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THE MECHANISM OF ORGANOCUPRATE CONJUGATE ADDITION REACTIONS[1]. ELECTROCHEMICAL REDUCTION OF (±)-cis-5-MESYLOXY-10-METHYL-1(9)-OCTAL-2-ONE

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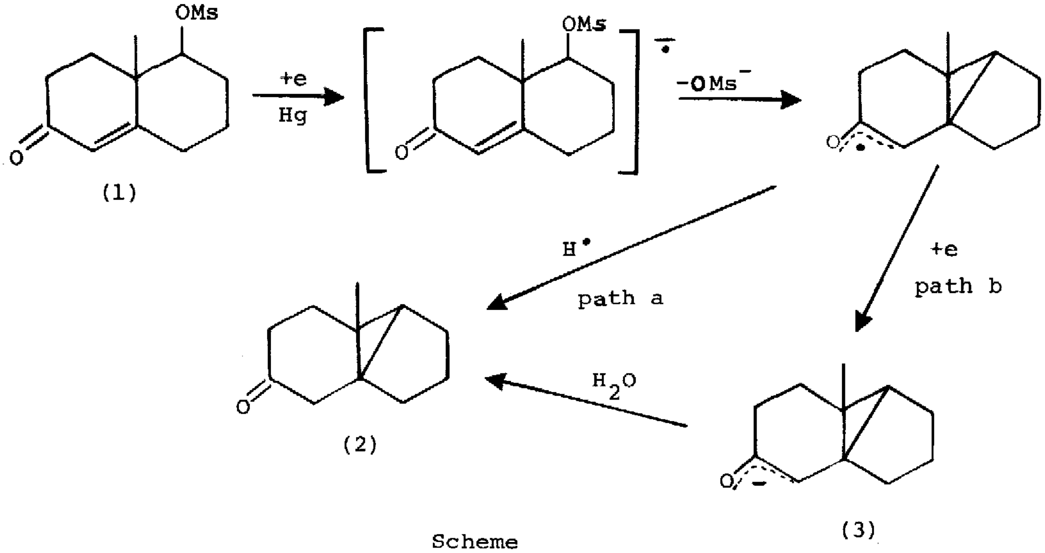
Abstract: Electrochemical reduction of the title compound (1) in nonaqueous solvent results in intramolecular displacement of the mesyloxy group to give the tricyclic ketone (2). The implications for the mechanism of organocuprate reactions are discussed.

The mechanism of conjugate addition reactions of organocuprates (R_2CuLi)[2] with α,β-unsaturated ketones has been investigated by several groups and the involvement of an electron transfer process has received considerable support[3] although paramagnetic species have not been detected[4] during conjugate addition reactions. Hence the possibility of either a two-electron transfer or a one-electron transfer followed by very rapid combination of the organic radical anion and the oxidized copper species to produce a formally organocopper(III)[5] species at the β-carbon has been proposed[4,6].

We have previously reported[4] that organocuprates react with suitably functionalized α,β-unsaturated ketones to give a product resulting from intramolecular displacement [e.g. (1) $\xrightarrow[2.\ H_2O]{1.\ R_2CuLi}$ (2)]. Therefore it was apparent that an electrochemical investigation to determine if these internal displacements occurred after one- or two-electron addition would be germane to organocuprate mechanistic investigations.

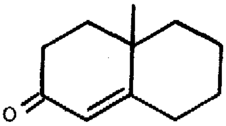
Polarography[7] of (1) (2.5×10^{-3} mol dm^{-3}) in anhydrous DMF containing 0.1 mol dm^{-3} $Bu_4N^+BF_4^-$ showed a reduction potential ($E_{\frac{1}{2}}$) of -1.96 V (vs s.c.e.) which was unchanged after the addition of 5 equivalents of AcOH or Ac_2O. The related compound (4) showed $E_{\frac{1}{2}} = -2.10$ V under similar conditions which shifted anodically by ≈ 100 mV on addition of AcOH or Ac_2O[8].

Controlled potential electrolysis[9] of (1) at -2.2 V (vs s.c.e.) followed by aqueous workup gave (2) in 74% yield with coulometry of 1.35 F mol^{-1}. Repetition of the electrolysis in the presence of 2-propanol (10 equivalents) as a hydrogen atom donor also gave (2) (72%) and consumed 1.05 F mol^{-1}. Displacement of the mesyloxy group at the one-electron reduction stage is therefore demonstrated. The Scheme outlines an analysis of these results involving formation of (2) from the intermediate keto radical occurring by a combination of hydrogen atom abstraction from the *solvent*[10] *and/or 2-propanol (path a) and diffusion back to the electrode* followed by reduction to enolate (3) (path b). In the presence of good hydrogen atom donors path a would become predominant.

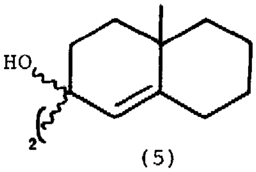


Scheme

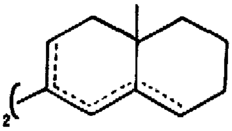
By contrast, controlled potential electrolysis[9] (-2.1 V) of (4) in the presence of $\sim$10 equivalents of proton donors (AcOH, Ac_2O) gave dimers (5) in good yield (0.94 F mol^{-1}). The structure for (5) is based on (i) ready oxidation [$Pb(OAc)_4$] to (4) and (ii) acid catalysed dehydration to (6)[11]. Reductive coupling of α,β-unsaturated ketones similar to (4) under protic conditions has been reported previously[12] however, in the electrolysis of (1), dimeric products could not be detected.



(4)



(5)



(6)

Reaction of (1) with $Li/NH_3/THF$[13] or $Cr(OAc)_2$/en/MeOH[14] also gave (2) in 21% and 40% yield respectively, further substantiating that the intramolecular displacement takes place at the one-electron addition stage.

Although these results do not exclude the possibility that organocuprates react by two-electron transfer mechanisms they demonstrate that this energetically demanding pathway is not necessary for internal displacement.

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5. For recent examples of organocopper(III) species c.f. G.H. Posner, Organic Reactions, 22, 253 (1975); R.A. Amos and J.A. Katzenellenbogen, J.Org.Chem., 42, 2537 (1977); Ibid. 43, 555 (1978); J-M. Dollat, J-L. Luche and P. Crabbé, J.Chem.Soc.Chem.Commun., 761 (1977); C.R. Johnston, R.W. Herr and D.M. Wieland, J.Org.Chem., 38, 4263 (1973).
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7. Polarography was carried out with a PAR model 174A polarographic analyzer under argon with a platinium counter electrode and Ag^+/AgCl reference electrode bridgedto the solution through a Vycor glass plug. The $E_{\frac{1}{2}}$ values were determined in the differential pulse mode and are corrected to saturated calomel electrode (s.c.e.) standard.
8. For a comprehensive discussion on this type of behaviour in the electrochemical reduction of α,β-unsaturated ketones cf. K.W. Bowers, R.W. Giese, J. Grimshaw, H.O. House, N.H. Kolodny, K. Kronberger and D.K. Roe, J.Am.Chem.Soc., 92, 2783 (1970).
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10. R.A. de la Torre and J.W. Sease, J.Am.Chem.Soc., 101, 1687 (1979).
11. Obtained as a photosensitive yellow oil; ($^m/e$ 294, M^+); Found: C, 89.39; H, 10.59. $C_{22}H_{30}$ requires: C, 89.73; H, 10.27%.
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