C-Alkylation of αβ-Acetylenic Esters using Electrochemically Generated Intermediates

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Summary Electrolysis at a platinum cathode of ethyl alk-2-ynoates in the presence of an excess of alkyl iodide in hexamethylphosphoramide or dimethylformamide solution containing tetra-n-butylammonium iodide gave the corresponding non-conjugated dialkylation products, ethyl 2,2-dialkylalk-3-ynoates, in good yield.

NEW electrochemical methods for carbon–carbon bond formation using alkyl halides[1] and trialkylboranes[2] have been successful. Most of these electrochemical reactions involve the alkylation by the alkyl halides[1a] or trialkylboranes,[2] of a substrate containing an acidic hydrogen; *e.g.*, electrolysis of phenylacetylene and alkyl halides produced the corresponding alkylphenylacetylenes in good yields.[1a] In a search for useful carbon–carbon bond forming reactions, we electrolysed ethyl propiolate (**1**) in the presence of alkyl iodides. Ethyl propiolate, upon treatment with alkylmagnesium halides[3] or alkyl-lithium,[4] did not give a metal acetylide but instead gave an addition product (at the carbonyl carbon), which rendered it difficult to ensure the alkylation of the terminal triple bond of (**1**). Even when lithium di-isopropylamide (LDA) was used, followed by the addition of methyl iodide, a mixture of alkylated products was obtained in very low yields. The electrochemical method using alkyl iodides was found to give the monoalkylated product in high yield, but the reaction proceeded to give di-, tri-, and tetra-alkylated products with isomerisation of the carbon–carbon triple bond. Here we report a ready electrochemical non-conjugative alkylation of an $\alpha\beta$-acetylenic ester.

Table 1. Electrochemical reaction of ethyl propiolate with methyl iodide[a]

Solvent	F/mol	Conversion of (**1**)/%	Yield (%)[b] (**2**)	(**3**)	(**4**)	(**5**)
DMF	5	89	15	14	15	37
HMPA	5	76	17	0	17	50
HMPA[c]	5	79	22	0	19	15
MeCN	3	89	37	0	37	7

[a] Constant current electrolysis (0·1 A/cm^2) of (**1**) (0·1 M) and methyl iodide (1·0 M) in DMF, HMPA, or acetonitrile solution containing 0·2 M Bu^n_4NI was carried out with platinum plate electrodes. [b] Based on consumed (**1**). [c] Methyl iodide (0·5 M) was employed.

Electrolysis of (**1**) in the presence of a tenfold excess of methyl iodide in dimethylformamide (DMF) solution containing 0·2 M tetra-n-butylammonium iodide (TBAI) as a supporting electrolyte produced ethyl but-2-ynoate (**2**), ethyl 2-methylbuta-2,3-dienoate (**3**), ethyl 2,2-dimethylbut-3-ynoate (**4**), and ethyl 2,2-dimethylpent-3-ynoate (**5**). These electrochemical reactions were carried out at a constant current in a divided cell using two platinum plate electrodes. Use of a mercury pool cathode failed to give (**2**)—(**5**). Hexamethylphosphoramide (HMPA) and acetonitrile were also effective solvents (Table 1). The

$$\underset{(\mathbf{1})}{HC{\equiv}CCO_2Et} + MeI \rightarrow \underset{(\mathbf{2})}{MeC{\equiv}CCO_2Et}$$

$$+ \underset{(\mathbf{3})}{H_2C{=}C{=}CMeCO_2Et} + \underset{(\mathbf{4})}{HC{\equiv}CCMe_2CO_2Et}$$

$$+ \underset{(\mathbf{5})}{MeC{\equiv}CCMe_2CO_2Et}$$

allenic ester (**3**) was isolated only in DMF solution. Since formation of non-conjugated products such as (**3**)—(**5**) under neutral electrolytic conditions is of synthetic interest, these electrochemical reactions were applied to other alk-2-ynoate esters. Electrolysis of (**2**) under similar conditions produced (**4**) and (**5**) (Table 2), which suggested that the reaction proceeded *via* the pathway (**1**) → (**2**) → (**4**) → (**5**). Electrochemical reduction of ethyl pent-2-ynoate (**6**) with methyl, ethyl, n-butyl, and allyl iodide gave the corresponding non-conjugated esters (**7a**)—(**7d**) in good yields (Table 2). Similarly, ethyl hept-2-ynoate (**8**) gave ethyl 2,2-dimethylhept-3-ynoate (**9**).

