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Intramolecular Hydrogen Abstraction in Radicals Derived from Inositol 1,3-Acetals: Efficient Access to Cyclitols

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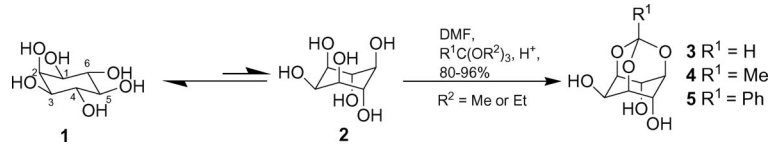
The benzylidene acetals obtained by cleavage of the orthobenzoate moiety in *myo*-inositol 1,3,5-orthobenzoate were used to prepare mono- as well as di-deoxy inositol derivatives via their xanthates. The dideoxygenation is a result of intramolecular abstraction of the benzylidene acetal hydrogen and subsequent cleavage of the acetal ring. Such a cleavage does not take place in analogous acetals derived from other orthoesters. The 1,3-acetals derived from *myo*-inositol 1,3,5-orthoesters were also used to prepare *neo*-inositol and isomeric deoxy-amino inositols. Most of the reactions in these synthetic sequences starting from *myo*-inositol give one product in each step. The results presented here show that *myo*-inositol 1,3,5-orthobenzoate offers many advantages over other orthoesters for the synthesis of cyclitol derivatives from *myo*-inositol.

Introduction

Cyclitols (polyhydroxy-substituted cycloalkanes), their alkylated and aminated analogs constitute a class of natural and synthetic compounds that are of interest to a wide cross section of chemists due to their biological activity.[1] The developments in chemical biology related to cyclitols, especially the phosphoinositol based signal transduction pathways and the associated *myo*-inositol cycle, in the last two decades, snow-balled and revived the interest of chemists in cyclitols and their derivatives.[2] Naturally occurring cyclitols have been used as starting materials for the synthesis of natural products,[3] scaffolds for the construction of metal ion complexing agents[4] and the preparation of molecular crystals that possess unusual properties.[5] Synthesis of cyclitols and their derivatives have been accomplished from various starting materials, such as *myo*-inositol,[6] quebrachitol,[7] carbohydrates,[8] tartaric acid,[9] norbornene,[10] benzoquinone,[11] benzene and its derivatives.[12] *myo*-Inositol is a convenient starting material as it is inexpensive, abundant and methods for the manipulation of its hydroxy groups is well studied.[13] In particular, *myo*-inositol 1,3,5-orthoesters which can be obtained in several gram quantities as single products (Scheme 1), have been exploited for the synthesis of phosphorylated inositol derivatives[6d,14] but their utility for the preparation of ring-modified cyclitol derivatives has not been exploited to the extent possible.[15] We herein present an interesting radical initiated cleavage of inositol-derived benzylidene acetals which led to the efficient synthesis of several cyclitol derivatives. Interestingly, we were able to obtain deoxy and dideoxy inositols from the same monoxanthate. It is pertinent to mention that in most of the reactions we have obtained a single product which circumvents the need for separation of isomeric products often observed in the published literature, pertaining to synthetic sequences involving cyclitols and their derivatives.

Results and Discussion

myo-Inositol 1,3,5-orthobenzoate[16] (**5**) was prepared and subsequently converted into the benzylidene derivative



Scheme 1. Synthesis of orthoesters from *myo*-inositol.

6 (Scheme 2) via the tribenzyl ether (of **5**) by a procedure described earlier.[17] The C5-hydroxy group was converted into the corresponding xanthate **7** and subjected to Barton-McCombie deoxygenation conditions when the *rac*-(1)3,5-dideoxyinositol derivative **9** was obtained as the sole prod-

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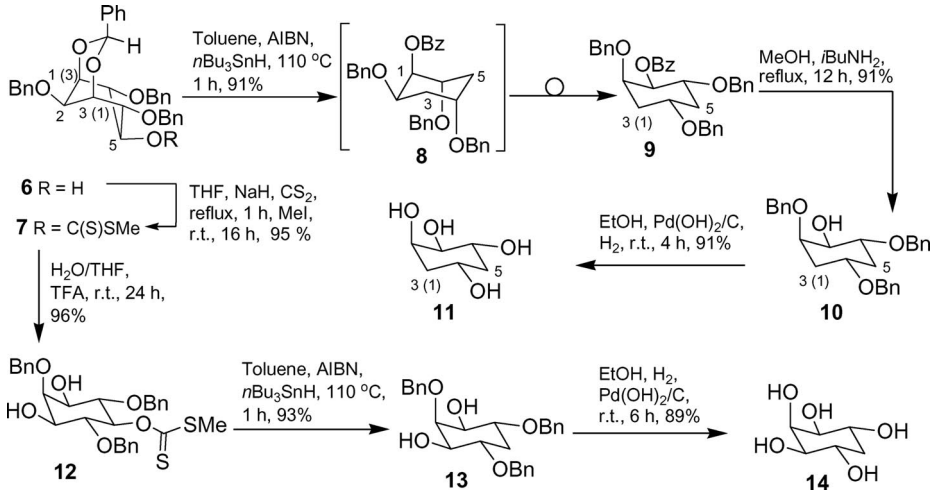
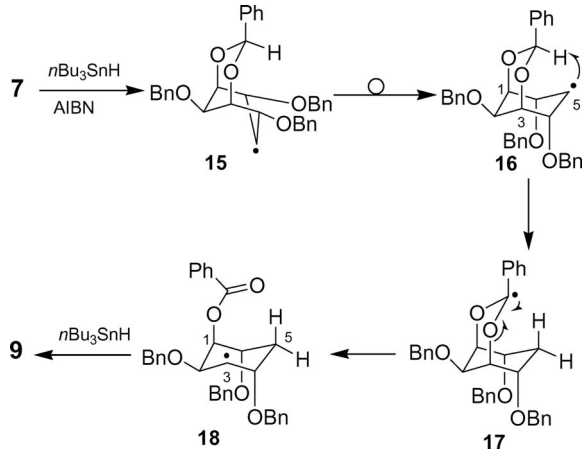


Scheme 2. Synthesis of (1)3,5-dideoxy-*myo*-inositol and *neo*-quercitol.

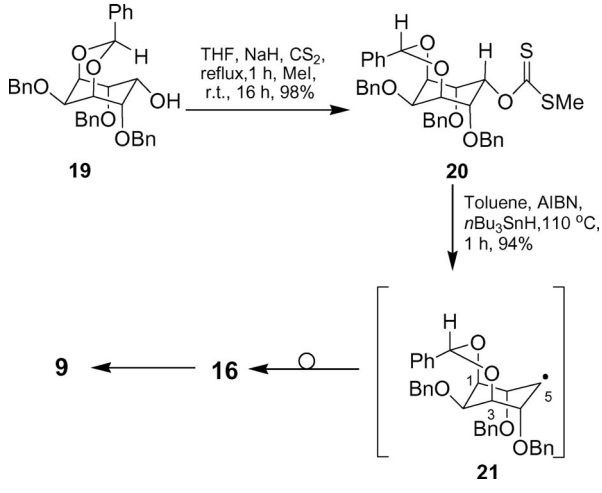
uct. The tetrol **11** was obtained by aminolysis of the benzoate in **9** followed by hydrogenolysis of the benzyl ethers. Dideoxy inositol derivatives have been used as tools to elucidate the structure-activity relationship of inositol phosphate binding proteins.[18] De-oxygenation of only the C5-oxygen could be achieved by first hydrolyzing the benzylidene acetal in **7** to obtain the corresponding diol **12** and subjecting it to Barton-McCombie de-oxygenation conditions. The benzyl ethers in the deoxy-derivative **13** were cleaved by hydrogenolysis to obtain *neo*-quercitol (**14**, Scheme 2) in an overall yield of 67% (7 steps from *myo*-inositol). The yield in earlier reports[19] did not exceed 27%. Hence di-deoxygenation or mono-deoxygenation in the xanthate **7** can be achieved by carrying out the deoxygenation reaction prior to or subsequent to the hydrolysis of the benzylidene acetal respectively.

The formation of the di-deoxygenated product **9** and conversion of the benzylidene acetal to the benzoate can be rationalized as shown in the Scheme 3. Radical initiated cleavage of benzylidene acetals of 1,3-diols leading to the formation of benzoates has earlier been reported.[20] That the cleavage of the benzylidene acetal in **15** occurred exclusively due to intramolecular hydrogen abstraction was evident by the fact that deoxygenation of the xanthate **7** in the presence of the benzylidene acetal **6** resulted in the formation of the benzoate **9** while the acetal **6** remained unaffected. Formation of the benzylidene radical via abstraction of hydrogen by any other radical (formed in the presence of AIBN) could be ruled out since the alcohol **6** was stable to the reaction conditions whereas deoxygenation occurred in the xanthate **7**.

Deoxygenation of the xanthate **20** (Scheme 4), having the *neo*-configuration also proceeded smoothly to afford the dideoxy derivative **9** (obtained from the xanthate **7** having the *myo*-configuration, Scheme 2). This result indicated that irrespective of the configuration of the starting xanthate, the deoxygenation proceeds through the same radical intermediate **16**. Conformation of the *myo*- and *neo*-xanthates **7** and **20** was established by single-crystal X-ray diffraction



Scheme 3. A plausible pathway for the formation of **9**.



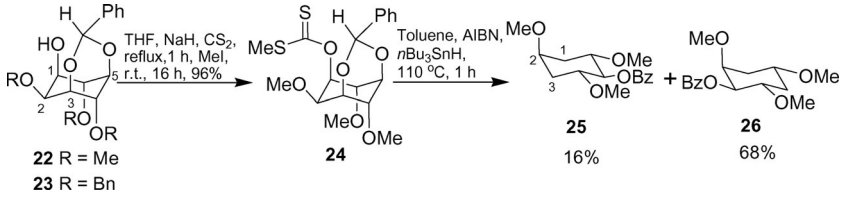
Scheme 4. Deoxygenation of the xanthate **20** having the *neo*-configuration.

methods. Results of 2D-NMR spectroscopy suggested that the molecular conformation in the crystal is conserved in the solution state as well (see Supporting Information).

