Stability of regioisomeric sugar allyltins. Cleavage of the carbon–oxygen bond under radical conditions

Sławomir Jarosz* and Katarzyna Szewczyk

Institute of Organic Chemistry, Polish Academy of Sciences, Kasprzaka 44, 01-224 Warszawa, Poland

Abstract—Secondary sugar allyltin derivatives [Sug–CH(SnBu$_3$)–CH=CH$_2$] decompose at high temperature (140°C) with elimination of the tin moiety and opening of the sugar ring. The *cis*-dienoaldehydes thus formed react with Ph$_3$P=CH–CO$_2$Me to afford the corresponding trienes, which spontaneously undergo stereoselective intramolecular [4+2] cycloaddition to optically pure, highly oxygenated bicyclo[4.3.0]nonene derivatives. Primary sugar allyltins [Sug–CH=CHCH$_2$–SnBu$_3$] are thermally stable and do not decompose up to 170°C. © 2001 Elsevier Science Ltd. All rights reserved.

Recently we elaborated[1] a convenient route to sugar allyltin derivatives **2** (as a ca 5:1 mixture of the *trans:cis* isomers) from allylic alcohols **1** by a sequence of reactions involving formation of a xanthate, its thermal isomerization to a thiocarbonate followed by reaction of the latter with Bu$_3$SnH. Treatment of **2** with a mild Lewis acid (ZnCl$_2$) induced rearrangement of the sugar skeleton with elimination of the tributyltin moiety providing dienoaldehyde **4** with the *trans* geometry of the internal double bond regardless of the configuration (*cis* or *trans*) of the olefin **2**.[1b] Such dienoaldehydes are useful starting materials for the preparation of optically

pure, highly oxygenated carbobicyclic derivatives: perhydroindenes[2] and decalins[3] (Scheme 1).

Sugar allyltins with defined geometry across the double bond (**2**-*cis* or **2**-*trans*) can be prepared from the corresponding allylic bromides **3** by reaction with tri-*n*-butyltin cuprate.[4] In this process, however, substantial amounts of the regioisomeric derivatives with the terminal –CH=CH$_2$ group **5** are formed.[4]

Secondary allytin derivatives are less thermodynamically stable than the primary ones and they can be
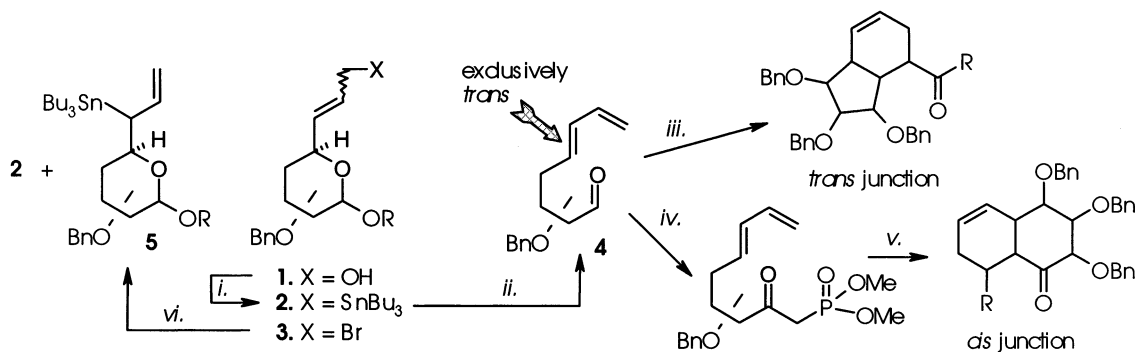
Scheme 1. (i) Ref. 1: (a) NaH/CS$_2$/MeI; (b) 110°C, 2 h; (c) Bu$_3$SnH, 110°C, 30 min; (ii) Ref. 1b: ZnCl$_2$, methylene chloride, rt, 2 h; (iii) Ref. 2a: Ph$_3$P=CH–CO$_2$Me, then cyclization; (iv) Ref. 3: (O), then CH$_2$N$_2$, then $^{(-)}$CH$_2$P(O)(OMe)$_2$; (v) RCHO, K$_2$CO$_3$, 18-crown-6-toluene, rt; (vi) Ref. 4: Bu$_3$SnCu.

readily isomerized to the R–CH=CH$_2$SnR$_3$ derivatives even with very mild Lewis acids.[5] We expected, therefore, that compound **5** could be converted into **2**. Of course, Lewis acids cannot be used, since they cause rearrangement of **2** to dienoaldehyde **4**.

