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RADICAL CYCLISATION OF 2,6-DINITROALKANES

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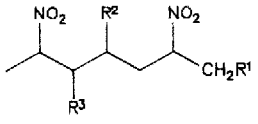
Summary: The dinitronate dianions of 2,6-dinitroalkanes were oxidised to 1,2-dinitrocyclopentanes *via* intermediate α-nitroalkyl radicals by stereoselective cyclisation in high yields.

The intermolecular addition of anions, *e.g.* nitronate anions, to $R_2\dot{C}\text{-}NO_2$ (α-nitroalkyl radicals) in $S_{RN}1$ and oxidative addition reactions is now well known.[1] However, only a few examples of reactions proceeding *via* intramolecular addition of anions to $R_2\dot{C}\text{-}NO_2$ have been reported.[2,3] In this communication, we report the first stereoselective radical cyclisation of 2,6-dinitroalkanes to 1,2-dinitrocyclopentanes *via* α-nitroalkyl radicals.

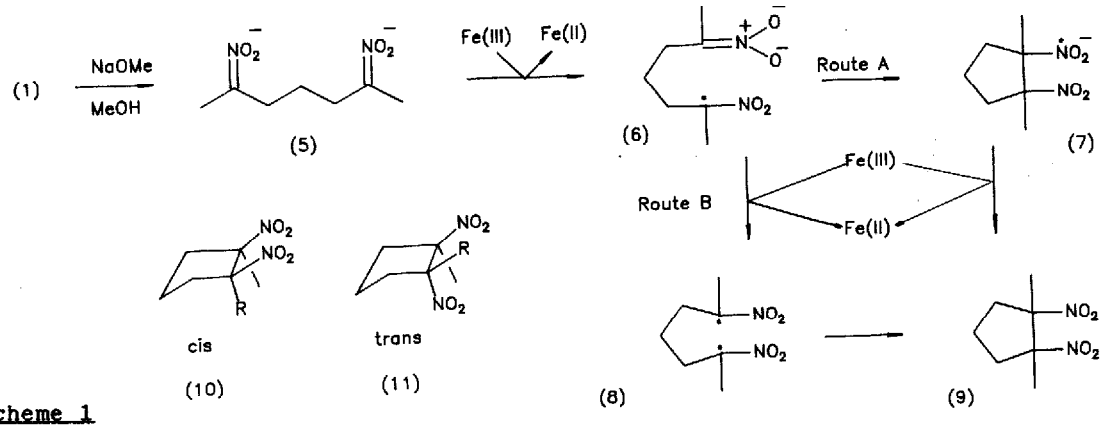
A representative group of 2,6-dinitroalkanes were prepared by a new synthetic route involving nitroalkene intermediates. Details will be reported in a full paper in the future.



(1) $R^1 = R^2 = R^3 = H$
(2) $R^1 = Me$, $R^2 = R^3 = H$
(3) $R^1 = R^3 = H$, $R^2 = Me$
(4) $R^1 = R^2 = H$, $R^3 = Me$

The use of $K_3Fe(CN)_6$ for carrying out oxidative additions of anions to nitronate anions has proved valuable for the preparation of α-substituted nitroalkanes.[1,4] Oxidation of the dinitronate dianion (5) using $K_3Fe(CN)_6$ (5 equivalents added in one portion, N_2 atmosphere, H_2O/Et_2O, 10 min) gave a 71-85% yield of 1,2-dinitrocyclopentane. The possible mechanisms for the oxidative cyclisation are shown in Scheme 1, using 2,6-dinitroheptane as an example. Loss of an electron from the dinitronate (5) yields the radical anion (6) which can react by either of two routes. Route A entails a favourable unimolecular reaction of (6) *via* the cyclised radical anion (7) and is therefore likely to be faster than the bimolecular reaction between (6) and $K_3Fe(CN)_6$ (Route B) *via* the diradical (8), and is also the accepted mechanism for the oxidative addition for anions to α-nitroalkyl radicals.

Oxidation of dianion (5) in the presence of a large excess of sodium benzenesulphinate, the anion which gives the best yields in in oxidative addition reactions of nitronate anions,[1,4] gave an unaltered yield of the cyclised product (9) with no traces of α-nitrosulphones, which further indicates that intermolecular reactions are not favoured.

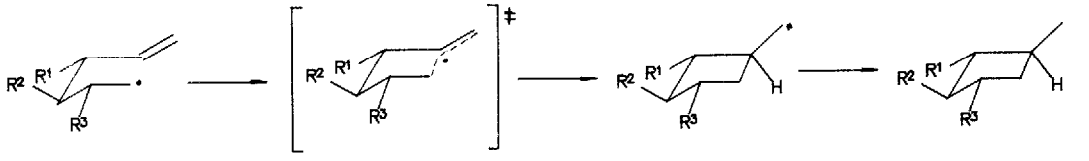


Scheme 1

The dinitroheptane (1) gave both the *cis* and *trans* diastereoisomers (10 and 11, with R = Me)(m.p.s 110°C*d* and 70°C*d*) in a *cis:trans* ratio of 60:40. The A-values of nitro (1.1) and methyl (1.7) groups are similar[2] and no marked steric effects would be expected. 2,6-Dinitro-octane (2) was also oxidatively cyclised to the diastereoisomers (10 and 11, R = Et)(m.p.s 32-33°C and liq.) (85%) in a *cis:trans* ratio of 65:35.

