Sec 4.13 – Hydrolysis (notes)

- Reaction between a salt (ion or ions in a salt) and water to produce an acidic or basic solution.

- Net ionic equations for hydrolysis:

  An ion + water → a molecule or ion + H₃O⁺ or OH⁻

SPECTATORS- ions which do NOT hydrolyze (need periodic table and acid table to find these)

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<th>Spectator Cations</th>
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<td>- ClO₄⁻, I⁻, Br⁻, Cl⁻, NO₃⁻</td>
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(HSO₄⁻ is not a spectator – it is amphiprotic – will be dealt with later)

- spectators are eliminated in net ionic equations for hydrolysis!

**Process** – if given salt (dissociate → eliminate → evaluate)

1. Write dissociation equation
2. Eliminate spectators
3. Remaining ions → left side of table – undergo acid hydrolysis is – produce H₃O⁺
   → right side of table – undergo base hydrolysis – produce OH⁻
   → amphiprotic – determine $K_a$ and $K_b$ to find dominant hydrolysis.

**Examples:**

1. Is the salt NaF acidic, basic or neutral in water?

   **Dissociation**: NaF → Na⁺ + F⁻

   Spectator (alkali cation)  Found on right side of acid table- forms a weak base.

   --- so NaF is basic ---

2. Is the salt NH₄NO₃ acidic, basic or neutral in aqueous solution?

   **Dissociation**: NH₄NO₃ → NH₄⁺ + NO₃⁻

   Spectator top 5 on right side of table

   Found on left side of table – forms a weak acid - so NH₄NO₃ is acidic.
3. **Is the salt KCl acidic, basic or neutral?**

Dissociation: $\text{KCl} \rightarrow \text{K}^+ + \text{Cl}^-$  --- since neither ion undergoes hydrolysis, this salt is **NEUTRAL**

4. **Cations Which Hydrolyze**

- **Hydrated cations**
  - metals from center of the periodic table (transition metals) are smaller ions and have larger charges - this attracts $\text{H}_2\text{O}$ molecules

  eg.) $\text{Fe}^{3+}$

  **Hydration:** $\text{Fe}^{3+} + 6\text{H}_2\text{O} \rightarrow \text{Fe(H}_2\text{O)}_6^{3+}$

  This ion acts as a weak acid (see it ~ 13th down on the acid table.)

  The equation for the **hydrolysis** is:

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

3 Common **Hydrated** cations (on left of acid chart):

- iron(III) $\text{Fe}^{3+}$ forms $\text{Fe(H}_2\text{O)}_6^{3+}$
- Chromium(III) $\text{Cr}^{3+}$ forms $\text{Cr(H}_2\text{O)}_6^{3+}$
- Aluminum $\text{Al}^{3+}$ forms $\text{Al(H}_2\text{O)}_6^{3+}$

  Eg.) $\text{AlCl}_3$ is the same as $\text{Al(H}_2\text{O)}_6\text{Cl}_3$

  $\text{NH}_4^+$ **Hydrolysis** equation: $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NH}_3$

5. **Anions which Hydrolyze**

Looking on the **RIGHT** side of the **ACID TABLE**:

- Remember the TOP 5 DO NOT hydrolyze – they are spectators
- $\text{HSO}_4^-$ is amphiprotic
- From $\text{IO}_3^-$ to $\text{PO}_4^{3-}$ under go base hydrolysis
- The BOTTOM 3 - act as STRONG BASES. They undergo 100% hydrolysis to form $\text{OH}^-$ ions

Some examples of **net-ionic hydrolysis equations** for these would be:

$\text{IO}_3^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HIO}_3(aq) + \text{OH}^-(aq)$

$\text{CH}_3\text{COO}^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CH}_3\text{COOH}(aq) + \text{OH}^-(aq)$
Eg.) Determine whether the salt sodium carbonate (Na₂CO₃) is acidic, basic or neutral in aqueous solution.

