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Synthesis of enantiomerically pure telluronium salts by the reaction of chiral tellurides with alkyl halides

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Abstract

Enantiomerically pure benzyl and ethoxycarbonylmethyl telluronium salts **4**, using 2-*exo*-hydroxy-10-bornyl group as a chiral ligand, have been prepared in good yield and diastereoselectivity by the reaction of chiral tellurides **3** with alkyl halides. A structure with R_{Te} absolute configuration at the tellurium atom was confirmed by an X-ray analysis of **4a**.

1. Introduction

Chiral chalcogenonium salts are important compounds in asymmetric synthesis as useful reagents for cyclopropanation, aziridination and epoxidation or participation in rearrangement reactions.[1] Since Furukawa's group reported the first successful example of the use of chiral sulfonium salts with camphor structure for asymmetric reactions,[2] there have been many papers on the asymmetric reactions using chiral sulfonium results to give high to excellent enantiomeric excess of the products.[1] However, although the mechanism of the reaction concerning chalcogenonium salts has been studied from various points of views, the stereochemical process of the reactions is still not too clear since most of the salts used in the reactions lack definitely determined stereochemistry.[3] On the other hand, compared with chiral sulfonium salts, almost no chiral telluronium salts have been known to date, and neither have their reactions.[4] We have reported the stereoselective synthesis of enantiomerically pure benzyl and allyl telluronium salts by reaction of halotelluranes with Grignard reagents (Scheme 1).[5] From previous results, a telluronium salt would be more configurationally stable than its sulfur analogues and asymmetric reaction using chiral telluronium salts might give better selectivity under similar conditions.[6]

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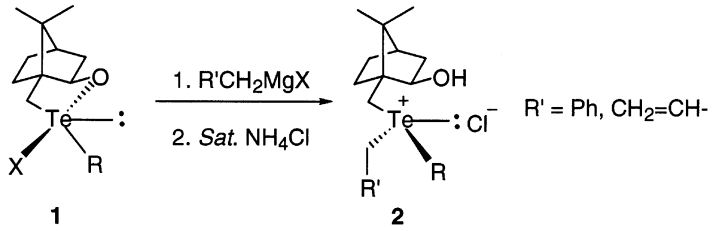
Generally, the simplest way to synthesize optically active telluronium salts is the reaction of homochiral tellurides with halides; however, there are no reports concerning the diastereselective synthesis of telluronium salts using this method.[7] Herein, we report our results on the diastereoselective synthesis and stereochemistry of enantiomerically pure benzyl and ethoxycarbonylmethyl telluronium salts by the reaction of chiral telluride **3** with alkyl halides.



Scheme 1.

2. Results and discussion

The chiral tellurides **3a**,**b** were prepared and separated as previously reported.[5] Reaction of methyl telluride **3a** with benzyl bromide was carried out in dichloromethane at room temperature overnight; after evaporation of the solvent the telluronium salt was obtained as a mixture of diastereomers. There are two products judging from the ^{1}H NMR spectra of the mixture, in the ratio of ca. 6:1 from the ^{1}H NMR integration of the crude sample. The major product **4a** could be isolated by simple recrystallization from hexane–CH_2Cl_2. The stereochemistry of **4a** has been determined by X-ray crystallographic analysis, which indicated that the absolute configuration of the central tellurium atom was R_{Te} as shown in Fig. 1. Average values of Te–C bond distances and C–Te–C angles are 2.13(8) Å, and 96.1(6)°, respectively.[4,5] Reaction of other substituted benzyl bromides also gave telluronium salts in similar yield and ratio, and all of the major products **4b–d** could be separated as crystals by recrystallization of the mixture from hexane–CH_2Cl_2. The structure and stereochemistry of the major products can be assigned by comparison of their ^{1}H NMR spectral characteristics with that of **4a**: the chemical shifts of the hydrogens of the two methyl groups bound to tellurium atom in the two diastereomers are quite different from each other. Therefore, the major products with similar ^{1}H NMR patterns to that of compound **4a** can be assigned as having the same stereochemistry as **4a** (Scheme 2).

