</sub>CO<sub>3</sub>  
D. H<sub>3</sub>BO<sub>3</sub>

### K10 44. An amphiprotic substance can act as

A. a base only.  
B. an acid only.  
C. both an acid and a base.  
D. neither an acid nor a base.

### K11 45. Which one(s) of the following substances is/are amphiprotic?

(1) H<sub>3</sub>PO<sub>4</sub>  
(2) H<sub>2</sub>PO<sub>4</sub>  
(3) HPO<sub>4</sub><sup>2-</sup>

A. 2 only  
B. 3 only  
C. 1 and 2  
D. 2 and 3

### K11 46. Which of the following is amphiprotic in water?

A. SO<sub>2</sub>  
B. SO<sub>3</sub><sup>2-</sup>  
C. HSO<sub>3</sub><sup>-</sup>  
D. H<sub>2</sub>SO<sub>3</sub>
K11 47. Consider the following:

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>I</td>
<td>H₃PO₄</td>
</tr>
<tr>
<td>II</td>
<td>H₂PO₄⁻</td>
</tr>
<tr>
<td>III</td>
<td>HPO₄²⁻</td>
</tr>
<tr>
<td>IV</td>
<td>PO₄³⁻</td>
</tr>
</tbody>
</table>

Which of the above are amphiprotic in an aqueous solution?

A. I and II only
B. II and III only
C. I, II and III only
D. II, III and IV only

K12 48. Water acts as a base when it reacts with

A. CN⁻
B. NH₃
C. NO₂⁻
D. NH₄⁺

K12 49. Water will act as a Brönsted-Lowry acid with

A. NH₃
B. H₂S
C. HCN
D. HNO₃

K12 50. Water will act as an acid with which of the following?

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<tbody>
<tr>
<td>I</td>
<td>H₂CO₃</td>
</tr>
<tr>
<td>II</td>
<td>HCO₃⁻</td>
</tr>
<tr>
<td>III</td>
<td>CO₃²⁻</td>
</tr>
</tbody>
</table>

A. I only.
B. III only.
C. I and II only.
D. II and III only.
<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
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<tbody>
<tr>
<td>L01 51.</td>
<td>At 25°C, the equation representing the ionization of water is</td>
</tr>
<tr>
<td>A.</td>
<td>( \text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons 2\text{H}^+ + \text{O}_2 )</td>
</tr>
<tr>
<td>B.</td>
<td>( \text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{H}_2 )</td>
</tr>
<tr>
<td>C.</td>
<td>( \text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons 4\text{H}^+ + 2\text{O}^{2-} )</td>
</tr>
<tr>
<td>D.</td>
<td>( \text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^- )</td>
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<tr>
<td>L02 52.</td>
<td>Consider the following equilibrium system:</td>
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<tr>
<td></td>
<td>( \text{H}_2\text{O}^{(l)} + \text{H}_2\text{O}^{(l)} \rightleftharpoons \text{H}_3\text{O}^{(aq)}^{+} + \text{OH}^{-{(aq)}} )</td>
</tr>
<tr>
<td>The equilibrium constant for this system is referred to as</td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>( K_w )</td>
</tr>
<tr>
<td>B.</td>
<td>( K_d )</td>
</tr>
<tr>
<td>C.</td>
<td>( K_b )</td>
</tr>
<tr>
<td>D.</td>
<td>( K_	ext{sp} )</td>
</tr>
<tr>
<td>L03 53.</td>
<td>If ( \text{OH}^- ) is added to a solution, the ([\text{H}_3\text{O}^+]) will</td>
</tr>
<tr>
<td>A.</td>
<td>remain constant.</td>
</tr>
<tr>
<td>B.</td>
<td>adjust such that ([\text{H}_3\text{O}^+] = \frac{[\text{OH}^-]}{K_w})</td>
</tr>
<tr>
<td>C.</td>
<td>increase such that ([\text{H}_3\text{O}^+] [\text{OH}^-] = K_w)</td>
</tr>
<tr>
<td>D.</td>
<td>decrease such that ([\text{H}_3\text{O}^+] [\text{OH}^-] = K_w)</td>
</tr>
<tr>
<td>L03 54.</td>
<td>Consider the following equilibrium:</td>
</tr>
<tr>
<td></td>
<td>( \text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^- )</td>
</tr>
<tr>
<td>When a solution of ( \text{Sr(OH)}_2 ) is added, the equilibrium shifts</td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>left and ([\text{H}_3\text{O}^+]) increases.</td>
</tr>
<tr>
<td>B.</td>
<td>left and ([\text{H}_3\text{O}^+]) decreases.</td>
</tr>
<tr>
<td>C.</td>
<td>right and ([\text{H}_3\text{O}^+]) increases.</td>
</tr>
<tr>
<td>D.</td>
<td>right and ([\text{H}_3\text{O}^+]) decreases.</td>
</tr>
</tbody>
</table>
### L03 55.
Consider the following:

\[ H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \]

When a small amount of 1.0 M KOH is added to the above system, the equilibrium

- A. shifts left and \([H^+]\) decreases.
- B. shifts left and \([H^+]\) increases.
- C. shifts right and \([H^+]\) decreases.
- D. shifts right and \([H^+]\) increases.

### L03 56.
An acid is added to water and a new equilibrium is established. The new equilibrium can be described by

- A. \(pH < pOH\) and \(K_w = 1 \times 10^{-14}\)
- B. \(pH < pOH\) and \(K_w < 1 \times 10^{-14}\)
- C. \(pH > pOH\) and \(K_w = 1 \times 10^{-14}\)
- D. \(pH > pOH\) and \(K_w > 1 \times 10^{-14}\)

### L03 57.
Consider the following equilibrium:

\[ 2H_2O(l) + \text{energy} \rightleftharpoons H_3O^+(aq) + OH^-(aq) \]

The \([H_3O^+]\) will decrease and the \(K_w\) will remain constant when

- A. a strong acid is added.
- B. a strong base is added.
- C. the temperature is increased.
- D. the temperature is decreased.

### L04 58.
The \([OH^-]\) is greater than the \([H_3O^+]\) in

- A. \(HCl(aq)\)
- B. \(NH_3(aq)\)
- C. \(H_2O(aq)\)
- D. \(CH_3COOH(aq)\)

### L04 59.
An aqueous solution that contains more hydronium ions than hydroxide ions is a(n)

- A. basic solution.
- B. acidic solution.
- C. neutral solution.
- D. standardized solution.
**L06 60.** Consider the following equilibrium:

\[ 2\text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{OH}^-_{(aq)} \quad \Delta H = +114 \text{ kJ} \]

At 10°C the value of $K_w$ is

A. equal to $1.00 \times 10^{-7}$
B. equal to $1.00 \times 10^{-14}$
C. less than $1.00 \times 10^{-14}$
D. greater than $1.00 \times 10^{-14}$

---

**L06 61.** Consider the following equilibrium:

\[ 2\text{H}_2\text{O}(l) + 57 \text{kJ} \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{OH}^-_{(aq)} \]

When the temperature is decreased, the water

A. stays neutral and $[\text{H}_3\text{O}^+]$ increases.
B. stays neutral and $[\text{H}_3\text{O}^+]$ decreases.
C. becomes basic and $[\text{H}_3\text{O}^+]$ decreases.
D. becomes acidic and $[\text{H}_3\text{O}^+]$ increases.