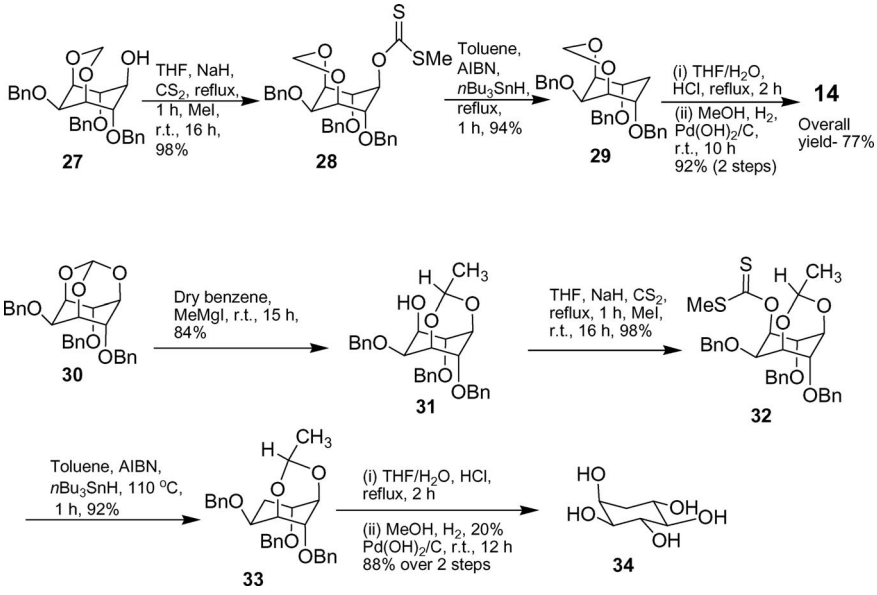
Deoxygenation of the racemic xanthate **24** containing the 1,3-benzylidene acetal gave a mixture of 1,3 (**25**) as well as racemic 1,5-dideoxy (**26**) derivatives, the latter being the major product (Scheme 5). The benzylidene derivative **22** could be prepared by the reaction of the trimethyl ether of the orthoformate **3** with phenylmagnesium bromide, as reported.[16a] However, our attempts to prepare the racemic C3-alcohol **23** by the cleavage of the orthoformate moiety in the tribenzyl ether **30** with phenylmagnesium bromide, provided the corresponding 1,3-diol (2,4,6-tri-*O*-benzyl-5-*O*-diphenylmethyl-*myo*-inositol) exclusively.

The deoxygenation of the xanthates containing the formaldehyde or the acetaldehyde acetals yielded the corresponding monodeoxy derivatives exclusively (Scheme 6). Hence monodeoxy or dideoxy *myo*-inositol derivatives can also be obtained by starting from the orthoformate or the orthobenzoate derivative respectively. Similar experiments with the acetaldehyde acetal **32** gave racemic viburnitol[21] (**34**) in 64% yield (7 steps from *myo*-inositol, Scheme 6).

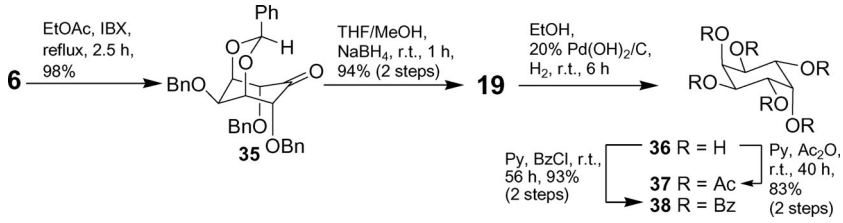
Oxidation of the C5-hydroxy group in **6** with IBX afforded the corresponding ketone **35** (Scheme 7) in good yield and the crude product was used in the next step. The pure ketone **35** could be obtained by crystallization of the crude product from dry methanol at low temperature (0 to –5 °C). Single-crystal X-ray diffraction analysis of the ketone (good crystals were obtained by crystallization from dichloromethane/light petroleum by vapor diffusion method in a closed container) showed that the inositol ring is slightly distorted from the chair form (see Supporting Information). Swern oxidation of the C-5 hydroxy group in **6** to obtain **35** did not give consistent yields, perhaps due to the concomitant de-protection of the acid sensitive benzylidene acetal. Yield of the ketone **35** on oxidation of **6** with pyridinium dichromate was much lower than when IBX was used. Reduction of the ketone **35** with sodium borohydride in a mixture of THF and methanol resulted in the exclusive formation of the C5-alcohol **19** with *neo*-configuration, in 94% yield (for two steps). The exclusive formation of the alcohol **19** with *neo*-configuration is perhaps due to the bulk of the diaxial-dibenzyl ether groups (at C4- and C6-positions) which prevent the attack by the borohydride on one face of the ketone **35**. Deprotection of the benzylidene acetal and three *O*-benzyl groups by catalytic hydrogenolysis in the presence of Pearlmann's catalyst afforded *neo*-inositol **36** which was characterized as its hexa acetate **37**. This sequence of reactions provided *neo*-inositol in an overall yield of 68% starting from *myo*-inositol (Scheme 7). Yield of *neo*-inositol in the previously reported procedures,[12d,22] did not exceed 20%. Our initial attempts



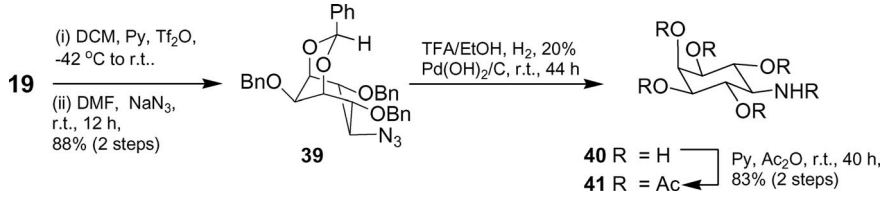
Scheme 5. Deoxygenation of the racemic xanthate **24**.



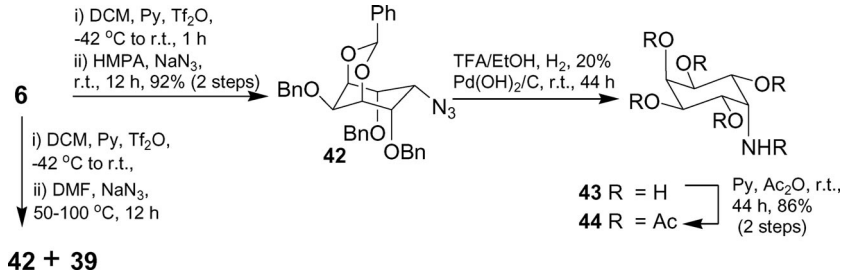
Scheme 6. Deoxygenation of xanthates containing formaldehyde and acetaldehyde acetal.



Scheme 7. Synthesis of *neo*-inositol.



Scheme 8. Synthesis of 5-*myo*-inosamine hexaacetate.



Scheme 9. Synthesis of 5-*neo*-inosamine hexaacetate.

for the inversion of alcohol at the C5-position in the bicyclic derivative **6** by Mitsunobu reaction[23] failed and in most of the experiments unreacted **6** was recovered.

myo-Inosamine **40** was prepared from the protected *neo*-alcohol **19** (Scheme 8) via the corresponding azide **39**. Reduction of the azide as well as deprotection of the hydroxy groups were achieved by hydrogenation in the presence of Pearlmann's catalyst. The crude 5-deoxy-5-*myo*-inosamine (**40**) obtained was isolated and characterized as its hexaacetate (**41**) in a good overall yield of 60% (6 steps from *myo*-inositol). The same inosamine has been synthesized from *cis*-1,2-diacetoxycyclohexa-3,5-diene in an overall yield of 7% (7 steps).[24]

2-*neo*-Inosamine (**43**) present in "Hygromycin A", an inhibitor of bacterial ribosomal peptidyltransferase produced by *Streptomyces hygroscopicus*[25] was prepared from the C5-alcohol **6** via the corresponding azide (Scheme 9). Reaction of the triflate of the alcohol **6** with sodium azide in HMPA provided the *neo*-azide **42** exclusively. When the same reaction was carried out in DMF (at 50 or 100 °C) a mixture of *neo*- and *myo*-azides was obtained (as revealed by ^{1}H and ^{13}C NMR spectra, see Supporting Information). A comparison of the ^{1}H NMR spectrum of the mixture of azides with that of the bicyclic azide **39** (having the *myo*-configuration, Scheme 8), showed that **39** was present in the mixture of azides. The ratio of the two diastereomeric azides (*neo*/*myo*) was estimated to be 2:1. It is interesting to see that the triflate of the bicyclic *neo*-alcohol **19** undergoes clean S_N2 displacement reaction with sodium azide to give the *myo*-azide **39** exclusively, while the triflate of the *myo*-alcohol **6** under similar reaction conditions gives a mixture of *myo*- and the *neo*-azides. The latter result could be due to displacement of the triflate group (of the *myo*-alcohol **6**) by azide ion via S_N1 mechanism or a combination of S_N1 and S_N2 mechanisms. We attempted to prepare 2-*neo*-inosamine by Mitsunobu reaction of the *myo*-inositol derivative **6** (with benzylamine). However, in all the attempts, the starting alcohol was recovered. We also attempted to prepare 2-*neo*-inosamine by the reductive amination of the ketone **35**, but this reaction resulted in the formation of a mixture of several products as revealed by the ^{1}H NMR spectrum of the corresponding acetates.

Conclusions

The benzylidene acetals derived from *myo*-inositol-1,3,5-orthobenzoate can be cleaved via intramolecular radical reactions to obtain inositol derivatives deoxygenated at specific positions. Similar acetal cleavage reactions do not occur in other analogous acetals. These 1,3-acetals can also be used to obtain other isomeric cyclitol derivatives in high yields. Thus, protection of inositol hydroxy groups as orthobenzoate offers advantages over other protected derivatives of *myo*-inositol and provides functionalized cyclohexane and cyclohexanone derivatives in six to eight steps in good overall yield from abundantly available *myo*-inositol.

