

Synthesis of Isolable Thiirane-2-thione (α -Dithiolactone) from Thioketene S-Oxide

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The chemistry of three-membered ring systems containing heteroatoms, such as dithiiranes¹ and α -lactams,² has been extensively studied. Such small heterocycles as epoxides, thiiranes, aziridines, and oxaziridines have been widely used by organic chemists.³ Although some α -dithiolactones (**1**) have been proposed as intermediates for the synthesis of 1,2,4,5-tetrathianes, 1,2,4-trithiolanes, and disulfides, despite much effort not one has been isolated thus far.⁴ We report herein the synthesis and characterization of the first isolable **1** from di-*tert*-butylthioketene S-oxide (**2**).

Di-*tert*-butylthioketene (**3**) was synthesized from di-*tert*-butyl ketone according to the reported method.⁵ Thioketene **3** was oxidized with *m*-chloroperbenzoic acid (*m*-CPBA) to give **2** in 92% yield.^{5,6} Treatment of **2** with Lawesson reagent at room temperature for 12 h resulted in the formation of 3,3-di-*tert*-butyl-thiirane-2-thione (**1a**) in 88% yield (Scheme 1).⁷

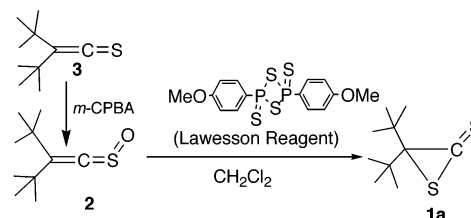
Compound **1a** is an isomer of 3-(2,2,4,4-tetramethylpentan-3-ylidene)dithiirane (**4**) and di-*tert*-butyl thioketene S-sulfide (**5**) (Scheme 2).

As some dithiiranes were isolable,¹ we initially thought that the product was not **1a** but **4**. However, a band assignable to C=S of the dithioester (stretching vibration) was observed at 1367 cm⁻¹ in the IR spectrum. In addition, in the ¹³C NMR spectrum, the signals for C=S carbon and ring carbon resonated at δ 226.7 and 76.3, respectively. Thus, the dithiirane structure was excluded. The possibility of a dimer (3,3,6,6-tetra-*tert*-butyl-dithiane-2,5-dithione) was also excluded on the basis of MS analysis; the M⁺ signal was observed at 202. In contrast to the reported synthesis of dithiiranes,¹ the reason α -dithiolactone **1a** was obtained may be the existence of an *exo*-methylene group that destabilized the dithiirane structure **4**. Compared to thiiranes, there are relatively few reports on the synthesis of methylenethiiranes.⁸ The stabilities of α -dithiolactone **1a**, dithiirane **4**, and thioketene S-sulfide **5** were then compared. By means of geometry optimization of the 6-31G(d,p) basis set, **1a** was calculated to be 56.4 and 79.7 kJ/mol more stable than **4** and **5**, respectively, at the ground-state S₀ (Scheme 3).⁹

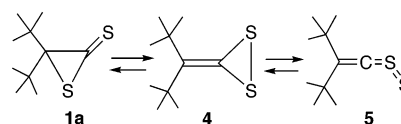
X-ray crystallographic analysis of **1a** was unsuccessful because of its unusual tendency to sublime; even at room temperature, 0.01 g of the solid disappeared within 8 h. Fortunately, oxidation of **1a** with *m*-CPBA gave the corresponding 3,3-di-*tert*-butylthiirane-2-thione S-oxide (**6**) almost quantitatively (Scheme 4). Structural proof was provided by X-ray structure determination (Figure 1).¹⁰

The C–S bond lengths of the three-membered ring of **6** are 1.923 and 1.697 Å. Nakayama and co-workers reported the synthesis and the X-ray crystallographic structure of dithiirane S-oxide (C–S bond lengths: 1.830 and 1.833 Å).¹¹ Schaumann and Behrens reported

