16.1 Introduction to Acids and Bases

Acid and Base Definitions

Arrhenius:

Acid :- A substance containing hydrogen that, when dissolved in water, increases the concentration of H^+ ions.

Base :- A substance containing the hydroxide group that, when dissolved in water, increases the concentration of OH^- ions.

Bronsted-Lowry:

Acid :- A substance that can donate a proton (H^+ ion).

Base :- A substance that can accept a proton.

As the Bronsted-Lowry definition is more inclusive, this is the definition that we will focus on. For example NH_3 is a base, which would not be obvious under the Arrhenius definition.

$$\underset{\text{Base}}{NH_3(aq)} + H_2O(l) \Leftrightarrow NH_4^+ + \underset{\text{obviously fits Arrhenius definition}}{OH^-}$$

↓ Proton acceptor.

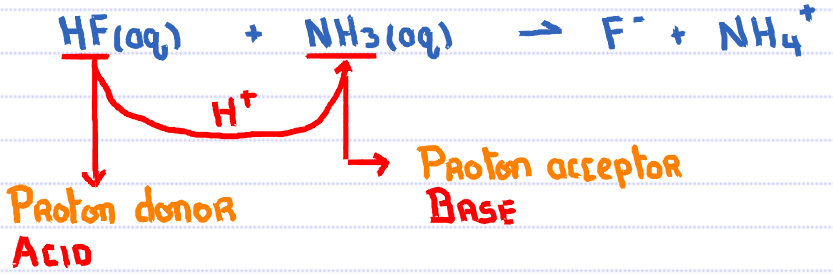
↳ OH^- ion concentration increase, thus it now obviously fits the Arrhenius definition

16.1 Introduction to Acids and Bases

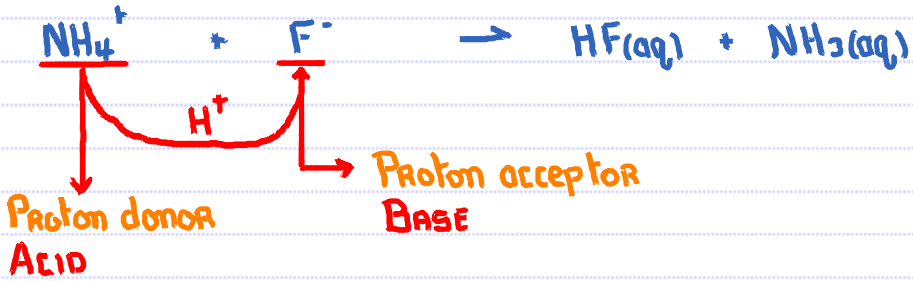
Simple Bronsted–Lowry Acids and Bases

$$HF(aq) + NH_3(aq) \Leftrightarrow F^- + NH_4^+$$

Forward Reaction :-



Reverse Reaction :-



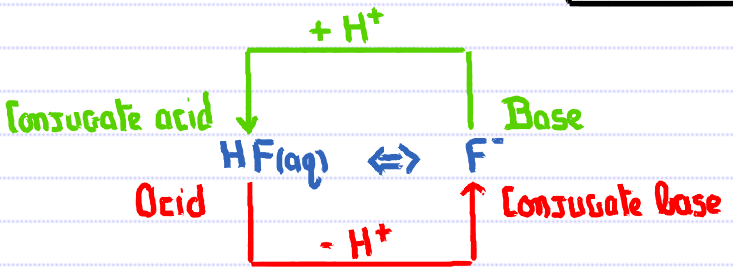
16.1 Introduction to Acids and Bases

Conjugate Acid–Base pairs

ACID	base	BASE	acid
donates H^+ to NH_3	accepts H^+ from HF	accepts H^+ from NH_4^+	donates H^+ to F^-

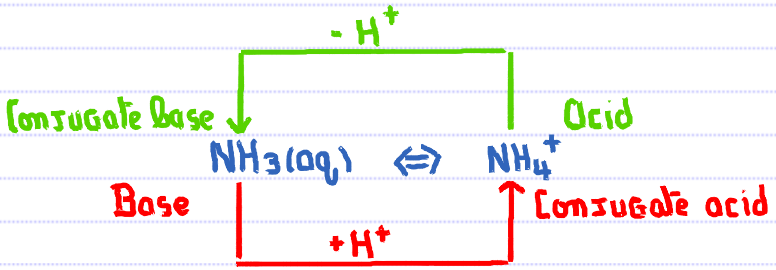
Conjugate acid - base pair.

Conjugate base - acid pair.



HF / F^-

Conjugate acid - base pair.



NH_4^+ / NH_3

Conjugate acid - base pair.

