RELATION BETWEEN KA AND KB

In the last post we have seen that K_a is directly proportional to the H^+ concentration and K_b is directly proportional to the OH^- concentration. As we know that H^+ and OH^- are related to each other too, so there must be some relation between K_a and K_b.

To find out their relation we have to study a reaction in which we can get both K_a and K_b, so that we can compare them with each other. And such a reaction can be provided by Brönsted acid base pair, so let's take an example of Brönsted acid base pair:

$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

In this reaction NH_3 acts as base and it's conjugate acid is NH_4^+. If we consider forward reaction, we can get the equation for K_b:

$NH_{3(aq)} + H_2O_{(l)} \longrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$ ---------------(1)

$K_b = [NH_4^+] [OH^-]/ [NH_3]$

If we write a reaction for dissociation of acid NH_4^+, we can get the following equation for K_a:

$NH_4^+{}_{(aq)} + H_2O_{(l)} \longrightarrow H_3O^+{}_{(aq)} + NH_{3(aq)}$ ---------------(2)

$K_a = [H_3O^+] [NH_3]/ [NH_4^+]$

If we add equation 1 and 2, we will get a new equation:

$2H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$

This is the dissociation reaction of water we have studied before and we know that:

$K_w = [H_3O^+][OH^-]$

Now you can see that if we multiply K_a and K_b we will get K_w

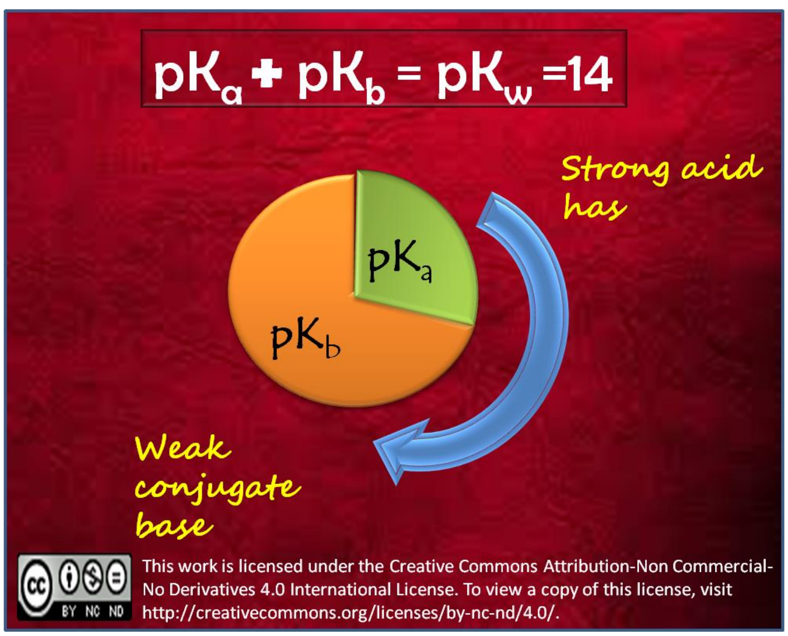
$K_a \times K_b = \{[H_3O^+] [NH_3]/ [NH_4^+]\}\{[NH_4^+] [OH^-]/ [NH_3]\}$

$K_a \times K_b = [H_3O^+] [NH_3] [NH_4^+] [OH^-]/[NH_4^+][NH_3]$

$K_a \times K_b = K_w$

If we take (–log) of both sides, we will get:

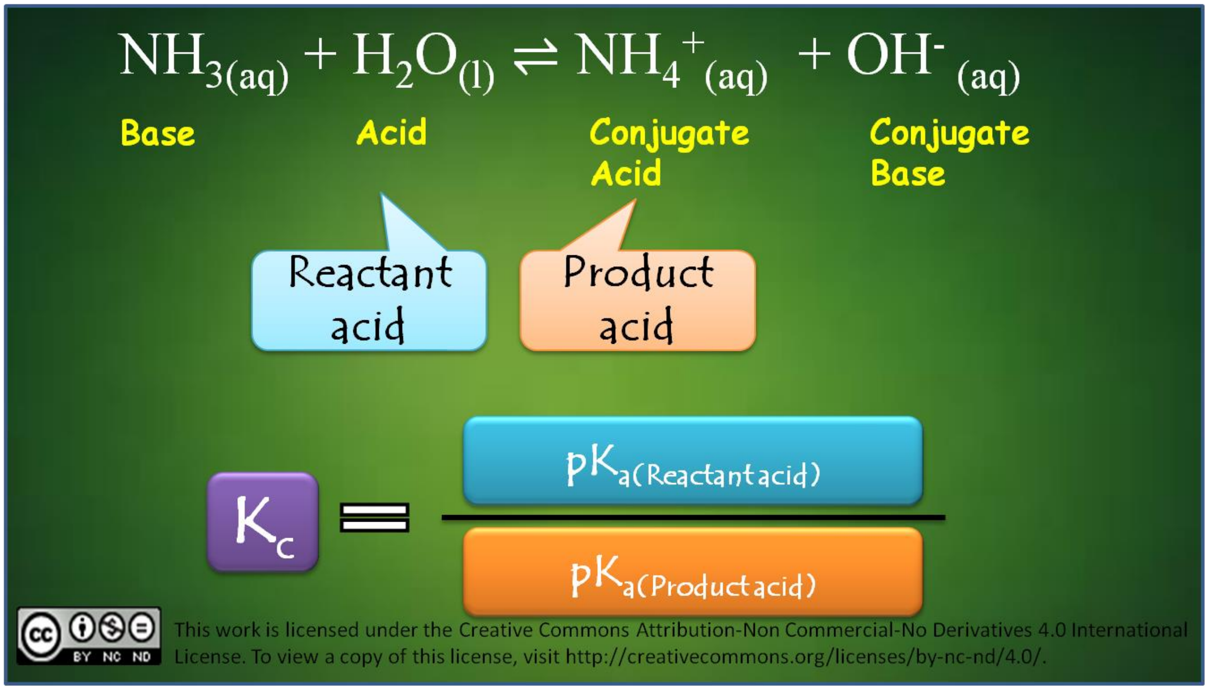
$pK_a + pK_b = pK_w = 14$



A very important conclusion can be drawn from the above equation. If pK_a of an acid is lower then its conjugate base must have higher pK_b and vise versa, which means strong acid has a weak conjugate base.

We know that smaller the pK_a, the stronger the acid. Very strong acids have pK_a less than 1, moderately strong acids have pK_ain between 1 to 5 and weak acids have pK_a in between 5 to 14.

Always remember that there is an important difference between pH and pK_a, we use pH scale to measure the acidity and pK_avalue indicates the strength of an acid. The pH is the characteristic of a solution, it means we can get solutions of different pH by dissolving the same acid in different quantities, like 1×10^{-2} M solution of HCl has pH 2 and 1×10^{-4} M solution of HCl has pH 4(HCl is a strong acid which dissociates completely i.e. its α is 1). On the other hand, pK_a is the characteristic of the particular compound, for example, pK_a of HCl is -7, HF is 3.5×10^{-4} and pK_a of HCN is 4.9×10^{-10}. It tells us how readily the compound gives up a proton H^+. By pK_a value you can also calculate the K_c



$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

$K_c = [NH_4^+][OH^-]/[NH_3][H_2O]$ -----------(3)

If we write equation for reactant acid H_2O:

$H_2O_{(l)} \longrightarrow H^+{}_{(aq)} + OH^-{}_{(aq)}$

$K_{a\ (Reactant\ acid)} = [H^+][OH^-]/[\ H_2O]$ -----------(4)

If we write equation for product acid NH_4^+

$NH_4^+{}_{(aq)} + H_2O_{(l)} \longrightarrow H^+{}_{(aq)} + NH_{3(aq)}$

$K_{a\ (Product\ acid)} = [H^+]\ [NH_3]/\ [NH_4^+]$ -----------(5)

When we compare equation 3, 4 and 5, we can infer that:

$K_c = K_{a\ (\text{Reactant acid})} / K_{a\ (\text{Product acid})}$

Now you are able to measure the strength of an acid, but what are the factors which make an acid strong or weak? Is it something which is hidden in its structure? In the next post we will try to reveal its secret.

Source : http://chemistrynotmystery.blogspot.in/2015/02/relation-between-ka-and-kb.html