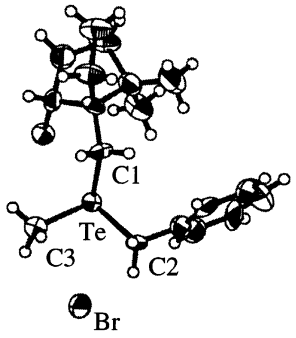
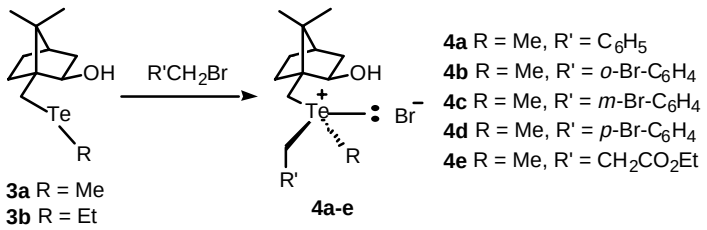


Figure 1.



Scheme 2.

Reaction of methyl telluride **3a** with ethyl bromoacetate under similar conditions also gave ethoxycarbonylmethyl telluronium salt as a mixture of diastereomers. After recrystallization from hexane–CH_2Cl_2, the major product **4e** was isolated as crystals in 43% yield. The telluronium salt **4e** can also be considered as having the same stereochemistry as **4a**. However, similar reactions of ethyl telluride with these halides unfortunately led to decomposition of the starting materials.

It is very interesting to note that the hydroxyl group plays a key role in the control of the diastereoselectivity of the reactions: when hydroxyl protected (-OMOM) methyl telluride reacted with benzyl bromide under the same conditions, the corresponding telluronium salts were obtained as a ca. 1:1 mixture of diastereomers.[8]

The stereoselectivity of the reaction may result from the hydrogen bonding interaction between the hydroxyl group and one of the two lone pairs of the tellurium atom.[9] Since the steric repulsion of **A** in Fig. 2 would be increased between the alkyl group and the bornyl moiety, interaction as shown in **B** of Fig. 2 might be more favorable, and selective reaction of one of the lone pairs gave telluronium salts with good diastereoselectivity.

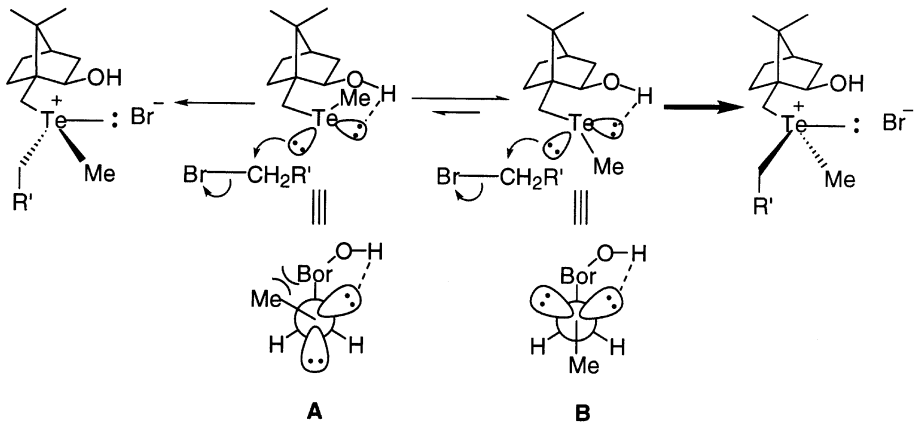


Figure 2.

In conclusion, the diastereoselective synthesis of enantiomerically pure benzyl and ethoxycarbonylmethyl telluronium salts has been achieved by reaction of homochiral hydroxybornyl tellurides with alkyl halides. Stereochemistry of the salts has been determined by X-ray crystallographic analysis. Our results may provide important information from the stereochemical viewpoint for understanding the mechanism of reactions using chiral chalcogenonium salts.

