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 = CH₂, C=CR₂, C=O) had been known for some time;

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) \(\rightarrow\) (4) \(\rightarrow\) (5)/(6) \(\rightarrow\) (7) \(\rightarrow\) (8) \(\rightarrow\) (9) \(\rightarrow\) (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\(_3\)): \(\tau = 3.24\) (m, 4H), 4.86 (m, 2H); \(^13\)C-nmr (CDCl\(_3\)): \(\delta = 143.5\) (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-

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\begin{align*}
(3) & \rightarrow (4) \rightarrow (5) \\
(8) & \rightarrow (7) \rightarrow (6)
\end{align*}
\]

ions) 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\text{H-nmr (CDCl}_3\text{)}: \tau = 6.42 \text{ (m, 2H), 8.40 (m, 4H);} \quad \text{13C-nmr (CDCl}_3\text{): } s = 44.8 \text{ (2C), 15.6 ppm}

R = p-Tos; \quad R' = \text{CO}_2\text{CH}_3; \quad R'' = \text{CO}_2\text{H}
(4C)). No additional, in particular coloured products e.g. the 6-amino-
fulvene resulting from a competing di-π-methane rearrangement 8, were
detected by TLC or 1H-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 (t1/2(70°C) ca. 2 min,
isolated 90 %, yellow crystals, m.p. 169°C (dec.), 1H-nmr (C6D6): 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 PdI2 [(C6H5)3Sb]2 at 20°C.

(9) can be used preparatively by addition of dimethyl acetylenedicarb-
oxylate to give (12) (80 - 85 %, m.p. 135°C, 1H-nmr (CDCl3): τ = 5.90

\[
\begin{align*}
(12) & \\
(13) & \\
(14) & \\
(15) & \\
(16) & 
\end{align*}
\]

(dt, 4-H), 6.20 (m, 6-H), 6.27 (s, 2 OCH3), 7.28 (ddd, 1-, 7-H), 8.13
(ddd, 2-, 3-H); J1,2(J3,7) = 1.2, J1,4(J4,7) = 1.2, J1,6(J6,7) = 2.5,
J2,4(J3,4) = 4.2, J2,9(J3,6) = 1.2, J4,6 = 0 Hz), or by two-phase-oxi-
dation (m-chloroperbenzoic acid) to yield (13) (m.p. 145°C, 1H-nmr
(CDCl₃): 7 = 3.56 (m, 6-, 7-H), 5.30 (m, 1-, 5-H), 6.49 (s, 2-, 4-H)
and (14) (m.p. 162°C, 1H-nmr (CDCl₃): 7 = 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-O-homobenzenes. Attempts to con-
vert (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, 1H-nmr (CDCl₃): 7 =
3.75 (s, 3-, 4-H), 5.38 (s, 1-, 6-H), 6.33 (s, 2 OCH₃), 7.23 (br. s,
2-, 5-H).

![Diagram](image)

The kinetic data obtained for the thermolyses of the azaquadricycla-
ne (10) (35–55°C) and the oxaquadricyclane (1) (X=O) (85–110°C)
(benzene, 1H-nmr, first-order rate law) are qualitatively in accord

<table>
<thead>
<tr>
<th></th>
<th>E&lt;sub&gt;a&lt;/sub&gt;</th>
<th>log A</th>
<th>ΔH&lt;sup&gt;+&lt;/sup&gt;</th>
<th>ΔS&lt;sup&gt;+&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>(10)</td>
<td>27.3 ± 0.9</td>
<td>15.2</td>
<td>26.7 ± 1.0</td>
<td>9.2 ± 2.9</td>
</tr>
<tr>
<td>(1)</td>
<td>32.6 ± 0.3</td>
<td>15.8</td>
<td>31.9 ± 0.3</td>
<td>11.5 ± 0.9</td>
</tr>
</tbody>
</table>

with the relative stability of the ylid intermediates and suggest why
the known stabilisation processes for the carbocyclic skeletons (1) 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=NCO₂CH₃).

\[ {^1}H\text{-nmr (CDCl}_3): \tau = 3.0 \text{ (m, 4H), 4.57 \text{ (m, 2H), 6.41 \text{ (s, OCH}_3}]} \]

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REFERENCES


2 For synthesis of different C-substituted derivatives s. review:

An alternative pathway to (5)/(6), hydrogenation of the N-tosyl-7-azanorbornadiene-2,3,5,6-tetracarboxyclic 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) $\rightarrow$ (8) $\rightarrow$ (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 dibromocyclohexeneeioxide (19) (H. Prinzbach, R. Keller and R. Schwesinger, Angew. Chem. 87, 627 (1975); Angew. Chem., internat. Edit. 14, 633 (1975)) in preparatively useful quantities ($R=\text{CH}_2\text{C}_6\text{H}_5$, 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.

\[\text{(19)} \quad \text{O} \quad \text{Br} \quad \text{Br} \quad \rightarrow \quad \text{(20)} \quad \text{R}\]


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