First dissociate the salt:  \( \text{Na}_2\text{CO}_3 \rightarrow 2\text{Na}^+ + \text{CO}_3^{2-} \)

The net-ionic equation for the hydrolysis taking place in this salt would be:

\( \text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^- \) and the salt would act as a weak base in water.

Remember that “net-ionic” means that any spectator ions have been removed!

Write the net-ionic equation for the hydrolysis taking place in aqueous magnesium sulphate:

\( \text{MgSO}_4 \rightarrow \text{Mg}^{2+} + \text{SO}_4^{2-} \)

\( \text{SO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HSO}_4^- + \text{OH}^- \)

6. Hydrolysis When BOTH Cation and Anion hydrolyze

Eg. Is the salt ammonium nitrite \( \text{NH}_4\text{NO}_2 \) acidic, basic or neutral?

Of course we start out by dissociating:  \( \text{NH}_4\text{NO}_2 \rightarrow \text{NH}_4^+ + \text{NO}_2^- \)

Remember that \( \text{NH}_4^+ \) produces \( \text{H}_3\text{O}^+ \)  
And \( \text{NO}_2^- \) produces \( \text{OH}^- \)

- The \( \text{Ka} \) for \( \text{NH}_4^+ \) tells how much \( \text{H}_3\text{O}^+ \) it produces
- The \( \text{Kb} \) for \( \text{NO}_2^- \) tells how much \( \text{OH}^- \) it produces

The \( \text{Ka} \) for \( \text{NH}_4^+ \) is \( 5.6 \times 10^{-10} \) (look up \( \text{NH}_4^+ \) on the left side of the table and it’s \( \text{Ka} \) is on the right)

The \( \text{Kb} \) for \( \text{NO}_2^- \) must be calculated:  \( \text{Kb (NO}_2^-) = \frac{\text{Kw}}{\text{Ka (HNO}_2^-)} = \frac{1.0 \times 10^{-14}}{4.6 \times 10^{-4}} = 2.2 \times 10^{-11} \)

Since the  \( \text{Ka of NH}_4^+ > \text{Kb of NO}_2^- \) - We can say that this salt is \( \text{ACIDIC} \)

So, in summary:

<table>
<thead>
<tr>
<th>If</th>
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<tbody>
<tr>
<td>( \text{Ka (cation)} &gt; \text{Kb (anion)} )</td>
<td><strong>Acidic</strong></td>
</tr>
<tr>
<td>( \text{Kb (anion)} &gt; \text{Ka (cation)} )</td>
<td><strong>Basic</strong></td>
</tr>
<tr>
<td>( \text{Ka (cation)} = \text{Kb (anion)} )</td>
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</table>

Determine whether the salt \( \text{NH}_4\text{CN} \) (ammonium cyanide) is acidic, basic or neutral.

\( \text{NH}_4\text{CN} \rightarrow \text{NH}_4^{+ (aq)} + \text{CN}^{- (aq)} \)

\( \text{Kb of CN}^- = \frac{1.0 \times 10^{-14}}{4.9 \times 10^{-10}} = 2.0 \times 10^{-5} \)

so since \( \text{Kb of CN}^- > \text{Ka of NH}_4^+ \) this solution is **basic**.
7. **Hydrolysis of Amphiprotic Anions**

Amphiprotic Anions \( \rightarrow \) Start with “H” and have a “-” charge.

Eg. \( \text{HSO}_4^- \), \( \text{HSO}_3^- \), \( \text{H}_2\text{PO}_4^- \), \( \text{HPO}_4^{2-} \), \( \text{HS}^- \) etc.

Amphiprotic Anions hydrolyze as *acids* to produce \( \text{H}_3\text{O}^+ \) but they also hydrolyze as *bases* to produce \( \text{OH}^- \). So, how can we tell whether they are acidic or basic or neutral? We need to determine the predominant hydrolysis.

