Buffers are compounds that resist changes in pH upon the addition of limited amounts of acids or bases. Buffer systems are usually composed of a weak acid or base and its conjugate salt. The components act in such a way that addition of an acid or base results in the formulation of a salt causing only a small change in pH.

The pH of a buffer system is given by the Henderson-Hasselbach equation:

$pH = pKa + \log\frac{[salt]}{[acid]}$ (for a weak acid and its salt)

$pH = pKw - pKb + \log\frac{[base]}{[salt]}$ (for a weak base and its salt)

where [salt], [acid] and [base] are the molar concentrations of salt, acid and base.

Buffer capacity

Buffer capacity is a measure of the efficiency of a buffer in resisting changes in pH. Conventionally, the buffer capacity (β) is expressed as the amount of strong acid or base, in gram-equivalents, that must be added to 1 liter of the solution to change its pH by one unit.

Calculate the buffer capacity as:

$$\beta = \frac{\Delta B}{\Delta pH}$$

ΔB = gram equivalent of strong acid/base to change pH of 1 liter of buffer solution

ΔpH = the pH change caused by the addition of strong acid/base

In practice, smaller pH changes are measured and the buffer capacity is quantitatively expressed as the ratio of acid or base added to the change in pH produced (e.g., mEq./pH for x volume). The buffer capacity depends essentially on 2 factors:

Ratio of the salt to the acid or base. The buffer capacity is optimal when the ratio is 1:1; that is, when pH = pKa**Total buffer concentration.** For example, it will take more acid or base to deplete a 0.5 M buffer than a 0.05 M buffer.

The relationship between buffer capacity and buffer concentrations is given by the Van Slyke equation:

$$\beta = 2.3\,C\,\frac{Ka[H_3O^+]}{(Ka + [H_3O^+])^2}$$

where C = the total buffer concentration (i.e. the sum of the molar concentrations of acid and salt).

Just as we must often compromise the optimal pH for a product, so must we compromise on the optimal buffer capacity of our solution. On the one hand, buffer capacity must be large enough to maintain the product pH for a reasonably long shelf-life. Changes in product pH may result from interaction of solution components with one another or with the product package (glass, plastic, rubber closures, etc.). On the other hand, the buffer capacity of ophthalmic and parenteral products must be low enough to allow rapid readjustment of the product to physiologic pH upon administration. The pH, chemical nature, and volume of the solution to be administered must all be considered. Buffer capacities ranging from 0.01 - 0.1 are usually adequate for most pharmaceutical solutions.