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The polar 1,4-cycloaddition of chlorosulfene (generated *in situ* from chloromethanesulfonyl chloride and triethylamine) to *N,N*-disubstituted (*E*)-2-aminomethylenecyclohexanones I gave mixtures of *N,N*-disubstituted *cis* and *trans* 4-amino-3-chloro-3,4,5,6,7,8-hexahydro-1,2-benzoxathiin 2,2-dioxides III and IV, except for *N,N*-diphenyl enaminone which did not react. Only compounds IV could be separated from these mixtures by silica gel chromatography, with the exception of the piperidino adducts (III + IV)d, from which also III d could be obtained pure. Compounds IV or mixtures III + IV were dehydrochlorinated with DBN in refluxing benzene to afford *N,N*-disubstituted 4-amino-5,6,7,8-tetrahydro-1,2-benzoxathiin 2,2-dioxides V in satisfactory yields. Structural and conformational features of compounds III, IV and V were determined from uv, ir and nmr spectral data.

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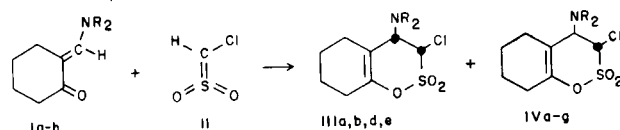
In the first paper of the series [1] we described the polar 1,4-cycloaddition of phenylsulfene to yield *N,N*-disubstituted (*E*)-2-aminomethylenecyclohexanones I. In pursuing our work on substituted sulfenes, we wish to report now the results obtained with chlorosulfene in the cycloaddition with enaminones I.

Reaction of Ia-g with chloromethanesulfonyl chloride and triethylamine (chlorosulfene prepared *in situ*) occurred in the case of dialiphatic and monoaromatic *N*-substitution (the *N,N*-diphenylenaminone Ih did not react) to give a mixture of two products (III + IV)a,b,d,e or a sole compound IVc,f,g. It should be observed, however, that also in the latter case both III and IV are probably present, but the less stable compounds III decomposed during column chromatography, as can be argued from the poor yield of compounds IV (Table I).

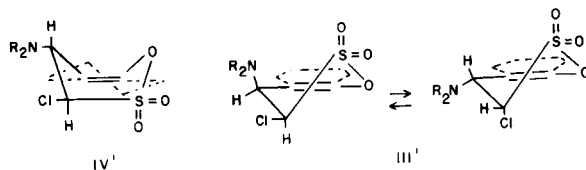
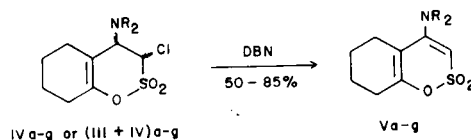
From the mixtures (III + IV) only compounds IV could be separated by silica gel chromatography, with the exception of (III + IV)d, from which also III d could be obtained pure.

Both compounds III and IV corresponded to the expected cycloadducts, namely *N,N*-disubstituted 4-amino-3-chloro-3,4,5,6,7,8-hexahydro-1,2-benzoxathiin 2,2-dioxides by elemental analyses and spectral data (Tables I, II and Experimental) and clearly were stereoisomers. By taking also into account the results obtained with phenylsulfene [1], we propose for isomers III a *cis* configuration for CH-3 and CH-4 in the less stable half-chair conformation III', and for isomers IV a *trans* configuration for the same protons in the more stable boat conformation IV'.

These statements arise from the following observations. Unlike similar adducts obtained with phenylsulfene [1], compound III d, as well as all compounds IV with the sole



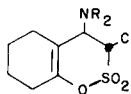
- NR<sub>2</sub>
- a N(CH<sub>3</sub>)<sub>2</sub>
  - b N(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>
  - c Pyrrolidino
  - d Piperidino
  - e Morpholino
  - f N'-Methylpiperazino
  - g N(CH<sub>3</sub>)C<sub>6</sub>H<sub>5</sub>
  - h N(C<sub>6</sub>H<sub>5</sub>)<sub>2</sub>



exception of methylphenylamino adduct IVg had practically no absorption in the uv region, nor showed any particular ir absorption due to symmetrical stretching of SO<sub>2</sub> group in the 1175 cm<sup>-1</sup> region. These data mean that C=C-O-SO<sub>2</sub> group is not planar [1].

