

how are we to account for the long dormant life of some organisms that possess a very small reserve of respirable material, as for example the spores of bacteria which in the dry state have a very long recorded life? Some refined experiment seems to be needed to try whether in such cases respiration, however infinitesimal, is not still going on.

This is not the only unsolved question that the dormancy of seeds presents. Every farmer and gardener is familiar with the growth of certain weeds, notably charlock, which follows the ploughing up of land which may have been in grass twenty or thirty years. But why in an ordinary arable field, subject to charlock, do we get a rush of growth in one year and few or no seedlings in another? Why do other rare plants suddenly spring up in unexpected places? In Dr. Brenchley's experiments on the germination of seeds contained in soils taken at different depths from the old Rothamsted plots, the soil samples are exposed to optimum conditions of aeration, moisture and temperature, but years elapse before all the seeds germinate.

In the past abnormal season many unexpected 'weeds' have appeared in the John Innes gardens. Some are comparatively uncommon plants, that as far as is known have never been grown here; for example, *Datura sp.*, *Ambrosia artemisiaefolia*, *Physalis edulis*, etc. It may be supposed the seed had been introduced in manure, but considering the rarity of the plants, that only shifts the locality of the problem. One piece of land here, after it had been cleared from sweet peas, has covered itself with *Nicotiana* seedlings. Nine years earlier the plot had carried *Nicotiana*, but in the intervening period not a seedling had been seen. We know something of the effects of 'vernalisation' and of chilling in stimulating the germination of certain seeds which may otherwise refuse to start, but this dormancy of buried seeds still offers problems for experiment.

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### Kinetics of Photosynthesis

I AM grateful to Emerson and Green<sup>1</sup> for directing attention to the fact that the equation expressing the velocity of photosynthesis during the photostationary state<sup>2</sup> was incorrect because it indicated that the temperature coefficient is a function of the external CO<sub>2</sub> concentration. Their alternative formula is open to the same criticism, since it indicates that the temperature coefficient increases with decrease in CO<sub>2</sub> concentration. The error is due to an incomplete definition of the conditions which govern the photostationary state.

There are three processes involved; namely, the primary light reaction in which the chlorophyll in its complex with CO<sub>2</sub> undergoes a change, the Blackman reaction in which this changed chlorophyll is restored to its original state, and the formation of the complex of chlorophyll with CO<sub>2</sub>. If the velocities of these three processes be equated to give the expression for the photostationary state, the resulting expression indicates that the rate of photosynthesis in flashing light is independent of the external CO<sub>2</sub> concentration, which is known not to be the case. If, however, the assumption be made that the rate of formation of the complex with CO<sub>2</sub> is very fast in the case of the chlorophyll formed in the Blackman

reaction, and that the establishment of the equilibrium between ordinary chlorophyll and CO<sub>2</sub> is slow, the equation for the photostationary state is simplified to

$$y = k_1 I(bA - x) = k_2 x e^{-Q/RT}$$

whence

$$\log \frac{y}{K - y} = \log \frac{k_2}{k_1 I} - \frac{Q}{T},$$

where  $A$  is the total concentration of chlorophyll in the irradiated surface,  $b$  is the fraction which exists as the complex,  $K = k_1 b A$  and  $Q' = Q/2.303R$ .

These equations indicate that the temperature coefficient is independent of the CO<sub>2</sub> concentration and that the rate in flashing light is a direct function of the CO<sub>2</sub> concentration, since  $b$  is a function of that concentration.

Emerson and Green's equation for the photostationary state

$$y = k_1 I x = k_2 (a - x) P e^{-Q/RT}$$

appears to be incorrect. Since  $k_2(a - x)P e^{-Q/RT}$  is the velocity of the dark or Blackman reaction,  $x$  will be a maximum after a period of darkness. It follows that  $k_1 I x$  will be a maximum the moment irradiation is commenced and will decrease with time until the photostationary state has been established. The above equation, therefore, cannot express the photostationary state.

It is not possible here to discuss the chemistry of the photosynthetic process, but it may be stated that it is not intended to represent the Blackman reaction as being uni-molecular. It is bi-molecular, but since the concentration of the second reactant is assumed to be large and sensibly constant, it is included in the constant  $k_2$ . A complete account will be given in a separate communication.