Find the Ka of the ion. (Look for ion on the LEFT SIDE of the acid table, read Ka on the right.)

Find the Kb of the ion. (Look for the ion on the RIGHT SIDE of the table and use:

\[
\text{Kb} = \frac{\text{Kw}}{\text{Ka (conj. Acid)}}
\]

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Eg. Find the predominant hydrolysis of the hydrogen carbonate ion (\( \text{HCO}_3^- \)) and write the net-ionic equation for it.

To find the Ka of \( \text{HCO}_3^- \), look it up on the **left** side of table. It’s \( \text{Ka} = 5.6 \times 10^{-11} \)

To find the Kb of \( \text{HCO}_3^- \), look it up on the **right** side of table.

( *It’s conjugate acid is \( \text{H}_2\text{CO}_3 \) and the Ka of \( \text{H}_2\text{CO}_3 = 4.3 \times 10^{-7} \)*)

So we calculate the Kb of \( \text{HCO}_3^- \) using:

\[
\text{Kb(\text{HCO}_3^-)} = \frac{\text{Kw}}{\text{Ka(\text{H}_2\text{CO}_3)}} = \frac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} = 2.3 \times 10^{-8}
\]

So, since \( \text{Kb} > \text{Ka} \), the ion \( \text{HCO}_3^- \) predominantly undergoes **BASE HYDROLYSIS**.

And the net-ionic equation for the **predominant hydrolysis** is:

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

Read p. 144 – 147 in SW & Do Ex. 69 (a-f) and Ex. 70 (a – j), 71, 72 & 73 on p. 148.

**Quiz** 4.11 – 4.12 – 4.13

**Thurs.**

**Test** 4.1 – 4.13

** Tues.**
Sec 4.13 – Hydrolysis
(student notes)

- Net ionic equations for hydrolysis:

**SPECTATORS**-

(need periodic table and acid table to find these)

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(HSO₄⁻ is not a spectator – it is amphiprotic – will be dealt with later)

- __________________________ in net ionic equations for hydrolysis!

**Process** – if given salt (______________ → ______________ → ______________)

1. Write dissociation equation
2. Eliminate **spectators**
3. Remaining ions → **left** side of table – undergo acid hydrolysis is – produce H₃O⁺ → **right** side of table – undergo base hydrolysis – produce OH⁻ → **amphiprotic** – determine Kₐ and Kₐ to find dominant hydrolysis.

**Examples:**

1. Is the salt NaF acidic, basic or neutral in water?

Dissociation: NaF $\rightarrow$ Na⁺ + F⁻

Found on **right** side of acid table- forms a weak **base**.

--- so NaF is _________ ---

2. Is the salt NH₄ NO₃ acidic, basic or neutral in aqueous solution?

Dissociation: NH₄NO₃ $\rightarrow$ NH₄⁺ + NO₃⁻

Found on **left** side of table – forms a ______________ - so NH₄NO₃ is __________.
3. Is the salt KCl acidic, basic or neutral?

Dissociation: KCl $\rightarrow$ $K^+$ + $Cl^-$ --- since neither ion undergoes hydrolysis, this salt is ___________.

4. Cations Which Hydrolyze

- Hydrated cations
  - metals from center of the periodic table (transition metals) are smaller ions and have larger charges - this attracts H$_2$O molecules

  eg.) Fe$^{3+}$
  
  Hydration: Fe$^{3+}$ + 6H$_2$O $\rightarrow$ Fe(H$_2$O)$_6^{3+}$

  This ion acts as a weak acid (see it ~ 13th down on the acid table.)

  The equation for the hydrolysis is:

  \[
  \text{Fe(H}_2\text{O)}_6^{3+} (aq) + H_2O(l) \rightleftharpoons H_3O^+ (aq) + \text{Fe(H}_2\text{O)}_5(OH)^{2+} (aq)
  \]

  3 Common Hydrated cations (on left of acid chart):

  - Iron(III) Fe$^{3+}$ forms Fe(H$_2$O)$_6^{3+}$
  - Chromium(III) Cr$^{3+}$ forms Cr(H$_2$O)$_6^{3+}$
  - Aluminum Al$^{3+}$ forms Al(H$_2$O)$_6^{3+}$

  Act as weak acids.

