Why?

Is water an acid, a base, neither, or both? There are three different ways to define a substance as an acid or base. One definition is based on the ions found in a compound (Arrhenius), another is based on how a compound behaves when added to water (Bronsted-Lowry), and a third is based on how a molecule reacts with other molecules (Lewis). These definitions address different behaviors of compounds and explain how seemingly different compounds can be classified as behaving like an acid or a base.

Success Criteria

- Define an acid according to the Arrhenius definition and the Bronsted-Lowry definition.
- Define a base according to the Arrhenius definition and the Bronsted-Lowry definition.
- Identify acids and bases that illustrate the Arrhenius definition and Bronsted-Lowry definition.
- Explain the acid-base properties of amphiprotic substances.

Information

Acid –
- a compound that yields hydronium ions, $\text{H}_3\text{O}^+\text{(aq)}$, as positive ions in aqueous solution (Arrhenius definition).
- a compound that donates a hydrogen ion ($\text{H}^+$) to another species (Bronsted-Lowry definition).

Base –
- a compound that yields hydroxide ions, $\text{OH}^-\text{(aq)}$, as negative ions in aqueous solution (Arrhenius definition).
- a compound that accepts a hydrogen ion, (H$^+$), from another species (Bronsted-Lowry definition).

Neutral solution –
- contains hydrogen ions and hydroxide ions in equal concentrations.

Note: In the context of acid-base chemistry, the hydrogen ion usually is referred as a proton because an atom of hydrogen contains one proton and one electron - when it loses the electron during ion formation all that is left is the nucleus, which is one proton.
**Model**

1. \( \text{NaOH(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Na}^+(\text{aq}) + \text{OH}^- (\text{aq}) \)

2. \( \text{HCl(aq)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^- (\text{aq}) \)

3. \( \text{NH}_3(\text{g}) + \text{H}_2\text{O(l)} \rightarrow \text{NH}_4^+(\text{aq}) + \text{OH}^- (\text{aq}) \)

4. \( \text{H}_2\text{CO}_3(\text{g}) + \text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{HCO}_3^- (\text{aq}) \)

5. \( \text{HCl(aq)} + \text{NH}_3(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^- (\text{aq}) \)

**Key Questions**

1. In equation 1, is \( \text{NaOH(s)} \) an acid or a base? Explain.

   Base, yields \( \text{OH}^- \) ions

2. In equation 2, is \( \text{HCl(aq)} \) an acid or a base? Explain.

   Acid, yields \( \text{H}_3\text{O}^+ \) ions

3. In equation 3, is \( \text{NH}_3(\text{g}) \) an acid or a base? Explain.

   Base, accepts \( \text{H}^+ \) from \( \text{H}_2\text{O} \)

4. In equation 3, is \( \text{H}_2\text{O(l)} \) and acid or a base? Explain.

   Base, accepts \( \text{H}^+ \) from \( \text{NH}_3 \)

5. In equation 4, is \( \text{H}_2\text{O(l)} \) and acid or a base? Explain.

   Base, accepts \( \text{H}^+ \) from \( \text{H}_2\text{CO}_3 \)

6. Is \( \text{H}_2\text{CO}_3(\text{g}) \) in equation 4 an acid or a base? Explain.

   Acid, donates \( \text{H}^+ \) to \( \text{H}_2\text{O} \).

7. Compare the behavior of \( \text{NH}_3 \) in equations 3 and 5. Identify any similarities and differences. Explain.

   In both cases, \( \text{NH}_3 \) accepts a \( \text{H}^+ \) from the other reactant.

8. Identify the substances in the Model that behave as both an acid and a base? Explain how this duplicity in behavior can or cannot occur.

   \( \text{H}_2\text{O} \) can accept and become \( \text{H}_3\text{O}^+ \) or donate and become \( \text{OH}^- \), called amphiprotic.
Exercises

1. In the reaction below identify which of the reactants is an acid and which is a base:

\[ \text{H}_2\text{C}_2\text{H}_3\text{O}_2(\text{aq}) + \text{H}_2\text{O}(l) \rightarrow \text{C}_2\text{H}_3\text{O}_2^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \]

2. Consider the atomic structure of the \( \text{H}^+ \) ion. Complete the table below indicating the correct number of each subatomic particle.

