Novel Oxidative Ring Opening Reaction of 1H-Isotellurochromenes to Bis(o-formylstyrlyl) Ditellurides

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Abstract: The oxidation of 1-unsubstituted or 1-phenyl-1H-isotellurochromenes with m-chloroperbenzoic acid (mCPBA) in CHCl₃ resulted in a ring opening reaction to produce as the sole products the corresponding o-formyl or benzoyl distyryl ditellurides, which were also produced by the hydrolysis of the 2-benzotelluropyrylium salts readily prepared from the parent isotellurochromene.

Keywords: isotellurochromene; mCPBA oxidation; 2-benzotelluropyrylium salt; distyryl ditelluride

1. Introduction

The preparation and investigation of the reactions of new tellurium-containing heterocycles have lately attracted increasing interest in the fields of both heterocyclic [1–3] and organotellurium chemistry [4–8]. We have been studying the syntheses and reactions of the novel tellurium- or selenium-containing heterocyclic compounds over the past twenty years. Our synthetic strategy [9,10] for the preparation of
these compounds is based on the intramolecular cyclization of the tellurol or selenol moieties to a triple bond. As a part of our continuing studies, we have previously reported the successful synthesis of the isotellurochromenes as the precursors for the preparation of the novel 2-benzotelluropyrylium salts [11,12]. In addition, the 1H-isotellurochromenes were found to transform into the 1,2-dihydro-2-metalanaphthalenes via (E)-o-(2'-lithiovinyl)benzyllithium generated by a tellurium-lithium exchange reaction [13]. In this study, an investigation of the oxidation of the isotellurochromenes is described as an extension of the known reactivity of these compounds.

There are several reports concerning the oxidation of mono and benzene ring fused six-membered heterocycles containing a chalcogen atom. The selenium dioxide oxidation of 4H-thiopyrans [14] and 4H-selenopyrans [14] produces a ring contraction to give hiophenes and selenophenes, respectively. The oxidation of dihydro-2H-selenopyrans [15] with sodium periodate is also known to produce selenophenes. Furthermore, the oxidation of thiochromenes [16], selenochromenes [16] and tellurochromenes [17] by selenium dioxide, trityl perchlorate or K 2CrO 7 produced the corresponding 2-formylbenzo[b]-thiophenes, -selenophenes and -tellurophenes, respectively. Whereas the isothiochromenes [18,19] are easily oxidized by mCPBA to afford the thermally stable normal S-oxide products, a similar oxidation of the highly substituted isoselenochromenes [20] produces the corresponding benzo[b]selenophene derivatives as the main product. These facts prompted us to investigate the oxidation of the isotellurochromenes 1.

2. Results and Discussion

When tert-butylisotellurochromene 1a was oxidized with 1.2 equiv. of mCPBA in CHCl 3 at 0 °C, the starting material immediately disappeared, and the bis(o-formylstyryl) ditelluride 2a was obtained in 83% yield as the sole product after the usual work up. The structure of the ditelluride 2a was characterized by NMR, IR and mass spectroscopy. The low-mass spectrum of this compound suggested the ditelluride molecular formula based on the molecular ion at m/z = 634 ( 130Te) and the expected isotope pattern for Te 2. In addition, the HRMS of 2a showed the same exact molecular formula. Similarly, the 1-nonsubstituted 2b, alkyl 2c-g and phenyl 2h derivatives were also obtained in moderate to good yields. These results are summarized in Table 1 (entries 1-8). The double bond in the products 2 was proven to have a (Z)-stereochemistry by the vicinal coupling constant (J = 10 Hz) in the 1H-NMR spectra of the nonsubstituted derivative 2b. A similar mCPBA oxidation of the 1-substituted isotellurochromenes 1 was examined (entries 9, 10). The 1-phenylisotellurochromene 1i [21] was oxidized to give the bis(o-benzoylstyryl) ditelluride 2i in 80% yield, while the similar oxidation of the 1-methyl isochromene 1j [21] resulted in decomposition to afford a complex mixture without any characterized products. The significant differences in the product yield according to whether or not the 1-substituent is a methyl group cannot be clearly explained at the present time. The structure of the products 2 including the geometry of the styryl moiety was finally determined by an X-ray crystallographic analysis using the tert-butyl derivative 2a.
Table 1. Oxidation of isotellurochromenes 1 with mCPBA.