In the nmr spectra of III d and IIIa,b,e (see Experimental), the signals of CH-3 and CH-4 appeared as a doublet at  $\delta$  5.28-5.34 ( $J = 5$  Hz) and as a multiplet at  $\delta$  4.2-4.4, respectively, whereas the same protons appeared as two doublets at  $\delta$  4.97-5.08 and 3.68-3.90 ( $J = 8.6-9$  Hz) in the

Table I

*N,N*-Disubstituted *trans*-4-Amino-3-chloro-3,4,5,6,7,8-hexahydro-1,2-benzoxathiin 2,2-Dioxides IVa-g

Formula Number	NR <sub>2</sub>	Yield %	Mp °C [a]	Molecular Formula	Analyses %		
					C	H	N
IVa	N(CH <sub>3</sub> ) <sub>2</sub>	10	70	C <sub>10</sub> H <sub>16</sub> ClNO <sub>3</sub> S	45.20 45.31	6.07 5.97	5.27 5.20
IVb	N(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	25	91	C <sub>12</sub> H <sub>20</sub> ClNO <sub>3</sub> S	49.06 48.87	6.86 6.82	4.77 4.71
IVc	Pyrrolidino	25	124	C <sub>12</sub> H <sub>18</sub> ClNO <sub>3</sub> S	49.39 49.18	6.22 6.11	4.80 4.96
IVd	Piperidino	42	84	C <sub>13</sub> H <sub>20</sub> ClNO <sub>3</sub> S	51.06 51.18	6.59 6.57	4.58 4.55
IVe	Morpholino	33	145	C <sub>12</sub> H <sub>18</sub> ClNO <sub>4</sub> S	46.83 46.90	5.89 5.80	4.55 4.75
IVf	<i>N'</i> -Methylpiperazino	51	123	C <sub>13</sub> H <sub>21</sub> ClN <sub>2</sub> O <sub>3</sub> S	48.67 48.79	6.60 6.68	8.73 8.56
IVg	N(CH <sub>3</sub> )C <sub>6</sub> H <sub>5</sub>	33	111	C <sub>15</sub> H <sub>18</sub> ClNO <sub>3</sub> S	54.96 54.82	5.53 5.45	4.27 4.46

[a] From petroleum ether (bp 40-70°).

Table II

IR and NMR Spectral Data of Compounds IVa-g

	IR, cm <sup>-1</sup>		NMR, δ
	C=C	O=S=O	
IVa	1694	1386, 1176	1.70 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.13 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.49 (s, 2 CH <sub>3</sub> N), 3.77 (near d, J = 8.6, CH-4), 5.04 (d, J = 8.6, CH-3)
IVb	1690	1387, 1175	1.11 (t, J = 7.2, 2 CH <sub>3</sub> -CH <sub>2</sub> ), 1.70 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.14 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.78 (q, J = 7.2, 2 CH <sub>2</sub> Me), 3.90 (near d, J = 9, CH-4), 4.97 (d, J = 9, CH-3)
IVc	1692	1386, 1174	1.80 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7, 2 CH <sub>2</sub> pyr), 2.17 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.87 (mc, 2 CH <sub>2</sub> N), 4.05 (near d, J = 8.6, CH-4), 5.03 (d, J = 8.6, CH-3)
IVd	1688	1378, 1175	1.53 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7, 3 CH <sub>2</sub> pip), 2.14 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.69 (mc, 2 CH <sub>2</sub> N), 3.74 (near d, J = 8.6, CH-4), 5.07 (d, J = 8.6, CH-3)
IVe	1693	1391, 1175	1.72 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.15 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.82 (mc, 2 CH <sub>2</sub> N), 3.68 (mc, 2 CH <sub>2</sub> O, CH-4), 5.07 (d, J = 9, CH-3)
IVf	1694	1389, 1175	1.70 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.18 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.30 (s, CH <sub>3</sub> N), 2.39 (mc, 2 CH <sub>2</sub> N), 2.87 (mc, 2 CH <sub>2</sub> N), 3.80 (near d, J = 9, CH-4), 5.08 (d, J = 9, CH-3)
IVg [a]	1695	1392, 1175	1.69 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 1.96 (mc, CH <sub>2</sub> -8), 2.29 (mc, CH <sub>2</sub> -5), 2.90 (s, CH <sub>3</sub> N), 4.84 and 5.17 (2 d, J = 9, CH-4 and CH-3), 6.95 (mc, 3 H ar), 7.30 (mc, 2 H ar)