<table>
<thead>
<tr>
<th>Subatomic particle</th>
<th>Number of subatomic particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protons</td>
<td>1</td>
</tr>
<tr>
<td>Electrons</td>
<td>0</td>
</tr>
<tr>
<td>Neutrons</td>
<td>0</td>
</tr>
</tbody>
</table>

3. In some textbooks, when explaining the Brønsted – Lowry definition, acids and bases are described as proton donors and proton acceptors. Based on your response to Exercise 2, explain why these are correct terms.

A \( \text{H}^+ \) ion can be described as a proton.

4. A definition of the prefix *amphi* is: "both or of both kinds." Define the term "amphiprotic" and based on the insight you gained from examining the model, explain why the term is used to describe water.

A substance that can behave like both a base & acid. It can donate & accept \( \text{H}^+ \) ions.
Applications

1. Ammonium chloride is one component of ordinary dry cell batteries. Ammonia gas can react with hydrogen chloride gas to form the solid salt ammonium chloride. Write the balanced equation for this reaction including the phases of each substance.

\[
\text{NH}_3(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NH}_4\text{Cl}(\text{s})
\]

2. Label the acid and the base in the reactants of your equation in Application 1.

3. Your blood contains an acid-base buffer system. A buffer system is a chemical system that resists changes in pH when small amounts of either acid or base are added to the system. It is important that our blood pH does not change suddenly. A pH balance ensures that chemical reactions in the body take place correctly. If the pH drops below 6.8 or rises above 7.8, death can occur. The buffer in blood is the bicarbonate ion, \text{HCO}_3^-(\text{aq}). Two equations that illustrate bicarbonate's buffering action are shown in these equations:

\[
\text{HCO}_3^- (\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{CO}_3(\text{aq})
\]

\[
\text{HCO}_3^- (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{CO}_3^{2-} (\text{aq}) + \text{H}_2\text{O}(l)
\]

Label the acid and the base in each of these equations.

4. Explain why bicarbonate ions are said to be amphiprotic.

\text{Can accept or donate } H^+ \text{ ions.}

5. When we exercise, \text{CO}_2 builds up in our blood and the following reactions occur.

1. \text{CO}_2 + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{CO}_3(\text{aq}) + \text{H}^+

2. \text{H}_2\text{CO}_3(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})

How does the buffer system in our blood respond to this reaction in order to keep the pH within the acceptable range?

\[
\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3
\]

\[
\text{HCO}_3^- + \text{OH}^- \rightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}
\]

Got It?

Is water an acid, a base, neither, or \textit{both}? Explain.

\text{Can donate or accept } H^+ \text{ ions?}
Honors Chemistry:  
Web Quest:  
Introduction to Acids and Bases

Answer the following questions for tomorrow's class. Ch. 10 in your book:

1. Define acid and base.
2. List the properties of Acids and Bases.
3. Define and give an example for each: monoprotic, diprotic, and triprotic.
4. Why are acids electrolytes?
5. How does acid rain form?
6. How can bases help your garden grow?
7. List the strong acids.
8. What kinds of bases are strong?
9. What is the difference between a weak acid and a strong acid?
10. What is pH?
11. Explain the relationship between pH and the concentration of the hydrogen ion.
12. What happens when an acid reacts with a base?
13. Define titration. What is the purpose of titration?
15. What is a buffer and what is its purpose?
17. Define Lewis acid and base.
18. Define amphoteric.
Naming Acids and Bases

Name the following acids and bases:

1) NaOH  sodium hydroxide
2) H₂SO₃  sulfurous acid
3) H₂S  hydrosulfuric acid
4) H₃PO₄  phosphoric acid
5) NH₃  ammonia
6) HCN  hydrosulfurous acid  hydrocyanic acid
7) Ca(OH)₂  calcium hydroxide
8) Fe(OH)₃  iron (III) hydroxide
9) H₃P  hydrophosphoric acid

Write the formulas of the following acids and bases:

10) hydrofluoric acid  HF
11) hydroselenic acid  HSe
12) carbonic acid  H₂CO₃
13) lithium hydroxide  LiOH
14) nitrous acid  HNO₂
15) cobalt (II) hydroxide  Co(OH)₂
16) sulfuric acid  H₂SO₄
17) beryllium hydroxide  Be(OH)₂
18) hydrobromic acid  HBr
CW: pH & pOH Calculations

Directions: Show work for all problems! Write what you put in the calculator!!

Let's Start with some basic powers of 10.