  Eg.) AlCl$_3$ is the same as Al(H$_2$O)$_6$Cl$_3$

  
\[
\text{NH}_4^+ \quad \text{Hydrolysis equation: NH}_4^+ (aq) + H_2O(l) \rightleftharpoons H_3O^+ (aq) + \text{NH}_3(aq)
\]

5. Anions which Hydrolyze

Looking on the RIGHT side of the ACID TABLE:

- Remember the TOP 5 DO NOT hydrolyze – they are spectators
- HSO$_4^-$ is amphiprotic
- From IO$_3^-$ to PO$_4^{3-}$ under go base hydrolysis
- The BOTTOM 3 - act as STRONG BASES. They undergo 100% hydrolysis to form OH$^-$ ions

Some examples of net-ionic hydrolysis equations for these would be:

\[
\text{IO}_3^-(aq) + H_2O(l) \rightleftharpoons \text{__________________________}
\]

\[
\text{CH}_3\text{COO}^- (aq) + H_2O(l) \rightleftharpoons \text{__________________________}
\]
Eg.) Determine whether the salt sodium carbonate (Na₂CO₃) is acidic, basic or neutral in aqueous solution.

First dissociate the salt: \( \text{Na}_2\text{CO}_3 \rightarrow \) __________________________

The net-ionic equation for the hydrolysis-taking place in this salt would be:

\[
\text{CO}_3^{2-} \text{(aq)} + \text{H}_2\text{O} \leftrightarrow \text{________________________} \quad \text{and the salt would act as a weak base in water.}
\]

Remember that “net-ionic” means that any spectator ions have been removed!

Write the net-ionic equation for the hydrolysis taking place in aqueous magnesium sulphate:

6. Hydrolysis When BOTH Cation and Anion hydrolyze

Is the salt ammonium nitrite \( \text{NH}_4\text{NO}_2 \) acidic, basic or neutral?

Start out by dissociating: \( \text{NH}_4\text{NO}_2 \rightarrow \) __________________________

Remember that \( \text{NH}_4^+ \) produces \( \text{H}_3\text{O}^+ \)

\( \text{And NO}_2^- \) produces \( \text{OH}^- \)

- The Ka for \( \text{NH}_4^+ \) tells how much \( \text{H}_3\text{O}^+ \) it produces
- The Kb for \( \text{NO}_2^- \) tells how much \( \text{OH}^- \) it produces

The Ka for \( \text{NH}_4^+ \) is ____________(look up \( \text{NH}_4^+ \) on the left side of the table and it’s Ka is on the right)

The Kb for \( \text{NO}_2^- \) must be calculated: \( \text{Kb} \text{ (NO}_2^-) = \left( \frac{\text{Kw}}{\text{Ka (HNO}_2^-)} \right) = \) ____________

Since the \( \text{Ka of NH}_4^+ > \text{Kb of NO}_2^- \) - We can say that this salt is _______________

So, in summary:

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Determine whether the salt \( \text{NH}_4\text{CN} \) (ammonium cyanide) is acidic, basic or neutral.
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Amphiprotic Anions → Start with “H” and have a “-“ charge.

Ex. $\text{HSO}_4^-$, $\text{HSO}_3^-$, $\text{H}_2\text{PO}_4^-$, $\text{HPO}_4^{2-}$, $\text{HS}^-$ etc.

Amphiprotic Anions hydrolyze as *acids* to produce $\text{H}_3\text{O}^+$ but they also hydrolyze as *bases* to produce $\text{OH}^-$. So, how can we tell whether they are acidic or basic or neutral? We need to determine the *predominant* hydrolysis.

