Acid - Base Theories

Arrhenius Theory of Acids and Bases

- acids are hydrogen-containing compounds that ionize in aqueous solutions to give H^+
- bases ionize to give OH^- ions

Monoprotic Acid - one hydrogen will ionize   Ex. HNO_3

Diprotic Acid - two hydrogens will ionize Ex. H_2SO_4

Triprotic Acid - three hydrogens will ionize Ex. H_3PO_4

Advantage: it explained neutralization as H^+ and OH^- combining to give H_2O

Disadvantage: not all hydrogen containing substances have acid properties (i.e., CH_4) and not all bases have OH^- (NH_3).

BRONSTED - LOWRY THEORY OF ACIDS & BASES

Bronsted-Lowry Acids and Bases

A new theory was needed because:
(i) not all acid/base reactions involve water.
(ii) not all bases contain hydroxide ions (Na_2CO_3, NH_3).

Bronsted - Lowry Acid - a proton (hydrogen-ion) donor
Bronsted - Lowry Base - a proton (hydrogen-ion) acceptor

- **acids lose a proton** to a water molecule (H^+ is a proton!)

Ex. $HCl_{(l)} + H_2O_{(l)} \longleftrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

↑

hydronium ion
(water molecule gains a proton)

- **bases gain a proton** from a water molecule

Ex. $H_2O + NH_{3(aq)} \longleftrightarrow OH^-_{(aq)} + NH_4^+{}_{(aq)}$

(H_2O acts as an acid, NH_3 acts as a base)

However water does not have to be present in order to have a proton exchange.

Ex. $HCl_{(g)} + NH_{3(g)} \longleftrightarrow NH_4^+{}_{(aq)} + Cl^-_{(aq)}$

HCl donates a proton (acid)
NH_3 accepts a proton (base)

amphoteric (amphiprotic) - substance that can act as a Bronsted-Lowry acid in some reactions and a Bronsted-Lowry base in other reactions.

H^+ H^+

$$\underset{B}{HSO_3^-{}_{(aq)}} + \underset{A}{H_3O^+_{(aq)}} \longleftrightarrow \underset{A}{H_2SO_{3(aq)}} + \underset{B}{H_2O_{(l)}}$$

$$\overset{A}{HSO_3^-{}_{(aq)}} + \overset{B}{OH^-_{(aq)}} \longleftrightarrow \overset{B}{SO_3^{2-}{}_{(aq)}} + \overset{A}{H_2O_{(l)}}$$

H^+ H^+

Conjugate Acid-Base Pairs

$$\overset{A}{CH_3COOH_{(aq)}} + \overset{B}{H_2O_{(l)}} \rightleftharpoons \overset{B}{CH_3COO^-_{(aq)}} + \overset{A}{H_3O^+_{(aq)}}$$

Acid-Base reactions are at equilibrium !

(Look at forward reaction and reverse reaction)

- Every acid-base reaction at equilibrium has two acids and two bases.
- Acid on 'product' side is formed by addition of proton to base on 'reactant' side
- Base on 'product' side is formed by removal of a proton from acid on 'reactant' side

Conjugate acid-base pair

A pair of substances that differ by only a proton

Ex.

LEWIS THEORY OF ACIDS & BASES

Lewis Acids and Bases

Lewis Acid - accepts a pair of electrons

Lewis Base - donates a pair of electrons

hydrogen ion + hydroxide ion

Homework

p. 593 #3-8 (omit #6)

p. 599 #11, 12

Water Equilibrium

Conductivity is due to the presence of ions. For water:

$$H_2O_{(l)} <==> H^+_{(aq)} + OH^-_{(aq)}$$

- therefore $K = \frac{[H^+]\,[OH^-]}{[H_2O]}$ is very small

- slight conductivity shows that equilibrium greatly favors water molecules (less than 2 H^+ per billion water)

- therefore the concentration of water in pure water and in dilute aqueous solutions is essentially constant and can be combined with the equilibrium constant to produce a new constant called the *Ion Product Constant*

Ionization Constant for water (ion product constant)

H^+

$K_w = [H^+]\,[OH^-] = 1.0 \times 10^{-14}$ at SATP

Since $[H^+]$ and $[OH^-]$ are found in 1:1 ratio
$(H_2O_{(l)} <==> H^+_{(aq)} + OH^-_{(aq)})$ $K_w = [H^+]^2 = 1.0 \times 10^{-14}$

$[H^+_{(aq)}] = [OH^-_{(aq)}] = 1.0 \times 10^{-7}$ mol/L in **neutral** solutions.

Arrhenius's Theory - acid is a substance that ionizes water t produce H^+ ions.
- additional ions produced by the acid increases the H^+ concentration in the water. (more acid, more H^+)

Therefore acids always have a $[H^+] > 10^{-7}$ mol/L

Basic solutions produce a $[OH^-]$ greater than 10^{-7} mol/L

K_w can be used to calculate either $[H^+]$ or $[OH^-]$

since $\mathbf{K_w = [H^+]\,[OH^-]}$ then $[H^+] = K_w / [OH^-]$

and $[OH^-] = K_w / [H^+]$

pH and pOH

$pH = -\log[H^+_{(aq)}]$ $pOH = -\log[OH^-_{(aq)}]$

$[H^+_{(aq)}] = 10^{-pH}$ $[OH^-_{(aq)}] = 10^{-pOH}$

Ex. Calculate the pH of a solution where $[H^+_{(aq)}] = 3.24 \times 10^{-4}$M.

$$pH = -\log[H^+_{(aq)}]$$
$$pH = -\log[3.24 \times 10^{-4}]$$
$$\boxed{pH = 3.489}$$

Ex. Calculate the concentration of hydroxide ions in a solution with a pOH of 10.14.

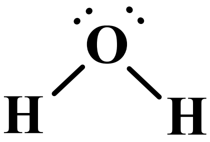
$$[OH^-_{(aq)}] = 10^{-pOH}$$
$$[OH^-_{(aq)}] = 10^{-10.14}$$
$$\boxed{[OH^-_{(aq)}] = 7.2 \times 10^{-11}\ M}$$

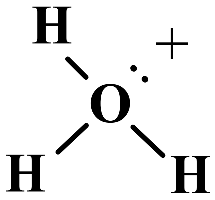
$\boxed{10^x}\ \boxed{-}\ \boxed{10.14}$

#11,12 p.599
#13,14 p.600
#15,16 p.601

#17-21 p.604

H^+





Write ionic equations for each of the following substances reacting with water:

a) $HNO_{3(aq)}$ forms an acidic solution

$$HNO_{3(aq)} + H_2O_{(\ell)} \rightleftharpoons NO_{3\,(aq)}^{-} + H_3O^{+}_{(aq)}$$

b) $HSO_4^{-}{}_{(aq)}$ forms a basic solution

$$HSO_{4\,(aq)}^{-} + H_2O_{(\ell)} \rightleftharpoons H_2SO_{4(aq)} + OH^{-}_{(aq)}$$

c) $H_2PO_4^{-}{}_{(aq)}$ forms a basic solution

$$H_2PO_{4\,(aq)}^{-} + H_2O_{(\ell)} \rightleftharpoons H_3PO_{4(aq)} + OH^{-}_{(aq)}$$

d) $NH_4^{+}{}_{(aq)}$ forms an acidic solution

$$NH_{4\,(aq)}^{+} + H_2O_{(\ell)} \rightleftharpoons NH_{3(aq)} + H_3O^{+}_{(aq)}$$