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Full Length Research Paper

Polyhedral charge-packing model for blood pH changes in disease states

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This work is the extension to an earlier report of a model, which explained the normal blood pH of 7.4 in terms of the octahedral packing of the six hydroxyl, OH^-, ions to one hydrogen, H^+, ion that exist at that pH, as this would be the most, naturally, stable arrangement. The logical, possible shifts from the octahedral ideal are suggested to be to the next most stable and efficient natural structures, the other regular polyhedra (tetrahedron, cube, dodecahedron and the icosahedron), depending on the hydroxyl to proton ratio available. Polyhedral charge-structuring is suggested to help define a 'polyhedral charge-packing pH zone' (From pH = 7.30, for tetrahedral, to pH = 7.65 for dodecahedral packing), which lies in the neighborhood of the well known physiological pH range. Literature is cited in support of pH 7.65 as the extreme upper limit of tolerable alkalosis. Experimental results from studies on two acidotic diseases (Sickle cell disease, pH = 7.32 ± 0.08 and Asthma, pH = 7.29 ± 0.03) are presented as evidence of the tetrahedron-based tolerable, stable, low limit pH in acidosis. Some medical implications of these ideas are discussed. For instance, the model suggests that the generalized definition of metabolic acidosis as pH less than 7.3 (pH < 7.3) is informed by the underlying tetrahedral charge-packing structure at this pH, which would collapse immediately the blood pH falls below this critical threshold.

Key words: Blood, pH, polyhedral, hydroxyl, charge-packing, ions, disease states.

INTRODUCTION

A model had suggested octahedral charge-packing as the main explanation for the stability of the pH of normal mammalian blood at 7.4 (Osuagwu, 2004). The normal blood pH range is 7.35 to 7.45 (Tasota and Wesmiller, 1998). The facts considered in the model include: i. Approximately 1: 6 ratio of proton, H^+, to hydroxyl ions, OH^-, at pH of 7.4 (pOH of 6.6); ii. "…tritrable acidity is reduced and becomes zero when pH is 7.4" (Valery et al., 1980), and iii. the octahedron is the most spatially compact, energy efficient and stable structure of nature (Fuller, 1975).

Table 1 shows the relationships of pH, proton, H^+, and hydroxyl ions, OH^- , concentration at pH of 7.4. Figure 1 shows the proposed octahedral packing of the charges at pH 7.4. The six negatively charged hydroxyl ions occupy the six vertices of the octahedron, while the lone proton, H^+, occupies the octahedral hole at the centroid. This shielded location of the proton, H^+, in the 'octahedral hole' makes its titration difficult. This titration would require the negatively charged hydroxyl ions, of the base, used in the titration; to pass though the electron-cloud formed by the six negatively charged hydroxyl groups surrounding the positively charged proton. Although other factors, like hemoglobin, H_2CO_3-HCO_3^- system and Gibbs-Donnan equilibrium systems, help to buffer the blood, the octahedral framework would be very important. Octahedral charge packing can account for the common pH of 7.4 of mammals, in spite of other differences that are well known (Jackson, 1997). In the original model (Osuagwu, 2004), it was pointed out that mammalian blood plasma is not alone in the exploitation of the octahedral charge-packing motif. On page 46 of the 1975 edition of his book (Principles of Biochemistry), Lehninger had listed the pH of some fluids. It is of interest that the list included pH of 7.4 for both blood plasma and interstitial fluid as well as pH 6.6 for milk; 5 - 8 for urine and 6.35 - 6.85 for saliva. The average of 5 and 8 is 6.5; average of 6.35 and 6.85 is 6.6. It is noted, then, that the average pH of the major internal fluids of the mammalian body listed (plasma and interstitial) is 7.4, while the average pH of the external (in

Table 1. pH, pOH, of blood and hydroxyl to hydrogen ion ratio at pH 7.4.

Factor	Value
pH	7.4
$[H^+]$	$10^{-7.4}$ mol-L^{-1}
pOH	6.6
$[OH^-]$	$10^{-6.6}$ mol-L^{-1}
[OH-]/[H$^+$]	$10^{-6}/10^{-7.4} = 10^{0.8} \sim 6.31 \sim 6$

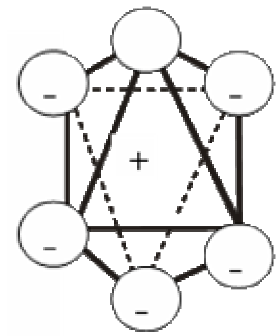

Figure 1. Octahedral charge-packing at pH 7.4.

