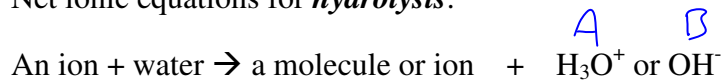


Sec 4.13 – Hydrolysis (notes)

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

- Net ionic equations for *hydrolysis*:



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^{2+} , Mg^{2+} , Ca^{2+} , Ba^{2+} , Sr^{2+} , Ra^{2+}

Spectator Anions (look on acid table)

Conjugate bases of strong acids.

- **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 : $\text{NaF} \rightarrow \overset{\text{Spectator}}{\cancel{\text{Na}^+}} + \text{F}^-$
 (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: $\text{NH}_4\text{NO}_3 \rightarrow \text{NH}_4^+ + \overset{\text{Spectator top 5 on right side of table}}{\cancel{\text{NO}_3^-}}$
 Found on **left** side of table – forms a weak **acid** - so **NH₄NO₃** is **acidic**.

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

SA
HCl

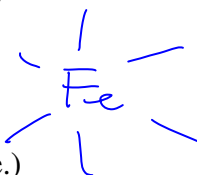
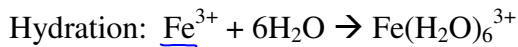
Dissociation: $KCl \rightarrow K^+ + Cl^-$ --- since **neither** ion undergoes hydrolysis, this salt is **NEUTRAL**.

4. Cations Which Hydrolyze

- Hydrated cations

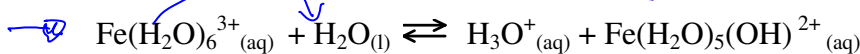
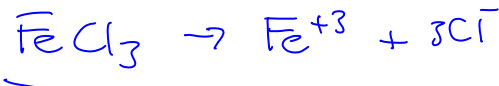
- i. metals from *center* of the periodic table (transition metals) are *smaller* ions and have *larger charges* - this attracts H₂O molecules

eg.) Fe³⁺



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

The equation for the hydrolysis is:



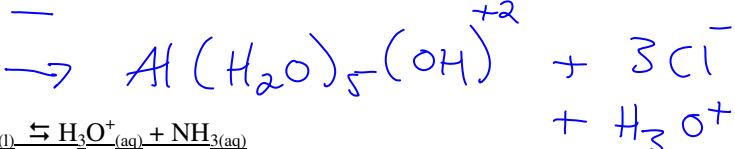
on your chart

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

- iron(III) Fe³⁺ forms Fe(H₂O)₆³⁺
- Chromium(III) Cr³⁺ forms Cr(H₂O)₆³⁺
- Aluminum Al³⁺ forms Al(H₂O)₆³⁺

} Act as **weak acids**.

Eg.) AlCl₃ is the same as Al(H₂O)₆Cl₃



NH₄⁺ Hydrolysis equation: NH₄⁺(aq) + H₂O(l) ⇌ H₃O⁺(aq) + NH₃(aq)

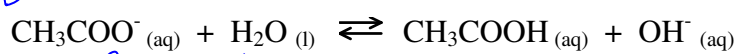
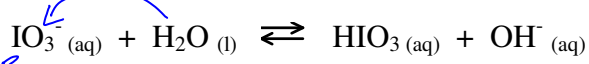
5. Anions which Hydrolyze

(←)

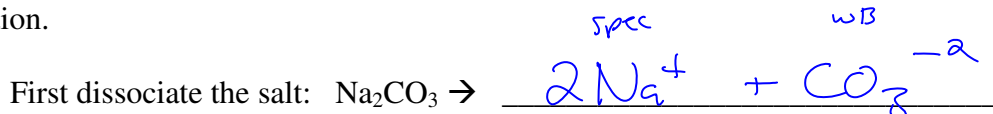
Looking on the **RIGHT** side of the **ACID TABLE**:

- Remember the TOP 5 DO NOT hydrolyze – they are spectators
- HSO₄⁻ is amphiprotic
- From IO₃⁻ to PO₄³⁻ under go base hydrolysis
- The BOTTOM 3 - act as STRONG BASES. They undergo 100% hydrolysis to form OH⁻ ions

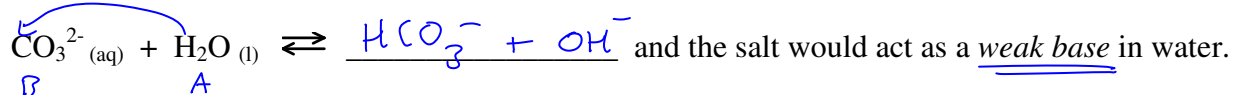
Some examples of net-ionic hydrolysis equations for these would be:



Eg.) Determine whether the salt sodium carbonate (Na_2CO_3) is acidic, basic or neutral in aqueous solution.

