The Nature of Acid-Base Equilibria

Properties of Acids and Bases

Acids

- Sour tasting
- React with some metal to form H_2 gas
- Turns blue litmus red
- Colourless in phenolphthalein
- Conduct electricity

Bases

- Bitter tasting
- Feels slippery
- Turns red litmus blue
- Pink in phenolphthalein
- Conduct electricity

Arrhenius Acids and Bases

- **Acid:** a substance that produces H_3O^+ when dissolved in water.
  - $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$
  - $H^+_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)}$ (Hydronium)
- **Base:** a substance that produces OH^- when dissolved in water
  - $NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Bronsted-Lowry Acids and Bases

* Acids: proton (H+) donors
  * $HF_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + F^-_{(aq)}$
* Bases: proton acceptors
  * $NH_{3\,(aq)} + H_2O_{(l)} \rightarrow NH_4^+_{(aq)} + OH^-_{(aq)}$

H_2O: acts as an acid and a base
AMPHOTERIC

Bronsted-Lowry Acids and Bases

* **Acid-Base Conjugate Pairs:** two species that differ by a proton
    * $HF + H_2O \rightarrow F^- + H_3O^+$
* HF and F^- make up a acid-base conjugate pair. F^- is the conjugate base of HF.

Ion Product Constant of Water (K_w)

Autoionization of Water

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

Acid | Base | Acid | Base

Ion Product Constant of Water (K_w)

* The equilibrium constant for this reaction is called K_w
    * $K_w = [H3O^+][OH^-] = 1.0 \times 10-14$
* K_w changes with temperature and is equal to 1.0×10^{-14} at 25ºC.

Example

* Calculate the hydroxide ion concentration of a solution in which the hydrogen ion concentration is 3.6×10^{-3} M

Solution

* $K_W = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$
* $(3.6 \times 10^{-3})[OH^-] = 1.0 \times 10^{-14}$
* $[OH^-] = 2.8 \times 10^{-12}$ M

pH Scale

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

Example

* The pH reading of a solution is 10.33. What is its hydrogen ion concentration?

Solution

* $pH = -\log[H^+]$
* $[H^+] = 10^{-pH}$
* $[H^+] = 10^{-10.33}$
* $[H^+] = 4.7 \times 10^{-11}$ M

P-notation

* The p-notation can be used for any scale with low numbers.
* $pOH = -\log[OH^-]$

The Relationship between pH and pOH

* $[H_3O^+][OH^-]$ = K_w
* pH + pOH = 14.00

Example 1

* Water taken from a lake was found to have $[H^+]=3.2 \times 10^{-5}$ M. Calculate the pH and pOH.

Solution

* pH = -log[3.2 x 10^{-5}]
* pH = 4.49

* pOH = 14 - 4.49
* pOH = 9.51

Strong Acids and Cases

* ionize (splits up into ions) almost 100% in water
* NO EQUILIBRIUM
* mostly ions in solution

Example

* Calculate the pH of a 0.017 M $Ba(OH)_2$ solution

Solution

* $Ba(OH)_{2(aq)} \rightarrow Ba^{2+}_{(aq)} + 2\ OH^{-}_{(aq)}$
* $[OH^-] = 2 \times [Ba(OH)_2] = 0.034$ M
* pOH= -log[OH-]
* = -log(0.034)
* pOH= 1.47
* pH = 14 - pOH
* = 12.53

Weak Acids and Bases

* Weak acids and weak bases are those that do not ionize completely in water
* A weak acid exists in equilibrium with its conjugate base.
* $HCN_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + CN^-_{(aq)}$

Competition for protons

* $HA + H_2O \rightleftharpoons H_3O^+ + A^-$

* Both H_2O and A^- are bases and compete for the proton

* If HA is a strong acid, A^- is an extremely poor proton acceptor

* If HA is a weak acid, A^- is good proton acceptor

Homework

* p 502 # 21, 22, 23