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Principal Absorption Axes of Rhodopsin and Prelumirhodopsin*

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Abstract. The experimental data on the absorption of plane polarized light by a solution of cattle rhodopsin at −196° C have been theoretically analysed to model the directional absorption properties of rhodopsin and prelumirhodopsin. It has been found that rhodopsin and prelumirhodopsin are planar absorbers having ratios of about 100 : 7 and 100 : 4, respectively, between the extinction coefficients along the long axis and perpendicular to it. These results support that the chromophore in prelumirhodopsin is more linear than the chromophore in rhodopsin.

Key words: Rhodopsin – Prelumirhodopsin – Absorption ratio

Gupta et al. (1979) analysed the experimental observations of Yoshizawa and Horiuchi (1973) on the absorption of a plane polarized light by the solution of cattle rhodopsin at −196° C. Similar to Strackee (1972) it was assumed, in the mathematical analysis, that the absorption axes of rhodopsin, prelumirhodopsin and isorhodopsin are the same and the values of the absorption ratios (K_1 and K_2) were determined by fitting the theoretical results in the experimental data. It was found that rhodopsin and its photoproducts are planar absorbers and using the values of the absorption ratios, a model for the configuration of the chromophores in the disc membrane was derived which explains the previous experimental observations. Although the values of the parameters reported by Gupta et al. (1979) explain the previous experimental observations, the assumption made in the analysis is critical, as mentioned by the authors themselves. It is possible that if the absorption axes of rhodopsin, prelumirhodopsin and isorhodopsin are considered to be different in the analysis then one may obtain much better agreement between theoretical and experimental results than obtained by Gupta et al. (1979). Further, such an analysis will also

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give information as to whether the absorption axes of rhodopsin and its photoproducts are the same or not and which molecule is more linear absorber than the other. Therefore, in the present paper we have analysed the same experimental observations of Yoshizawa and Horiuchi (1973) considering rhodopsin, prelumirhodopsin and isorhodopsin to be different asymmetric absorption ellipsoids.

The mathematical analysis is similar to that of Gupta et al. (1979) and the difference is only in the definition of the effective extinction coefficient[1] of i^{th} type of molecule which is, here, defined as:

$$\alpha_i(\theta,\psi) = \alpha_{z',i} f_i(\theta, \psi) , \tag{1}$$

where

$$f_i(\theta, \psi) = K_{1i} \sin^2\theta \sin^2\psi + K_{2i} \sin^2\theta \cos^2\psi + \cos^2\theta ,$$

$$\alpha_{z',i} = 3\alpha(i)/(K_{1i} + K_{2i} + 1) ,$$

$$K_{1i} = \frac{\alpha_{x',i}}{\alpha_{z',i}} \quad \text{and} \quad K_{2i} = \frac{\alpha_{y',i}}{\alpha_{z',i}} .$$

($i = 1, 2$, and 3 corresponds to rhodopsin, prelumirhodopsin and isorhodopsin, respectively) θ and ψ are two of the three Eulerian angles (θ, ϕ, and ψ) used by Gupta et al. (1979). α_i (θ, ψ) is independent of ϕ because of the rotational symmetry about the z-axis.

Similar to Gupta et al. (1979) we compare our theoretical results with the experimental data of Yoshizawa and Horiuchi (1973) on the change in absorbance with time for three randomly chosen wavelengths (480 nm, 550 nm, and 570 nm) of the measuring light (see Fig. 1). The extinction coefficients of rhodopsin, prelumirhodopsin and isorhodopsin at −196° C have been taken from the paper of Gupta et al. (1979) and the values of the quantum efficiencies which will be needed in the analysis have been chosen to be those reported by Strackee (1972) and used by Gupta et al. (1979). To start with, we have used the following values of the parameters (Gupta et al. 1979):

$$K_{11} = K_{12} = K_{13} = 0.0 ,$$
$$K_{21} = K_{22} = K_{23} = 0.07 .$$

Although these values of the parameters give an agreement of the theoretical results with the experimental data, the experimental observations can be

