Suppose ... I add N moles of an acid to 1 L of H_2O. What will happen?

Before

Water molecules react w/ each other

$$H_2O + H_2O \rightleftharpoons H_3O^+ + {}^-OH$$

Expt'l observation

$$[H_3O^+] = [HO^-] = 10^{-7} M$$

Define K_w as

$$K_w = [H_3O^+]_{eq}[HO^-]_{eq} = 10^{-14} M^2$$

Organic tradition: calc $[H_2O]$

$d = 1$ g/mL
$MW = 18$ g/mol

$$[H_2O] = \frac{d}{MW} = \frac{1000\,g}{1\,L}\left(\frac{1\,mol}{18\,g}\right) \approx 56 M$$

$$[H_3O^+] \,\&\, [OH^-] << [H_2O]$$

Back to

Suppose ... I add N moles of an acid to 1 L of H_2O. What will happen?

What should N be?

too small $(< 10^{-7})$ → nothing happens

too large (≥ 0.5) → I change $[H_2O]$

So ... say $N = 0.1$

what's gonna happen?

What CAN happen?

Reactions between HA, H_2O, $H_3O^{\oplus}$ & ${}^{\ominus}OH$

① $HA + H_2O \rightleftharpoons A^{\ominus} + H_3O^{\oplus}$

② $H_2O + H_2O \rightleftharpoons {}^{\ominus}OH + H_3O^{\oplus}$

③ $HA + {}^{\ominus}OH \rightleftharpoons A^{\ominus} + H_2O$

so small, ignore this reaction?

So I expect

① HA to react w/ H_2O & boost $H_3O^{\oplus}$ $(> 10^{-7}\ M)$

② elevated $H_3O^{\oplus}$ to drive down $HO^{\ominus}$ $(< 10^{-7}\ M)$

Now I want to calculate these changes

Useful tool: K_{eq}

(i) $HA + H_2O \rightleftharpoons A^{\ominus} + H_3O^{\oplus}$

when system reaches equilibrium (usually fast), concentrations no longer change noticeably (but individual molcecules still react)

Expt observation re: $[\cdots]_{eq}$

$$\frac{[A^{\ominus}][H_3O^{\oplus}]}{[HA][H_2O]} = K_{eq}$$

Organic tradition: use K_a

$$K_a \equiv K_{eq}\underset{\substack{\nearrow \\ 56\,M}}{[H_2O]} = \frac{[A^{\ominus}][H_3O^{\oplus}]}{[HA]}$$

HA = "strong acid" if "completely ionizes"

	Initial	Final
[HA]	0.1	0
[A⁻]	0	0.1

Since initial material is electrically neutral final material must be too.

$$\longrightarrow [H_3O^{\oplus}] = [A^{\ominus}] + [HO^{\ominus}] \approx [A^{\ominus}]$$

$$= 0.1 \text{ or } 10^{-1}$$

☺ $$[HO^-] = \frac{K_w}{[H_3O^+]} = \frac{10^{-14}}{10^{-1}} = 10^{-13} \ll [A^{\ominus}]$$

(?) $[HA] \ll 0.1$?

$$[HA] = \frac{[A^{\ominus}][H_3O^{\oplus}]}{K_a} = \frac{0.01}{K_a}$$

let's see . . .

☺ STRONG ACIDS

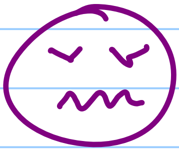
K_a	0.01	0.1	1	10	100
[HA]	1	0.1	0.01	0.001	0.0001

HA = "weak acid" if partially ionizes

	Initial	Change	End
[HA]	0.1	−x	0.1−x
$[A^-]$	0	+x	x
$[H_3O^+]$	10^{-7}	+x	~x ?

$$K_a = \frac{[A^\ominus][H_3O^\oplus]}{[HA]} = \frac{x^2}{0.1-x}$$

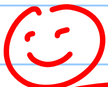
rearrange & solve for x $0 = x^2 - K_a(0.1-x)$



assume "very weak acid" →

only a little ionizes, or

$0.1 - x \approx 0.1$



VERY WEAK ACIDS

$0 = x^2 - 0.1\,K_a$

K_a	10^{-1}	10^{-3}	10^{-5}	10^{-7}
x	0.1	0.01	0.001	0.0001

$[H_3O^+] >> 10^{-7}$