

## 16.3 Acid and Base Strength

### Acid and Base Strength

#### Acid Ionization

See Class Web Site.

Acid:

- $\text{H}_3\text{PO}_4$
- $\text{CH}_3\text{CO}_2\text{H}$
- $\text{H}_2\text{CO}_3$
- $\text{HCl}$
- $\text{HNO}_3$
- $\text{HClO}_4$

Ionize

#### 6 STRONG ACIDS:

$\text{HCl}$	$\text{HNO}_3$
$\text{HBr}$	$\text{H}_2\text{SO}_4$
$\text{HI}$	$\text{HClO}_4$

#### 6 STRONG BASES:

$\text{LiOH}$	$\text{Ca(OH)}_2$
$\text{NaOH}$	$\text{Ba(OH)}_2$
$\text{KOH}$	$\text{Sr(OH)}_2$

**Ionized acid is indicated by red in the above diagram**

## 16.3 Acid and Base Strength

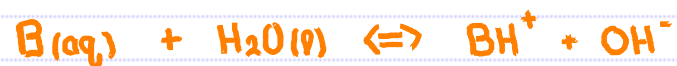
### Acid and Base Hydrolysis Equilibria, $K_a$ , and $K_b$

#### WEAK ACIDS:



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$

#### WEAK BASES:



$$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$$

## 16.3 Acid and Base Strength

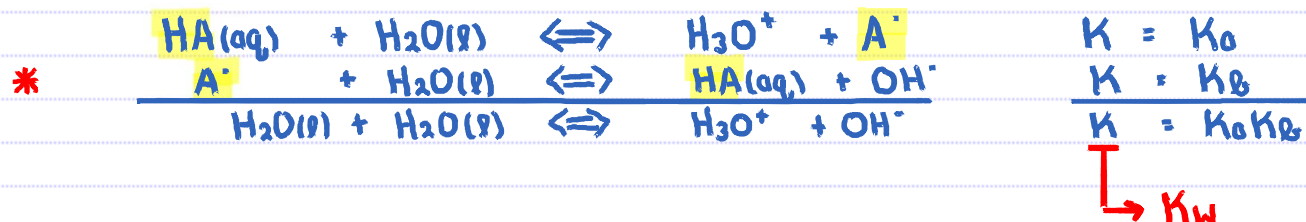
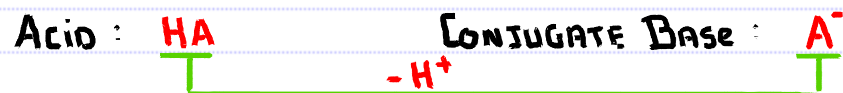
### Acid and Base Hydrolysis Equilibria, $K_a$ , and $K_b$

$K_a$ Values			$K_a$ Values		
Name of Acid	Acid	$K_a$	Name of Acid	Acid	$K_a$
Sulfuric acid	$H_2SO_4$	large	Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	$7.9 \times 10^{-6}$
Hydrochloric acid	HCl	large	Carbonic acid	$H_2CO_3$	$4.2 \times 10^{-7}$
Nitric acid	$HNO_3$	large	Hydrogen sulfide	$H_2S$	$1 \times 10^{-7}$
Hydronium ion	$H_3O^+$	1.0	Dihydrogen phosphate ion	$H_2PO_4^-$	$6.2 \times 10^{-8}$
Hydrogen sulfate ion	$HSO_4^-$	$1.2 \times 10^{-2}$	Hypochlorous acid	HClO	$3.5 \times 10^{-8}$
Phosphoric acid	$H_3PO_4$	$7.5 \times 10^{-3}$	Ammonium ion	$NH_4^+$	$5.6 \times 10^{-10}$
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	$6.3 \times 10^{-3}$	Hydrocyanic acid	HCN	$4.0 \times 10^{-10}$
Hydrofluoric acid	HF	$7.4 \times 10^{-4}$	Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	$3.2 \times 10^{-10}$
Formic acid	$HCO_2H$	$1.8 \times 10^{-4}$	Hydrogen carbonate ion	$HCO_3^-$	$4.8 \times 10^{-11}$
Benzoic acid	$C_6H_5CO_2H$	$6.3 \times 10^{-5}$	Hydrogen phosphate ion	$HPO_4^{2-}$	$3.6 \times 10^{-13}$
Acetic acid	$CH_3CO_2H$	$1.8 \times 10^{-5}$	Water	$H_2O$	$1.0 \times 10^{-14}$
			Hydrogen sulfide ion	$HS^-$	$1 \times 10^{-19}$

The larger the  $K_a$ , the stronger the acid.

## 16.3 Acid and Base Strength

### Relationship Between $K_a$ and $K_b$ – Conjugate Acid-Base Pair



$K_a K_b = K_w$  for a conjugate acid-base pair.

\* Can anion acting as a base?  
 We will address this in more detail shortly.

