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ELECTROCHEMICAL ENANTIOMER-DIFFERENTIATING OXIDATION OF A RACEMIC ALCOHOL ON POLY(L-VALINE)-COATED ELECTRODES[1)]

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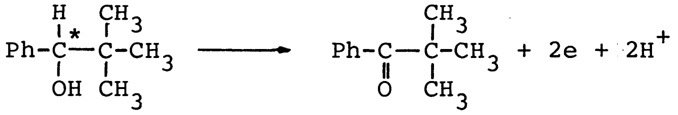
It was found that the enantiomer-differentiating oxidation of racemic 2,2-dimethyl-1-phenyl-1-propanol (1) to the corresponding ketone (2) occurred on poly(L-valine)-coated electrodes. This reaction seemed to be the first example of electrochemical enantiomer-differentiating reaction and to be available for kinetic optical resolution: 43% optically-pure S-(-)-1 was recovered as an unreacted part, when a half amount of starting 1 was converted using a lead dioxide anode coated doubly with polypyrrole and poly-(L-valine).

Various methods for chemical and electrochemical[2)] enantioface- and enantiotopos-differentiating reactions are known and some of them have been reported to be abailable for asymmetric syntheses. Recently, we have reported that graphite and platinum electrodes coated with poly(L-valine) result in good optical yields in electrochemical asymmetric reduction[3-6)] and oxidation,[7,8)] respectively, of prochiral compounds.

In this paper, we wish to report that poly(L-valine)-coated electrodes were found to have an ability to bring about not only enantioface- and enantiotopos-differentiating but also enantiomer-differentiating reactions.

Poly(L-valine)-coated platinum electrodes, which resulted in very high optical yields in the asymmetric oxidation of prochiral sulfides to the corresponding chiral sulfoxides at anodic potentials less positive than 2.0 V vs. Ag/AgCl,[7,8)] were first examined in the enantiomer-differentiating oxidation of a racemic alcohol, 2,2-dimethyl-1-phenyl-1-propanol (1), to the corresponding ketone, 2,2-dimethyl-1-phenyl-1-propanone (**2**). A considerably high k_R/k_S value (k_R and k_S indicate oxidation rates for R-**1** and S-**1**, respectively.)[9] was obtained at an initial period of electrolysis at 2.8 V vs. Ag/AgCl in 0.1 mol dm^{-3} tetra-n-butylammonium tetrafluorobarate/acetonitrile, but the value was rapidly decreased during the electrolysis. The decrease of the k_R/k_S value was rationalized as due to unstableness of the coated platinum electrodes at such an extremely positive potential required the oxidation of **1**.



$$\mathrm{Ph{-}\overset{H}{\underset{OH}{C^{*}}}{-}\overset{CH_3}{\underset{CH_3}{C}}{-}CH_3} \longrightarrow \mathrm{Ph{-}\underset{O}{\overset{}{C}}{-}\overset{CH_3}{\underset{CH_3}{C}}{-}CH_3} + 2e + 2H^{+}$$

1 **2**

More durable coated electrodes for the enantiomer-differentiating oxidation of **1** could be prepared by coating lead dioxide with poly(L-valine). Three types (A, B, and C) of the coated lead dioxide electrodes were prepared by similar methods to those described in earlier reports.[7,8] The coated electrode A was prepared by dipping a lead dioxide plate (2.5 cm x 4.0 cm) into 0.5%(w/v) poly(L-valine)[3]/trifluoroacetic acid. To prepare the coated electrode B, the lead dioxide plate was first coated with polypyrrole by anodic polymerization at 1.5 V vs. Ag/AgCl for 2 min in 0.01 mol dm^{-3} pyrrole – 0.1 mol dm^{-3} tetra-n-butylammonium tetrafluoroborate/acetonitrile and then with poly(L-valine) in layers by a dipping method similar to the above. The coated electrode C was also prepared by double coating with polypyrrole, which was covalently bound by Pb-O-Si-$(CH_2)_3$-N (pyrrole nucleus) bondings to the lead dioxide surface, and poly(L-valine). Coating of the polypyrrole film was carried out by a modified method of Simon et al.[10] The lead dioxide plate was chemically modified with monomeric pyrrole by the reaction of its surface with N-[3-(trimethoxysilyl)propyl]pyrrole in ethanol and then was anodically treated at 1.5 V vs. Ag/AgCl for 2 min in 0.01 mol dm^{-3} pyrrole – 0.1 mol dm^{-3} tetra-n-butylammonium tetrafluoroborate/acetonitrile. The polypyrrole-coated lead dioxide plate prepared thus was also coated with poly(L-valine) by the dipping method.