| Entry | Product | R<sup>1</sup> | R<sup>2</sup> | Yield (%) | Appearance (mp, °C) |
|-------|---------|---------------|--------------|-----------|---------------------|
| 1     | 2a      | t-Bu          | H            | 83        | orange prisms, 140–143 |
| 2     | 2b      | H             | H            | 43        | orange prisms, 95–97  |
| 3     | 2c      | Me            | H            | 57        | orange oil           |
| 4     | 2d      | n-Pro         | H            | 60        | orange oil           |
| 5     | 2e      | n-Bu          | H            | 70        | orange oil           |
| 6     | 2f      | 1-cyclohexenyl| H            | 83        | orange oil           |
| 7     | 2g      | n-Oct         | H            | 62        | orange oil           |
| 8     | 2h      | Ph            | H            | 67        | orange oil           |
| 9     | 2i      | t-Bu          | Ph           | 80        | orange oil           |
| 10    | 2j      | t-Bu          | Me           | 0         | ---                 |

The telluroxides 3, which are presumed to be produced by the oxidation of the isotellurochromene 1 with mCPBA in this reaction, were too unstable to isolate. The oxidation of 1a with mCPBA, followed by treatment with Ac<sub>2</sub>O resulted in a Pummerer-type rearrangement to afford 1-acetoxy-isotellurochromene 4a as a pale yellow oil, together with a small amount of the ditelluride 2a. The hydrolysis of the acetoxy derivative 4a with NaHCO<sub>3</sub> aq. produced the ditelluride 2a in almost quantitative yield.

In addition, the ditellurides 2a and 2b could be obtained in high yields by the hydrolysis of the 2-benzotelluropyrylium tetrafluoroborates 5 [15], which had previously been prepared by the treatment of the isotellurochromenes 1 with triphenylcarbenium tetrafluoroborate (Ph<sub>3</sub>C<sup>+</sup> BF<sub>4</sub>–) in MeNO<sub>2</sub> in almost quantitative yields. The initial intermediates 6 were produced by the nucleophilic attack of water at the C-1 position of the telluropyrylium cation 5, and then oxidized to give 2. The ditelluride 2a was easily converted to the tellulium trichloride 8 by fission of the Te-Te bond by sulfuryl chloride in benzene in quantitative yield.

A plausible mechanism for the formation of the ditellurides 2 from the isotellurochromenes 1 and 2-benzotelluropyrylium salts 5 is outlined in Figure 1. The telluroxides 3 generated by the oxidation of the isotellurochromenes 1 rearranged to afford the 1-hydroxyisochromenes 6 by a Pummerer-type reaction. The intermediate 6 undergoes ring opening with migration of the hydroxy proton to form the vinyltellurol 7. The resulting tellurol tautomer 7 is immediately oxidized by mCPBA or air to give the distyryl ditelluride 2.

In summary, the oxidation of the isotellurochromenes with mCPBA resulted in the unprecedented ring-opening reaction to give the bis[o-formyl(benzoyl)-α-styryl] ditellurides in moderate to good yields. The
reaction might proceed through a Pummerer-type reaction via the telluroxides. Further detailed studies of this reaction, an expanding the applications and selenium analogues are now in progress.

**Figure 1.** Reaction conditions and a plausible mechanism.

**Reagents and Conditions:** i, mCPBA, CHCl₃, 0 °C to room temp., ii, Ac₂O, room temp., iii, 5% NaHCO₃, room temp., iv, Ph₃C⁺BF₄⁻, MeNO₂, room temp., v, H₂O, room temp., vi, SO₂Cl₂, benzene, room temp.

