N38 – Acid Base

Target: I can determine if a salt will make a solution acidic, basic, and can calculate the pH of a salt solution.

N38 – Acid Base

Salts

Important!

You HAVE to have your strong acids and bases memorized!

What is a salt?

An ionic compound formed when an acid and a base react with each other

$NaOH + HCl \rightarrow H_2O + \mathbf{NaCl}$

$NH_4OH + HCl \rightarrow H_2O + \mathbf{NH_4Cl}$

How do salts behave when you put them in water?

They dissociate – the ions separate

$NaCl \rightarrow Na^+ + Cl^-$

$NH_4Cl \rightarrow NH_4^+ + Cl^-$

How do the ions behave once they have dissociated?

The ions can sometimes “hydrolyze”

Meaning they can react with the water.

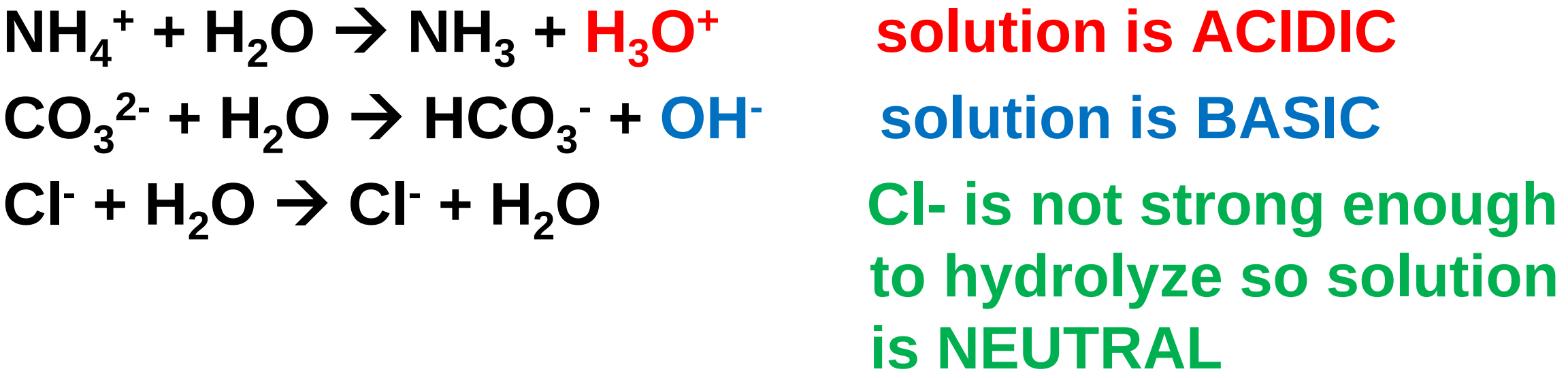
$$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$$

The ion has to be “strong” enough for this to happen

(we will explain which ions are strong in a minute!)

What is the result of This (potential) hydrolysis?

Once the ion hydrolyzes with the water it can make the salt solution acidic, basic, or neutral



How do you know if it is "strong" enough to hydrolyze?

Have to think about the properties of the acids/bases that the ion came from

	Turns into a…	Hydrolyzes?
Strong Acid	**Weaker** conjugate **base**	**No**
Weak Acid	**Stronger** conjugate **base**	**Yes**
Strong Base	**Weaker** conjugate **acid**	**No**
Weak Base	**Stronger** conjugate **acid**	**Yes**

Why does strong turn into weak and vice versa?

Think about where equilibrium lies for the original acid/base…

$$HCl \leftrightarrow H^+ + Cl^-$$

- Strong acid, most dissociates so eq. lies to the right.
- It “wants” to be broken into its ions.
- So if it wants to be broken into H^+ and Cl^- …
  - Is the Cl^- going to be able to go around taking H^+ off water to form HCl???

No!

