Conduction of electrons through the solid protein cytochrome oxidase particle in accord with Ohm's law, driven by the difference in electrode potentials of two substrates which exchange electrons with the two sides of the enzyme particle, was previously shown to explain the inhibitory effect of cytochrome c on the first order rate constant, and to predict the low semiconduction activation energy of dried cytochrome oxidase. If the solid conduction path in the cytochrome oxidase particle shows electron injection from sites of electron exchange with substrate, and shows trapping of conduction electrons by reversible O₂ complexes, then one may also predict that the first order kinetics observed at high O₂ concentrations will change to second order kinetics at lower O₂ concentrations, as observed by Gibson and Wharton. One may also predict quantitatively the inhibitory effect of increasing O₂ concentrations on the second order rate constant as observed by Gibson and Wharton. The same concept of electron trapping by O₂ complexes provides a possible reason for the unusually low semiconduction activation energy of cytochrome oxidase.

I. Introduction. Conventional theories of enzyme kinetics are derived from the mass action principle, which means that one assumes that the rate of reaction is proportional to the frequency of collisions of the reactant molecules, which float freely in solution. Many enzymes show good agreement of experimental behavior with the predictions of mass action theory. An alternative theory of enzyme kinetics based on solid state physical mechanisms has been developed...
in recent years (Cope 1963, 1965, 1970; Cope and Straub, 1969). The solid state theory assumes that a redox reaction catalyzed by an enzyme particle is rate-limited by the electron current flowing across the solid particle, driven by the difference in redox potentials of two substrates (Figure 1). The solid state theory predicts the observed inhibitory effect of cytochrome c on the first order rate constant of cytochrome oxidase (Cope 1963, 1965) and predicts the observed similarity between the activation energy of the cytochrome oxidase reaction and the activation energy of semiconduction of the dried enzyme (Cope and Straub, 1969). The solid state theory also describes various other electron transport phenomena in particulate and membraneous systems (Cope, 1970). In the author's opinion, these correlations indicate that, although the postulates of the mass action theory are realistic for analysis of many small enzymes, redox pro-

\[ X_{ox} + e^- \rightarrow X_r \]

\[ Y_{ox} + e^- \rightarrow Y_r \]

Figure 1. Postulated model of solid cytochrome oxidase enzyme particle. The X-site on the particle acts like an electrode immersed in a solution of redox substrate X (cytochrome c), so that the X-site develops an equilibrium electrode potential governed by the percent reduction of substrate X. The X-site is assumed to have enzymatic specificity for reaction with X-substrate. In other words, X-site can exchange electrons freely with X-substrate but will not react with Y-substrate. The Y-site, at the other end of the enzyme particle, acts like a second electrode immersed in a solution of a second redox substrate Y (O₂), and develops an equilibrium electrode potential governed by percent reduction of Y. The direct reaction of X- and Y-substrates in solution is assumed to be insignificantly slow. The difference in electrode potentials at the X- and Y-sites causes a current of electrons to flow through the conductive solid enzyme particle. The rate of current flow, and hence the rate of oxidation of X-substrate by Y-substrate, is governed by the ohmic or square law voltage-current equation for the solid protein or lipoprotein material of the particle between the X- and Y-sites. Electrons may be injected from substrates at the X- and Y-sites into the conduction band of the solid protein of the particle.