---

**L06 62.** Consider the following:

\[ 2\text{H}_2\text{O}(l) + 57 \text{kJ} \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{OH}^-_{(aq)} \]

When the temperature of the above system is increased, the equilibrium shifts

A. left and $K_w$ increases.
B. left and $K_w$ decreases.
C. right and $K_w$ increases.
D. right and $K_w$ decreases.

---

**L07 63.** An aqueous solution at room temperature is analyzed and the $[\text{H}_3\text{O}^+]$ is found to be $2.0 \times 10^{-3}$ M. The $[\text{OH}^-]$ is

A. $5.0 \times 10^{-12}$ M
B. $2.0 \times 10^{-11}$ M
C. $4.0 \times 10^{-6}$ M
D. $2.0 \times 10^{-3}$ M
The \([\text{OH}^-]\) in 0.050 M HNO₃ at 25°C is

A. \(5.0 \times 10^{-16}\) M  
B. \(1.0 \times 10^{-14}\) M  
C. \(2.0 \times 10^{-13}\) M  
D. \(5.0 \times 10^{-2}\) M

In a solution at 25°C, the \([\text{H}_3\text{O}^+]\) is \(3.5 \times 10^{-6}\) M. The \([\text{OH}^-]\) is

A. \(3.5 \times 10^{-20}\) M  
B. \(2.9 \times 10^{-9}\) M  
C. \(1.0 \times 10^{-7}\) M  
D. \(3.5 \times 10^{-8}\) M

In a 100.0 mL sample of 0.0800 M NaOH the \([\text{H}_3\text{O}^+]\) is

A. \(1.25 \times 10^{-13}\) M  
B. \(1.25 \times 10^{-12}\) M  
C. \(8.00 \times 10^{-3}\) M  
D. \(8.00 \times 10^{-2}\) M

The \([\text{OH}^-]\) in an aqueous solution always equals

A. \(K_w \times [\text{H}_3\text{O}^+]\)  
B. \(K_w - [\text{H}_3\text{O}^+]\)  
C. \(\frac{K_w}{[\text{H}_3\text{O}^+]}\)  
D. \(\frac{[\text{H}_3\text{O}^+]}{K_w}\)

Sodium potassium tartrate (NaKC₄H₄O₆) is used to raise the pH of fruit during processing. In this process, sodium potassium tartrate is being used as a/an

A. salt.  
B. acid.  
C. base.  
D. buffer.
L08 69. A student records the pH of 0.1 M solutions of two acids:

<table>
<thead>
<tr>
<th>Acid</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>4.0</td>
</tr>
<tr>
<td>Y</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Which of the following statements can be concluded from the above data?

A. Acid X is stronger than acid Y.
B. Acid X and acid Y are both weak.
C. Acid X is diprotic while acid Y is monoprotic.
D. Acid X is 100 times more concentrated than acid Y.

L08 70. A student adds 10.0 mL of 1.0 M HClO₂ into 990.0 mL of water. The pH of the solution has changed by

A. 0.01
B. 1
C. 2
D. 100

L09 71. The pH scale is

A. direct.
B. inverse.
C. logarithmic.
D. exponential.

L09 72. Which of the following equations correctly relates pH and $[\text{H}_3\text{O}^+]$?

A. $\text{pH} = \log \left[\text{H}_3\text{O}^+\right]$
B. $\text{pH} = 14 - \left[\text{H}_3\text{O}^+\right]$
C. $\text{pH} = -\log \left[\text{H}_3\text{O}^+\right]$
D. $\text{pH} = \text{pK}_w - \left[\text{H}_3\text{O}^+\right]$

L09 73. The pOH of an aqueous solution is equal to

A. $14 + \text{pH}$
B. $\text{pK}_w - \text{pH}$
C. $-\log \text{pK}_w$
D. $-\log \left[\text{H}_3\text{O}^+\right]$
<table>
<thead>
<tr>
<th>L09 74.</th>
<th>Which of the following graphs describes the relationship between ([H_3O^+]) and pH?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>![Graph A]</td>
</tr>
<tr>
<td>B.</td>
<td>![Graph B]</td>
</tr>
<tr>
<td>C.</td>
<td>![Graph C]</td>
</tr>
<tr>
<td>D.</td>
<td>![Graph D]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>L09 75.</th>
<th>When the ([H_3O^+]) in a solution is increased to twice the original concentration, the change in pH could be from</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>1.7 to 1.4</td>
</tr>
<tr>
<td>B.</td>
<td>2.0 to 4.0</td>
</tr>
<tr>
<td>C.</td>
<td>5.0 to 2.5</td>
</tr>
<tr>
<td>D.</td>
<td>8.5 to 6.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>L10 76.</th>
<th>Which of the following statements concerning pKₐ are true?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>(pK_a = -\log K_a)</td>
</tr>
<tr>
<td>II.</td>
<td>(pK_a = pH + pOH)</td>
</tr>
<tr>
<td>III.</td>
<td>(pK_a = [H_3O^+] [OH^-])</td>
</tr>
<tr>
<td>A.</td>
<td>I and II only</td>
</tr>
<tr>
<td>B.</td>
<td>I and III only</td>
</tr>
<tr>
<td>C.</td>
<td>II and III only</td>
</tr>
<tr>
<td>D.</td>
<td>I, II and III only</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>L11 77.</th>
<th>The pH of an aqueous solution is 4.32. The ([OH^-]) is</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>(6.4 \times 10^{-1}) M</td>
</tr>
<tr>
<td>B.</td>
<td>(4.8 \times 10^{-5}) M</td>
</tr>
<tr>
<td>C.</td>
<td>(2.1 \times 10^{-10}) M</td>
</tr>
<tr>
<td>D.</td>
<td>(1.6 \times 10^{-14}) M</td>
</tr>
</tbody>
</table>
The pH of a 0.025 M HClO₄ solution is

A. 0.94  
B. 1.60  
C. 12.40  
D. 13.06

A solution is prepared by adding 100 mL of 10 M of HCl to a 1 litre volumetric flask and filling it to the mark with water. The pH of this solution is

A. −1  
B. 0  
C. 1  
D. 7

The pH of 0.15 M HCl is

A. 0.15  
B. 0.71  
C. 0.82  
D. 13.18

The pH of 0.20 M HNO₃ is

A. 0.20  
B. 0.63  
C. 0.70  
D. 1.58

Consider the following data:

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>INITIAL pH</th>
<th>FINAL pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>4</td>
<td>9.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

In which solution has the $[\text{H}_3\text{O}^+]$ increased 1000 times?

A. 1  
B. 2  
C. 3  
D. 4

Calculate the pOH of 3.50 M NaOH.

A. −14.54  
B. −0.54  
C. 0.54  
D. 13.46
<table>
<thead>
<tr>
<th>Question</th>
<th>Details</th>
</tr>
</thead>
</table>
| L11 84. | Calculate the pH of $4.0 \times 10^{-4}$ M KOH.  
A. 3.40  
B. 4.60  
C. 9.40  
D. 10.60 |
| L11 85. | A beaker contains 200.0 mL of 0.40 M HNO$_3$. The calculation for pH is  
A. $\text{pH} = -\log (0.40 \text{ M})$  
B. $\text{pH} = -\log \left(10^{-14} \div 0.40 \text{ M} \right)$  
C. $\text{pH} = -\log (0.40 \text{ M} \times 0.200 \text{ L})$  
D. $\text{pH} = -\log (0.40 \text{ M} \div 0.200 \text{ L})$ |
| L11 86. | The pH of 100.0 mL of 0.0050 M NaOH solution is  
A. 2.30  
B. 3.30  
C. 10.70  
D. 11.70 |
| L11 87. | A solution of 1.0 M HF has  
A. a lower pH than a solution of 1.0 M HCl  
B. a higher pOH than a solution of 1.0 M HCl  
C. a higher $[\text{OH}^-]$ than a solution of 1.0 M HCl  
D. a higher $[\text{H}_3\text{O}^+]$ than a solution of 1.0 M HCl |
| L11 88. | The pOH of 0.050 M HCl is  
A. 0.30  
B. 1.30  
C. 12.70  
D. 13.70 |
| L12 89. | The $[\text{H}_3\text{O}^+]$ in a solution of pH 0.60 is  
A. $4.0 \times 10^{-14}$ M  
B. $2.2 \times 10^{-1}$ M  
C. $2.5 \times 10^{-1}$ M  
D. $6.0 \times 10^{-1}$ M |
### Problem 90
In a solution with a pOH of 4.22, the $[\text{OH}^-]$ is

- A. $1.7 \times 10^{-10}$ M
- B. $6.0 \times 10^{-5}$ M
- C. $6.3 \times 10^{-1}$ M
- D. $1.7 \times 10^2$ M

### Problem 91
The $[\text{H}_3\text{O}^+]$ in a solution with pOH of 0.253 is

- A. $5.58 \times 10^{-15}$ M
- B. $1.79 \times 10^{-14}$ M
- C. $5.58 \times 10^{-1}$ M
- D. $5.97 \times 10^{-1}$ M