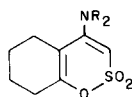
[a] UV λ max nm (log ε): 250.5 (4.23), 293 (3.33).

case of IVa,b,d,e (Table II). By applying the Karplus rules to the molecular models, a J value of about 9 Hz is consistent with a dihedral angle of about 170° between C-3 and C-4 protons found in compounds IV when both protons are near axial, whereas a J value of 5 Hz is consistent with a dihedral angle of about 45° found in compounds III when the C-3 proton is near axial and C-4 proton is near equatorial. Another feature concerns CH-4, that in conformers III appears as a multiplet. This is due to an homoallylic coupling between CH-4 and CH<sub>2</sub>-8, possible only when the former is located in the half-chair conformation III'

and is not coplanar with the endocyclic double bond. Once more, the lack of stereospecificity in the 1,4-cycloaddition of chlorosulfene to enamines I supports the existence of a dipolar intermediate similar to that suggested in the case of sulfene (see [1]).

Compounds IVc,f,g or mixtures (III + IV)a,b,d,e were dehydrochlorinated with DBN [2] in refluxing benzene to give *N,N*-disubstituted 4-amino-5,6,7,8-tetrahydro-1,2-benzoxathiin 2,2-dioxides Va-g (Table III) in satisfactory yield. In these compounds, C-3 protons appear as a singlet at δ 5.2-5.9 (Table IV), in agreement with the values found

Table III

*N,N*-Disubstituted 4-Amino-5,6,7,8-tetrahydro-1,2-benzoxathiin 2,2-Dioxides Va-g

Formula Number	NR <sub>2</sub>	Yield %	Mp °C	Molecular Formula	Analyses %		
					Calcd./Found	C	H
Va	N(CH <sub>3</sub> ) <sub>2</sub>	58	123 [a]	C <sub>10</sub> H <sub>15</sub> NO <sub>3</sub> S	52.38	6.59	6.11
					52.62	6.67	6.22
Vb	N(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	62	106 [a]	C <sub>12</sub> H <sub>19</sub> NO <sub>3</sub> S	56.01	7.44	5.44
					55.98	7.41	5.66
Vc	Pyrrolidino	55	153 [b]	C <sub>12</sub> H <sub>17</sub> NO <sub>3</sub> S	56.45	6.71	5.48
					56.38	6.69	5.61
Vd	Piperidino	85	135 [a]	C <sub>13</sub> H <sub>19</sub> NO <sub>3</sub> S	57.97	7.11	5.20
					58.17	7.15	5.17
Ve	Morpholino	75	134 [a]	C <sub>12</sub> H <sub>17</sub> NO <sub>4</sub> S	53.12	6.32	5.16
					53.08	6.35	5.41
Vf	<i>N'</i> -Methylpiperazino	61	124 [b]	C <sub>13</sub> H <sub>20</sub> N <sub>2</sub> O <sub>3</sub> S	54.91	7.09	9.85
					54.73	7.01	9.58
Vg	N(CH <sub>3</sub> )C <sub>6</sub> H <sub>5</sub>	50	165 [a]	C <sub>15</sub> H <sub>17</sub> NO <sub>3</sub> S	61.83	5.88	4.81
					61.76	5.75	4.95

[a] From diethyl ether. [b] From diethyl ether-acetone 2:1.

