Identifying Acids and Bases

<table>
<thead>
<tr>
<th></th>
<th>Acids</th>
<th>Acid (anhydrides)</th>
<th>Bases</th>
<th>Base (anhydrides)</th>
<th>Salts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contains H⁺ ions as the cation, with and other element as the anion</td>
<td>H₂SO₄</td>
<td>H₂S</td>
<td>Non-metal oxide</td>
<td>P₂O₅</td>
<td>Ca(OH)₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A metal with oxygen</td>
<td>MgF₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ionic compound</td>
<td>Fused from a cation and an anion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Metal and non-metal</td>
<td></td>
</tr>
</tbody>
</table>

Acid/Base Definitions

- **Arrhenius:**
  Acids: Any substance which releases H⁺ ion in water solution.
  Bases: Any substance which releases OH⁻ ion in water solution.

- **Bronsted - Lowry:**
  Acids: Any substance which donates a proton.
  Bases: Any substance which accepts a proton.

- **Lewis:**
  Acids: Any substance which can accept an electron pair.
  Bases: Any substance which can donate an electron pair.

Acid/Base Definitions

- **Hydrogen ion concentration = [H⁺]**
- **Hydroxide ion concentration = [OH⁻]**
- **Pure H₂O – neutral substance –**
  - pH=7 and [H⁺]=[OH⁻]
- **H₂O will self-dissociate**
  - H₂O > H⁺ + OH⁻

  Note: the number of H₂O molecules that will self dissociate is very small; only 2 molecules per a billion, therefore [H₂O] is unchanged.

Acid/Base Definitions

- **Hydrogen ion concentration = [H⁺]**
- **Hydroxide ion concentration = [OH⁻]**
- **Pure H₂O – neutral substance –**
  - pH=7 and [H⁺]=[OH⁻]
- **H₂O will self-dissociate**
  - H₂O > H⁺ + OH⁻
Acid / Base Chemistry
- $K_w$ - is the ion product constant for water
  - $K_w = 1.0 \times 10^{-14} \text{ M}^2$
  - For H$_2$O: $K_w = [1.0 \times 10^{-7} \text{ M}][1.0 \times 10^{-7}\text{M}]

- there is an indirect relationship between [H+] and [OH-]

Acid / Base Chemistry
• Calculate [OH-] if [H+] is 1.0 x $10^{-2}$ M
• $K_w = [H^+] [OH^-]$
• $[OH^-] = \frac{K_w}{[H^+]} = 1.0 \times 10^{-14} \text{ M}^2$
• $[H^+] = 1.0 \times 10^{-2} \text{ M}$
• $[OH^-] = 1.0 \times 10^{-12} \text{ M}$

Acid / Base Chemistry
• Calculate [H+] if [OH-] is 6.5 x $10^{-11}$ M
• $K_w = [H^+] [OH^-]$
• $[H^+] = \frac{K_w}{[OH^-]} = 1.0 \times 10^{-14} \text{ M}^2$
• $[OH^-] = 6.5 \times 10^{-11} \text{ M}$
• $[H^+] = 1.0 \times 10^{-9} \text{ M}$
• [H+] will tell us if a soln is acidic or basic.

Acid / Base Chemistry
• If [H+] = 1.0 x $10^{-9}$M, will the solution be basic or acidic?
• Basic
• Why?
  • because the pH is 9 and this solution contains less [H+] than [OH-]

Acidic solutions
<table>
<thead>
<tr>
<th>pH</th>
<th>[H+]</th>
<th>[OH^-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>$1.0 \times 10^{-6} \text{ M}$</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
</tr>
</tbody>
</table>

Neutral solutions
<table>
<thead>
<tr>
<th>pH</th>
<th>[H+]</th>
<th>[OH^-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
</tr>
</tbody>
</table>

Basic solutions
<table>
<thead>
<tr>
<th>pH</th>
<th>[H+]</th>
<th>[OH^-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-14</td>
<td>$1.0 \times 10^{-8} \text{ M}$</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
</tr>
</tbody>
</table>

Acid / Base Chemistry
<table>
<thead>
<tr>
<th>pH</th>
<th>[H+]</th>
<th>[OH^-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>$1.0 \times 10^{-6} \text{ M}$</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
</tr>
</tbody>
</table>

Neutral solutions
<table>
<thead>
<tr>
<th>pH</th>
<th>[H+]</th>
<th>[OH^-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
</tr>
</tbody>
</table>

Basic solutions
<table>
<thead>
<tr>
<th>pH</th>
<th>[H+]</th>
<th>[OH^-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-14</td>
<td>$1.0 \times 10^{-8} \text{ M}$</td>
<td>$1.0 \times 10^{-7} \text{ M}$</td>
</tr>
</tbody>
</table>
### Acid / Base Chemistry
- If \([\text{OH}^-] = 2.63 \times 10^{-4}\) M, will the solution be basic or acidic or neutral?
  - Why?

### Acid / Base Formulas
- \(\text{pH} = -\log [\text{H}^+]\)
- \(\text{pOH} = -\log [\text{OH}^-]\)
- \(\text{pH} + \text{pOH} = 14\)
- \([\text{H}^+] = \text{antilog} (-\text{pH})\)
- \([\text{OH}^-] = \text{antilog} (-\text{pOH})\)

#### How to use the calculator!!
- Calculate the pH of a solution with \([\text{H}^+] = 0.001\) M. Is this acidic, basic, or neutral?

### Acid / Base Formulas
- Calculate the pH of a solution with \([\text{OH}^-] = 7.9 \times 10^{-3}\) M. Is this acidic, basic, or neutral?
- Calculate the pH of a solution with \([\text{H}^+] = 4.2 \times 10^{-6}\) M. Acidic, basic, or neutral?

