

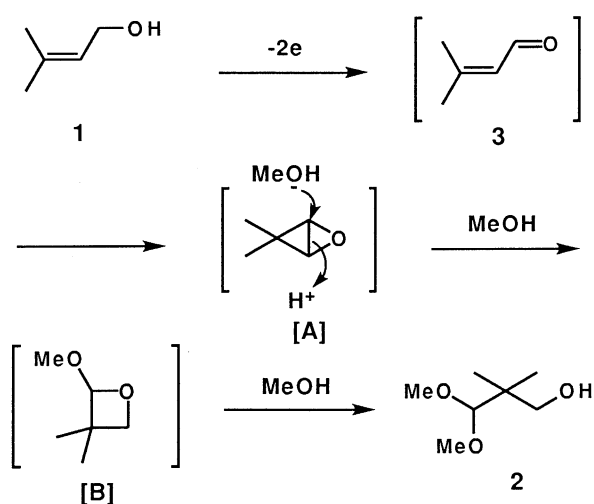
Oxidation of Allylic Alcohols by Means of Electrochemical Methodology. Novel Rearrangement of Prenol under Direct Anodic Oxidation Conditions

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Electrochemical oxidation of naturally occurring allylic alcohols is described. Under direct anodic oxidation conditions, prenil **1** was readily oxidized, followed by rearrangement presumably on the surface of the anodic electrode, to give 3-hydroxy-2,2'-dimethyl-1,1'-dimethoxy propane **2** in high yield, whereas geraniol **5** afforded citral **6** under the same conditions.

The means of electrochemical methodology has proved to be useful for organic synthesis. For example, phenol derivatives are readily converted into tricyclic compounds, which in turn lead to various natural products.¹ Alcohols are also oxidized in indirect manner to give carbonyl compounds in good yield.² However, there have been no reports on electrochemical oxidation of allylic alcohols. We describe here the first successful results of electrochemical oxidation of naturally occurring allylic alcohols as substrates.

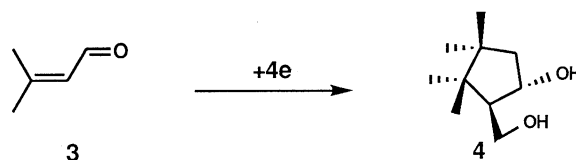


Scheme 1.

Prenol **1** was subjected to anodic oxidation³ in MeOH-MeCN-pyridine (10:10:1) containing LiClO₄ under argon atmosphere to give, unexpectedly, a rearranged product 3-hydroxy-2,2'-dimethyl-1,1'-dimethoxy propane **2**⁴ in more than 75% yield. When acrylaldehyde **3** was subjected to the same conditions, the reaction proceeded in the same way to give **2** in 73% yield, suggesting that **1** was initially oxidized to **3**.

Additionally, **3** did not react at all without electrolysis nor in acidic media that could promote acid catalyzed rearrangement (*p*-TsOH or camphorsulfonic acid in MeOH-MeCN (1:1), and BF₃·OEt₂ in CH₂Cl₂), indicating that the rearrangement took place on the surface of the anodic electrode promoted by electrical general acid. Accordingly, formation of the rearranged product **2** was inferred as the following (Scheme 1).⁵ Prenol **1** is initially oxidized to give acrylaldehyde **3**, which subsequently rearranges to produce an intermediate [A]. The intermediate [A] is so reactive that solvolysis by MeOH readily takes place to give an oxetane intermediate [B]. Finally, acetal exchange of the intermediate [B] with MeOH affords the rearranged product **2**.

In order to examine possible involvement of the cathode in this reaction, **1** and **3** were subjected to the cathodic reduction conditions.⁶ Under this conditions, the results were totally different from those under the anodic oxidations, that is, **3** afforded a dimerized product **4**⁴ in 63% yield (Scheme 2), whereas **1** remained unchanged. Thus, involvement of the cathode in the reaction of **1** to **2** was ruled out.



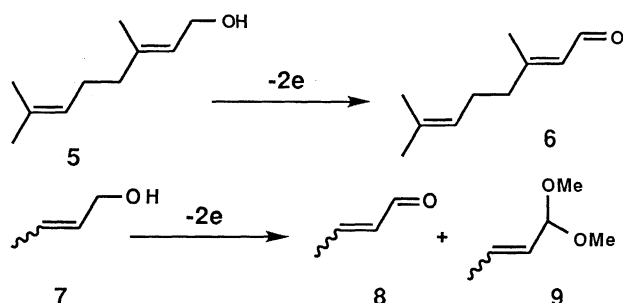
Scheme 2.

Geraniol **5**, an isoprene unit homolog of **1**, was also oxidized under the same conditions to provide the corresponding aldehyde citral **6**⁷ in 66% yield, but, in this case, no further rearranged product was obtained. Similarly, crotylalcohol **7**, a simpler analog of **1**, afforded crotonaldehyde **8**⁷ along with its dimethylacetal **9**⁷ in 38% and 27% yield, respectively (Scheme 3). These results indicated that the rearrangement is affected by subtle change in structure and occurs particularly for **1** (and **3**) due to combined effects of electron donating character of gem-dimethyl group (push) and electrical general acid (pull).

