SALTS

- Compounds that result from the reaction of an acid and a base.

- Salts are strong electrolytes (completely dissociate in water) IF SOLUBLE (not all salts dissolve appreciably).

- Most ionic compounds are considered salts (they can be made by some reaction between the appropriate acid and base)

- Salts have acidic and basic properties! The ions that form when salts are dissolved can be acidic, basic, or neutral.

- Salts made from WEAK ACIDS tend to form BASIC solutions
- Salts made from WEAK BASES tend to form ACIDIC solutions

Na_2CO_3 : $Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$

Do any of these ions have acidic or basic properties?

Na^+: neutral. Not a proton donor or a proton acceptor

CO_3^{2-}: BASIC, since it can accept protons to form the weak acid CARBONIC ACID in solution.

$H_2CO_3 + 2H_2O \rightleftharpoons 2H_3O^+ + CO_3^{-2}$

ACID BASE

SALT OF A WEAK ACID

ex; $NaC_2H_3O_2$

$$NaA \longrightarrow Na^+ + A^-$$

The salt dissolves completely!

For this reaction to occur, HA MUST be stable in water. In other words, a weak acid.

$$A^- + H_2O \rightleftharpoons HA + OH^-$$

... but the ionization of the salt's anion is an EQUILIBRIUM!

The anion is a BASE. It can accept a proton from water to form the weak (therefore stable as a molecule!) acid HA

$$K_b = \frac{[HA][OH^-]}{[A^-]}$$

This is the base ionization constant for A^-

Since A^- and HA are a conjugate pair, the ionization constants are related!

$$K_w = (K_{a,HA})(K_{b,A^-})$$

1.0×10^{-14}

$14 = pK_a + pK_b$

You will generally not find both the Ka AND Kb for a conjugate pair in the literature, since one can be easily converted to the other!

SALT OF A WEAK BASE

ex: NH_4Cl

$$BHCl \longrightarrow BH^+ + Cl^-$$

The salt dissociates completely!

$$BH^+ + H_2O \rightleftharpoons B + H_3O^+$$

... but this ionization is an EQUILIBRIUM process!

$$K_a = \frac{[B][H_3O^+]}{[BH^+]}$$

Acid ionization constant for BH^+

$$K_w = (K_{a,BH^+})(K_{b,B})$$

1.0×10^{-14}

Find the pH for salt solutions just like you would find pH for any other weak acid or weak base solutions. Only trick is to find out whether the salt is actually acidic or basic!

0.100 M NH_4Cl ... Find the pH of the solution

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

Acidic, basic, or neutral salt?

This is the WEAK BASE ammonia. Stable in water.

NH_4^+: $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ ✓

Cl^-: $Cl^- + H_2O \rightleftharpoons HCl + OH^-$ X

This is a STRONG ACID, which does not exist as a stable molecule in water.

The conjugate of a strong acid or base is NEUTRAL - does not affect pH!

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ This equilibrium affects the pH, so it is the equilibrium we'll need to solve to find pH!

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

$K_{a,NH_4^+} = \dfrac{[NH_3][H_3O^+]}{[NH_4^+]}$

We can get Ka for the acid from Kb for the base!

$K_{b,NH_3} = 1.8 \times 10^{-5}$ pA-14

$K_a \times K_b = 1.0 \times 10^{-14}$

So, $K_a = 5.56 \times 10^{-10}$ (for NH_4^+)

Species	[Initial]	Δ	[Equilibrium]
H_3O^+	0	+X	X
NH_3	0	+X	X
NH_4^+	0.100	−X	0.100 − X

$\dfrac{x^2}{0.100 - x} = 5.56 \times 10^{-10}$

$x \ll 0.100$

$0.100 - x \approx 0.100$

$\dfrac{x^2}{0.100} = 5.56 \times 10^{-10}$

$x = 7.46 \times 10^{-6} = [H_3O^+]$

$[H_3O^+] = 7.46 \times 10^{-6}$

pH = 5.13

Compare:
pH = 1.00 for 0.100 M strong acid
pH = 2.16 for 0.100 M nitrous acid
pH = 7.00 for distilled water

0.100 M $NaC_2H_3O_2$, Find pH

$$NaC_2H_3O_2 \longrightarrow Na^+ + C_2H_3O_2^-$$

Check the ions formed to see if they have acidic or basic properties:

Na^+: Cannot be B-L acid (no H), and not likely to be B-L base, since it's a simple positively charged metal ion.