Experimental Section

General: All the solvents were purified according to the literature procedures[26] before use. A 60% dispersion of sodium hydride in mineral oil was used for *O*-substitution reactions. Thin layer chromatography was performed on E. Merck pre-coated 60 F_{254} plates and the spots were rendered visible either by shining UV light or by charring the plates with conc H_2SO_4. Work up implies the washing of organic layer successively with water, dilute aqueous HCl (ca. 2%), water, saturated sodium hydrogen carbonate solution, water followed by brine. Column chromatographic separations were carried out on silica gel (60–120 or 230–400 mesh) with solvent system as mentioned in experimental procedures. The compounds previously reported in the literature were characterized by comparison of their melting points and/or ^{1}H NMR spectra with reported data. Proton and carbon NMR spectra were recorded on Bruker 200 or 400 or 500 MHz NMR spectrometer in solvents as mentioned in the experimental procedures. IR spectra were recorded either in $CHCl_3$ solution or as Nujol mull or as thin film (neat) on a Shimadzu FTIR-8400 spectrophotometer. Microanalytical data were obtained using a Carlo–Erba CHNS-0 EA 1108 elemental analyzer. All the melting points were recorded on a Büchi B-540 electrothermal melting point apparatus. Yields refer to chromatographically and spectroscopically pure compounds. All the asymmetrically substituted racemic *myo*-inositol derivatives are shown as one of the enantiomers for convenience and clarity.

General Procedure for the Preparation of Xanthates (Procedure A): To a cooled (0 °C) solution of the required alcohol (2 to 6 mmol) in dry THF (5 to 30 mL), sodium hydride (10 to 30 mmol) was added and stirred at ambient temperature for 30 min. Carbon disulfide (30 to 80 mmol) was added to the reaction mixture and refluxed for 1 h. The reaction mixture was allowed to cool to room temperature; methyl iodide (10 to 30 mmol) was added and stirred for 16 h. The reaction mixture was diluted with ethanol (4 to 12 mL), water (8 to 24 mL) and extracted with ethyl acetate. The organic layer was washed with saturated ammonium chloride solution followed by brine and dried with anhydrous sodium sulfate. The gummy residue obtained after evaporation of the solvent was purified by column chromatography (eluent: ethyl acetate/light petroleum) to obtain the xanthate.

2,4,6-Tri-*O*-benzyl-1,3-*O*-benzylidene-5-*O*-[(methylthio)thiocarbonyl]-*myo*-inositol (7): The alcohol **6** (2.77 g, 5.15 mmol), dry THF (25 mL), sodium hydride (1.03 g, 25.75 mmol), carbon disulfide (4.68 mL, 77.80 mmol), methyl iodide (1.60 mL, 25.75 mmol) were used (Procedure A) to obtain the xanthate **7** as a colorless solid (3.12 g, 96%) after column chromatography (eluent: 15% ethyl acetate/light petroleum); m.p. 112–114 °C (crystals from dichloromethane). IR ($CHCl_3$): $\tilde{\nu}$ = 1215, 1062 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.50–7.58 (m, 2 H, Ar H), 7.16–7.48 (m, 18 H, Ar H), 6.27 (t, J = 7.2 Hz, 1 H, Ins H), 5.81 (s, 1 H, $PhCHO_2$), 4.73 (s, 2 H, CH_2), 4.63 (ABq, J = 12.1 Hz, 4 H, 2 × CH_2), 4.45 (d, J = 2.3 Hz, 2 H, Ins H), 4.13 (d, J = 7.2 Hz, 2 H, Ins H), 3.83 (t, J = 2.3 Hz, 1 H, Ins H), 2.56 (s, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 215.4 (C=S), 138.0 (C_{arom}), 137.8 (C_{arom}), 136.9 (C_{arom}), 129.3 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 127.9 (C_{arom}), 127.69 (C_{arom}), 127.65 (C_{arom}), 126.5 (C_{arom}), 92.9 ($PhCO_2$), 81.8 (Ins C), 79.1 (Ins C), 73.4 (Ins C), 71.5 (CH_2), 70.8 (CH_2), 68.1 (Ins C), 19.2 (CH_3) ppm. $C_{36}H_{36}O_6S_2$ (628.80): calcd. C 68.76, H 5.77; found C 69.04, H 5.63.

General Procedure for the Deoxygenation of Xanthates (Procedure B): To a solution of the required xanthate (1 to 5 mmol) in dry toluene (5 to 40 mL), tri-*n*-butyltin hydride (5 to 20 mmol) and AIBN (0.02 to 0.10 g) were added and heated at 100 °C for 1 h. The solvents were removed under reduced pressure and the residue obtained was purified by column chromatography (eluent: ethyl acetate/light petroleum).

***rac*-1-*O*-Benzoyl-2,4,6-tri-*O*-benzyl-3,5-dideoxy-*myo*-inositol (9):** The xanthate **7** (3.11 g, 4.95 mmol), dry toluene (40 mL), tri-*n*-butyltin hydride (5.73 g, 19.70 mmol) and AIBN (0.10 g) were used (Procedure B) to obtain **9** as a gum (2.35 g, 91%) after column chromatography (eluent: 10% ethyl acetate/light petroleum): IR ($CHCl_3$): $\tilde{\nu}$ = 1720 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 8.01–8.12 (m, 2 H, Ar H), 7.13–7.66 (m, 18 H, Ar H), 5.14 (dd, J = 9.5, 2.9 Hz, 1 H, Ins H), 4.45–4.76 (m, 6 H, 3 × CH_2), 3.97–4.17 (m, 2 H, Ins H), 3.71–3.95 (m, 1 H, Ins H), 2.48–2.64 (m, 1 H, CH_2), 2.27–2.46 (m, 1 H, CH_2), 1.48–1.71 (m, 2 H, CH_2) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 166.0 (C=O), 138.49 (C_{arom}), 138.46 (C_{arom}), 138.3 (C_{arom}), 133.0 (C_{arom}), 130.2 (C_{arom}), 129.7 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 128.21 (C_{arom}), 128.19 (C_{arom}), 127.59 (C_{arom}), 127.56 (C_{arom}), 127.5 (C_{arom}), 127.4 (C_{arom}), 77.4 (Ins C), 74.3 (Ins C), 74.0 (Ins C), 72.1 ($PhCH_2$), 71.9 ($PhCH_2$), 71.4 (Ins C), 70.6 ($PhCH_2$), 36.0 (Ins CH_2), 34.3 (Ins CH_2) ppm. $C_{34}H_{34}O_5$ (522.63): calcd. C 78.14, H 6.56; found C 78.28, H 6.54.

***rac*-2,4,6-Tri-*O*-benzyl-1,5-dideoxy-*myo*-inositol (10):** A mixture of the benzoate **9** (2.34 g, 4.48 mmol), isobutylamine (11 mL) and methanol (20 mL) was refluxed for 12 h. Solvents were removed under reduced pressure and the residue obtained was purified by column chromatography (eluent: 10% ethyl acetate/light petroleum) to afford **10** as a colorless solid (1.74 g, 93%); m.p. 54–57 °C (crystals from ethyl acetate). IR ($CHCl_3$): $\tilde{\nu}$ = 3276–3616 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.25–7.42 (m, 15 H, Ar H), 4.35–4.75 (m, 6 H, 3 × $PhCH_2$), 3.88–4.02 (m, 1 H, Ins H), 3.50–3.84 (m, 3 H, Ins H), 2.44–2.69 (m, 3 H, 1 × OH, 2 × CH_2), 1.29–1.51 (m, 2 H, Ins CH_2) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 138.42 (C_{arom}), 138.39 (C_{arom}), 138.22 (C_{arom}), 128.2 (C_{arom}), 127.55 (C_{arom}), 127.47 (C_{arom}), 127.43 (C_{arom}), 76.7 (Ins C), 76.1 (Ins C), 75.3 (Ins C), 71.8 ($PhCH_2$), 71.4 ($PhCH_2$), 70.4 ($PhCH_2$), 35.2 (Ins CH_2), 33.7 (Ins CH_2) ppm. $C_{27}H_{30}O_4$ (418.52): calcd. C 77.48, H 7.23; found C 77.44, H 7.23.

***rac*-1,5-Dideoxy-*myo*-inositol (11):** The tribenzyl ether **10** (0.80 g, 1.90 mmol) was hydrogenolyzed in ethanol (6 mL) in the presence of $Pd(OH)_2$/C at 50 psi for 4 h on a Parr hydrogenator. The catalyst was filtered using a short bed of Celite and the catalyst was washed with ethanol (2 × 25 mL). The combined ethanol solution was evaporated under reduced pressure to obtain an off white solid which was dissolved in hot ethanol and allowed to cool to room temp. Cooling the solution to 0 °C afforded the crystalline tetrol **11** (0.24 g, 84%); m.p. 154–157 °C (crystals from ethanol). IR (nujol): $\tilde{\nu}$ = 3090–3520 cm^{-1}. ^{1}H NMR (D_2O, 200 MHz): δ = 3.89–4.16 (m, 2 H, Ins H), 3.67–3.84 (m, 1 H, Ins H), 3.41 (dd, J = 9.6, 3.3 Hz, 1 H, Ins H), 1.96–2.32 (m, 2 H, CH_2), 1.24–1.60 (m, 2 H, CH_2) ppm. ^{13}C NMR [D_2O (0.6 mL) + MeOH (0.02 mL), 50.3 MHz]: δ = 75.9 (CHOH), 69.5 (CHOH), 68.2 (CHOH), 64.6 (CHOH), 41.1 (CH_2), 39.1 (CH_2) ppm. $C_6H_{12}O_4$ (148.16): calcd. C 48.64, H 8.16; found C 48.78, H 7.94.

2,4,6-Tri-*O*-benzyl-5-*O*-[(methylthio)thiocarbonyl]-*myo*-inositol (12): A mixture of the xanthate **7** (1.26 g, 2.00 mmol), TFA (1 mL) and THF/water mixture (10 mL + 0.5 mL) was stirred at room temp. for 24 h. The solvents were removed under reduced pressure and the residue was co-evaporated with dry toluene (2 × 10 mL) to afford a gummy residue which was purified by column chromatography [eluent: ethyl acetate and light petroleum mixture (1:3)] to afford the diol **12** as a colorless gum (1.04 g, 96%): IR ($CHCl_3$): $\tilde{\nu}$ = 3323–3580, 1211, 1059 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.27–7.46 (m, 15 H, Ar H), 6.17 (t, J = 9.5 Hz, 1 H, Ins H), 4.82

(s, 2 H, CH_2) 4.68 (ABq, J = 11 Hz, 4 H, 2 × CH_2), 4.01 (t, J = 2.6 Hz, 1 H, Ins H), 3.94 (t, J = 9.6 Hz, 2 H, Ins H), 3.58–3.74 (m, 2 H, Ins H), 2.61 (s, 3 H, CH_3), 3.41 (d, J = 5.5 Hz, 2 H, 2 × OH) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 215.8 (C=S), 138.4 (C_{arom}), 137.8 (C_{arom}), 128.4 (C_{arom}), 128.2 (C_{arom}), 127.9 (C_{arom}), 127.8 (C_{arom}), 83.7 (Ins C), 80.0 (Ins C), 78.6 (Ins C), 75.3 (CH_2), 75.0 (CH_2), 72.0 (Ins C), 19.4 (CH_3) ppm. $C_{29}H_{32}O_6S_2$ (540.69): calcd. C 64.42, H 5.97; found C 64.58, H 5.62.