16.2 Water and the pH Scale

Autoionization of Water

Chemistry Interactive: Autoionization of Water

See Class Web Site

$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+ + OH^-$

$K_w = [H_3O^+][OH^-]$

@ 25°C, $K_w = 1 \times 10^{-14}$

@ 25°C, $K_w = 1 \times 10^{-14}$

$[H_3O^+][OH^-] = 1 \times 10^{-14}$

$[H_3O^+] = [OH^-] = \sqrt{1 \times 10^{-14}}$

$[H_3O^+] = 1 \times 10^{-7}$

$[OH^-] = 1 \times 10^{-7}$

16.2 Water and the pH Scale

Autoionization of Water

The autoionization of water is an endothermic process.

$$H_2O(l) + H_2O(l) \Leftrightarrow H_3O^+ + OH^-$$

Thus as the temperature increases then – the $[H_3O^+]$ should – 

a) Decrease b) Increase ✓ c) Remain the same

$H_2O_{(l)} + H_2O_{(l)} + \text{'heat'} \Leftrightarrow H_3O^+ + OH^-$

Heat the reaction = addition of a reactant.
Results in a shift towards more products ... $[H_3O^+]\uparrow$

16.2 Water and the pH Scale

Autoionization of Water

With the $[H_3O^+]$ increasing with increasing temperature this must mean that as the temperature of water increases the water –

a) becomes acidic b) becomes basic c) remain neutral ✓

$$H_2O(l) + H_2O(l) + \text{'heat'} \Leftrightarrow H_3O^+ + OH^-$$

Shift →

Yes the $[H_3O^+]\uparrow$
But so does the $[OH^-]$
Thus $[H_3O^+]$ still equals $[OH^-]$

