or otherwise of the movement indicated should be obtained during the future work of the survey.

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A Biological Agent for securing Large Numbers of *Amœba proteus*

THE role of *Oscillatoria* for purifying freshwater reservoirs is well known. For some years now, I have been applying successfully this biological agent to 'cleaning up' amœba cultures. Ordinary laboratory cultures, unless rigidly controlled, tend to become choked with algæ in the course of time. It is a tiresome manipulation to separate out the amœbæ in sufficient numbers when it is desirable to make a quantity of stained preparations, or to secure the large numbers of young amœbæ which are required when a study of mitosis is being made. If, however, among the algal contents one introduces *Oscillatoria*, the filaments of this grow over and bind together the wheat grains and the algal contents into a cylindrical mass. The rest of the vesicle is quite free from weed; but young amœbæ, some rotifers and small flagellates creep out on to it and multiply, and so a white carpet is formed consisting mainly of amœbæ quite free from debris. These can then be pipetted off into the fixative, or used for a study of mitosis.

If now a new receptacle with water and wheat be prepared, the cylindrical mass can be removed bodily, placed into the prepared receptacle and squeezed, when a new culture results, which will be ready for use in about three months.

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Laws of Addition and Substitution in Atomic Reactions of Halogens

QUANTITATIVE developments of the observations communicated some time ago[1] on the reaction of N-chlorosuccinimide with toluene has led to a clarification of the reaction mechanism.

Let us, however, consider first the reactions between an organic substance (RH) and a halogen (X_2) in homogeneous gaseous systems or in non-polar solutions. If the reaction proceeds by atoms and free radicals, the following reactions (substitution *s*, addition *a*) must be expected:

$$X_2+M \rightarrow 2\,X+M \qquad (1)$$

$$X+\mathrm{H}R \rightarrow \mathrm{H}X+R \ (2s) \qquad X+R\mathrm{H} \rightarrow XR\mathrm{H} \ (2a)$$

$$R+X_2 \rightarrow RX+X \ (3s) \qquad XR\mathrm{H}+X_2 \rightarrow XR\mathrm{H}X+X \ (3a)$$

$$R+\mathrm{H}X \rightarrow R\mathrm{H}+X \ (4s) \qquad XR\mathrm{H} \rightarrow R\mathrm{H}+X \ (4a)$$

$$X+XR \rightarrow X_2+R \ (5s) \qquad X+XR\mathrm{H}X \rightarrow X_2+XR\mathrm{H} \ (5a)$$

$$2X+M \rightarrow X_2+M \qquad (6)$$

$$X+R \rightarrow XR \ (7s) \qquad X+XR\mathrm{H} \rightarrow XR\mathrm{H}X \ (\text{or } X_2+R\mathrm{H}) \ (7a)$$

$$R+R \rightarrow R_2 \ (8s) \qquad XR\mathrm{H}+XR\mathrm{H} \rightarrow XR\mathrm{H}R\mathrm{H}X \ (\text{or } XR\mathrm{H}X+R\mathrm{H}) \ (8a)$$

By applying the usual stationary state method, the rate laws in $(X_2)^{1/2}$, (X_2) or $(X_2)^{3/2}$, which were found empirically by Bodenstein, Kistiakowsky, Schumacher, Van Artsdalen and others[2], are obtained. But it can be shown, in agreement with all previous observations, which of these rate laws must be expected in any specific case, by estimating the rate constants, that is, activation energies and partition functions for the eight different elementary steps. A quite satisfactory 'first approximation' is obtained in the following way: it is assumed that activation energies exceed endothermicities by 2 to 5 k.cal.; electronic and vibrational partition functions are assumed to be equal for all particles, and rotational partition functions are calculated neglecting structural particularities.

Further, the rules governing the competition of addition and substitution may be calculated; the ratio of addition to substitution being:

$$r(a/s) = k_{2a}/k_{2s}(1 + k_{4a}/k_{3a}\,(X_2)\,),$$

or for low concentrations of (X_2)—the order of magnitude of which can be estimated satisfactorily:

$$r(a/s) = k_{2a}k_{3a}\,(X_2)/k_{2s}k_{4a}.$$

Thus addition is favoured by high, substitution by low, values of (X_2); this explains the 'perturbations' of addition reactions observed, for example, by Schumacher[3].

It has been shown that in the reaction of N-chlorosuccinimide with toluene, traces of impurities (for example, 10^{-5} water) lead, in the course of an induction period[4], to formation of HX, which yields with N-chlorosuccinimide halogen molecules (X_2); the latter give by thermal dissociation the primary halogen atoms. These could now react according to (2*s*) or (2*a*). In the first case, the following reaction chain would be started:

$$X + \mathrm{H}R \rightarrow X\mathrm{H} + R \qquad (a)$$

$$\mathrm{SN}X + X\mathrm{H} \rightarrow \mathrm{SNH} + X_2 \qquad (b)$$

$$R + X_2 \rightarrow RX + X \qquad (c)$$

It can easily be understood that (2*a*) cannot be followed by a rapid reaction: (i) actually the above substitution–addition rule means that (3*a*) is slow as compared to (4*a*) so long as (X_2) is low; (ii) the alternative reaction, $\mathrm{SN}X+XR\mathrm{H} \rightarrow \mathrm{SN}+XR\mathrm{H}X$, is only possible if the dissociation energy of the SN—X bond is smaller than or equal to an X—X bond; we have several indirect arguments for the contrary. (This reaction is certainly negligible compared with 3*a* because of its high (negative) entropy of activation.)

Thus the reactions (*a*), (*b*) and (*c*) are the only alternative. They explain all the observed facts[4], and we believe that they can be applied also in the case of other reagents giving atomic halogenations. It is not necessary to admit *ad hoc* a 'specificity' of the SN radical, as has been done previously[5].

Actually it appears, for the first time quantitatively, that the high specificity of reagents is due to the concentration at which reagents are maintained in a system, much more than to the inherent specificity of these reagents. We believe that this may have general importance in biological reactions. In fact,