Steps to predict pH OF A SALT SOLUTION

1. Identify acid or base that the salt ions came from

Steps to predict pH OF A SALT SOLUTION

2. Determine if the ions will hydrolyze

– Figure out if they came from a strong or weak acid/base

- From strong → ion won't hydrolyze – neutral contribution
- From weak → ion will hydrolyze – acidic or basic contribution

Steps to predict pH OF A SALT SOLUTION

3. If it hydrolyzes identify if the hydrolysis of the ion would form acid or base.

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weaker** conjugate **base**	No	Neutral
Weak Acid	**Stronger** conjugate **base**	Yes	Basic
Strong Base	**Weaker** conjugate **acid**	No	Neutral
Weak Base	**Stronger** conjugate **acid**	Yes	Acidic

Steps to predict pH OF A SALT SOLUTION

4. Figure out what the combo of each ion's contribution would be to the solution

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

Steps to predict pH OF A SALT SOLUTION

5. To determine the "winner" when acidic + basic

- Compare the Ka and Kb values
- The higher one means it is stronger, more dissociation so it will contribute more to the resulting solution

$Ka_{(ion)} > Kb_{(ion)}$	**Acidic**
$Ka_{(ion)} < Kb_{(ion)}$	**Basic**
$Ka_{(ion)} = Kb_{(ion)}$	**Neutral**

The problem…

You rarely have Ka and Kb for the CONJUGATE IONS you are interested in. You usually only have them for the STARTING acid/base they came from. Ugh…

Finding $K_{A(ION)}$ AND $K_{b(ion)}$

Kw = Ka x Kb

If you want Ka of an ion → need Kb of the base it came from

If you want Kb of an ion → need Ka of the acid it came from

Practice Problem: What is the Ka of NH_4^+ ?

Use Kb of NH_3 (1.8×10^{-5})

plug in and solve for $Ka_{(ion)}$

$(1 \times 10^{-14}) = Ka_{(ion)} \times (1.8 \times 10^{-5})$

$Ka_{(ion)}\ NH_4^+ = 5.56 \times 10^{-10}$

Practice problem #1

Is KBr an acidic, basic, or neutral salt?

K^+ → KOH Strong Base
→ so K^+ is Weaker acid
→ No Hydrolysis
→ **Neutral effect**

K^+ Br^-

Br^- → HBr Strong Acid
→ so Br^- is Weaker base
→ No Hydrolysis
→ **Neutral effect**

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weaker** conjugate base	No	**Neutral**
Weak Acid	**Stronger** conjugate base	Yes	**Basic**
Strong Base	**Weaker** conjugate acid	No	**Neutral**
Weak Base	**Stronger** conjugate acid	Yes	**Acidic**

Practice problem #1

Is KBr an acidic, basic, or neutral salt?

K^+ Br-

K^+ → KOH Strong Base → so K^+ is Weaker acid → No Hydrolysis
→ **Neutral effect**

Br^- → HBr Strong Acid → so Br^- is Weaker base → No Hydrolysis
→ **Neutral effect**

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

So KBr is a NEUTRAL SALT!

Practice problem #2

Is $KHCO_3$ an acidic, basic, or neutral salt?

K^+ HCO_3^-

$K^+ \rightarrow KOH$ Strong Base → so K^+ is Weaker acid → No Hydrolysis → **Neutral effect**

$HCO_3^- \rightarrow H_2CO_3$ Weak Acid → so HCO_3^- is Stronger Base → Hydrolysis → **Basic effect**

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weaker** conjugate base	No	**Neutral**
Weak Acid	**Stronger** conjugate base	Yes	**Basic**
Strong Base	**Weaker** conjugate acid	No	**Neutral**
Weak Base	**Stronger** conjugate acid	Yes	**Acidic**

Practice problem #2

Is $KHCO_3$ an acidic, basic, or neutral salt?

K^+ HCO_3^-

K^+ → KOH Strong Base → so K^+ is Weaker acid → No Hydrolysis

→ **Neutral effect**

HCO_3^- → H_2CO_3 Weak Acid → so HCO_3^- is Stronger Base → Hydrolysis

→ **Basic effect**

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

So $KHCO_3$ is a BASIC SALT!

Practice problem #3

Is NH_4Br an acidic, basic, or neutral salt?