3. Experimental

3.1. General methods

Melting points were taken with a Yanaco micromelting point apparatus and are uncorrected. Spectroscopic measurements were carried out with the following instruments: IR, Perkin–Elmer 1600 Series FTIR; mass (MS) and high resolution mass spectra (HRMS), JMS-AX 505H; ^{1}H NMR, Varian Gemini-300 (300 MHz) for solutions in $CDCl_3$ with Me_4Si as an internal standard, J values in Hz. The chemical shifts from Me_4Si were calculated based on $CDCl_3$; ^{13}C NMR, Varian Gemini-300 (75 MHz) for solutions in $CDCl_3$ (or other solvent as mentioned) with $^{13}CDCl_3$ (77 ppm) as an internal standard. ^{125}Te NMR, Varian Unity 500 (157.9 MHz) for solutions in $CDCl_3$ with Ph_2Te_2 (0.5 M in CH_2Cl_2, 422 ppm) as an external standard. Dry CH_2Cl_2 was distilled over P_2O_5 and stored over 4 Å molecular sieves.

3.2. General procedure for the synthesis of telluronium salts **4**

The alkyl halides (1.5 mmol) were added to a solution of telluride **3a** (1 mmol) in dry CH_2Cl_2 (8 ml) under a N_2 atmosphere at room temperature. Then, the whole mixture was stirred at room temperature overnight. Removal of the solvent under reduced pressure gave the crude product, which after purification by recrystallization from hexane and CH_2Cl_2 afforded the product as colorless crystals.

Satisfactory analytical (combustion and high resolution mass) and spectral data were obtained for all new isolable compounds. Selected data for these salts are as follows.

3.2.1. *Benzyl({(1*S*,2*R*,4*R*)-2-hydroxy-7,7-dimethylbicyclo[2.2.1]heptan-1-yl}methyl)-methyltelluronium bromide* ***4a***

Yield 73%, colorless crystals. mp 142–143°C; $[\alpha]_D^{26}$ −14.7 (c 0.67, $CHCl_3$); IR (KBr): 2961, 1560, 1454, 1070, 758, 702 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.67 (s, 3H), 1.03 (s, 3H), 1.06–1.26 (m, 3H), 1.46–1.9 (m, 4H), 2.25 (s, 3H), 2.26 (d, J=12.1 Hz, 1H), 2.86 (d, J=12.1 Hz, 1H), 3.95 (dd, J=3.8 Hz, 7.7, 1H), 4.49 (d, J=11.5 Hz, 1H), 4.66 (d, J=11.5 Hz, 1H), 7.29–7.41 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 10.7, 20.1, 20.7, 26.9, 27.2, 34.1, 34.3, 40.6, 45.2, 48.2, 50.8, 128.3, 128.9, 130.0, 132.5; ^{125}Te NMR (157.9 MHz, $CDCl_3$): δ 506; Ms m/z: 298 [M^+–Br–$C_6H_5CH_2$, ^{130}Te], 296 [M^+–Br–$C_6H_5CH_2$, ^{128}Te], 294 [M^+–Br–$C_6H_5CH_2$, ^{126}Te], 174, 172, 170, 135, 108, 93, 79, 67, 55; anal. calcd for $C_{18}H_{27}BrOTe$: C, 46.28; H, 5.83. Found: C, 46.19; H, 5.65. Recrystallization of the **4a** from hexane and CH_2Cl_2 gave crystals that were suitable for X-ray analysis. Selected crystallographic data for **4a**: prismatic, space group, $P2_12_12_1$ (#19) with a=13.460(3) Å, b=21.058(3), c=6.749(3) Å, V=1913(1) Å^3, and Z=4 (D_{calc}=1.621 g cm^{-3}), μ (Mo Kα)=36.48 cm^{-1} absorption collected by ω scans; 2545 unique reflections; 1237 with $I>3.00\sigma(I)$ were used in refinement; R=4.1%, R_w=4.4%. Selected bond lengths (Å) and angles (°) are as follows: Te–C(1), 2.13(1); Te–C(2), 2.16(1); Te–C(3), 2.12(2); C(1)–Te–C(2), 93.6(6); C(1)–Te–C(3), 97.4(8); C(2)–Te–C(3), 97.3(6). Further details of the crystal structure investigation are available on request from the Director of the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK, on quoting the full journal citation.

