Conjugate Acids and Bases

According to the Lowry- Brønsted theory of acids and bases, for a molecule to behave as an acid, it must be in the presence of a base that it can **donate** a proton to.

When we dissolve a strong acid in water, the acid fully protonates the water molecules which are behaving as a base.

$$\boxed{HCl_{(aq)} + H_2O_{(aq)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}}$$

Strictly speaking, this is an equilibrium that lies so far to the right-hand side that we say that the reaction goes to completion. Once the dissolved HCl molecule has donated its proton, it would seem sensible to assume that the Cl^- has no 'desire' to take it back.

Now compare this to the situation with a typical weak acid such as ethanoic acid.

$$\boxed{CH_3COOH_{(aq)} + H_2O_{(aq)} \rightleftharpoons H_3O^+_{(aq)} + CH_3COO^-_{(aq)}}$$

In this case, the ethanoic acid is far more reluctant to donate its proton. Furthermore, water isn't that great at accepting a proton from the acid. So, it seems reasonable to think that ethanoic acid molecules that have lost their proton (the ethanoate ions) may be reasonably 'keen' to get them back again from the water molecules that are holding onto them (H_3O^+) and become ethanoic acid molecules again.

That means that on the right-hand side of this equilibrium, we have another acid (H_3O^+) and another base (CH_3COO^-). This second pair of acid and a base are called the conjugate acid and conjugate base of the acid and base on the left.

H_3O^+ is the **conjugate acid** of H_2O (a conjugate pair)

CH_3COO^- is the **conjugate base** of CH_3COOH (a conjugate pair)

In general, we can write the following for all acids in water:

$$\boxed{HA_{(aq)} + H_2O_{(aq)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}}$$

The **stronger the acid HA**, the **weaker its conjugate base** (also often called **salt**).
A moderately weak acid, such as ethanoic acid with have a conjugate base (or salt) that has some base strength! In fact, a 0.100 mol dm^{-3} solution of the salt sodium ethanoate has a pH of about 9.4. It's an alkaline salt! Many salts are **NOT NEUTRAL**!

Strong acids (assumed to be 100% dissociated) have conjugate bases that have no measurable base strength. However, it is wrong to assume that a typical weak acid will have a strong conjugate base. Only if the acid is extremely weak (**very high pKa**) would its conjugate base be considered strong.
Ethanol is never normally considered to be an acid. But it is an extremely weak acid! It has a pKa of 16.0. Its conjugate base is the ethoxide ion ($CH_3CH_2O^-$).This is considered to be a strong base and produces highly alkaline solutions when the salt (sodium ethoxide, for example) is added to water.

Showing How Conjugate Bases (Salts) Produce Alkaline Solutions

If we take sodium ethanoate salt and put some into water, it reacts with the water to form an equilibrium. The Na^+ ions have been left out as they are only spectator ions!

This raises the $[OH^-]$ which raises the pH above 7

$$\boxed{CH_3COO^-_{(aq)} + H_2O_{(aq)} \rightleftharpoons CH_3COOH_{(aq)} + OH^-_{(aq)}}$$

BASE ACID CONJUGATE ACID CONJUGATE BASE

For HC*l*, the equilibrium position lies so far to the right that we don't consider it to be an equilibrium (which it strictly is).
The conjugate base of HC*l* is the Cl^- ion and we don't think of this to be basic in any way. That's why a 0.100 mol dm^{-3} solution of NaC*l* has a pH of 7.

Another way of expressing this is to say that the equilibrium when NaC*l* is dissolved in water lies **completely to the left.**
Cl^- ion accepts no protons from water and so no extra OH^- ions are produced and the salty solution remains neutral at pH 7 (@25ºC)

This has no effect on $[OH^-]$ so the solution remains pH 7

$$\boxed{Cl^-_{(aq)} + H_2O_{(aq)} \leftarrow HCl_{(aq)} + OH^-_{(aq)}}$$

BASE ACID CONJUGATE ACID CONJUGATE BASE

We can write a general equation to represent the ACID-BASE conjugate pairs idea.

$$\boxed{HA_{(aq)} + B_{(aq)} \rightleftharpoons BH^+_{(aq)} + A^-_{(aq)}}$$

ACID 1 BASE 2 CONJUGATE ACID 2 CONJUGATE BASE 1

Conjugate Pairs

Here's an interesting example from organic chemistry:

Nitric 'acid' behaving as a base! This must be done with little or **no water** or the H_2O will compete for the proton because it's a better base than HNO_3!

$$\boxed{HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-}$$

B2 A1 CONJ. A2 CONJ. B1

The $H_2NO_3^+$ then decomposes to give the nitronium cation NO_2^+