Chemistry of Natural Compounds and Bioorganic Chemistry

Free-radical reactions of carbohydrate derivatives in the synthesis of carbocyclic compounds

3*. Cyclization of methyl 3-*O*-benzyl-6-bromo-4,6-dideoxy-2-methoxycarbonylmethylene-α(β)-D-*erythro*-hexopyranosides and methyl 3,4-di-*O*-benzyl-6-bromo-6-deoxy-2-methoxycarbonylmethylene-α-D-*arabino*-hexopyranosides

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The effect of substituent at C(4) of the pyranose ring in 3,4-disubstituted carbohydrate derivatives on the process of their intramolecular free-radical C(2)—C(6) cyclization was demonstrated. The absence of the effect of the C(1) and C(3) centers on the result of cyclization in 4-deoxymonosaccharides was confirmed experimentally.

Key words: free-radical reactions, carbohydrates, chiral cyclopentanes.

In the present work, in a continuation of investigations on the influence of various factors on the process of intramolecular free-radical C(2)—C(6)-cyclization of monosaccharide derivatives, we studied the cyclization of α- (**1a**) and β-bromides (**1b**) and α-bromide **2**, which differ from the previous example (compound **1d**),[1] in the configuration of the C(3) atom in compound **1** and the presence of an equatorial benzyloxy group at C(4) in compound **2**, respectively. 2-Oxabicyclo[2.2.1]heptane derivatives **3** and **4**, respectively, by-product **5**, and compounds of the cyclopentane series (**6**, **7**), prepared by the action of 1,3-propanedithiol on derivatives **3** and **4** are presented in Scheme 1.* Compounds **1a**, **1b**, and α-bromide **1c** have an axial benzyloxy group at C(3) of the pyranose ring and hence one could assume that their cyclization would be more difficult than that of the diastereomeric D-*threo*-derivative[2] **1d**, because in com-

* For Part 1 see Ref. 1.

† Deceased.

* To make the spectral information comprehensible, the numeration of atoms in compounds **3**, **4**, **6**, and **7** corresponds to that of the starting carbohydrates (Scheme 1).

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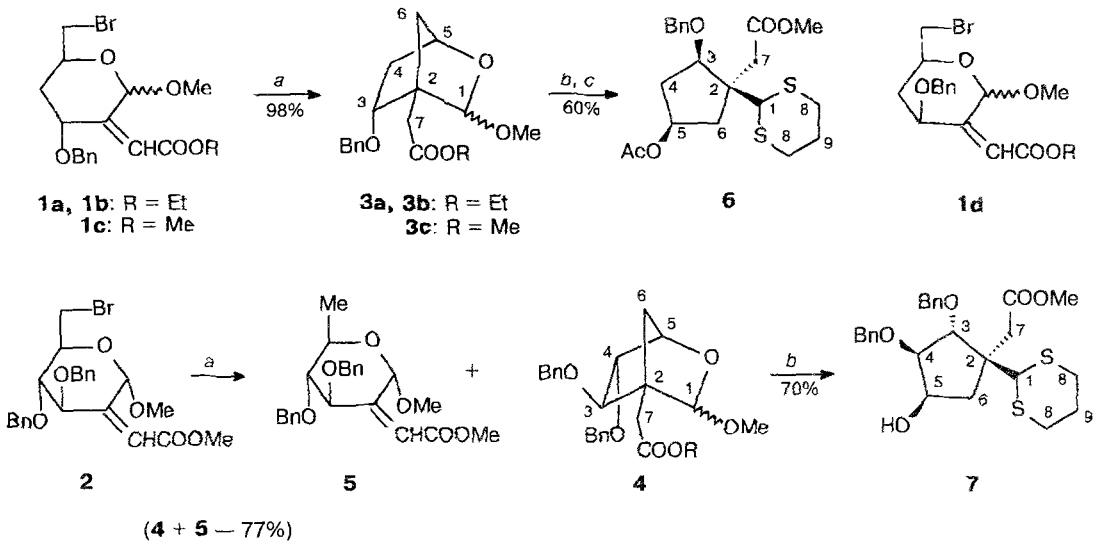
Scheme 1