The propanol, **1** (2 mmol) was partially oxidized using the above coated electrodes at 2.8 V vs. Ag/AgCl at 0 °C in 70 cm^3 of 0.1 mol dm^{-3} tetra-n-butylammonium tetrafluoroborate/acetonitrile. After the electrolysis, **1** unreacted and **2** formed in the anodic solution were analyzed by gas chromatography (a 2 m PEG-20M column at 180 °C). The anodic solution was evaporated and the residue was extracted with ether. The ether solution was dried over anhydrous sodium sulfate and concentrated to a volume suitable for measurement of its optical rotation. The concentration of **1** in the concentrated solution was measured by the gas chromatography. The $[\alpha]_D^{20}$ of the **1** recovered thus was estimated from the optical rotation and the concentration. The optical purity of the **1** was calculated with reference to a value reported for the optically pure S-enantiomer: $[\alpha]_D^{20}$ −36.2° (c 9.49 in ether).[11)]

As shown in Table 1, among the three electrodes used, the electrode C gave the highest k_R/k_S value and the highest optical purity of recovered **1**, when 96500 C mol^{-1} of charge was passed (Runs 1-3). Recoating of the electrode C on a halfway of the electrolysis increased both the k_R/k_S value and the optical purity (Run 4). It stands to reason that the increase of conversion of **1** by passing larger amounts of charge (193000 C mol^{-1}) resulted in a lower k_R/k_S value and a higher optical purity (Run 5).

Table 1. Electrochemical Enantiomer-Differentiating Oxidation of 2,2-Dimethyl-1-phenyl-1-propanol (**1**) to 2,2-Dimethyl-1-phenyl-1-propanone (**2**) on Poly(L-valine)-Coated Lead Dioxide Electrodes

Run no.	Type[a)] of electrode	Charge passed / C mol^{-1}	Conversion of **1**/%	Recovered **1**[b)]		k_R/k_S[a)]	Yield[d)] of **2**/%
				Recovery / %	Optical purity[c)]/%		
1	A	96500	22	78	10	1.13	59
2	B	96500	31	69	20	1.63	77
3	C	96500	38	62	31	2.13	92
4	C[e)]	96500	40	60	38	2.70	95
5	C	193000	48	52	43	1.71	67

a) See the text. b) The absolute configuration of excess enantiomer was S. c) For the S-enantiomer. d) Based on **1** consumed. e) The electrode was recoated when 48250 C mol^{-1} of charge was passed.

It is noticeable that this electrochemical enantiomer-differentiating reaction should be regarded as a new type of kinetic optical resolution, since auxiliary asymmetric centers required in ordinary kinetic methods are present in substrates or reagent molecules.[12)] Because optical purities obtained by such methods are very rarely higher than 10%, the methods seem to be useful for configurational analysis of compounds rather than optical resolution. Therefore, the value of 43% obtained in this work should be judged to be fairly good, though Auret et al.15) reported the highest value of 70% in the biochemical resolution of a racemic sulfoxide with aerobic microorganisms.

Furthermore, if **2** formed on the chiral coated electrodes used in this work can be efficiently reduced to racemic **1** on an achiral cathode in the same (undivided) cell, or more favorably to S-**1** on a chiral cathode, it may be possible to develop an entirely unique optical resolution method in which whole amounts of the starting racemic **1** can be converted into the S-**1** in principle. At least, such a method should be generally useful in the case of low k_R/k_S values.

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