1,3,5-Tri-*O*-benzyl-2-deoxy-*neo*-inositol (13): The xanthate **12** (1.00 g, 1.85 mmol), tri-*n*-butyltin hydride (2.15 g, 7.40 mmol), AIBN (0.04 g) and dry toluene (15 mL) were used (Procedure B) to obtain **13** (0.75 g, 93%) as a colorless gum after column chromatography [eluent: ethyl acetate and light petroleum mixture, (1:3)]: IR ($CHCl_3$): $\tilde{\nu}$ = 3200–3650 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.26–7.45 (m, 15 H, Ar H), 4.84 (s, 2 H, $PhCH_2$), 4.62 (ABq, J = 11.5 Hz, 4 H, 2 × $PhCH_2$), 4.07 (t, J = 2.4 Hz, 1 H, Ins H), 3.55–3.78 (m, 4 H, Ins H), 2.30–2.69 (m, 3 H, 1 × Ins H, 2 × OH), 1.19–1.40 (m, 1 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 138.7 (C_{arom}), 138.2 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 127.7 (C_{arom}), 127.6 (C_{arom}), 79.3 (Ins C), 76.6 (Ins C), 75.1 ($PhCH_2$), 74.7 (Ins C), 71.7 ($PhCH_2$), 31.1 (Ins CH_2) ppm. $C_{27}H_{30}O_5$ (434.52): calcd. C 74.63, H 6.96; found C 74.60, H 6.62.

2-Deoxy-*neo*-inositol (*neo*-Quercitol) (14): The tribenzyl ether **13** (0.70 g, 1.69 mmol) was hydrogenolyzed in the presence of $Pd(OH)_2$/C (0.03 g) in ethanol (8 mL) at 50 psi for 6 h. The catalyst was allowed to settle and the supernatant liquid was removed using a pipette. The catalyst was repeatedly washed with warm (50 °C) aqueous ethanol (1:1, 3 × 150 mL). Combined washings were filtered through a short column of Celite. The filtrate was evaporated under reduced pressure to obtain a colorless solid which was crystallized from hot methanol to afford *neo*-quercitol (**14**) as colorless crystals (0.245 g, 88%); m.p. 235–238 °C (lit[19d] m.p. 237–241 °C).

2,4,6-Tri-*O*-benzyl-1,3-*O*-benzylidene-5-*O*-[(methylthio)thiocarbonyl]-*neo*-inositol (20): The alcohol **19** (1.50 g, 2.80 mmol), dry THF (20 mL), sodium hydride (0.56 g, 14.0 mmol), carbon disulfide (2.5 mL, 41.70 mmol), methyl iodide (0.90 mL, 14.46 mmol) were used (Procedure A) to obtain the xanthate **20** as a colorless solid (1.68 g, 96%) after column chromatography (eluent: 10% ethyl acetate/light petroleum); m.p. 100–102 °C (crystallized from 15% hot ethyl acetate/light petroleum). IR ($CHCl_3$): $\tilde{\nu}$ = 1377 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.50–7.60 (m, 2 H, Ar H), 7.27–7.47 (m, 18 H, Ar H), 6.49 (t, J = 4.4 Hz, 1 H, Ins H), 5.93 (s, 1 H, $PhCHO_2$), 4.66 (ABq, J = 12.1 Hz, 4 H, $PhCH_2$), 4.65 (s, 2 H, CH_2), 4.30–4.40 (m, 4 H, Ins H), 4.27 (t, J = 2.1 Hz, 1 H, Ins H), 2.58 (s, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 215.8 (C=S), 139.5 (C_{arom}), 137.7 (C_{arom}), 129.3 (C_{arom}), 128.3 (C_{arom}), 127.8 (C_{arom}), 126.6 (C_{arom}), 95.4 ($PhCO_2$), 77.8 (Ins C), 76.2 (Ins C), 73.9 (Ins C), 71.8 (CH_2), 70.6 (CH_2), 65.7 (Ins C), 19.3 (CH_3) ppm. $C_{36}H_{36}O_6S_2$ (628.80): calcd. C 68.76, H 5.77, S 10.20; found C 68.65, H 5.57, S 9.95.

***rac*-2,4,6-Tri-*O*-benzyl-1-*O*-benzoyl-3,5-dideoxy-*myo*-inositol (9):** The xanthate **20** (1.25 g, 2.00 mmol), dry toluene (15 mL), tri-*n*-butyltin hydride (2.0 mL, 7.43 mmol) and AIBN (0.04 g) were used (Procedure B) to obtain **9** as a gum (0.95 g, 91%) after column chromatography (eluent: 10% ethyl acetate/light petroleum).

(1)3,5-*O*-Benzylidene-2,4,6-tri-*O*-methyl-1(3)-*O*-[(methylthio)thiocarbonyl]-*myo*-inositol (24): The alcohol **22** (1.15 g, 3.7 mmol), dry THF (20 mL), sodium hydride (0.74 g, 18.50 mmol), carbon disulfide (3.5 mL, 58.33 mmol) and methyl iodide (1.1 mL, 17.67 mmol) were used (Procedure A) to obtain the xanthate **24** as a gum (1.42 g, 96%) after column chromatography (eluent: 7% ethyl acetate/light petroleum): IR ($CHCl_3$): $\tilde{\nu}$ = 1062, 1213 cm^{-1}. ^{1}H NMR (CD_2Cl_2, 400 MHz): δ = 7.41–7.49 (m, 2 H, Ar H), 7.28–7.38 (m, 3 H, Ar H), 5.98 (t, J = 8.3 Hz, 1 H, Ins H), 5.95 (s, 1 H, $PhCHO_2$), 4.61–4.67 (m, 1 H, Ins H), 4.40–4.44 (m, 1 H, Ins H), 4.38 (t, J = 7.5 Hz, 1 H, Ins H), 4.07 (d, J = 8.3 Hz, 1 H, Ins H), 3.91 (t, J = 3.4 Hz, 1 H, Ins H), 3.44 (s, 3 H, OCH_3), 3.41 (s, 3 H, OCH_3), 3.40 (s, 3 H, OCH_3), 2.58 (s, 3 H, CH_3) ppm. ^{13}C NMR (CD_2Cl_2, 125.4 MHz): δ = 216.1 (C=S), 138.6 (C_{arom}), 129.3 (C_{arom}), 128.5 (C_{arom}), 126.6 (C_{arom}), 93.5 ($PhCO_2$), 81.1 (Ins C), 81.0 (Ins C), 74.9 (Ins C), 73.3 (Ins C), 71.8 (Ins C), 68.6 (Ins C), 59.2 (OCH_3), 58.3 (OCH_3), 57.3 (OCH_3), 19.5 (SCH_3) ppm. $C_{18}H_{24}O_6S_2$ (400.51): calcd. C 53.98, H 6.04, S 16.01; found C 53.90, H 5.72, S 16.11.

Deoxygenation of 24: The xanthate **24** (1.00 g, 2.50 mmol), dry toluene (15 mL), tri-*n*-butyltin hydride (3.40 mL, 12.50 mmol) and AIBN (0.06 g) were used (Procedure B) to obtain **25** (gum, 0.12 g, 16%) and **26** (colorless solid, 0.51 g, 69%) after column chromatography (eluent: 10% ethyl acetate/light petroleum). **25**: IR ($CHCl_3$): $\tilde{\nu}$ = 1722 cm^{-1}. ^{1}H NMR ($CHCl_3$, 400 MHz): δ = 8.06 (d, J = 7.3 Hz, 2 H, Ar H), 7.56–7.59 (m, 1 H, Ar H), 7.42–7.49 (m, 2 H, Ar H), 5.20 (t, J = 9 Hz, 1 H, Ins H), 3.68–3.74 (m, 1 H, Ins H), 3.58–3.67 (m, 2 H, Ins H), 3.37 (s, 3 H, CH_3), 3.34 (s, 6 H, 2 × CH_3), 2.33–2.41 (m, 2 H, Ins H), 1.46–1.55 (m, 2 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 166.0 (C=O), 132.7 (C_{arom}), 130.6 (C_{arom}), 129.7 (C_{arom}), 128.3 (C_{arom}), 78.1 (Ins C), 73.6 (Ins C), 57.7 (CH_3), 56.1 (CH_3), 32.9 (Ins CH_2) ppm. $C_{16}H_{22}O_5$ (294.34): calcd. C 65.29, H 7.53; found C 65.66, H 7.70.

Data for 26: M.p. 54–55 °C (crystals from ethyl acetate). IR ($CHCl_3$): $\tilde{\nu}$ = 1710 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.10 (d, J = 7.3 Hz, 2 H, Ar H), 7.57 (t, J = 7.3 Hz, 1 H, Ar H), 7.46 (t, J = 7.8 Hz, 2 H, Ar H), 5.07 (dd, J_1 = 3.9, J_2 = 6.3 Hz, 1 H, Ins H), 3.85–3.89 (m, 1 H, Ins H), 3.71–3.78 (m, 1 H, Ins H), 3.53–3.61 (m, 1 H, Ins H), 3.42 (s, 3 H, OCH_3), 3.39 (s, 3 H, OCH_3), 3.38 (s, 3 H, OCH_3), 2.44–2.52 (m, 1 H, Ins H), 2.30–2.39 (m, 1 H, Ins H), 1.32–1.52 (m, 2 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 166.0 (C=O), 132.9 (C_{arom}), 130.1 (C_{arom}), 129.7 (C_{arom}), 128.2 (C_{arom}), 76.8 (Ins C), 76.0 (Ins C), 75.6 (Ins C), 73.1 (Ins C), 58.0 (CH_3), 57.1 (CH_3), 56.1 (CH_3), 34.6 (Ins CH_2), 33.1 (Ins CH_2) ppm. $C_{16}H_{22}O_5$ (294.34): calcd. C 65.29, H 7.53; found C 65.13, H 7.90.

