Find the pH and the degree of ionization for an 0.10 M solution of formic acid: $HCHO_2$

$$HCHO_2 + H_2O \rightleftharpoons H_3O^+ + CHO_2^-$$

$$K_a = \frac{[H_3O^+][CHO_2^-]}{[HCHO_2]} = 1.7 \times 10^{-4}$$

Value of Ka from Ebbing, page A-13

Species	[Initial]	Δ	[Equilibrium]
H_3O^+	0	+x	x
CHO_2^-	0	+x	x
$HCHO_2$	0.10	−x	0.10 − x

$$\frac{(x)(x)}{0.10 - x} = 1.7 \times 10^{-4}$$

$$\frac{x^2}{0.10 - x} = 1.7 \times 10^{-4}$$

If we assume x is small compared to 0.10 ...

$$0.10 - x \simeq 0.10$$

$$\frac{x^2}{0.10} = 1.7 \times 10^{-4}$$

$$x = 0.004123105 6 = [H_3O^+]$$

So, $\boxed{pH = 2.38}$

... But what is DEGREE OF IONIZATION? The fraction of a weak acid (or base) that ionizes in water.

$$\frac{[CHO_2^-]}{[HCHO_2]_{initial}} \approx \frac{[H_3O^+]}{[HCHO_2]_{initial}} = \frac{0.0041231056}{0.10} = \boxed{0.041} = DOI$$

Sometimes, we express this in terms of a percentage. We call this PERCENT IONIZATION

$$\%\ ionization = DOI \times 100\% = \boxed{4.1\%\ ionized}$$

When you do Experiment 16A. By Le Chateleir's Principle, adding water to the equilibrium should force it to the right - meaning that more acid will ionize - even as the pH goes up!. Therefore, the degree of (or percent) ionization should INCREASES as the concentration of the acid DECREASES. Check this with your experiment 16A data on acetic acid.

An aqueous solution of 0.25 M trimethylamine has a pH of 11.63. What's the experimental value of Kb?

$(CH_3)_3N$

$$(CH_3)_3N + H_2O \rightleftharpoons (CH_3)_3NH^+ + OH^-$$

$$K_b = \frac{[(CH_3)_3NH^+][OH^-]}{[(CH_3)_3N]}$$

How do we find Kb? First, we will set this up like a traditional equilibrium problem:

Species	[Initial]	Δ	[Equilibrium]
$(CH_3)_3NH^+$	0	+x	x
OH^-	0	+x	x
$(CH_3)_3N$	0.25	−x	0.25−x

$$K_b = \frac{(x)(x)}{(0.25-x)}$$

$$K_b = \frac{x^2}{0.25-x}$$

If we want to find the value of Kb, we must find some other way to determine the value of 'x' ...

$$K_b = \frac{x^2}{0.25 - x}$$

We know the pH of the solution. This will give us the HYDRONIUM ION concentration. We can calculate the HYDROXIDE ION concentration using the pH identities, and that will give us 'x'.

$$pH = 11.63 \text{ , so } [H_3O^+] = 10^{-11.63} = 2.34422882 \times 10^{-12}$$

$$[H_3O^+][OH^-] = 1.0 \times 10^{-14}$$

$$(2.34422882 \times 10^{-12})[OH^-] = 1.0 \times 10^{-14}$$

$$[OH^-] = 0.0042657952 \ M = x$$

<-- We defined 'x' as concentration of hydroxide ion!

Plug the value of 'x' into the equilibrium expression to find Kb

$$K_b = \frac{(0.004265 7952)^2}{0.25 - 0.0042657952} = 7.4 \times 10^{-5} = K_b$$

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

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

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

Ammonia is a WEAK base. This means that it exists is water as a molecule. Since ammonia is stable in water, AMMONIUM ION should function as an ACID.

Cl^-; $Cl^- + H_2O \rightleftharpoons HCl + OH^-$

HCl is a STRONG ACID. It completely ionizes in water (in other words, it's unstable). Therefore, CHLORIDE ION is NEUTRAL.

So, to find the pH of the solution, we will have to solve the equilibrium of the ammonium ion ...

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

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

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

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

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]} = 5.56 \times 10^{-10}$$

Value for Ka? Chart on A-13 to A-14 does not give Ka for ammonium, but DOES give Kb for ammonia!

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

$$K_{a,NH_4^+} \times K_{b,NH_3} = 1.0 \times 10^{-14}$$

$$K_{a,NH_4^+} = 5.56 \times 10^{-10}$$

Species	[Initial]	Δ	[Equilibrium]
NH_3	0	+x	x
H_3O^+	0	+x	x
NH_4^+	0.100	-x	0.100 - x

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

Assume x is small
0.100 -x = 0.100

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

$x = 7.45 \times 10^{-6} = [H_3O^+]$

So, pH = 5.13

Compare!
pH = 1.00 for 0.100 M strong acid
pH = 2.17 for 0.100 M nitrous acid
pH = 7.00 for distilled water