$$(\mathbf{2}) + MeI \rightarrow (\mathbf{4}) + (\mathbf{5})$$

$$\underset{(\mathbf{6})}{EtC{\equiv}CCO_2Et} + RI \rightarrow \underset{(\mathbf{7})}{MeC{\equiv}CCR_2CO_2Et}$$

a; $R = Me$ **c**; $R = Bu^n$
b; $R = Et$ **d**; $R = CH_2{=}CHCH_2$

$$\underset{(\mathbf{8})}{Bu^nC{\equiv}CCO_2Et} + MeI \rightarrow \underset{(\mathbf{9})}{Pr^nC{\equiv}CCMe_2CO_2Et}$$

Table 2. Electrochemical non-conjugative alkylation of ethyl alk-2-ynoates with alkyl iodides RI[a]

Ester	Alkyl iodide R	Conversion of ester/%	Product	Yield/%[b]
(**2**)[c]	Me	49	(**4**)	45
			(**5**)	29
(**6**)	Me	47	(**7a**)	71
(**6**)	Et	68	(**7b**)	59
(**6**)	Bu^n	70	(**7c**)	82
(**6**)	$CH_2{=}CHCH_2$	49	(**7d**)	74
(**8**)	Me	54	(**9**)	72

[a] Electrolysis (0·1 A/cm^2) of esters (0·1 M) and alkyl iodides (1·0 M) in DMF solution containing 0·2 M Bu^n_4NI was carried out using 5 F/mol. [b] Based on (**2**), (**6**), or (**8**) consumed. [c] Electrolysis in HMPA solution was carried out using 3·7 F/mol.

Although the detailed mechanism of these non-conjugative dialkylations is not clear at present, the reaction may proceed *via* intermediate carbanions. Treatment of (**2**) with LDA at −78 °C followed by the addition of methyl iodide actually gave (**3**) and (**4**), and similar chemical reactions of (**3**) with methyl iodide gave (**4**). These results demonstrate that a strong base comparable in strength with lithium dialkylamide or alkyl-lithium was easily formed by electrolysis. In our system, the electrochemically generated base must come from the alkyl iodides. A voltammetric study showed that the half-wave potentials of (**1**), (**2**), and methyl iodide in 0·1 M TBAI–DMF using a dropping mercury cathode are −2·22, −2·35, and −1·85 V *vs.* the standard calomel electrode and that the electrode potentials of (**1**) and methyl iodide in 0·1 M TBAI–DMF using a Pt disc electrode are −2·10 and −1·62 V *vs.* Ag/Ag$^+$, respectively. Furthermore, these electrochemical reactions proceeded only at the cathode, and the gas evolved at the cathode in the electrolysis of (**1**) and methyl iodide was found to be methane. Accordingly, an alkyl anion formed by two-electron reduction of the alkyl iodide probably acts as a base. This base abstracts an acidic hydrogen from acetylenic or allenic esters to produce the intermediate carbanion which may be trapped by alkyl iodide to give the non-conjugated alkylation products. It is noteworthy that the electrochemically generated carbanion from alkyl iodides acts as an efficient base for the conversion of (**1**) into (**2**), although the conversion (**1**) → (**2**) using LDA, alkyl-lithium, or alkylmagnesium halide was unsuccessful.

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[1] (a) M. Tokuda, T. Taguchi, O. Nishio, and M. Itoh, *J.C.S. Chem. Comm.*, 1976, 606; (b) S. Satoh, M. Itoh, and M. Tokuda, *ibid.*, 1978, 481; (c) S. Satoh, T. Taguchi, M. Itoh, and M. Tokuda, *Bull. Chem. Soc. Japan*, 1979, **52**, 951.

[2] Y. Takahashi, M. Tokuda, M. Itoh, and A. Suzuki, *Chem. Letters*, 1975, 523; *Synthesis*, 1976, 616; *Chem. Letters*, 1977, 999; Y. Takahashi, K. Yuasa, M. Tokuda, M. Itoh, and A. Suzuki, *Bull. Chem. Soc. Japan*, 1978, **51**, 339.

[3] K. B. Becker, *J. Org. Chem.*, 1977, **42**, 2647.

[4] K. Yamada, N. Miyaura, M. Itoh, and A. Suzuki, *Synthesis*, 1977, 679.