---

### $K_a$ and $K_b$ Problem Solving

#### Problem 92
The equilibrium constant expression for sulphurous acid is

- A. $K_a = \frac{[\text{H}^+][\text{HSO}_3^-]}{[\text{H}_2\text{SO}_3]}$
- B. $K_a = \frac{[\text{H}^+][\text{HSO}_3^-]}{[\text{H}_2\text{SO}_3]}$
- C. $K_a = \frac{2[\text{H}^+][\text{SO}_3^{2-}]}{[\text{H}_2\text{SO}_3]}$
- D. $K_a = \frac{[\text{H}^+][\text{SO}_3^{2-}]}{[\text{H}_2\text{SO}_3]}$

#### Problem 93
Which of the following is represented by a $K_b$ expression?

- A. $\text{Al(OH)}_3(\text{aq}) \rightleftharpoons \text{Al}^{3+}(\text{aq}) + 3\text{OH}^-$(aq)
- B. $\text{HF}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_2\text{O}^+_{(aq)} + \text{F}^-_{(aq)}$
- C. $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 2\text{OH}^-_{(aq)} \rightleftharpoons 2\text{CrO}_4^{2-}_{(aq)} + \text{H}_2\text{O}_{(l)}$
- D. $\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{CH}_3\text{NH}_3^+_{(aq)} + \text{OH}^-_{(aq)}$

#### Problem 94
The $K_b$ expression for $\text{HPO}_4^{2-}$ is

- A. $K_b = \frac{\text{HPO}_4^{2-}[\text{H}_3\text{O}^+]}{[\text{HPO}_4^{2-}]}$
- B. $K_b = \frac{\text{HPO}_4^{2-}[\text{OH}^-]}{[\text{H}_2\text{PO}_4^-]}$
- C. $K_b = \frac{\text{H}_2\text{PO}_4^-[\text{OH}^-]}{[\text{HPO}_4^{2-}]}$
- D. $K_b = \frac{\text{HPO}_4^{2-}[\text{H}_3\text{O}^+]}{[\text{PO}_4^{3-}]}$
Consider the following equilibrium constant expression:

\[
K = \frac{[\text{H}_2\text{S}][\text{OH}^-]}{[\text{HS}^-]}
\]

This expression represents the

A. \(K_b\) for \(\text{H}_2\text{S}\)
B. \(K_a\) for \(\text{H}_2\text{S}\)
C. \(K_b\) for \(\text{HS}^-\)
D. \(K_a\) for \(\text{HS}^-\)

The relationship \(\frac{[\text{H}_2\text{P}_2\text{O}_7^{2-}][\text{H}_3\text{O}^+]}{[\text{H}_3\text{P}_2\text{O}_7^-]}\) is the

A. \(K_a\) for \(\text{H}_3\text{P}_2\text{O}_7^-\)
B. \(K_b\) for \(\text{H}_3\text{P}_2\text{O}_7^-\)
C. \(K_a\) for \(\text{H}_2\text{P}_2\text{O}_7^{2-}\)
D. \(K_b\) for \(\text{H}_2\text{P}_2\text{O}_7^{2-}\)

In water, the hydrogen sulphide ion, \(\text{HS}^-\), will act as

A. an acid because the \(K_a < K_b\)
B. an acid because the \(K_a > K_b\)
C. a base because the \(K_a < K_b\)
D. a base because the \(K_a > K_b\)

The concentration, \(K_a\) and pH values of four acids are given in the following table:

<table>
<thead>
<tr>
<th>Acid</th>
<th>Concentration</th>
<th>(K_a)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA</td>
<td>3.0 M</td>
<td>(2.0 \times 10^{-5})</td>
<td>2.1</td>
</tr>
<tr>
<td>HB</td>
<td>0.7 M</td>
<td>(4.0 \times 10^{-5})</td>
<td>2.3</td>
</tr>
<tr>
<td>HC</td>
<td>4.0 M</td>
<td>(1.0 \times 10^{-5})</td>
<td>2.2</td>
</tr>
<tr>
<td>HD</td>
<td>1.5 M</td>
<td>(1.3 \times 10^{-5})</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Based on this data, the strongest acid is

A. HA
B. HB
C. HC
D. HD
M02 99. Consider the following data table:

<table>
<thead>
<tr>
<th></th>
<th>HCO$_3^-$</th>
<th>HSO$_3^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_a$</td>
<td>$5.6 \times 10^{-11}$</td>
<td>$1.0 \times 10^{-7}$</td>
</tr>
<tr>
<td>$K_b$</td>
<td>$2.3 \times 10^{-8}$</td>
<td>$6.7 \times 10^{-13}$</td>
</tr>
</tbody>
</table>

Which of the following statements is correct?

A. HCO$_3^-$ is a stronger acid than HSO$_3^-$
B. HCO$_3^-$ is a stronger base than HSO$_3^-$
C. HCO$_3^-$ is stronger as an acid than as a base
D. HSO$_3^-$ is stronger as a base than as an acid

M02 100. Which of the following favours products?

A. $\text{C}_6\text{H}_5\text{OH} + \text{CH}_3\text{COO}^- \rightleftharpoons \text{C}_6\text{H}_5\text{O}^- + \text{CH}_3\text{COOH}$
B. $\text{H}_2\text{C}_2\text{O}_4 + \text{H}_3\text{C}_6\text{H}_5\text{O}_7^- \rightleftharpoons \text{HC}_2\text{O}_4^- + \text{H}_3\text{C}_6\text{H}_5\text{O}_7$
C. $\text{C}_6\text{H}_5\text{COOH} + \text{HCOO}^- \rightleftharpoons \text{C}_6\text{H}_5\text{COO}^- + \text{HCOOH}$
D. $\text{CH}_3\text{COOH} + \text{C}_6\text{H}_5\text{COO}^- \rightleftharpoons \text{CH}_3\text{COO}^- + \text{C}_6\text{H}_5\text{COOH}$

M02 101. Consider the following equilibrium:

$$\text{HF}_{(aq)} + \text{NH}_3_{(aq)} \rightleftharpoons \text{NH}_4^+_{(aq)} + \text{F}^-_{(aq)}$$

Which of the following statements is true?

A. The products are favoured because HF is a stronger acid than NH$_4^+$
B. The products are favoured because NH$_4^+$ is a stronger acid than HF
C. The reactants are favoured because HF is a stronger acid than NH$_4^+$
D. The reactants are favoured because NH$_4^+$ is a stronger acid than HF

M02 102. The hydrogen oxalate ion, HC$_2$O$_4^-$, is amphiprotic.

$$K_a = 6.4 \times 10^{-5}$$
$$K_b = 1.7 \times 10^{-13}$$

The predominant reaction is

A. $\text{HC}_2\text{O}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{H}_2\text{C}_2\text{O}_4$ because $K_a < K_b$
B. $\text{HC}_2\text{O}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_2\text{O}_4^{2-}$ because $K_a < K_b$
C. $\text{HC}_2\text{O}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{H}_2\text{C}_2\text{O}_4$ because $K_a > K_b$
D. $\text{HC}_2\text{O}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_2\text{O}_4^{2-}$ because $K_a > K_b$
Which of the following solutions has the highest pH?

A. 1.0 M NaO₃
B. 1.0 M Na₂CO₃
C. 1.0 M Na₃PO₄
D. 1.0 M Na₂SO₄

The equation for the predominant reaction between HSO₃⁻ and H₂O is

A. HSO₃⁻ + H₂O ⇌ H₂SO₄ + H⁺
B. HSO₃⁻ + H₂O ⇌ SO₃²⁻ + H₃O⁺
C. HSO₃⁻ + H₂O ⇌ H₂SO₃ + OH⁻
D. HSO₃⁻ + H₂O ⇌ H₂SO₄ + ½ H₂

Which of the following describes the relationship between acid strength and $K_a$ value for weak acids?