## 16.4 Estimating the pH of Acid and Base Solutions

### Strong Acid and Strong Base Solutions

What is the pH of an aqueous solution of  $1.15 \times 10^{-2}$  M hydrobromic acid?

	HBr	+ H <sub>2</sub> O(l)	=	H <sub>3</sub> O <sup>+</sup>	+	Br <sup>-</sup>
I	$1.15 \times 10^{-2}$			0		0
C	$- 1.15 \times 10^{-2}$			$1.15 \times 10^{-2}$		$1.15 \times 10^{-2}$
E	0			$1.15 \times 10^{-2}$		$1.15 \times 10^{-2}$

HBr : Strong acid ... 100%

I : Initial concentrations

C : Change in concentrations

E : Equilibrium concentrations

$$\begin{aligned} [\text{H}_3\text{O}^+] &= 1.15 \times 10^{-2} \\ \text{pH} &= -\log_{10}(1.15 \times 10^{-2}) \\ &= 1.94 \end{aligned}$$

## 16.4 Estimating the pH of Acid and Base Solutions

### Strong Acid and Strong Base Solutions

What is the **pH** of an aqueous solution of  $1.0 \times 10^{-5}$  M sodium hydroxide?

pH = ?.

- a) 5
- b) 6
- c) 7

- d) 8
- e) 9



	NaOH	+ <del>H<sub>2</sub>O(l)</del>	=	Na <sup>+</sup>	+	OH <sup>-</sup>
I	$1.0 \times 10^{-5}$			0		0
C	$-1.0 \times 10^{-5}$			$1.0 \times 10^{-5}$		$1.0 \times 10^{-5}$
E	0			$1.0 \times 10^{-5}$		$1.0 \times 10^{-5}$

NaOH : Strong Base  $\rightarrow$  100%

$$\begin{aligned}
 [\text{OH}^-] &= 1.0 \times 10^{-5} \\
 \text{pOH} &= -\log_{10}(1.0 \times 10^{-5}) \\
 &= 5
 \end{aligned}$$

$$\begin{aligned}
 \text{pH} + \text{pOH} &= 14 \text{ @ } 25^\circ\text{C} \\
 \text{pH} + 5 &= 14 \\
 \text{pH} &= 9
 \end{aligned}$$

## 16.4 Estimating the pH of Acid and Base Solutions

### pH of a Weak Acid – Quadratic Equation

Calculate the pH of a 0.372 M aqueous solution of hypochlorous acid (HClO,  $K_a = 3.5 \times 10^{-8}$ ).

	HClO	+ H <sub>2</sub> O(l)	=	H <sub>3</sub> O <sup>+</sup>	+ ClO <sup>-</sup>
I	0.372			0	0
C	-x			x	x
E	0.372 - x			x	x

$$K_a = \frac{[H_3O^+][ClO^-]}{[HClO]}$$

$$3.5 \times 10^{-8} = \frac{(x)(x)}{(0.372 - x)}$$

$$3.5 \times 10^{-8} (0.372 - x) = x^2$$

$$x^2 + 3.5 \times 10^{-8} x - 1.302 \times 10^{-8} = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = 1.141 \times 10^{-4}, -1.141 \times 10^{-4}$$

$$\left. \begin{array}{l} a = 1 \\ b = 3.58 \times 10^{-8} \\ c = -1.302 \times 10^{-8} \end{array} \right\}$$

↳ Disregard as this solution makes no chemical sense!

$$x = 1.141 \times 10^{-4} = [H_3O^+]$$

$$pH = -\log_{10}(1.141 \times 10^{-4}) = 3.94$$

While this method is the most accurate, solving a quadratic equation can be problematic on "bad math days!" ☹ ... as in on exam days!!

## 16.4 Estimating the pH of Acid and Base Solutions

### pH of a Weak Acid – Approx Method

Calculate the pH of a 0.372 M aqueous solution of hypochlorous acid (HClO,  $K_a = 3.5 \times 10^{-8}$ ).

	HClO	+ H <sub>2</sub> O(l)	=	H <sub>3</sub> O <sup>+</sup>	+	ClO <sup>-</sup>
I	0.372			0		0
C	-x			x		x
E	0.372 - x			x		x

If  $[HA]_i > 100 K_a$  then  $\therefore [HA]_i - x \approx [HA]_i$

$$0.372 > 100(3.5 \times 10^{-8})$$

then  $0.372 - x \approx 0.372$

$$K_a = \frac{[H_3O^+][ClO^-]}{[HClO]}$$

$$3.5 \times 10^{-8} = \frac{x \cdot x}{0.372}$$

$$x^2 = 0.372(3.5 \times 10^{-8})$$

$$x = \sqrt{0.372(3.5 \times 10^{-8})}$$

$$= 1.141 \times 10^{-4} = [H_3O^+]$$

$$pH = -\log_{10}(1.141 \times 10^{-4}) = 3.94$$

After you have done some of these you will notice :-  
That as long as  $[HA]_i > 100 K_a$

$$x = \sqrt{[HA]_i K_a}$$