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<sup>1</sup> NATURE, 134, 289, August 25, 1934.

<sup>2</sup> NATURE, 133, 414, March 17, 1934.

### Inhibitors of Catalase Reaction

It is well known that the activity of catalase is greatly inhibited by very small concentrations of potassium cyanide, hydrogen sulphide and especially hydroxylamine. To these reagents we can now add sodium azide (NaN<sub>3</sub>) which also acts as a strong inhibitor of catalase.

In a recently published note, Sevag and Maiweg<sup>1</sup> have announced the discovery of a new type of catalase poison belonging to the group of oximes. They have found, however, that these compounds when used freshly prepared have no poisoning properties. The inhibitory property of the oxime solution is manifested only after acidifying it with dilute hydrochloric acid, warming for twenty minutes and neutralising with dilute soda. It is interesting to note that this inhibitory property was found by these authors to be proportional to the strength of acid used in their manipulation.

Following the technique described by Sevag and Maiweg, 0.232 gm. of dimethylglyoxime (CH<sub>3</sub>C(OH).C(OH).CH<sub>3</sub>) was dissolved in 100 c.c. of water, containing 10 c.c. normal hydrochloric acid, warmed for 20 minutes on a water bath and neutralised with normal caustic soda.

The solution thus prepared, contrary to the



statement made by these authors, was found to contain a large concentration of hydroxylamine. This solution, like hydroxylamine and unlike oxime, on addition of sodium nitroprusside and a little caustic soda, turns red on heating. Like hydroxylamine it oxidises haemoglobin to methaemoglobin. It precipitates cuprous oxide from an alkaline solution of copper sulphate, and the titration of this solution with Fehling solution reveals the presence of about 87 mgm. of free hydroxylamine. We find therefore that about 66 per cent oxime was decomposed, liberating a corresponding amount of hydroxylamine.

On testing this solution with nickel it was found to contain only 29 per cent of undecomposed dimethylglyoxime, which conforms fairly well with the previous estimation of the free hydroxylamine.

These results show that 0.018 *M* solution of oxime treated by the method of Sevag and Maiweg gives approximately 0.024 *M* solution of hydroxylamine. In other words, the molar concentration of hydroxylamine (a well-known catalase inhibitor) in Sevag and Maiweg's solution, at the end of their manipulation, was higher than the initial concentration of the oxime. It is not surprising, therefore, that their solution had such a powerful inhibitory action on catalase.

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<sup>1</sup> Sevag, M. G., and Maiweg, Lore, *Naturwissenschaften*, **22**, 561; 1934.

### Passage of Very Fast Protons through Matter

It is now generally assumed in nuclear theories<sup>1</sup> that the interaction between a neutron and a proton is of the form

$$-J(r)S \quad (1)$$

where  $J(r)$  is some function of the distance  $r$  between them, and  $S$  is the operator which interchanges the space co-ordinates but not the spin of the two particles. Such an interaction has some important consequences in the passage of very fast protons through matter.

We consider a collision in which the neutron is initially at rest, and the proton moving with a large momentum such that the wave-length is small compared to the effective radius of the interaction  $J(r)$ . Then, as Wick<sup>2</sup> has pointed out, with an exchange interaction of the type (1), most of the neutrons are thrown in the forward direction. (With a non-exchange interaction, most of the protons would be scattered in the forward direction.) To calculate the magnitude of the collision cross section we must make some assumption about the form of  $J(r)$ , of which we know very little. Assuming  $J(r)$  to be of the form

$$J(r) = a e^{-br} \quad (2)$$

the effective cross section, calculated by the Born approximation, for the scattering of the neutron in the solid angle  $d\omega$  making an angle  $\theta$  with the original direction of the proton is

$$\frac{256\pi^4}{h^4} \frac{a^2 b^2}{\left\{ b^2 + \frac{4\pi^2}{h^2} \left| \underline{p}_1 - \underline{p}_0 \right|^2 \right\}^4} \times \frac{p_1^3 E_0 E_1}{p_0 \left\{ p_1 + \frac{E_1}{E_0 + Mc^2 - E_1} (p_1 - p_0 \cos \theta) \right\}^2 c^4} d\omega \quad (3)$$