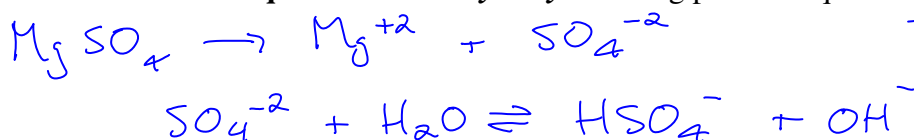


The **net-ionic equation** for the **hydrolysis** taking place in this salt would be:



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

Eg. Is the salt ammonium nitrite NH_4NO_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 NH_4^+ produces H_3O^+ ($\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$) (equation 1)

And NO_2^- produces OH^- ($\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-$) (equation 2)

- The K_a for NH_4^+ tells how much H_3O^+ it produces
- The K_b for NO_2^- tells how much OH^- it produces

The K_a for NH_4^+ is 5.6×10^{-10} (look up NH_4^+ on the left side of the table and its K_a is on the right)

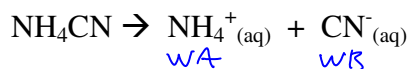
The K_b for NO_2^- must be calculated: $K_b(\text{NO}_2^-) = \frac{K_w}{K_a(\text{HNO}_2)} = \frac{1.0 \times 10^{-14}}{4.6 \times 10^{-4}} = 2.2 \times 10^{-11}$

Since the K_a of $\text{NH}_4^+ > K_b$ of NO_2^- - We can say that this salt is **ACIDIC**

So, in summary:

If	Then the salt is:
$K_a(\text{cation}) > K_b(\text{anion})$	Acidic
$K_b(\text{anion}) > K_a(\text{cation})$	Basic
$K_a(\text{cation}) = K_b(\text{anion})$	Neutral

Determine whether the salt NH_4CN (ammonium cyanide) is acidic, basic or neutral.



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

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

so since K_b of $\text{CN}^- > K_a$ of NH_4^+ this solution is **basic**.

net ionic eq.



7. Hydrolysis of Amphiprotic Anions

Amphiprotic Anions → Start with “H” and have a “-“ charge.

Eg. HSO_4^- , HSO_3^- , H_2PO_4^- , HPO_4^{2-} , HS^- etc.

Amphiprotic Anions hydrolyze as *acids* to produce H_3O^+ 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 K_a of the ion. (Look for ion on the LEFT SIDE of the acid table, read K_a on the right.)

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

$$K_b = K_w / K_a(\text{conj. Acid})$$

If	Then the predominant hydrolysis is:	And, in aqueous solution, the ion:
$K_a(\text{the ion}) > K_b(\text{the ion})$	ACID HYDROLYSIS	Acts as an Acid
$K_b(\text{the ion}) > K_a(\text{the ion})$	BASE HYDROLYSIS	Acts as a Base

Eg. Find the predominant hydrolysis of the hydrogen carbonate ion (HCO_3^-) and write the net-ionic equation for it.

To find the K_a of HCO_3^- , look it up on the **left** side of table. It's $K_a = 5.6 \times 10^{-11}$

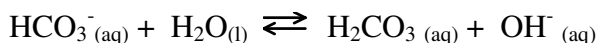
To find the K_b of HCO_3^- , look it up of the **right** side of table.

(It's conjugate acid is H_2CO_3 and the K_a of $\text{H}_2\text{CO}_3 = 4.3 \times 10^{-7}$)

So we calculate the K_b of HCO_3^- using: $K_b(\text{HCO}_3^-) = \frac{K_w}{K_a(\text{H}_2\text{CO}_3)} = \frac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} = 2.3 \times 10^{-8}$

So, since $K_b > K_a$, the ion HCO_3^- predominantly undergoes **BASE HYDROLYSIS**.

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



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
Thursday ?

Test 4.1 – 4.13 Tuesday

Sec 4.13 – Hydrolysis (student notes)

-
- Net ionic equations for *hydrolysis*:

SPECTATORS-

(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^{2+} , Mg^{2+} , Ca^{2+} , Ba^{2+} , Sr^{2+} , Ra^{2+}

Spectator Anions (look on acid table)

- Conjugate bases of strong acids.
- **Top 5 ions on the right** side of table.
- ClO_4^- I^- Br^- Cl^- NO_3^-

(HSO_4^- is not a spectator – it is amphoteric – will be dealt with later)

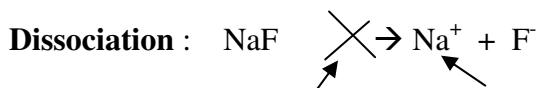
- _____ in net ionic equations for hydrolysis!