Table IV

UV, IR and NMR Spectral Data of Compounds Va-g

Compound No.	UV $\lambda$ max nm (log $\epsilon$ )	IR, cm <sup>-1</sup>		NMR, $\delta$
		C=C	O=S=O	
Va	257 (3.84)	1647	1352	1.75 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.42 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.80 (s, 2 CH <sub>3</sub> N), 5.50 (s, CH-3)
	290 sh (3.72)	1552	1147	
Vb	259 (3.82)	1648	1352	1.12 (t, J = 7, 2 CH <sub>3</sub> -CH <sub>2</sub> ), 1.72 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.33 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 3.08 (q, J = 7, 2 CH <sub>2</sub> Me), 5.53 (s, CH-3)
	293 sh (3.73)	1545	1170	
Vc	251 (3.87)	1643	1340	1.85 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7, 2 CH <sub>2</sub> pyr), 2.40 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 3.25 (mc, 2 CH <sub>2</sub> N), 5.18 (s, CH-3)
	297 (3.80)	1530	1155	
Vd	263 (3.83)	1648	1352	1.64 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7, 3 CH <sub>2</sub> pip), 2.35 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.94 (mc, 2 CH <sub>2</sub> N), 5.60 (s, CH-3)
	290 sh (3.70)	1547	1163	
Ve	263 (3.89)	1645	1355	1.74 (near s, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.35 (near s, CH <sub>2</sub> -5, CH <sub>2</sub> -8), 2.97 (near t, J = 4.8, 2 CH <sub>2</sub> N), 3.78 (near t, J = 4.8, 2 CH <sub>2</sub> O), 5.68 (s, CH-3)
	288 sh (3.73)	1552	1158	
Vf	263 (3.93)	1643	1352	1.75 (mc, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.35 (s, CH <sub>3</sub> N), 2.49 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -8, 2 CH <sub>2</sub> N), 3.03 (mc, 2 CH <sub>2</sub> N), 5.66 (s, CH-3)
	285 sh (3.79)	1547	1158	
Vg	250 sh (3.72)	1648	1353	1.49 (mc, CH <sub>2</sub> -5, CH <sub>2</sub> -6, CH <sub>2</sub> -7), 2.39 (mc, CH <sub>2</sub> -8), 3.20 (s, CH <sub>3</sub> N), 5.86 (s, CH-3), 7.25 (mc, C <sub>6</sub> H <sub>5</sub> N)
	280 sh (3.80) 302 (3.87)	1545	1164	

for similar protons in the 1,2-oxathiin 2,2-dioxide ring [3]. On the other hand, the above values confirm that this ring is a non-aromatic  $6\pi$ -electron system [4], although it has a planarity limited to the C(3)=C(4)-C(5)=C(6)-O(1) grouping, as can be seen from the absorptions in the uv region ( $\lambda$  max at 250-263 and 280-297 nm) (Table IV).

The dehydrochlorination occurred in general by a prolonged heating in benzene. Because in six-membered cycles E2 is strictly an *anti* process, cycloadducts IV in the thermodynamically more stable boat conformation IV' should adopt the less stable half-chair conformation III',

where the proper proton *anti* to chlorine arrangement can take place.

Finally, the dehydrochlorination leads to a fully dehydrogenated 4-amino-1,2-benzoxathiin 2,2-dioxide ring, a result that cannot be reached by treating with DDQ the dihydro adducts obtained by reacting sulfene with *N,N*-disubstituted 2-aminomethyleneketones (see [5,6]).