<table>
<thead>
<tr>
<th>Acid Strength</th>
<th>$K_a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. increases</td>
<td>increases</td>
</tr>
<tr>
<td>B. increases</td>
<td>decreases</td>
</tr>
<tr>
<td>C. decreases</td>
<td>increases</td>
</tr>
<tr>
<td>D. decreases</td>
<td>remains constant</td>
</tr>
</tbody>
</table>

If reactants are favoured in the following equilibrium, the stronger base must be

$$\text{HCN} + \text{HS}^- \rightleftharpoons \text{H}_2\text{S} + \text{CN}^-$$

A. H₂S
B. HS⁻
C. CN⁻
D. HCN

When added to water, the hydrogen carbonate ion, HCO₃⁻, produces a solution which is

A. basic because $K_b$ is greater than $K_a$
B. basic because $K_b$ is greater than $K_a$
C. acidic because $K_a$ is greater than $K_b$
D. acidic because $K_b$ is greater than $K_a$
| M03 | 108 | The pH of a 0.3 M solution of NH₃ is approximately  
A. 14.0  
B. 11.0  
C. 6.0  
D. 3.0 |
|-----|-----|----------------------------------|
| M03 | 109 | The approximate pH of a 0.06 M solution of CH₃COOH is  
A. 1  
B. 3  
C. 11  
D. 13 |
| M03 | 110 | Which of the following solutions will have the largest \([H_3O^+]\)?  
A. 1.0 M HNO₂  
B. 1.0 M H₃BO₃  
C. 1.0 M H₂C₂O₄  
D. 1.0 M HCOOH |
| M04 | 111 | The \(K_b\) for the dihydrogen phosphate ion is  
A. \(1.4 \times 10^{-12}\)  
B. \(6.3 \times 10^{-8}\)  
C. \(1.6 \times 10^{-7}\)  
D. \(7.1 \times 10^{-3}\) |
| M04 | 112 | Consider the following equilibrium:  
\[\text{HPO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{OH}^-\]  
The value of the base ionization constant is  
A. \(2.2 \times 10^{-13}\)  
B. \(6.2 \times 10^{-8}\)  
C. \(1.6 \times 10^{-7}\)  
D. \(4.5 \times 10^{-2}\) |
M04 113  The value of $K_b$ for $\text{HPO}_4^{2-}$ is

A. $2.2 \times 10^{-13}$  
B. $6.2 \times 10^{-8}$  
C. $1.6 \times 10^{-7}$  
D. $4.5 \times 10^{-2}$

---

HYDROLYSIS OF SALTS

N02 114  The net ionic equation for the hydrolysis of the salt, $\text{Na}_2\text{S}$, is

A. $\text{Na}_2\text{S} \rightleftharpoons 2\text{Na}^+ + \text{S}^{2-}$
B. $\text{S}^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{HS}^-$
C. $\text{Na}_2\text{S} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{NaOH} + \text{H}_2\text{S}$
D. $2\text{Na}^+ + \text{S}^{2-} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{Na}^+ + 2\text{OH}^- + \text{H}_2\text{S}$

N02 115  The net ionic equation for the hydrolysis reaction occurring in a solution of $\text{NaF}$ is

A. $\text{F}^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HF}(aq) + \text{OH}^-(aq)$
B. $\text{NaF}(s) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NaOH}(aq) + \text{HF}(aq)$
C. $\text{NaF}(s) + 2\text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) + \text{Na}^+(aq) + \text{F}^-(aq)$
D. $\text{Na(H}_2\text{O})_6(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{Na(H}_2\text{O})_4(aq) + \text{OH}^-(aq)$

N02 116  The net ionic equation for the predominant hydrolysis reaction of $\text{KHSO}_4$ is

A. $\text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{SO}_4^{2-} + \text{H}_3\text{O}^+$
B. $\text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{SO}_4 + \text{OH}^-$
C. $\text{KHSO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{K}^+ + \text{SO}_4^{2-} + \text{H}_3\text{O}^+$
D. $\text{KHSO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{K}^+ + \text{H}_2\text{SO}_4 + \text{OH}^-$

N02 117  The equilibrium constant expression for the predominant hydrolysis reaction in 1.0 M $\text{K}_2\text{HPO}_4$ is

A. $K_{eq} = \frac{[\text{H}_2\text{PO}_4^-][\text{OH}^-]}{[\text{HPO}_4^{2-}]}$  
B. $K_{eq} = \frac{[\text{H}_3\text{PO}_4][\text{OH}^-]}{[\text{H}_2\text{PO}_4^-]}$
C. $K_{eq} = \frac{[\text{K}^+][\text{KHPO}_4^-]}{[\text{K}_2\text{HPO}_4]}$  
D. $K_{eq} = \frac{[\text{K}^+]^2[\text{HPO}_4^{2-}]}{[\text{K}_2\text{HPO}_4]}$
Which one of the following salts will produce an acidic solution?

A. KBr
B. LiCN
C. NH₄Cl
D. NaCH₃COO

Which of the following salt solutions would be acidic?

A. sodium acetate
B. iron(III) chloride
C. sodium carbonate
D. potassium chloride

Consider the following salts:

I. NaF  II. NaClO₄  III. NaHSO₄

Which of these salts, when dissolved in water, would form a basic solution?

A. I only
B. I and II only
C. II and III only
D. I, II and III

Which of the following, when dissolved in water, produces a basic solution?

A. KCl
B. NaClO₄
C. Na₂CO₃
D. NH₄NO₃

Which of the following 0.10 M solutions is the most acidic?

A. AlCl₃
B. FeCl₃
C. CrCl₃
D. NH₄Cl

Which of the following has a pH greater than 7.0?

A. 0.10 M H₂S
B. 0.10 M NH₄Cl
C. 0.10 M Cr(NO₃)₃
D. 0.10 M KCH₃COO
N03  124  Arrange the following 0.10 M solutions in order of increasing $[\text{H}_3\text{O}^+]$.

\[
\text{NaBr} \quad \text{NH}_4\text{Cl} \quad \text{LiCN}
\]

A.  \text{LiCN}, \text{NaBr}, \text{NH}_4\text{Cl}  \\
B.  \text{NH}_4\text{Cl}, \text{NaBr}, \text{LiCN}  \\
C.  \text{NH}_4\text{Cl}, \text{LiCN}, \text{NaBr}  \\
D.  \text{NaBr}, \text{LiCN}, \text{NH}_4\text{Cl}

N03  125  List the following 1.0 M solutions in order of decreasing pH.

\[
\text{CaBr}_2 \quad \text{FeCl}_3 \quad \text{NaF}
\]

A.  \text{NaF} > \text{CaBr}_2 > \text{FeCl}_3  \\
B.  \text{FeCl}_3 > \text{CaBr}_2 > \text{NaF}  \\
C.  \text{CaBr}_2 > \text{NaF} > \text{FeCl}_3  \\
D.  \text{FeCl}_3 > \text{NaF} > \text{CaBr}_2

N03  126  An aqueous solution of \text{NH}_4\text{CN} is

A.  basic because $K_a < K_b$  \\
B.  basic because $K_a > K_b$  \\
C.  acidic because $K_a < K_b$  \\
D.  acidic because $K_a > K_b$

N03  127  Consider the following:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>ammonium nitrate</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>calcium nitrate</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>iron(III) nitrate</td>
<td></td>
</tr>
</tbody>
</table>

When dissolved in water, which of these salts would form a neutral solution?

A.  II only  \\
B.  III only  \\
C.  I and III only  \\
D.  I, II and III

N03  128  A 1.0 M solution of sodium dihydrogen phosphate is

A.  acidic and the pH < 7.00  \\
B.  acidic and the pH > 7.00  \\
C.  basic and the pH < 7.00  \\
D.  basic and the pH > 7.00
The solution with the highest pH is

A. 1.0 M NaCl  
B. 1.0 M NaCN  
C. 1.0 M NaIO₃  
D. 1.0 M Na₂SO₃

Which of the following 1.0 M solutions would have a pH greater than 7.00?