We decided, therefore, to perform this rearrangement at high temperature; the results are summarized in Scheme 2. Heating the D-*gluco*-configured compound **5a**[4] (a single isomer of unknown configuration) at 140°C for 4 h did not give the desired primary allyltin **2a**, but a product which did not contain the tin moiety. This compound underwent facile reduction with NaBH$_4$ providing a compound which was identified as the dienoalcohol[6] **7a** with the *cis*-configuration ($J_{5,6} = 10.5$ Hz) at the internal double bond.

We reasoned that this unusual process (→**6**) might provide an easy access to carbobicyclic derivatives such as those shown in Scheme 1, but with the opposite stereochemistry at the ring junction. Thermal decomposition (boiling xylene) of the allyltin **5a** in the presence of the simplest stabilized ylide (Ph$_3$P=CH–CO$_2$Me) was expected to induce the tandem Wittig/Diels–Alder process which should provide bicyclo[4.3.0]nonene derivative(s). Indeed, the formation of compound **9a**—as the single stereoisomer—was noted under these conditions. The configuration of this cycloadduct was assigned by careful NMR experiments: COSY ^{1}H–^{1}H and NOESY correlations.[7] The very high stereoselectivity of this reaction can be rationalized assuming the *endo* transition state for the cycloaddition. The attack of the dienophile part from 'the top' **A** results in formation of **9a**. Transition state **B** (attack from 'the bottom') should be prevented by the severe steric interaction of the benzyloxy group at the C-6 position with the diene part of the molecule (Fig. 1).

The D-*manno*-configured compound **5b**[8] (obtained from the bromide **3b** according to Ref. 4) behaved similarly.

Its thermal decomposition (at 140°C) provided the *cis*-dienoaldehyde **6b** (75%), characterized as alcohol **7b** (obtained in 70% yield from **6b**)[9] (Scheme 2).

Such high-temperature reactions strongly suggest a rearrangement involving radicals formed by homolytic cleavage of the C–Sn bond. The radical **10** would then need to rearrange with breaking of the C–O bond, a process which is very unlikely (route a in Scheme 3).

To check out if this unprobable mechanism is possible, we performed the reaction of **5b** in the presence of tributyltin hydride and separately hexabutyldistannane. The first process should afford the reduction products **11** (from radical **10**) and, the regioisomer **2b**. The reaction of **5b** with the tributyltin radical (generated by homolytic cleavage of the Sn–Sn bond in Bu$_3$Sn–SnBu$_3$) should lead to the more stable regioisomer **2b**. However, in both reactions only the product of decomposition of **5b**—dienoaldehyde **6b**—was formed. These results excluded the possibility of decomposition of **2b** via a radical mechanism.

The alternative mechanism had, therefore, to be considered. Tin atoms are only slightly more electropositive than carbon (organostannanes, because of the weak Sn–C bond, exhibit reactivity as carbanions or radicals[10]) and, therefore, tetraalkylstannanes might be regarded as extremely mild Lewis acids. Complexation of such tin derivatives (Bu$_3$Sn–Sug route b in Scheme 3), although very weak, is possible. At high temperature (boiling xylene, 140°C)[11] decomposition of **5b** according to the ionic mechanism could occur with elimination of the tributyltin cation. This species is a much stronger Lewis acid and complexes the methoxy group of **5b** inducing again, decomposition and providing dienoaldehyde **6b** (Scheme 3).

