

**Chemistry of Sulphines. Part XVI.<sup>1</sup> Aliphatic Sulphines from Non-enethiolisable Thioketones and their Cycloaddition Reactions with Diazoalkanes**

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## Chemistry of Sulphines. Part XVI.<sup>1</sup> Aliphatic Sulphines from Non-enethiolisable Thioketones and their Cycloaddition Reactions with Diazoalkanes

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Oxidation with peroxy-acid of the non-enethiolisable thioketones adamantanethione, 2,2,4,4-tetramethyl-3-thioxocyclobutanone and 2,2,4,4-tetramethylcyclobutane-1,3-dithione gives the corresponding sulphines in high yields. Cycloaddition reactions of these sulphines with 2-diazopropane lead to  $\Delta^3$ -1,3,4-thiadiazoline *S*-oxides; from diazomethane and 2,2,4,4-tetramethyl-3-thioxocyclobutanone *S*-oxide an episulphoxide was isolated.

SEVERAL types of sulphines (thione *S*-oxides) can conveniently be synthesised by peroxy-acid oxidation of the corresponding thiocarbonyl compounds.<sup>2</sup> Aliphatic sulphines have not been prepared hitherto by this oxidation method, presumably because of the limited stability<sup>3</sup> of the parent thiones. Thioacetone *S*-oxide has been reported<sup>4</sup> as a transient intermediate during the dehydrohalogenation of propane-2-sulphinyl chloride.

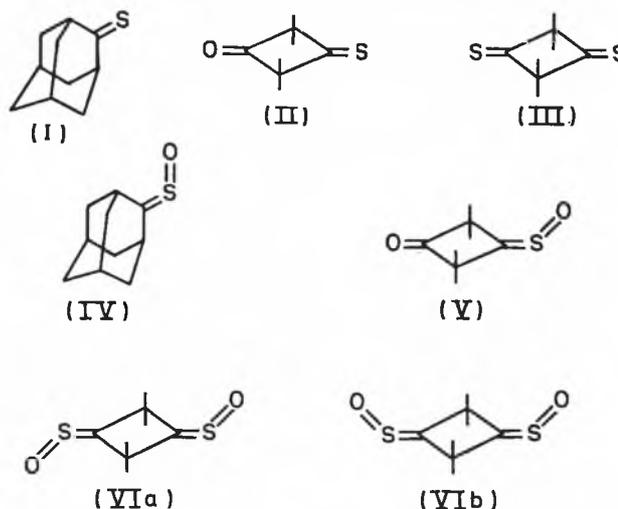
With the aim of studying the chemical and spectroscopic properties of aliphatic sulphines, we selected three aliphatic thioketones, (I)—(III), which show no tendency towards enethiolisation or di-, tri-, or polymerisation at ordinary temperatures, and which therefore would probably be oxidisable to sulphines. Indeed, adamantanethione<sup>5</sup> (I) smoothly reacted with *m*-chloroperbenzoic acid (MCPBA) in ether at 5° to give the stable aliphatic sulphine (IV) (75%). The product showed the characteristic  $>C=S=O$  i.r. absorption at 1070  $\text{cm}^{-1}$ , its u.v. spectrum (hexane) exhibited a maximum at 270 nm ( $\epsilon$  9555), and its n.m.r. spectrum ( $\text{CCl}_4$ ) revealed, besides a broad absorption at  $\delta$  2.00 (12H), broad one-proton singlets at  $\delta$  2.87 and 4.02 p.p.m. The

<sup>1</sup> Part XV, B. F. Bonini, G. Maccagnani, A. Wagenaar, L. Thijs, and B. Zwanenburg, *J.C.S. Perkin I*, 1972, 2490.

<sup>2</sup> B. Zwanenburg, L. Thijs, and J. Strating, (a) *Rec. Trav. Chim.*, 1967, **86**, 577; (b) *Tetrahedron Letters*, 1969, 4461; (c) *Rec. Trav. chim.*, 1970, **89**, 687; (d) *Rec. Trav. chim.*, 1971, **90**, 614; (e) B. Zwanenburg and J. Strating, *Quart. Reports Sulphur Chem.*, 1970, **5**, 79.

<sup>3</sup> R. Mayer, J. Morgenstern, and J. Fabian, *Angew. Chem.*, 1964, **76**, 157; R. Mayer in 'Organic Sulfur Chemistry,' ed. M. J. Janssen, Interscience, New York, 1967.

separation of 68 Hz between the latter two signals shows the difference between the deshielding properties



of the two sides of the bent sulphine system unperturbed by other anisotropic effects.<sup>6</sup>

Tetramethyl-3-thioxocyclobutanone<sup>7</sup> (II) was readily

<sup>4</sup> W. A. Sheppard and J. Diekmann, *J. Amer. Chem. Soc.*, 1964, **86**, 1891.