### 3. Experimental

Melting points were measured on a Yanagimoto micro melting point hot stage apparatus and are uncorrected. IR spectra were determined with a Horiba FT-720 spectrometer. Mass spectra (MS) and HRMS were recorded on a JEOL SX-102A instrument. NMR spectra were determined with a JEOL ECP-500 (500 MHz) spectrometer in CDCl₃ using tetramethylsilane as internal standard and J values are given in Hz. Microanalyses (MT-5) were performed in the Microanalytical Laboratory in this Faculty. The starting materials, isotellurochromenes (1) were prepared by the literature method [12].

**Oxidation of 3-tert-butyloisotellurochromene (1a) with mCPBA:** formation of (Z)-bis(o-formyl-α-tert-butyldstyryl) ditelluride (2a): mCPBA (70%, 296 mg, 1.2 mmol) was added to a solution of 3-tert-butyloisotellurochromene (1a, 302 mg, 1.0 mmol) in dry CHCl₃ (10 mL) at 0 °C and the mixture was
stirred at room temperature for 1h. After addition of sat. NaHCO₃ aq. (10 mL), aqueous mixture was extracted with CH₂Cl₂ (50 mL × 3). The organic layers were washed with brine (30 mL × 2), dried (MgSO₄) and evaporated. The resulting residue was chromatographed on silica gel using n-hexane-CH₂Cl₂ (2:1) as an eluent to give pure 2a (263 mg, 83%), dark red prisms, mp 140-143 °C (from acetone-hexane); MS m/z (%): 634, 632, 630, 628 (1, 2, 2, 1, M⁺), 187 (100), 145 (33), 115 (22). IR (KBr) cm⁻¹: 1690 (C=O); ¹H-NMR (500 MHz, CDCl₃) δ 1.24 (18H, s, t-Bu × 2), 6.88 (2H, s, Ph-C=CH- × 2), [7.20 (2H, d, J = 7.6 Hz), 7.36 (2H, dd, J = 7.7, 7.7 Hz), 7.47 (2H, ddd, J = 7.7, 7.6, 1.4 Hz), 7.80 (2H, dd, J = 7.7, 1.4 Hz) Ph-H], 10.06 (2H, s, CHO × 2). ¹³C-NMR (125 MHz, CDCl₃) δ 30.7 (q), 41.3 (s) 127.5 (d), 128.3 (d), 131.6 (d), 133.5 (s), 133.6 (d), 134.6 (s), 138.0 (s), 144.4 (s), 191.5 (s); HRMS m/z Calcd for C₂₆H₃₀¹³⁰Te₂: 634.0374. Found: 634.0352.

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References and Notes

1. Kuthan, J.; Sebek, P.; Bohm, S. In Advances in Heterocyclic Chemistry: Developments in the Chemistry of Thiopyrans, Selenopyrans, and Telluropyrans, 1st ed.; Katritzky, A.R., Ed.; Academic Press: London, UK, 1994; Volume 59, pp. 179–244.
2. Sadekov, I.D.; Minkin, V.I. In Advances in Heterocyclic Chemistry: Six-Membered Heterocycles with a Tellurium Atom, 1st ed.; Katritzky, A.R., Ed.; Academic Press: London, UK, 1995; Volume 63, pp. 1–60.
3. Detty, M.R.; O’Regan, M.B. In The Chemistry of Heterocyclic Compounds: Tellurium-Containing Heterocycles; Taylor, E.C., Ed.; John Wiley & Sons: New York, USA, 1994; Volume 53, pp. 1–490.
4. Irgolic, K.Y. The Organic Chemistry of Tellurium; Gordon and Breach: New York, USA, 1974.
5. Engman, L. Synthetic applications of organotellurium chemistry. Acc. Chem. Res. 1985, 18, 274–279.
6. Patai, S.; Rappoport, Z. The Chemistry of Organic Selenium and Tellurium Compounds; John Wiley & Sons: New York, USA, 1986; Volume I, pp. 1–939.
7. Patai, S.; Rappoport, Z. The Chemistry of Organic Selenium and Tellurium Compounds; John Wiley & Sons: New York, USA, 1987; Volume II.
8. Petragnani, N. Tellurium in Organic Synthesis; Academic Press: London, UK, 1994.
9. Sashida, H. Synthesis of tellurium-containing heterocycles by intramolecular hydrotelluration of tellurols to a triple bond. Rev. Heteroatom. Chem. 2000, 22, 59–78.
10. Sashida, H. Preparations of heterocycles by intramolecular cyclization of tellurols and related compounds to a triple bond. J. Syn. Org. Chem. Jpn. 2001, 59, 355–362.
11. Sashida, H.; Ohyanagi, K. Studies on tellurium-containing heterocycles. 2-Benzotelluropyrylium salts: First preparation and reactions with Grignard reagents. J. Chem. Soc. Perkin Trans. I 1998, 2123–2124.