NH_4^+ Br^-

NH_4^+ → NH_3 Weak Base → so NH_4^+ is Stronger acid → Hydrolysis → **Acidic effect**

Br^- → HBr Strong Acid → so Br^- is Weaker Base → No Hydrolysis → **Neutral effect**

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weaker** conjugate base	No	**Neutral**
Weak Acid	**Stronger** conjugate base	Yes	**Basic**
Strong Base	**Weaker** conjugate acid	No	**Neutral**
Weak Base	**Stronger** conjugate acid	Yes	**Acidic**

Practice problem #3

Is NH_4Br an acidic, basic, or neutral salt?

NH_4^+ Br^-

$NH_4^+ \rightarrow NH_3$ Weak Base → so NH_4^+ is Stronger acid → Hydrolysis → **Acidic effect**

$Br^- \rightarrow HBr$ Strong Acid → so Br^- is Weaker Base → No Hydrolysis → **Neutral effect**

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

So NH_4Br is an ACIDIC SALT!

Practice problem #4

Is NH_4CN an acidic, basic, or neutral salt?

NH_4^+ CN^-

$NH_4^+ \rightarrow NH_3$ Weak Base → so NH_4^+ is Stronger acid → Hydrolysis → **Acidic effect**

$CN^- \rightarrow HCN$ Weak Acid → so CN^- is Stronger Base → Hydrolysis → **Basic effect**

	Turns into a…	Hydrolyzes?	Ion makes sol'n
Strong Acid	**Weaker** conjugate base	No	**Neutral**
Weak Acid	**Stronger** conjugate base	Yes	**Basic**
Strong Base	**Weaker** conjugate acid	No	**Neutral**
Weak Base	**Stronger** conjugate acid	Yes	**Acidic**

Practice problem #4

Is NH_4CN an acidic, basic, or neutral salt?

$NH_4^+ \rightarrow NH_3$ Weak Base →so NH_4^+ is Stronger acid →Hydrolysis → **Acidic effect**

$CN^- \rightarrow HCN$ Weak Acid→ so CN^- is Stronger Base→ Hydrolysis→ **Basic effect**

$Kb\ NH_3 = 1.8 \times 10^{-5} \longrightarrow Ka\ NH_4^+ = (1.0 \times 10^{-14})/(1.8 \times 10^{-5})$

$Ka\ HCN = 4.9 \times 10^{-10} \longrightarrow Kb\ CN^- = (1.0 \times 10^{-14})/(4.9 \times 10^{-10})$

$Ka_{(NH4+)} = 5.56 \times 10^{-10}$

$Kb_{(CN-)} = 2.04 \times 10^{-5}$

$Ka_{(NH4+)} < Kb_{(CN-)}$

NH_4CN is a Basic Salt!

Calculating the actual pH of salts

What if you want the actual pH value?

1. Do all the steps needed to determine which ion is the "strong" one – which one is being hydrolyzed?
2. Write the hydrolysis reaction for that ion (or ions)
3. ICE Table time! Yes! More ICE tables! They just won't go away! ☺ Use your hydrolysis rxn for ICE Table
4. Find $[H_3O^+]$ or $[OH^-]$ from ICE Tables
5. Continue on with normal pH type calculations

Practice problem #5

What is the pH of a 0.25M NH_4NO_3 salt solution?

NH_4^+ NO_3^-

NH_4^+ → NH_3 Weak Base → so NH_4^+ is Stronger acid → Hydrolysis → **Acidic effect**

NO_3^- → HNO_3 Strong Acid → so NO_3^- is Weaker Base → No Hydrolysis → **Neutral effect**

	Makes the solution…
Acidic + Neutral	Acidic
Basic + Neutral	Basic
Neutral + Neutral	Neutral
Acidic + Basic	Compare Ka and Kb to determine which "wins"

So NH_4NO_3 is an ACIDIC SALT!

Practice problem #5

What is the pH of a 0.25M NH_4NO_3 salt solution?

