CLIL - Buffers

Most simply defined, a buffer is composed of a weak acid and its conjugate base. A buffer is an aqueous solution containing partly neutralized weak acids or bases that shows little change in pH when small amounts of strong acids or bases are added. The concentration of hydrogen ions is of critical importance in biological and chemical systems. Measurement of pH is actually another way of expressing the concentration of hydronium ions [H_3O^+] in a solution. Hydronium ion concentrations have important implications in cell metabolism by affecting the rate of enzymatic reactions and the stability of biological molecules. For example, maintenance of an appropriate pH range in tissue culture media is critical to the growth and viability of all cultured cells. The efficiency of many chemical separations and the rate of many chemical reactions are ruled by the pH of the solution. Buffers can be used to control the rate and yields in organic synthesis. The hydrogen ion concentration is also an important parameter to control in numerous laboratory research techniques such as: electrophoresis, chromatography, and immunoassays. Uncontrolled pH can result in unsuccessful immunoassays since the required protein-protein interactions cannot occur efficiently outside the range of physiological pH. The ionization of water is a reversible reaction which can be described as the dissociation of H_2O into its component ion products [H_3O^+] and [OH^-]:

$$2H_2O \rightleftarrows H_3O^+ + OH^-$$

The equilibrium of this reaction (Kw) can be described in terms of the ion products where $[H_3O^+]\cdot[OH^-] = Kw = 1 \cdot 10^{-14}$. At neutral conditions and a temperature of 25°C, $[H_3O^+] = [OH^-] = 1 \cdot 10^{-7}$ M, or pH = 7.0. The hydrogen ion concentration of a solution is usually expressed as pH (-log [H_3O^+]). Most biological systems have pH values between 6.5 and 8.0, while biochemical reactions may occur optimally at pH values ranging from 4.5 to 9.7. The optimal pH of a system depends upon the chemical nature of the ionizable groups in the reactive molecules. Many biologically important molecules contain chemical constituents which act as weak acids or bases in an aqueous solution. While strong acids dissociate completely into their component ion groups, weak acids dissociate incompletely and form an equilibrium between the weak acid and its conjugate base. For example, formic acid (HCOOH) dissociates into [H_3O^+] and [COO^-] where the equilibrium constant (Ka) for the weak acid can be described mathematically as:

$$Ka = [H_3O^+] \cdot [HCOO^-] / [HCOOH]$$

and pKa = -log Ka. For example, if a 1M solution of formic acid is half neutralized with 0.5M base such as NaOH, the resulting pH should be equal to 3.75, the pKa of formic acid. Because of the above relationship between weak acid dissociation and pKa, pKa values approximate the midpoint in pH values for effective buffering. From this relationship, we see that the pKa value will vary inversely with the strength of the acid. Substitution into this equation gives the Henderson-Hasselbach equation, where:

$$pH = pKa + \log [A-] / [HA]$$

When 50% of a weak acid is dissociated, [A-] = [HA] and the log [A-] will be zero. [HA] Thus, the pKa of weak acid will be equal to its pH at 50% dissociation. This relationship can be used to determine the pKa of a weak acid. Buffers consist of two ionic components, a weak acid (the proton donor) and a corresponding base (the proton acceptor). The ionic character of an aqueous buffer makes the solution relatively resistant to changes in pH upon the addition of small amounts of exogenous acid or base. The most effective pH range for a buffer is generally one pH unit and is centered around the pKa for the system. This relationship is important in choosing a buffer.