1a, 1b: R = Et
1c: R = Me

3a, 3b: R = Et
3c: R = Me

6

1d

2

5

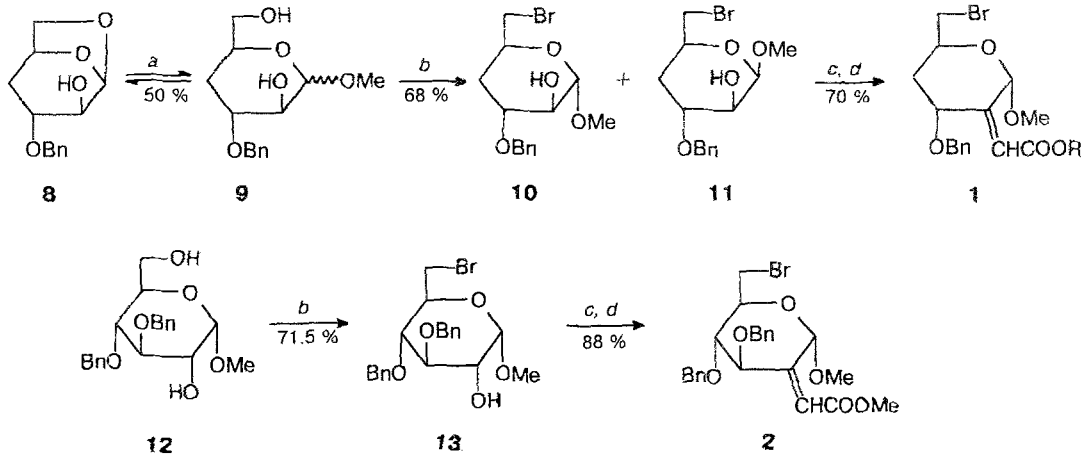
4

7

(**4** + **5** — 77%)

a. Bu_3SnH, AIBN, PhH; *b*. $HS(CH_2)_3SH$, $ZnCl_2$, CH_2Cl_2, −60°C; *c*. Ac_2O, Py.

Scheme 2



8

9

10

11

1

12

13

2

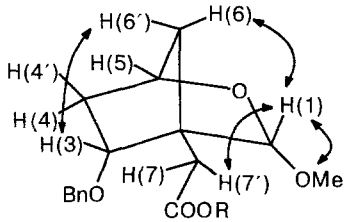
a. 5% H_2SO_4 в MeOH; *b*. Ph_3P, CBr_4, Py; *c*. $(COCl)_2$, DMSO, CH_2Cl_2, −60 °C, Et_3N, 1 *M* HCl; *d*. $Ph_3PCHCOOR$, THF.

pounds **3**, which are probably formed in the process, the substituent at C(3) would also be in the axial position. One can also assume that the cyclization of derivative **2** would be more difficult than that of the 4-deoxyglycoside,[2] because the axial benzyloxy group would appear at C(4) in the expected compound **4**.

Alcohol **8**, synthesized previously in five stages from levoglucosan,[3] was taken as the starting compound in the synthesis of bromides **1a—c**. Because the benzyloxy and hydroxy groups occupy the equatorial position in compound **8**, but in diol **9** they are in the axial position, methanolysis of **8** proceeds incompletely, and the conversion does not exceed 50 % (Scheme 2). However, separation of compounds **8** and **9** and repeated methanolysis of 1,6-anhydro derivative **8** made it possible to transform the latter to a mixture of α- and β-methyl glycosides **9** in high total yield. Using the route, thoroughly described in the previous report,[4] diols **9** were transformed to bromides **10** and **11**, which were separated by column chromatography on silica gel. Then these bromides were easily converted to unsaturated type **1** esters by Swern oxidation[5] followed by the Wittig reaction. Analogously, starting from monosaccharide **12** prepared as described previously,[6] compound **2** was synthesized.

Unexpectedly, it appeared that bromides **1a—c**, like D-*threo*-derivatives[2] of type **1d** (see Scheme 1), easily cyclize to give compounds **3a—c**, respectively, in a high yield (98 %). However, cyclization of bromide **10** was more difficult than cyclization of **1d**[2] (total yield 77 %). It required a higher temperature (boiling toluene instead of benzene), and afforded an unseparable mixture of two products.