Process – if given salt (_____ \rightarrow _____ \rightarrow _____)

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 **amphoteric** – determine K_a and K_b to find *dominant* hydrolysis.

Examples:

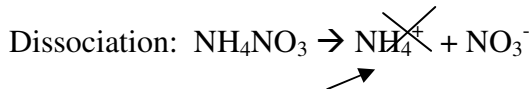
1. Is the salt NaF acidic, basic or neutral in water?



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

--- so NaF is _____ ---

2. Is the salt NH_4NO_3 acidic, basic or neutral in aqueous solution?



Found on **left** side of table – forms a _____ - so NH_4NO_3 is _____.

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

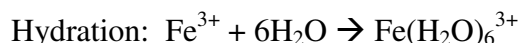
Dissociation: $\text{KCl} \rightarrow \text{K}^+ + \text{Cl}^-$ --- since **neither** ion undergoes hydrolysis, this salt is _____.

4. Cations Which Hydrolyze

- Hydrated cations

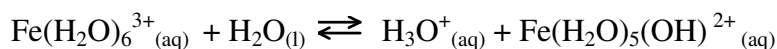
- metals from *center* of the periodic table (transition metals) are *smaller* ions and have *larger charges* - this attracts H_2O molecules

eg.) Fe^{3+}

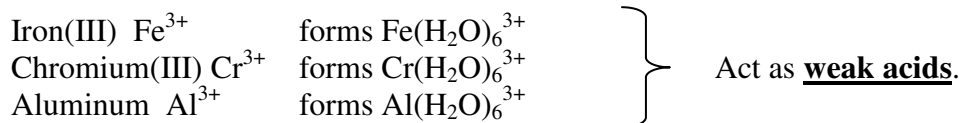


This ion acts as a weak acid (see it ~ 13th down on the acid table.)

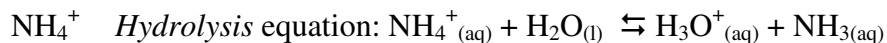
The equation for the **hydrolysis** is:



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



Eg.) AlCl_3 is the same as $\text{Al}(\text{H}_2\text{O})_6\text{Cl}_3$

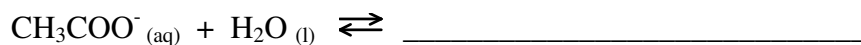
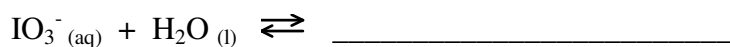


5. Anions which Hydrolyze

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

- Remember the TOP 5 DO NOT hydrolyze – they are spectators
- HSO_4^- is amphoteric
- 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:



Eg.) Determine whether the salt sodium carbonate (Na_2CO_3) 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:

$\text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons$ _____ 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 NH_4NO_2 acidic, basic or neutral?

Start out by *dissociating*: $\text{NH}_4\text{NO}_2 \rightarrow$ _____

Remember that NH_4^+ produces H_3O^+ ($\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NH}_3$) (equation 1)

And NO_2^- produces OH^- ($\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-$) (equation 2)

- The K_a for NH_4^+ tells how much H_3O^+ it produces
- The K_b for NO_2^- tells how much OH^- it produces

The K_a for NH_4^+ is _____ (look up NH_4^+ on the left side of the table and its K_a is on the right)

The K_b for NO_2^- must be calculated: $K_b(\text{NO}_2^-) = \frac{K_w}{K_a(\text{HNO}_2)} =$ _____

Since the K_a of $\text{NH}_4^+ > K_b$ of NO_2^- - We can say that this salt is _____

So, in summary:

If	Then the salt is:
Ka (cation) > Kb (anion)	<i>Acidic</i>
Kb (anion) > Ka (cation)	<i>Basic</i>
Ka (cation) = Kb (anion)	<i>Neutral</i>

Determine whether the salt NH_4CN (ammonium cyanide) is acidic, basic or neutral.

7. Hydrolysis of Amphoteric Anions

Amphoteric Anions → Start with “H” and have a “-“ charge.

Ex. HSO_4^- , HSO_3^- , H_2PO_4^- HPO_4^{2-} HS^- etc.

Amphoteric Anions hydrolyze as *acids* to produce H_3O^+ 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 K_a of the ion. (Look for ion on the LEFT SIDE of the acid table, read K_a on the right.)

