Effect of Transferrin on Diffusion of Oxygen in Plasma

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Previous studies have determined that the diffusivity of oxygen through blood plasma decreases as the protein levels increase. It appears, however, that one particular plasma protein, transferrin, has the opposite effect, with the diffusivity increasing when its level is raised.

INTRODUCTION

Diffusion of oxygen may play an important role in the transport of oxygen through blood plasma. Since plasma contains many constituents, it is possible that variations in concentrations of these constituents could affect the diffusivity. Most previous investigations in this area have studied the effect that altering the plasma protein levels have on the oxygen diffusion (Dorson et al., 1971; Goldstick et al., 1976; Navari et al., 1971). Although the data from these studies do not agree quantitatively, they all show the same general trend of decreasing oxygen diffusivities with increasing protein concentrations in plasma.

We have recently been investigating the effect of iron-containing proteins on the apparent diffusivity of oxygen through plasma. One of the main iron-containing proteins in the plasma is transferrin. Almost all of the iron circulating in the body is bound to transferrin (Putnam, 1975). In fact, plasma transferrin levels were originally measured by the amount of iron that can be specifically bound by the plasma. The iron that is transported by the transferrin is used in the synthesis of hemoglobin, and this requires a daily turnover of six to ten times the amount of iron carried at any one time in the serum (Bowman, 1968). All of this iron is carried by transferrin and reversibly unloaded for the synthesis, and the transferrin then returns to the circulatory system.

Many conditions will alter the transferrin concentrations. Higher levels are found during pregnancy and in chronic iron deficiency (Laurell, 1960). It also appears to have a bacteriostatic effect, and patients with low transferrin levels have more recurrent infections (Fletcher, 1971; Weinberg, 1974). Thus the levels of transferrin are frequently elevated in the initial phases of infection. We decided to determine if an increase in transferrin concentrations had any effect on the apparent diffusivity of oxygen in plasma. Since increasing transferrin levels correlate directly with increasing plasma iron levels, the concentration of iron ions were also increased in the samples studied.

EXPERIMENTAL

The apparatus used to determine the diffusion coefficients of oxygen in plasma was almost identical to one used previously by other investigators (Goldstick et al., 1976), and is described in detail elsewhere (Brumgard, 1980). With this apparatus, an oxygen electrode is used to measure the concentration of oxygen at one edge of a thin layer of liquid, and how that concentration changes when the oxygen concentration at the other boundary of the layer is altered. One-dimensional diffusion is assumed and the unsteady-state diffusion equation is used with the data obtained in order to calculate the diffusivity of oxygen through the liquid sample. Although the principle of the experimental method is not complex, the actual use of the apparatus can pose some problems. If the plasma sample has a lower surface tension, due to higher concentrations of proteins, building vibrations are very difficult to dampen out and convection can occur. It is important to analyze each set of data by comparing it to the results of solving the diffusion equation. By doing that, one can easily see when convection has occurred during a run. That was done for all experiments reported in this study, and runs where convection occurred were disregarded. This problem appears less severe when dealing with a liquid having a higher surface tension, such as water, as might be expected.

The plasmas used for the analysis were a human sample, as well as a lyophilized horse plasma, both obtained from Miles Laboratories, and both were sterile. In addition, they contained normal levels of transferrin, approximately 0.3 g per 100 mL of plasma as determined in the Clinical Laboratories at the University of Virginia. The protein levels could be varied by dissolving different amounts of the lyophilized materials in water, and we found that we obtained the same results whether using the human plasma or the reconstituted horse plasma.

We augmented the transferrin level of each of the plasmas by adding around 0.6 g per 100 mL of transferrin obtained from Sigma Chemical Co. The transferrin came as iron-and carbonate-free material. It is known that each transferrin molecule can bind two iron and two carbonate ions (Putnam, 1975), and that transferrin is normally 30% saturated with these ions. Accordingly, we added iron and carbonate to our plasmas containing elevated levels of transferrin to ensure that our system was like that which exists naturally.

RESULTS AND DISCUSSION

We determined the diffusivity of oxygen through plasma for different protein concentrations. Then we increased the protein concentration of each of the plasmas by adding the iron-containing transferrin. In the past, all researchers have noted a decrease in the diffusion of oxygen with increasing protein concentrations. However, as is shown in Table 1, increasing transferrin levels appears to cause an increase in the diffusivity of oxygen. The standard deviations for the data shown in Table 1 were determined to be ±0.5%.