The structures of all prepared compounds were established on the basis of a comparison of their ^{1}H NMR spectra with those of the corresponding D-*threo*-derivatives.[2] The disappearance of the H(7) signal at 5.81 ppm and the appearance of the double-proton signal with multiplicity characteristic of these cyclic systems at 2.62—2.68 ppm, and also the upfield shift of the H(6) and H(6′) signals from 3.49 and 3.42 ppm to 1.62 and 1.99 ppm, respectively, suggests the cyclization of bromide **1** into oxabicycloheptane **3**. Like previously observed spectral changes,[2] the signal of the H(1) proton is shifted from 6.21 in compound **1a** to 5.02 ppm in derivative **3a**.



The basic confirmation of the structure of **3a** is the result of a study of the nuclear Overhauser effect (NOE). This demonstrated the interaction of the H(1) protons with the protons of the methoxyl group at C(1), H(6) and H(7), which indicates the α-configuration of the C(1) center, and an interaction of the H(3) proton with the H(6′) proton, which suggests the axial position of the benzyloxy group at C(3). The combination of all these data confirmed unequivocally the structure of oxabicycloheptane **3a**.

Finally, mercaptolysis of oxabicycloheptane **3c** at low temperatures catalyzed by $ZnCl_2$ followed by acetylation gave cyclopentane **6** in good yield, and the ^{1}H NMR spectrum of **6** was rather similar to that of the corresponding diastereomer prepared using the analogous route from the *threo*-derivative.[1] Thus, the H(1) signal appears as a singlet at 4.68 ppm, and H(3) gives a doublet at 4.03 ppm. The H(4) protons give well-splitted multiplets at 2.59 (d.d) and 2.28 (d.d.d) ppm, thus allowing easy identification of them in conjunction with the other data. The position and multiplicity of the other protons are completely in accordance with the structure of cyclopentane **6**.

The transfer from bromide **2** to oxabicycloheptane **4** is accompanied by similar changes in their ^{1}H NMR spectra. Thus, the signal of the H(1) proton shifts upfield (from 6.19 to 5.01 ppm), that of the H(6,6′) shifts from 3.58—3.76 to 1.99 and 2.05 ppm. The signal of the H(7) proton (6.46 ppm) disappears in the spectrum of compound **4** and two new signals of the H(7) and H(7′) protons (2.64 and 2.72 ppm), possessing multiplicity characteristic of this bicyclic system, appear in the corresponding area instead. The positions of the signals of the other protons and their multiplicity are completely in accordance with the structure of derivative **4**. Along with the major product **4**, by repeated chromatography we isolated in pure form a minor amount of hydrodebromination product **5** from the reaction mixture obtained during the cyclization of bromide **2**. The ^{1}H NMR spectrum of **5** is quite characteristic: the signals of the CH_2Br group disappear and the three-proton doublet at 1.28 ppm with J_{5,CH_3} = 6.5 Hz appears instead. The positions and multiplicities of the signals of the other protons in the spectrum of **5** in comparison with those of derivative **2** are changed slightly.

Thus, using this data and taking into account the data from the previous reports[1,2] one can conclude that the direction of cyclization of type **1** 4-deoxy derivatives is not dependent on the configuration of the C(1) and C(3) centers. This cyclization affords oxabicycloheptanes **3** in high yield and then optically pure polyfunctional cyclopentanes of type **6** (and also **7**), having a quaternary carbon atom (C-2) with the exactly determined configuration. However, the introduction of an equatorial benzyloxy group at the C(4) position (compound **2**) impedes the reaction. The corresponding oxabicycloheptane **4** is formed in smaller yield and under more drastic conditions. The effects of the C(3) and C(4) configurations and the character of their substituents on the course of intramolecular free-radical C(2)—C(6) cyclization will be the subjects of further investigations.