<sup>5</sup> J. W. Greidanus and W. J. Schwalm, *Canad. J. Chem.*, 1969, **47**, 3715.

<sup>6</sup> B. Zwanenburg, L. Thijs, and A. Tangerman, *Tetrahedron*, 1971, **27**, 1731.

<sup>7</sup> E. U. Elam and H. E. Davis, *J. Org. Chem.*, 1967, **32**, 1562. This compound was supplied by Dr. J. A. Boerma (Groningen).

oxidised by MCPBA (1.0 equiv.) in ether at 0° to give the aliphatic sulphine (V) in 80% yield. The n.m.r. spectrum (CCl<sub>4</sub>) showed the expected singlets for the two types of methyl protons at  $\delta$  1.48 and 1.63 p.p.m. The characteristic i.r. absorptions (CCl<sub>4</sub>) were observed at 1795 (C=O) and 1065 cm<sup>-1</sup> (CSO).

On treatment of the dithione<sup>7</sup> (III) with MCPBA in ether at 0° a rapid discharge of the red coloration was observed. A crystalline substance isolated in 86% yield consisted of a mixture of *anti*- and *syn*-bis-sulphines (VIa and b). The n.m.r. spectrum (CDCl<sub>3</sub>) showed the four methyl groups of the *anti*-isomer (VIa) as one singlet at  $\delta$  1.84 and those of the *syn*-compound as two singlets at  $\delta$  1.71 and 1.98 p.p.m. According to the n.m.r. spectrum the *anti*-*syn* ratio varied from 9:1 to 4:1 depending on the conditions of the oxidation. Despite several attempts, separation of these isomers was not achieved. Isomerisation (*syn* to *anti*) took place readily on warming a solution of the mixture. The *anti*-isomer could then be obtained as a single compound.

The aliphatic sulphines (IV)—(VI) are reasonably stable at room temperature, in spite of the lack of conjugative stabilisation (*cf.* ref. 2a). Their cycloaddition reactions offer a unique possibility for the preparation of heterocyclic compounds.<sup>4,8</sup> We have studied reactions with diazomethane and 2-diazopropane, particularly to compare the results with those obtained recently for the parent thiones.<sup>9,10</sup>

Adamantanethione S-oxide (IV) reacted with 2-diazopropane at -10° to give a 1:1 adduct to which structure (VII) was assigned on the basis of elemental analysis and the following spectral data:  $\nu_{\max}$  (KBr) 1040s (S=O) and 1570m (N=N) cm<sup>-1</sup>;  $\delta$  (CDCl<sub>3</sub>; -30°) 1.50 (s, Me), 1.88 (s, Me), 2.70—3.20 (1H, m), and 1.80—2.70 p.p.m. (13H, m). The alternative mode of addition which would lead to a 1,2,3-thiadiazoline S-oxide is ruled out, because then the N=N i.r. absorption would be expected<sup>1,9-11</sup> at a lower wavenumber. Moreover, the position of the methyl n.m.r. signals agrees well with those of 2,2,5,5-tetramethyl- $\Delta^3$ -1,3,4-thiadiazoline S-oxide [ $\delta$  (CCl<sub>4</sub>) 1.47 and 1.70 p.p.m.] prepared *via* an independent route.\*

As observed previously,<sup>1</sup> diazomethane reacts much more slowly with sulphines than 2-diazopropane. With compound (IV) and diazomethane no reaction took place. However, adamantanethione (I) does react with diazomethane: Krapcho *et al.*<sup>9</sup> report two different modes of addition, *viz.* to give an adamantane-spiro- $\Delta^3$ -1,3,4-thiadiazoline and an adamantane-spiro- $\Delta^2$ -1,2,3-thiadiazoline in the ratio of 3:1.