the sense that they can leave the body) body fluids listed (saliva, urine and milk) is 6.6. Other sources indicate the average pH of urine to be 6.6 (Smoot et al., 1983). Cerebrospinal fluid, an internal fluid also has pH of 7.4 (http://www.pura.com.sq). The pOH of a fluid with a pH of 7.4 is 6.6 and vice-versa (it is noted that 7.4 + 6.6 = 14 = pKw). So, whereas the proton, H^+, to hydroxyl, OH^- ratio is 1: 6 in the internal fluids, it flips to 6:1 in the external body fluids. The evidence is that these are charge-reciprocal structures based on the most stable natural structure (the structure of diamond), the octahedron. This explains the high resistance to change (buffering) of both blood at pH 7.4 and milk at pH 6.6 (http://www.ilri.cgiar.org). These facts, taken together, suggest, therefore, that it is the conservation of an underling stable, physical, structure that is given the chemical term "buffer".

That pH changes are associated with certain disease states is known (Tietz, 1970). This would imply a shift from the H^+ to OH^- ratio of 1:6, in which case octahedral charge-packing would not be possible. The body as self-conserving system would do the best possible under the circumstance to self-preserve. The best choice left would be to shift to any one of the other four regular polyhedral structures (tetrahedron, cube, dodecahedron and icosahedron). These are also relatively stable, compared to any other alternate structures. Two of these are of particular interest because they have the least (tetrahedron = 4) and most (dodecahedron = 20) vertices, which are the points of attachment of the hydroxyl groups. This makes a tetrahedral structure, with a proton, H^+ to hydroxyl, OH^- ratio of 4, the least allowed ratio. This is equivalent to pH 7.30. Therefore, any acidosis below a pH 7.30 would be severe, as no three-dimensional charge-packing structure would be possible. This, then, would account for the observation that the threshold for metabolic acidosis is pH = 7.3 (English and Williams, 2004). For alkalosis, there are three critical pHs: pH 7.45, yielding H^+ to OH^- ratio of 1: 8 for cube; pH 7.54, with ratio of 1:12 for the icosahedron; A dodecahedron would be equivalent to pH of 7.65, and H^+ to OH^- ratio of 1:20. pH of 7.65 would indicate extremely severe or fatal alkalosis, beyond which there is no more very stable charge-packing regular polyhedral structure to sustain life. The literature suggests that these are reasonable assumptions, as can be seen from the following quotation; "Mortality rates have been reported as 45% in patients with an arterial blood pH of 7.55 and 80% when the pH was greater than 7.65 (Yaseen, 2000). pH of 7.55 does, from the literature, define severe alkalosis as 7.65 sets the upper limit of alkalosis, compatibility with life. Again the literature definition of alkalosis is pH greater than 7.45. The model, effectively, predicts the observed pattern. The lower limit for tolerable acidosis is less well defined, from the litera-ture review. Experiments were carried out to study this phenomenon in sickle cell disease and asthma, diseases that are associated with acidic blood in steady state. These are common diseases and, therefore, samples are easy to obtain.

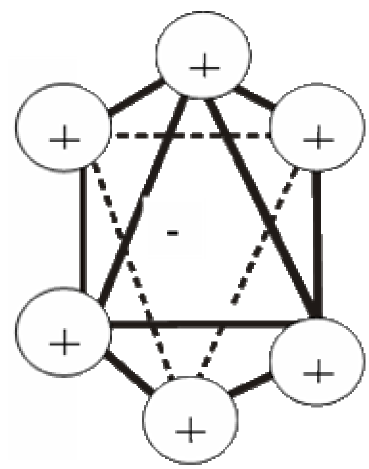

Figure 2. Octahedral charge-packing at pH 6.6.

MATERIALS AND METHOD

Two independent studies were made to determine the pHs in sickle cell disease (SCD) and asthma. For the SCD sample venous blood were collected from 42 individuals of HbAA and 42 individuals of HbSS genotypes (equal number of males and females in each group). For the asthma study, blood samples were collected from 22 individuals with asthma as well as 22 normal individuals. The samples were collected from the laboratories of Federal Medical Center, Ikenegbu Hospital and Holy Rosary Hospital, all in Owerri, Nigeria. The pHs of the blood samples were determined using El

Table 2. Blood pH in SCD compared to normal.

GENOTYPE	HbAA	HbSS
pH	7.39 ± 0.07	7.32 ± 0.08
$[H^+]$	$10^{-7.39}$	$10^{-7.32}$
pOH	6.61	6.68
$[OH^-]$mol-L^{-1}	$10^{-6.61}$	$10^{-6.68}$
$[OH^-]/[H^+]$	$10^{-6.61}/10^{-7.39} \approx$ 6.03	$10^{-6.68}/10^{-7.32} = 4.37$
Whole number ratio	≈6	≈4

Table 3. Blood pH in asthma compared to normal.