Experimental

Melting points were measured on a heating stage in capillaries and are uncorrected. Specific rotations were measured with a Jasco DIP-360 polarimeter in chloroform. The ^{1}H NMR spectra were registered with a Bruker WM-250 spectrometer in $CDCl_3$. Signals in the proton spectra were assigned by homonuclear double resonance in the differential mode.

Monitoring of the reactions and determination of the purity of the isolated compounds were performed by TLC on Kieselgel 60 silica gel plates. Chromatograms were sprayed with 5% H_2SO_4 in MeOH followed by heating to *ca.* 200 °C. Separation of the reaction mixtures was performed by column chromatography on Silpearl 60 silica gel (25—40 μm) in a benzene — ether eluent. The solvents for the reactions were distilled under argon over the appropriate drying agent (CaH_2, $LiAlH_4$).

During free-radical cyclizations the solutions were evacuated to remove dissolved oxygen until the solvent began to boil, and then the reactor was filled with argon.

Methyl 3-*O*-benzyl-4-deoxy-α,β-D-*arabino*-hexopyranosides (9). Starting alcohol **8** (5 g, 0.02 mol) was dissolved in 5%(v/v) H_2SO_4 in MeOH (50 mL) and refluxed for 4 h with a reflux condenser. The acid was neutralized with $NaHCO_3$, the mixture was diluted with chloroform (50 mL), and the salts

were filtered off. The filtrate was concentrated, diluted with chloroform (50 mL), filtered again, and the solvent was removed. The residue was separated by chromatography on silica gel in a benzene — THF gradient. A mixture of α- and β-methyl glycosides **9** (2.7 g, *ca.* 50%) was obtained as syrup.

Methyl 6-bromo-3-*O*-benzyl-4,6-dideoxy-α,β-D-*arabino*-hexopyranosides (10, 11). A mixture of α- and β-methyl glycosides **9** (2.7 g, 0.01 mol) was dissolved in anhydrous pyridine (20 mL), Ph_3P was added (3.9 g, 0.015 mol) and after dissolution, CBr_4 (5 g, 0.015 mol) was added. The mixture heated up and darkened. The reaction mixture was kept at 20 °C for 1.5 h and diluted with a hexane—ether mixture (1:1) (20 mL). The precipitate of triphenylphosphine oxide was filtered off. The filtrate was washed with 1 *M* HCl to acidic reaction, then with a saturated NaCl solution, and a saturated $NaHCO_3$ solution. It was dried over Na_2SO_4, and the solvent was removed. A mixture of α- and β-bromides **10** and **11** (2.2 g, 68%) was obtained as syrup.

The obtained mixture was separated into isomers by column chromatography on silica gel (chloroform was used as the eluent). α-Isomer **10** (0.7 g): $([\alpha]_D = +19.22$ °, *c* 1.0, $CHCl_3$). ^1H NMR: (δ, ppm, *J*/Hz): 4.63 (d, 1 H, H-1, $J_{1,2}$ = 2.5); 3.60—3.74 (m, 2 H, H-2, H-3); 1.88 (d.d.d, 1 H, H-4a, $J_{4a,5}$ = 10; $J_{4a,3}$ = 4; $J_{4a,4e}$ = 14); 1.72 (m, 1 H, H-4e, $J_{4e,5} = J_{4e,3}$ = 4); 4.25 (m, 1 H, H-5); 3.40 (m, 2 H, H-6, H-6′); 4.63—4.54 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12.5); 3.46 (s, 3 H, COOMe); 3.02 (br.s, 1 H, OH); 7.30 (m, 5 H, C_6H_5); β-isomer **11** (1.4 g): $([\alpha]_D = -35.2$ °, c 1.0, $CHCl_3$). ^1H NMR: (δ, ppm, *J*/Hz): 4.73 (d, 1 H, H-1, $J_{1,2}$ = 1.5); 3.75 (m, 1 H, H-2); 3.87 (q, 1 H, H-3, $J_{3,4} = J_{3,4} = J_{3,2}$ = 3.5); 1.76—1.91 (m, 2 H, H-4a, H-4e); 4.05 (m, 1 H, H-5); 3.47 (d.d, 1 H, H-6, $J_{6,6'}$ = 11, $J_{5,6}$ = 7); 3.41 (d.d, 1 H, H-6′, $J_{5,6'}$ = 5.5); 4.63—4.57 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12); 3.56 (s, 3 H, COOMe); 2.39 (d, 1 H, OH); 7.30 (m, 5 H, C_6H_5).

