Chemistry Lecture #89: Acids and Bases

An acid solution is a water based solution that has an excess amount of H^+. Acid solutions have a sour taste. Lemon juice is an example of an acid solution.

A basic solution is a water based solution that has an excess amount of OH^-. Basic solutions have a bitter taste and feel slippery. Soap solutions are basic solutions. If you've ever had the misfortune of tasting soapy water, you'll know that it taste bitter. And when mixed with water, soap is a slippery substance.

A basic solution can be made if a substance dissociates and forms OH^- when placed in water. For example, solid NaOH will dissolve and form Na^+ and OH^- when it is placed in water.

$$NaOH\,(s) \xrightarrow{\text{water}} Na^+(aq) + OH^-\,(aq)$$

An acid solution can be made if a substance ionizes and forms H^+ when placed in water. For example, when gaseous HCl molecules are bubbled through water, they will form H^+ and Cl^- .

$$HCl(g) \xrightarrow{\text{water}} H^+(aq) + Cl^-(aq)$$

An HCl molecule produces a single hydrogen ion when placed in water. If a molecule produces a single hydrogen ion, it is a monoprotic acid.

Some molecules can produce more than one hydrogen ion. These are called polyprotic acids. For example, H_2SO_4 can ionize to produce two hydrogen ions, which makes it a diprotic acid.

H_2SO_4 ionizes in two steps:

$$H_2SO_4 \rightleftarrows H^+ + HSO_4^-$$

$$HSO_4^- \rightleftarrows H^+ + SO_4^{2-}$$

H_3PO_4 can produce three hydrogen ions, making it a triprotic acid. It can produce three hydrogen ions in three steps:

$$H_3PO_4 \rightleftarrows H^+ + H_2PO_4^-$$

$$H_2PO_4^- \rightleftarrows H^+ + HPO_4^{2-}$$

$$HPO_4^{2-} \rightleftarrows H^+ + PO_4^{3-}$$

Substances do not necessarily have to contain hydrogen or hydroxide to produce H^+ or OH^-. Oxides of nonmetallic elements can produce an acid in an aqueous solution. For example, if sulfur trioxide gas is bubbled through water, it produces H_2SO_4, which then ionizes to produce H^+.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$H_2SO_4 \rightleftarrows H^+ + HSO_4^-$$

$$HSO_4^- \rightleftarrows H^+ + SO_4^{2-}$$

Oxides of metallic elements usually form basic solutions when placed in water. For example, Na_2O will produce NaOH, which then dissociates to form OH^-.

$$Na_2O + H_2O \longrightarrow 2NaOH$$

$$NaOH \longrightarrow Na^+ + OH^-$$

Oxides of nonmetals and metals that can be turned into acids or bases by placing them in water are called anhydrides.

Soluble ionic compounds can react with water to form acidic or basic solutions. This process is called salt hydrolysis. For example, if Na_2CO_3 is dissolved in water, it will produce a basic solution. It first dissociates to form sodium and carbonate ions.

$$Na_2CO_3 \longrightarrow 2Na^+ + CO_3^{2-}$$

The carbonate ion will then react with water to form OH^-.

$$CO_3^{2-} + 2H_2O \rightleftarrows H_2CO_3 + 2OH^-$$

An acidic solution can also be made by adding NH_4Cl to water. NH_4Cl first dissociates into ammonium and chloride ions.

$$NH_4Cl \longrightarrow NH_4^+ + Cl^-$$

The ammonium will then produce a hydrogen ion.

$$NH_4^+ \longrightarrow NH_3 + H^+$$

Actually, you never find H^+ floating around by itself in an aqueous solution. It always attaches itself to a water molecule.

$$H^+ + H_2O \longrightarrow H_3O^+$$

H_3O^+ is called a hydronium ion. So when you see H^+, it's short hand for H_3O^+.

Hydrogen ion = H^+ = H_3O^+ = hydronium ion

So another way to write the reaction of NH_4^+ with water would be

$$NH_4^+ + H_2O \longrightarrow NH_3 + H_3O^+$$