# Electrochemical Reduction in the Presence of Tertiary Amines: an Asymmetric Synthesis of 3,4-Dihydro-4-methylcoumarin

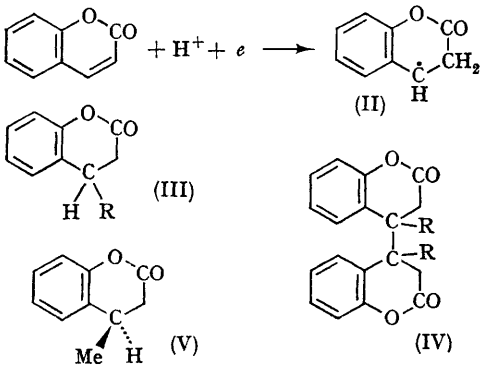
By R. N. GOURLEY, J. GRIMSHAW,* and P. G. MILLAR
(*Department of Chemistry, Queen's University, Belfast, N. Ireland*)

THE overpotential required for the evolution of hydrogen at a mercury cathode is substantially lowered in the presence of organic bases. Mechanisms which have been suggested[1] for hydrogen evolution under these conditions, while differing in details, all require the radical (I) as an intermediate. We considered that this radical (I) should act as a hydrogen donor.

$$R_3N^+H + e \rightarrow R_3\dot{N}H\ (I) \rightarrow R_3N + \tfrac{1}{2}H_2$$

The presence of an amine was thus expected to alter the course of the electrochemical reduction of coumarin, which gives the radical (II) initially, so as to yield some dihydrocoumarin by reaction between (I) and (II) in addition to the mixture of *meso*- and (±)-forms of (IV; R=H) obtained by reduction in the absence of amine.[2]

To test this suggestion, coumarin and also 4-methylcoumarin, were reduced in the presence of alkaloids known[3] to lower the hydrogen overpotential, and the yields of dimer (IV) and dihydrocoumarin obtained are given in Tables 1 and 2. The coumarin (2 g.) was reduced with the appropriate alkaloid in aqueous methanol (200 ml., 40%) buffered to pH 5—6 with sodium citrate and hydrochloric acid. A mercury cathode was used and its potential was regulated electronically at −1·8 volt *versus* a saturated calomel electrode. During experiments the pH of the catholyte was maintained by addition of hydrochloric acid which replaced protons lost as hydrogen. The anode




and cathode compartments of the electrolysis cell were separated by a porous glass disc. The dimer (IV) was precipitated during the course of an experiment and collected by filtration. Extraction of the acidified filtrate with ether afforded a

TABLE 1

*Electroreduction of coumarin*

| Alkaloid present | Mol. ratio of alkaloid to coumarin | % yield products (IV; R=H) | (III; R=H) |
|---|---|---|---|
| None | — | 89·0 | 5·5 |
| Narcotine | 0·07 | 61·8 | 29·0 |
| Nicotine | 0·07 | 79·1 | 2·6 |
| Codeine | 0·07 | 75·6 | 22·3 |
| Brucine | 0·07 | 73·3 | 13·2 |
| Sparteine | 0·07 | 93·0 | 4·3 |
| Yohimbine | 0·025 | 31·0 | 66·9 |

TABLE 2

*Electroreduction of 4-methylcoumarin*

| Alkaloid present | Mol. ratio of alkaloid to coumarin | % yield products (IV; R=Me) | (III; R=Me) | (III; R=Me) $[\alpha]_D$ in benzene |
|---|---|---|---|---|
| None | — | 93·2 | 3·8 | — |
| Narcotine | 0·077 | 69·0 | 9·6 | −5·34° |
| Codeine | 0·077 | 70·0 | 28·0 | +4·15° |
| Brucine | 0·079 | 57·6 | 31·7 | 0·00° |
| Emetine | 0·023 | 83·9 | 13·0 | +4·30° |
| Apocodeine | 0·060 | 62·7 | 37·3 | −0·35° |
| Sparteine | 0·078 | 89·0 | 3·5 | +5·94° |
| Yohimbine | 0·070 | 41·5 | 56·6 | +4·21° |

mixture of dihydrocoumarin and unreduced coumarin. This was distilled and the proportion of dihydrocoumarin estimated by v.p.c.

In the presence of some alkaloids a substantial amount of dihydrocoumarin is formed. A possible reason why not all the bases tried were so effective is that adsorption of the base on the electrode is known to be important for the hydrogen evolution process so these less effective bases may suffer from the competitive adsorption of coumarin. The 3,4-dihydro-4-methylcoumarin isolated from these reductions in the presence of asymmetric bases was found to be optically active. This points very conclusively to the added base being involved in dihydrocoumarin formation. The hydrogen atom is most likely transferred to radical (II) from the nitrogen of radical (I) thus regenerating the base. In support of this, yohimbine, which gives the highest yields of dihydrocoumarin, was recovered unchanged (61% yield) at the end of the experiment listed in Table 1.

Pure enantiomers of 3,4-dihydro-4-methylcoumarin were prepared from the enantiomers of 3-phenylbutyric acid of known absolute configuration.[4] The acid was cyclised to 3-methylhydrindan-1-one using polyphosphoric acid and a specimen of this ketone was recovered unchanged in optical rotation (at 5896 Å) and circular dichroism after prolonged treatment under the reaction conditions. Oxidation of the ketone with perlauric acid gave 3,4-dihydro-4-methylcoumarin whose purity was checked by v.p.c. Oxidation of hydrindan-1-one with per-acids affords 3,4-dihydrocoumarin.[5] Thus (−)-*R*-3-phenylbutyric acid, $[\alpha]_D$ −52° (*c* 1, in benzene), gave (+)-*R*-3,4-dihydro-4-methylcoumarin (V), $[\alpha]_D$ +32° (*c* 1, in benzene). The maximum optical yield obtained in the electrochemical reduction is therefore 19%.

We are indebted to the Ministry of Education, N. Ireland, for Studentships (to R.N.G. and P.G.M.).

(*Received, October 16th*, 1967; *Com.* 1111.)

[1] S. G. Mairanovskii, *Russ. Chem. Rev.*, 1964, **33**, 38; M. von Stackelberg and H. Fassbender, *Z. Elektrochem.*, 1958, **62**, 834; M. von Stackelberg, W. Hans, and W. Jensch, *ibid.*, p. 839.
[2] A. J. Harle and L. E. Lyons, *J. Chem. Soc.*, 1950, 1575; R. Patzak and L. Neugebauer, *Monatsh.*, 1951, **82**, 662.
[3] H. F. W. Kirkpatrick, *Quart. J. Pharm.*, 1945, **18**, 245, 338; 1946, **19**, 127, 526; 1947, **20**, 87.
[4] V. Prelog and H. Scherrer, *Helv. Chim. Acta*, 1959, **42**, 2227; A. M. Weidler and G. Bergson, *Acta Chem. Scand.*, 1964, **18**, 1484.
[5] M. Clerc-Bory and C. Mentzer, *Compt. rend.*, 1955, **241**, 1316.