2,4,6-Tri-*O*-benzyl-1,3-*O*-methylidene-5-*O*-[(methylthio)thiocarbonyl]-*myo*-inositol (28): The alcohol **27** (2.31 g, 5.0 mmol), dry THF (30 mL), sodium hydride (1.0 g, 25 mmol), carbon disulfide (4.5 mL, 75.0 mmol) and methyl iodide (1.50 mL, 24.19 mmol) were used (Procedure A) to obtain the xanthate **28** as a colorless solid (2.71 g, 98%) after column chromatography (eluent: 5% ethyl acetate/light petroleum); m.p. 86–87 °C (crystallized from 10% hot ethyl acetate/light petroleum). IR ($CHCl_3$): $\tilde{\nu}$ = 1377 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.27–7.45 (m, 15 H, Ar H), 6.07 (s, 1 H, Ins H), 5.55 (d, J = 4.5 Hz, 1 H, $HCHO_2$), 4.80 (d, J = 12 Hz, 2 H, CH_2), 4.6–4.71 (m, 5 H, $HCHO_2$ and $PhCH_2O$), 4.32–4.4 (m, 3 H, Ins H), 4.0 (q, J = 1.7 Hz, 2 H, Ins H), 2.52 (s, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 214.1 (C=S), 137.5 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 127.8 (C_{arom}), 127.7 (C_{arom}), 127.6 (C_{arom}), 85.3 (H_2CO_2), 78.7 (Ins C), 76.4 (Ins C), 72.1 (CH_2), 70.8 (Ins C), 70.6 (CH_2), 70.0 (Ins C), 18.3 (CH_3) ppm. $C_{30}H_{32}O_6S_2$ (552.70): calcd. C 65.19, H 5.84; found C 64.79, H 5.74.

2,4,6-Tri-*O*-benzyl-5-deoxy-1,3-*O*-methylidene-*myo*-inositol (29): The xanthate **28** (1.66 g, 3.0 mmol), dry toluene (20 mL), tri-*n*-butyltin hydride (3.0 mL, 11.13 mmol) and AIBN (0.08 g) were used (Procedure B) to obtain deoxy inositol derivative **29** as a colorless solid (1.26 g, 94%) after column chromatography (eluent: 10% ethyl acetate/light petroleum); m.p. 60–62 °C (crystalized from 20% hot ethyl acetate/light petroleum). IR ($CHCl_3$): $\tilde{\nu}$ = 1454 cm^{-1}.

^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.2–7.4 (m, 15 H, Ar H), 5.6 (d, J = 4.3 Hz, 1 H, HCO_2), 4.55–4.71 (m, 5 H, $HCHO_2$ and 2 × CH_2), 4.32–4.51 (m, 5 H), 3.90 (br. s, 2 H, Ins H), 2.16–2.32 (m, 1 H, CH_2), 1.95–2.1 (m, 1 H, CH_2) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 138.4 (C_{arom}), 137.8 (C_{arom}), 128.2 (C_{arom}), 128.1 (C_{arom}), 127.7 (C_{arom}), 127.5 (C_{arom}), 127.3 (C_{arom}), 85.4 (H_2CO_2), 77.4 (Ins C), 71.3, (Ins C), 71.0 (CH_2), 70.2 (CH_2), 70.1 (Ins C), 23.2 (CH_2) ppm. $C_{28}H_{30}O_5$ (446.53): calcd. C 75.31, H 6.77; found C 75.32, H 6.82.

2,4,6-Tri-*O*-benzyl-(1)3,5-*O*-ethylidene-*myo*-inositol (31): To a cooled (0 °C) solution of **30** (2.76 g, 6.0 mmol) in dry benzene (30 mL) was added methylmagnesium iodide (1 M *solution* in diethyl ether, 12.0 mL, 12 mmol) and stirred for 15 h at room temperature. The reaction mixture was then diluted with diethyl ether (100 mL) and washed with saturated solution of NH_4Cl. The organic layer was washed with brine and dried with anhydrous sodium sulfate. The gummy residue obtained after evaporation of the solvent was purified by column chromatography (eluent: 10% ethyl acetate/light petroleum) to obtain the alcohol **31**[17a] as a syrupy liquid (2.40 g, 84%).

2,4,6-Tri-*O*-benzyl-3(1),5-*O*-ethylidene-1(3)-*O*-[(methylthio)thiocarbonyl]-*myo*-inositol (32): The alcohol **31** (1.43 g, 3.0 mmol), dry THF (20 mL), sodium hydride (0.60 g, 15 mmol), carbon disulfide (2.70 mL, 45.0 mmol) and methyl iodide (0.93 mL, 15.0 mmol) were used (Procedure A) to obtain the xanthate **32** (1.66 g, 98%) as a thick oil after column chromatography (eluent: 10% ethyl acetate/light petroleum): IR ($CHCl_3$): $\tilde{\nu}$ = 1359 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.2–7.4 (m, 15 H, Ar H), 6.27 (t, J = 8.2 Hz, 1 H, Ins H), 5.20 (q, J = 4.8 Hz, 1 H, CO_2), 4.5–4.8 (m, 6 H), 4.16–4.46 (m, 4 H, Ins H), 3.98 (t, J = 3.8 Hz, 1 H, Ins H), 2.51 (s, 3 H, SCH_3), 1.22 (d, J = 4.8 Hz, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 215.3 (C=S), 137.7 (C_{arom}), 137.4 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 128.1 (C_{arom}), 128 (C_{arom}), 127.9 (C_{arom}), 127.8 (C_{arom}), 127.64 (C_{arom}), 127.59 (C_{arom}) 90.7 (HCO_2), 80.6 (Ins C), 77.8 (Ins C), 73.3 (Ins C), 72.9 (CH_2), 71.5 (CH_2), 71.4 (CH_2), 69.1 (Ins C), 68.1 (Ins C), 20.7 (CH_3), 19.0 (CH_3) ppm. $C_{31}H_{34}O_6S_2$ (566.73): calcd. C 65.70, H 6.05; found C 65.42, H 5.97.

2,4,6-Tri-*O*-benzyl-(1)3,5-*O*-ethylidene-1(3)-deoxy-*myo*-inositol (33): The xanthate **32** (1.50 g, 2.65 mmol), dry toluene (20 mL), tri-*n*-butyltin hydride (3.50 mL, 13.01 mmol) and AIBN (0.07 g) were used (Procedure B) to obtain the deoxy inositol derivative **33** as a gum (1.12 g, 92%) after column chromatography (eluent: 10% ethyl acetate/light petroleum): IR ($CHCl_3$): $\tilde{\nu}$ = 1514 cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.2–7.4 (m, 15 H, Ar H), 5.44 (q, J = 4.8 Hz, 1 H, HCO_2), 4.64 (d, J = 11.8 Hz, 1 H, CH_2), 4.61 (t, J = 4.1 Hz, 1 H, Ins H) 4.55–4.58 (m, 3 H), 4.47–4.52 (m, 2 H, Ins H), 4.42 (d, J = 11.8 Hz, 1 H, CH_2), 4.35 (br. s, 1 H, Ins H), 4.09–4.13 (dd, J_1 = 11.2, J_2 = 4.3 Hz, 1 H, Ins H), 3.75–3.82 (m, 1 H, Ins H), 2.24–2.42 (m, 1 H, Ins H), 2.05–2.17 (m, 1 H, Ins H), 1.25 (d, J = 4.8 Hz, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 138.6 (C_{arom}), 138.5 (C_{arom}), 137.6 (C_{arom}), 128.2 (C_{arom}), 127.6 (C_{arom}), 127.4 (C_{arom}), 127.3 (C_{arom}), 89.6 (HCO_2), 77.3 (Ins C), 71.7 (Ins C), 71.4 (CH_2), 71.2 (Ins C), 71.2 (CH_2), 70.9 (CH_2), 69.3 (Ins C), 67.3 (Ins C), 26.8 (CH_2), 21.4 (CH_3) ppm. $C_{29}H_{32}O_5$ (460.56): calcd. C 75.63, H 7.00; found C 75.52, H 7.24.

Racemic *vibo*-Quercitol (Viburnitol) (34): A mixture of **33** (0.92 g, 2.00 mmol), THF/water mixture (10 mL + 0.5 mL), and concd. HCl (1 mL) was refluxed for 2 h. The solvents were removed under reduced pressure to obtain a gummy residue which was dissolved in ethyl acetate (100 mL). The solution was washed with saturated sodium hydrogen carbonate solution followed by brine and dried with anhydrous sodium sulfate. The crude product (0.90 g) obtained after evaporation of the solvent was used in the next step.

The crude tribenzyl ether (0.90 g) was debenzylated in the presence of Pearlmann's catalyst [20% $Pd(OH)_2$/C, 0.03 g] in ethanol by hydrogenolysis (60 psi) at room temp. for 12 h. The catalyst was allowed to settle and the supernatant liquid was removed using a pipette. The catalyst was repeatedly washed with warm (50 °C) aqueous methanol (1:1, 3 × 150 mL). Combined washings were filtered through a short column of Celite. The filtrate was evaporated under reduced pressure to obtain a colorless solid which was crystallized from hot methanol to afford colorless crystals (0.29 g, 88%) of racemic **34**; m.p. 158–160 °C (ref.[21] m.p. 163 °C). IR (nujol): $\tilde{\nu}$ = 3540, 1445 cm^{-1}. ^{1}H NMR (D_2O, 200 MHz): δ = 4.0–4.07 (m, 1 H), 3.66–3.82 (m, 1 H), 3.42–3.6 (m, 2 H), 3.17–3.32 (m, 1 H), 2.0–2.14 (m, 1 H), 1.46–1.60 (m, 1 H) ppm. ^{13}C NMR (D_2O, 50.3 MHz): δ = 73.2, 73.5, 72.5, 68.2, 68.2, 34.9 (CH_2) ppm. $C_6H_{12}O_5$ (164.16): calcd. C 43.90, H 7.37; found C 44.22, H 7.24.