Methyl 3-*O*-benzyl-6-bromo-2-ethoxycarbonylmethylene-4,6-dideoxy-α-D-*erythro*-hexopyranoside (1a). Oxalyl chloride (0.53 g, 0.34 mL, 4.2 mmol) was dissolved in anhydrous CH_2Cl_2 (2 mL) and the solution was cooled in a flow of argon to −60 °C (dry ice—acetone bath). A solution of anhydrous DMSO (0.66 g, 8.4 mmol, 0.6 mL) in anhydrous CH_2Cl_2 (0.5 mL) was added dropwise to the reaction mixture over a period of 5 min. The mixture was stirred at −60 °C for 10 min. Then a solution of **10** (0.7 g, 2.1 mmol) was added dropwise over a period of 5 min. The mixture was stirred at −60 °C for 30 min. Triethylamine (2.9 mL, 2.1 g, 21 mmol) and, after 5 min, 1 *M* HCl (29.4 mL, 29.4 mmol) were added to the reaction mixture. The mixture was heated with stirring to *ca.* 20 °C, and the product of the reaction was extracted with chloroform. The organic layer was separated and washed with a saturated NaCl solution, then with a saturated $NaHCO_3$ solution, dried over Na_2SO_4, and the solvent was removed. The residue was dissolved in anhydrous THF (5 mL), Ph_3P=CHCOOEt (1 g, *ca.* 3 mmol) was added and the mixture was refluxed for 1.5 h. The solvent was removed and the residue was chromatographed on silica gel (benzene was used as the eluent). Compound **1a** (0.56 g, 70 %) was obtained as syrup; ^1H NMR: (δ, ppm, *J*/Hz): 5.81 (s, 1 H, H-1); 4.01 (t, 1 H, H-3; $J_{3,4a} = J_{3,4e}$ = 3.5); 1.88 (d.d.d, 1 H, H-4a; $J_{4a,4e}$ = 14; $J_{4a,5}$ = 11); 2.08 (d.t, 1 H, H-4e, $J_{4e,5}$ = 3.5); 4.57 (m, 1 H, H-5); 3.49 (d.d, 1 H, H-6; $J_{6,6'}$ = 10; $J_{5,6}$ = 3.5); 3.42 (d.d, 1 H, H-6′; $J_{5,6'}$ = 6.5); 6.21 (s, 1 H, H-7); 4.63—4.27 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12); 3.58 (s, 3 H, OMe); 4.23 (q, 2 H, $O\underline{CH_2}CH_3$; J_{CH_2,CH_3} = 7); 1.32 (t, 3 H, $OCH_2\underline{CH_3}$); 7.30 (m, 5 H, C_6H_5).

Analogously, bromide **1b** was prepared from β-derivative **11** and **1c** was prepared from **10** and Ph_3P=CHCOOMe.

