

Viologen Catalyst for Direct-Carbohydrate Fuel Cell

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We have identified a class of organic catalysts that under the right conditions are able to oxidize a variety of carbohydrate fuels, including glucose, to a degree that has not previously been reported. Testing, including the construction of a rudimentary fuel cell based on these molecules, suggests that this catalyst system has the potential to operate at low temperatures and relatively high coulombic efficiencies.

The remarkable catalyst molecules we identified are variations of cationic 1,1'-dialkyl-4,4'-dipyridyl compounds called viologens that readily form stable free radical cations in the absence of oxidizing agents. When viologens and various sugars are combined under alkaline conditions the viologens oxidize the sugars and are in turn oxidized by O₂ (in a vial experiment) or by a current collector (in a fuel-cell experiment), setting up a catalytic cycle in which sugar oxidation is mediated by the viologen catalyst. This catalyst system is free of biological constraints and has been able to achieve notable success in oxidizing glucose. Here we summarize some of our experimental evidence of the catalytic activity of the viologens.

We performed “sealed vial” tests in which methyl viologen (MV) and glucose are introduced into a pH-buffered solution in contact with air and oxygen uptake is measured to determine extent of reaction. We present data showing how the extent of glucose oxidation depends on the initial MV/glucose concentration ratio. As the catalyst ratio increases the degree of oxidation appears to asymptotically approach complete oxidation of glucose to carbonate (24 electrons), showing a synergistic catalyst effect that is currently being investigated.

We demonstrated similarly notable performance of the catalyst in a preliminary experiment of a precious-metal-free alkaline fuel cell. The fuel cell in this test was far from optimized, yet it showed the potential of this catalyst system for enabling low-cost low-temperature fuel cells operated from bio-derived fuels. The cathode was a commercial oxygen cathode, as would be used in a zinc-air battery. A porous separator was used that is not an ion-exchange membrane. The cell generated around 0.4 V potential for 1.5 hours under a constant current of 1.4 mA/cm² (based on the separator area). The total charge passed during the reaction time showed that around 7 electrons had been removed from the added glucose (29% conversion). A control experiment in which MV was not added showed no passage of current, demonstrating the enabling effect of the catalyst.

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