where  $p_0 = Mv/\sqrt{1-v^2/c^2}$  is the initial momentum of the proton,  $v$  its velocity,  $M$  the mass of the proton

or neutron assumed equal, and  $E_0 = c\sqrt{p_0^2 + M^2c^2}$  the initial energy of the proton.  $E_1, p_1$  are the energy and momentum of the neutron given by the conservation of energy and momentum for a particle scattered at an angle  $\theta$ . The effective cross section for the scattering of the neutron in any angle less than  $\theta$  is

$$q(\theta) = \frac{64\pi^3}{3} \frac{E_0^2}{c^2 p_0^2} \frac{a^2 b^2}{h^2 c^2} \left[ \frac{1}{b^6} - \frac{1}{\left\{ b^2 + \left( \frac{2\pi p_0}{h} \right)^2 \sin^2 \theta \right\}^3} \right] \quad (4)$$

where we have neglected terms of the order  $(hb/2\pi Mc)^2$ . When  $2\pi p_0/h \gg b$ , (3) has a very strong maximum in the forward direction, and in this case the mean angle  $\bar{\theta}$  at which the neutrons are ejected is

$$\bar{\theta} = \frac{1}{\sqrt{2}} \frac{hb}{2\pi p_0}, \quad (5)$$

and the neutron has on the average an energy less than the original energy of the proton by an amount  $\delta$ , where

$$\delta = \frac{1}{16\pi^2} \frac{h^2 b^2}{M}. \quad (6)$$

Taking  $a = 1.4 \times 10^{-4}$  erg,  $b = 6.8 \times 10^{12}$  cm.<sup>-1</sup>, being the values determined by Wick<sup>3</sup> from the stability of oxygen, the total cross section for an encounter  $q$ , got by neglecting the last term in square brackets in (4), is  $0.16 \times 10^{-24}$  cm.<sup>2</sup>,  $\bar{\theta} = 1.1^\circ$ , and  $\delta \approx 0.47 \times 10^6$  e.v., for a proton with  $E_0 = 5 \times 10^9$  e.v.  $\approx 5.4$   $Mc^2$ , such as might possibly occur in cosmic radiation.

Thus, such a proton in its passage through matter will go on until it collides with a neutron and gives nearly all its energy to the neutron. The neutron will travel until it collides with a proton in the material as given by (4), (5), (6), and the proton which is thus ejected will have very nearly the same energy as the original proton, and travel in very nearly the same direction. Further, for protons of such high energies we should expect to be able to treat the neutrons in nuclei as free, so that, using the cross section given above, the mean 'range' of a proton in lead is about 1.5 cm., and that of the neutron about 2.3 cm., as the lead nucleus contains 82 protons and about 125 neutrons. Therefore in going through a metre of lead there will be roughly twenty-five changes from proton to neutron and back, and the total energy loss due to ionisation of the emerging proton will be about half that to be expected theoretically since more than half the distance will be travelled by neutrons.

We may remark, that with the values of  $a$  and  $b$  assumed above, an accurate calculation<sup>3</sup> of the cross section for the collision of neutrons of energy roughly  $3.8 \times 10^6$  e.v. with protons gives a result which is nearly four times larger than the cross section found by Chadwick. Our results may therefore be too large by a factor four.

The above expressions are further inaccurate inasmuch as (a) there is no relativistic wave equation for the proton, and (b) the interaction energy (1) can be represented by a potential  $J(r)$  probably only in non-relativistic approximation. One might hope that the correct relativistic treatment would reduce the total cross section given above.

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<sup>1</sup> W. Heisenberg, *Z. Phys.*, **80**, 587; 1933. E. Majorana, *Z. Phys.*, **82**, 137; 1933.

<sup>2</sup> G. C. Wick, *Z. Phys.*, **84**, 799; 1933.

<sup>3</sup> G. C. Wick, *Nuovo Cimento*, **11**, 235; 1934.