(1*R*,3*R*,4*R*,5*R*)-5-Benzyloxy-4-ethoxycarbonylmethyl-3-methoxy-2-oxabicyclo[2.2.1]heptane (3a). A solution of **1a** (0.56 g, *ca.* 1.5 mmol) in anhydrous benzene (50 mL) was placed into a dry flask. The flask was evacuated until benzene began to boil intensely and then it was filled with argon. Then a solution of AIBN (33 mg, 0.2 mmol) and Bu_3SnH (0.73 g, 2.5 mmol, 620 μL) in anhydrous and degassed benzene (20 mL) was added dropwise over a periof of 2 h in a flow of argon to a refluxing solution of **1**. When the addition was completed the solution was refluxed for 30 min and the solvent was removed. The obtained syrup was chromatographed on silica gel in a benzene — ether gradient. Compound **3** (450 mg, 98 %) was obtained as syrup, $[\alpha]_D = -137.5°$ (*c* 1.0, $CHCl_3$). ^1H NMR: (δ, ppm, *J*/Hz): 5.02 (d, 1 H, H-1, $J_{1,3}$ = 2); 3.95 (d.d.d, 1 H, H-3, $J_{3,4e}$ = 5.5; $J_{3,4a}$ = 10); 2.01 (d.d.d, 1 H, H-4a, $J_{4a,4e}$ = 13.5; $J_{4a,5}$ = 3); 1.77 (d.d.d, 1 H, H-4e, $J_{4e,5}$ = 3); 4.31 (t, 1 H, H-5); 1.99 (d.t, 1 H, H-6, $J_{6,6'}$ = 11; $J_1 = J_2$= 3); 1.62 (d, 1 H, H-6′); 2.62—2.69 (d, 2 H, H-7, H-7′, AB spin system, J_{gem} = 15); 4.50—4.68 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12.5); 3.51 (s, 3 H, COOMe); 4.09 (d.q, 2 H, $O\underline{CH_2}CH_3$; J_{CH_2,CH_3} = 7; J_1 = 1.2); 1.20 (t, 3 H, $OCH_2\underline{CH_3}$); 7.30 (m, 5 H, C_6H_5);

NOE: H(1) interacts with the H(6), CH_2—COOEt, and OMe protons, H(5) interacts with H(1), H(6), H(6′), H(4), and H(4′); H(3) interacts with H(6), H(4), H(4′), and CH_2Ph protons.

Analogously, **(1*R*,3*R*,4*S*,5*R*)-5-benzyloxy-4-ethoxycarbonylmethyl-3-methoxy-2-oxabicyclo[2.2.1]heptane (3b)** was prepared from **1b**. $[\alpha]_D = -105.25°$ (c 1.0, $CHCl_3$); ^1H NMR: (δ, ppm, *J*/Hz): 4.95 (s, 1 H, H-1); 4.02 (d.d, 1 H, H-3, $J_{3,4e}$ = 4; $J_{3,4a}$ = 9.5); 1.90 (m, 1 H, H-4a, $J_{4a,4e}$ = 13.5); 1.56 (d.t, 1 H, H-4e, $J_{4e,5}$ = 4); 4.38 (m, 1 H, H-5); 1.95 (d.d.d, 1 H, H-6, $J_{6,6'}$ = 11; *J* = 2.5, *J* = 4, *J* = 9); 1.62 d (1 H, H-6′); 2.75—2.66 (d.d, 2 H, H-7, H-7′, AB spin system, J_{gem} = 12); 4.55—4.36 (d.d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12.5); 3.88 (s, 3 H, COOMe); 4.05 (d.q, 2 H, $O\underline{CH_2}CH_3$; J_{CH_2,CH_3} = 7; J_1 = 1.2); 1.20 (t, 3 H, $OCH_2\underline{CH_3}$); 7.30 (m, 5 H, C_6H_5).

(1*R*,2*R*,4*R*)-4-Acetoxy-2-benzyloxy-1-methoxycarbonylmethyl-1-(1,3-dithian-2-yl)cyclopentane (6). 1,3-Propanedithiol (163 mg, 1.5 mmol) was added to a solution of **3c** (306 mg, 1 mmol) (prepared from **1c**, see **1a**) in CH_2Cl_2 (1 mL) and cooled to −40 °C. Then $ZnCl_2$ (164 mg, 0.2 mmol) was added, and the mixture was stirred for 1 h. The mixture was neutralized with $NaHCO_3$, heated to *ca.* 20 °C, filtered off, and the residue was washed with benzene, the filtrate was concentrated, the residue was chromatographed on SiO_2 in a benzene — THF gradient. After removal of the solvent the obtained syrup was dissolved in anhydrous pyridine (2 mL), Ac_2O (0.5 mL) was added and the solution was kept for 12 h. The reaction mixture was cooled to 0°C, MeOH (1.5 mL) was added portionwise (0.2 mL) in 15 min, then the mixture was heated to *ca.* 20 °C. The mixture was diluted with chloroform (20 mL), washed with 1 *M* HCl (50 mL), H_2O (20 mL), a saturated $NaHCO_3$ solution (20 mL), and H_2O (20 mL), dried over Na_2SO_4, and the solvent was removed. The residue was chromatographed on SiO_2 in a benzene — THF gradient. Compound **6** (245 mg, 60 %) was obtained as syrup, $[\alpha]_D = -24.96°$ (*c* 1.0; $CHCl_3$). ^1H NMR: (δ, ppm, *J*/Hz): 4.68 (s, 1 H, H-1); 4.03 (d, 1 H, H-3, $J_{3,4'}$ = 5); 2.59 (d.d, 1 H, H-4, $J_{4,4'}$ = 14); 2.28 (d.d.d, 1 H, H-4′, $J_{4',5}$ = 9); 5.13 (m, 1 H, H-5); 1.73-2.12 (m, 4 H, H-6, H-6′, H-9, H-9′); 2.41—2.48 (d, 2 H, H-7, H-7′, AB spin system, J_{gem} = 15); 4.45—4.54 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12); 2.83 (m,

