16.3 Acid and Base Strength

Acid and Base Strength

Acid Ionization

See Class Web Site.

Acid:

- H_3PO_4
- CH_3CO_2H
- H_2CO_3
- HCl
- HNO_3
- $HClO_4$

Ionize

6 Strong Acids:

HCl	HNO_3
HBr	H_2SO_4
HI	$HClO_4$

6 Strong Bases:

LiOH	$Ca(OH)_2$
NaOH	$Ba(OH)_2$
KOH	$Sr(OH)_2$

Ionized acid is indicated by red in the above diagram

16.3 Acid and Base Strength

Acid and Base Hydrolysis Equilibria, Ka, and Kb

Weak Acids:

$$HA_{(aq)} + H_2O_{(l)} \Leftrightarrow H_3O^+ + A^-$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

Weak Bases:

$$B_{(aq)} + H_2O_{(l)} \Leftrightarrow BH^+ + OH^-$$

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

16.3 Acid and Base Strength

Acid and Base Hydrolysis Equilibria, Ka, and Kb

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

The larger the K_a, the stronger the acid.

16.3 Acid and Base Strength

Relationship Between Ka and Kb – Conjugate Acid-Base Pair

Acid : HA — $-H^+$ → Conjugate Base : A^-

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+ + A^- \qquad K = K_a$$

* $$A^- + H_2O_{(l)} \rightleftharpoons HA_{(aq)} + OH^- \qquad K = K_b$$

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+ + OH^- \qquad K = K_aK_b$$

$K = K_w$

$K_aK_b = K_w$ for a conjugate acid-base pair.

* An 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 1.15×10^{-2} M hydrobromic acid?

	HBr	+	$H_2O(l)$	=	H_3O^+	+	Br^-
I	1.15×10^{-2}				0		0
C	-1.15×10^{-2}				1.15×10^{-2}		1.15×10^{-2}
E	0				1.15×10^{-2}		1.15×10^{-2}

HBr : Strong acid ... 100%

I : Initial concentrations
C : Change in concentrations
E : Equilibrium concentrations

$[H_3O^+] = 1.15 \times 10^{-2}$

$pH = -\log_{10}(1.15 \times 10^{-2})$

$= 1.94$

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 1.0×10^{-5} M sodium hydroxide?

pH = ?.0

a) 5 b) 6 c) 7 d) 8 e) 9

	$NaOH$	+	~~$H_2O(l)$~~	=	Na^+	+	OH^-
I	1.0×10^{-5}				0		0
C	-1.0×10^{-5}				1.0×10^{-5}		1.0×10^{-5}
E	0				1.0×10^{-5}		1.0×10^{-5}

$NaOH$: Strong Base → 100%

$$[OH^-] = 1.0 \times 10^{-5}$$
$$pOH = -\log_{10}(1.0 \times 10^{-5})$$
$$= 5$$

$$pH + pOH = 14 \quad @ \ 25°C$$
$$pH + 5 = 14$$
$$pH = 9$$

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, Ka = 3.5×10^{-8}).

	HClO	+ $H_2O(l)$ =	H_3O^+	+ ClO^-
I	0.372		0	0
C	$-x$		x	x
E	$0.372 - x$		x	x

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

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

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

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

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

$a = 1$
$b = 3.58 \times 10^{-8}$
$c = -1.302 \times 10^{-8}$

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

↳ 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, Ka = 3.5×10^{-8}).

	HClO	+ $H_2O(l)$ =	H_3O^+	+ ClO^-
I	0.372		0	0
C	-x		x	x
E	0.372 - x		x	x

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

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

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 $[HA]_i > 100\,K_a$

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

16.4 Estimating the pH of Acid and Base Solutions

pH of a Weak Base – Approx Method

Calculate the **pH** of a 0.372 M aqueous solution of isoquinoline (C_9H_7N, $K_b = 2.5\times10^{-9}$)

pH = ?.0

a) 5 b) 6 c) 7 d) 8 e) 9

	C_9H_7N	+	$H_2O(l)$	=	$C_9H_7NH^+$	+	OH^-
I	0.372				0		0
C	$-x$				x		x
E	$0.372 - x$				x		x

