CHLOROPHYLL CATALYSIS AND EINSTEIN'S PHOTOCHEMICAL LAW IN PHOTOSYNTHESIS

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We have reported [1] that the quantum requirement of the splitting of the photolyte is 1 and [2] that the quantum requirement of the splitting plus resynthesis of the photolyte is 3. This agrees with Einstein's photochemical law and with thermodynamics.

Yet our results were not accepted by the late James Franck or by Melvin Calvin, who reported much higher and erratic quantum requirements. The discrepancies were so enormous that they baffled everyone concerned with photosynthesis.

An explanation for the discrepancies is now offered. Photosyntehsis is a chlorophyll catalysis. There are two states of the chlorophyll : chlorophyll combined with carbonic acid (relation 1:1) and free chlorophyll. Only light absorbed by the combined chlorophyll is the photolyte, whereas light absorbed by the free chlorophyll is lost for photosynthesis.

The quantum requirement of photosynthesis can be determined only when the photolyte is known and when it is measured during photosynthesis. Then only light absorbed by the photolyte is introduced into the calculation and light absorbed by the free chlorophyll is ignored, using the equation:

$$\frac{1}{\varphi^*} = \frac{I\alpha(c/A)}{dO_2/dt} = \frac{I\alpha\epsilon}{dO_2/dt}, \qquad (1)$$

where I is the incident quantum intensity, α the fraction absorbed by the total chlorphyll, dO_2/dt the rate of oxygen evolution, c the combined chlorophyll, A the total chlorophyll and $\epsilon = c/A$ is the fraction of light that is absorbed by the combined chlorphyll.

It is assumed in this derivation that the light absorption coefficients of the combined and free chlorophyll are equal, whereas Edmund Birkicht and Günter Pahlke in this laboratory recently discovered a difference of 2% at 600 mμ. This difference is negligible in comparison to the enormous differences that are obtained if eq. (2) instead of eq. (1) is used for the calculation of the quantum requirement:

$$\frac{1}{\varphi} = \frac{I\alpha}{dO_2/dt}. \qquad (2)$$

Equations (2) and (1) are equivalent only in extreme cases when the factor ϵ approaches 1, as in our pioneer-work of 1922 and 1923. In all other conditions erratic and nonsensical results were obtained with eq. (2), because light absorptions by an active and an inactive pigment were mixed in the calculation.

Methods were developed to determine ϵ under all possible conditions in dark and illuminated Chlorella. This we succeeded in doing at CO_2-pressures from 2 to 10% of an atmosphere and at incident light intensities from 100 to 1200 μl quanta per minute.

A few results are described in the figure. For the same cell suspension, under different conditions, the quantum requirements were calculated with the light absorbed by the *total* chlorophyll or the light absorbed by the *combined* chlorophyll only. In the latter case, the same quantum requirements were obtained, namely 3, at light intensities from 100 to 800, in accordance with Einstein's law. When the light-absorption by the total chlorophyll was used in the calculation the well known nonsensical quantum requirements were obtained, namely 12 up to 34 at the highest intensity. Thus the reason for the 100 to 1000% discrepancy between Dahlem and the other institutes has

Table 1
The table gives the data from which the quantum requirements shown in fig. 1 were calculated.

CO_2-pressure	I	α	A	c_{dark}	c_{light}	$\frac{c_{light}}{\Sigma\ chlorophyll}$	$\frac{dx_{O_2}}{dt}$	$\frac{1}{\varphi}$	$\frac{1}{\varphi^*}$
	incident light intensity	fraction of I absorbed by Σ chlorophyll	= Σ chlorophyll	= photolyte dark	= photolyte light	= ϵ_{light}		$\frac{I\alpha}{dx_{O_2}/dt}$	$\frac{I\alpha\epsilon}{dx_{O_2}/dt}$
(% of an atmosphere)	$\frac{\mu l\ quanta}{min}$	(O)	(μl)	(μl)	(μl)	(O)	$\frac{\mu l\ O_2}{min}$	(O)	(O)
5	100	0.868	27.8	18.9	7.2	0.259	7.41	11.7	3.03
5	200	0.875	32.7	17.1	6.7	0.208	12.98	13.5	2.81
5	400	0.856	27.6	16.2	4.1	0.1485	16.97	20.2	3.00
5	800	0.870	30.2	15.5	2.4	0.0795	20.43	34.0	2.70

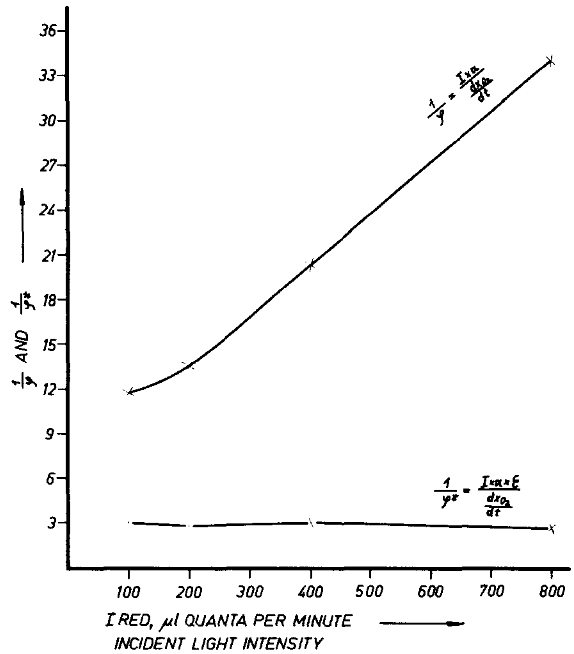

Fig. 1. Quantum requirements of photosynthesis. The curves are based on the data given in the table. When the quantum requirements of the upper curve are multiplied with the factor ϵ (chlorophyll combined with CO_2/total chlorophyll) the nonsensical values of the upper curve are transformed into the value of 3 which is in accordance with Einstein's law.

been the failure to distinguish between the two forms of chlorophyll.

The experiments will be described in full detail in the American Journal of Botany.

References

[1] O.Warburg and G.Krippahl, Z. Naturforsch. 15b (1960) 788.
[2] O.Warburg and G.Krippahl, Biochem. Z. 346 (1967) 418.