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

$$K_b = K_w / K_a(\text{conj. acid})$$

If	Then the predominant hydrolysis is:	And, in aqueous solution, the ion:
$K_a(\text{the ion}) > K_b(\text{the ion})$	<i>ACID HYDROLYSIS</i>	<i>Acts as an Acid</i>
$K_b(\text{the ion}) > K_a(\text{the ion})$	<i>BASE HYDROLYSIS</i>	<i>Acts as a Base</i>

Ex. Find the predominant hydrolysis of the hydrogen carbonate ion (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

- 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 \rightarrow a molecule or ion + H_3O^+ or OH^-

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)

Conjugate bases of strong acids.

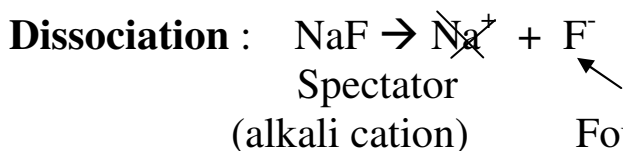
- **Top 5 ions on the right** side of table.
- ClO_4^- I^- Br^- Cl^- NO_3^-

(HSO_4^- is not a spectator – it is amphiprotic – will be dealt with later)

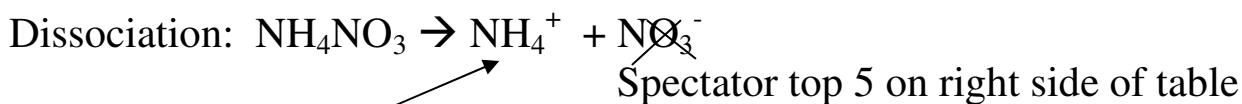
- spectators are eliminated in net ionic equations for hydrolysis!

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

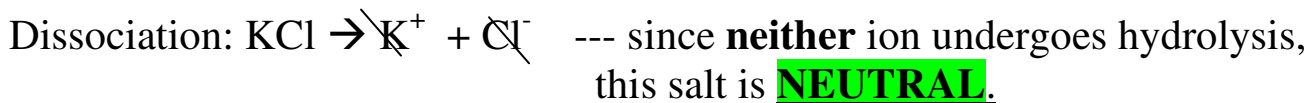
1. Write **dissociation** equation
2. Eliminate **spectators**
3. Remaining ions
 - \rightarrow left side of table – undergo **acid** hydrolysis is – produce H_3O^+
 - \rightarrow right side of table – undergo **base** hydrolysis – produce OH^-
 - \rightarrow **amphiprotic** – determine K_a and K_b to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

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

Found on **right** side of acid table- forms a weak **base**. --- so NaF is **basic** ---

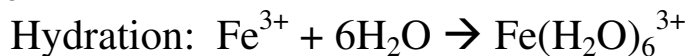
2. Is the salt NH₄NO₃ acidic, basic or neutral in aqueous solution?

Found on **left** side of table – forms a weak **acid**
 - so NH₄NO₃ is **acidic**.

3. Is the salt KCl acidic, basic or neutral?**4. Cations Which Hydrolyze****- Hydrated cations**

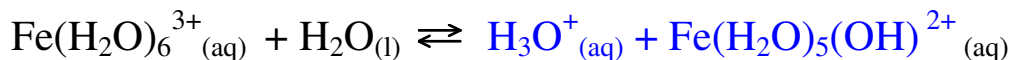
metals from *center* of the periodic table (transition metals) are *smaller* ions and have *larger charges* - this attracts H₂O molecules

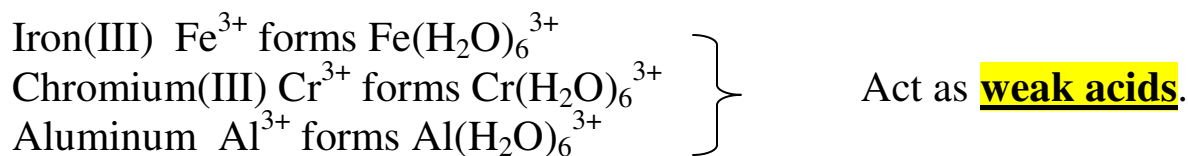
eg.) Fe³⁺



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

The equation for the **hydrolysis** is:



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

Eg.) AlCl_3 is the same as $\text{Al}(\text{H}_2\text{O})_6\text{Cl}_3$

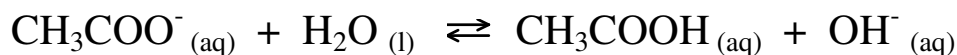
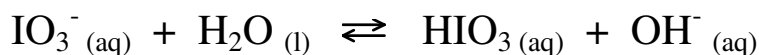
NH_4^+ *Hydrolysis* equation: $\text{NH}_4^+_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \rightleftharpoons \text{H}_3\text{O}^+_{(\text{aq})} + \text{NH}_{3(\text{aq})}$

