Oxidative Dimerisation of 1,3-Bis(dimethylamino)isoquinolines to yield *C*-Protonated 4,4′-Bi-isoquinolyls

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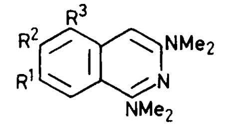
1,3-Bis(dimethylamino)isoquinolines (**1a**—**d**) dimerise in the presence of silver perchlorate to yield the *C*-protonated diperchlorates (**2a**—**d**), which are irreversibly deprotonated to the corresponding hindered 4,4′-bi-isoquinolyls (**3a**—**d**); the dimerisation also occurs by cyclic voltammetry.

While investigating the chemistry of the readily available 1,3-bis(dimethylamino)isoquinolines (**1a**—**e**),[1] we found that when a solution of the parent compound (**1a**) in acetonitrile was treated with aqueous silver perchlorate, a colourless precipitate containing silver was formed and the filtrate yielded a salt of m.p. 228 °C (decomp.) and molecular formula $(C_{13}H_{17}ClN_3O_4)_2$† in 54% yield. It was also obtained (82%) by reaction of the isoquinoline with copper(II) nitrate, followed by perchloric acid. The salt was stable as a solid and in solution in boiling acetonitrile and in trifluoroacetic acid. Its ^1H n.m.r. spectrum showed a multiplet at δ 7.76—7.53 (aromatic), a singlet at 4.98 (benzylic), and four singlets at 3.82, 3.59, 3.35, and 3.19 (NMe) in the ratio 4 : 1 : 1 : 2. The compound was accordingly assigned the dimeric formula (**2a**).

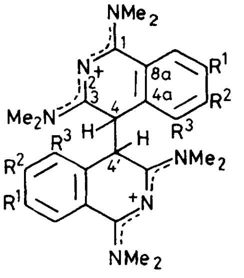
The structure was confirmed by *X*-ray analysis,‡ which, moreover, showed it to be a racemate. The molecules lie on crystallographic two-fold axes, which bisect the C(4)–C(4′) bond joining the two isoquinoline moieties. The two halves of the molecule are staggered in a manner reminiscent of that found in graphite, although the least-squares planes defined by the respective isoquinolyl groups are not precisely parallel. Within each isoquinoline moiety the benzene ring is planar but the heterocyclic ring adopts a conformation which is predominantly that of a boat, with C(1) and C(4) displaced by 0.246(4) and 0.422(4) Å out of the least-squares plane defined by N(2), C(3), C(4a), and C(8a) in a direction towards C(4′) in the two-fold related half of the molecule. The most striking feature of the structure is the length of the interannular bond, 1.597(4) Å, which is only surpassed by the C(1)–C(2) distance of 1.606(3) Å in *cis*-1,2-bis(methoxycarbonyl)-1,2-bis(*p*-nitrophenyl)cyclobutane.[2]

We attribute the stability of this unusual salt to the circumstance that each half is a protonated dienediamine; this outweighs the loss of aromaticity of the heterocyclic rings brought about by *C*-protonation.

The extensive delocalisation of the positive charge in the dication is reflected in the ^{13}C n.m.r. spectrum of the diperchlorate (**2a**) (determined for a solution in CF_3CO_2H). The carbon atoms bearing dimethylamino groups resonate at δ 169.33 and 165.84, which indicates substantial C=N double-bond character. The aromatic carbon atoms resonate at δ 135.88, 134.40, 131.52, 129.72, and 126.89, with two coincidental peaks at 134.40, as determined by off-resonance techniques. The benzylic carbon atoms resonate at δ 46.49. The four pairs of *N*-methyl carbon atoms generate four spectral lines at 44.75, 41.83, 41.76, and 41.72, as detected by resolution enhancement of the spectrum. These four resonances are attributed to hindered rotation about the carbon-to-exocyclic-nitrogen bonds, resulting from the charge delocalisation over the three nitrogen atoms in each half of the dimeric cation. The same effect is apparent in the ^1H n.m.r. spectrum described above.

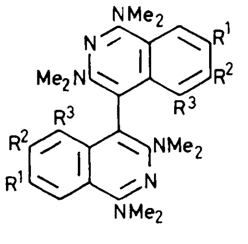


(**1**)



2 ClO_4^-

(**2**)



(**3**)

a; $R^1 = R^2 = R^3 = H$
b; $R^1 = Me, R^2 = R^3 = H$
c; $R^1 = MeO, R^2 = R^3 = H$
d; $R^1 = H, R^2R^3 =$ benzo
e; $R^1 = O_2N, R^2 = R^3 = H$

Table 1. Voltammetric peak potentials for the oxidation of (**1**) and the reduction of (**2**).[a]

Compound	E_p^{ox} (**1**)	E_p^{red} (**2**)
(**1a**)	+0.50	−0.82
(**1b**)	+0.51	−0.79
(**1c**)	+0.45	−0.75
(**1d**)	+0.59	−0.29, −0.46
(**1e**)	+0.74	−0.46

[a] Potentials (V *vs.* SCE) were measured at a Pt-button electrode in acetonitrile containing Bu_4NBF_4 (0.1 M) as supporting electrolyte. The voltage sweep rate was 0.2 V/s and the temperature 22 °C.