$0.372 > 100(2.5\times10^{-9})$

Thus $0.372 - x \approx 0.372$

$$K_b = \frac{[C_9H_7NH^+][OH^-]}{[C_9H_7N]}$$

$$2.5\times10^{-9} = \frac{x\,x}{0.372}$$

$$x^2 = 0.372(2.5\times10^{-9})$$

$$x = \sqrt{0.372(2.5\times10^{-9})}$$

$$= 3.05\times10^{-5} = [OH^-]$$

$$pOH = -\log_{10}(3.05\times10^{-5}) = 4.52$$

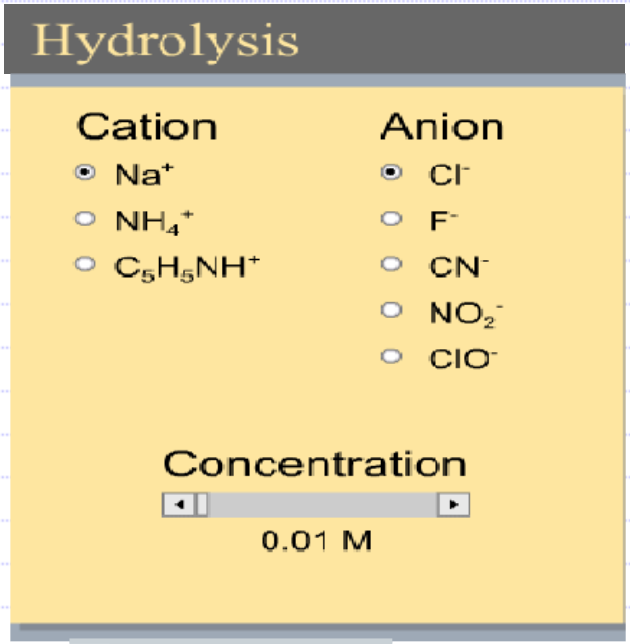
$$pH + pOH = 14 \text{ @ } 25°C$$

$$pH = 14 - 4.52$$

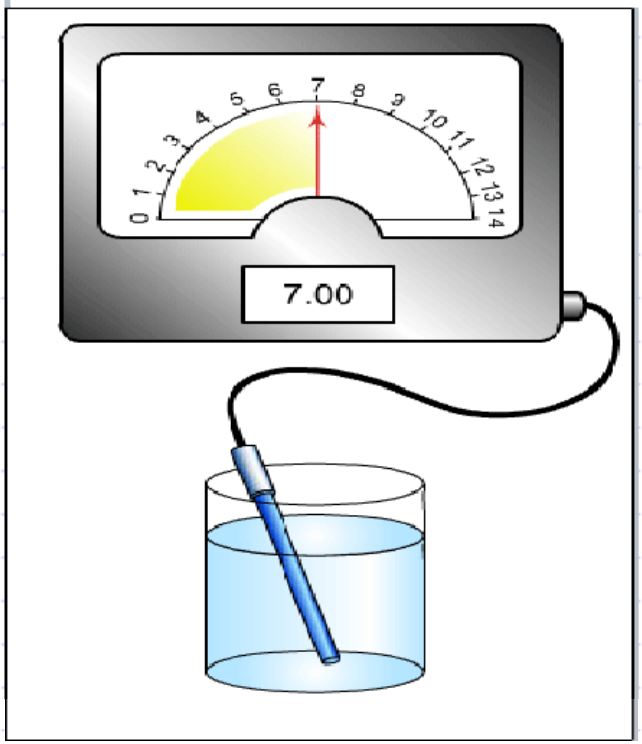
$$= 9.48$$

16.5 Acid-Base Properties of Salts

Hydrolysis – Neutral Cations and Anions



See Class Web Site



Neutral Cations

The 6 cations associated with the six strong bases:

Li^+	$LiOH$
Na^+	$NaOH$
K^+	KOH
Ca^{2+}	$Ca(OH)_2$
Ba^{2+}	$Ba(OH)_2$
Sr^{2+}	$Sr(OH)_2$

Non neutral cations are all potential weak acids ... ie NH_4^+

Neutral Anions

The 6 anions associated with the six strong acids.

Cl^-	HCl
Br^-	HBr
I^-	HI
NO_3^-	HNO_3
SO_4^{2-}	H_2SO_4
ClO_4^-	$HClO_4$

Non neutral anions are all potential weak bases ... ie F^-