N38 – Acid Base

Salts

Link to YouTube Presentation: https://youtu.be/k28s1ynGZhM

N38 – Acid Base

Salts

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

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

$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$ **solution is ACIDIC**

$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$ **solution is BASIC**

$Cl^- + H_2O \rightarrow Cl^- + H_2O$ **Cl- is not strong enough to hydrolyze so solution is 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**

$K_b\ NH_3 = 1.8 \times 10^{-5}$ ⟶ $K_a\ NH_4^+ = (1.0 \times 10^{-14})/(1.8 \times 10^{-5})$

$K_a\ HCN = 4.9 \times 10^{-10}$ ⟶ $K_b\ CN^- = (1.0 \times 10^{-14})/(4.9 \times 10^{-10})$

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

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

$K_{a(NH4+)} < K_{b(CN-)}$

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:

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

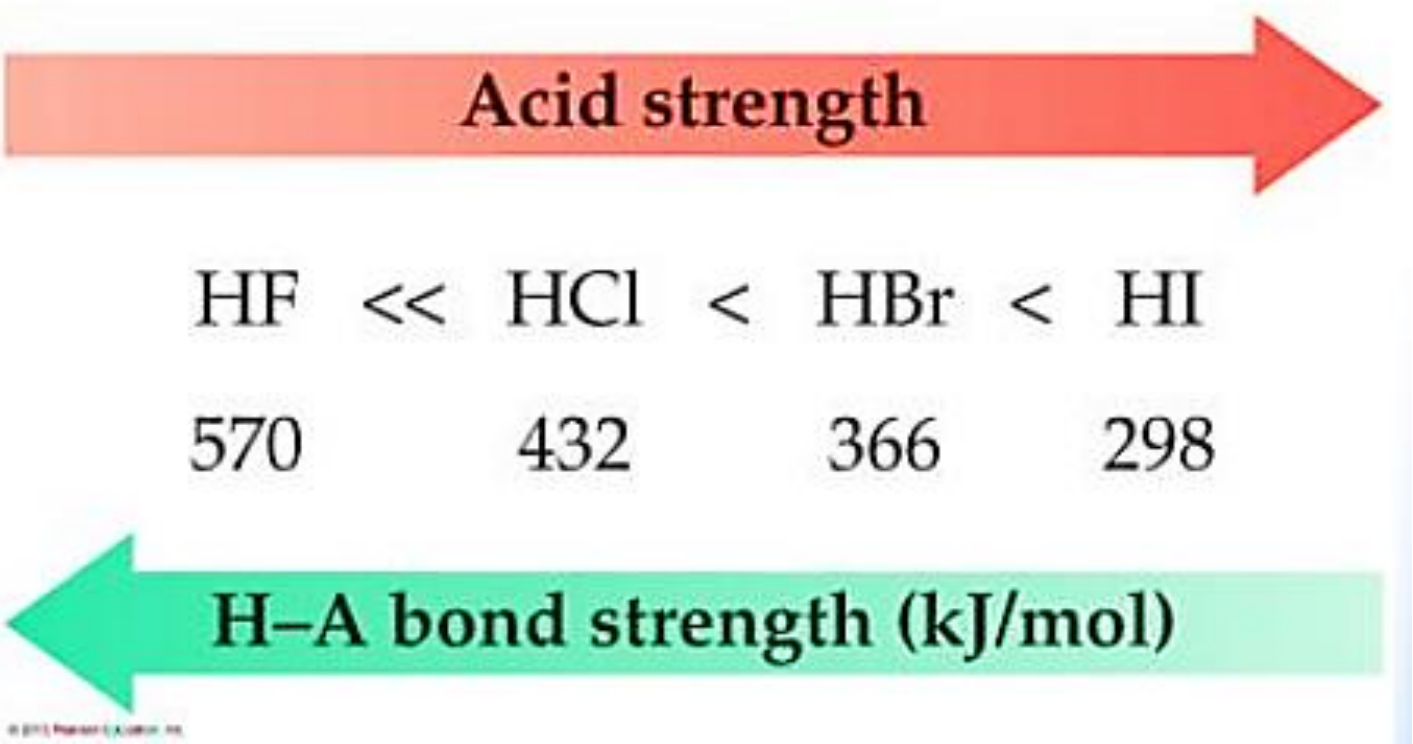
Salt water Complex ion anion

Step #2:

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

Acid Conjugate base Proton

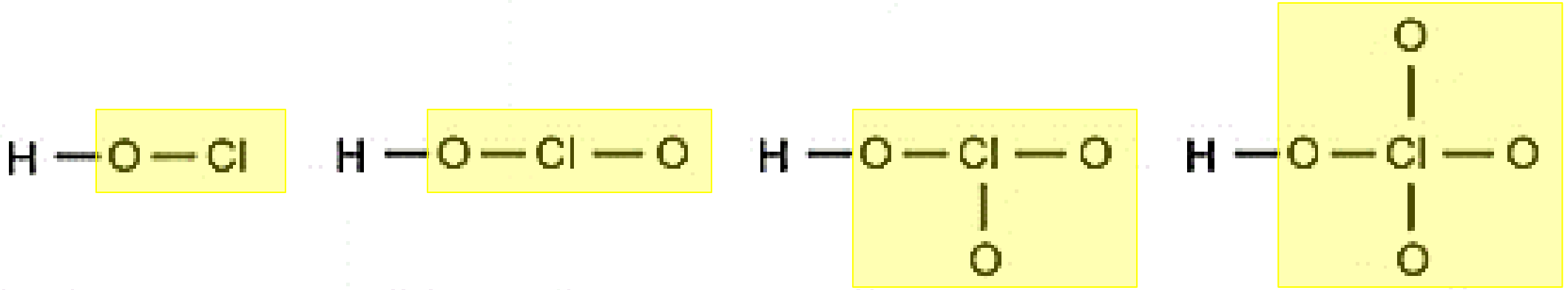
Strength of Binary Acids



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