We do not have an explanation for the stereospecific formation of the *cis*-dienoaldehydes (**6a** and **6b**) in the
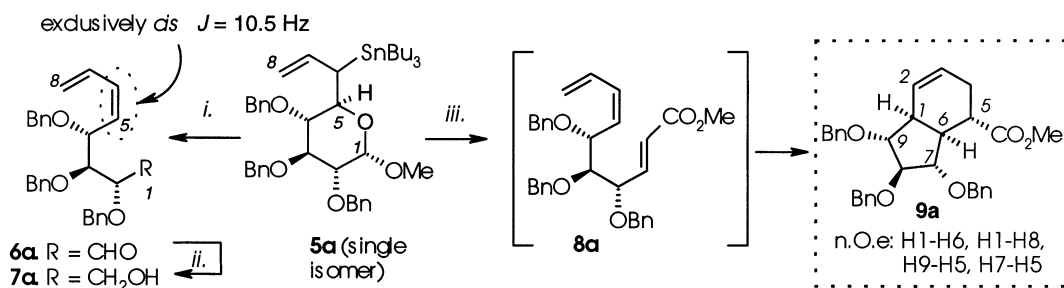
Scheme 2. (i) Xylene, reflux 4 h (80%); (ii) NaBH$_4$ (85%); (iii) Ph$_3$P=CHCO$_2$Me, xylene, reflux (75% from **5a**).
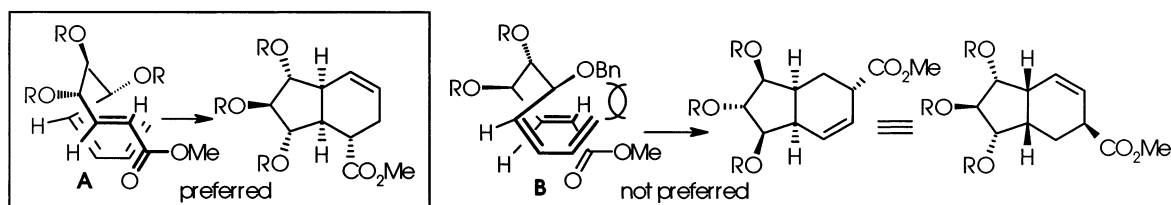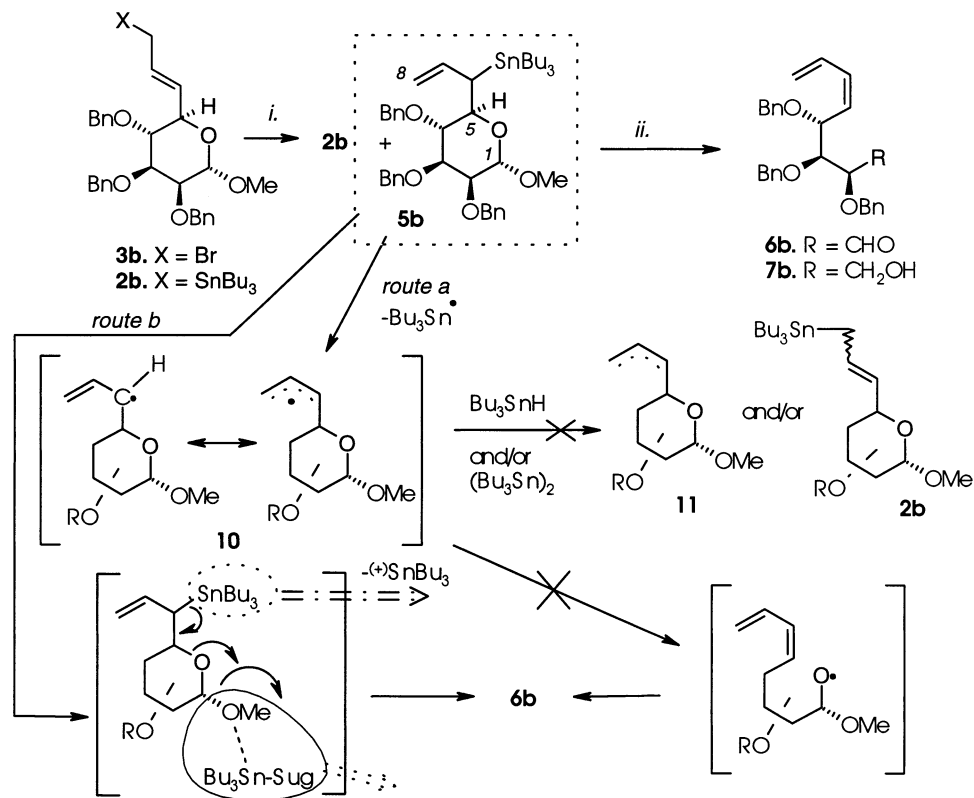

