SYNTHESIS OF DIISOPROPYLIDENETHIIRANE (THIIRANORADIALENE)

AND ITS REACTIONS

WATARU ANDO*, YUKIO HANYU, YORIO KUMAMOTO, and TOSHIKAZU TAKATA

Department of Chemistry, The University of Tsukuba Sakuramura, Ibaraki 305, Japan

(Received in Japan 13 November 1985)

Abstract - The first stable 2,3-methylenethiirane, 2,3-diisopropylidenethiirane 6, was prepared by pyrolysis of lithium salt of tosylhydrazone of 2,2-dimethyl-4-isopropylidene-3-thietanone. The desulfurization of 6 by phosphines and carbenes gave 2,5-dimethyl-2,3,4-hexatriene <u>15</u>. Photosensitized oxygenation of 6 gave acetone via (2 +2) cycloaddition of a double bond with singlet oxygen. MCPBA oxidation of 6 afforded the desired corresponding sulfoxide <u>16</u> quantitatively.

Special interest has long been focused on the synthesis of three membered rings bearing exocyclic double bonds. Among these are methylenecyclopropanes (1), $^{1-9}$ allene oxides (2), $^{10-12}$ allene episulfide (3) 13,14 and methyleneaziridines (4).



They possess unique reactivities and undergo reactions at nearly every site on their skeleta. In addition, some of these systems undergo interconversion $(7 \neq 8 \neq 9 \text{ or } 7 \neq 8' \neq 9)$, as has been theoretically implicated and experimentally demonstrated, and produces a wealth of complex and interesting chemistry.



Despite their potential works for methylenecyclopropanes, the few examples known of dimethylene derivatives involve dimethylene(alkyl)cyclopropanes 5,¹⁹ which have some interesting properties resulting from conjugated dienes. We recently reported ²⁰ synthesis of dimethylenethiirane <u>6</u> and its reactions, the first dimethylenecyclopropane containing heteroatom, through rearrangement of sulfur ylide via intramolecular carbene reactions.

W. ANDO et al.

RESULTS AND DISCUSSION

According to Kellogg's method,²¹ 2,2-dimethyl-4-isopropylidene-3-thietanone <u>10</u> was prepared by ring contraction of five-membered ring keto carbene containing sulfur.



The thietanone <u>10</u> was treated with excess tosylhydrazine for a few minutes in the presence of catalytic amount of BF_3 etherate in ethanol at 50-70°C, yielding hydrazone <u>11</u> in 30% yield along with considerable amount of unreacted <u>10</u> (ca. 40%) by chromatographic separation. Hydrogen chloride, toluenesulfonic acid or acetic acid as common catalysts did not give the corresponding hydrazone <u>11</u> except BF_3 etherate. One of the reasons should be the instability of the hydrazone under drastic and prolonged reaction conditions.



The purified hydrazone <u>11</u> was treated with equimolar of n-BuLi at -70°C in dry tetrahydrofuran and the resulting lithium salt (<u>12</u>) of <u>11</u> was subjected to the common vacuum pyrolysis at 130-150°C (at ca.10⁻⁴ torr). During the pyrolysis, nitrogen was evolved and colorless crystalline solid was collected in a liq. nitrogen trap. The solid material was purified by silica gel column chromatography using hexane as an eluent (70% yield) and showed mp. of 42.5-43.5°C as colorless stable crystal. The structure of <u>6</u> was suggested to be diisopropylidenethiirane from its spectroscopic data. The ¹H NMR spectrum of <u>6</u> shows resonances at 1.97(s, CH₃ x 2), 2.05(s, CH₃ x 2), ppm characteristic of its C₂ symmetry. Simple ¹³C NMR of four signals at 115.5 (s), 111.3(s), 23.0(q), 22.7(q) also supports the structure <u>6</u>. The exact structure of the thiirane <u>6</u> was determined by X-ray crystal structure analysis.



The molecule is almost planar. The $C_4-C_2-C_3$ and $C_2-C_3-C_5$ angles (149.7° and 159.6°) are similar to those in methylenecyclopropane (150°).²² It indicates that this termini of the diene chromophere are separated by a greater distance than in normal cisoid dienes in a solid state. As for the mechanism, the ring contraction of carbene²⁰ <u>13</u> derived from the pyrolysis of lithium salt <u>12</u> may afford the thiirane <u>6</u> via an intermediacy of bicyclic sulfur ylide <u>14</u>. The product <u>6</u> is named as diisopropylidenethiirane or "thiiranoradialene".