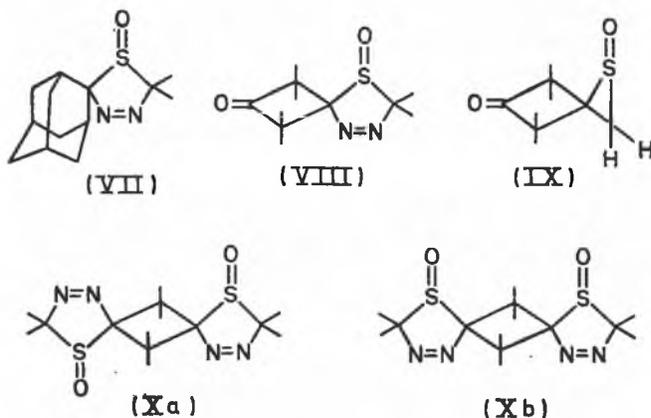
The sulphine (V) reacted smoothly with 2-diazopropane to give the spiro-adduct (VIII) in 87% yield,  $\nu_{\max}$  (CCl<sub>4</sub>) 1785 (C=O), 1570 (N=N), and 1060 (S=O) cm<sup>-1</sup>;

\* From acetone azine, chlorine, and hydrogen sulphide, with subsequent oxidation. We thank Dr. R. M. Kellogg and Mr. J. Buter for providing this information prior to publication.

<sup>8</sup> B. Zwanenburg, L. Thijs, and J. Strating, *Rec. Trav. chim.*, 1972, **91**, 443.

<sup>9</sup> A. P. Krapcho, D. R. Rao, M. P. Silvon, and B. Abegaz, *J. Org. Chem.*, 1971, **36**, 3885.

$\delta$  (CDCl<sub>3</sub>) 0.98, 1.28, 1.47, 1.58, 1.88, and 1.99 p.p.m. (each s, Me). Oxidation of compound (VIII) with MCPBA gave the corresponding sulphone (26%) which showed, as expected, only three methyl signals in the n.m.r. spectrum [ $\delta$  (CDCl<sub>3</sub>) 1.30, 1.68, and 1.69 p.p.m.].



To our surprise the reaction of compound (V) with diazomethane did not lead to a thiadiazoline S-oxide; instead a tetramethylcyclobutanone-spiro-thiiran S-oxide (IX) was isolated (29%). The structure became evident from elemental analysis and spectra. The i.r. spectrum (Nujol) showed absorption at 3060 cm<sup>-1</sup> (C-H) indicative of the three-membered ring system,<sup>12</sup> strong bands in the S=O region at 1015, 1050, and 1065 cm<sup>-1</sup>, and no absorption in the N=N region (1500—1600 cm<sup>-1</sup>). N.m.r. signals were observed at  $\delta$  0.94, 1.30, 1.44, and 1.68 (each s, Me) and 2.44 and 2.80 p.p.m. (AB pattern, *J* 8.0 Hz, CH<sub>2</sub>). Apparently, the initially formed five-membered ring loses nitrogen easily to give the episulphoxide. This behaviour of the primary cycloadduct is similar to that of the thiadiazoline<sup>10</sup> derived from the parent thione (II) and diazomethane, which also readily loses nitrogen, to give an episulphide.<sup>10</sup>

The bis-sulphine (VI), as a mixture of isomers, reacted with 2-diazopropane in an analogous way to (V), to give a mixture of isomeric dispiro-compounds (Xa and b, with one form predominating) containing two 1,3,4-thiadiazoline S-oxide units (yield 66%). The product composition changed according to the *anti*-*syn* ratio of the starting material. When pure *anti*-sulphine (VIa) was used, a mixture of compounds was still obtained, in which the same main product dominated. If we assume a stereospecific † cycloaddition reaction the *anti*-sulphine (VIa) would give a mixture of *trans*-(Xa) and *trans*-(Xb) bis-sulphoxide. If we also consider that the approach of diazopropane to the two sulphine functions occurs from opposite sides of the

† Other types of sulphines indeed show stereospecific cycloaddition reactions with diazo-compounds (B. Zwanenburg and A. Wagenaar, in preparation).

<sup>10</sup> C. E. Diebert, *J. Org. Chem.*, 1970, **35**, 1501.

<sup>11</sup> *Cf.* R. M. Kellogg, S. Wassenaar, and J. Buter, *Tetrahedron Letters*, 1970, 4689; D. H. R. Barton, E. H. Smith, and B. J. Willis, *Chem. Comm.*, 1970, 1226; D. H. R. Barton and B. J. Willis, *J.C.S. Perkin I*, 1972, 305.

<sup>12</sup> G. E. Hartzell and J. N. Paige, *J. Amer. Chem. Soc.*, 1966, **88**, 2616.

molecule, the main product most likely would be *trans*-(Xa). Attempts to separate the mixture of products or to gain more definite information about the geometry of the constituents, failed.

Diazomethane reacted very sluggishly with the bis-sulphine (VI), yielding a small amount of a mixture of products to which bis-spiro-thiiran S-oxide structures were tentatively assigned. This behaviour of the sulphine (VI) is in line<sup>9</sup> with that observed for the parent dithione (III) and the respective diazo-compounds.

