THE APPLICATION OF THE BRÖNSTED THEORY[1] TO BIOCHEMISTRY AND NUTRITION

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When Arrhenius introduced his theory on acids and bases, developments in chemistry were just beginning. Fortunately, his theory does not contradict the more modern theory introduced by Brönsted. The latter theory is merely an advancement which brings out a clearer understanding of acids and bases.

In a recent article[2], it was pointed out that there is need to break away from the older theory and apply the more modern concept to the biochemical field. If one uses the Bronsted theory, as pointed out by others, it is unnecessary to consider the solvent as far as protons are concerned. Although HOH is the biological solvent, it does seem that biochemists have been rather cautious in applying the Brönsted theory of acids and bases to the field of biochemistry. This is probably because the old Arrhenius theory does explain the facts fairly satisfactorily. However, the more recent theory is simple to understand and is certainly an advancement in theoretical chemistry because of its introduction after a better understanding of ionization was presented.

Buffers of the Blood

The buffers of the blood are usually expressed as:

$$\frac{H_2CO_3}{BHCO_3} \quad \frac{BH_2PO_4}{B_2HPO_4} \quad \frac{HHbO_2}{BHbO_2} \quad \frac{HHb}{BHb} \quad \frac{HPr}{BPr}$$

(B=base=metallic ion, Hb=hemoglobin and Pr=protein). The mathematical equation of expressing pH is given as:

$$pH = -\log K_a - \log \frac{(acid)}{(salt)} \quad \text{or } pH = pK_a + \log \frac{(salt)}{(acid)}$$

(assuming complete dissociation of the salt). If one applies

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[1] (1) An acid is anything (particles, ions or molecules) that will furnish hydrogen ions (protons). A base is anything that will combine with hydrogen ions.

[2] (2) Devor, Arthur W., On the Theory of Acids and Bases, Science **104**, 492, 1946.

the Brönsted theory, the buffers of the blood would be expressed as:

$$\frac{H_2CO_3}{HCO_3^{--}} \quad \frac{H_2PO_4^-}{HPO_4^{--}} \quad \frac{HHbO_2}{HbO_2^-} \quad \frac{HHb}{Hb^-} \quad \frac{HPr}{Pr^-}$$

(or in general $\frac{(acid)}{(base)}$). Then the equation for expressing pH becomes:

$$pH = -\log K_a - \log \frac{(acid)}{(base)} \quad \text{or } pH = pK_a + \log \frac{(base)}{(acid)}$$

In showing the equilibrium between the acid and the base, we can use the expressions:

$$\begin{array}{l} \text{base} + \text{proton} \rightleftarrows \text{acid} \\ HCO_3^- + H^+ \rightleftarrows H_2CO_3 \\ HPO_4^{--} + H^+ \rightleftarrows H_2PO_4^- \\ HbO_2^- + H^+ \rightleftarrows HHbO_2 \\ Hb^- + H^+ \rightleftarrows HHb \\ Pr^- + H^+ \rightleftarrows HPr \\ OH^- + H^+ \rightleftarrows HOH \\ H_2O + H^+ \rightleftarrows H_3O^+ \end{array}$$

When the H^+ions are formed in the body, they are absorbed by the bases (negative ions listed above) and there is very little change in the concentration of the H^+ ions (H_3O^+). When OH^- or any other strong base is formed, the acids in the blood release H^+ ions so that there is almost no change in pH.

Such an explanation of the action of buffers in the body is simple and to the point. We need only to speak of those molecules and ions involved in the buffer action. One can explain why the Ca^{++}, K^+ and Na^+ ions have been called the bases of the blood by pointing out the fact that there must be positive ions occurring with the bases (negative ions).

This explanation of buffers in the blood makes it clear that one can **not** increase the alkalinity of the blood by increasing the Na^+ ion concentration when introducing NaCl into the circulatory system because the Cl^- ion is such a weak base.

Isoelectric Point of Proteins

The application of the Brönsted theory to the amphoteric behavior of proteins simplifies the explanation of isoelectric point as far as proteins are concerned. When we consider the protein as both an acid and a base, we can write the expression:

$$\begin{array}{l} H^+ + HPr \rightleftarrows HHPr^+ \\ \qquad\quad \downarrow \uparrow \\ H^+ + Pr^- \end{array}$$

When the protein molecules are placed in a base, the hydrogen ion is taken up by the base, thus leaving the protein molecules carrying a negative charge. In an acid solution, they carry a positive charge while at the isoelectric point the average charge is zero.

With this idea in mind, one can easily understand why the protein must be on the acid side of the isoelectric point to be precipitated with negative ions, such as WO_4^{--} while for precipitation with positive ions such as Zn^{++} the protein must be on the basic side of the isoelectric point. Biochemistry students often say that this is easy to remember because the basic form of protein carries a negative charge just as the other bases do.

Application to Nutrition

This topic was discussed to a limited extent in the previous article. The fact that a vegetable diet results in an alkaline urine and that meats cause an acid urine can be explained very easily by the more modern theory. The vegetables are low in proteins but do contain metallic ions (largely K^+) and there must be negative ions with the positive ions. After absorption the metallic ions remain as positive ions, while the negative ions are largely changed to bicarbonate ions and these ions are alkaline. This causes an increase in the concentration of bases (negative ions) in the blood, thus causing an increase in the base of the urine. Of course, the positive ions must be excreted along with the negative ions. A diet rich in protein would result in oxidation of sulfur to sulfuric acid which is immediately neutralized by the bases in the blood and excreted as sulfates. To prevent the body from being depleted of bases, the kidney produces a base, NH_3, which takes up the excess hydrogen ions and is excreted as ammonium sulfate. The kidney will function in similar manner during acidosis.

The Brönsted theory is an advancement in chemistry which should not be overlooked by biochemists and biologists. It is a marvelous "tool" for explaining the acidic and basic behavior of biological materials. After teaching the principles of acids and bases to students from freshmen to the graduate level, I find the application of the more modern concept to be the easiest to present and the easiest for the students to understand.