Chemical Properties: Thiiranoradialene <u>6</u> was treated with tri-n-butyl phosphine at 130°C for 2 hrs to give 2,5-dimethyl-2,3,4-hexatriene <u>15</u> in 60% yield. However, <u>6</u> did not react with triphenyl phosphine under the same conditions. Reaction of <u>6</u> with carbene produced from dimethyldiazomalonate also gave desulfurization product 15 in 58% yield.



Methyl lithium and ethylmagnesium chloride which are known to be desulfurization reagents for thiiranes, 23 did not react with 6.

Irradiation of <u>6</u> by high pressure mercury lamp resulted in complex product mixture. Although thiiranes are well-known to react with acyl chloride giving ring opening product, ²⁴ <u>6</u> did not react with acetyl chloride as an electrophile at all. Treatment of <u>6</u> with triethyl oxonium 2,4,6-trinitrobenzene sulfonate, a strong electrophile, gave complex mixture in stead of thiiranium salt.²⁵



Photosensitized oxygenation of $\underline{6}$ gave acetone probably via (2 + 2) cycloaddition of singlet oxygen with the double bond. MCPBA oxidation of $\underline{6}$ in dichloromethane at ca. 0°C gave readily desired diisopropylidenethiirane oxide, that is "thiiranoradialene S-oxide $\underline{16}$ " in quantitative yield.



The sulfaxide <u>16</u> is colorless crystal having mp. $58.0-58.5^{\circ}$ C and more labile than sulfide <u>6</u>, slowly decomposing to unidentified complex even at -20° C. The IR absorption at 1035 cm^{-1} is characteristic of S-O vibration. ¹³C NMR spectrum of <u>16</u> shows the olefinic carbon resonance down field shifted at 131.2 and 125.2 ppm, compared with those of <u>6</u> (111.3 and 115.5 ppm), owing to electron-withdrawing sulfaxide moiety.

In summary, the first dimethylenecyclpropane containing heteroatom, "thiiranoradialene <u>6</u>" was synthesized by the ring contraction of carbene of isoprophylidene thietanone <u>13</u>. The X-ray crystal analysis of <u>6</u> revealed the unique structure of hetero(3)radialene. Attempted reactions of <u>6</u> with several desulfurizing agents suggested extra stability toward desulfurization reaction or ring opening reaction. Photosensitized oxygenation of <u>6</u> gave acetone as the C=C double bond cleavage product, similar to usual vinyl sulfide.²⁶ The desired three-membered ring diene, thiiranoradialene sulfoxide <u>16</u>, was easily obtained by the oxidation of <u>6</u> with MCPBA.

EXPERIMENTAL SECTION

¹H NMR spectra were recorded at 60MHz with a Varian EM-360A spectrometer; chemical shifts (\mathcal{E}) are expressed in parts per million down field from internal standard tetramethylsilane. ¹³C NMR spectra were obtained on a JEOL-FX090Q spectrometer. IR spectra were obtained on a Hitachi 260-50 infrared spectrometer. Intensity data for X-ray crystal analysis were collected on a NICOLET automated four circle diffractometer. Coloum chromatography was performed by use of Merck Kiesegel (70-230 mesh).

Synthesis of 2,2-dimethyl-4-isopropylidene-3-thietanone 10. Preparation of the thietanone 10 was carried out according to literature.²⁵ To a solution of \mathcal{A} , \mathcal{A}' -dibromoisobutyrile (421g, 1.4 mol) in 600ml of methanol was slowly added sodium sulfate (337g, 1.4 mol) in 1 liter of methanol. After stirring for 1 hr, methanol was removed to half volume under reduced pressure. The residue was extracted with large volume of water and pentane. The combined extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was distilled under reduced pressure to give 2,2,4,4-tetramethyl-3-thiolanedione (105g, 43%): b.p. 65-67°C/2mmHg. Then, to a solution of thiolanedione (105g, 0.61 mol) in 100ml of methanol was added tosyl hydrazide (113.5g, 0.6lmol). After stirring overnight at room temperature, pure hydrazone was precipitated. Pale yellow crtystals were filtered, washed with cold methanol, and dried in vacuo (113g, 55%). Then, to a suspension of the \measuredangle -ketohydrazone (113g, 0.16mol) in pentane was added sodium hydroxide dissolved in 500ml of water. The mixture was stirred until the suspension almost disappeared. Pentane layer was washed with water and dried over anhydrous magnesium sulfate. Solvent pentane was removed under reduced pressure and the -diazoketone was crystallized as yellow crystals (61g, 100%).

The \checkmark -diazokeotne (50g, 0.27mol) in 100ml of isooctane was gently refluxed for 4 hrs. The mixture was, then, evaporated and the residue was 2,2-dimethyl-4-isopropylidene-3-thietanone (42g, 100%) which was used in the following reaction without further purification.

