SUGGESTED EQUATIONS FOR THE PHOTOSYNTHETIC REACTION.

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The recent monograph by Spoehr* gives a very complete summary of the work on photosynthesis. The importance of the process can hardly be overestimated, and the combined researches that have been carried on by botanists, biochemists, and plant physiologists have resulted in a large amount of data regarding the qualitative and quantitative aspects of the photosynthetic reaction. In the light of these results nearly all of the equations suggested to explain the reaction to students of botany are open to some very serious objections. The one that most frequently appears in text-books is the following:

$6H_2O + 6CO_2 +$ light energy acting on chlorophyll $\longrightarrow$ $C_6H_{12}O_6$ (glucose) $+ 6O_2$.

This equation avoids all intermediate steps by not mentioning them. An attempt is made in this paper to call attention to two simple equations which make use of definitely known substances common to plants in which photosynthesis takes place, and which seem to fit the known facts far better than the abbreviated equation above. Nearly all of the previous explanations have postulated intermediate products such as formaldehyde, glycollic aldehyde, carbon monoxide, and various peroxides, which are either unknown in plants or are found in such minute quantities as to make their significance questionable. It is definitely known, however, that photosynthesis does not take place in plants in the absence of chlorophyll, of which two kinds have been isolated by Willstätter and Stoll, who termed them Chlorophyll "a" and Chlorophyll "b." These two kinds of chlorophyll exist in the proportions of 2.58–2.75:1. During photosynthesis it is found that the total quantity of chlorophyll remains the same.

It is also definitely known that the ratio between the amount of carbon dioxide absorbed and the amount of oxygen evolved is approximately unity, and that water is necessary for the reaction. All of the observers have been impressed

*Spoehr, H. A. Photosynthesis. Chemical Catalog Co. (1926).

by the fact that vegetable tissues are capable of absorbing carbon dioxide in quantities considerably above that accounted for by the solubility of the gas in the water of the tissues. Willstätter and Stoll observed a decided absorption of carbon dioxide by leaves that had been dried and powdered and had subsequently been allowed to absorb water. Under these conditions, in the presence of sunlight, oxygen is evolved. However, if the leaves are first treated with ether and dried, oxygen is not liberated.

There is much in favor of the view, variously expressed by Willstätter and Stoll, Warburg, and others, that one of the steps in photosynthesis is not a splitting of CO_2 under the influence of light, but that the CO_2 undergoes a primary change through absorption by some constituent of the leaf.

Dixon and Ball have suggested the following formulæ to show the absorption of CO_2 by chlorophyll:

$C_{55}H_{72}O_5N_4Mg + CO_2 \rightarrow C_{55}H_{70}O_6N_4Mg + CH_2O$
(Chlorophyll "a" + Carbon dioxide $\rightarrow$ Chlorophyll "b" + formaldehyde)
$C_{55}H_{70}O_6N_4Mg + H_2O \rightarrow C_{55}H_{72}O_5N_4Mg + O_2$
(Chlorophyll "b" + water $\rightarrow$ Chlorophyll "a" + oxygen).

They assume, of course, as do all adherents of the so-called "formaldehyde theory," that formaldehyde is polymerized into a hexose sugar, such as glucose.

Maquenne evidently believes that in the colloidal state three molecules of chlorophyll are linked through secondary valencies of the single magnesium atom in each molecule. He assumes the final formation of a compound containing a chain of carbon atoms, for instance glyceric aldehyde or dioxyacetone, instead of formaldehyde. Spoehr suggested that in order to conceive of the direct formation of a hexose sugar it "suffices to admit the possibility of six chlorophyll molecules which absorb six molecules of carbonic acid."

Many of the investigators in this field are agreed that the photosynthetic process is composed of two reactions, one a chemical reaction with a temperature coefficient of about 2, and the other a photo-chemical reaction with a low temperature coefficient. The two following equations are suggested as a better representation of the probable behavior of chlorophyll in the process of photosynthesis:

(1) $6C_{55}H_{70}O_6N_4Mg + 6H_2O \rightarrow 6C_{55}H_{72}O_5N_4Mg + 6O_2$
(Chlorophyll "b" + water $\rightarrow$ Chlorophyll "a" + oxygen)
(2) $6C_{55}H_{72}O_5N_4Mg + 6CO_2 \rightarrow 6C_{55}H_{70}O_6N_4Mg + C_6H_{12}O_6$
(Chlorophyll "a" + carbon dioxide $\rightarrow$ Chlorophyll "b" + glucose).