Figure 1. The *endo* transition states leading to bicyclic adducts.

Scheme 3. (i) 'Bu$_3$SnCu' according to Ref. 4 (40% **2b**+35% **5b**); (ii) xylene, reflux, 4 h (75%) then NaBH$_4$ (70%).

thermal decomposition of the secondary sugar allyltins. Especially in the light of the fact that in the presence of 'external' mild Lewis acids, these compounds behave exactly as the primary analogs! Treatment of the secondary allyltin **5b** with zinc chloride in CH$_2$Cl$_2$ at room temperature[12] afforded the dienoaldehyde with the *trans* configuration at the internal double bond![12] (Fig. 2).

We also tested the thermal stability of the primary sugar allyltin derivatives. Methyl 2,3,4,-tri-*O*-benzyl-6,7-dideoxy-8-tributylstannyl-a-D-*gluco*-oct-6(*E*)-1,5-pyranoside (D-*gluco*-**2**) remained unchanged at 170°C (boiling *t*-butylbenzene) for 12 h.

Conclusions

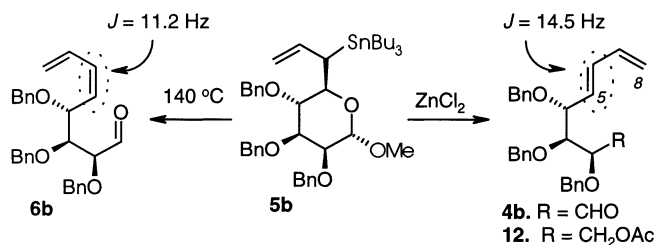Secondary sugar allyltin derivatives are not thermally stable and undergo decomposition at 140°C with elimination of the stannyl moiety and cleavage of the C–O bond in the sugar ring, providing dienoaldehydes with the *cis*-configuration of the internal C=C bond. This reaction performed in the presence of a stabilized ylide (Ph$_3$P=CH–CO$_2$Me) leads to the bicyclo[4.3.0]nonene system (with the *cis*-junction between both rings) via a tandem Wittig/Diels–Alder reaction.

Treatment of secondary sugar allyltins with a mild Lewis acid induces similar decomposition, but the *trans*-dienoaldehydes are formed (as in the analogous process performed for the primary analogs).

References

1. (a) Jarosz, S.; Fraser-Reid, B. *J. Org. Chem.* **1989**, *54*, 4011; (b) Kozlowska, E.; Jarosz, S. *J. Carbohydr. Chem.* **1994**, *13*, 889.
2. (a) Jarosz, S.; Kozlowska, E.; Jezewski, A. *Tetrahedron* **1997**, *53*, 10775; (b) Jarosz, S.; Skóra, S. *Tetrahedron: Asymmetry* **2000**, *11*, 1425 and references therein.
3. Jarosz, S.; Skóra, S. *Tetrahedron: Asymmetry* **2000**, *11*, 1433.
4. Jarosz, S. *Tetrahedron* **1997**, *53*, 10765.
5. Verdone, J. A.; Mangravite, J. A.; Scarpa, N. M.; Kuivila, H. G. *J. Am. Chem. Soc.* **1975**, *97*, 843.
6. Selected ^{1}H NMR data for **7a** (as acetate); δ: 6.55 (m, H-7), 6.28 ($\sim$t, $J_{6,7}=J_{5,6}=10.5$ Hz, H-6), 5.49 (dd, $J_{4,5}=10$ Hz, H-5), 5.29 (dd, $J_{8,8}=1.8$, $J_{7,8trans}=16.6$ Hz, H-8t), 5.14 ($J_{7,8cis}=11.8$ Hz, H-8c), 1.96 (OAc).
7. **Compound 9a:** m/z: calcd for C$_{32}$H$_{34}$NaO$_5$ (M+Na): 521.2304. Found: 523.2336. δ_H: 5.74 (m, H-2), 5.71 (m,