2,4,6-Tri-*O*-benzyl-1,3-*O*-benzylidene-5-*myo*-inosose (35): To a solution of the alcohol **6** (2.69 g, 5.00 mmol) in ethyl acetate (25 mL) was added 2-iodoxybenzoic acid (2.80 g, 10 mmol) and refluxed for 3 h. The reaction mixture was filtered through sintered glass funnel, and the residue washed with ethyl acetate (2 × 15 mL). The combined filtrate and washings was evaporated under reduced pressure to get the ketone **35** (2.71 g) as a colorless solid. Crystals of the pure ketone **35** could be obtained by crystallization from methanol or from dichloromethane/light petroleum mixture at low temperature (–5 °C); m.p. 106–108 °C. IR ($CHCl_3$): $\tilde{\nu}$ = 1717 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.40–7.52 (m, 2 H, Ar H), 7.17–7.39 (m, 18 H, Ar H), 5.67 (s, 1 H, $PhCHO_2$), 4.65–4.80 (m, 4 H, 2 × CH_2), 4.45–4.62 (m, 4 H), 4.25 (t, J = 2.1 Hz, 1 H, Ins H), 4.17 (d, J = 4 Hz, 2 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 200.9 (C=O), 137.8 (C_{arom}), 137.7 (C_{arom}), 136.5 (C_{arom}), 129.4 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 128.2 (C_{arom}), 128.0 (C_{arom}), 127.8 (C_{arom}), 127.6 (C_{arom}), 126.2 (C_{arom}), 93.8 ($PhCHO_2$), 79.2 (Ins C), 73.6 (Ins C), 71.8 (CH_2), 70.9 (CH_2), 66.4 (Ins C) ppm. $C_{34}H_{32}O_6$ (536.61): calcd. C 76.10, H 6.01; found C 76.34, H 5.96.

2,4,6-Tri-*O*-benzyl-1,3-*O*-benzylidene-*neo*-inositol (19): The crude ketone **35** (2.71 g) was dissolved in a mixture of THF (5 mL) and methanol (20 mL) and cooled to 0 °C. To this solution, sodium borohydride (0.57 g, 15.07 mmol) was added in one lot and stirred for 1 h at ambient temperature. TLC analysis of the reaction mixture showed the absence of the starting material. The solvents were removed under reduced pressure and the gummy residue obtained was worked up with dichloromethane. The product was purified by column chromatography [eluent: ethyl acetate/dichloromethane/light petroleum (1:1:8)] to afford the alcohol **19** as a colorless solid (2.52 g, 94%); m.p. 98–102 °C (crystals from dichloromethane). IR ($CHCl_3$): $\tilde{\nu}$ = 3332–3593 cm^{-1}. ^{1}H NMR ($CDCl_3$, 200 MHz): δ = 7.47–7.59 (m, 2 H, Ar H), 7.16–7.44 (m, 18 H, Ar H), 5.81 (s, 1 H, $PhCHO_2$), 4.55–4.76 (m, 6 H, 3 × CH_2), 4.27–4.49 (m, 3 H, Ins H), 4.04–4.13 (m, 3 H, Ins H), 3.22 (d, J = 11.0 Hz, 1 H, OH) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 139.5 (C_{arom}), 138.2 (C_{arom}), 137.7 (C_{arom}), 129.3 (C_{arom}), 128.4 (C_{arom}), 128.3 (C_{arom}), 127.82 (C_{arom}), 127.79 (C_{arom}), 127.6 (C_{arom}), 127.5 (C_{arom}), 126.9 (C_{arom}), 126.5 (C_{arom}), 95.4 ($PhCHO_2$), 78.7 (Ins C), 73.9 (CH_2), 71.0 (Ins C), 70.4 (CH_2), 67.7 (Ins C), 65.4 (Ins C) ppm. $C_{34}H_{34}O_6$ (538.63): calcd. C 75.82, H 6.36; found C 75.84, H 6.49. The alcohol **19** formed crystals with the inclusion of dichloromethane in its crystal lattice (see Supporting Information).

***neo*-Inositol (36):** The *neo*-alcohol **19** (2.3 g, 4.27 mmol) was hydrogenolyzed (50 psi) in ethanol (15 mL) in the presence of $Pd(OH)_2$/C (20%, 0.16 g) for 36 h at room temp. The catalyst was allowed

to settle and the supernatant liquid was removed using a pipette. The catalyst was repeatedly washed with warm (50 °C) distilled water (6 × 100 mL). The combined washings were filtered through a short column of Celite. The filtrate was evaporated under reduced pressure to get an off white solid which was washed with hot ethyl acetate to afford *neo*-inositol (**36**) as a colorless solid (0.64 g, 83%); m.p. 305–310 °C (ref.[27] m.p. 315 °C).

***neo*-Inositol Hexaacetate (37):** *neo*-Inositol **36** (0.05 g, 0.28 mmol) was suspended in dry pyridine (6 mL) and cooled to 0 °C. Acetic anhydride (0.47 mL, 4.98 mmol) was added drop wise and stirring continued at ambient temperature until the reaction mixture turned to a clear solution (≈ 40 h). The solvents were removed under reduced pressure and the residue obtained was worked up with dichloromethane followed by drying over anhydrous sodium sulfate. The solvent was removed under reduced pressure and the crude product was purified by column chromatography (eluent: 5% ethyl acetate/dichloromethane) to afford the hexaacetate **37** as a colorless solid (0.115 g, 96%); m.p. 255–258 °C (ref.[28] m.p. 257–259 °C).

***neo*-Inositol Hexabenzoate (38):** *neo*-Inositol **36** (0.03 g, 0.17 mmol) was suspended in dry pyridine (2 mL) and cooled to 0 °C. Benzoyl chloride (0.6 mL, 5.17 mmol) was added dropwise and stirring continued at ambient temperature for 56 h. Excess of benzoyl chloride was quenched with ice cold water and the solvent removed under reduced pressure. The gummy residue was worked up with dichloromethane followed by drying over anhydrous sodium sulfate. The crude product was purified by column chromatography (eluent: 7% ethyl acetate/dichloromethane) to afford *neo*-inositol hexabenzoate (**38**) as a colorless solid (0.125 g, 93%); m.p. 287–290 °C (crystals from methanol). IR ($CHCl_3$): $\tilde{\nu}$ = 1732 cm^{-1}. ^1H NMR ($CDCl_3$, 200 MHz): δ = 8.07–8.20 (m, 4 H, Ar H), 7.78–7.92 (m, 8 H, Ar H), 7.39–7.74 (m, 10 H, Ar H), 7.20–7.35 (m, 8 H, Ar H), 6.44 (s, 2 H, Ins H), 6.20 (s, 4 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 100.6 MHz): δ = 165.35 (C=O), 165.33 (C=O), 133.7 (C_{arom}), 133.4 (C_{arom}), 129.9 (C_{arom}), 129.7 (C_{arom}), 129.0 (C_{arom}), 128.8 (C_{arom}), 128.7 (C_{arom}), 128.3 (C_{arom}), 69.1 (Ins C), 68.7 (Ins C) ppm. $C_{48}H_{36}O_{12}$ (804.79): calcd. C 71.64, H 4.51; found C 71.44, H 4.86.

5-Azido-2,4,6-tri-*O*-benzyl-1,3-*O*-benzylidene-5-deoxy-*myo*-inositol (39): To a cooled (–42 °C) solution of the *neo*-alcohol **19** (1.35 g, 2.50 mmol) in dry pyridine (5 mL) and dry dichloromethane (5 mL), triflic anhydride (1.06 g, 3.75 mmol) was added dropwise over a period of 15 min. The temperature of the reaction mixture was allowed to rise to room temperature and stirring was continued for 2 h. The solvents were removed under reduced pressure and the crude reaction mixture was dissolved in dichloromethane, washed successively with water, saturated sodium hydrogen carbonate solution followed by brine and dried with anhydrous sodium sulfate. The solvent was removed under reduced pressure to afford the triflate as a gum (1.53 g), which was used in the next step.

A mixture of the crude triflate (1.53 g), sodium azide (0.97 g, 15.00 mmol) and dry DMF (8 mL) was stirred at room temperature for 12 h under argon atmosphere. The solvent was removed under reduced pressure and the residue obtained was dissolved in ethyl acetate and washed with water and brine followed by drying over anhydrous sodium sulfate. The solvent was removed and the crude product was purified by column chromatography (eluent: 10% ethyl acetate/light petroleum) to afford the *myo*-azide **39** (1.24 g, 88%) as a colorless solid; m.p. 90–93 °C (crystals from dichloromethane). IR ($CHCl_3$): $\tilde{\nu}$ = 2106 cm^{-1}. ^1H NMR ($CDCl_3$, 200 MHz): δ = 7.47–7.56 (m, 2 H, Ar H), 7.26–7.46 (m, 18 H, Ar H), 5.59 (s, 1 H, $PhCHO_2$), 4.72 (s, 2 H, $PhCH_2$), 4.67 (ABq, J = 11.4 Hz, 4 H, 2 × $PhCH_2$), 4.40 (d, J = 2.4 Hz, 2 H, Ins H), 3.93 (d, J = 9.3 Hz, 2 H, Ins H), 3.53–3.62 (m, 2 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 137.6 (C_{arom}), 136.7 (C_{arom}), 129.4 (C_{arom}), 128.5 (C_{arom}), 128.4 (C_{arom}), 128.1 (C_{arom}), 127.8 (C_{arom}), 127.7 (C_{arom}), 126.4 (C_{arom}), 92.7 ($PhCHO_2$), 80.2 (Ins C), 73.0 (Ins C), 71.7 (CH_2), 70.8 (CH_2), 68.1 (Ins C), 65.0 (Ins C) ppm. $C_{34}H_{33}N_3O_5$ (563.64): calcd. C 72.45, H 5.90, N 7.46; found C 72.30, H 5.77, N 7.35.

