7-AZANORBORNADIENE - 3-AZAQUADRICYCLANE **

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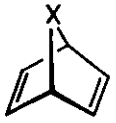
A synthesis for the C-unsubstituted 7-azanorbornadiene skeleton (9) has been devised. Its transformation to the 3-azaquadricyclane (10) by sensitised photoexcitation is uniform and quantitative. The latter can, without any competition, be thermally isomerised into the N-tosylazepine (11). The clear preference for this [4+2]-cycloreversion reaction via the ylid (17) can be understood on the basis of the kinetic data.

Structural and energetic peculiarities make the valence isomeric systems (1)/(2) unusually suitable for theoretical and experimental studies. Of the basic skeletons providing the principal information, the carbocycles (X = CH_2, $C{=}CR_2$, C=O) had been known for some time;



(1)

(2)

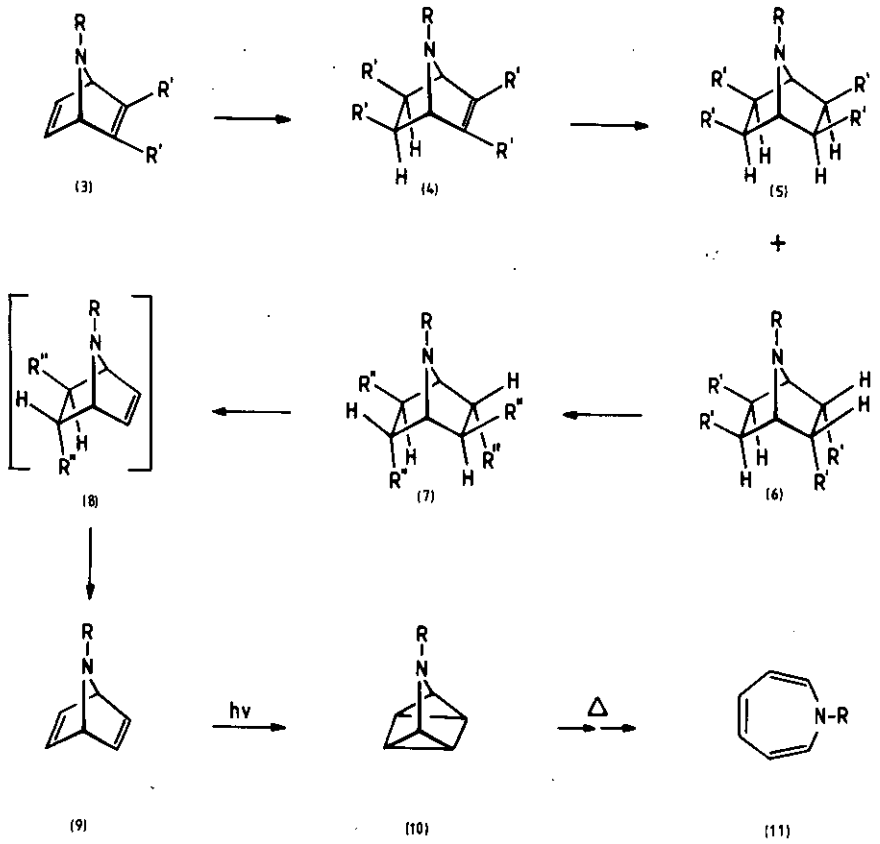
we have recently developed a synthesis for the oxa-compounds (X=O) [1]

** Dedicated to our esteemed colleague and friend, Prof. Dr. T. Nozoe, on the occasion of his 77th birthday.

and have now been able to prepare the aza-systems (X=N-Tos, i.e. N-substituted) [2] by the reaction sequence (3) ⟶ (4) ⟶ (5)/(6) ⟶ (7) ⟶ (8) ⟶ (9) ⟶ (10). The key step is the electrolytical decarboxylation of the tetracarboxylic acid (7). In this way the thermal lability of the azanorbornenes (8) - cf. the difficulties with the oxanorbornene [1] - is taken into account. Since the azanorbornadiene-diester (3) is easily accessible [3] and all other steps occur with high yields [4], the loss caused by the low yielding electrolysis is acceptable.

