Acids & Bases - 1 - Additional Ideas

1. Neutral solutions, pH and temperature

The pH of a neutral solution depends on the temperature of the solution.

This occurs because if the temperature of a solution is changed, the value of the equilibrium constant also changes. In any aqueous solution, the following equilibrium exists:

$$2H_2O(l) \leftrightharpoons H_3O^+(aq) + OH^-(aq)$$

At 25ºC, the value of the equilibrium constant for this equilibrium is 1×10^{-14}. That is, in any aqueous solution at 25ºC

$$[H_3O^+] \times [OH^-] = 1 \times 10^{-14}$$

At different temperatures, the value of the equilibrium constant will not be equal to 1×10^{-14}. Because the self-ionisation reaction of water is an endothermic reaction, if the temperature of the aqueous solution is increased, the value of the ionisation constant will increase, and if the temperature is decreased, the value of the constant will decrease.

A solution is neutral when $[H_3O^+] = [OH^-]$.

At 25ºC, the pH of a neutral solution is 7 because in a neutral solution $[H_3O^+] = [OH^-]$ and so

$$[H_3O^+]^2 = 1 \times 10^{-14}$$

i.e. $[H_3O^+] = 1 \times 10^{-7}$ i.e. the pH will be 7

However, for neutral solutions at temperatures higher than 25ºC, the pH will be less than 7. This is because the relationship, $[H_3O^+] = [OH^-]$ still exists, but the equilibrium constant is larger than 1×10^{-14}, for example 1×10^{-12}

i.e $[H_3O^+]^2 = 1 \times 10^{-12}$

i.e. $[H_3O^+] = 1 \times 10^{-6}$ i.e. the pH will be 6 i.e. less than 7.

At temperatures less than 25ºC, the pH of a neutral solution will be greater than 7.

2. Why is the pH of 1×10^{-8} mol L^{-1} HCl not 8?

In any aqueous acidic solution, the H_3O^+ ions are formed from the hydrolysis reaction of the acid, and the self-ionisation reaction of water. Normally the number of hydronium ions formed from the self-ionisation of water is so small, that they can be ignored. However, if only an extremely small amount of acid is present, then we need to include the hydronium ions produced in this water self-ionisation reaction.

For example, if 1×10^{-8} moles of HCl are added to 1 L if water, the moles of H_3O^+ ions formed is 1×10^{-8} i.e. 0.00000001 moles.

Also the 1 L of water has self-ionised to form 1×10^{-7} moles of H_3O^+ (i.e. 0.0000001 moles).

So in total there are 0.00000011 moles of H_3O^+ ions in 1 L of the solution.

The pH is therefore $-\log(1.1 \times 10^{-7}) = 6.96$ i.e. not 8.