Discussion

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The experiments on the disinfection by oxygen of bacteria dried either by aerosolization or by lyophilization presented by Mr. Zentner are delightfully clean and precise, and are adequate for some kinetic studies. This fact relieves us of the relatively unrewarding task of discussing the experimental techniques, accuracy of the data, and validity of the conclusions. It makes it possible to attempt to place the conclusions in broader perspective, to attempt to interpret them, and to examine whether they suggest or point the way to further investigation.

It is perhaps surprising at first glance that oxygen is toxic to Serratia marcescens under the experimental conditions described. Mr. Zentner has, I think quite correctly, related this implicitly to dehydration of the bacteria. The observation has been amply confirmed and is even intuitively reasonable in terms of several hypothetical mechanisms; for example, the concentration of some toxic metabolite may increase at a critical location because diffusion is limited by dehydration, or dehydration may distort some structure and render it more susceptible to oxidation.

It is even more surprising that the biological reactions observed follow so nicely the kinetic laws described by the figures; in particular, there is no threshold concentration for the toxicity of oxygen (Fig. 2, 5, 7, and 9), and the data form a straight line on the Arrhenius plot (Fig. 8) over an extraordinarily wide range of temperature (−78 to +40 C). Data on disinfection with a variety of disinfectants commonly follow similar kinetic laws (see, for example, F. H. Johnson, H. Eyring, and M. J. Polissar, The Kinetic Basis of Molecular Biology, p. 453 ff, John Wiley & Sons, Inc., New York, 1954). The generality of this type of biological data simply emphasizes the importance of understanding why the biological data follow these chemical laws.

The Arrhenius relation is usually derived from a thermodynamic consideration of a chemical reaction at equilibrium or from a statistical mechanical consideration of reaction rates. In the latter case, it is found necessary to introduce the concept of an "activated state" in or near equilibrium with the chemical reactants of the system. Each molecule in an activated state has a certain probability of decaying into its products (or, by analogy, dying). The logical essence of the reasoning leading to the Arrhenius relation, then, is the existence of two states of the system at, or nearly at, equilibrium with each other. One of these states may be the "activated state" in which
the organism has a certain probability of dying. It places less strain on our credulity to accept a rather abstract interpretation of the experimental results such as this than to believe that each organism behaves like or is dependent upon a single molecule.

The very abstractness or generality of this interpretation of the kinetic data is a serious handicap, because it does not point the way toward a critical chemical substance or chemical or physical reaction, nor does it even say whether there are one or more "activated states" of the bacterium. In fact J. B. Bateman has gathered evidence that several different "activated states" may be involved in bacterial death due to dehydration. We may hope that the situation with regard to oxygen toxicity is not as complex, and hence as depressing, as that pictured by Bateman for dehydration disinfection. Continuing in this happy but somewhat illogical vein, we may say that the data presented by Zentner are consistent with the existence of a single "activated state," and even suggest that the "activated state" is related to the accumulation of some intermediary metabolite closely involved with oxidative metabolism. In this way, the experiments presented by Zentner do suggest new experiments through which our understanding of oxygen toxicity might be improved, but they do not exclude wholly different types of possible mechanisms, such as free radical production, direct oxidation of critical material, or structural change in the bacterium induced by oxygen.

It is possible that a clever guess may permit an experiment which will elucidate the nature of an "activated state." Otherwise, before the disinfection of dried bacteria by oxygen or by other disinfectants can be understood and adequately described, a great number of experiments and measurements on many independent variables will be necessary, followed by a complex relaxation analysis of the kind outlined by Bateman.