Announcements – Lecture XIV – Tuesday, Mar 20th

1. iClicker:  Pick any letter a-e

2. Quiz 6: Due in class on Thursday, March 22nd.

3. Exam II: Moved to Saturday, April 7th.

Autoionization of Water – Neutral/Acidic/Basic Solutions

A solution at 25°C has a hydronium ion concentration of 4.5×10^{-4} M. This solution is:

a) Acidic ✓
b) Basic
c) Neutral

$[H_3O^+] = 4.5\times10^{-4}$

$[H_3O^+][OH^-] = 1\times10^{-14}$ @ 25°C

$(4.5\times10^{-4})[OH^-] = 1\times10^{-14}$

$[OH^-] = \dfrac{1\times10^{-14}}{4.5\times10^{-4}}$

$= 2.2\times10^{-11}$

$[H_3O^+] > [OH^-]$

16.2 Water and the pH Scale

pH and pOH Calculations

In general : $pX = -\log_{10} X$

$pH = -\log_{10}[H_3O^+]$

$pOH = -\log_{10}[OH^-]$

@ 25°C :

$$[H_3O^+][OH^-] = 1\times10^{-14}$$

$$\log_{10}([H_3O^+][OH^-]) = \log_{10}(1\times10^{-14})$$

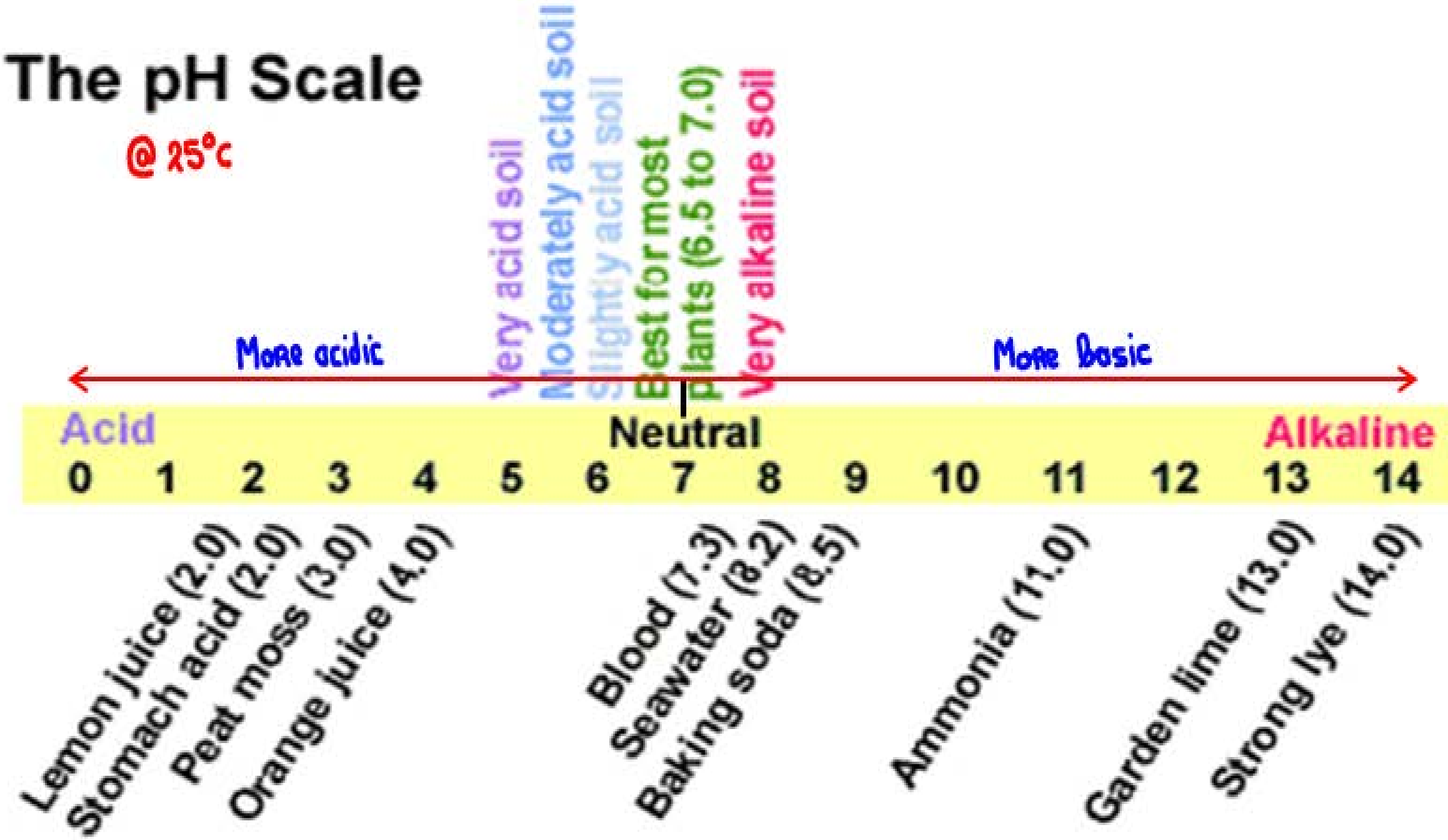
$$\log_{10}[H_3O^+] + \log_{10}[OH^-] = -14$$