5. Anions which Hydrolyze

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

- Remember the TOP 5 DO NOT hydrolyze – they are spectators
- 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

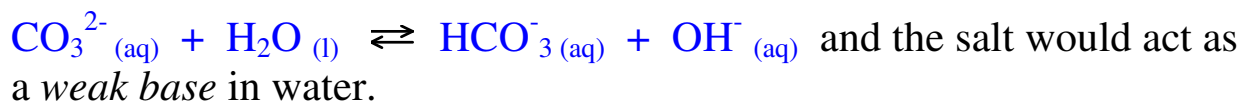
Some examples of net-ionic hydrolysis equations for these would be:



Eg.) Determine whether the salt sodium carbonate (Na_2CO_3) is acidic, basic or neutral in aqueous solution.

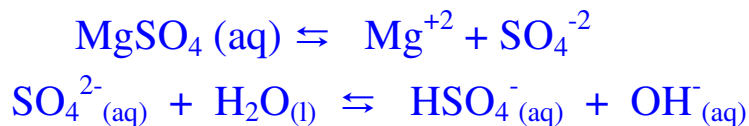


The net-ionic equation for the *hydrolysis* taking place in this salt would be:



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

Ex. Is the salt ammonium nitrite NH_4NO_2 acidic, basic or neutral?

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

Remember that NH_4^{+} produces H_3O^{+} ($\text{NH}_4^{+} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^{+} + \text{NH}_3$)

And NO_2^{-} produces OH^{-} ($\text{NO}_2^{-} + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^{-}$)

- The K_a for NH_4^{+} tells how much H_3O^{+} it produces
- The K_b for NO_2^{-} tells how much OH^{-} it produces

The K_a for NH_4^{+} is 5.6×10^{-10} (look up NH_4^{+} on the left side of the table and it's K_a is on the right)

The K_b for NO_2^{-} must be calculated: $K_b (\text{NO}_2) = \frac{K_w}{K_a (\text{HNO}_2)} = \frac{1.0 \times 10^{-14}}{4.6 \times 10^{-4}} = 2.2 \times 10^{-11}$

Since the K_a of $\text{NH}_4^{+} > K_b$ of NO_2^{-} - We can say that this salt is **ACIDIC**

So, in summary:

If	Then the salt is:
$K_a (\text{cation}) > K_b (\text{anion})$	<i>Acidic</i>
$K_b (\text{anion}) > K_a (\text{cation})$	<i>Basic</i>
$K_a (\text{cation}) = K_b (\text{anion})$	<i>Neutral</i>

Determine whether the salt NH_4CN (ammonium cyanide) is acidic, basic or neutral.



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

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

so since $K_b \text{ of } \text{CN}^- > K_a \text{ of } \text{NH}_4^+$ 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_2PO_4^- , HPO_4^{2-} , HS^- etc.

Amphiprotic Anions hydrolyze as *acids* to produce H_3O^+ 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 K_a of the ion. (Look for ion on the LEFT SIDE of the acid table, read K_a on the right.)
- Find the K_b of the ion. (Look for the ion on the RIGHT SIDE of the table and use: $K_b = K_w / K_a(\text{conj. Acid})$)

If	Then the predominant hydrolysis is:	And, in aqueous solution, the ion:
$K_a \text{ (the ion)} > K_b \text{ (the ion)}$	<i>ACID HYDROLYSIS</i>	<i>Acts as an Acid</i>
$K_b \text{ (the ion)} > K_a \text{ (the ion)}$	<i>BASE HYDROLYSIS</i>	<i>Acts as a Base</i>

Eg. Find the predominant hydrolysis of the hydrogen carbonate ion (HCO_3^-) and write the net-ionic equation for it.

To find the K_a of HCO_3^- , look it up on the **left** side of table.

$$\text{It's } K_a = 5.6 \times 10^{-11}$$

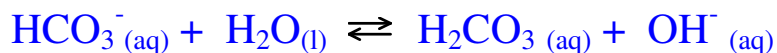
To find the K_b of HCO_3^- , look it up of the **right** side of table.

(*It's conjugate acid is H_2CO_3 and the K_a of $\text{H}_2\text{CO}_3 = 4.3 \times 10^{-7}$*)

So we calculate the K_b of HCO_3^- using : $K_b(\text{HCO}_3^-) = \frac{K_w}{K_a(\text{H}_2\text{CO}_3)} = \frac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} = 2.3 \times 10^{-8}$

So, since $K_b > K_a$, the ion HCO_3^- predominantly undergoes BASE HYDROLYSIS.

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



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