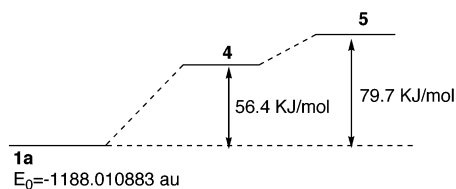
Scheme 1



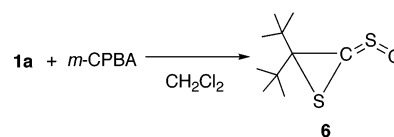
Scheme 2



Scheme 3. Calculated Zero Vibration Energies of 1a, 4, and 5



Scheme 4



the synthesis of α -thiolactone by oxidation of thioketenes (C–S bond lengths: 1.916 and 1.726 Å).¹² The three-membered ring structure of **6** is similar to that of α -thiolactone.¹³

As **1a** is an isomer of dithiirane **4** or thiosulfine **5**, the thermal isomerization of **1a** is the next interest. By analyzing calculated data, we surmised that the conversion between **1a**, **5**, and **6** very likely proceeds at elevated temperatures. When **1a** was refluxed in toluene, di-*tert*-butyl thioketene **3** was obtained almost quantitatively, suggesting that **4** might be unstable under these conditions. Thiirane-2-thione **1a** might isomerize to **4**, which extruded the sulfur to give **3**. Similarly, the episulfide sulfur of **1a** was eliminated by treatment with triphenylphosphine (1.1 equiv) in refluxing chloroform for 3 days to give **3** in 95% yield along with triphenylphosphine sulfide. To confirm dipolarophilic reactivity, the reaction of **1a** with acetylenes was carried out. Treatment of **1a** with dimethyl acylenedicarboxylate (DMAD) afforded 1,3-dithiole **7** in an almost quantitative yield (Scheme 5).

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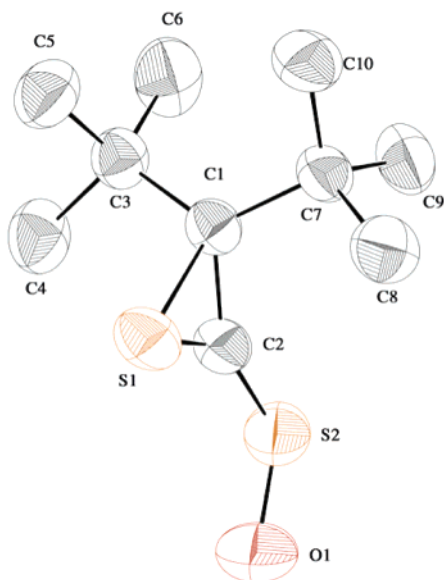
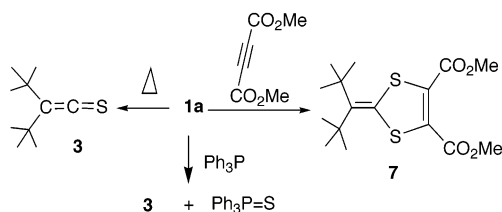


Figure 1. ORTEP Drawing of *S*-oxide **6**.

Scheme 5



1,3-Dithioles were previously synthesized by the reaction of DMAD with inner salts,¹⁴ thiazolethiones,¹⁵ or phosphonium betaines.¹⁶ The present reaction is another straightforward method for the synthesis of sterically crowded 1,3-dithioles. We are currently investigating the stability and reactivity of **1a** and **6**.

Supporting Information Available: Experimental procedures, spectroscopic characterization of **1a**, **6**, and **7**, and X-ray crystallographic data for **6**. This material is available free of charge via the Internet at <http://pubs.acs.org>.

