Chemistry Lecture #92: Strengths of Acids and Bases

An acid is a substance that can produce H^+ when placed in water. If the substance can produce a lot of H^+, it is a strong acid. If it produces very little, it is a weak acid.

For example, when HCl gas is bubbled through water, it produces H^+ and Cl^-.

$$HCl\,(g) \xrightarrow{\text{water}} H^+(aq) + Cl^-\,(aq) \qquad \text{100\% ionization}$$

100% ionization means that all the HCl molecules become H^+ and Cl^-. This means that a lot of H^+ is made, so HCl is a strong acid. Notice that there is a single arrow in the equation pointing to the right. This means that there is no reverse reaction, and the H^+ continues to exist.

Acetic acid, or $HC_2H_3O_2$, also produces H^+ when added to water.

$$HC_2H_2O_2 \rightleftharpoons H^+ + C_2H_3O_2^- \qquad \text{1.3\% ionization at 0.1 M}$$

In a 0.1 M solution , only 1.3 percent of the $HC_2H_2O_2$ molecules will ionize to produce H^+. Thus, there is very little H^+, so acetic acid is a weak acid. Notice that this is a reversible reaction. This means that any H^+ produced can be reunited with $C_2H_3O_2^-$.

A base is a substance that produces OH^- when added to water. If a substance produces lots of OH^-, it is a strong base. If it produces very little, it is a weak base.

For example, when NaOH is placed in water, it produces Na^+ and OH^-.

$$NaOH\ (s) \xrightarrow{\text{water}} Na^+\ (aq) + OH^-\ (aq) \quad 100\%\ \text{ionization}$$

All the NaOH becomes Na^+ and OH^- in an irreversible reaction. NaOH is a strong base.

Ammonia, or NH_3 also produces OH^- when placed in water.

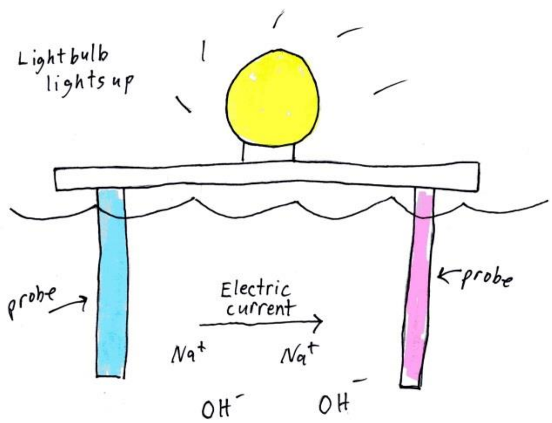
$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^- \quad 4.2\%\ \text{ionization at}\ 0.01\ M$$

At a concentration of 0.01 M, only 4.2% of the NH_3 will react to form OH^-. Notice also that the reaction is reversible, so any OH^- produced can react and turn back into H_2O. Thus, there is not very much OH^- in solution. NH_3 is a weak base.

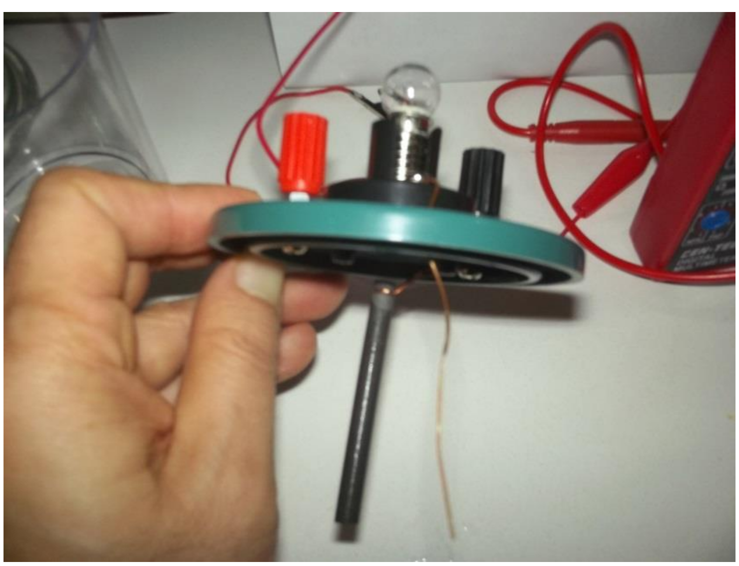
How can we tell if a solution is a weak base or a strong acid? One way is to use an electrical conductivity meter. This is a device that measures the amount of ions (like H^+ and OH^-) in a solution by passing an electric current through it. If there are a lot of ions, a lot of current will pass through, and we can conclude that we have a strong acid or base.

The electrical conductivity meter that I'll use in my demonstration has an ammeter attached and a light bulb. If there is a lot of current, the light bulb will light up. Most of the time it doesn't light up, so you have to watch the numbers on the ammeter to see how much current you have.

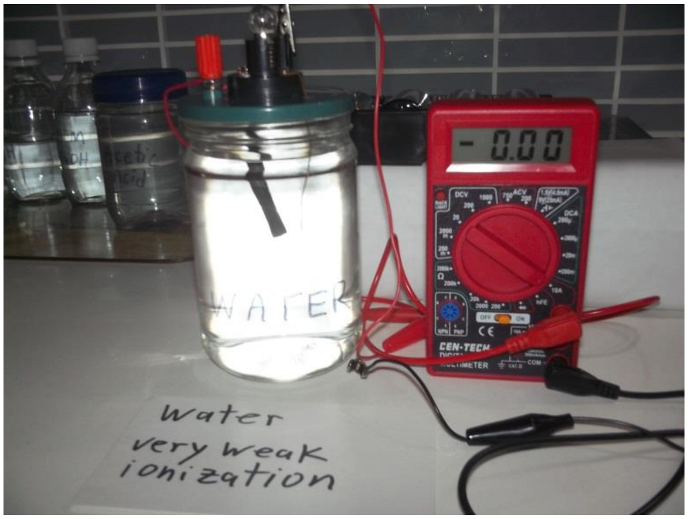
The conductivity meter has two probes that are lowered into the solution. If there are enough ions between the probes, an electric current can flow from one probe to another.



Below is a picture of the conductivity meter. The black rod and the copper wire are the probes.



Below is a picture of the conductivity meter immersed in a jar of water. Notice that the ammeter reads 0.00.



Here are the substances that we'll test using the conductivity meter, and the predicted outcome.

Water

$H_2O \rightleftharpoons H^+ + OH^-$ Very little ionization

Acetic Acid

$HC_2H_2O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$ Little ionization; weak acid

Ammonia

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ Little ionization; weak base

Sodium Hydroxide

$NaOH\ (s) \longrightarrow Na^+\ (aq) + OH^-\ (aq)$ 100% ionization; strong base

Sodium chloride

$NaCl \longrightarrow Na^+ + Cl^-$ 100% ionization

Test Results

SOLUTION	CURRENT THROUGH SOLUTION (in amperes)	
Water	0.00	
$HC_2H_3O_2$/vinegar	0.01	
NH_3	0.04	
NaOH	0.27	light bulb went on
NaCl	0.32	light bulb went on