1. Calculate pH from the following [H⁺]: Identify each solutions as acidic, basic, or neutral.
   a. 1.00 x 10⁻⁴ M  b. 1.00 x 10⁻¹² M  c. 1.00 x 10⁻⁸ M  d. 1.00 x 10⁻¹³ M
   4       12       6       13
   A       B       A       B

2. Calculate [H⁺] from the following pH: Identify each solution as acidic, basic, or neutral.
   a. 2.00  b. 5.00  c. 10.00  d. 12.00
   a. 1 x 10⁻² M  b. 1 x 10⁻⁵ M  c. 10 x 10⁻¹⁰ M  d. 10 x 10⁻¹² M
   A       A       B       B

3. Calculate pOH from the following [OH⁻]: Identify each solutions as acidic, basic, or neutral.
   a. 1.00 x 10⁻² M  b. 1.00 x 10⁻¹³ M  c. 1.00 x 10⁻⁵ M  d. 1.00 x 10⁻¹¹ M
   a. 2     b. 13    c. 5     d. 11
   B       A       B       A

4. Calculate [OH⁻] from the following pOH: Identify each solution as acidic, basic, or neutral.
   a. 3.00  b. 7.00  c. 11.00  d. 9.00
   a. 1.0 x 10⁻³ M  b. 1.0 x 10⁻⁷ M  c. 1.0 x 10⁻¹¹ M  d. 1.0 x 10⁻⁹ M
   B       Neutral  A       A
Now some that require a little more work:

Calculate the pH for the following:
1. \([H^+] = 1.6 \times 10^{-4} \text{ M}\)
   \[-\log(1.6 \times 10^{-4}) = 3.8\]
2. \([H^+] = 6.7 \times 10^{-5} \text{ M}\)
   \[-\log(6.7 \times 10^{-5}) = 4.2\]
3. \([\text{OH}^-] = 5.6 \times 10^{-11} \text{ M}\)
   \[-\log(5.6 \times 10^{-11}) = 10 = \text{pOH}\]
   \[14 - 10 = 4 = \text{pH}\]

Calculate the pOH for the following:
1. \([\text{OH}^-] = 7.7 \times 10^{-7} \text{ M}\)
   \[6.1\]
2. \([\text{OH}^-] = 9.6 \times 10^{-5} \text{ M}\)
   \[4.0\]
3. \([H^+] = 1.7 \times 10^{-3} \text{ M}\)
   \[\left[\begin{array}{c}
   [H^+] \\
   \text{pH} \\
   \text{pOH} = 11
   \end{array}\right]\]

Calculate the \([H^+]\) for the following:
1. \(\text{pH} = 4.1\)
   \[10^{-4.1} = 7.9 \times 10^{-5} \text{ M}\]
2. \(\text{pH} = 7.9\)
   \[1.3 \times 10^{-8} \text{ M}\]
3. \(\text{pH} = 10.2\)
   \[6.3 \times 10^{-11} \text{ M}\]
4. \(\text{pOH} = 7.1\)
   \[\text{pH} = 6.9\]
   \[\left[\begin{array}{c}
   [H^+] \\
   = 1.3 \times 10^{-7} \text{ M}
   \end{array}\right]\]
5. \(\text{pOH} = 2.1\)
   \[\text{pH} = 11.9\]
   \[\left[\begin{array}{c}
   [H^+] \\
   = 1.3 \times 10^{-12} \text{ M}
   \end{array}\right]\]
Calculate the \([\text{OH}^-]\) for the following:

1. \(p\text{OH} = 12.1\)
   \[7.94 \times 10^{-13}\text{ M}\]

2. \(p\text{OH} = 1.6\)
   \[0.025\text{ M} = 2.5 \times 10^{-2}\text{ M}\]

3. \(p\text{OH} = 13.2\)
   \[6.31 \times 10^{-14}\text{ M}\]

4. \(p\text{H} = 10.9\)
   \[p\text{OH} = 3.1\]
   \([\text{OH}^-] = 7.94 \times 10^{-4}\text{ M}\]

5. \(p\text{H} = 2.5\)
   \[p\text{OH} = 11.5\]
   \([\text{OH}^-] = 3.2 \times 10^{-12}\text{ M}\]
Neutralization Reactions Worksheet