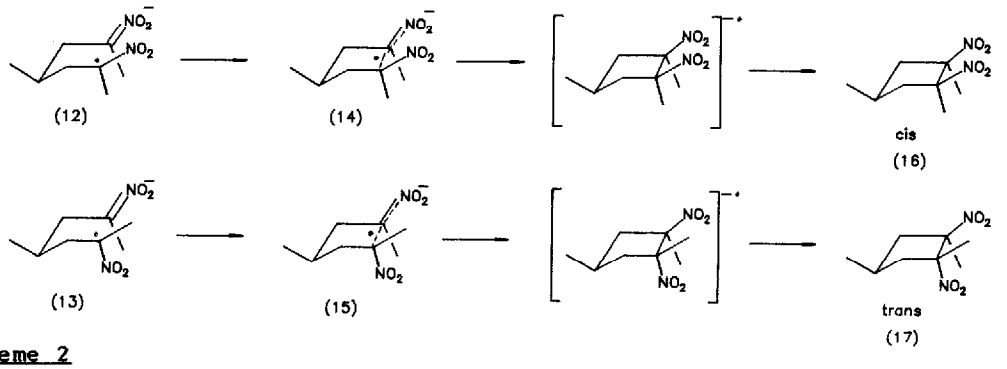
However, the dinitroheptanes, (3) and (4), each gave largely only two of the possible diastereoisomers (3 and 4 diastereoisomers respectively) indicating stereoelectronic control of the cyclisation. Studies using high resolution n.m.r. spectroscopy including COSY and NOESY n.m.r. techniques indicated that the structures of these diastereoisomers are as shown in Schemes 2 and 3 [(16) and (17)(m.p.s 42-42.5°C and 36-36.5°C)(93%, *cis:trans* = 40:60), and (22) and (21) (m.p.s 110-110.5°C and 104.5-105.5°C)(93%, *cis:trans* = 50:50) respectively]. The structures of (16) and (17) were confirmed by X-ray crystallography, and further studies are underway to confirm the other assignments.

The observed stereoselectivity can be explained by proposing transition states for radical cyclisation akin to those proposed by Beckwith and co-workers[5] for 5-hexenyl radicals (see equation A), assuming that the nitronate double bond behaves similarly to an alkene.



(A)

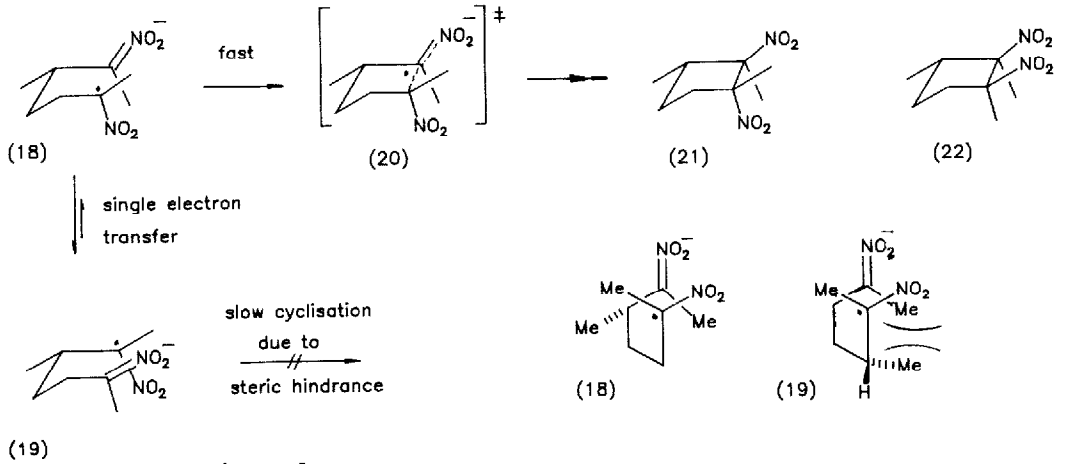
Using the Beckwith model to explain the cyclisation of (3), the intermediate radical anions (12 and 13) react *via* transition states (14 and 15) which have "cyclohexane-*chair*" conformations with the 4-methyl substituent in the equatorial position to yield the cyclised products, (16) and (17), (Scheme 2). The third possible diastereoisomer (all three methyls *cis*, with the 4-methyl *trans* to the nitro groups) was observed in trace amounts (< 5%).