From the results in Table 1, it can be seen that elevated transferrin levels appear to cause an increase in the apparent diffusivity of oxygen in plasma, and that the increase is greater at the higher protein concentration. It is difficult to definitely state how transferrin is responsible for this behavior. It is possible that the iron-containing transferrin binds oxygen, as some of the other iron-containing proteins can do. Also, previous research has indicated that the protein part of the transferrin complex serves as a catalyst for the oxidation of the iron part from a plus 2 state to a plus 3 valence state (Gates et al., 1973). In any event, it is probable that transferrin does not increase the diffusivity of oxygen *per se*, but increases the apparent diffusivity calculated without regard for any possible "reactions" occurring in the plasma.

This effect of transferrin may have been seen in some previously published data. Two sets of data for diffusion of oxygen through plasma exhibit apparently conflicting results (Goldstick et al., 1976; Navari et al., 1971). However, one set of data was obtained for plasmas containing normal levels of transferrin (Navari et al., 1971), while, in the other study, 86% of the samples tested contained high transferrin concentrations (Goldstick et al., 1976). These previous data are plotted as lines in Figure 1, with the data obtained in this study plotted as points. As can be seen, different transferrin levels could possibly be responsible for the apparent discrepancy between the previous data.

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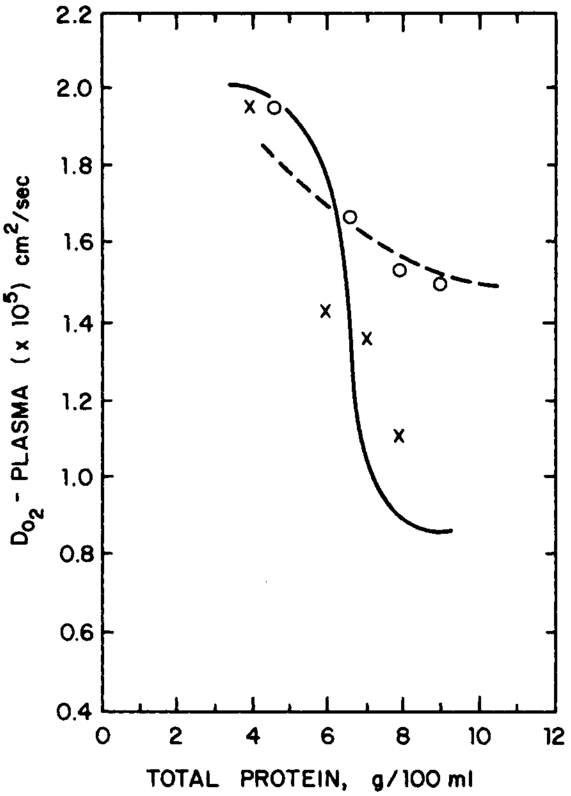

Figure 1. - - - -, data from Goldstick et al., 1976; ——, data from Navari et al., 1971; *x*, plasmas having normal transferrin levels; 0, plasmas having elevated transferrin levels. Standard deviations for all points is $\pm 0.05 \times 10^5 \cdot cm^2/s$.

Blood plasma is really a very complex system, and, although this paper has pointed out how a particular protein, transferrin, may cause an apparent increase in oxygen transport in this system, it is obvious that other constituents in plasma can have different effects. It would appear that more study is needed before a definitive answer can be made as to the factors controlling the diffusivity through plasma.

TABLE 1. TRANSFERRIN LEVEL VS. OXYGEN DIFFUSIVITY

Total Protein Concentration of Plasma, g/100 mL	% Increase in Diffusivity If Transferrin Level Elevated
4	0
6	18
7	15
8	35

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Simple and Accurate Vapor Pressure Equations for the Near Critical Region

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Vapor pressure is an important thermodynamic property used in the chemical process industry. Many equation forms have been presented to correlate experimental data (Miller, 1964; Reid et al., 1977), many of which require numerous parameters or coefficients. Also, many of the simpler equations have relatively high percentage errors (Miller, 1964). More recently, equations containing five or more coefficients, many of which are nonlinear, have been developed that fit the data very well, but are overly complex to work with.

Vapor pressure equations based on theories describing the universality of critical point behavior have been one of the more recent developments. The purpose of this article is to present empirical values of certain critical exponents from scaling theory that describe the vapor pressure curvature at and near the critical point. These values are used in the general form of the vapor pressure equation derived from scaling theory and produce a simple, but highly precise, equation. Three related forms of the equation are developed and applied, all of which have only linear coefficients to be determined.

THEORY

A basic universality has been observed in the region of a phase transition critical point in many physical systems, and this similarity