Groups	Normal	Asthmatics
pH	7.38 ± 0.03	7.29 ± 0.03
$[H^+]$, mol-L^{-1}	$10^{-7.38}$	$10^{-7.29}$
pOH	6.62	6.71
$[OH^-]$, mol-L^{-1}	$10^{-6.62}$	$10^{-6.71}$
$[OH^-]/[H^+]$	$10^{-6.62}/10^{-7.38} = 5.75$	$10^{-6.71}/10^{-7.29} \approx 3.80$
Simple ratio	≈ 6	≈ 4

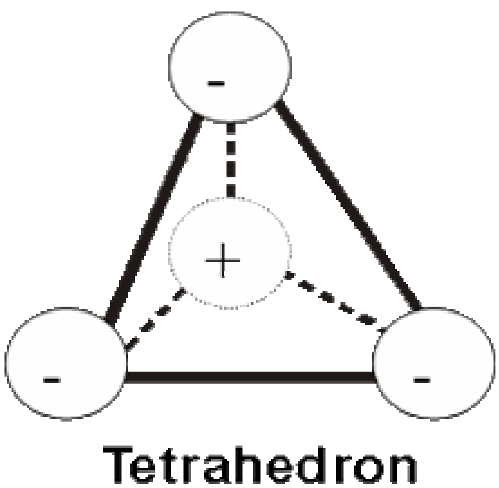

Figure 3. Tetrahedral charge-packing at pH 7.3.

1182 Mommert pH-meter. The pH measurements were made at room temperature; 30°C (303 K).

RESULTS AND DISCUSSION

The results of the experiments are shown, separately for sickle cell disease (SCD) and asthma in Tables 2 and 3. In both experiments, the results show that the ratio of hydrogen, H^+, to hydroxyl, OH^-, ion is 1:6 for normal and 1:4 for the diseased, acidosis state. The most efficient explanation for this, in synergistic terms, is polyhedral charge-packing (octahedron in normal and tetrahedron in acidosis).

This suggests a discrete, quantized, pattern of blood pH shift governed by underlying polyhedral framework. This would explain the sudden nature of onset of crises in acid-base disorders. This, in effect, is a quantized structural shift based on the regular polyhedra. This model would provide the, apparent, explanation for the measured pH of 7.15 ± 0.12 observed for sickle cell crisis in a study by this author as compared to 7.32 ± 0.08 in sickle cell steady-state and 7.39 ± 0.07 for HbAA genotype (it is noted that, theoretically, body fluid pH = 7.39, yielding proton to hydroxyl ions ratio of 1.00:6.03, would be more natural than the normally quoted 7.40, with a ratio of 1.00:6.31).

These results suggest that a general strategy for the management of acid base disorders would be to do those things, respiratory and metabolic, that keep the pH in the neighborhood of 7.4, as the greater stability of the octahedral framework would favor its conservation. The pH would be a good predictive marker in such acid-base disorders such as sickle cell asthma, and general metab-olic acidosis or alkalosis. Regular monitoring of the pH of disease sufferers could predict acidotic crises as it tends below the tetrahedral charge-packing threshold of 7.30, below which no three-dimensional charge-packing option exits, as the tetrahedron is the smallest of the polyhedra, or above 7.54 of icosahedron, where normal oxidative processes would be, effectively, quenched, by an excess of negatively charged hydroxyl ions.

Conclusion

This paper suggests, on the evidence, that the polyhedral charge-packing of proton, H^+, and hydroxyl, OH^-, ions is a major, physical, factor that determines the observed pH in normal blood as well as different disease conditions that involve acid-base disorder. Sickle cell and asthma are two such diseases. Blood pH tends to stabilize around 7.30 in these disease states so as to have a 1 to 4 proton , H^+, to hydroxyl, OH^-, ion ratio (1:4) that can be tetrahedral packed, as against the ideal pH of 7.4, consistent with the most compact and efficient octahedral packing, and a proton to hydroxyl ratio of 1:6. The observation that, generally, metabolic acidotic crisis tends to set in just below this pH supports this conclusion. The pHs 7.45, 7.54 and 7.65 are marker pHs for the onset and severity of alkalosis, because of the underling polyhedral structures (cube, icosahedron and dodecahedron) they reflect. The understanding of the polyhedral charge-packing phenomenon in disease states pHs, would lead to more efficient management of acid-base disorders; and more efficient management of the body as a whole. Both acidosis and alkalosis are troublesome, because the charge-packing structures associated with them are less efficient and stable than the octahedron associated with pH 7.4. The model, also, offers a basis for the better appreciation of the stable pHs of other natural fluids.

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