NH_4^+ is the ion contributing an acidic effect

Hydrolysis

$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

We don't have Ka NH_4^+

BUT…we do have…

Kb (NH_3) = 1.8×10^{-5}

And remember…

Kw = Ka x Kb

We know the Kb for our conjugate (NH_3), so we just solve for the Ka of the ion we are interested in!

Practice problem #5

What is the pH of a 0.25M NH_4NO_3 salt solution?

Hydrolysis

$$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$$

$$Ka\ (NH_4^+) = \quad (1.0 \times 10^{-14})/(1.8 \times 10^{-5}) \ = 5.56 \times 10^{-10}$$

Time for an ICE Table!

Practice problem #5

What is the pH of a 0.25M NH_4NO_3 salt solution?

Hydrolysis

$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

	NH_4^+	**+ H_2O**	**→ NH_3**	**+ H_3O^+**
I	0.25	---	0	0
C	- x	---	+ x	+ x
E	0.25 – x	---	x	x
5%	0.25	---	x	x
Ans.		---		

Practice problem #5

What is the pH of a 0.25M NH_4NO_3 salt solution?

	NH_4^+	+ H_2O	→ NH_3	+ H_3O^+
I	0.25	---	0	0
C	- x	---	+ x	+ x
E	0.25 – x	---	x	x
5%	0.25	---	x	x
Ans.	0.25	---	$1.18\ x\ 10^{-5}$	$1.18\ x\ 10^{-5}$

$$Ka = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

$$5.56 \text{ x } 10{-}10 = \frac{(x)(x)}{(0.25)}$$

$$x = 1.18\ x\ 10^{-5}$$

Time for pH calculation!

Practice problem #5

What is the pH of a 0.25M NH_4NO_3 salt solution?

$$[H_3O^+] = 1.18\ x\ 10^{-5}$$

$$pH = -\log(1.18\ x\ 10^{-5})$$

$$\boldsymbol{pH = 4.93}$$

Finally finished!

A few last things to keep in mind...

Highly Charged Metals

Type of Salt	Examples	Comment	pH of solution
Cation is a highly charged metal ion; Anion is from strong acid	$Al(NO_3)_3$ $FeCl_3$	Hydrated cation acts as an acid; Anion is neutral	Acidic

Step #1:

$$AlCl_3(s) + 6H_2O \rightarrow Al(H_2O)_6^{3+}(aq) + Cl^-(aq)$$

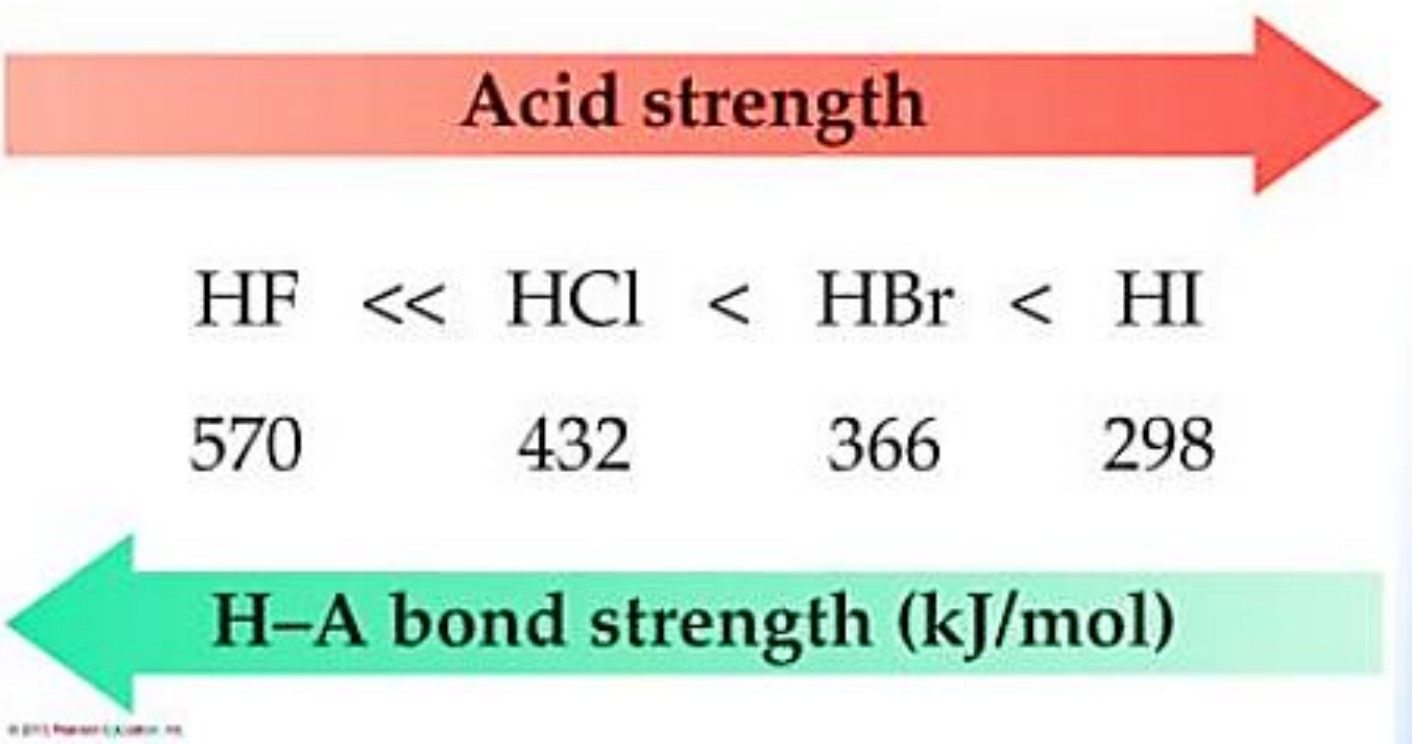
Salt water Complex ion anion

Step #2:

$$Al(H_2O)_6^{3+}(aq) \rightarrow Al(OH)(H_2O)_5^{2+}(aq) + H^+(aq)$$

Acid Conjugate base Proton

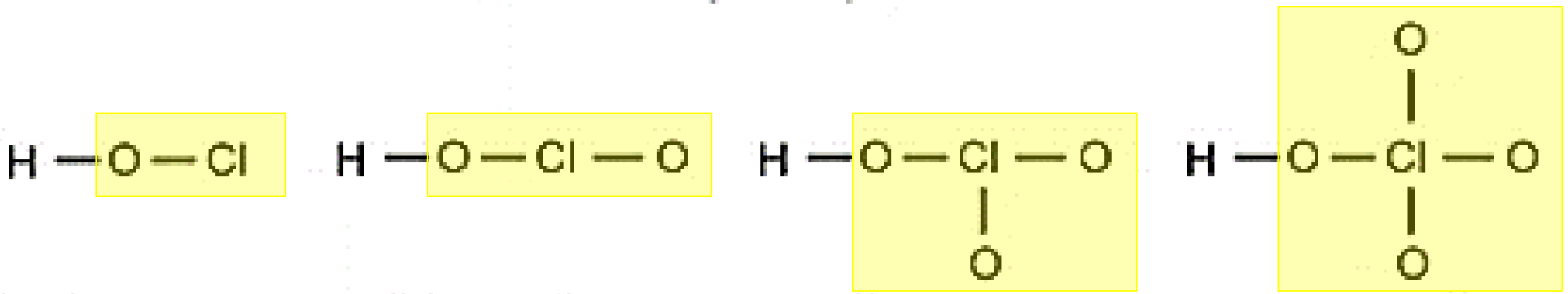
Strength of Binary Acids



Small radius, and high electronegativity of F pulling on the e- of H, results in a shorter/stronger bond between H and the other element. Reduces acidity because H cannot dissociate as easily.

Strength of Oxyacids (and other similar)

Increasing Acidity



hypochlorous acid

chlorous acid

chloric acid

perchloric acid

High electronegativity of the *side group* pulls electron density AWAY from the bond involving Hydrogen. Bond is therefore weakened so it breaks more easily, therefore more acidic.

YouTube Link to Presentation

https://youtu.be/k28s1ynGZhM