gen plays an important part. This method will also be useful for measuring interferometrically the dry mass of protein in cells where considerable amounts of carbohydrate are present.

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PHYSIOLOGY

Diffusion Coefficient of Oxyhaemoglobin

IN work described elsewhere¹ we showed how to understand the steady-state transport of oxygen through haemoglobin solution by the application of Fick's law of mass transport. The oxygen flux was shown to depend not only on the pressure difference across the diffusion cell but also on the absolute partial pressures of oxygen at the cell boundaries. This behaviour is a direct consequence of the non-linear relation between oxyhaemoglobin concentration and oxygen partial pressure. We pointed out, for example, that if the haemoglobin is saturated with oxygen at both ends of the diffusion path it cannot contribute to the transport of oxygen and all the oxygen transport must therefore take place through the plasma.

Hemmingsen² recently reported a series of experiments which he interprets as showing that although the haemoglobin is oxygen saturated at both ends of the diffusion path it still contributes to oxygen transport. His conclusions are, however, largely incorrect and the experiments prove instead to be an ingenious way of determining the diffusion coefficient for oxyhaemoglobin.

Hemmingsen measured the transport of oxygen-18 through a haemoglobin solution under conditions where the total oxygen pressure was identical at both ends of the diffusion path and maintained large enough to ensure that the haemoglobin was in the oxygenated form. A difference was established, however, in the partial pressures of ¹⁸O at the diffusion cell boundaries which caused a transport of ¹⁸O across the cell. In comparing results for identical experiments with haemoglobin, methaemoglobin, and water, Hemmingsen found the ¹⁸O flux through the haemoglobin to be about 2.6 times that through methaemoglobin or water.

Fick's law is again quite applicable to understanding these experimental results. It must be stressed, however, that the law applies only to the ¹⁸O, since it is only the flux of this component of the system which has been measured. Now although the total pressures of oxygen are maintained equal at each end of the diffusion path, the partial pressures of ¹⁸O are not. Similarly, though the concentrations of oxyhaemoglobin are the same at each cell boundary, the concentrations of the ¹⁸O-haemoglobin are not equal. This is an important point because it is true whether or not all the haemoglobin is in the oxygenated form. In fact a simple equilibrium argument shows

that the fractional amount of ¹⁸O-oxyhaemoglobin is just equal to the fractional partial pressure of dissolved ¹⁸O. One can easily picture exactly what must happen in the diffusion cell. The concentration gradient of dissolved ¹⁸O causes an ¹⁸O flux through the plasma while the gradient in ¹⁸O-oxyhaemoglobin causes an additional flux of the ¹⁸O-oxyhaemoglobin. There must also be a flux of ¹⁶O-haemoglobin in the opposite direction to preserve a mass balance on the haemoglobin. We can now use our previous results to write a mathematical expression for the ¹⁸O flux:

$$J(^{18}\text{O}) = \frac{D_A k(P_i - P_f)}{x_f} + \frac{D_E \{f(kP_i) - f(kP_f)\}}{x_f} \quad (1)$$

where P_i and P_f are the initial and final partial pressures of ¹⁸O respectively, k is a Henry's law constant, D_A and D_E are the diffusion coefficient of ¹⁸O through plasma and the diffusion coefficient of ¹⁸O-oxyhaemoglobin respectively, $f(kP_i)$ is the initial concentration of ¹⁸O containing haemoglobin and $f(kP_f)$ the final concentration, and x_f is the length of the diffusion path.

The first term in equation (1) is the oxygen flux through the plasma, the second is an additional flux due to the presence of a gradient in the oxyhaemoglobin concentration. In Hemmingsen's experiments on water or methaemoglobin the entire flux is described by the first term of equation (1). In the experiments on haemoglobin the second term is also important and accounts for the enhanced ¹⁸O flux through this solution. Using a value of 20–21 vol. per cent for the oxygen capacity of the haemoglobin solution, the data from Fig. 2 in ref. 2, and applying equation (1), we obtain 1.9×10^{-7} cm.²/sec. for the diffusion coefficient of oxyhaemoglobin, D_E . We should point out that one must be very careful in using the numbers in Hemmingsen's Fig. 2, since he has not reported the ¹⁸O flux but has scaled that flux up by the experimental ¹⁶O/¹⁸O ratio. This is a spurious correction and must be removed to obtain the data. The previous experiments of Scholander and Hemmingsen³ wherein the haemoglobin was oxygen saturated at one end of the path and kept at zero oxygen partial pressure at the other end also give a value of 1.9×10^{-7} cm.²/sec. for D_E . This value was chosen by us in our treatment of the steady-state oxygen transport in whole blood⁴ and leads to an adequate description of the experimental data on whole blood obtained by Scholander⁵.

The ¹⁸O experiments might profitably be done as a function of haemoglobin concentration to determine the concentration dependence of D_E . As it stands they merely show once again that Fick's law is applicable to any component of a system providing the equilibrium with the other components is fast compared with diffusion-rates.

This work was supported by U.S. Public Health Service grant No. H6796.

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