1. Write the balanced chemical equations for the neutralization reactions between:

a) HI and NaOH
\[ \text{HI} + \text{NaOH} \rightarrow \text{NaI} + \text{H}_2\text{O} \]

b) H₂CO₃ and Sr(OH)₂
\[ \text{H}_2\text{CO}_3 + \text{Sr(OH)}_2 \rightarrow \text{SrCO}_3 + 2\text{H}_2\text{O} \]

c) Ca(OH)₂ and H₃PO₄
\[ 3\text{Ca(OH)}_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 6\text{H}_2\text{O} \]

d) hydrobromic acid and barium hydroxide
\[ 2\text{HBr} + \text{Ba(OH)}_2 \rightarrow \text{BaBr}_2 + 2\text{H}_2\text{O} \]

e) zinc hydroxide and nitric acid
\[ \text{Zn(OH)}_2 + 2\text{HNO}_3 \rightarrow \text{Zn(NO}_3)_2 + 2\text{H}_2\text{O} \]

f) aluminum hydroxide and hydrochloric acid
\[ \text{Al(OH)}_3 + 3\text{HCl} \rightarrow 3\text{H}_2\text{O} + \text{AlCl}_3 \]

2. Give the name and the formula of the ionic compound produced by neutralization reactions between the following acids and bases:

<table>
<thead>
<tr>
<th>Acid and Base reactants</th>
<th>Name of ionic compound</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) nitric acid and sodium hydroxide</td>
<td>sodium nitrate</td>
<td>NaNO₃</td>
</tr>
<tr>
<td>b) hydroiodic acid and calcium hydroxide</td>
<td>calcium iodide</td>
<td>CaI₂</td>
</tr>
<tr>
<td>c) magnesium hydroxide and hydrosulfuric acid</td>
<td>magnesium sulfide</td>
<td>MgS</td>
</tr>
<tr>
<td>d) ammonium hydroxide and hydrofluoric acid</td>
<td>ammonium fluoride</td>
<td>NH₄F</td>
</tr>
<tr>
<td>e) barium hydroxide and sulfuric acid</td>
<td>barium sulfate</td>
<td>BaSO₄</td>
</tr>
<tr>
<td>f) chloric acid and rubidium hydroxide</td>
<td>rubidium chlorate</td>
<td>RbClO₃</td>
</tr>
<tr>
<td>g) calcium hydroxide and carbonic acid</td>
<td>calcium carbonate</td>
<td>CaCO₃</td>
</tr>
</tbody>
</table>
3. For each of the following ionic compounds, identify the acid and base that reacted to form them.

<table>
<thead>
<tr>
<th>Salt</th>
<th>Acid</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) NaCl</td>
<td>HCl hydrochloric acid</td>
<td>NaOH sodium hydroxide</td>
</tr>
<tr>
<td>b) Ca₃(PO₄)₂</td>
<td>H₃PO₄ phosphoric acid</td>
<td>Ca(OH)₂</td>
</tr>
<tr>
<td>c) Zn(NO₃)₂</td>
<td>HNO₃ nitric acid</td>
<td>Zn(OH)₂</td>
</tr>
<tr>
<td>d) Al(ClO)₃</td>
<td>HClO hypochlorous acid</td>
<td>Al(OH)₃</td>
</tr>
<tr>
<td>e) NH₄I</td>
<td>HI hydroiodic acid</td>
<td>NH₄OH</td>
</tr>
</tbody>
</table>
Acid-Base Neutralization Reactions

Information:

**Acid** – a compound that produces $H^+$ (aq), hydrogen ions (or hydronium ions, $H_3O^+$ (aq) as positive ions in aqueous solution.

**Base** – a compound that produces $OH^-$ (aq), hydroxide ions as negative ions in aqueous solution.

**Neutral solution** – contains hydrogen (or hydronium) ions and hydroxide ions in equal concentrations.

**Spectator ions** – present in acidic and basic solutions, but do not participate in the neutralization reaction between the $H^+$ (aq) (hydrogen ions) and $OH^-$ (aq) (hydroxide ions). Spectator ions can be positive or negative, and they are present in quantities needed to produce electrically neutral solutions.

Model:

![Chemical Diagram](Image)

Note: spectator ions are not shown in this model, but they are present in each solution.