Scheme 2

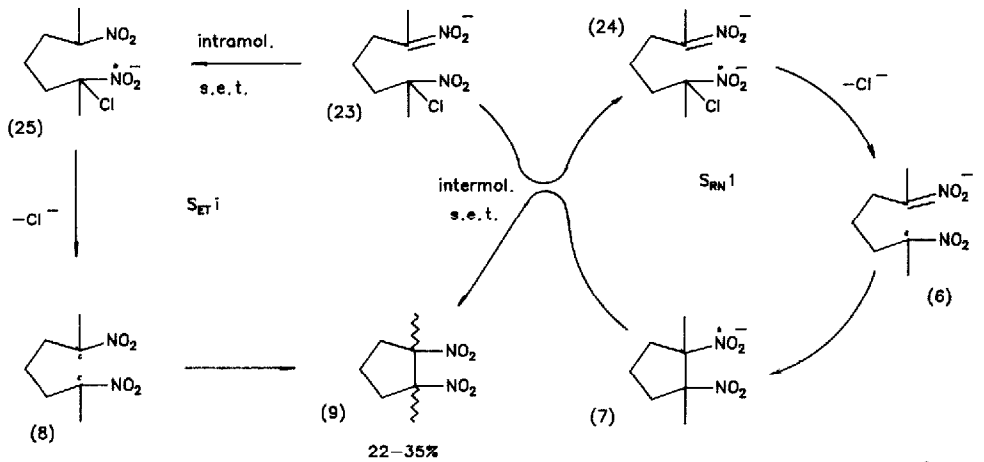
Using the Beckwith model to explain the cyclisation of (4) (Scheme 3), three diastereoisomers are predicted, resulting from the *trans* radical anions, (18) and (19), and their *cis* analogues. However, only the *trans* and *cis* products, (21) and (22), resulting from the radical anions, (18) and its *cis* analogue, proceeding *via* the transition states, (20) and its *cis* derivative, were observed. The absence of products resulting from one of the other intermediate radical anions (19) [the *cis* analogue of (19) would give the same product as the *cis* analogue of (18)] is probably explained by assuming some level of staggering of groups in the transition states as indicated in the Newman projections in Scheme 3. The radical anions, (19) and its *cis* analogue, have serious steric interactions between the methyl groups whereas the radical anions, (18) and its *cis* isomer, do not. We therefore suggest that cyclisation from (19) is slow and that rapid intramolecular single electron transfer (Scheme 3) takes place between (19) and (18) and cyclisation proceeds *via* the more favoured transition states, (20) and its *cis* analogue.

We suggest that this stereoselectivity for the reactions of (3) and (4) is explained by the Beckwith model, and would not be observed in the diradical mechanism (Route B, Scheme 1).



Scheme 3

We were interested to observe whether an intermolecular radical-nucleophilic substitution ($S_{RN}1$)[1] reaction (as shown in Scheme 4), proceeding *via* intramolecular addition of a nitronate onto an α-nitroalkyl radical, would take place. The anion of 2-chloro-2,6-dinitroheptane (23) was reacted (nitrogen atmosphere, irradiation with fluorescent lamps, 2 h) to give a low yield (22-35%) of the expected 1,2-dinitrocyclopentanes, (10 and 11, R = Me) (*cis:trans* = 60:40) (Scheme 4). Studies using normal diagnostic methods[1] for the radical chain $S_{RN}1$ mechanism indicated a chain reaction suggesting a $S_{RN}1$ rather than a $S_{ET}i$ (substitution, electron transfer, intramolecular)[1,6] mechanism (see Scheme 4). Slight inhibition (18% yield) was observed with the addition of 25 mol.% *p*-dinitrobenzene and complete inhibition when carried out in the dark and under an atmosphere of oxygen in place of nitrogen. The chain $S_{RN}1$ reaction [(*via* bimolecular s.e.t. to (24)] appears to be faster than the non-chain $S_{ET}i$ reaction [*via* unimolecular s.e.t. to (25)]. The same *cis:trans* ratios for the $S_{RN}1$ and oxidative addition reactions provide further evidence for a mechanism proceeding *via* the radical anions, (6) and (7).



Scheme 4

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References

1 W.R. Bowman, *Chem. Soc. Rev.*, 1988, 3, 285; W.R. Bowman in "Photoinduced Electron Transfer, Part C", eds. M.A. Fox and M. Chanon, Elsevier, 1988, chap. 4.8, p487.
2 P.A. Wade, W.P. Dailey, and P.J. Carroll, *J.Am.Chem.Soc.*, 1987, 109, 5452.
3 A.P. Marchand, P-W. Jin, J.L. Flippen-Anderson, R. Gilardi, and G. George, *J. Chem. Soc., Chem. Commun.*, 1987, 1108.
4 N. Kornblum, H.K. Singh, and W.J. Kelly, *J. Org. Chem.*, 1983, 48, 332.
5 A.L.J. Bechwith and C.H. Schieser, *Tetrahedron*, 1985, 41, 3925; A.L.J. Beckwith, T. Lawrence, A.K. Sterelis, *J.Chem.Soc., Chem.Commun.*, 1980, 484.

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