Figure 2. Decomposition of secondary sugar allyltin derivatives.

H-3), 4.04 (~t, $J_{7,8}=J_{8,9}=5.0$ Hz, H-8), 3.69 (H-7), 3.66 (H-9), 3.65 (OMe), 2.80 (H-1), 2.68 (H-5), 2.63 (H-6), 2.31 and 2.27 (both H-4); δ_C: 175.5 (OAc), 127.8 (C-2), 124.8 (C-3), 90.4 (C-8), 88.4 (C-7), 83.1 (C-9), 72.1, 71.8, 71.5 (3×$\underline{C}H_2Ph$), 51.7 (OMe), 40.6 (C-6), 39.9 (C-1), 38.5 (C-5), 25.4 (C-1). NOESY see Scheme 2.

8. NMR data for **5b**; δ_H: 6.20 (m, H-7), 3.31 (s, OCH$_3$), 2.82 (dd, $J=2.2$ and 11.1 Hz, H-6); δ_C: 127.3 (C-7), 110.6 (C-8), 99.5 (C-1), 80.1, 77.3, 75.3, 74.0 (C-2, 3, 4, 5), 74.9, 72.5, 72.1 (3×$\underline{C}H_2Ph$), 55.7 (OMe), 35.0 (C-6), 29.2, 27.6, 13.8 and 9.4 (Bu$_3$Sn).

9. NMR data for **7b** (as acetate); δ_H: 6.58 (m, H-7), 6.25 (dd, $J_{6,7}=11.2$, $J_{5,6}=10.3$ Hz, H-6), 5.55 (~t, H-5), 5.29 (dd, $J_{8,8}=1.8$, $J_{7,8t}=16.7$ Hz, H-8t), 5.19 ($J_{7,8c}=10.0$ Hz, H-8c), 4.57 (dd, $J=3.5$ and 5.1 Hz, H-4), 4.51 (dd, $J=2.8$ and 12.1 Hz, one of H-1), 4.17 (dd, $J=5.3$ Hz, second

H-1), 3.86 (m, H-2), 3.67 (dd, $J=6.2$ and 4.2 Hz, H-3), 1.98 (OAc); δ_C: 170.8 ($\underline{C}OCH_3$), 133.3 (C-6), 131.8 (C-7), 129.2 (C-5), 119.9 (C-8), CH=CH$_2$), 81.5 (C-3), 77.0 (C-2), 74.2 (C-4), 75.0, 72.2 and 70.3 (3×$\underline{C}H_2Ph$), 20.9 (CO$\underline{C}H_3$).

10. Sato, T. *Synthesis* **1990**, 259 and references cited therein.

11. At lower temperatures (boiling toluene) this decomposition was not observed.

12. These are typical conditions for the conversion of the primary sugar allyltins to *trans*-dienoaldehydes; cf. Scheme 1. Data for **12** δ: 6.45–6.20 (m, H-6,7), 5.72 (dd, $J_{5,6}=14.6$, $J_{4,5}=8.0$ Hz, H-5), 5.30–5.10 (m, both H-8), 2.00 (OAc); δ_C: 170.7 ($\underline{C}OCH_3$), 136.1, 134.3, 131.2 (C-5,6,7), 118.0 (C-8), 81.3, 79.3, 76.8 (C-2,3,4), 74.9, 72.1, 70.6 (3×$\underline{C}H_2Ph$), 63.1 (C-1), 21.0 (CO$\underline{C}H_3$).