Adapted from: http://wolfson.huji.ac.il

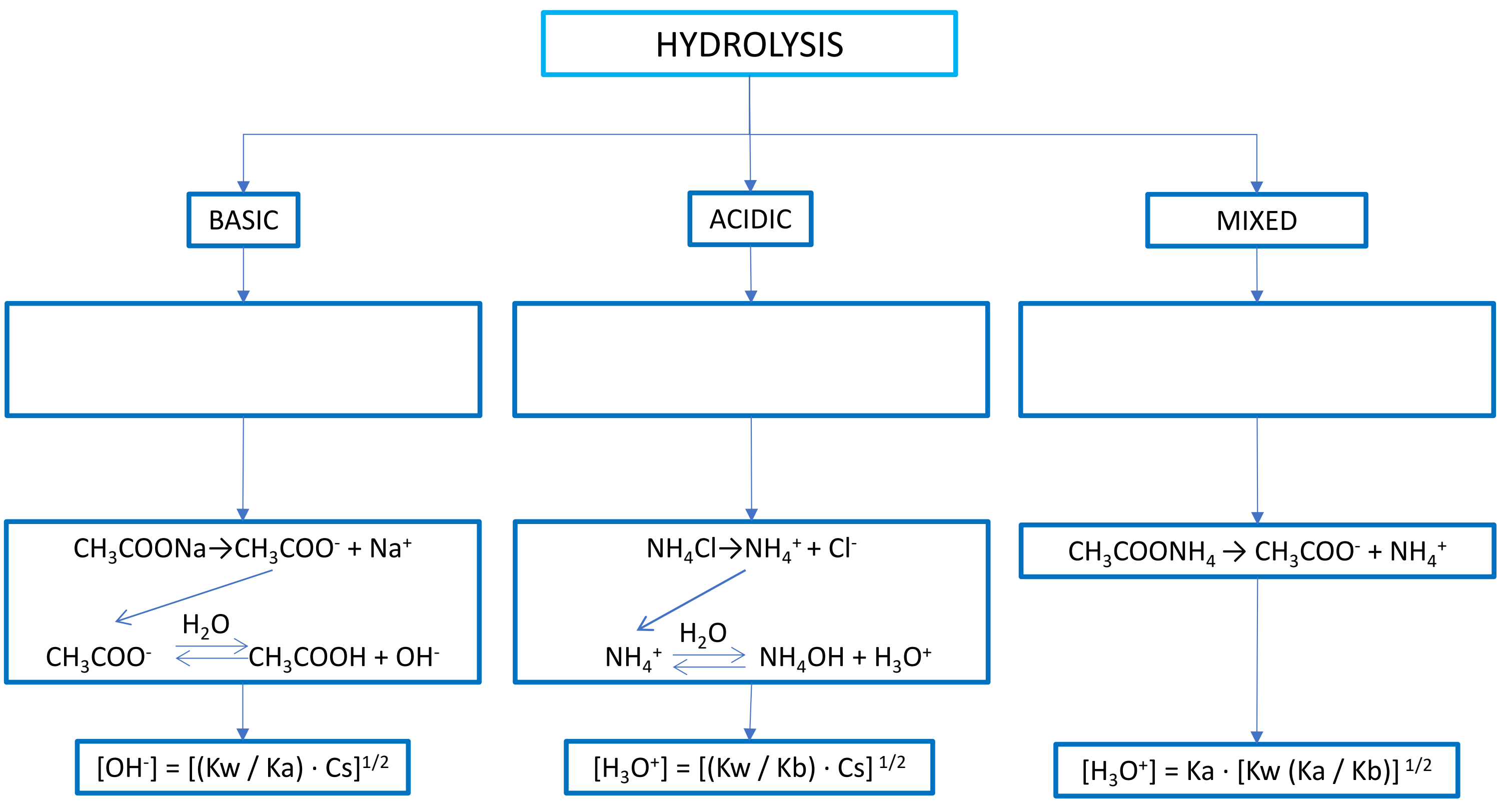
TEACHING AIMS:

- Understanding the meaning of buffer solution;
- Understanding the meaning of Henderson-Hasselbach equation;
- Understanding the differences between the different types of buffer solution;
- Understanding the different method o fuse of buffer solution;

EXERCISES (read the text)

1 Complete the scheme with the correct sentences

A) Salts composed by the cation of a weak base (e.g. NH_4OH) and the anion of a strong acid (e.g. HCl)
B) Salts composed by the cation of a strong base (e.g. NaOH) and the anion of a weak acid (e.g. CH_3COOH)
C) Salts composed by the cation of a weak base (e.g. NH_4OH) and the anion of a weak acid (e.g. CH_3COOH)



2 Read the definitions in the scheme and complete the missing spaces