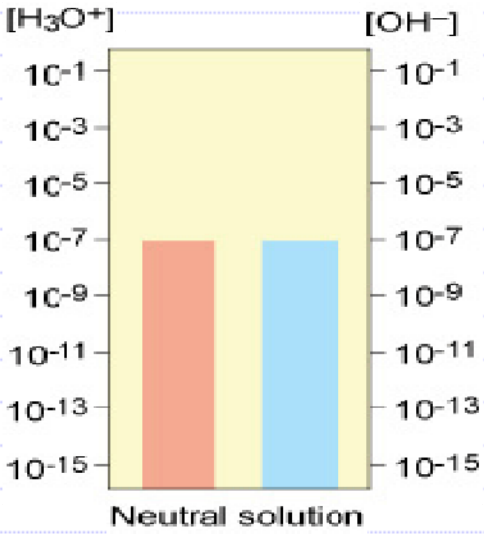
Some K_w Values

0°C	:	1.4×10^{-15}
25°C	:	1.0×10^{-14}
90°C	:	5.57×10^{-13}

16.2 Water and the pH Scale

Autoionization of Water – Neutral/Acidic/Basic Solutions

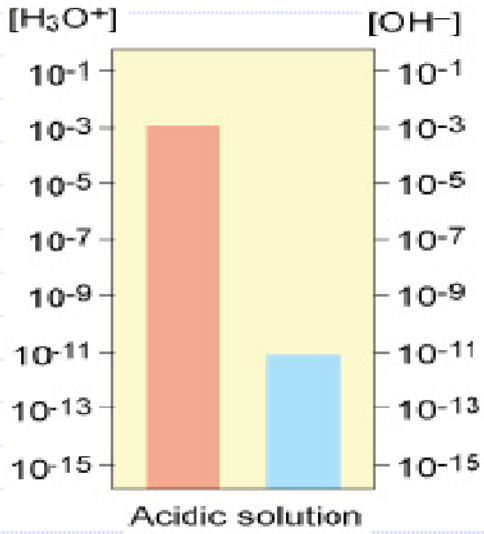
K_w at 25°C : $K_w = 1 \times 10^{-14}$



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

$[H_3O^+] = 1 \times 10^{-7}$

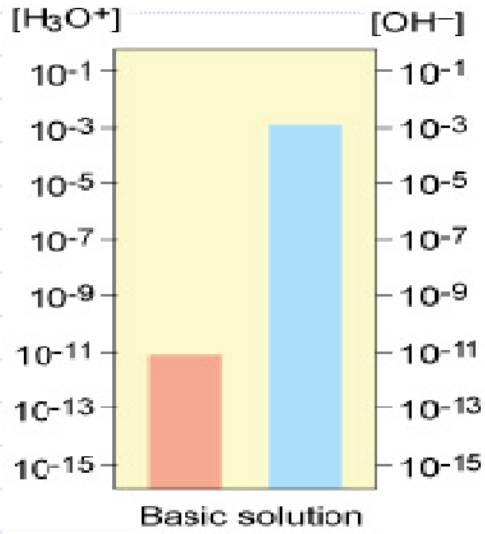
$[OH^-] = 1 \times 10^{-7}$



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

$[H_3O^+] = 1 \times 10^{-3}$

$[OH^-] = 1 \times 10^{-11}$



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

$[H_3O^+] = 1 \times 10^{-11}$

$[OH^-] = 1 \times 10^{-3}$

16.2 Water and the pH Scale

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

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

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

$$= 2.2\times10^{-11}$$

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

16.2 Water and the pH Scale

pH and pOH Calculations

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

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

@ 25°C:

$$[H_3O^+][OH^-] = 1 \times 10^{-14}$$

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

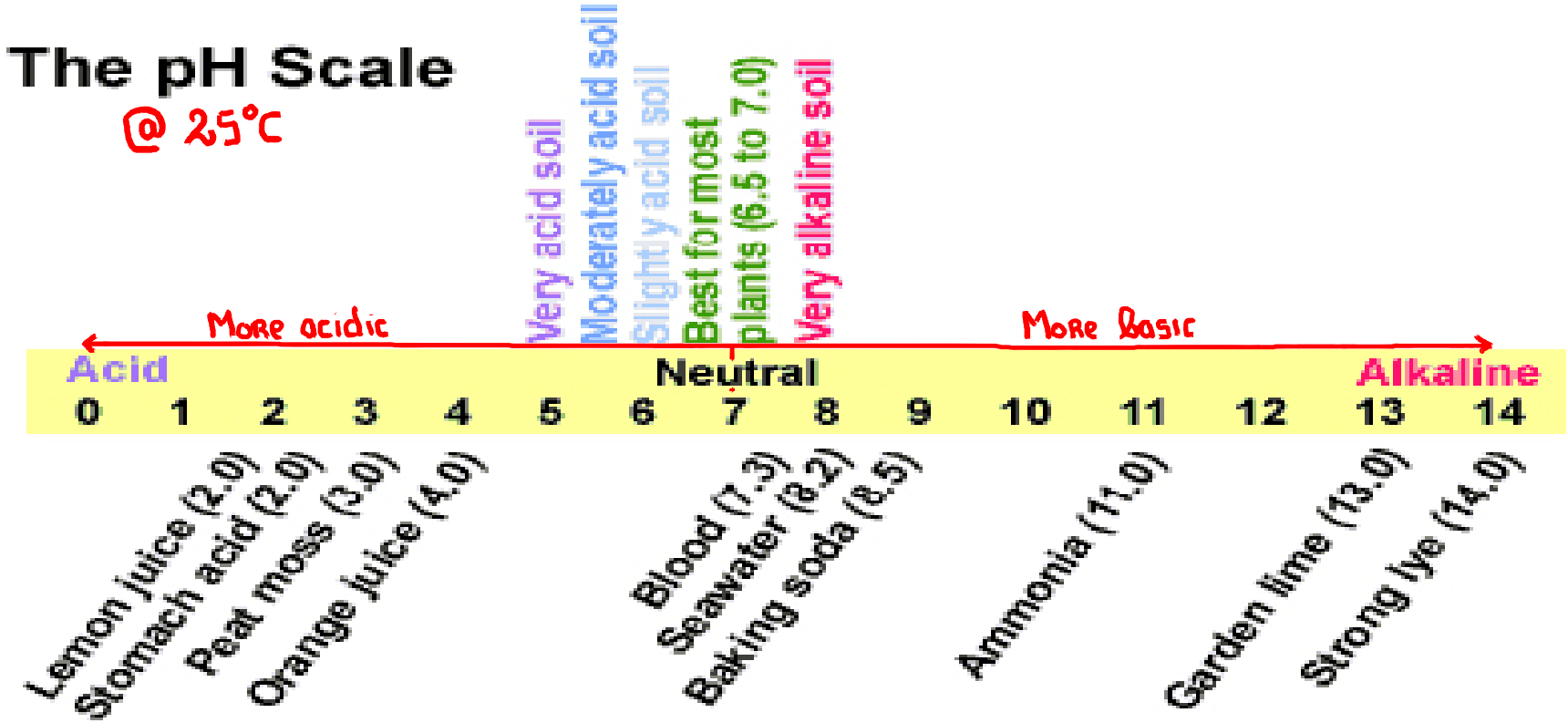
$$\log_{10}[H_3O^+] + \log_{10}[OH^-] = -14$$

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

$$pH + pOH = 14 \text{ @ } 25°C$$

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

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