A. HCN  
B. KNO₃  
C. NH₄Cl  
D. NaCH₃COO

Consider the following:

<table>
<thead>
<tr>
<th></th>
<th>( \text{H}_2\text{CO}_3 + \text{F}^- \rightarrow \text{HCO}_3^- + \text{HF} )</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>( \text{HCO}_3^- + \text{HC}_2\text{O}_4^- \rightarrow \text{H}_2\text{CO}_3 + \text{C}_2\text{O}_4^{2-} )</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>( \text{HCO}_3^- + \text{H}_2\text{C}_2\text{H}_2\text{O}_2^- \rightarrow \text{H}_2\text{CO}_3 + \text{HC}_2\text{H}_2\text{O}_2^{2-} )</td>
<td></td>
</tr>
</tbody>
</table>

The \( \text{HCO}_3^- \) is a base in

A. I only  
B. I and II only  
C. II and III only  
D. I, II and III

The amphiprotic ion \( \text{HSeO}_3^- \) can undergo hydrolysis according to the following equations:

| \( \text{HSeO}_3^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SeO}_3^- + \text{OH}^- \) | \( \text{K}_1 \) |
| \( \text{HSeO}_3^- + \text{H}_2\text{O} \rightarrow \text{SeO}_3^{2-} + \text{H}_3\text{O}^+ \) | \( \text{K}_2 \) |

An aqueous solution of \( \text{HSeO}_3^- \) is found to be acidic. This observation indicates that when it is added to water, \( \text{HSeO}_3^- \) behaves mainly as a

A. proton donor, and \( \text{K}_1 \) is less than \( \text{K}_2 \)  
B. proton donor, and \( \text{K}_1 \) is greater than \( \text{K}_2 \)  
C. proton acceptor, and \( \text{K}_1 \) is less than \( \text{K}_2 \)  
D. proton acceptor, and \( \text{K}_1 \) is greater than \( \text{K}_2 \)

The indicator methyl red is red in a solution of \( \text{NaH}_2\text{PO}_4 \). Which of the following equations is consistent with this observation?

A. \( \text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}^+ \)  
B. \( \text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + \text{OH}^- \)  
C. \( \text{HPO}_4^{2-} + \text{H}_2\text{O} \rightarrow \text{PO}_4^{3-} + \text{H}_3\text{O}^+ \)  
D. \( \text{HPO}_4^{2-} + \text{H}_2\text{O} \rightarrow \text{H}_2\text{PO}_4^- + \text{OH}^- \)
An indicator, HInd, produces a yellow colour in 0.1 M HCl solution and a red colour in 0.1 M HCN solution. Therefore, in the following equilibrium

$$\text{HCN} + \text{Ind}^- \rightleftharpoons\text{HInd} + \text{CN}^-$$

A. products are favoured and the stronger acid is HInd.
B. products are favoured and the stronger acid is HCN.
C. reactants are favoured and the stronger acid is HInd.
D. reactants are favoured and the stronger acid is HCN.

Consider the following acid-base indicator:

$$\text{HInd} \rightleftharpoons H^+ + \text{Ind}^-$$

When this indicator is added to different solutions, the following data are obtained:

<table>
<thead>
<tr>
<th>Solution</th>
<th>1.0 M HCl</th>
<th>1.0 M HA_1</th>
<th>1.0 M HA_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>yellow</td>
<td>blue</td>
<td>yellow</td>
</tr>
</tbody>
</table>

The acids HA_1, HA_2 and HInd listed in the order of **decreasing** acid strength is

A. HA_2, HInd, HA_1
B. HInd, HA_1, HA_2
C. HA_2, HA_1, HInd
D. HA_1, HInd, HA_2

Consider the following acid-base indicator equilibrium:

$$\text{HInd}_{(aq)} + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{Ind}^-_{(aq)}$$

Which of the following statements describes the conditions that exist in an indicator equilibrium system at its transition point?

A. \([\text{HInd}] = [\text{Ind}^-]\)
B. \([\text{Ind}^-] = [\text{H}_3\text{O}^+]\)
C. \([\text{HInd}] = [\text{H}_3\text{O}^+]\)
D. \([\text{H}_3\text{O}^+] = [\text{H}_2\text{O}]\)

Which of the following acid-base indicators has a transition point between pH 7 and pH 9?

A. ethyl red, \(K_a = 8.0 \times 10^{-2}\)
B. congo red, \(K_a = 9.0 \times 10^{-3}\)
C. cresol red, \(K_a = 1.0 \times 10^{-8}\)
D. alizarin blue, \(K_a = 7.0 \times 10^{-11}\)

Identify the indicator that is blue in a solution when \([\text{H}_3\text{O}^+] = 2.5 \times 10^{-6}\). 

A. thymol blue
B. thymolphthalein
C. bromthymol blue
D. bromcresol green
Consider the following equilibrium:

\[ \text{HInd} \rightleftharpoons \text{H}^+ + \text{Ind}^- \]

Which of the following relationships is true for an indicator at the transition point?

A. \[ [\text{H}^+] = K_w \]
B. \[ [\text{H}^+] = \text{pH} \]
C. \[ [\text{H}^+] = K_a \]
D. \[ [\text{H}^+] = [\text{OH}^-] \]

Consider the following equilibrium for an indicator:

\[ \text{HInd} + \text{H}_2\text{O} \rightleftharpoons \text{Ind}^- + \text{H}_3\text{O}^+ \]

At the transition point,

A. \[ [\text{HInd}] > [\text{Ind}^-] \]
B. \[ [\text{HInd}] = [\text{Ind}^-] \]
C. \[ [\text{HInd}] < [\text{Ind}^-] \]
D. \[ [\text{HInd}] = [\text{H}_3\text{O}^+] \]

A new indicator, “B.C. Blue (HInd),” is red in bases and blue in acids. Describe the shift in equilibrium and the resulting colour change if 1.0 M HI\text{O}_3 is added to a neutral, purple solution of this indicator.

\[ \text{HInd} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Ind}^- \]

A. Equilibrium shifts left, colour becomes red.
B. Equilibrium shifts left, colour becomes blue.
C. Equilibrium shifts right, colour becomes red.
D. Equilibrium shifts right, colour becomes blue.

Consider the following equilibrium for an acid-base indicator:

\[ \text{HInd} \rightleftharpoons \text{H}^+ + \text{Ind}^- \quad K_a = 1.0 \times 10^{-10} \]

Which of the following statements is correct at pH 7.0?

A. \[ [\text{Ind}^-] < [\text{HInd}] \]
B. \[ [\text{Ind}^-] = [\text{HInd}] \]
C. \[ [\text{Ind}^-] > [\text{HInd}] \]
D. \[ [\text{Ind}^-] = [\text{H}^+] = [\text{HInd}] \]
### O03 143
Consider the following equilibrium for phenolphthalein:

$$\text{HIn} \rightleftharpoons \text{H}^+ + \text{Ind}^-$$

When phenolphthalein is added to 1.0 M NaOH, the colour of the resulting solution is

A. pink as $[\text{HIn}]$ is less than $[\text{Ind}^-]$
B. pink as $[\text{HIn}]$ is greater than $[\text{Ind}^-]$
C. colourless as $[\text{HIn}]$ is less than $[\text{Ind}^-]$
D. colourless as $[\text{HIn}]$ is greater than $[\text{Ind}^-]$

### O03 144
Consider the following equilibrium for the indicator bromthymol blue:

$$\text{HIn} \rightleftharpoons \text{H}^+ + \text{Ind}^-$$

A solution of bromthymol blue is yellow. What should a student do to change the colour of the solution to blue?

A. Add a base to shift the equilibrium left.
B. Add an acid to shift the equilibrium left.
C. Add a base to shift the equilibrium right.
D. Add an acid to shift the equilibrium right.

