Buffer and buffer capacity

A buffer system is a mixture of a weak acid or a weak base and its salt (conjugate base or conjugate acid, respectively) that permits solutions to resist large changes in pH upon the addition of small amounts of hydrogen ions (H+) or hydroxide ions (OH-). If the same amount of the buffer is added, the pH may only change a fraction of a unit. Our blood is a good example of a buffered system. It is maintained under a pH of 7. 4. Thus, buffers are important in many areas of chemistry especially so in biochemistry – in cases when proteins and enzymes are being studied.

The hydrogen ion is one of the most important ions in biological systems. The concentration of this ion affects most cellular processes. For example, the structure and function of most biological macromolecules and the rates of most biochemical reactions are strongly affected by [H+]. The pH scale has been devised as a convenient method of expressing hydrogen ion concentration. Body fluids contain buffering agents and buffer systems that maintain pH at or near pH= 7. 4.

Important endogenous (natural) buffer systems include carbonic acid/sodium bicarbonate and sodium phosphate in the plasma and hemoglobin, and potassium phosphate in the cells. An in vivo value of pH < 6. 9 or pH > 7. 8 can be life threatening. Differences in only a few tenths of a pH unit can cause illness or death. So it is important for our body system to maintain its physiologic pH. Acidosis is the condition when pH drops too low. Alkalosis results when the pH is higher than normal. Two species are required in a buffer solution.

One is capable of reacting with OH- and the other will react with H3O+ and they must not react with each other. Many buffers are prepared by combining a weak acid and its conjugate (as in this experiment, acetic acid and sodium acetate) or a weak base and its conjugate (ammonia and ammonium chloride). In general, the pH range in which a buffer solution is effective if +/- one pH unit on either side of the pKa. The Henderson–Hasselbalch provides the information needed to prepare a buffer.

In the experiment, the Henderson-Hasselbalch equation was used to determine the amount of acetic acid and sodium acetate required to prepare a series of buffer solutions (calculation for the preparation are shown in part IV). After preparing the buffer solutions and titrating, their average buffer capacity was then determined. The average buffer capacity of 0. 1M, 0. 3M, and 0. 5M acetate/acetic acid buffer solution was 0. 0276, 0. 0741 and 0. 1328, respectively.

The equilibrium equation for the acetic acid/acetate buffer solution is shown below: It should be noted that reference is made to weak acids and bases - acids and bases that do not undergo complete ionization in water. In the experiment, the acetic acid (CH3COOH) is mixed with its conjugate base, acetate (CH3COO -) . The mixture contains both an acid and a base that reacted with the added base (NaOH). When, for example, a source of H+ is added, the conjugate base, acetate, will react as follows:

H+ + CH3COO - ---------> CH3COOH

When a source of OH - is added, as what is in the experiment, the weak acid acetic acid, reacts as follows:

CH3COOH + OH - -------> H2O + CH3COO –

In either case, the invading species is not allowed to change the pH of the solution. One must use weak acids in buffers so the conjugate bases will have a tendency to react with protons. If a strong acid were mixed with its conjugate base, the conjugate base would have no tendency to react with protons. The buffer capacity depends upon two factors. The concentration of the buffer is one major factor. The more concentrated the buffer, the more ingredients are available to attack added H+ and OH – ions. The second factor relates to what is being added to the buffer and how much of each component, acid and conjugate base, is available to react.

So buffers with higher concentrations offer higher buffering capacity and it can be seen on the results shown in Table 1. Theoretically, however, pH is dependent not on the absolute concentrations of buffer components, but on their ratio. A buffer capacity of 1 is when 1 mole of acid or alkali is added to 1 liter of buffer and pH changes by 1 unit. The buffer capacity of a mixed weak acid-base buffer is much greater when the individual pKa values are in close proximity with each other. It is important to note that the buffer capacity of a mixture of buffers is additive.