#### EXPERIMENTAL

M.p.s were determined with a Kofler hot-stage apparatus. Combustion analyses were performed in the Micro-Analytical Department of the University at Groningen under the supervision of Mr. W. M. Hazenberg. I.r. spectra were taken on a Perkin-Elmer 125 or 257 grating spectrometer; n.m.r. spectra were recorded with a Varian A60 spectrometer (tetramethylsilane as internal standard).

**Adamantanethione S-Oxide (IV).**—MCPBA (600 mg, 3 mmol) in ether (10 ml) was added gradually to a stirred ice-cooled solution of adamantane<sup>5</sup> (500 mg, 3 mmol) in ether (15 ml). Rapid discharge of the pink colour took place. The mixture was washed with aqueous sodium hydrogen sulphite, saturated sodium hydrogen carbonate solution, and water, dried (Na<sub>2</sub>SO<sub>4</sub>), and evaporated to leave a white solid (530 mg). Crystallisation from light petroleum (b.p. 60–80°) at –20° gave the *sulphine* (IV) (410 mg, 75%), m.p. 130° (sublimes) (Found: C, 65.8, 65.85; H, 7.85, 7.9; S, 17.7, 17.8. C<sub>10</sub>H<sub>14</sub>OS requires C, 65.9; H, 7.75; S, 17.6%); for spectra see Discussion section.

**2,2,4,4-Tetramethyl-3-thioxocyclobutanone S-Oxide (V).**—MCPBA (1.0 g, 5 mmol) in dry ether (25 ml) was added dropwise to a stirred solution of 2,2,4,4-tetramethyl-3-thioxocyclobutanone<sup>7</sup> (II) in ether (50 ml) at 0°. The orange-red colour disappeared. *m*-Chlorobenzoic acid was removed as described for the sulphine (IV). The residual oil was dissolved in pentane (5 ml); cooling overnight at –20° gave the white crystalline *sulphine* (V) (534 mg), m.p. 52.3–53.2°. Work-up of the mother liquor afforded a further 157 mg (total yield 80%) (Found: C, 55.75; H, 7.1; S, 18.35. C<sub>8</sub>H<sub>12</sub>O<sub>2</sub>S requires C, 55.8; H, 7.0; S, 18.6%); λ<sub>max</sub> (hexane) 273 nm (ε 7400).

**2,2,4,4-Tetramethylcyclobutane-1,3-dithione SS'-Dioxide (VIa and b).**—MCPBA (2 g, 10 mmol) in ether (25 ml) was added gradually to a chilled (0°), stirred solution of 2,2,4,4-tetramethylcyclobutane-1,3-dithione<sup>7</sup> (III) (860 mg, 5 mmol) in ether (50 ml). Rapid decolorisation took place. The *m*-chlorobenzoic acid was removed as described for (IV). After removal of the solvent *in vacuo* the remaining white solid was dissolved immediately in dichloromethane–pentane (1:1; 10 ml) and cooled. The crystalline product (474 mg), m.p. 140–146° (decomp.), consisted of the *anti*-sulphine (VIa) and the *syn*-sulphine (VIb) (ratio 3:1).

Another sample (410 mg) that crystallised from the mother liquor consisted of (VIa) and (VIb) in the ratio of 35:65 (total yield 86%) (Found: C, 47.0, 46.95; H, 6.1, 6.0; S, 31.2, 31.0. C<sub>8</sub>H<sub>12</sub>O<sub>2</sub>S<sub>2</sub> requires C, 47.0; H, 5.9; S, 31.4%). When a mixture of (VIa) and (VIb) (any ratio) dissolved in carbon tetrachloride was heated at 70–75° for 2.0–2.5 h, isomerisation (according to the n.m.r. spectrum) to almost exclusively the *anti*-isomer took place. Upon cooling the *anti*-isomer crystallised; m.p.

145–147° (decomp.), λ<sub>max</sub> (hexane) 271 nm (ε 17,130), ν<sub>max</sub> (KBr) 1040 and 1120 cm<sup>-1</sup>.

**5',5'-Dimethyladamantane-2-spiro-2'-Δ<sup>3</sup>-1',3',4'-thiadiazoline S-Oxide (VII).**—The sulphine (IV) (182 mg, 1 mmol) dissolved in pentane (5 ml) and ether (1 ml) was treated with 2-diazopropane<sup>13</sup> (1 equiv.) at –10°. The mixture was left overnight at –20°; crystals of the *product* (70 mg) had then appeared. Work-up of the mother liquor gave a further 128 mg (total yield 78.5%), m.p. 115° (decomp.) (Found: C, 61.7; 61.6; H, 8.05, 7.9; N, 11.3, 11.3; S, 12.9, 12.8. C<sub>13</sub>H<sub>20</sub>N<sub>2</sub>OS requires C, 61.85; H, 8.0; N, 11.1; S, 12.7%); for spectra see Discussion section.

