ACIDS AND BASES

Chapter Fourteen

Acids and Bases

- We have already considered the reactions of acids with bases to form water and a salt
  - All of these compounds mentioned so far contain H^+, called a proton.
- There are at least three common methods for defining acids and bases.
- The method named for Swedish chemist Svante Arrhenius defines them as follows:
  - Acids are compounds which produce H^+ ions in solution
  - Bases are compounds which produce OH^- ions in solution

Brønsted-Lowry Acids and Bases

- The Brønsted-Lowry definition of acids and bases is broader than that of Arrhenius
- In particular, you will notice that we can classify many more compounds as bases under this definition
- According to this definition,
  - an acid donates H^+ in a reaction
  - a base accepts H^+ in a reaction
- As with the Arrhenius definition, acetic acid is the acid in the reaction below, and OH^- is the base

$$HC_2H_3O_{2\,(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Conjugate Acid-Base Pairs

- The <u>conjugate base</u> of a given acid is the compound and/or ion produced after the acid has donated a proton
- Examples:

Acid	Conjugate Base
$HF_{(aq)}$	$F^-_{(aq)}$
$HNO_{3(aq)}$	$NO_3^-{}_{(aq)}$
$H_2SO_{4(aq)}$	$HSO_4^-{}_{(aq)}$
$H_3PO_{4(aq)}$	$H_2PO_4^-{}_{(aq)}$

Note that the charge of the conjugate base is one less than that of the acid.

Conjugate Acid-Base Pairs

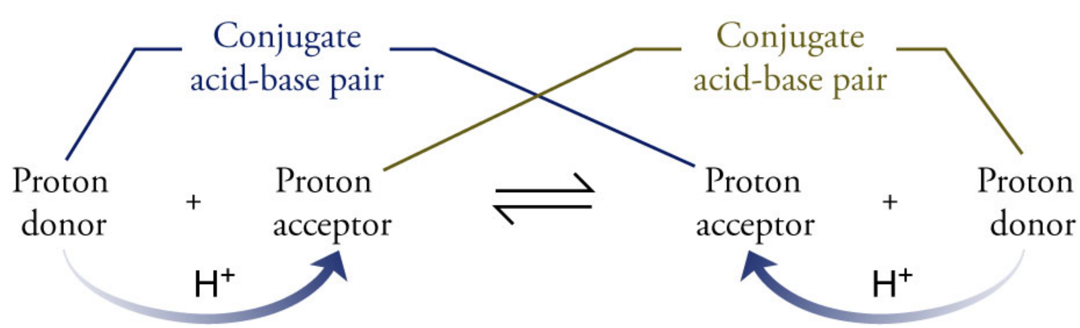
- Similarly, the conjugate acid of a given base is the compound and/or ion produced after the base has accepted a proton
- Examples:

Base	Conjugate Acid
$OH^-_{(aq)}$	$H_2O_{(l)}$
$CO_3^{2-}{}_{(aq)}$	$HCO_3^-{}_{(aq)}$
$HSO_4^-{}_{(aq)}$	$H_2SO_{4(aq)}$
$ClO^-_{(aq)}$	$HClO_{(aq)}$

Note that the charge of the conjugate acid is one greater than that of the base.

Conjugate Acid-Base Pairs

- Given the net-ionic equation for a reaction between a Brønsted-Lowry acid and base, we can classify the products as the conjugate base and acid of the reactants



Conjugate Acid-Base Pairs

Example: Identify the acid, base, conjugate acid, and conjugate base in the following net-ionic equations:

$$H_2S_{(aq)} + NH_{3(aq)} \text{ Ý } HS^-_{(aq)} + NH_4^+{}_{(aq)}$$

$$PO_4^{3-}{}_{(aq)} + H_2C_2O_{4(aq)} \text{ Ý } + HC_2O_4^-{}_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