### O03 145
Which of the following 0.10 M solutions will be yellow in the presence of the indicator chlorphenol red?

A. AlCl$_3$
B. CuCl$_2$
C. K$_2$CO$_3$
D. Na$_3$PO$_4$

### O03 146
Consider the following equilibrium:

$$\text{HIn} \rightleftharpoons \text{H}^+ + \text{Ind}^-$$

In a basic solution, the indicator bromoresol green will be

A. blue and $[\text{HIn}]$ is less than $[\text{Ind}^-]$
B. yellow and $[\text{HIn}]$ is less than $[\text{Ind}^-]$
C. blue and $[\text{HIn}]$ is greater than $[\text{Ind}^-]$
D. yellow and $[\text{HIn}]$ is greater than $[\text{Ind}^-]$

### O03 147
Consider the following equilibrium for an indicator:

$$\text{HIn} + \text{H}_2\text{O} \rightleftharpoons \text{Ind}^- + \text{H}_3\text{O}^+$$

When a few drops of the indicator chlorphenol red are added to a colourless solution of pH 4.0, the resulting solution is

A. red as $[\text{HIn}] < [\text{Ind}^-]$
B. red as $[\text{HIn}] > [\text{Ind}^-]$
C. yellow as $[\text{HIn}] < [\text{Ind}^-]$
D. yellow as $[\text{HIn}] > [\text{Ind}^-]$
### NEUTRALIZATIONS OF ACIDS AND BASES

**O03** 148

Consider the following equilibrium for an indicator:

\[ \text{HInd} + \text{H}_2\text{O} \rightleftharpoons \text{Ind}^- + \text{H}_3\text{O}^+ \]

When a few drops of the indicator methyl red are added to 1.0 M HCl, the colour of the resulting solution is

A. red and the products are favoured.
B. red and the reactants are favoured.
C. yellow and the products are favoured.
D. yellow and the reactants are favoured.

**O04** 149

What is the pH at the transition point of an indicator if its \( K_a \) is \( 7.9 \times 10^{-3} \) ?

A. 0.98  
B. 2.10  
C. 7.00  
D. 11.90

**O04** 150

What is the pH at the transition point for an indicator with a \( K_a \) of \( 2.5 \times 10^{-4} \) ?

A. \( 2.5 \times 10^{-4} \)  
B. 3.60  
C. 7.00  
D. 10.40

**O05** 151

The approximate \( K_a \) for the indicator phenolphthalein is

A. \( 6 \times 10^{-19} \)  
B. \( 8 \times 10^{-10} \)  
C. \( 6 \times 10^{-8} \)  
D. \( 2 \times 10^{-2} \)

**P01** 152

Which of the following indicators would be used when titrating a weak acid with a strong base?

A. methyl red  
B. methyl violet  
C. indigo carmine  
D. phenolphthalein
Which of the following indicators would be yellow at pH 7 and blue at pH 10?

A. thymol blue  
B. methyl violet  
C. bromthymol blue  
D. bromresol green

33. Which of the following indicators should be used in the titration represented by the above titration curve?

A. orange II  
B. methyl red  
C. phenolphthalein  
D. alizarin yellow

An indicator was added to solutions of different pH and the following was observed:

The indicator is

A. methyl red  
B. thymol blue  
C. methyl orange  
D. bromthymol blue

Which of the following standardized solutions should a chemist select when titrating a 25.00 mL sample of 0.1 M NH₃, using methyl red as an indicator?

A. 0.114 M HCl  
B. 6.00 M HNO₃  
C. 0.105 M NaOH  
D. 0.100 M CH₃COOH
Which of the following indicators should be used when 1.0 M HNO₂ is titrated with NaOH_{(aq)}? 

A. methyl red  
B. thymol blue  
C. methyl orange  
D. indigo carmine

A 0.10 M solution was tested with four indicators and the following was observed.

The [OH⁻] in this solution is

A. 1×10⁻⁸ M  
B. 1×10⁻⁴ M  
C. 1×10⁻⁹ M  
D. 1×10⁻⁵ M

In a titration, 10.0 mL of H₃SO₄_{(aq)} is required to neutralize 0.0400 mol of NaOH. From this data, the [H₂SO₄] is

A. 0.0200 M  
B. 2.00 M  
C. 4.00 M  
D. 8.00 M

The stoichiometric point of a titration is reached when 35.50 mL 0.40 M HBr is added to a 25.00 mL sample of LiOH. The original [LiOH] is

A. 0.014 M  
B. 0.024 M  
C. 0.28 M  
D. 0.57 M

The equivalence point in a titration is reached when 20.0 mL of H₂SO₄ is added to 20.0 mL of 0.420 M KOH. The [H₂SO₄] in the original solution is

A. 0.00840 M  
B. 0.210 M  
C. 0.420 M  
D. 0.840 M

How many moles of Mg(OH)₂ are required to neutralize 30.00 mL of 0.150 M HCl?

A. 2.25×10⁻³ mol  
B. 4.50×10⁻³ mol  
C. 5.00×10⁻³ mol  
D. 9.00×10⁻³ mol
What volume of 0.100 M NaOH is required to neutralize a 10.0 mL sample of 0.200 M H₂SO₄?

A. 5.0 mL  
B. 10.0 mL  
C. 20.0 mL  
D. 40.0 mL

Consider the following data table:

<table>
<thead>
<tr>
<th>BEAKER</th>
<th>VOLUME</th>
<th>CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 mL</td>
<td>0.1 M Sr(OH)₂</td>
</tr>
<tr>
<td>2</td>
<td>20 mL</td>
<td>0.2 M NH₃OH</td>
</tr>
<tr>
<td>3</td>
<td>25 mL</td>
<td>0.1 M KOH</td>
</tr>
<tr>
<td>4</td>
<td>50 mL</td>
<td>0.2 M NaOH</td>
</tr>
</tbody>
</table>

Identify the beaker that requires the smallest volume of 0.1 M HCl for complete neutralization.

A. beaker 1  
B. beaker 2  
C. beaker 3  
D. beaker 4

What volume of 0.250 M H₂SO₄ is required to neutralize 25.00 mL of 2.50 M KOH?

A. 125 mL  
B. 150 mL  
C. 250 mL  
D. 500 mL

The volume of 0.200 M Sr(OH)₂ needed to neutralize 50.0 mL of 0.200 M HCl is

A. 10.0 mL  
B. 25.0 mL  
C. 50.0 mL  
D. 100.0 mL

The volume of 0.450 M HCl needed to neutralize 40.0 mL of 0.450 M Sr(OH)₂ is

A. 18.0 mL  
B. 20.0 mL  
C. 40.0 mL  
D. 80.0 mL

What volume of 0.100 M NaOH is required to completely neutralize 15.00 mL of 0.100 M H₃PO₄?

A. 5.00 mL  
B. 15.0 mL  
C. 30.0 mL  
D. 45.0 mL
The net ionic equation for the neutralization of HBr by Ca(OH)₂ is

A. \( \text{H}^+ + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} \)

B. \( \text{Ca}^{2+} + 2\text{Br}^- \rightleftharpoons \text{CaBr}_2 \)

C. \( 2\text{HBr} + \text{Ca(OH)}_2 \rightarrow 2\text{H}_2\text{O} + \text{CaBr}_2 \)

D. \( 2\text{H}^+ + 2\text{Br}^- + \text{Ca}^{2+} + 2\text{OH}^- \rightleftharpoons 2\text{H}_2\text{O} + \text{Ca}^{2+} + 2\text{Br}^- \)

The complete ionic equation for the neutralization of acetic acid by sodium hydroxide is

A. \( \text{H}^+ + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} \)

B. \( \text{CH}_3\text{COOH} + \text{OH}^- \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_2\text{O} \)

C. \( \text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{NaCH}_3\text{COO} + \text{H}_2\text{O} \)

D. \( \text{CH}_3\text{COOH} + \text{Na}^+ + \text{OH}^- \rightarrow \text{Na}^+ + \text{CH}_3\text{COO}^- + \text{H}_2\text{O} \)

A net ionic equation for the reaction between \( \text{CH}_3\text{COOH} \) and \( \text{KOH} \) is

A. \( \text{CH}_3\text{COO}^- + \text{K}^+ \rightleftharpoons \text{CH}_3\text{COOK} \)

B. \( \text{CH}_3\text{COOH} + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} + \text{CH}_3\text{COO}^- \)

C. \( \text{CH}_3\text{COOH} + \text{KOH} \rightarrow \text{H}_2\text{O} + \text{CH}_3\text{COOK} \)

D. \( \text{CH}_3\text{COOH} + \text{K}^+ + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} + \text{KCH}_3\text{COO} \)

Which equation represents a neutralization reaction?