#### What is the \([\text{OH}^-]\)?

### Acid / Base Formulas
- A solution with a pH of 9.1 has what \([\text{H}^+]\)?
  - \(-2^\text{nd} \log -9.1\ \text{ENTER}\)
  - What is the \([\text{OH}^-]\)?
  - What is the \(\text{pOH}\)?

### Acids, Bases, and Their Conjugates
- Water is amphoteric – has basic + acidic properties.
- Conjugate Acid: Substances formed in a reaction when a base gains a H⁺
- Conjugate Base: Substances formed in a reaction when an acid donates H⁺

### Acids, Bases, and Their Conjugates
- \(\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-\)
- \(\text{HCl} + \text{H}_2\text{O} \rightarrow \text{---}\)
Acids, Bases, and Their Conjugates

- $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow \text{HCO}_3^- + \text{OH}^-$
- $\text{Ca(OH)}_2 + 2\text{HNO}_3 \rightarrow \text{Ca(NO}_3)_2 + 2\text{HOH}$

Identifying monoprotic, diprotic, and triprotic:

**monoprotic:**
- $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$

**diprotic:**
- $\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^-$
- $\text{HSO}_4^- \rightarrow \text{H}^+ + \text{SO}_4^{2-}$

**triptetic:**
- $\text{H}_3\text{PO}_4 \rightarrow \text{H}^+ + \text{H}_2\text{PO}_4^-$
- $\text{H}_2\text{PO}_4^- \rightarrow \text{H}^+ + \text{HPO}_4^{2-}$
- $\text{HPO}_4^{2-} \rightarrow \text{H}^+ + \text{PO}_4^{3-}$

Strengths of Acids and Bases

- Strong acids and bases will completely dissociate
  - ex. $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$
- The six strong acids - HCl, HBr, HI, H$_2$SO$_4$, HNO$_3$, HClO$_4$
- All others are weak.
- Strong Bases: Groups I and II with OH except Be
- Weak acids and bases slightly dissociate
  - ex. $\text{HClO} \leftrightarrow \text{ClO}^- + \text{H}^+$

Electrolytes and Non-Electrolytes

- **Strong Electrolytes:**
  - Compounds that conduct electricity in aqueous solution
  - Substances that completely dissociate
  - Strong acids and bases
  - Soluble salts
Electrolytes and Non-Electrolytes

**Weak Electrolytes:**
- Slight electron conductivity
- Slight dissociation in aqueous
- Weak acids and bases
- Insoluble salts if in molten state

**Non-Electrolytes:**
- Don’t conduct electricity
- No ions to carry current
- Organic, molecular

---

Examples of Electrolytes and Nonelectrolytes:

- H$_2$SO$_3$
- weak acid/weak elect.
- CsOH
- strong base/strong elect.
- HClO$_4$
- strong acid/strong elect.
- CsH$_3$O$_8$
- nonelectrolyte- covalent, molecular, organic b/c carbon

- Al(OH)$_3$
- weak base/weak electrolyte
- HF
- weak acid/weak electrolyte
- CCl$_4$
- nonelectrolyte- molecular compound
- NaN$_3$
- soluble salt/strong electrolyte
- S$_3$
- acid anhydride/weak electrolyte

---

Neutralization

- Acid + Base $\rightarrow$ Salt + H$_2$O
- Neutralization is found using titration
- Titration: Analytical method used to determine the concentration of acids, bases in a neutralization reaction.

Neutralization Reactions:

**General Equation:**

- Acid + Base $\rightarrow$ Salt + Water

- HCl + NaOH $\rightarrow$ NaCl + H$_2$O

Acid | Base | Salt | Water
Neutralization Reactions:

**Titration**: Analytical method used to determine the concentration of acids and bases in a neutralization reaction.

1. Measured volume of an acid or base with unknown concentration. Put in Erlenmeyer.
2. Add a few drops of indicator to the Erlenmeyer.
3. A measured volume of titrant is delivered into the flask through a buret (base or acid)
4. Concentration of the titrant is known—Standard Solution.
5. Neutralization occurs when indicator is revealed → End Point
6. Equivalence Point
   
   \[ \text{MOL ACID} = \text{MOL BASE} \]

---

**Neutralization practice problems**:  

1. What volume of calcium hydroxide in a 3.0 M solution is needed to neutralize 45.0 mL of 2.6 M perchloric acid?

\[ \text{G: 45 mL Ca(OH)₂ + 2 HClO₄ → 2 HOCl + Ca(ClO₄)₂} \]

\[ \text{2.6 M HClO₄} \times 0.45 \text{ L HClO₄} = 1 \text{ mol Ca(OH)₂} \]

\[ \text{3.0 M Ca(OH)₂} \times 1 \text{ L Ca(OH)₂} \]

\[ \text{U: vol Ca(OH)₂} \]

2. Determine the [Ba(OH)₂] solution if 300.0 mL was titrated to neutrality with 220.5 mL of 6.0 M solution of phosphoric acid?

\[ \text{G: 220.5 mL 3Ba(OH)₂ + 2H₃PO₄ → Ba₃(PO₄)₂ + 6HOH} \]

\[ \text{6.0 M H₃PO₄} \times 0.2205 \text{ L H₃PO₄} = 6 \text{ mol H₃PO₄} \]

\[ \text{300.0 mL Ba(OH)₂} \times 1 \text{ L Ba(OH)₂} \]

\[ \text{U: vol Ba(OH)₂} \]

\[ \text{1.985 mol Ba(OH)₂} \]

\[ \text{0.300L Ba(OH)₂} \]

\[ \text{= 6.62 M Ba(OH)₂} \]