12. Sashida, H.; Ohyanagi, K.; Minoura, M.; Akiba, K.Y. Studies on tellurium-containing heterocycles. Synthesis and structure of 2-benzotelluropyrylium salts and 2-benzoselenopyrylium salts. J. Chem. Soc. Perkin Trans. I 2002, 606–612.

13. Sashida, H. 1,5-Dilithiated synthetic building block, (E)-o-(2'-lithiovinyl)benzylolithium by tellurium-lithium exchange. Synthesis 1999, 1866–1868.

14. Drevko, B.I.; Fomenko, L.A.; Kharchenko, V.G. Oxidation of 2,4,6-triaryl-4H-thio(selenol)pyrans with selenium dioxide. Khim. Geterotiks. Soedin. 1989, 767-769.

15. Kataoka, T.; Ohe, Y.; Umeda, A.; Iwamura, T.; Yoshimatsu, M.; Shimizu, H. Novel oxidative ring contraction of dihydrotelluropyranos to selenophenes. J. Chem. Soc. Chem. Commun. 1993, 577–579.

16. Ruwet, A.; Messen, J.; Renson, M. Selective oxidation of 1-thio- and 1-selenochromenes. Formation of 1-thio- and selenocoumarins, 2-formylbenzo[b]thiophenes, 2-formylbenzo[b] selenophenes, and other isomers. Bul. Soc. Chim. Belg. 1969, 78, 459–464.

17. Dereu, N.; Renson, M. Oxidation de telluro-1 chromenes. J. Organomet. Chem. 1983, 258, 163–169.

18. Sadekov, I.D.; Nivorozhkin, V.L.; Ladatko, A.A.; Minkin, V.I. Reactions of 2H-tellurochromene. Khim. Geterotiks. Soedin. 1988, 1050–1054.

19. Hori, M.; Kataoka, T.; Shimizu, H.; Hongo, J.; Kido, M. Reaction of 1H-2-benzothiopyran 2-oxides with active methylene compounds: A novel ring contraction of 1-aryl derivatives to benzo[c]thiophenes. X-ray molecular structure of 1-(2,2-diacyclvinyl)-3-phenylbenzo[c]thio-phenes. J. Chem. Soc, Perkin Trans. I 1989, 1611–1618.

20. Okuma, K.; Kojima, K.; Y. Koga, Y.; Shioji, K. Oxidation of 1H-benzoselenopyrans. Generation of benzoselenophenes, benzaldehydes, and benzophenones. Heterocycles 2000, 52, 1021–1024.

21. Sashida, H.; Satoh, H.; Ohyanagi, K. Reaction of 2-benzotelluropyrylium salts with organocopper reagents: Introduction of a carbon functional group at the C-1 position of the tellurium cation ring. Heterocycles 2004, 63, 309–317.

Appendix 1

This paper constitutes Part 28 in the ‘Studies on Tellurium-Containing Heterocycles’, For Part 27: Sashida, H.; Nakabayashi, S.; Kaname, M., Minoura, M. 2-Substituted Isotellurochromenium Salt Derivatives: Preparations, Structures, Spectroscopic Properties. Heterocycles 2010, 80, 1339–1352.
Appendix 2

The details of the X-ray data of bis(o-formylstyryl) ditelluride \(2a\) will be reported in a full paper that will appear in the near future.

*Sample Availability:* Samples of the compounds 1,2 are available from the authors.