A. \( \text{Pb}^{2+} + 2\text{Cl}^- \rightarrow \text{PbCl}_2 \)

B. \( \text{HCl} + \text{NH}_3 \rightarrow \text{NH}_4\text{Cl} \)

C. \( \text{BaI}_2 + \text{MgSO}_4 \rightarrow \text{BaSO}_4 + \text{MgI}_2 \)

D. \( \text{MnO}_4^- + 5\text{Fe}^{2+} + 8\text{H}^+ \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O} \)

The reaction of a strong acid with a strong base produces

A. a salt and water.

B. a base and an acid.

C. a metallic oxide and water.

D. a non-metallic oxide and water.
The net ionic equation for the titration of $\text{HClO}_4(aq)$ with $\text{LiOH}(aq)$ is

A. $\text{H}^+(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}(l)$
B. $\text{HClO}_4(aq) + \text{OH}^-(aq) \rightarrow \text{ClO}_4^-(aq) + \text{H}_2\text{O}(l)$
C. $\text{HClO}_4(aq) + \text{LiOH}(aq) \rightarrow \text{LiClO}_4(aq) + \text{H}_2\text{O}(l)$
D. $\text{H}^+(aq) + \text{ClO}_4^-(aq) + \text{Li}^+(aq) + \text{OH}^-(aq) \rightarrow \text{LiClO}_4(aq) + \text{H}_2\text{O}(l)$

The balanced formula equation for the neutralization of $\text{H}_2\text{SO}_4$ by KOH is

A. $\text{H}_2\text{SO}_4 + \text{KOH} \rightarrow \text{KSO}_4 + \text{H}_2\text{O}$
B. $\text{H}_2\text{SO}_4 + \text{KOH} \rightarrow \text{K}_2\text{SO}_4 + \text{H}_2\text{O}$
C. $\text{H}_2\text{SO}_4 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + \text{H}_2\text{O}$
D. $\text{H}_2\text{SO}_4 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$

A student combines 0.25 mol of NaOH and 0.20 mol of HCl in water to make 2.0 litres of solution. The pH of this solution is

A. 1.3
B. 1.6
C. 12.4
D. 12.7

What is the pH of a solution prepared by adding 0.50 mol KOH to 1.0 L of 0.30 M $\text{HNO}_3$?

A. 0.20
B. 0.70
C. 13.30
D. 13.80

Calculate the pH of a solution formed when 50.0 mL of 4.0 M HCl is added to 50.0 mL of 2.0 M NaOH.

A. 0.00
B. 1.00
C. 2.00
D. 7.00

The pH at the equivalence point of a strong acid–strong base titration is

A. equal to 0.00
B. less than 7.00
C. equal to 7.00
D. greater than 7.00
What is the pH of the solution formed when 0.060 moles NaOH is added to 1.00 L of 0.050 M HCl?

A. 2.00  
B. 7.00  
C. 12.00  
D. 12.78

Which of the following curves best represents the titration of sodium hydroxide with hydrochloric acid?

A.  

B.  

C.  

D.  

At the equivalence point in a titration involving 0.1 M solutions, which of the following combinations would have the lowest conductivity?

A. nitric acid and barium hydroxide  
B. acetic acid and sodium hydroxide  
C. sulphuric acid and barium hydroxide  
D. hydrochloric acid and sodium hydroxide

Which of the following titrations would have an equivalence point less than pH 7?

A. NH₃ and HCl  
B. NaOH and HNO₃  
C. Ba(OH)₂ and H₂SO₄  
D. KOH and CH₃COOH

Consider the following 0.100 M solutions:

I. H₂SO₄  
II. HCl  
III. HF

The equivalence point is reached when 10.00 mL of 0.100 M NaOH has been added to 10.00 mL of solution(s)

A. II only.  
B. I and II only.  
C. II and III only.  
D. I, II, and III.
Which of the following acid-base pairs would result in an equivalence point with pH greater than 7.0?

A. HCl and LiOH  
B. HNO₃ and NH₃  
C. HClO₄ and NaOH  
D. CH₃COOH and KOH

Which pair of 0.10 M solutions would result in the above titration curve?

A. HF and KOH  
B. HCl and NH₃  
C. H₂S and NaOH  
D. HNO₃ and KOH

A suitable indicator for the above titration is

A. methyl violet.  
B. alizarin yellow.  
C. thymolphthalein.  
D. brom cresol green.

Which of the following solutions should be used when titrating a 25.00 mL sample of CH₃COOH that is approximately 0.1 M?

A. 0.150 M NaOH  
B. 0.001 M NaOH  
C. 3.00 M NaOH  
D. 6.00 M NaOH
Consider the following titration curve:

This curve represents the titration of a
A. strong base by adding a weak acid.
B. strong acid by adding a weak base.
C. strong acid by adding a strong base.
D. strong base by adding a strong acid.

In a titration between a weak acid and a strong base, the pH at the equivalence point is
A. 3
B. 5
C. 7
D. 9

Consider the following titration curve:

Which pair of solutions would result in the above curve?
A. HCl and NH₃
B. HCl and NaOH
C. CH₃COOH and NH₃
D. CH₃COOH and NaOH

BUFFERS

A few drops of strong acid are added to 1.0 L of a pH 8.0 buffer solution. The resulting solution will have an approximate pH of
A. 5.6
B. 7.0
C. 7.9
D. 8.1
Q01 193 Which of the following graphs describes the relationship between the pH of a buffer and the volume of NaOH added to the buffer?

A.  

B.  

C.  

D.  

Q02 194 Which one of the following combinations would act as an acidic buffer?

A.  HCl and NaOH  
B.  KOH and KBr  
C.  NH₃ and NH₄Cl  
D.  CH₃COOH and NaCH₃COO  

Q02 195 Which of the following compounds, when added to a solution of ammonium nitrate, will result in the formation of a buffer solution?

A.  ammonia  
B.  nitric acid  
C.  sodium nitrate  
D.  ammonium chloride  

Q02 196 Consider the following acid solutions:

| I. H₂CO₃ | II. HClO₄ | III. HF |

Which of the above acids would form a buffer solution when its conjugate base is added?

A.  I only  
B.  II only  
C.  I and III only  
D.  I, II and III  

Q02 197 Consider the following equilibrium:

\[ \text{HF}_{(aq)} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{F}^- \]

The above system will behave as a buffer when the [F⁻] is approximately equal to

A.  \( K_u \)  
B.  [HF]  
C.  [H₂O]  
D.  [H₃O⁺]
Q02 198 Which of the following represents a buffer equilibrium?

A. $\text{HI} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{I}^-$
B. $\text{HCl} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Cl}^-$
C. $\text{HCN} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CN}^-$
D. $\text{HClO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{ClO}_4^-$

Q03 199 A basic buffer solution can be prepared by mixing equal numbers of moles of

A. $\text{NH}_4\text{Cl}$ and $\text{HCl}$
B. $\text{NaCl}$ and $\text{NaOH}$
C. $\text{Na}_2\text{CO}_3$ and $\text{NaHCO}_3$
D. $\text{NaCH}_3\text{COO}$ and $\text{CH}_3\text{COOH}$

Q03 200 Which of the following would produce a buffer solution when added to 1.0 M $\text{NH}_3$?

A. $\text{HNO}_3$
B. $\text{KNH}_2$
C. $\text{NaOH}$
D. $\text{NH}_4\text{Cl}$

Q03 201 A buffer solution is prepared by adding 1.0 mol of $\text{NaCH}_3\text{COO}$ to 1.0 L of 1.0 M $\text{CH}_3\text{COOH}$.
The molar concentration of $\text{CH}_3\text{COO}^-$ is approximately

A. 0.0
B. 0.5
C. 1.0
D. 2.0

Q03 202 A buffer solution can be prepared from

A. nitric acid and sodium nitrate.
B. sulphuric acid and sodium hydroxide.
C. hydrocyanic acid and sodium cyanide.
D. sodium hydroxide and sodium chloride.