Find the $\text{Ka}$ of the ion. (Look for ion on the LEFT SIDE of the acid table, read $\text{Ka}$ on the right.)

Find the $\text{Kb}$ of the ion. (Look for the ion on the RIGHT SIDE of the table and use:

$$\text{Kb} = \frac{\text{Kw}}{\text{Ka (conj. acid)}}$$

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Ex. Find the predominant hydrolysis of the hydrogen carbonate ion ($\text{HCO}_3^-$) and write the net-ionic equation for it.

Read p. 144 – 147 in SW & Do Ex. 69 (a-f) and Ex. 70, 71, 72 & 73 on p. 148.
Sec 4.13 – Hydrolysis

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- Net ionic equations for hydrolysis:

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SPECTATORS- ions which do NOT hydrolyze (need periodic table and acid table to find these)

**Spectator Cations**

- **Group 1** (Alkali Metal ions) eg. $Li^+$, $Na^+$, $K^+$, $Rb^+$, $Cs^+$, $Fr^+$
- **Group 2** (Alkaline Earth ions) eg. $Be^+$, $Mg^{2+}$, $Ca^{2+}$, $Ba^{2+}$, $Sr^{2+}$, $Ra^{2+}$

**Spectator Anions** (look on acid table)

- **Top 5 ions on the right** side of table.
- $ClO_4^-$ $I^-$ $Br^-$ $Cl^-$ $NO_3^-$

(HSO$_4^-$ is not a spectator – it is amphiprotic – will be dealt with later)

- **spectators are eliminated** in net ionic equations for hydrolysis!

**Process** – if given salt (dissociate $\rightarrow$ eliminate $\rightarrow$ evaluate)

1. Write dissociation equation
2. Eliminate spectators
3. Remaining ions
   $\rightarrow$ **left** side of table – undergo acid hydrolysis is – produce $H_3O^+$
   $\rightarrow$ **right** side of table – undergo base hydrolysis – produce $OH^-$
   $\rightarrow$ **amphiprotic** – determine $K_a$ and $K_b$ to find dominant hydrolysis.
**Examples:**

1. **Is the salt NaF acidic, basic or neutral in water?**

   **Dissociation:** \( \text{NaF} \rightarrow \text{Na}^+ + \text{F}^- \)

   **Spectator** (alkali cation) Found on **right** side of acid table - forms a **weak base.** --- so NaF is **basic.** ---

2. **Is the salt NH\(_4\)NO\(_3\) acidic, basic or neutral in aqueous solution?**

   **Dissociation:** \( \text{NH}_4\text{NO}_3 \rightarrow \text{NH}_4^+ + \text{NO}_3^- \)

   Found on **left** side of table – forms a weak **acid** - so NH\(_4\)NO\(_3\) is **acidic.**

3. **Is the salt KCl acidic, basic or neutral?**

   **Dissociation:** \( \text{KCl} \rightarrow \text{K}^+ + \text{Cl}^- \) --- since **neither** ion undergoes hydrolysis, this salt is **NEUTRAL.**

4. **Cations Which Hydrolyze**

   - **Hydrated cations**

     metals from center of the periodic table (transition metals) are smaller ions and have larger charges - this attracts H\(_2\)O molecules

     eg.) Fe\(^{3+}\)

     **Hydration:** \(\text{Fe}^{3+} + 6\text{H}_2\text{O} \rightarrow \text{Fe(H}_2\text{O)}_6^{3+}\)

     This ion acts as a **weak acid** (see it ~ 13\(^{th}\) down on the acid table.)