Key Questions

1. Compare the concentration of $H^+$ and $OH^-$ in the each solution above.

<table>
<thead>
<tr>
<th>Solution A</th>
<th>Solution B</th>
<th>Solution C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[H^+]=3$</td>
<td>$[H^+] = 0$</td>
<td>$[H^+] = 1$</td>
</tr>
<tr>
<td>$[OH^-]=1$</td>
<td>$[OH^-] = 3$</td>
<td>$[OH^-] = 1$</td>
</tr>
</tbody>
</table>

2. Identify the acidic solution in the model. **A**

3. Identify the basic solution in the model. **B**

4. Identify the neutral solution in the model. **C**

Modified from POGIL 2005, 2006; Stony Brook University

Authored by: Neil Brosnan and Kenneth Levy; Revised by: Kelly Levy
Refer to the example above to solve #12-13.

12. How many mL of 2.0 M HBr are needed to exactly neutralize 20.0 mL of 4.0 M KOH? Remember, write a balanced equation first.

\[
\begin{align*}
20.0 \text{ mL KOH} & \quad 1 \text{ L KOH} & \quad 4.0 \text{ mol KOH} & \quad 1 \text{ mol HBr} & \quad 1 \text{ L HBr} & \quad 1000 \text{ mL} \\
1000 \text{ mL KOH} & \quad 1 \text{ L KOH} & \quad 1 \text{ mol KOH} & \quad 2.0 \text{ mol HBr} & \quad 1 \text{ L HBr} & \quad = 40.0 \text{ mL HBr}
\end{align*}
\]

13. How many mL of 2.0 M Mg(OH)\(_2\) are required to exactly neutralize 100.0 mL of a 3.0 M solution of HBr? Remember, write a balanced equation first.

\[
\begin{align*}
2 \text{ HBr} + \text{Mg(OH)}_2 & \rightarrow \text{MgBr}_2 + 2 \text{H}_2\text{O} \\
100.0 \text{ mL HBr} & \quad 1 \text{ L HBr} & \quad 3.0 \text{ mol HBr} & \quad 1 \text{ mol Mg(OH)}_2 & \quad 1 \text{ L Mg(OH)}_2 & \quad 1000 \text{ mL} \\
1000 \text{ mL} & \quad 1 \text{ L HBr} & \quad 2 \text{ mol HBr} & \quad 2 \text{ mol Mg(OH)}_2 & \quad 1 \text{ L} & \quad = 75 \text{ mL Mg(OH)}_2
\end{align*}
\]

Another (shorter) method of solving titration calculations

\[
M_A V_A N_A = M_B V_B N_B
\]

- \(M_A\) = molarity of acid
- \(V_A\) = volume of acid
- \(N_A\) = # of H\(^+\) ions in acid
- \(M_B\) = molarity of base
- \(V_B\) = volume of base
- \(N_B\) = # of OH\(^-\) ions in base

Use the short-cut above to solve for 14-16.

14. If 50.0 mL of 3.0 M HNO\(_3\) completely neutralized 150.0 mL of KOH, what was the molarity (M) of the KOH solution?

\[
\begin{align*}
&M = 3.0 \text{ M} & \quad x \quad V = 50.0 \text{ mL} & \quad 150.0 \quad n = 1 \\
&\frac{\eta M V_A}{\eta B V_B} = \frac{M_B}{M_A} = \frac{(1)(3.0)(50.0)}{(1)(150.0)} = 1.0 \text{M KOH}
\end{align*}
\]

15. How many mL of 2.0 M HBr are required to exactly neutralize 30.0 mL of a 4.0 M solution of Mg(OH)\(_2\)?

\[
\begin{align*}
&M = 2.0 \text{ M} & \quad 4.0 \text{ M} & \quad V_A = \frac{\eta_B M_B V_B}{\eta_A M_A} = \frac{(2)(4.0)(30.0)}{(1)(2.0)} = 120.0 \text{ mL} \\
&V = 30.0 \text{ mL} & \quad n = 2 & \quad = 120 \text{ mL HBr}
\end{align*}
\]

16. If 50.0 mL of 3.0 M H\(_3\)PO\(_4\) completely neutralized 150.0 mL of Mg(OH)\(_2\), what was the molarity of the Mg(OH)\(_2\) solution?

\[
\begin{align*}
&M = 3.0 \text{ M} & \quad x \quad V = 50.0 \text{ mL} & \quad 150.0 \quad n = 3 \\
&M_B = \frac{\eta_A M_A V_A}{\eta_B M_B} = \frac{(3)(3.0)(50.0)}{(2)(150.0)} = 1.5 \text{M Mg(OH)}_2
\end{align*}
\]