**2',2',4',4',5,5-Hexamethyl-Δ<sup>3</sup>-1,3,4-thiadiazoline-2-spiro-cyclobutan-3'-one S-Oxide (VIII).**—In the same manner as described for (VII), the sulphine (V) (344 mg) was treated with 2-diazopropane.<sup>13</sup> After 2 weeks at –20° the crystalline *product* was collected (300 mg, 87%), m.p. 107° (decomp.) (Found: C, 54.45, 54.6; H, 7.45, 7.6; N, 11.55, 11.5; S, 13.1, 13.15. C<sub>11</sub>H<sub>18</sub>N<sub>2</sub>O<sub>2</sub>S requires C, 54.5; H, 7.5; N, 11.55; S, 13.3%); for spectra, see Discussion section. This mono-oxide was converted into the SS-dioxide by treatment with MCPBA (1.05 equiv.) in dichloromethane–ether (2:5) at 20°. After 1 week the mixture was worked up by thick-layer chromatography on silica (development with dichloromethane–ether, 2:1). The *sulphone* crystallised from light petroleum (b.p. 60–80°) at –20° (yield 26%); m.p. 60–61° (correct CHNS analysis for C<sub>11</sub>H<sub>18</sub>N<sub>2</sub>O<sub>2</sub>S<sub>2</sub>), ν<sub>max</sub> (KBr) 1785 (CO), 1512 (N=N), and 1120 and 1315 (SO<sub>2</sub>) cm<sup>-1</sup>; for n.m.r. see Discussion section. Starting material was recovered (58%) from the chromatogram.

**2,2,4,4-Tetramethylcyclobutanespiro-2'-thiiran-3-one 1'-Oxide (IX).**—An ethereal solution of diazomethane (1.5 equiv.) was added to a chilled (0°) solution of the sulphine (V) (2.71 g, 15.8 mmol) in pentane (10 ml). Nitrogen evolution took place. The mixture was kept for 24 h at 3° and for 3 days at –20°. The crystalline *material* was collected (564 mg). Careful concentration of the mother liquor gave another 285 mg (total yield 29%), m.p. 106–107° (Found: C, 57.75; 57.8; H, 7.6, 7.6; S, 17.05, 17.35. C<sub>9</sub>H<sub>14</sub>O<sub>2</sub>S requires C, 58.0; H, 7.6; S, 17.2%); for spectra, see Discussion section.

**Reactions of the SS-Dioxide (VI) with 2-Diazopropane and Diazomethane.**—A solution of compound (VI) (mixture of *anti*- and *syn*-isomers) (155 mg, 0.75 mmol) in dichloromethane (1 ml) and ether (3 ml) was treated with 2-diazopropane<sup>13</sup> (2.2 equiv.). The mixture was left for 2 weeks at –20°. The crystalline product was collected (170 mg, 66%); m.p. 120° (decomp.) (Found: C, 48.9, 49.05; H, 6.95, 7.1; N, 16.0, 15.9; S, 18.75, 18.6. Calc. for C<sub>14</sub>H<sub>24</sub>N<sub>4</sub>O<sub>2</sub>S<sub>2</sub>: C, 48.8; H, 7.0; N, 16.3; S, 18.6%), ν<sub>max</sub> (KBr) 1565 (N=N) and 1035 and 1045 (SO) cm<sup>-1</sup>. It consisted of a mixture of isomers (Xa, *cis* and *trans*; Xb, *cis* and *trans*) of which one predominated according to the n.m.r. spectrum [methyl signals at δ 1.38 and 1.17 (C-2 and C-4) and at 2.06 and 1.98 p.p.m. (C-2')].

When diazomethane was used instead of 2-diazopropane, after 2 weeks only a small amount of material had crystallised. The i.r. spectrum showed absorptions at 3060 (C–H) and 1045 and 1060 cm<sup>-1</sup> (S=O), compatible with an episulphoxide structure. The n.m.r. spectrum exhibited, besides several methyl signals, an AB pattern at δ 2.56 and 2.80 p.p.m. (J 8 Hz).

[2/1705 Received, 19th July, 1972]

<sup>13</sup> A. C. Day, P. Raymond, R. M. Southam, and M. C. Whiting, *J. Chem. Soc. (C)*, 1966, 467; *cf. Org. Synth.*, 1970, 50, 27.