The introduction of two methoxycarbonyl groups at C-5 and C-6 in (3) is achieved with yields of over 90 % using the method of James and Stille [6]; hereby the methanolic solution of (3) together with $PdCl_2$/$CuCl_2$ is stirred at 20°C under a CO-atmosphere (3 atm.) for 10 h (exclusively exo,exo-product (4), m.p. 155°C, $J_{1,6}(J_{4,5}) < 1$ Hz). Hydrogenation over Raney-Ni (ethyl acetate, 100 atm. H_2, 50°C, 48 h) leads almost quantitatively to a ca. 2:1 mixture of (5) (m.p. 155°C) and (6) (m.p. 134°C). After saponification (KOH, methanol, 25°C) the thermodynamically most stable tetracarboxylic acid (7) (m.p. 285°C (dec.), $J_{1,2}(J_{4,5}) = 4.8$, $J_{1,6}(J_{3,4}) = 0$, $J_{2,3}(J_{5,6}) = 5.8$ Hz) is isolated exclusively. Using the proven procedure [7] the solution of (7) can be electrolysed (6.4 g, pyridine/ water/ triethylamine (265:30:5), 20 - 25°C, 80 V). Upon chromatography (silica gel, benzene/ethyl acetate) (9) is then eluted as an oil (480 - 500 mg, 13 - 15 %), which crystallises slowly as colourless, rhombic crystals from ether (m.p. 129°C, ^{1}H-nmr ($CDCl_3$): τ = 3.24 (m, 4H), 4.86 (m, 2H); ^{13}C-nmr ($CDCl_3$): δ = 143.5 (4C), 67.2 ppm (2C); $J_{C-2,H} = 182$, $J_{C-1,H} = 164$ Hz). The longwave UV-absorption of (9) is largely determined by the N-tosyl residue; in order to

exclude side reactions caused by this absorption the photoisomerisation to (10) is carried out with sensitisation; in acetone (750 mg (9), 300 ml, -40°C, Hanau Q 81, pyrex; (10) is photostable under these condi-

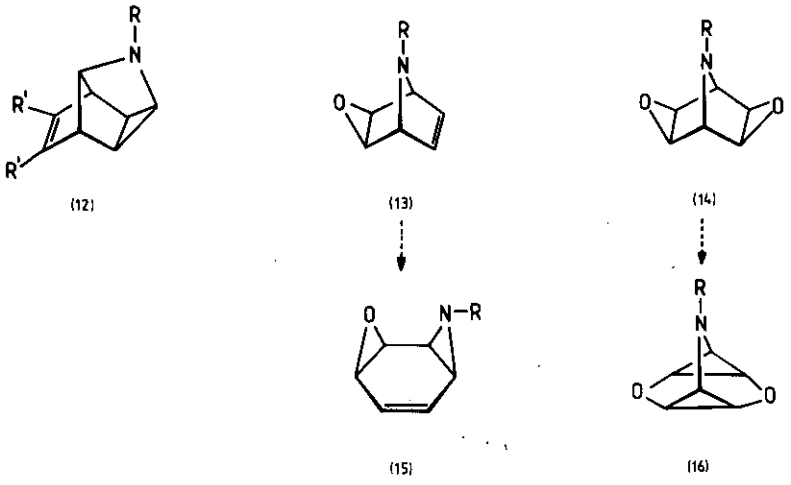


R = p-Tos; R' = CO_2CH_3; R'' = CO_2H

tions) the conversion is practically quantitative. When proper care is taken of the thermal instability of the product - all work-up procedures below 25°C - the azaquadricyclane (10) is isolated as colourless needles (from ether at -35°C) in 94 - 96 % yield. ^{1}H-nmr ($CDCl_3$): τ = 6.42 (m, 2H), 8.40 (m, 4H); ^{13}C-nmr ($CDCl_3$) : δ = 44.8 (2C), 15.6 ppm

(4C)). No additional, in particular coloured products e.g. the 6-aminofulvene resulting from a competing di-π-methane rearrangement [8], were detected by TLC or ^{1}H-nmr. Upon rapid heating the m.p. of (10) was 125°C; if kept at 20°C or heated slowly, isomerisation into the yellow N-tosylazepine (11) occurs gradually. The latter transformation is effected quantitatively in benzene solution ($t_{1/2}$(70°C) ca. 2 min, isolated 90 %, yellow crystals, m.p. 169°C (dec.), ^{1}H-nmr (C_6D_6): τ = 4.33 (d, 2-, 7-H), 4.35 - 4.5 (m, 4-, 5-H), 4.65 - 4.8 (m, 3-, 6-H)). As observed in earlier examples, no competitive transformation to (9) can be seen (TLC). This isomerisation is however easily and uniformally achieved in the presence of PdI_2 $[(C_6H_5)_3Sb]_2$ at 20°C.

