Announcements – Lecture XIII – Thursday, Mar 8th

1. iClicker:  Pick any letter a-e

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Production of ammonia – an equilibrium dilemma!

The production of ammonia is an exothermic process –

$N_2(g) + 3\,H_2(g) \Leftrightarrow 2\,NH_3(g)$ $\quad K_c = 3.5 \times 10^8$ @ 25°C

How can we maximize the production of $[NH_3]$.

a) At Room Temperature, K_c is product favored.
However at Room Temperature this Reaction is extremely slow.
To speed up a Reaction ... heat it ... and/or use a catalyst to lower the Activation Energy.

b) However this Reaction is exothermic ... thus heating it will reduce K_c.
As we saw earlier this process is done at 450°C in the presence of a catalyst.
At 450°C, $K_c = 1.19 \times 10^{-3}$. Thus while we have speeded up how quickly equilibrium is achieved, the equilibrium is now Reactant favored!

c) Not daunted!, $\Delta n < 0$, thus if P is increased then $Q > K_c$ and there will be a shift towards products ... increasing the $[NH_3]$!

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 (H^+ ion).

As the Bronsted-Lowry definition is more inclusive, this is the definition we will focus on. For example NH_3 is a base which would be obvious under the Arrhenius definition.

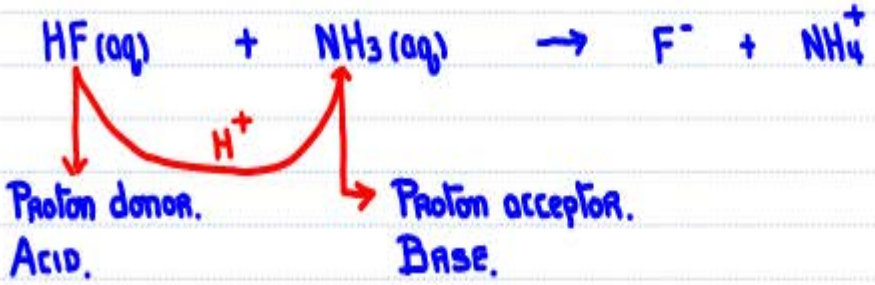
$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+ + OH^-$$

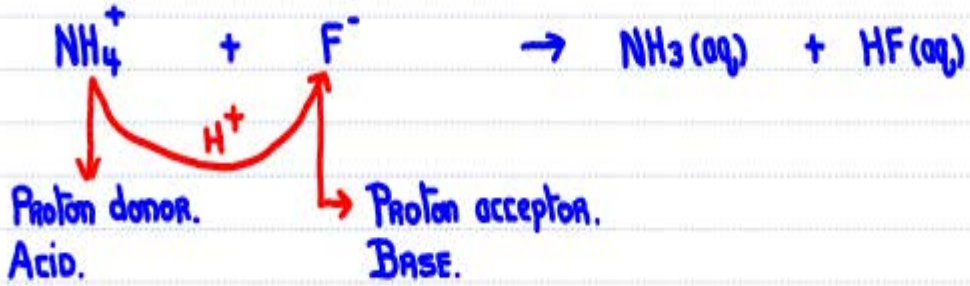
↳ proton acceptor. Base

↳ OH^- ion concentration increases, thus it now fits the Arrhenius definition.

16.1 Introduction to Acids and Bases

Simple Bronsted–Lowry Acids and Bases





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

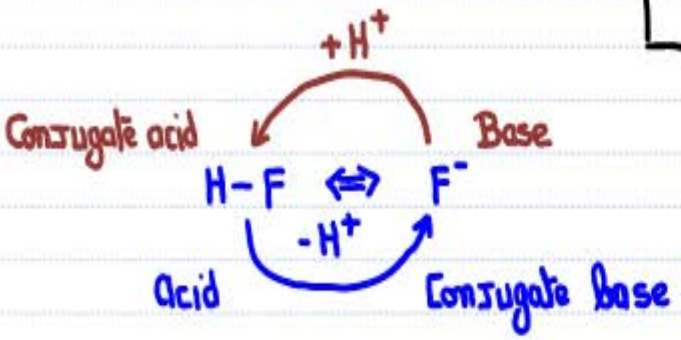
16.1 Introduction to Acids and Bases

Conjugate Acid–Base pairs

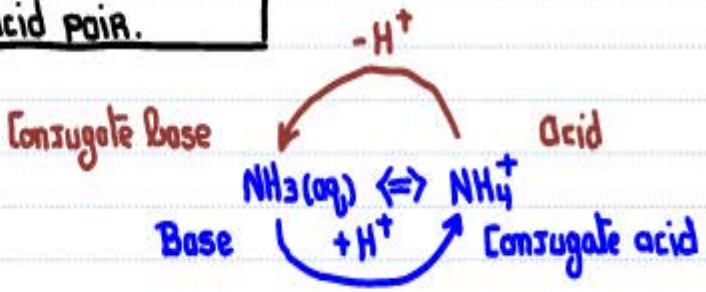
ACID	base	BASE	acid
donates H^+ to NH_3	accepts H^+ from HF	accepts H^+ from NH_4^+	donates H^+ to F^-