*3.2.2. (2-Bromo-benzyl)({(1*S*,2*R*,4*R*)-2-hydroxy-7,7-dimethylbicyclo[2.2.1]heptan-1-yl}methyl)-methyltelluronium bromide* ***4b***

Yield 41%, colorless crystals. mp 109–110.5°C; $[\alpha]_D^{26}$ −54.9 (*c* 0.67, $CHCl_3$); IR (KBr): 2950, 1069, 1023, 759 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 0.74 (s, 3H), 1.10 (s, 3H), 1.12–1.26 (m, 3H), 1.46–1.9 (m, 4H), 2.44 (s, 3H), 2.88 (d, $J=12.1$ Hz, 1H), 2.96 (d, $J=12.1$ Hz, 1H), 4.01 (dd, $J=3.8$, 7.7 Hz, 1H), 4.43 (d, $J=11.5$ Hz, 1H), 4.50 (d, $J=11.5$ Hz, 1H), 7.17–7.24 (m, 1H), 7.28–7.38 (m, 1H), 7.51–7.54 (m, 1H), 7.62–7.65 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 12.3, 20.1, 21.3, 26.9, 27.0, 32.7, 33.4, 34.7, 40.8, 45.4, 47.9, 50.4, 124.6, 128.3, 129.6, 131.8, 133.2, 133.9; anal. calcd for $C_{18}H_{26}Br_2OTe$: C, 39.51; H, 4.79. Found: C, 39.51; H, 4.81.

*3.2.3. (3-Bromo-benzyl)({(1*S*,2*R*,4*R*)-2-hydroxy-7,7-dimethylbicyclo[2.2.1]heptan-1-yl}methyl)-methyltelluronium bromide* ***4c***

Yield 46%, colorless crystals. mp>205°C; $[\alpha]_D^{26}$ −24.8 (*c* 0.73, $CHCl_3$); IR (KBr): 2957, 1564, 1473, 1071, 784, 697 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 0.72 (s, 3H), 1.05 (s, 3H), 1.09–1.25 (m, 3H), 1.55–1.88 (m, 4H), 2.30 (s, 3H), 2.35 (d, $J=12.1$ Hz, 1H), 2.86 (d, $J=12.1$ Hz, 1H), 3.96 (dd, $J=3.8$, 7.7 Hz, 1H), 4.43 (d, $J=11.5$ Hz, 1H), 4.59 (d, $J=11.5$ Hz, 1H), 7.25–7.30 (m, 1H), 7.31–7.47 (m, 2H), 7.54 (t, $J=1.6$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 11.1, 20.2, 20.9, 27.0, 27.2, 32.0, 33.2, 34.4, 40.7, 45.2, 48.3, 50.7, 122.9, 128.6, 130.5, 131.4, 132.5, 135.1; anal. calcd for $C_{18}H_{26}Br_2OTe$: C, 39.51; H, 4.79. Found: C, 39.63; H, 4.84.