(9) can be used preparatively by addition of dimethyl acetylenedicarboxylate to give (12) (80 - 85 %, m.p. 135°C, ^{1}H-nmr ($CDCl_3$): τ = 5.90

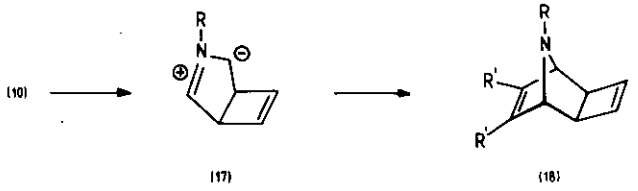


(12) (13) (14) (15) (16)

(dt, 4-H), 6.20 (m, 6-H), 6.27 (s, 2 OCH_3), 7.28 (ddd, 1-, 7-H), 8.13 (ddd, 2-, 3-H); $J_{1,2}(J_{3,7})$ = 1.2, $J_{1,4}(J_{4,7})$ = 1.2, $J_{1,6}(J_{6,7})$ = 2.5, $J_{2,4}(J_{3,4})$ = 4.2, $J_{2,6}(J_{3,6})$ = 1.2, $J_{4,6}$ = 0 Hz), or by two-phase-oxi-

dation (m-chloroperbenzoic acid) to yield (13) (m.p. 145°C, ^{1}H-nmr ($CDCl_3$): τ = 3.56 (m, 6-, 7-H), 5.30 (m, 1-, 5-H), 6.49 (s, 2-, 4-H) and (14) (m.p. 162°C, ^{1}H-nmr ($CDCl_3$): τ = 5.56 (s, 1-, 5-H), 6.52 (s, 2-,4-,6-,8-H). We are interested in the epoxides as isomers of the oxa, aza-cis-bis- and the oxa, aza-cis-tris-σ-homobenzenes. Attempts to convert (13) into (15) and (14) into the "trisheteroasterane" (16) have thus far been unsuccessful.

The thermolysis of (10) in the presence of a ca. ten-fold excess of dimethyl acetylenedicarboxylate (80°C, 10 min) yields as well as 21 % of (11) ca. 75 % of the [4+2]-adduct (18) (m.p. 150°C, ^{1}H-nmr ($CDCl_3$): τ = 3.75 (s, 3-, 4-H), 5.38 (s, 1-, 6-H), 6.33 (s, 2 OCH_3), 7.23 (br. s, 2-, 5-H).



(17) (18)

The kinetic data obtained for the thermolyses of the azaquadricyclane (10) (35 - 55°C) and the oxaquadricyclane (1) (X=0) [1] (85 - 110°C) (benzene, ^{1}H-nmr, first-order rate law) are qualitatively in accord

	E_a (kcal/mol)	log A	$\Delta H^{\ddagger}$ (kcal/mol)	$\Delta S^{\ddagger}$ (e.u.)
(10)	27.3 ± 0.9	15.2	26.7 ± 1.0	9.2 ± 2.9
(1) (X=0)	32.6 ± 0.3	15.8	31.9 ± 0.3	11.5 ± 0.9

with the relative stability of the ylid intermediates [9] and suggest why

the known stabilisation processes for the carbocyclic skeletons (1) [10] cannot compete here.

The isolation of the free amines (1)/(2) (X=NH) from the N-tosyl-derivatives (9)/(10) is problematic. Preliminary findings indicate, that the species generated from (10) with sodium/ammonia already rearranges below -50°C to the azepine (isolated as 3H-azepine). We expect, however, to reach this goal insofar, as the reaction sequence given above for (9) can be applied to other N-derivatives, e.g. the readily saponified urethane ($X=NCO_2CH_3$, ^{1}H-nmr ($CDCl_3$): τ = 3.0 (m, 4H), 4.57 (m, 2H), 6.41 (s, OCH_3)) [11].

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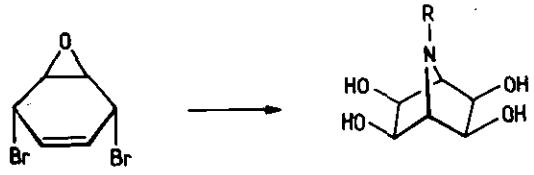
4 An alternative pathway to (5)/(6), hydrogenation of the N-tosyl-7-azanorbornadiene-2,3,5,6-tetracarbocyclic ester was frustrated as N-tosyl-pyrrol-3,4-dicarboxylic ester failed to give a Diels-Alder-adduct with dimethyl acetylenedicarboxylate. To avoid the limiting electrolytic steps (7) ⟶ (8) ⟶ (9) a second synthetic route via the 7-azanorbornan-2,3,5,6-tetraole (20) was planned allowing more scope to vary the N-substitution; the compound (20) is available from the dibromocyclohexeneepoxide (19) (H. Prinzbach, R. Keller and R. Schwesinger, Angew. Chem. 87, 627 (1975); Angew. Chem., internat. Edit. 14, 633 (1975)) in preparatively useful quantities (R=$CH_2C_6H_5$ ca. 40 %,m.p. 156°C). With several methods of olefin formation from cis-1,2-diols we ran, however, into difficulties, which are partially caused by ready retro-Diels-Alder reactions in the 7-azanorbornene intermediates [2,5].



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