$C_2H_3O_2^-$: Has protons, but also a negative charge - so it might be a more likely proton acceptor rather than a donor.

$$C_2H_3O_2^- + H_2O \rightleftharpoons \underline{HC_2H_3O_2} + OH^-$$

Acetic acid is a WEAK ACID and stable in water, so the acetate ion CAN function as a base.

$$C_2H_3O_2^- + H_2O \rightleftharpoons HC_2H_3O_2 + OH^-$$

$$K_{b,C_2H_3O_2^-} = \frac{[HC_2H_3O_2][OH^-]}{[C_2H_3O_2^-]}$$

Kb for acetate ion isn't in our chart, but we DO hace the Ka for acetic acid (the conjugate of acetate).

$K_{a,HC_2H_3O_2} = 1.7 \times 10^{-5}$; $K_a \times K_b = 1.0 \times 10^{-14}$, so $K_b = 5.88 \times 10^{-10}$

$$C_2H_3O_2^- + H_2O \rightleftharpoons HC_2H_3O_2 + OH^-$$

$$K_{b,C_2H_3O_2^-} = \frac{[HC_2H_3O_2][OH^-]}{[C_2H_3O_2^-]} = 5.88 \times 10^{-10}$$

Species	[Initial]	Δ	[Equilibrium]
OH^-	0	$+x$	x
$HC_2H_3O_2$	0	$+x$	x
$C_2H_3O_2^-$	0.100	$-x$	$0.100 - x$

$$\frac{x^2}{0.100 - x} = 5.68 \times 10^{-10}$$

$x \ll 0.100$

$$\frac{x^2}{0.100} = 5.88 \times 10^{-10}$$

$$x = 7.67 \times 10^{-6} = [OH^-]$$

Calculate pOH first...

$$pOH = -\log_{10}(7.67 \times 10^{-6})$$

$$= 5.12$$

Convert to pH

$pH + pOH = 14.00$

$pH + 5.12 = 14.00$

$pH = 8.88$

Compare:

pH = 7.00 for pure distilled water

pH = 11.13 for 0.100 M ammonia

pH = 13.00 for 0.100 M strong base

0.100 M NaCl, Find pH

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

Check the ions formed to see if they have acidic or basic properties:

Na^+: Cannot be B-L acid (no H), and not likely to be B-L base, since it's a simple positively charged metal ion.

Cl^-: Cannot be B-L acid (no H), but can it accept protons?

$$Cl^- + H_2O \rightleftharpoons \boxed{HCl} + OH^-$$

This is hydrochloric acid, a STRONG ACID, which does not exist readily in water in the molecular form.

... so chloride ion will not function as a base and will be NEUTRAL.

Since neither sodium ion nor chloride ion affect the water equilibrium, the pH of the solution will be the same as that of pure distilled water: 7.00

POLYPROTIC ACIDS

Find pH of 0.10 M H_3PO_4

... what's special about phosphoric acid?

① $H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$

② $H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$

③ $HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$

Phosphoric acid has THREE acidic protons!

$K_{a1} = 6.9 \times 10^{-3}$

$K_{a2} = 6.2 \times 10^{-8}$

$K_{a3} = 4.8 \times 10^{-13}$

The first dissocation is dominant here, and for simple calculations of phosphoric acid in water, we will simply use the first ionization and ignore the other two.

Remember: This is a weak acid. It exists in water mostly as undissociated phosphoric acid molecules.

Solving the equilibrium of phosphoric acid's first proton:

$$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$$

$$K_a = 6.9 \times 10^{-3} = \frac{[H_2PO_4^-][H_3O^+]}{[H_3PO_4]}$$

Species	[Initial]	Δ	[Equilibrium]
H_3O^+	0	$+x$	x
$H_2PO_4^-$	0	$+x$	x
H_3PO_4	0.10	$-x$	$0.10 - x$

$$\frac{x^2}{0.10 - x} = 6.9 \times 10^{-3}$$

This time, let's use the quadratic. We're not as confident $x \ll 0.10$ as we were in the previous few examples.

$$x^2 = 6.9 \times 10^{-4} - 6.9 \times 10^{-3} x$$

$$x^2 + 6.9 \times 10^{-3} x - 6.9 \times 10^{-4} = 0$$

$$a = 1, \quad b = 6.9 \times 10^{-3}, \quad c = -6.9 \times 10^{-4}$$

$$x = 2.3043 \times 10^{-2} \text{ or } -2.9943 \times 10^{-2}$$

$$= [H_3O^+]$$

$$\boxed{pH = 1.64}$$