Modified from POGIL 2005, 2006; Stony Brook University
Authored by: Neil Brosnan and Kenneth Levy; Revised by: Kelly Levy
Exercises

5. Base upon the information presented in the key of the Model, draw reactants and products that form when an \( H^+ \) ion is added to an \( OH^- \) ion.

\[
\text{0} \quad + \quad \text{ } \quad \rightarrow \quad \text{ } \quad \text{ }
\]

6. Would the final solution be acidic or basic if solution A and solution B were mixed? Explain your answer.

\[
\text{Basic because more OH}^- \quad \text{than} \quad H^+. \quad \text{(4)} \quad \text{(3)}
\]

Titration Calculations

In a neutral solution the moles of \( H^+ \) = moles of \( OH^- \)

\[
\text{Molarity (M) = moles solute} \quad \frac{\text{1 liter solution}}{}
\]

Problems

7. How many moles of \( H^+ \) ions are present in one liter of 2.0 M HCl? Explain your reasoning.

\[
2.0 \text{ M} = \frac{x}{1 \text{ L}} \quad x = 2.0 \text{ mol} \quad \text{strong acid = completely ionizes}
\]

8. How many moles of \( OH^- \) ions are needed to completely neutralize one liter of 2.0 M HCl?

\[
2.0 \text{ mol} \quad \text{moles must be equal}
\]

9. How many moles of \( OH^- \) ions are present in one liter of 0.50 M NaOH? Explain your reasoning.

\[
0.50 \text{ M} = \frac{x}{1 \text{ L}} \quad x = 0.50 \text{ mol} \quad \text{strong base, completely ionizes}
\]

10. How many moles of \( H^+ \) ions are needed to completely neutralize one liter of 0.50 M NaOH?

\[
0.50 \text{ mol}
\]

11. How many moles of \( OH^- \) are needed to completely neutralize 0.50 liter of 2.0 M HCl?

\[
2.0 \text{ M} = \frac{x}{0.5} \quad 1.0 \text{ mol} \quad \text{H}^+ \quad \text{so you need} \quad 1.0 \text{ mol} \quad \text{OH}^- \]

Using Stoichiometry in Titrations

Refer to the following example to solve the following problems.

How many mL of 2.0 M NaOH are required to exactly neutralize 100.0 mL of a 3.0 M solution of HBr?

a. Write a balanced equation: \[ \text{NaOH} + \text{HBr} \rightarrow \text{NaBr} + \text{H}_2\text{O} \]

Remember that 2.0 M NaOH = 2.0 mol NaOH

\[
1 \text{ L NaOH}
\]

b. If you want to solve for mL of NaOH, begin with the mL of HBr.

\[
\begin{array}{cccccc}
100.0 \text{ mL HBr} & 1 \text{ L} & 3.0 \text{ mol HBr} & 1 \text{ mol NaOH} & 1 \text{ L NaOH} & 1000 \text{ mL} \\
1000 \text{ mL} & 1 \text{ L HBr} & 1 \text{ mol HBr} & 2.0 \text{ mol NaOH} & 1 \text{ L}
\end{array}
\]

\[
= 150 \text{ mL NaOH}
\]
Titration Classwork

Part I. Fill in the Blank.

1. A titration is a controlled addition of a titrant used to determine the concentration of an unknown.

2. The titrant goes into the buret.

3. The titrant is the solution of known concentration.

4. The analyte is the solution of unknown concentration.

5. The point when an indicator changes color is known as the end point.

6. A weak acid or base that changes color when the pH changes is called an indicator.

7. The equivalence point is when there are equal amounts of hydrogen ions and hydroxide ions.

Part II. Problems.
Directions: Show ALL work and CIRCLE your final answer.

