Buffer Solutions

A small amount of strong acid or base is sufficient to change $[H^+]$ ion concentration of water in the slightly acidic or basic region; one drop of strong concentrated acid added to a liter of water increases the hydrogen ion concentration as much as 5000 fold making it appreciably acidic, and two drops of strong alkali decreases the $[H^+]$ ion concentration by a factor of over a million making it more basic. However, there are some solutions to which small amount of acid or base can be added without appreciably changing the $[H^+]$ ion concentration (pH). These solutions are known as buffer solutions.

Buffer solutions or simply buffers are very important in chemical, biological, and biochemical systems as well as in research. They help to sustain the life process by maintaining the pH in the body at a constant level. For example, a particular pH is needed for enzymes to function properly (the optimal function of enzymes is vital for survival of life) and also for osmotic pressure to balance properly. The pH in human body varies greatly from fluid to fluid; pH of blood is about 7.4 and of gastric juice secreted in stomach is about 1.5. There are many buffer systems in the body to maintain the pH. For example, bicarbonate/carbonic acid (HCO_3^-/H_2CO_3) buffer present in the blood.

A **buffer solution** is a solution of weak acid and its salt or a weak base and its salt that resists the change in pH when a small amount of either an acid or a base is added.

Characteristic of a Buffer Solution

A buffer solution has the ability to resist change in pH upon the addition of **small amount** of either acid or base.

Requirements

There are three requirements for buffer:

- Must be a mixture of weak acid and its salt or weak base and its salt
- A buffer must contain relatively large concentration of acid to react with added base (OH^-) and also must contain similar concentration of base to reaction with added acid (H^+).
- The acid and base components of the buffer must not consume each other in a neutralization reaction.

Preparation of Buffer Solution

A buffer solution is prepared by mixing equal amount of weak acid and its salt, such as, acetic acid (CH_3COOH) and sodium acetate (CH_3COONa) or weak base and its salt, such as, ammonia (NH_3) and ammonium chloride (NH_4Cl).

Buffer Action

Let us see how the buffer reacts to the addition of small amount of acid or base. To illustrate this, consider the buffer containing acetic acid and sodium acetate.

Sodium acetate, a strong electrolyte, dissociates completely in water:

$$CH_3COONa(s) \longrightarrow CH_3COO^-(aq) + Na^+(aq)$$

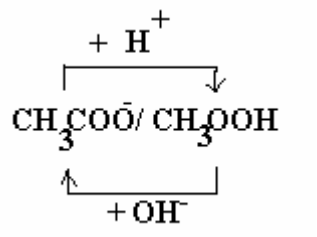
If an acid added, the H^+ ions will react with conjugate base (CH_3COO^-) in the buffer according to the equation

$$CH_3COO^-(aq) + H^+(aq) \longrightarrow CH_3COOH(aq)$$

The acid, thus regenerated, is a part of the buffer solution. On the other hand, if a base is added to the system, the OH^- ions will react with acid (CH_3COOH) according the following equation.

$$CH_3COOH(aq) + OH^- \longrightarrow CH_3COO^-(aq) + H_2O(l)$$

The conjugate base, thus regenerated, is also a part of the buffer solution. Therefore, you can see that no buffer solution is consumed. This is how the buffer action takes.



Buffer Capacity

The **buffer capacity** is defined as the effectiveness of the buffer solution that depends on the amounts of acid and conjugate base used to make the buffer solution; the larger amount, the greater the buffer capacity.

Representing the Buffer System

In general, a buffer system can be represented by writing a salt followed by slash and an acid or conjugate base followed by slash and an acid like

salt/acid or **conjugate base/acid**

Thus, the sodium acetate-acetic acid buffer system can be written as

CH_3COONa/ CH_3COOH or CH_3COO^-/CH_3COOH

Similarly, ammonia-ammonium chloride buffer system can be represented as

NH_3 / NH_4^+

Note that NH_4^+ is an acid and NH_3 is a conjugate base.

Example

Which of the following are buffer systems?

(a) KF/HF
(b) KBr/HBr
(c) $Na_2CO_3/NaHCO_3$
(d) $NaClO_4/HClO_4$
(e) NH_3/NH_4NO_3

Answer

(a) HF is a weak acid and KF is its salt. Therefore, this is a buffer system.
(b) HBr is a strong acid and hence this is not a buffer system.
(c) $NaHCO_3$ contains a weak acid (HCO_3^-) and Na_2CO_3 is a salt of weak acid. Therefore, this is a buffer system.
(d) $HClO_4$ is a strong acid and hence this is not a buffer system.
(e) NH_3 is a weak base and NH_4NO_3 is a salt of weak base, and therefore this is a buffer system.