Tosylhydrazone of 2,2-dimethyl-4-isopropylidene-3-thietanone 11. To a mixture of $\underline{8}$ (30g, 0.91mol) and tosylhydrazide (100g, 0.53mol) was added BF₃ etherate (10ml). After refluxing for 40 min, the reaction mixture was neutralized by aqueous sodium bicarbonate and extracted with dichloromethane. The extract was dried over anhydrous magnesium sulfate. The purification was accomplished by eluting on silica gel with benzene (18.5g, 30%; <u>10</u> recovered 11.8g, 40%): ¹H NMR(CDCl₃) of <u>11</u>: \S 1.60(s,3H), 1.76(s, 6H)., 2.03(s, 3H), 2.49(s, 3H), 7.39(d, 2H, J=8.4Hz), 7.93

(d, 2H, J=8.4Hz); 13 C NMR(CDCL₃) \int 21.2(q), 21.6(q), 26.8(q), 57.0(s), 123.6(s), 129.1(d), 129.6 (d), 130.6(s), 134.6(s), 144.3(s), 159.0(s); IR(CDCl₃) 3225_m, 2970_m, 2920_w, 1350_s, 1165_s cm⁻¹.

Diisogropylidenethiirane 6. To a solution of the hydrazone <u>11</u> (3.24g, 10mmol) in 50 ml of dry tetrahydrofuran was added n-butyl lithium (10mmol) at -78°C. The reaction mixture was warmed to room temperature and was transferred to a round bottom flask, and then tetrahydrofurm was removed under reduced pressure. The flask was fitted with a cold trap (liq. nitrogen) and was carefully pyrolized at 130-150°C under reduced pressure at ca. 10^{-4} mmHg using a vacuum line. Almost pure crystals of <u>6</u> were collected in the cold trap and was purified by silica gel chromgatography (eluent: hexane); Yield of <u>6</u> is 98%, colorless crystal, mp. 42.5-43.5°C; ¹H NMR(CDCl₃) δ 1.97(s, 6H), 2.05(s, 6H); ¹³C NMR(CDCl₃) δ 22.7(q), 23.0(q), 111.3(s), 115.5(s); IR(KBr) 2960, 2900, 2850, 1440, 1360, 1060, cm⁻¹; EIMS, m/e 140 (M⁺); Anal. Calcd for C₀H₁₃S: C, 68.57; H, 8.57; S, 22.86; Found C, 68.69; H, 8.66; S, 22.59.

Reaction of 6 with Tri-n-butyl Phosphine. A solution of <u>6</u> (14 mg, 0.1mmol) dissolved in 0.4 ml of tri-n-butyl phosphine was heated at 130°C using an NMR sample tube (5 mm ϕ) as a reaction vessel. After heating for 2 hrs, the product <u>15</u> separated by GLC as identified by ¹H NMR and mass spectra and the melting point. Yield was determined by ¹H NMR integral (60%). Similar result was obtained with tris(diethylamino)phosphine.

Reaction of 6 with Directlyl Directual constet in the Presence of Ris-Rudium Directate. To a mixture of <u>6</u> (14mg, 0.1mmol) and dimethyl diazomalonate (47.4mg, 0.3mmol) in 0.3ml of dichloromethane was added bis-rhodium directate (0.2mg, 4.5×10^{-4} mmol) using the sample tube as the reaction vessel. After allowing to stand for 2 hrs to complete the reaction, <u>15</u> was purified by GLC and was determined by ¹H NMR and mass spectra as well as the melting point. Yield was determined by ¹H NMR intergral (61%).

Photosensitized Oxygenation of 6. A solution of $\underline{6}$ (54mg, 0.37mmol) in 30 ml of chloroform was photoirradiated in the presence of ca. 70 mg of tetraphenylporphine as sensitizer with 500W halogen lamp for 1 hr. Disappearance of $\underline{6}$ was monitored by thin layer chromatography (silica gel/benzene). To the reaction mixture was added 2,4-dinitrophenyl hydrazine (100mg, 0.5mmol) and catalytic amount of acetic acid. The resulting mixture was refluxed for 2 hrs and evaporated. The residue was subjected to column chromatography (silica gel/dichloromethane) to give the corresponding hydrazone of acetone as yellow crystals (49.2mg, 37%). mp. 125-127°C.

meta-Chloroperbenzoic Acid (MCFBA) Oxidation of 6. To a solution of $\underline{6}$ (140mg, 1.0mmol) in 20 ml of dichloromethane was added solid MCPBA (190mg) at 0°C, monitoring the reaction by thin layer chromatography. After stirring for 1 hr, the mixture was washed with aqueous sodium bicarbonate three times to remove MCPBA and dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was crystallized from hexane-dichloromethane at low temperature (ca. -10°C). Yield of <u>16</u> is 140mg, 90%, colorless crystals, mp. 58.0-58.5°C; ¹H NMR (CDCl₃) 2.17(s, 6H), 2.22(s, 6H); ¹³C NMR(CDCl₃) S 23.0(q), 3.4(q), 125.2(s), 131.2(s); IR(KBr) 1035 ($)_{S=0}$) cm⁻¹.