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[1] The effective extinction coefficient depends upon the orientation of the molecule (x', y', z') with respect to a coordinate system (x, y, z) in which the direction of polarization of the bleaching light is fixed. In Eq. (1) the direction of propagation of the plane polarized bleaching light is taken to be along the x-axis and its electric vector is assumed to be parallel to the z-axis; z'-axis of the molecule is along the long axis of the molecule (see Gupta et al. 1979)

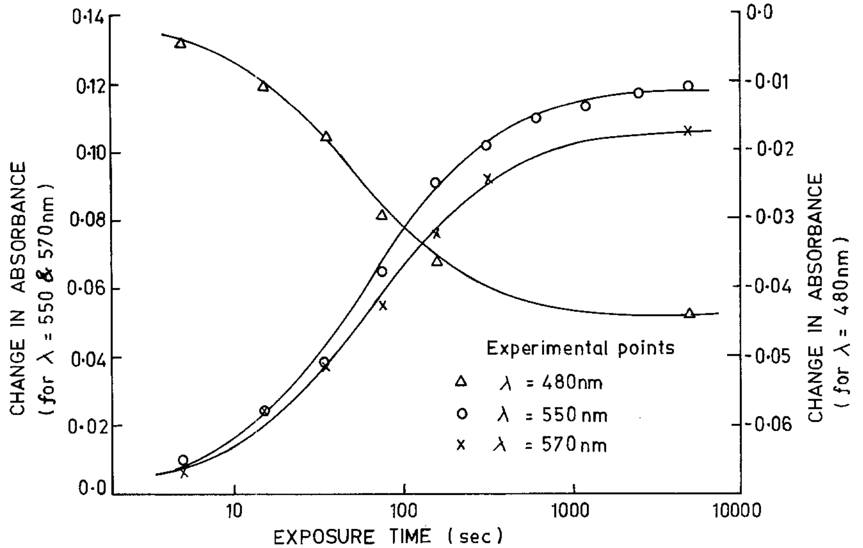

Fig. 1. Variation of change in absorbance of a solution of cattle rhodopsin at −196° C for three different wavelengths of the measuring light as a function of the light exposure. The solution was bleached with a plane polarized light of wavelength 437 nm. The experimental points have been taken from the paper of Yoshizawa and Horiuchi (1973) and the curves are theoretical

explained much better than Gupta et al. (1979)[2] if the absorption ratios have the values $K_{11} = 0$, $K_{21} = 0.07$, $K_{12} = 0$, and $K_{22} = 0.04$ (see Fig. 1); the effect of K_{23} is found to be negligible and hence its value cannot be reported. These results imply that prelumirhodopsin is a more linear absorber than rhodopsin. We know that the chromophores of rhodopsin and prelumirhodopsin are 11-*cis* and all-trans retinal, respectively. When 11-*cis* converts into all-trans an appreciable geometry change occurs which involves 40° change in absorption axis of 11-*cis* retinal. But, here, we see that the conversion of rhodopsin into prelumirhodopsin involves a smaller change in the absorption axis of rhodopsin than that of 11-*cis* retinal. As we know that when 11-*cis* retinal interacts with opsin the absorption spectrum, the value of λ_{max} and the value of extinction coefficient at λ_{max} of the resulting molecule change considerably from that of 11-*cis* retinal, therefore one may assume that the small change in the absorption axis is due to the association of chromophores with the opsin. But the results obtained here support that the chromophore in prelumirhodopsin is more linear than the chromophore in rhodopsin. It should be noted that the values $K_{11} = 0$ and $K_{21} = 0.07$ are the same as those reported by Gupta et al. (1979) and give the same model for the configuration of chromophores in the disc membrane which was proposed by Gupta et al. (1979). Thus, we conclude that rhodopsin

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[2] The agreement between theoretical and experimental observations is nearly the same for $\lambda = 480$ nm and 570 nm in the two analysis [i.e., Gupta et al. (1979) and this paper] but the agreement obtained in this paper for $\lambda = 550$ nm is much better than that obtained by Gupta et al. (1979)

and prelumirhodopsin are planar absorbers having ratios of about 100 : 7 and 100 : 4, respectively, between the extinction coefficients along the long axis and perpendicular to it.

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