     The equation for the **hydrolysis** is:

     \[
     \text{Fe(H}_2\text{O)}_6^{3+}\text{(aq)} + \text{H}_2\text{O}_\text{(l)} \rightleftharpoons \text{H}_3\text{O}^+\text{(aq)} + \text{Fe(H}_2\text{O)}_5\text{(OH)}^{2+}\text{(aq)}
     \]
3 Common **Hydrated** cations (on *left* of acid chart):

Iron(III) $\text{Fe}^{3+}$ forms $\text{Fe(H}_2\text{O)}_6^{3+}$
Chromium(III) $\text{Cr}^{3+}$ forms $\text{Cr(H}_2\text{O)}_6^{3+}$
Aluminum $\text{Al}^{3+}$ forms $\text{Al(H}_2\text{O)}_6^{3+}$  
\[ \text{Act as weak acids.} \]

Eg.) $\text{AlCl}_3$ is the same as $\text{Al(H}_2\text{O)}_6\text{Cl}_3$

$\text{NH}_4^+$ **Hydrolysis** equation: $\text{NH}_4^+ (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}_3\text{O}^+ (\text{aq}) + \text{NH}_3(\text{aq})$

### 5. Anions which Hydrolyze

Looking on the **RIGHT** side of the **ACID TABLE**:

- Remember the TOP 5 DO NOT hydrolyze – they are spectators
- $\text{HSO}_4^-$ is amphiprotic
- From $\text{IO}_3^-$ to $\text{PO}_4^{3-}$ undergo base hydrolysis
- The BOTTOM 3 - act as STRONG BASES. They undergo 100% hydrolysis to form $\text{OH}^-$ ions

Some examples of **net-ionic hydrolysis equations** for these would be:

\[
\begin{align*}
\text{IO}_3^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) & \rightleftharpoons \text{HIO}_3 (\text{aq}) + \text{OH}^- (\text{aq}) \\
\text{CH}_3\text{COO}^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) & \rightleftharpoons \text{CH}_3\text{COOH} (\text{aq}) + \text{OH}^- (\text{aq})
\end{align*}
\]

Eg.) Determine whether the salt sodium carbonate ($\text{Na}_2\text{CO}_3$) is acidic, basic or neutral in aqueous solution.

First dissociate the salt: $\text{Na}_2\text{CO}_3 \rightarrow 2 \text{Na}^+ (\text{aq}) + \text{CO}_3^{2-} (\text{aq})$

The **net-ionic equation** for the **hydrolysis** taking place in this salt would be:

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

and the salt would act as a *weak base* in water.

Remember that “net-ionic” means that any spectator ions have been removed!
Write the **net-ionic equation** for the **hydrolysis** taking place in aqueous magnesium sulphate:

\[
\text{MgSO}_4 (aq) \rightleftharpoons \text{Mg}^{2+} + \text{SO}_4^{2-} \\
\text{SO}_4^{2-} (aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HSO}_4^-(aq) + \text{OH}^-(aq)
\]

6. **Hydrolysis When BOTH Cation and Anion hydrolyze**

Ex. Is the salt ammonium nitrite \( \text{NH}_4\text{NO}_2 \) acidic, basic or neutral?

Of course we start out by **dissociating**: \( \text{NH}_4\text{NO}_2 \rightarrow \text{NH}_4^{+}(aq) + \text{NO}_2^{-}(aq) \)

Remember that \( \text{NH}_4^{+} \) produces \( \text{H}_3\text{O}^+ \) \( (\text{NH}_4^{+} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NH}_3) \)

And \( \text{NO}_2^{-} \) produces \( \text{OH}^- \) \( (\text{NO}_2^{-} + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-) \)

- The Ka for \( \text{NH}_4^{+} \) tells how much \( \text{H}_3\text{O}^+ \) it produces
- The Kb for \( \text{NO}_2^{-} \) tells how much \( \text{OH}^- \) it produces

The Ka for \( \text{NH}_4^{+} \) is \( 5.6 \times 10^{-10} \) (look up \( \text{NH}_4^{+} \) on the left side of the table and it’s Ka is on the right)