## EXPERIMENTAL

The uv spectra were measured in 95% ethanol with a Hitachi-Perkin-Elmer Model EPS-3T spectrophotometer. The ir spectra were taken in

chloroform on a Perkin-Elmer Model 398 spectrophotometer; the nmr spectra were recorded in deuteriochloroform on a Perkin-Elmer Model R-600 instrument (60 MHz, TMS as internal standard, J in Hz). Melting points were determined with a Mettler FP1 apparatus.

General Procedure for *N,N*-Disubstituted 4-Amino-3-chloro-3,4,5,6,7,8-hexahydro-1,2-benzoxathiin 2,2-Dioxides III and IV.

A solution of chloromethanesulfonyl chloride (3.28 g, 22 mmoles) in anhydrous benzene (20 ml) was slowly added under nitrogen with stirring to a solution of I (20 mmoles) and triethylamine (10 g, ~0.1 moles) in the same solvent (100 ml) at room temperature. The reaction mixture was refluxed under nitrogen for 40 minutes, cooled and filtered, and the solution was evaporated under reduced pressure. The oily residue was worked up as described below. In the case of Ic,f,g, only adducts IVc,f,g could be obtained by silica gel chromatography (petroleum ether bp 40-70°). The reaction with Ia,b,d,e afforded after silica gel chromatography (diethyl ether-acetone 5:1) variable mixtures of (III + IV)a,b,d,e in 52, 64, 63, 66% overall yield, respectively. These mixtures were further chromatographed on silica gel to give pure adducts IVa,b,d,e (petroleum ether) and new mixtures (III + IV)a,b,e (diethyl ether). We were unable to isolate pure IIIa,b,e from such mixtures also by repeated chromatography. The following nmr data for compounds IIIa,b,e were obtained from the nmr spectra of mixtures (III + IV)a,b,e. IIIa:  $\delta$  2.58 (s, 2 CH<sub>3</sub>N), 4.22 (mc, CH-4), 5.34 (d, J = 5, CH-3); IIIb:  $\delta$  4.38 (mc, CH-4), 5.28 (d, J = 5, CH-3); IIIe:  $\delta$  4.18 (mc, CH-4), 5.31 (d, J = 5, CH-3). Only compound IIIId could be obtained pure by silica gel chromatography (diethyl ether-acetone 2:1); yield, 16%, mp 101° from the same solvent; ir:  $\nu$  max 1690, 1385, 1176 cm<sup>-1</sup>; nmr  $\delta$  1.53 (mc, CH<sub>2</sub>-6, CH<sub>2</sub>-7, 3 CH<sub>2</sub> pip), 2.17 (mc, CH<sub>2</sub>-5, CH<sub>2</sub>-8), 2.85 (mc, 2 CH<sub>2</sub>N), 4.22 (mc, CH-4), 5.24 (d, J = 5, CH-3).

Anal. Calcd. for C<sub>13</sub>H<sub>20</sub>ClNO<sub>3</sub>S: C, 51.06; H, 6.59; N, 4.58. Found: C, 51.20; H, 6.55; N, 4.49.

General Procedure for *N,N*-Disubstituted 4-Amino-5,6,7,8-tetrahydro-1,2-benzoxathiin 2,2-Dioxides V.

Compounds IVc,f,g or mixtures (III + IV)a,b,d,e (10 mmoles) in anhydrous benzene (50 ml) were treated with DBN (3.73 g, 30 mmoles) and the solution was refluxed under nitrogen for 40 minutes (a,b) or 5 hours (c-g). The crude liquids obtained followed our described procedure [7] were purified by silica gel chromatography, using diethyl ether as eluant for compounds Va-e and diethyl ether-acetone 2:1 for compounds Vf-g, followed by recrystallization from a suitable solvent.

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