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

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

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

↳ @ 25°C = 1×10^{-14}

@ 25°C, $K_w = 1 \times 10^{-14}$

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

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

$= 1 \times 10^{-7}$

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

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

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

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

↳ Heat reaction = addition of a product.
Thus shift towards 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 ✓

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

shift →

Yes the $[H_3O^+]\uparrow$
But also $[OH^-]\uparrow$

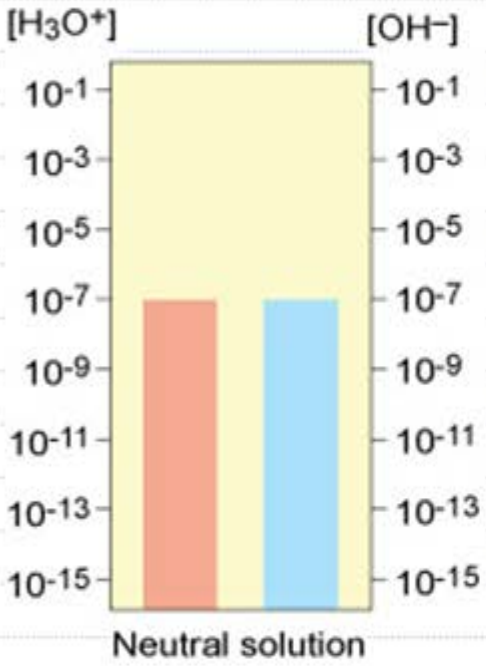
Thus $[H_3O^+] = [OH^-]$

K_w values:

$0^\circ C = 1.4 \times 10^{-15}$
$25^\circ C = 1.0 \times 10^{-14}$
$90^\circ C = 5.57 \times 10^{-13}$

16.2 Water and the pH Scale

Autoionization of Water – Neutral/Acidic/Basic Solutions



Neutral solution

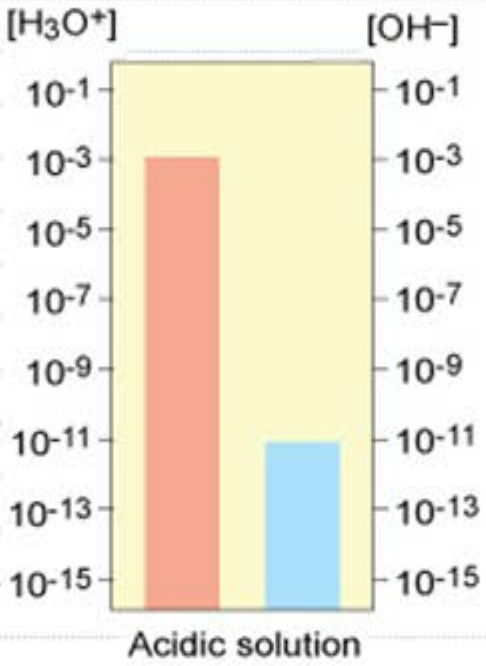
$[H_3O^+] = [OH^-]$

@ 25°C

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

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

$K_w = 1 \times 10^{-14}$



Acidic solution

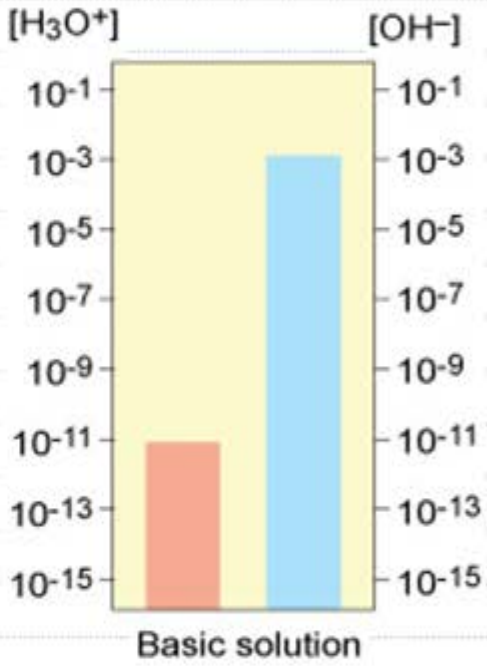
$[H_3O^+] > [OH^-]$

@ 25°C

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

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

$K_w = 1 \times 10^{-14}$



Basic solution

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

@ 25°C

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

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

$K_w = 1 \times 10^{-14}$