The Kb for \( \text{NO}_2^{-} \) must be calculated: \( \text{Kb} (\text{NO}_2^-) = \frac{\text{K}_w}{\text{Ka} (\text{HNO}_2)} = \frac{1.0 \times 10^{-14}}{4.6 \times 10^{-4}} = 2.2 \times 10^{-11} \)

Since the Ka of \( \text{NH}_4^{+} \) > Kb of \( \text{NO}_2^{-} \) - We can say that this salt is **ACIDIC**

So, in summary:

<table>
<thead>
<tr>
<th>If</th>
<th>Then the salt is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ka (cation) &gt; Kb (anion)</td>
<td><strong>Acidic</strong></td>
</tr>
<tr>
<td>Kb (anion) &gt; Ka (cation)</td>
<td><strong>Basic</strong></td>
</tr>
<tr>
<td>Ka (cation) = Kb (anion)</td>
<td><strong>Neutral</strong></td>
</tr>
</tbody>
</table>
Determine whether the salt NH$_4$CN (ammonium cyanide) is acidic, basic or neutral.

\[ \text{NH}_4\text{CN} \rightarrow \text{NH}_4^+ \text{(aq)} + \text{CN}^- \text{(aq)} \]

Ka of NH$_4^+$ = $5.6 \times 10^{-10}$

Kb of CN$^-$ = $\frac{1.0 \times 10^{-14}}{4.9 \times 10^{-10}} = 2.0 \times 10^{-5}$

so since Kb of CN$^-$ > Ka of NH$_4^+$ this solution is **basic**.

7. **Hydrolysis of Amphiprotic Anions**

Amphiprotic Anions $\rightarrow$ Start with “H” and have a “-“ charge.

Eg. HSO$_4^-$, HSO$_3^-$, H$_2$PO$_4^-$, HPO$_4^{2-}$, HS$^-$ etc.

Amphiprotic Anions hydrolyze as *acids* to produce H$_3$O$^+$ but they also hydrolyze as *bases* to produce OH$^-$. So, how can we tell whether they are acidic or basic or neutral? We need to determine the **predominant** hydrolysis.

- Find the Ka of the ion. (Look for ion on the LEFT SIDE of the acid table, read Ka on the right.)

- Find the Kb of the ion. (Look for the ion on the RIGHT SIDE of the table and use: $\text{Kb} = \frac{\text{Kw}}{\text{Ka(conj. Acid)}}$)

<table>
<thead>
<tr>
<th>If: Ka (the ion) &gt; Kb (the ion)</th>
<th>Then the predominant hydrolysis is:</th>
<th>And, in aqueous solution, the ion:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACID HYDROLYSIS</strong></td>
<td>Acts as an Acid</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>If: Kb (the ion) &gt; Ka (the ion)</th>
<th>Then the predominant hydrolysis is:</th>
<th>And, in aqueous solution, the ion:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BASE HYDROLYSIS</strong></td>
<td>Acts as a Base</td>
<td></td>
</tr>
</tbody>
</table>
Eg. Find the predominant hydrolysis of the hydrogen carbonate ion (HCO$_3^-$) and write the net-ionic equation for it.

To find the Ka of HCO$_3^-$, look it up on the left side of table. 
It’s Ka = 5.6 x 10$^{-11}$

To find the Kb of HCO$_3^-$, look it up of the right side of table.

( It’s conjugate acid is H$_2$CO$_3$ and the Ka of H$_2$CO$_3$ = 4.3 x 10$^{-7}$ )

So we calculate the Kb of HCO$_3^-$ using: \[ \text{Kb(HCO}_3^-) = \frac{\text{Kw}}{\text{Ka(H}_2\text{CO}_3)} = \frac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} \]
= 2.3 x 10$^{-8}$

So, since Kb > Ka, the ion HCO$_3^-$ predominantly undergoes BASE HYDROLYSIS.

And the net-ionic equation for the predominant hydrolysis is:

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

Read p. 144 – 147, Do Ex. 69 (a-f) and Ex. 70, 71, 72 & 73 on p. 148.