In addition, formation of the acetal **9** suggested again the involvement of electrical general acid in this reaction.

In contrast to the above cases, farnesol, a next higher homolog of **5**, was not oxidized under the same conditions and

only the starting material recovered. At present, it is not clear why farnesol remained unchanged.



Scheme 3.

In the present study, we have demonstrated that allylic alcohols can be electrochemically oxidized under direct anodic oxidation conditions. This procedure would be synthetically advantageous over the known oxidation reactions, since it proceeds without use of any oxidants or mediators. Moreover, the novel rearrangement of prenyl and acrylaldehyde, which presumably takes place on the surface of the electrode, shows an attractive feature of electrochemical methodology. Furthermore, the rearranged product **2** would become useful intermediate for natural products synthesis.⁸

References and Notes

- a) Y. Shizuri, S. Maki, M. Ohkubo, and S. Yamamura, *Tetrahedron Lett.*, **31**, 7167 (1990); b) S. Maki, N. Asaba, S. Kosemura, and S. Yamamura, *Tetrahedron Lett.*, **33**, 4169 (1992); c) See for a review: S. Yamamura "Electroorganic Synthesis: Festschrift for Manual M. Baizer", ed by R. D. Little and M. L. Weinberg, Marcel Dekker, Inc., New York (1989), pp. 309-315.
- a) T. Shono, Y. Matsumura, M. Mizoguchi, and J. Hayashi, *Tetrahedron Lett.*, **1979**, 3861; b) S. Torii, T. Inokuchi, S. Matsumoto, T. Saeki, and T. Oki, *Bull. Chem. Soc. Jpn.*, **63**, 852 (1990).
- Anodic oxidation was carried out at a constant current [C.C.E. at 1.90~2.00 mA/cm² (+1.54~1.62 V vs. SCE); 195854.4~202608.0 C/mol] in MeOH-MeCN-pyridine (10:10:1) including LiClO₄ (0.02 mol/dm⁻³) using a glassy carbon beaker and a platinum wire tip as an anode and a cathode under undivided condition, respectively.
- The structures of the new compounds were unambiguously determined by NMR analysis (COSY, NOESY, HMQC and HMBC) and the spectral data were in accord with the structures assigned: **2**: IR (film) 3443 cm⁻¹; ¹H-NMR δ (CDCl₃) 0.92 (6H, s), 3.43 (2H, s), 3.53 (6H, s), 4.01 (1H, s); ¹³C-NMR δ (CDCl₃) 20.06 (q), 40.59 (s), 58.51 (q), 69.19 (t), 113.90 (d); MS m/z 149 (M+H)⁺, 117 [(M+H)⁺-MeOH], 99 [(M+H)⁺-MeOH-H₂O]; HR-MS m/z 117.0917 [(M+H)⁺-MeOH] calcd. for C₆H₁₃O₂ 117.0916; **4**: IR (film) 3364 cm⁻¹; ¹H-NMR δ (CDCl₃) 0.67 (3H, s), 0.85 (3H, s), 0.89 (3H, s), 1.05 (3H, s), 1.10 (2H, br.s, OH), 1.47 (1H, dd, J = 3.6, 14.3 Hz), 2.06 (1H, ddd, J = 4.4, 7.5, 9.5 Hz), 2.07 (1H, dd, J = 9.5, 14.3 Hz), 3.70 (1H, dd, J = 9.5, 9.9 Hz), 3.85 (1H, dd, J = 4.4, 9.5 Hz), 4.19 (1H, ddd, J = 3.6, 7.6, 9.5 Hz); ¹³C-NMR δ (CDCl₃) 19.99 (q), 22.41 (q), 23.45 (q), 26.86 (q), 42.89 (s), 44.12 (s), 47.86 (t), 58.03 (d), 64.70 (t), 77.20 (d); MS m/z 154 (M-H₂O); HR-MS m/z 154.1361 (M-H₂O) calcd. for C₁₀H₁₈O 154.1357.
- A similar rearrangement has been reported; A. F. Thomas, and W. Pawlak, *Helv. Chem. Acta.*, **54**, 1822 (1971).
- Cathodic reduction was carried out at a constant current [C.C.E. at 2.2 mA/cm² (-645~-660 mV vs. SCE); 485294.4 C/mol] in MeOH-MeCN-pyridine (10:10:1) including LiClO₄ (0.02 mol/dm⁻³) using a platinum plate and a platinum wire tip as a cathode and an anode under undivided condition, respectively.
- All the spectral data of the product are completely identical with those of the authentic sample.
- T. Matsumoto, F. Matsuda, K. Hasegawa, and M. Yanagiya, *Tetrahedron*, **40**, 2337 (1984).