*3.2.4. (4-Bromo-benzyl)({(1*S*,2*R*,4*R*)-2-hydroxy-7,7-dimethylbicyclo[2.2.1]heptan-1-yl}methyl)-methyltelluronium bromide* ***4d***

Yield 72%, colorless crystals. mp 158–160°C; $[\alpha]_D^{26}$ −17.7 (*c* 0.71, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$): δ 0.74 (s, 3H), 1.05 (s, 3H), 1.07–1.20 (m, 3H), 1.50–1.90 (m, 4H), 2.20 (s, 3H), 2.32 (d, $J=11.5$ Hz, 1H), 2.91 (d, $J=12.1$ Hz, 1H), 3.95 (dd, $J=3.8$ Hz, 7.7, 1H), 4.51 (d, $J=11.5$ Hz, 1H), 4.56 (d, $J=12.1$ Hz, 1H), 7.30 (d, $J=8.2$ Hz, 2H), 7.53 (d, $J=8.2$ Hz, 2H); anal. calcd for $C_{18}H_{26}Br_2OTe$: C, 39.51; H, 4.79. Found: C, 39.65; H, 5.33.

*3.2.5. (Ethoxycarbonylmethyl)({(1*S*,2*R*,4*R*)-2-hydroxy-7,7-dimethylbicyclo[2.2.1]heptan-1-yl}-methyl)methyltelluronium bromide* ***4e***

Yield 43%, colorless crystals. mp 121–122°C; $[\alpha]_D^{26}$ −55.8 (*c* 3.40, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$): δ 0.93 (s, 3H), 1.21 (s, 3H), 1.06–1.34 (m, 3H), 1.31 (t, $J=7.1$ Hz, 3H), 1.52–2.02 (m, 4H), 2.72 (s, 3H), 3.00 (s, 3H), 3.57 (d, $J=13.2$ Hz, 1H), 3.82 (d, $J=13.2$ Hz, 1H), 4.04 (dd, $J=3.3$, 7.7 Hz, 1H), 4.23 (q, $J=7.1$ Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 12.7, 14.3, 20.1, 21.2, 26.6, 27.0, 28.5, 34.8, 40.9, 45.4, 47.8, 50.0, 62.1, 77.8, 168.9; anal. calcd for $C_{15}H_{27}BrO_3Te$: C, 38.90; H, 5.88. Found: C, 38.88; H, 5.44.

Acknowledgements

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References

1. Li, A.-H.; Dai, L.-X.; Aggarwal, V. K. *Chem. Rev*. **1997**, *97*, 2341–2372.
2. Furukawa, N.; Sugihara, Y.; Fujihara, H. *J. Org. Chem*. **1989**, *54*, 4222–4224.
3. (a) Aggarwal, V. K.; Calamai, S.; Ford, J. G. *J. Chem. Soc*., *Perkin Trans. 1* **1997**, 593–599. (b) Lindvall, M. K.; Koskinen, A. M. P. *J. Org. Chem*. **1999**, *64*, 4596–4606.
4. (a) Shimizu, T.; Urakubo, T.; Kamigata, N. *Chem. Lett*. **1996**, 297–298. (b) *J. Org. Chem*. **1996**, *61*, 8032–8038. (c) Shimizu, T.; Kamigata, N. *Org. Prep. Proc. Int*. **1997**, *29*, 605–629.
5. (a) Zhang, J.; Saito, S.; Koizumi, T. *Tetrahedron: Asymmetry* **1997**, *8*, 3357–3361. (b) Zhang, J.; Saito, S.; Koizumi, T. *J. Org. Chem*. **1998**, *63*, 5423–5429.
6. Shimizu, T.; Matsuhisa. A.; Kamigata, N.; Ikuta, S. *J. Chem. Soc*., *Perkin Trans 2*, **1995**, 1805–1808.
7. Tang, Y.; Huang, Y.-Z.; Dai, L.-X.; Sun, J.; Xia, W. *J. Org. Chem*. **1997**, *62*, 954–959 and references therein.
8. Zhang, J.; Koizumi, T., unpublished results.
9. Yoshida, H.; Harada, T.; Murase, T.; Ohno, K.; Matsuura, H. *J. Phys. Chem. A* **1997**, *101*, 1731–1737.