1,2,3,4,6-Penta-*O*-acetyl-5-deoxy-5-acetylamino-*myo*-inositol (41): The azide **39** (0.64 g, 1.10 mmol) was hydrogenolyzed (50 psi) in the presence of $Pd(OH)_2/C$ (20%, 0.04 g) in ethanol (4 mL) and acetic acid (2 mL) at room temp. for 44 h. The catalyst was filtered by using a short bed of Celite and the catalyst was washed with water (2 × 10 mL). The combined filtrate and washings was evaporated under reduced pressure and the residue co-evaporated with dry toluene (2 × 5 mL) to get the crude product (0.26 g) as an off white solid. The crude product was dissolved in dry pyridine (5 mL), cooled with ice and acetic anhydride (2.0 mL) was added dropwise. The resulting mixture was stirred for 40 h and the solvents were removed under reduced pressure. The residue obtained was worked up with dichloromethane by washing with water, saturated sodium hydrogen carbonate solution and brine followed by drying over anhydrous sodium sulfate. The solvent was evaporated under reduced pressure and the crude product was purified by column chromatography (eluent: 1:1 dichloromethane/ethyl acetate) to afford the hexa-acetate **41** as a colorless solid (0.41 g, 83% for two steps); m.p. 264–270 °C (crystals from dichloromethane). IR ($CHCl_3$): $\tilde{\nu}$ = 3385, 1751, 1690, 1686 cm^{-1}. ^1H NMR ($CDCl_3$, 200 MHz): δ = 5.63 (t, J = 2.8 Hz, 1 H, Ins H), 5.55 (d, J = 9.8 Hz, 1 H, NH), 5.07–5.36 (m, 4 H, Ins H), 4.23–4.44 [m, 1 H, (CHNHAc)], 2.19 (s, 3 H, CH_3), 2.04 (s, 6 H, CH_3), 2.00 (s, 6 H, CH_3), 1.91 (s, 3 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 170.9 (C=O), 170.1 (C=O), 169.5 (C=O), 169.2 (C=O), 69.6 (Ins C), 68.8 (Ins C), 68.3 (Ins C), 51.7 (Ins CH-NH), 22.9 (CH_3), 20.6 (CH_3), 20.5 (CH_3), 20.4 (CH_3) ppm. $C_{18}H_{25}NO_{11}$ (431.39): calcd. C 50.12, H 5.84, N 3.25; found C 49.9, H 6.0, N 3.2.

5-Azido-2,4,6-tri-*O*-benzyl-1,3-*O*-benzylidine-5-deoxy-*neo*-inositol (42): To a cooled (–42 °C) solution of the alcohol **6** (2.15 g, 4.00 mmol) in a mixture of dry pyridine (8 mL) and dry dichloromethane (8 mL), triflic anhydride (1.00 mL, 5.94 mmol) was added dropwise over 10 min with stirring. The cooling bath was removed and stirring was continued at ambient temperature for 2 h. The solvents were removed under reduced pressure and the residue was dissolved in dichloromethane, washed successively with water, saturated sodium hydrogen carbonate solution followed by brine and dried with anhydrous sodium sulfate. The solvent was removed under reduced pressure and the crude product was dissolved in HMPA (10 mL), sodium azide (1.62 g, 25 mmol) was added and stirred for 12 h under argon atmosphere. The reaction mixture was diluted with diethyl ether and washed successively with water and brine and dried with anhydrous sodium sulfate. The solvent was removed under reduced pressure and the crude product was purified by column chromatography (eluent: 10% ethyl acetate/light petroleum) to afford the *neo*-azide **42** (2.07 g, 92%) as a colorless solid; m.p. 87–89 °C (crystals from 15% hot ethyl acetate/light petroleum). IR ($CHCl_3$): $\tilde{\nu}$ = 2109 cm^{-1}. ^1H NMR ($CDCl_3$, 200 MHz): δ = 7.44–7.52 (m, 2 H, Ar H), 7.22–7.41 (m, 18 H, Ar H), 5.78 (s, 1 H, $PhCHO_2$), 4.70 (ABq, J = 12 Hz, 4 H, 2 × $PhCH_2$), 4.53 (s, 2 H, $PhCH_2$), 4.18–4.32 (m, 5 H, Ins H), 3.66 (t, J = 5 Hz, 1 H, Ins H) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 139.7 (C_{arom}), 138.0 (C_{arom}), 137.2 (C_{arom}), 129.2 (C_{arom}), 128.4 (C_{arom}), 128.2 (C_{arom}), 128.0 (C_{arom}), 127.7 (C_{arom}), 127.6 (C_{arom}), 126.4 (C_{arom}), 94.8 ($PhCHO_2$), 79.2 (Ins C), 73.6 (CH_2), 70.8 (Ins C), 70.5 (CH_2),

65.8 (Ins C), 57.46 (Ins C) ppm. $C_{34}H_{33}N_3O_5$ (563.64): calcd. C 72.45, H 5.90, N 7.46; found C 72.10, H 6.19, N 7.42.

1,2,3,4,6-Penta-*O*-acetyl-5-acetylamino-5-deoxy-*neo*-inositol (44): The azide **42** (0.96 g, 1.65 mmol) was hydrogenolyzed (at 50 psi) in the presence of $Pd(OH)_2$/C (20%, 0.07 g) in ethanol (6 mL) and trifluoroacetic acid (3 mL) at room temp. for 32 h. The catalyst was filtered by using a short bed of Celite and the catalyst was washed with water (2 × 15 mL). The combined filtrate and washings was evaporated under reduced pressure and the residue co-evaporated with dry toluene (2 × 7 mL) to get the crude product (0.39 g) as an off white solid. The crude product was dissolved in dry pyridine (7 mL), cooled with ice and acetic anhydride (3.0 mL) was added dropwise. The resulting mixture was stirred for 45 h and the solvents were removed under reduced pressure. The residue obtained was taken in dichloromethane, washed with water, saturated sodium hydrogen carbonate solution followed by brine and dried with anhydrous sodium sulfate. The solvent was evaporated and the crude product was purified by column chromatography (eluent: 1:1 dichloromethane/ethyl acetate) to afford the hexaacetate **44** as a colorless solid (0.63 g, 86% for two steps); m.p. 276–278 °C (ref.[25a,25b] m.p. 278–279 °C). IR ($CHCl_3$): $\tilde{\nu}$ = 3385, 1751, 1690, 1686 cm^{-1}. ^1H NMR ($CDCl_3$, 200 MHz): δ = 6.24–6.44 (m, 1 H, NH), δ = 5.61 (t, J = 2.6 Hz, 1 H, Ins H), 5.21–5.43 (m, 4 H, Ins H), 4.96–5.1 [m, 1 H, (CHNHAc)], 2.18 (s, 3 H, CH_3), 2.06 (s, 3 H, CH_3), 2.04 (s, 6 H, CH_3), 2.03 (s, 6 H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 50.3 MHz): δ = 171.3 (C=O), 170.5 (C=O), 170.0 (C=O), 169.6 (C=O), 169.3 (C=O), 67.6 (Ins C), 66.9 (Ins C), 46.8 (Ins CH-NH), 22.8 (CH_3), 20.8 (CH_3), 20.6 (CH_3), 20.5 (CH_3) ppm. $C_{18}H_{25}NO_{11}$ (431.39): calcd. C 50.12, H 5.84, N 3.25; found C 49.80, H 6.12, N 3.06.

Supporting Information (see also the footnote on the first page of this article): Experimental procedures for compounds **14**, **35**, ^1H, ^{13}C NMR spectra of all new compounds, NOESY spectrum of xanthate **7**, **20** and **24**, crystallographic data for compounds **7**, **19**, **20**, **28**, **29**, **35**, **39** and **42**.

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[1] a) S. V. Ley, L. L. Yeung, *Synlett* **1992**, 291–292; b) L. Pingli, M. Vanderwalle, *Synlett* **1994**, 228–230; c) A. V. R. Sudha, M. Nagarajan, *Chem. Commun.* **1998**, 925–926; d) E. Maudru, G. R. H. Wightman, *Chem. Commun.* **1998**, 1505–1506; e) M. T. Rudolf, W. H. Li, N. Wolfson, A. E. Traynor-Kaplan, C. Schultz, *J. Med. Chem* **1998**, *41*, 3635–3644; f) G. Mehta, M. Narinder, S. Lakshminath, *Tetrahedron Lett.* **2000**, *41*, 3505–3508; g) N. Gathergood, K. R. Knudsen, K. A. Jørgensen, *J. Org. Chem.* **2001**, *66*, 1014–1017; h) J. B. Walker, *Appl. Environ. Microbiol.* **2002**, *68*, 2404–2410; i) M. Egido-Gabas, P. Serrano, J. Casas, A. Llebaria, A. Delgado, *Org. Biomol. Chem.* **2005**, *3*, 1195–1201; j) G. F. Busscher, F. P. J. T. Rutjes, F. L. van Delft, *Chem. Rev.* **2005**, *105*, 775–791 and references cited therein; k) O. Arjona, A. M. Gomez, J. C. Lopez, J. Plumet, *Chem. Rev.* **2007**, *107*, 1919–2036; l) R. Beniazza, V. Desvergnes, Y. Landais, *Org. Lett.* **2008**, *10*, 4195–4198.

[2] a) T. Schmittberger, H. Waldmann, *Synlett* **1988**, 574–584; b) K. Hinchliffe, R. Irvine, *Nature* **1997**, *390*, 123–124; c) A. Schnaars, C. Schultz, *Tetrahedron* **2001**, *57*, 519–524; d) C. Dinkel, C. Schultz, *Tetrahedron Lett.* **2003**, *44*, 1157–1159; e) M. T. Rudolf, C. Dinkel, A. E. Traynor-Kaplan, C. Schultz, *Bioorg. Med. Chem.* **2003**, *11*, 3315–3329; f) *Cell Signaling*, J. T. Hancock, Oxford University Press, New York, **2005**.

[3] a) B. Tse, Y. Kishi, *J. Am. Chem. Soc.* **1993**, *115*, 7892–7893; b) D. R. Gauthier, S. L. Bender, *Tetrahedron Lett.* **1996**, *37*, 13–16; c) N. Chida, S. Ogawa, *Chem. Commun.* **1997**, 807–813; d) T. Suzuki, S. T. Suzuki, I. Yamada, Y. Koashi, K. Yamada, N. Chida, *J. Org. Chem.* **2002**, *67*, 2874–2880; e) K. Sato, S. Akai, N. Sugita, T. Ohsawa, T. Kogure, H. Shoji, J. Yoshimura, *J. Org. Chem.* **2005**, *70*, 7496–7505; f) M. Li, A. Wu, P. Zhou, *Tetrahedron Lett.* **2006**, *47*, 3707–3710.

[4] a) K. Hegetschweiler, *Chem. Soc. Rev.* **1999**, *28*, 239–249 and references cited therein; b) K. M. Sureshan, M. S. Shashidhar, A. J. Varma, *J. Chem. Soc. Perkin Trans. 2* **2001**, 2298–2302; c) K. M. Sureshan, M. S. Shashidhar, A. J. Varma, *J. Org. Chem.* **2002**, *67*, 6884–6888; d) L. A. Paquette, P. R. Selvaraj, K. M. Keller, J. S. Brodbelt, *Tetrahedron* **2005**, *61*, 231–240; e) S. S. Dixit, M. S. Shashidhar, *Tetrahedron* **2008**, *64*, 2160–2171 and references cited therein.

