

Strong & Weak Bases

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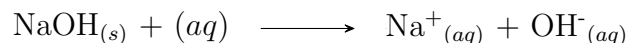
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1 Introduction

Bases are substances that are alkali, meaning that they can accept protons from proton donors. They are considered to be the opposite of acids.

2 Strong Bases

A strong base is something like sodium hydroxide or potassium hydroxide which is fully ionic. You can think of the compound as being 100% split up into metal ions and hydroxide ions in solution. Each mole of sodium hydroxide dissolves to give a mole of hydroxide ions in solution.



Some strong bases like calcium hydroxide aren't very soluble in water. That doesn't matter - what does dissolve is still 100% ionised into calcium ions and hydroxide ions. Calcium hydroxide still counts as a strong base because of that 100% ionisation. One way to determine the strength of a base is by working out the pH of that strong base. The general formula to calculate pH is as shown:

$$pH = -\log_{10}[H^+] \quad (1)$$

This equation is used to determine the pH of an acid which will dissociate to produce H^+ ions. Bases however, do not produce any H^+ ions through dissociation. So to calculate the pH of a base, you need to use the ionic product of water, K_w :

$$K_w = [H^+][OH^-] \quad (2)$$

Which we can re-arrange to give the following equation:

$$[H^+] = \frac{K_w}{[OH^-]} \quad (3)$$

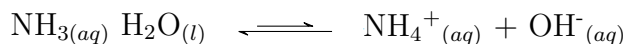
Then, by substituting equation (3) into equation (1), we get:

$$pH = -\log_{10} \frac{K_w}{[OH^-]} \quad (4)$$

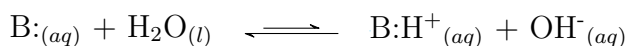
For example, to find the pH of 0.500 mol dm⁻³ sodium hydroxide solution, you would substitute $[OH^-]$ with 0.500, because the sodium hydroxide is fully ionic, and each mole of it gives that same number of moles of hydroxide ions in solution. You would also then substitute K_w with 1.00×10^{-14} . This would give you a pH value of 13.7. This makes sense since all alkaline solutions have a pH value that is above 7, and this value of 13.7 is on the higher end of the spectrum. This equation also shows that a pH of 14 can only be obtained by an $[OH^-]$ concentration of 1 mol dm⁻³.

3 Weak Bases

Ammonia is a typical weak base. Ammonia itself obviously doesn't contain hydroxide ions, but it reacts with water to produce ammonium ions and hydroxide ions.



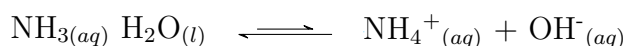
As you can see, this reaction is reversible, and it heavily favours the left hand side. At any one time about 99% of the ammonia is still present as ammonia molecules. Only about 1% has actually produced hydroxide ions. A weak base is one which doesn't convert fully into hydroxide ions in solution. When a weak base reacts with water, the position of equilibrium varies from base to base. The further to the left it is, the weaker the base. This is the general equation of the reaction between a weak base and water:



The two dots represent the lone pair of electrons on the base which accepts the hydrogen ion. You can get a measure of the position of an equilibrium by writing an equilibrium constant for the reaction. The lower the value for the constant, the more the equilibrium lies to the left. In this case the equilibrium constant is called K_b . This is defined as:

$$K_b = \frac{[\text{B:H}^+][\text{OH}^-]}{[\text{B:}]} \quad (5)$$

The $[\text{H}_2\text{O}]$ term is removed since it is so much larger than the other terms and it is virtually a constant regardless of the values of the other terms. Using the example shown above, we can calculate the value of the base dissociation constant.



Which gives an equilibrium constant of the form:

$$K_b = \frac{[\text{NH}_4^+(aq)][\text{OH}^-(aq)]}{[\text{NH}_3(aq)]} \quad (6)$$

The following table shows some values of K_b for some weak bases:

Base	K_b (mol dm ⁻³)
$\text{C}_6\text{H}_5\text{NH}_2$	4.17E -10
NH_3	1.78E -5
CH_3NH_2	4.37E -4
$\text{CH}_3\text{CH}_2\text{NH}_2$	5.37E -4

These are all weak bases because their values of K_b are very small. These values are listed in increasing base strength. However the notation of K_b is such that it is not easy to differentiate between the various values of K_b due to the addition of the exponent values. To avoid confusion, and to aid readability, we convert the values from K_b to pK_b . pK_b bears exactly the same relationship to K_b as pH does to hydrogen ion concentration:

$$pK_b = -\log_{10}K_b \quad (7)$$

Now, if you use your calculator, and use the equation above on all of the K_b values in the table from before, you get:

Base	$K_b(\text{mol dm}^{-3})$	pK_b
$C_6H_5NH_2$	4.17E -10	9.38
NH_3	1.78E -5	4.75
CH_3NH_2	4.37E -4	3.36
$CH_3CH_2NH_2$	5.37E -4	3.27

Notice that the weaker the base, the larger the value of pK_b . It is now comparatively easier to see the trend between the values in the table.