4 H, H-8, H-8, H-8′, H-8′); 3.67 (s, 3 H, COOMe); 1.98 (s, 3 H, $CO\underline{CH_3}$); 7.30 (m, 5 H, $OCH_2C_6\underline{H_5}$).

Methyl 3,4-di-*O*-benzyl-6-bromo-6-deoxy-α-D-glucopyranoside (13) was obtained analogously (see **10**) from methyl 3,4-di-*O*-benzyl-α-D-glucopyranoside **12** (700 mg, 1.9 mmol),[6] Ph_3P (500 mg, 1.9 mmol), and CBr_4 (650 mg, 1.9 mmol), **13**: (580 mg, 71.5%); $[\alpha]_D$ = +97.81° (*c* 1.0, $CHCl_3$); m.p. 92 °C; ^1H NMR: (δ, ppm, *J*/Hz): 4.61 (d, 1 H, H-1, $J_{1,2}$ = 3.5); 3.77 (d.d, 1 H, H-2, $J_{2,3}$ = 9.5); 3.81 (d.d, 1 H, H-3, $J_{3,4}$ = 8); 3.51 (d.d, 1 H, H-4, $J_{4,5}$ = 9.5); 3.83 (d.d.d, 1 H, H-5, $J_{5,6}$ = 2.5, $J_{5,6'}$ = 5.5); 3.68 (d, 1 H, H-6, $J_{6,6'}$ = 11); 3.58 (d.d, 1 H, H-6′); 2.12 (br.s, 1 H, OH); 3.47 (s, 3 H, OMe); 4.95—4.70 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 11); 4.96—4.66 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 11); 7.30 (m, 10 H, C_6H_5).

Methyl 3,4-di-*O*-benzyl-6-bromo-2-methoxycarbonylmethylene-6-deoxy-α-D-*arabino*-hexopyranoside (2) was prepared analogously (see **1a**) from $(COCl)_2$ (254 mg, 2 mmol, 175 mL), DMSO (312 mg, 4 mmol, 283 mL), **13** (580 mg, 1.33 mmol), 1.01 g (10 mmol, 1.4 mL) Et_3N, 1 *M* HCl (14 mL, 14 mmol), and Ph_3P=CHCOOMe (534 mg, 1.6 mmol). Compound **2** (576 mg, 88%) was obtained as syrup. ^1H NMR: (δ, ppm, *J*/Hz): 6.19 (d, 1 H, H-1, $J_{1,3}$ = 2); 4.60 (d.d, 1 H, H-3, $J_{3,4}$ = 9.5); 3.65 (t, 1 H, H-4, $J_{4,5}$ = 9.5); 4.05 (d.d.d, 1 H, H-5, $J_{5,6}$ = 5, $J_{5,6'}$ = 2.5); 3.71 (d.d, 1 H, H-6, $J_{6,6'}$ = 11); 3.61 (d.d, 1 H, H-6′); 6.48 (s, 1 H, H-7); 3.55 (s, 3 H, OMe); 3.71 (s, 3 H, COOMe); 5.01—4.74 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 11); 4.78—4.73 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 11.5); 7.30 (m, 10 H, C_6H_5).