Amphoteric Substances

- Some substances are <u>amphoteric,</u> meaning that they can act as either an acid or a base, depending on the environment
- The classic example is the bicarbonate ion, which acts as a base when added to acid, and acts as an acid when added to base
- This allows us to treat both acid and base spills with baking soda (sodium bicarbonate)

$$HCO_3^-{}_{(aq)} + HCl_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + Cl^-_{(aq)}$$

base acid

$$HCO_3^-{}_{(aq)} + OH^-_{(aq)} \text{ Ý } CO_3^{2-}{}_{(aq)} + H_2O_{(l)}$$

acid base

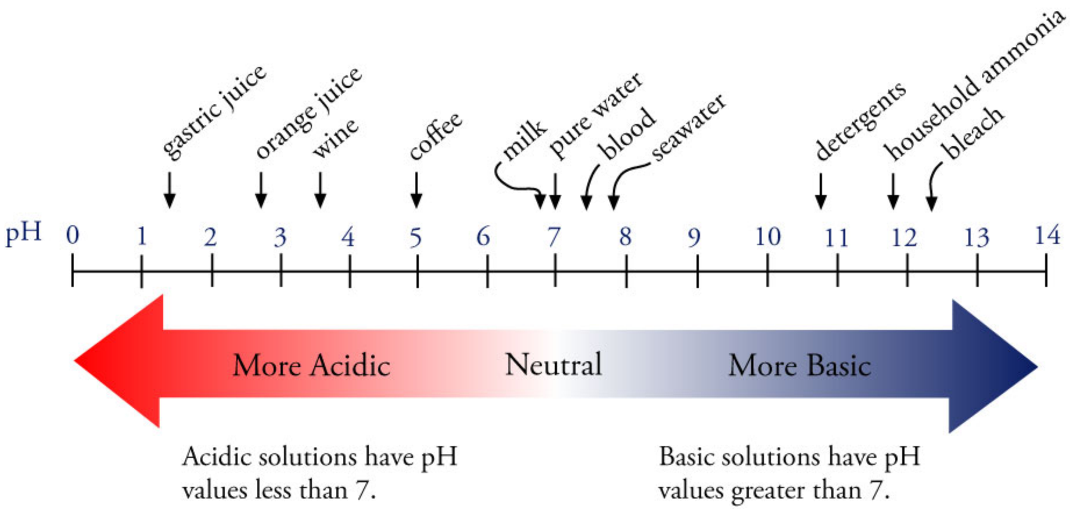
pH: The Acidity of Solutions

- The pH is a scale employed to measure the acidity (or basicity) of a solution.
- Most solutions have a pH between 0 and 14.
- A solution with pH = 7.0 is considered neutral, less than 7 is acidic, and greater than 7 is basic.
- "p" stands for $-\log_{10}$, and the H stands for $[H^+]$ (the concentration of protons).

$$pH = -\log [H^+]$$

pH

- The pH scale is a logarithmic scale, with a change of one pH-unit indicating a 10-fold change in the acidity/basicity
- For example, a solution that has pH 5 is ten-times more acidic than a solution with pH 6
  - That is, the solution with the lower pH has ten-times the concentration of H^+ ions as the other
- A solution with pH 4 is one-hundred times as acidic as one with pH 6
- Etc.



pH: The Acidity of Solutions

- Examples:

What is the pH of:

a) 0.10 M HCl
b) 0.125 M HCl
c) 1.784×10^{-2} M HNO_3

What is the molarity of an HBr solution with pH of

a) 2.00 b) 0.16

pH: The Acidity of Solutions

- The pOH is a similar measure of the basicity of a solution:

$$pOH = -\log[OH^-]$$

- The scale is like the pH scale, only inverted:
  - pOH of 7.0 is neutral, less is basic, more is acidic.

pH: The Acidity of Solutions

- A fundamental relationship for aqueous solutions at 25 °C is the following:

$$K_w = [H^+][OH^-] = 10^{-14.}$$

- We call K_w the ion product constant for water
- From this, we can derive the equivalent mathematical statement

$$pH + pOH = 14.0$$

- It is easy to see that, if we know the acidity of a solution, we can determine the basicity as well.

pH: The Acidity of Solutions

Examples:

A solution has pH = 0.67. Find the concentrations of H^+ and OH^-, and the value of pOH.

What is the value of pH, pOH, $[H^+]$, and $[OH^-]$ for a 0.0125 M NaOH solution?

Buffers

- A <u>buffer</u> is a solution that resists major changes to its pH when acid or base is added to it
- A buffer contains two essential components
  - A *weak* acid and its conjugate base, <u>or</u>
  - A *weak base* and its conjugate acid

How a Buffer Works

- Suppose we have a buffer made up of acetic acid (a weak acid) and acetate ions
  - Note that the acetate ion comes from a soluble salt, such as sodium acetate or potassium acetate
- What happens if we add some acid to this solution?
- What happens if we add some base to this solution?
- Would HCl and chloride ion form a good buffer solution?