[5] a) T. Steiner, W. Hinrichs, W. Saenger, R. Gigg, *Acta Crystallogr., Sect. B* **1993**, *49*, 708–711; b) R. G. Gonnade, M. S. Shashidhar, M. M. Bhadbhade, *J. Indian Inst. Sci.* **2007**, *87*, 149–161; c) C. Murali, M. S. Shashidhar, R. G. Gonnade, M. M. Bhadbhade, *Chem. Eur. J.* **2009**, *15*, 261–269, and references cited therein.

[6] a) H. W. Lee, Y. J. Kishi, *J. Org. Chem.* **1985**, *50*, 4402–4404; b) D. C. Billington, *The Inositol Phosphates: Chemical synthesis and biological significance*, VCH Publishers, New York, **1993**; c) B. V. L. Potter, D. Lampe, *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 1933–1972; d) S. W. Garrett, C. Liu, A. M. Riley, B. V. L. Potter, *J. Chem. Soc. Perkin Trans. 1* **1998**, 1367–1368; e) M. A. Biomonte, A. Vasella, *Helv. Chim. Acta* **1998**, *81*, 688–694; f) K. M. Sureshan, K. Ikeda, N. Asano, Y. Watanabe, *Tetrahedron* **2008**, *64*, 4072–4080.

[7] N. Chida, N. Sakata, K. Murai, T. Tobe, T. Nagase, S. Ogawa, *Bull. Chem. Soc. Jpn.* **1998**, *71*, 259–272.

[8] a) J. L. Chiara, M. Martin-Lomas, *Tetrahedron Lett.* **1994**, *35*, 2969–2972; b) J. P. Guidot, T. Le Gall, C. Mioskowski, *Tetrahedron Lett.* **1994**, *35*, 6671–6672; c) G. D. Prestwich, *Acc. Chem. Res.* **1996**, *29*, 503–513; d) D. Dubreuil, J. Cleophax, M. V. Almeida, C. Verre-Sebrie, J. Liaigre, G. Vass, S. D. Gero, *Tetrahedron* **1997**, *53*, 16747–16766; e) D. J. Jenkin, B. V. L. Potter, *J. Chem. Soc. Perkin Trans. 1* **1998**, 41–50; f) D. L. J. Clive, X. He, M. H. D. Poslema, M. J. Mashimbye, *J. Org. Chem.* **1999**, *64*, 4397–4410.

[9] T. Sawada, R. Shirai, S. Iwasaki, *Tetrahedron Lett.* **1996**, *37*, 885–886.

[10] G. Mehta, S. R. Pujar, S. S. Ramesh, K. Islam, *Tetrahedron Lett.* **2005**, *46*, 3373–3376, and references cited therein.

[11] a) S. Knapp, R. M. Ornaf, K. E. Rodriques, *J. Am. Chem. Soc.* **1983**, *105*, 5494–5495; b) M. A. L. Podeschwa, O. Plettenburg, H. J. Altenbach, *Org. Biomol. Chem.* **2003**, *1*, 1919–1929; c) G. F. Busscher, S. Groothuys, R. Gelder, F. P. J. T. Rutjes, F. L. van Delft, *J. Org. Chem.* **2004**, *69*, 4477–4481; d) P. Gonzalez-Bulnes, J. Casas, A. Delgado, A. Llebaria, *Carbohydr. Res.* **2007**, *342*, 1947–1952.

[12] a) M. Mandel, T. Hudlicky, *J. Chem. Soc. Perkin Trans. 1* **1993**, 741–743; b) T. Hudlicky, *Chem. Rev.* **1996**, *96*, 3–30; c) P. M. J. Jung, W. B. Motherwell, A. S. Williams, *Chem. Commun.* **1997**, 1283–1284; d) T. Hudlicky, N. Restrepo-Sanchez, P. D. Kary, L. M. Jaramillo-Gomez, *Carbohydr. Res.* **2000**, *324*, 200–203.

[13] a) K. M. Sureshan, M. S. Shashidhar, T. Praveen, T. Das, *Chem. Rev.* **2003**, *103*, 4477–4503; b) S. Devaraj, M. S. Shashidhar, S. S. Dixit, *Tetrahedron* **2005**, *61*, 529–536; c) M. S. Rosello, A. L. A. Puchlopek, A. J. Morgan, S. J. Miller, *J. Org. Chem.* **2008**, *73*, 1774–1782; d) S. Devaraj, R. C. Jagdhane, M. S. Shashidhar, *Carbohydr. Res.* **2009**, *344*, 1159–1166.

[14] a) L. Schmitt, B. Spiess, G. Schlewer, *Bioorg. Med. Chem. Lett.* **1995**, *5*, 1225–1230; b) A. M. Riley, B. V. L. Potter, *Tetrahedron*

Lett. **1998**, *39*, 6769–6772; c) O. Plettenburg, S. Adelt, G. Vogel, H. J. Altenbach, *Tetrahedron: Asymmetry* **2000**, *11*, 1057–1061; d) B. R. Sculimbrene, S. J. Miller, *J. Am. Chem. Soc.* **2001**, *123*, 10125–10126, and references cited therein.

[15] M. P. Sarmah, M. S. Shashidhar, K. M. Sureshan, R. G. Gonnade, M. M. Bhadbhade, *Tetrahedron* **2005**, *61*, 4437–4446.

[16] a) S. M. Yeh, G. H. Lee, Y. Wang, T. Y. Luh, *J. Org. Chem.* **1997**, *62*, 8315–8318; b) G. Bhosekar, C. Murali, R. G. Gonnade, M. S. Shashidhar, M. M. Bhadbhade, *Cryst. Growth Des.* **2005**, *5*, 1977–1982; c) A. M. Riley, H. Y. Godage, M. F. Mahon, B. V. L. Potter, *Tetrahedron: Asymmetry* **2006**, *17*, 171–174; d) H. Y. Godage, A. M. Riley, T. J. Woodman, B. V. L. Potter, *Chem. Commun.* **2006**, 2989–2991.

[17] a) I. H. Gilbert, A. B. Holmes, M. J. Pestchanker, R. C. Young, *Carbohydr. Res.* **1992**, *234*, 117–130; b) C. Murali, M. S. Shashidhar, C. S. Gopinath, *Tetrahedron* **2007**, *63*, 4149–4155.

[18] a) G. E. McCasland, E. C. Horswill, *J. Am. Chem. Soc.* **1953**, *75*, 4020–4026; b) G. E. McCasland, E. C. Horswill, *J. Am. Chem. Soc.* **1954**, *76*, 2373–2379; c) R. Baker, C. Carrick, P. D. Leeson, I. C. Lennon, N. J. Liverton, *J. Chem. Soc., Chem. Commun.* **1991**, 298–300; d) L. Schmidt, B. Spiess, G. Schlewer, *Tetrahedron Lett.* **1998**, *39*, 4817–4820; e) A. J. Morgan, Y. K. Wang, M. F. Roberts, S. J. Miller, *J. Am. Chem. Soc.* **2004**, *126*, 15370–15371.

[19] a) G. E. McCasland, S. Furuta, L. F. Johnson, J. N. Shoolery, *J. Am. Chem. Soc.* **1961**, *83*, 2335–2344; b) S. Ogawa, Y. Hongo, H. Fujimori, K. Iwata, A. Kasuga, T. Suami, *Bull. Chem. Soc. Jpn.* **1978**, *51*, 2957–2963; c) A. Kee, P. O'Brien, C. D. Pilgram, S. T. Watson, *Chem. Commun.* **2000**, 1521–1522, and references cited therein; d) T. L. Shih, Y. L. Lin, W. S. Kuo, *Tetrahedron* **2005**, *61*, 1919–1924.

[20] H. S. Dang, B. P. Roberts, J. Sekhon, T. M. Smits, *Org. Biomol. Chem.* **2003**, *1*, 1330–1341.

[21] a) Th. Posternak, *Helv. Chim. Acta* **1950**, *33*, 1597–1605; b) G. E. McCasland, S. Furuta, L. F. Johnson, J. N. Shooleri, *J. Am. Chem. Soc.* **1961**, *83*, 2335–2343.

[22] a) C. R. Kowarski, S. Sarel, *J. Org. Chem.* **1973**, *38*, 117–119; b) M. Carpintero, A. Fernández-Mayoralas, C. Jaramillo, *J. Org. Chem.* **1997**, *62*, 1916–1917; c) A. M. Riley, D. J. Jenkins, B. V. L. Potter, *Carbohydr. Res.* **1998**, *314*, 277–281; d) S. K. Chung, Y. U. Kwon, *Bioorg. Med. Chem. Lett.* **1999**, *9*, 2135–2140; e) M. Podeschwa, O. Plettenburg, J. vom Brocke, O. Block, S. Adelt, H. J. Altenbach, *Eur. J. Org. Chem.* **2003**, 1958–1972, and references cited therein; f) J. N. Heo, E. B. Holson, W. R. Roush, *Org. Lett.* **2003**, *5*, 1697–1700.

[23] O. Mitsunobu, *Synthesis* **1981**, 1–28.

[24] C. Sanfilippo, A. Patti, M. Piattelli, G. Nicolosi, *Tetrahedron: Asymmetry* **1998**, *9*, 2808–2817.

[25] a) J. B. Patrik, R. P. Williams, C. W. Waller, B. L. Hutchings, *J. Am. Chem. Soc.* **1956**, *78*, 2652–2652; b) J. R. Anderson, *J. Am. Chem. Soc.* **1956**, *78*, 5692–5693; c) E. S. E. Habib, J. N. Scarsdale, K. A. Reynolds, *Antimicrob. Agents Chemother.* **2003**, *47*, 2065–2671, and references cited therein.

[26] *Purification of Laboratory Chemicals* (Eds.: D. D. Perrin, W. L. F. Armarego), 2nd edition, Pergamon Press, Oxford, UK, **1988**.

[27] S. J. Angyal, N. K. Matheson, *J. Am. Chem. Soc.* **1955**, *77*, 4343–4346, and references cited therein.

[28] T. Tschamber, F. Backenstrass, H. Fritz, J. Streith, *Helv. Chim. Acta* **1992**, *75*, 1052–1060.

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