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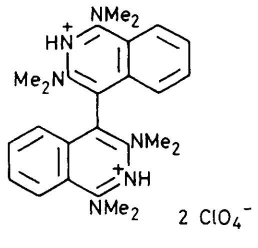
† Satisfactory analytical data were obtained.

‡ *Crystal data:* (**2a**), $C_{28}H_{34}N_6{\cdot}2ClO_4$, monoclinic, space group *I*2/*a*, $a = 14.579(1)$, $b = 10.760(1)$, $c = 18.635(1)$ Å, $\beta = 90.695(3)°$, $U = 2923.1(4)$ Å^3, $Z = 4$, $\mu(Cu\text{-}K_\alpha) = 23.81$ cm^{-1}, $R = 0.066$, for 2482 reflections with $I > 3\sigma(I)$. (**3a**), $C_{26}H_{32}N_6$, monoclinic, space group $P2_1/c$, $a = 9.844(9)$, $b = 10.580(9)$, $c = 24.355(21)$ Å, $\beta = 109.860(8)°$, $U = 2385.7(36)$ Å^3, $Z = 4$, $\mu(Cu\text{-}K_\alpha) = 4.96$ cm^{-1}, $R = 0.052$ for 3716 reflections with $I > 3\sigma(I)$.

The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Rd., Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.



(**4**)

Treatment of the diperchlorate (**2a**) with sodium hydroxide gave the yellow conjugate base (**3a**), m.p. 137.5 °C,† which reversibly formed the normal yellow diperchlorate (**4**), m.p. 205 °C (decomp.)† with perchloric acid. *X*-Ray analysis‡ of the bi-isoquinolyl (**3a**) showed that the two halves of this overcrowded molecule are twisted at a dihedral angle of 62.8(1)°. The central C(4)–C(4′) separation is 1.496(7) Å, as expected for a bond between sp^2-hybridised carbon atoms.

Both the ^{13}C and ^{1}H n.m.r. spectra of the bi-isoquinolyl indicate free rotation about the carbon-to-exocyclic-nitrogen bonds. In the ^{13}C spectrum the number of *N*-methyl resonances is reduced to two, at δ 43.09 and 40.67; similarly, the ^{1}H spectrum shows only two methyl signals at δ 3.14 and 2.73. The crowded nature of this molecule is reflected in the resonances of the aromatic carbon atoms, which are spread over a much wider range than in the diperchlorate (**2a**), occurring at δ 142.26, 128.90, 125.85, 125.09, 120.71, and 115.38.[3]

The isoquinolines (**1b**) and (**1c**) reacted analogously with silver perchlorate to form the dimeric salts (**2b**) and (**2c**), m.p. (decomp.) 234 and 218 °C,† respectively, in 74 and 88% yields, from which the corresponding bi-isoquinolyls (**3b**) and (**3c**), m.p. 147 and 173 °C,† respectively, were obtained. The benzoisoquinoline (**1d**) gave the diperchlorate (**2d**) (56%), m.p. 258 °C (decomp.),† whose ^{1}H n.m.r. spectrum indicated that it was a mixture of two diastereoisomers. This yielded the yellow bi(benzoisoquinolyl) (**3d**), m.p. 200.5 °C.† The nitro-derivative (**1e**) did not react with silver perchlorate.

The oxidation of the isoquinolines by silver ions suggested that the conversion might also be observed by cyclic voltammetry and this was indeed the case. During the positively going scan a single irreversible one-electron oxidation peak was observed for all the compounds listed in Table 1. That the oxidation peaks corresponded only to the exchange of one electron per molecule was unambiguously demonstrated for the nitro-compound (**1e**), for which the height of the oxidation peak was found to be almost identical to that of the reduction peak for the reversible formation of the anion radical of the same compound [E_p = −1.30 V *vs.* saturated calomel electrode (SCE)]. The products formed, the dimers (**2**), were reduced back to the starting materials during the negatively going scan. This voltammetric pattern is similar to that observed for a number of organic sulphur compounds.[4] It is noteworthy that two reduction peaks were observed for the benzo-derivative (**1d**), indicating the presence of two dimers of different structure, in agreement with the results obtained in the silver perchlorate oxidation. Finally, it should be noted that the nitroisoquinoline (**1e**) could be oxidised to (**2e**) voltammetrically, whereas attempts to carry out this reaction with silver perchlorate failed.

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3 Similar phenomena have been observed in the ^{13}C n.m.r. spectra of numerous hindered biphenyls (H. Hasegawa, M. Imanari, and K. Ishizu, *Bull. Chem. Soc., Jpn.*, 1972, **45**, 1153).

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