References

- (1) (a) Ishii, A.; Akazawa, T.; Maruta, T.; Nakayama, J.; Hoshino, M.; Shiro, M. *Angew. Chem., Int. Ed. Engl.* **1994**, *33*, 777–778. (b) Ishii, A.; Akazawa, T.; Ding, M.-X.; Honjo, T.; Maruta, Nakamura, S.; Nagaya, H.; Ogura, M.; Teramoto, K.; Shiro, M.; Hoshino, M.; Nakayama, J. *Bull. Chem. Soc. Jpn.* **1997**, *70*, 509–523. (c) Mloston, G.; Romanski, J.; Reisenauer, H. P.; Maier, G. *Angew. Chem., Int. Ed.* **2001**, *113*, 393–397. (d) Shimada, K.; Kodaki, K.; Aoyagi, S.; Takikawa, Y.; Kabuto, C. *Chem. Lett.* **1999**, 695–696.
- (2) (a) Cohen, A. D.; Showalter, B. M.; Toscano, J. P. *Org. Lett.* **2004**, *6*, 401–403. (b) Hoffmann, R. V.; Zhao, Z.; Costales, A.; Clarke, D. J. *Org. Chem.* **2002**, *67*, 5284–5294. (c) Sheehan, J. C.; Beeson, J. H. *J. Am. Chem. Soc.* **1967**, *89*, 362–366.
- (3) For reviews, see: Padwa, A.; Murphree, S. S. In *Progress in Heterocyclic Chemistry*; Gribble, G. W.; Gilchrist, T. L., Eds.; Elsevier: Oxford, 1998; Vol. 10, Chapter 3 and 1999; Vol. 11, Chapter 4.
- (4) (a) Masaki, K.; Akimoto, K.; Ishii, A.; Kumakura, S.; Nakayama, J. *Sulfur Lett.* **1995**, *19*, 73–83. (b) Sudhakar, P.; Chandrasekhar, J. *Mol. Struct.* **1989**, *194*, 135–147. (c) Kunze, U.; Merkel, R.; Winter, W. *Chem. Ber.* **1982**, *115*, 3653–3662. (d) Winter, W.; Hanspeter, B.; Meier, H. Z. *Naturforsch.* **1980**, *35b*, 1015–1018. (e) Shoenberg, A.; Frese, E.; Brosowski, K.-H. *Ber.* **1962**, *95*, 3077–3083.
- (5) (a) Elam, E. U.; Rash, F. H.; Dougherty, J. T.; Gootlett, V. W.; Brannock, K. C. *J. Org. Chem.* **1968**, *33*, 2738–2741. (b) Schaumann, E. *Chem. Ber.* **1982**, *115*, 2755–2765.
- (6) Rao, V. J.; Ramamurthy, V. *J. Chem. Soc., Chem. Commun.* **1981**, 638–639.
- (7) Compound **1a**: yellow crystals; mp 98–101 °C. ¹H NMR (CDCl₃, 400 MHz) δ 1.28 (s, 18 H, *tert*-Bu). ¹³C NMR (CDCl₃, 100 MHz) δ 30.4 (*tert*-Bu), 39.5 (q-C), 76.3 (S–C–C), 226.7 (C=S). IR (KBr) ν (cm⁻¹) 2967, 1475, 1392, 1367 (C=S), 1331, 1207, 1043, 912, 825, 698, 675. Calcd⁹ C=S stretching 1378.
- (8) (a) Brock, E.; Schwan, A.; Dixon, D. A. *J. Am. Chem. Soc.* **1992**, *114*, 3492–3499. (b) Green, M.; Verkoczy, B.; Lown, E. M.; Strausz, O. P. *Can. J. Chem.* **1985**, *63*, 667–675. (c) Block, E.; Penn, R. E.; Ennis, M. D.; Owens, T. A.; Yu, S.-L. *J. Am. Chem. Soc.* **1978**, *100*, 7436–7437.