(1*R*,3*S*,4*R*,5*R*,6*S*)-5,6-Dibenzyloxy-3-methoxy-4-methoxycarbonylmethyl-2-oxabicyclo[2.2.1]heptane (4) was prepared analogously (see **3c**) from **2** (0.491 g, 1 mmol), AIBN (16 mg, 0.1 mmol), and Bu_3SnH (0.44 g, 1.5 mmol, 370 mL); toluene was used as the solvent. Compound **4** (180 mg, 44 %) was obtained (a part of the product was obtained as a mixture with **5**) as syrup $[\alpha]_D$ = +4.0° (c 1.0, $CHCl_3$). ^1H NMR: (δ, ppm, *J*/Hz): 5.01 (s, 1 H, H-1); 3.99 (t, 1 H, H-3, $J_{3,4}$ = 2); 3.70 (m, 1 H, H-4, $J_{4,5}$ = 2); 3.40 (m, 1 H, H-5, $J_{5,6}$ = 2); 1.99 (d, 1 H, H-6, $J_{6,6'}$ = 11; J_1 = J_2 = 3); 2.05 (d.t, 1 H, H-6′, J_1 = J_2 = 2); 2.72—2.64 (d, 2 H, H-7, H-7′, AB spin system, J_{gem} = 14); 4.71—4.52 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12); 4.52—4.46 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12); 3.59 (s, 3 H, COOMe); 3.48 (s, 3 H, OMe); 7.30 (m, 10 H, C_6H_5).

(1*R*,2*S*,3*R*,4*R*)-2,3-Dibenzyloxy-1-methoxycarbonylmethyl-4-oxy-1-(1,3-dithian-2-yl)cyclopentane (7) was prepared analogously (see **6**), omitting the acetylation step, from **4** (180 mg, 0.44 mmol), 1,3-propanedithiol (110 mg, 1 mmol), and $ZnCl_2$ (82 mg, 0.1 mmol). Compound **7** (150 mg, 70 %) was obtained as syrup, $[\alpha]_D$ = −17.98° (*c* 1.0; $CHCl_3$). ^1H NMR: (δ, ppm, *J*/Hz): 4.56 (s, 1 H, H-1); 4.34 (d, 1 H, H-3, $J_{3,4}$ = 7); 4.16—4.25 (m, 2 H, H-4, H-5); 2.10 (m, 1 H, H-6); 1.80 (m, 1 H, H-6′); 2.81—2.57 (d, 2 H, H-7, H-7′, AB spin system, J_{gem} = 16.5); 4.45—4.54 (d, 2 H, CH_2Ph, AB spin system, J_{gem} = 12); 2.90 (m, 4 H, H-8, H-8, H-8′, H-8′); 2.48 (m, 2 H, H-9, H-9′); 3.67 (s, 3 H, COOMe); 1.98 (s, 3 H, $CO\underline{CH_3}$); 7.30 (m, 10 H, $OCH_2C_6\underline{H_5}$).

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References

1. A. F. Sviridov, A. B. Frolov, and N. K. Kochetkov, *Izv. Akad. Nauk, Ser. Khim.*, 1993, 1989 [*Russ. Chem. Bull.*, 1993, **42**, 1906 (Engl. Transl.)].
2. A. F. Sviridov and N. K. Kochetkov, *Izv. Akad. Nauk, Ser. Khim.*, 1992, 650 [*Russ. Chem. Bull.*, 1992, **41**, 511 (Engl. Transl.)].
3. A. F. Sviridov, A. Yu. Romanovich, and O. S. Chizhov, *Bioorg. Khim.*, 1987, **12**, 1665 [*Russ. J. Bioorg. Chem.*, 1987, **12** (Engl. Transl.)].
4. A. K. M. Anisuzzman and R. L. Whistler, *Carbohydr. Res.*, 1978, **61**, 511.
5. K. Omura and D. Swern, *Tetrahedron*, 1978, **34** (11), 1651.
6. A. Liptak, I. Jodal, and P. Nanasi, *Carbohydr. Res.*, 1975, **44**, 1.

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