X-Ray Crystal Analysis of 6. The crystal has monoclinic space group Cc with a=10.973, b=6.946, c=11.189 A, and β =102.26°, z=4. Intensity data were collected on a four circle diffractomerter with graphite monochromated Cu/K_X radiation. The structure was refined to a value of 0.105.

PERCES

- 1) J.P.Chesick, J. Am. Chem. Soc., 85, 2720(1963)
- 2) J.J.Gajewski, J. Amer. Chem. Soc., 90, 7178(1968).
- 3) J.C.Gilbert and J.R.Butler, J. Amer. Chem. Soc., 92, 2168(1970).
- 4) W. von E.Doering and H.D.Roth, Tetrahedron 26, 2825(1970).

- 5) M.J.S.Dewar, J. Amer. Chem. Soc., 93, 3081(1971).
- 6) D.R.Yarkony and H.F.Schaefer, III, J. Amer. Chem. Soc., 96, 3754(1974).
- 7) W.T.Borden, J. Amer. Chem. Soc., 97, 3754(1974).
- 8) J.H.Davis and W.A.Goddard, III, J. Amer. Chem. Soc., 98, 303(1976).
- 9) W.R.Roth and G.Wegener, Angew. Che., Int. Ed. Engl. 14, 758(1975).
- 10) N.J.Turro, Acc. Chem. Res., 2, 25(1969).
- 11) T.H.Chan and B.S.Ong, J. Org. Chem., 43, 2994(1978), Tetrahedron, 36, 2269(1980).
- 12) Y.Osamura, W.T.Borden and K.Morokuma, J. Amer. Chem. Soc., 106, 5112(1984).
- 13) A.G.Hortmann and A.Bhattacharijya, J. Amer. Chem. Soc., 98, 7081(1976).
- 14) E.Block, R.E.Penn, M.D.Ennis, T.A.Owens and S.L.Yu, J. Amer. Chem. Soc., 100, 7436(1978).
- 15) R.Noyori, Acc. Chem. Res., 12, 61(1979).

16) R.Noyori, Y.Hayakawa, H.Takaya, S.Murai, R.Kobayashi, N.Sonoda, J. Amer. Chem. Soc., **100**, 1759 (1978).

- 17) W.Ando, T.Furuhata, Y.Hanyu and T.Takata, Tetrahedron Lett., 25, 4011(1984).
- 18) W.Ando, Y.Hanyu, T.Takata, K.Ueno, Tetrahedron Lett., 26, 3019(1985).
- 19) D.R.Paulson, J.K.Crandall and C.A.Bunnell, J. Org. Chem., 35, 3708(1970).
- 20) W.Ando, Y.Hanyu and T.Takata, Tetrahedron Lett., 22, 4815(1981).
- 21) J.Bolster and R.M.Kellogg, J. Org. Chem., 45, 4804(1980).
- 22) G.Kobrich, H.Heinemann and W.Zundorf, Tetrahedron, 23, 565(1967); T.Fukunaga, M.D.Gordon and
- D.J.Krusic, J. Amer. Chem. Soc., **98**, 611(1976); A.J.Barlovich, E.S.Strauss and K.P.C.Vollhardt, J. Amer. Chem. Soc., **99**, 8322(1977).
- 23) N.P.Neureiter and F.G.Bordwell, J. Amer. Chem. Soc., **81**, 578(1959); F.G.Bordwell, H.M.Anderson and B.M.Pitt, J. Amer. Chem. Soc., **76**, 1082(1954).
- 24) E.M.Meade and F.N.Woodward, J. Chem. Soc., 1894(1948); E.E. Van Tamelen, J. Amer. Chem. Soc., 73, 3444(1958); J.M.Stewart, J. Org. Chem., 28, 596(1963); H.Morita and S.Oae, Tetrahedron Lett., 1347(1969).
- 25) J.Pettit and G.K.Helmkamp, J. Org. Chem., 28, 2932(1963), 29, 2702(1964).
- 26) W.Ando and T.Takata, "Singlet O₂" Ed. A.A.Frimer, Vol. III, CRC Press, Boca Raton, Florida, 1985.

Acknowledgment. We gratefully acknowledge Dr. Katsuhiko Ueno, Research Institute for Polymers and Textile for X-ray measurements.