Q05 203 A student prepares a buffer by placing ammonium chloride in a solution of ammonia. Equilibrium is established according to the equation:

$$\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$$

When a small amount of base is added to the buffer, the base reacts with the

A. $\text{NH}_3$ and the pH decreases.
B. $\text{NH}_4^+$ and the pH decreases.
C. $\text{NH}_3$ to keep the pH relatively constant.
D. $\text{NH}_4^+$ to keep the pH relatively constant.
Q05 204
Consider the following equilibrium for a buffer solution:
\[
\text{NH}_4^+ + H_2O (aq) \rightleftharpoons \text{H}_3\text{O}^+ + \text{NH}_3 (aq)
\]
When a few drops of HCl are added,
A. both the [\text{NH}_3] and the [\text{NH}_4^+] increase.
B. both the [\text{NH}_3] and the [\text{NH}_4^+] decrease.
C. the [\text{NH}_3] decreases and the [\text{NH}_4^+] increases.
D. the [\text{NH}_3] increases and the [\text{NH}_4^+] decreases.

Q05 205
Consider the following:
\[
\text{CH}_3\text{COOH} + H_2O \rightleftharpoons \text{CH}_3\text{COO}^- + H_3\text{O}^+
\]
A buffer solution is prepared by adding NaCH_3COO(s) to CH_3COOH(aq). When a few drops of NaOH solution are added to the buffer, the equilibrium
A. shifts left and [\text{CH}_3\text{COO}^-] increases.
B. shifts left and [\text{CH}_3\text{COO}^-] decreases.
C. shifts right and [\text{CH}_3\text{COO}^-] increases.
D. shifts right and [\text{CH}_3\text{COO}^-] decreases.

Q06 206
Which of the following pairs of substances form a buffer system for human blood?
A. HCl and Cl^-
B. NH_3 and NH_2^-
C. H_2CO_3 and HCO_3^-
D. H_3C_6H_5O_7 and HC_6H_5O_7^{2-}

ACID RAIN

R01 207
Which of the following oxides will form the most acidic solution?
A. SO_2
B. MgO
C. Na_2O
D. Al_2O_3

R01 208
The balanced equation for the reaction between sodium oxide and water is
A. Na_2O + H_2O → 2NaOH
B. Na_2O + H_2O → 2NaH + O_2
C. Na_2O + H_2O → 2Na + H_2O_2
D. Na_2O + H_2O → 2Na + H_2 + O_2
<table>
<thead>
<tr>
<th>R01 209</th>
<th>Which of the following oxides would hydrolyze to produce hydroxide ions?</th>
</tr>
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<tbody>
<tr>
<td>A. NO</td>
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<tr>
<td>B. SO₂</td>
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<tr>
<td>C. Cl₂O</td>
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<tr>
<td>D. Na₂O</td>
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</table>

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<tr>
<th>R01 210</th>
<th>Which of the following oxides would hydrolyze to produce hydronium ions?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. CaO</td>
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<tr>
<td>B. SO₂</td>
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<tr>
<td>C. MgO</td>
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<td>D. Na₂O</td>
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</tbody>
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<tr>
<th>R01 211</th>
<th>Which of the following oxides forms a basic solution?</th>
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<tbody>
<tr>
<td>A. K₂O</td>
<td></td>
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<tr>
<td>B. CO₂</td>
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<tr>
<td>C. SO₃</td>
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<td>D. NO₂</td>
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<tr>
<th>R01 212</th>
<th>Which of the following is the weakest acid?</th>
</tr>
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<tbody>
<tr>
<td>A. HClO</td>
<td></td>
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<tr>
<td>B. HClO₂</td>
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<tr>
<td>C. HClO₃</td>
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<tr>
<td>D. HClO₄</td>
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<tr>
<th>R01 213</th>
<th>Sulphur dioxide gas forms an acidic solution. The equation representing this reaction is</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. SO₂(g) + H₂O(l) → H₂SO₃(aq)</td>
<td></td>
</tr>
<tr>
<td>B. SO₂(g) + 2H₂O(l) → H₂SO₄(aq) + H₂(g)</td>
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<tr>
<td>C. SO₂(g) + H₂O(l) → SO₃²⁻(aq) + 2H⁺(aq)</td>
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<tr>
<td>D. SO₂(g) + H₂O(l) → HSO₃⁺(aq) + OH⁻(aq)</td>
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<tr>
<th>R01 214</th>
<th>The equation for the reaction of Cl₂O with water is</th>
</tr>
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<tbody>
<tr>
<td>A. Cl₂O + H₂O ⇌ 2HClO</td>
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<tr>
<td>B. Cl₂O + H₂O ⇌ 2ClO + H₂</td>
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<tr>
<td>C. Cl₂O + H₂O ⇌ Cl₂ + H₂O₂</td>
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<tr>
<td>D. Cl₂O + H₂O ⇌ Cl₂ + O₂ + H₂</td>
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</table>
| R01 | 215 | A basic solution can be prepared from  
|   |   | A. NO  
|   |   | B. SrO  
|   |   | C. CO₂  
|   |   | D. SO₃  
| R02 | 216 | The pH range of ‘acid rain’ is often  
|   |   | A. 3 to 6  
|   |   | B. 6 to 8  
|   |   | C. 7 to 9  
|   |   | D. 10 to 12  
| R03 | 217 | ‘Normal’ rain water is slightly acidic due to the presence of dissolved  
|   |   | A. methane.  
|   |   | B. carbon dioxide.  
|   |   | C. sulphur dioxide.  
|   |   | D. nitrogen dioxide.  
| R03 | 218 | The approximate pH of “normal” rain water is  
|   |   | A. 0  
|   |   | B. 6  
|   |   | C. 7  
|   |   | D. 8  
| R03 | 219 | Normal rainwater has a pH of approximately 6 as a result of dissolved  
|   |   | A. oxygen.  
|   |   | B. carbon dioxide.  
|   |   | C. sulphur dioxide.  
|   |   | D. nitrogen dioxide.  
| R04 | 220 | Which of the following pairs of gases are primarily responsible for producing “acid rain”?  
|   |   | A. O₂ and O₃  
|   |   | B. N₂ and O₂  
|   |   | C. CO and CO₂  
|   |   | D. NO₂ and SO₂  


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<tr>
<th>R04 221</th>
<th>Which of the following gases results in the formation of acid rain?</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>A. H₂</td>
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<td>B. O₃</td>
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<td>C. SO₂</td>
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<td>D. NH₃</td>
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<tr>
<th>R05 222</th>
<th>Which of the following is primarily responsible for acid rain?</th>
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<tbody>
<tr>
<td></td>
<td>A. HCl</td>
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<td>B. H₃SO₄</td>
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<td></td>
<td>C. HClO₄</td>
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<td>D. CH₃COOH</td>
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<th>R05 223</th>
<th>A gas which is produced by internal combustion engines and contributes to the formation of acid rain is</th>
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<tbody>
<tr>
<td></td>
<td>A. H₂</td>
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<td>B. O₃</td>
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<td>C. CH₄</td>
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<td>D. NO₂</td>
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### ANSERS TO STUDY GUIDE QUESTIONS:

#### PROPERTIES AND DEFINITIONS

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#### STRONG/WEAK ACIDS AND BASES

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#### $K_w$, pH, pOH

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#### $K_a$ and $K_b$ PROBLEM SOLVING

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#### HYDROLYSIS OF SALTS

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**INDICATORS**

| 133. A | 140. B | 147. D |
| 135. A | 142. A | 149. B |
| 136. A | 143. A | 150. B |
| 137. C | 144. C | 151. B |
| 138. D | 145. A | |
| 139. C | 146. A | |

**NEUTRALIZATIONS OF ACIDS AND BASES**

| 152. D | 166. B | 180. C |
| 153. A | 167. D | 181. A |
| 155. B | 169. A | 183. A |
| 156. A | 170. D | 184. C |
| 160. D | 174. A | 188. A |
| 161. B | 175. D | 189. D |
| 162. A | 176. C | 190. D |
| 163. D | 177. C | 191. D |
| 164. C | 178. A | |
| 165. A | 179. C | |

**BUFFERS**

| 193. D | 198. C | 203. D |
| 194. D | 199. C | 204. C |
| 196. C | 201. C | 206. C |

**ACID RAIN**

| 208. A | 214. A | 220. D |
| 211. A | 217. B | 223. D |
| 212. A | 218. B | |