8. What is the concentration of phosphoric acid if 10.0mL of acid is neutralized by 20.0mL of 0.20M sodium hydroxide?

\[ \frac{M_B V_A n_A}{V_A n_A} = \frac{M_B V_B n_B}{V_B n_B} \]

\[ M_A = \frac{M_B V_B n_B}{V_A n_A} = \frac{(0.20)(20)(1)}{(10)(3)} = 3.33 \text{M} \]

9. What is the concentration of sulfuric acid if 30.0mL of acid is neutralized by 20.0mL of 0.5M aluminum hydroxide?

\[ M_A = \frac{M_B V_B n_B}{V_A n_A} = \frac{(0.5)(20)(3)}{(30)(2)} = 0.75 \text{M} \]

10. What is the concentration of hydrochloric acid if 20.0mL of acid is neutralized by 40.0mL of 0.20M aluminum hydroxide?

\[ M_A = \frac{M_B V_B n_B}{V_A n_A} = \frac{(0.20)(40)(3)}{(30)(1)} = 1.2 \text{M} \]

11. What is the concentration of sulfuric acid if 50.0mL of acid is neutralized by 30.0mL of 0.5M sodium hydroxide?

\[ M_A = \frac{M_B V_B n_B}{V_A n_A} = \frac{(0.5)(30)(1)}{(50)(2)} = 0.60 \text{M} \]
1. If 25 mL of KOH were needed to neutralize 15 mL of 3.5 M HBr, calculate the molarity of the base.

\[
\text{KOH} \quad \text{HBr} \\
M \times 3.5 \text{ M} \\
V \ 25 \text{ mL} \quad 15 \text{ mL} \\
n \ 1 \quad 1 \\
\text{M}_B = \frac{M_A V_A n_A}{V_B n_B} = \frac{(3.5)(15)(1)}{(25)(1)} = 2.1 \text{ M}
\]

2. Calculate the molarity of a Ca(OH)\(_2\) solution if 46.5 mL were needed to neutralize 25 mL of 1.5 M HCl.

\[
\begin{array}{ccc}
\text{Ca(OH)}_2 & \text{HCl} \\
M \times 1.5 \text{ M} \\
V \ 46.5 \text{ mL} \quad 25 \text{ mL} \\
n \ 2 \quad 1 \\
\text{M}_B = \frac{M_A V_A n_A}{V_B n_B} = \frac{(1.5)(25)(1)}{(46.5)(2)} = 0.40 \text{ M}
\end{array}
\]

3. What volume of 5.0 M HC\(_2\)H\(_3\)O\(_2\) would be needed to neutralize 30 mL of 0.2 M Al(OH)\(_3\)?

\[
\begin{array}{ccc}
\text{HC}_2\text{H}_3\text{O}_2 & \text{Al(OH)}_3 \\
M \ 5.0 \text{ M} \quad 0.2 \text{ M} \\
V \ x \quad 30 \text{ mL} \\
n \ 1 \quad 3 \\
\text{M}_A = \frac{M_B V_B n_B}{M_A n_A} = \frac{(0.2)(30)(3)}{(5.0)(1)} = 3.6 \text{ M}
\end{array}
\]

4. A student titrated 20 mL of 0.5 M HNO\(_3\) with NaOH. Her data is shown in the following table.
   a. Complete the following table:

<table>
<thead>
<tr>
<th>INITIAL VOLUME NaOH</th>
<th>0.00 mL</th>
<th>15.32 mL</th>
<th>30.43 mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINAL VOLUME NaOH</td>
<td>15.32 mL</td>
<td>30.43 mL</td>
<td>45.32 mL</td>
</tr>
<tr>
<td>VOLUME NaOH used</td>
<td>15.32</td>
<td>15.11</td>
<td>14.89</td>
</tr>
</tbody>
</table>

b. Calculate the average volume NaOH used from the three trials.

\[
\text{Average} = \frac{15.32 + 15.11 + 14.89}{3} = 15.11 \text{ mL}
\]

c. Use your average volume of NaOH used to calculate the molarity of the base.

\[
\begin{array}{ccc}
\text{HNO}_3 & \text{NaOH} \\
M \ 0.5 \text{ M} \times \quad x \\
V \ 20 \text{ mL} \quad 15.11 \text{ mL} \\
n \ 1 \quad 1 \\
\text{M}_B = \frac{M_A V_A n_A}{V_B n_B} = \frac{(0.5)(20)}{(15.11)} = 0.60 \text{ M}
\end{array}
\]
5. Draw the laboratory set up for a titration and label all of the parts. Refer to your notes to make sure all vocabulary words are used.

6. Define all words used in previous problem in your own words.
Honors Chemistry: Interpreting a Titration Curve

Directions: Answer the questions below using the titration curves below.