- (9) Ab initio MO calculations were conducted by using Gaussian 98 program at B3LYP/6-31G(d,p) level. 1 au = 2624.6 kJ/mol. Calculated vibration frequencies of **1a**, **4**, and **5** were not imaginary. Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Zakrzewski, V. G.; Montgomery, J. A., Jr.; Stratmann, R. E.; Burant, J. C.; Dapprich, S.; Millam, J. M. A.; Daniels, D.; Kudin, K. N.; Strain, M. C.; Farkas, O.; Tomasi, J.; Barone, V.; Cossi, M.; Cammi, R.; Mennucci, B.; Pomelli, C.; Adamo, C.; Clifford, S.; Ochterski, J.; Petersson, G. A.; Ayala, P. Y.; Cui, Q.; Morokuma, K.; Malick, D. K.; Rabuck, A. D.; Raghavachari, K.; Foresman, J. B.; Cioslowski, J.; Ortiz, J. V.; Baboul, A. G.; Stefanov, B. B.; Liu, G.; Liashenko, A.; Piskorz, P.; Komaromi, I.; Gomperts, R.; Martin, R. L.; Fox, D. J.; Keith, T.; Al-Laham, M. A.; Peng, C. Y.; Nanayakkara, A.; Challacombe, M.; Gill, P. M. W.; Johnson, B.; Chen, W.; Wong, M. W.; Andres, J. L.; Gonzalez, C.; Head-Gordon, M.; Replogle, E. S.; Pople, J. A. *Gaussian 98*, revision A.9; Gaussian, Inc., Pittsburg, PA, 1998. Recently, the relative energies of H₂C₂S₂ were reported, which stated that the dithioester is more stable than the dithiirane. Vilay, D.; Priyakumar, U. D.; Sastry, G. N. *J. Chem. Phys. Lett.* **2004**, *383*, 192–197.
- (10) Compound **6**: yellow crystals; mp. 97–99 °C. ¹H NMR (CDCl₃, 400 MHz) δ 1.25 (s, 18H, *tert*-Bu). ¹³C NMR (CDCl₃, 100 MHz) δ 31.5 (*tert*-Bu), 40.9 (q-C), 83.4 (S–C–C), 181.0 (C=S=O). IR (KBr) ν (cm⁻¹) 2964, 1477, 1395, 1370, 1262, 1095 (S=O), 1027, 803. Calcd⁹ S=O stretching 1104. Crystal data for C₁₃H₁₅O₂S₂: *M* = 218.38, *a* = 8.7860(3) Å, *b* = 12.0280(4) Å, *c* = 11.2040(4) Å, *V* = 1183.00(7) Å³, *T* = 298 K, monoclinic, space group = *P*21/*c*, *Z* = 4, μ(Cu Kα) = 2.38 cm⁻¹. The final *R* and *wR* were 0.0664 and 0.2104, respectively, using 1843 reflections.
- (11) Ishii, A.; Akazawa, T.; Ding, M.-X.; Honjo, T.; Nakayama, J.; Hoshino, M.; Shiro, M. *J. Am. Chem. Soc.* **1993**, *115*, 4914–4915.
- (12) Schaumann, E.; Behrens, U. *Angew. Chem., Int. Ed. Engl.* **1977**, *16*, 722–723.
- (13) Selected bond lengths [Å] and bond angles [deg] of **6**. S1–C1 1.923 (2), S1–C2 1.697(3), C1–C2 1.464 (3), C2–S2 1.608 (3), S2–O1 1.485 (3), C1–C7 1.559 (3), C1–C3 1.563 (3); C2–S1–C1 47.21 (1), C2–C1–S1 58.27 (1), C1–C2–S1 74.52 (2), C1–C2–S2 143.2 (2), S1–C2–S2 142.15 (2), S1–C1–C3 110.75 (2), C2–C1–C7 114.2 (2), S1–C1–C3 110.75 (2), C3–C1–C7 123.1 (2), C2–S2–O1 113.22 (2).
- (14) Nakayama, J. *Sulfur Lett.* **1993**, *15*, 239–245.
- (15) Jenny, C.; Heimgartner, H. *Helv. Chim. Acta* **1986**, *69*, 419–429.
- (16) Drozd, V. N.; Vyazgin, A. S.; Mosk, S. A. *Z. Org. Khim.* **1985**, *21*, 1335–1440.

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