$$\underbrace{-\log_{10}[H_3O^+]}_{pH} \underbrace{- \log_{10}[OH^-]}_{pOH} = 14$$

$pH + pOH = 14$ @ 25°C

16.2 Water and the pH Scale

Autoionization of Water – Neutral/Acidic/Basic Solutions



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

Six Strong Acids:

HCl	HNO_3
HBr	H_2SO_4
HI	$HClO_4$

Six 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:

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

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

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}

Larger the Ka, the stronger the acid.

16.3 Acid and Base Strength

Relationship Between Ka and Kb – Conjugate Acid-Base Pair

Acid: HA(aq) → A⁻ : Conjugate base
($-H^+$)

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+ + A^- \qquad K = K_a$$

$$* \; A^- + H_2O(l) \rightleftharpoons HA(aq) + OH^- \qquad K = K_b$$

$$2\,H_2O(l) \rightleftharpoons H_3O^+ + OH^- \qquad K = K_aK_b$$

↳ 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	=	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

$[H_3O^+] = 1.15\times10^{-2}$

$pH = -\log_{10}(1.15\times10^{-2})$

$= 1.94$

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 $1.0x10^{-5}$ M sodium hydroxide? pH = ?.0 (9)

	NaOH	+		=	Na^+	+	OH^-
I	$1.0x10^{-5}$				0		0
C	$-1.0x10^{-5}$				$1.0x10^{-5}$		$1.0x10^{-5}$
E	0				$1.0x10^{-5}$		$1.0x10^{-5}$

NaOH = Strong base
↳ Dissociates 100%

$[OH^-] = 1.0x10^{-5}$

$pOH = -\log_{10}(1.0x10^{-5})$

$= 5$

$pH + pOH = 14$
$pH + 5 = 14$
$pH = 9$

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	$\rightleftharpoons$	H_3O^+	+	ClO^-
I	0.372				0		0
C	−x				x		x
E	0.372 − x				x		x

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

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

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

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

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

$a = 1$

$b = 3.5 \times 10^{-8}$

$c = -1.302 \times 10^{-8}$

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

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

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

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

While this method is the most accurate but solving a quadratic 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_2O	⇌	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 $[HA]_i - x$ is $\approx [HA]_i$

$0.372 > 100(3.5\times10^{-8})$

thus $0.372 - x \approx 0.372$

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

$$3.5\times10^{-8} = \frac{x \cdot x}{0.372}$$

$$x^2 = 0.372(3.5\times10^{-8})$$

$$x = \sqrt{0.372(3.5\times10^{-8})}$$

$$x = 1.141\times10^{-4} = [H_3O^+]$$

$$pH = -\log_{10}(1.141\times10^{-4}) = 3.94$$

Short cut: So long as $[HA]_i > 100 K_a$

$$x = \sqrt{0.372(3.5\times10^{-8})}$$

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