1. Write "Acid" where the solution has an acidic pH and "base" where it has a basic pH.

2. Write "EP" where the equivalence point is.

3. What is the pH at the equivalence point?

4. What volume of titrant would have to be added for the pH of the solution to be 5.00? 35 mL

5. What is the pH of the solution when 15.00mL of titrant has been added? ~ pH=1

6. Write "Acid" where the solution has an acidic pH and "base" where it has a basic pH.

7. Write "EP" where the equivalence point is.

8. What is the pH at the equivalence point? ~7

9. What volume of titrant would have to be added for the pH of the solution to be 8.00? ~16mL

10. What is the pH of the solution when 10.00mL of titrant has been added? ~5

Vinegar Trial 1
Titration Curve Graphing Activity

<table>
<thead>
<tr>
<th>Volume of Titrant Added</th>
<th>pH of solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>10.00</td>
<td>1.36</td>
</tr>
<tr>
<td>24.90</td>
<td>3.70</td>
</tr>
<tr>
<td>24.99</td>
<td>4.70</td>
</tr>
<tr>
<td>25.00</td>
<td>7.00</td>
</tr>
<tr>
<td>25.01</td>
<td>9.30</td>
</tr>
<tr>
<td>25.10</td>
<td>10.30</td>
</tr>
<tr>
<td>26.00</td>
<td>11.29</td>
</tr>
<tr>
<td>50.00</td>
<td>12.52</td>
</tr>
</tbody>
</table>

Directions:
1. Graph the above data on graph paper.

2. Label where the solution has an acidic pH and where it has a basic pH.

3. Identify where the equivalence point is.

4. What is the pH at the equivalence point?

5. What volume of titrant would have to be added for the pH of the solution to be 5.00?

6. What is the pH of the solution when 15.00mL of titrant has been added?
MODERN MARVELS: ACIDS
VIDEO GUIDE

Name _____________________________ Mods __________ Date ________________

1. The U.S. manufacturer's approximately ________________ tons of acid per year.
2. List some products that are manufactured using acids.

3. ________________ acid is one of the most dangerous acids and is the primary catalyst in the 3,000,000 tons of explosives detonated annually in North America.
4. ________________ is the leading explosive used in civil construction.
5. ________________ is the key ingredient used by the military in explosives.
6. Superficial nitric acid burns begin in approximately ____________ seconds and 3rd degree burns begin in approximately ____________ seconds.
7. C-4 is made of approximately ______% of RDX, which is made from nitric acid.
8. Most of the nitric acid produced goes into the production of ____________ (chemical formula) fertilizer.
9. This fertilizer can also be used as an ________________ for explosives.
10. In 1947, a freighter packed with ammonium nitrate fertilizer exploded in Texas City and killed ____________ people and another 5,000 were injured. This disaster is considered the worst industrial accident in the history of the United States.
11. ________________ acid is stronger than nitric acid and is the leading chemical produced in the United States.
12. Why is sulfuric acid considered a strong acid?

13. Why shouldn't water be added to acid?

14. List some observations when the aluminum foil and sulfuric acid reacted:
15. What happens to sugar when sulfuric acid is added to it?

16. The Mosaic company produces _______________ tons of sulfuric acid per day, which is comparable to the weight 17,000 automobiles.

17. List some uses of sulfuric acid.

18. Describe the process for producing sulfuric acid.

19. Why do your eyes water when cutting onions?

20. How long does it take for acid to dissolve a body?

21. What acid is produced in your stomach to dissolve food?

22. How is gelatin produced?

23. List some products that are produced with gelatin.

24. What type of acid is found in cola?

25. How many tons of vinegar are consumed in a year?
26. ________________ is also known as “mother of vinegar.”

27. ________________ acid is used to make “sugar of lead.”

28. What are the key ingredients (acids) in the electropolishing vats?

29. During electropolishing, acid reacts with chromium to form a protective layer of ________________ that passivates stainless steel keeping it sterile.

30. What catalysts are used in the production of gasoline and jet fuel?

31. Why is sulfuric acid used to recover platinum?

32. What is the name of the acid cocktail used to dissolve precious metals?

33. What acids are found in acid rain?

34. Acid rain has a similar pH to ________________.

35. What is another name for hydrochloric acid?

36. What happens to mustard gas when inhaled?

37. In the Middle Ages, goldsmiths used acid to ________________, one of the earliest known applications of acid etching.

38. More people have died in Yellowstone due to ________________ than from bear attacks.

39. Thermoacidophiles produce ________________ that protect them from acidic conditions.

40. Hyperthermophiles produce an enzyme that is being synthesized to produce clean burning ________________ from corn.