Cyclopolymerisation of an oriented 4,6-bis(4-vinylbenzyl)-*myo*-inositol orthoformate

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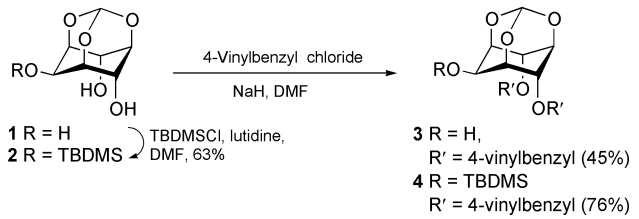
Free radical-promoted cyclopolymerisation of a 4,6-bis(4-vinylbenzyl)-*myo*-inositol orthoformate 4, whose X-ray structure has been determined, was studied and the first formed intermediate was trapped using (tetramethylpiperidine *N*-oxyl) (TEMPO) 7.

Cyclopolymerisation[1,2] is a useful method for controlling the regio- and stereochemistry of monomer additions, leading to polymers with well-defined microstructures.[3] We were interested in the use of a scaffold with oriented hydroxy functionality based on a rigid monomer which would undergo cyclopolymerisation to afford a polymer with an organised backbone and oriented functional groups. We selected the 4,6-bis(4-vinyl)-benzyl)-*myo*-inositol orthoformates **3** and **4** as suitable monomers to deliver these features.

The monomers **3** and **4** were prepared from *myo*-inositol orthoformate **1**[4] either by selective derivatisation[5] at positions 4 and 6 with 4-vinylbenzyl chloride (to give **3**) or selective silylation[6] at the 2-position followed by benzylation at positions 4 and 6 (Scheme 1). The key structural feature offered by these monomers includes the orthoformate group which, after the polymerisation reaction, may be easily deprotected to yield (ideally) an all-axial triol repeat unit.



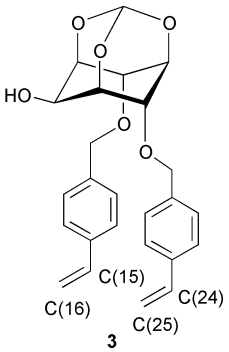
Scheme 1 Preparation of monomers **3** and **4**.

Both monomers gave suitable crystals for X-ray analysis, but disorder in the silyl side chain of **4** yielded data with an unacceptably high *R* factor. The X-ray structure† of monomer **3** revealed two conformations (ratio 3:1) in the unit cell with a characteristic edge-to-face interaction of the aromatic rings.[7] The monomer structures differed only in the relative orientation of the vinyl groups. The important interatomic bond distances of the major conformer of **3** measured from the X-ray data, are presented in Fig. 1.

Heating a toluene solution of the monomer **4** at 65 °C in the presence of 2–3 wt% AIBN afforded an organic soluble polymer of M_n 10 000–20 000 which is formulated as a linear cyclopolymer **5** (Scheme 2).‡ The evidence for the cyclopolymer **5** comes from the X-ray structure of the monomer and the trapping of the first formed cyclic radical intermediate.

Thermal decomposition of the AIBN initiator would give the cyanoisopropyl radical which would add selectively to the less substituted end of the vinyl group.[8] Intramolecular cyclisation by 'head' to 'tail' addition, from C(15) to C(25), is likely to be the more favourable reaction pathway as the distance from C(15) to C(25) shown in Fig. 1, is significantly shorter than the other measured distances. Supporting evidence for this pathway is provided by the trapping experiment discussed below. Similar interatomic bond distances were found in **4**.

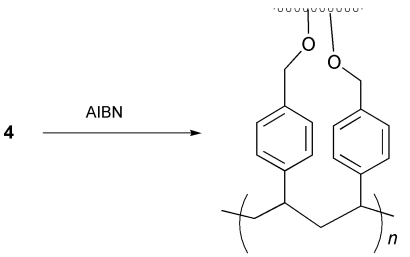
Interatomic distances (Å)	
C(15)-C(24)	4.907
C(15)-C(25)	3.935
C(16)-C(24)	5.167
C(16)-C(25)	4.151



3

Fig. 1 Selected interatomic bond distances in a crystal of the monomer **3**.

The TEMPO radical trapping technique, developed by Rizzardo, Solomon and Moad,[9–11] and also exploited by Busfield and Jenkins,[8] was used to isolate the reactive radical intermediate generated during cyclopolymerisation. The optimum trapping experiment involved heating a 29 mM benzene



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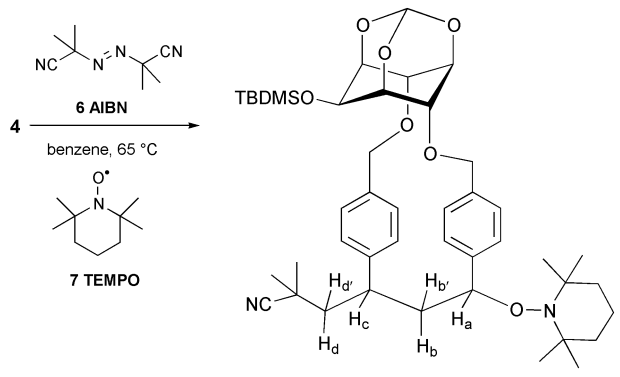
Scheme 2 Cyclopolymerisation of the monomer **4**.



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Scheme 3 TEMPO trapping of the first formed cyclic intermediate after AIBN-initiated addition to the monomer **4**.

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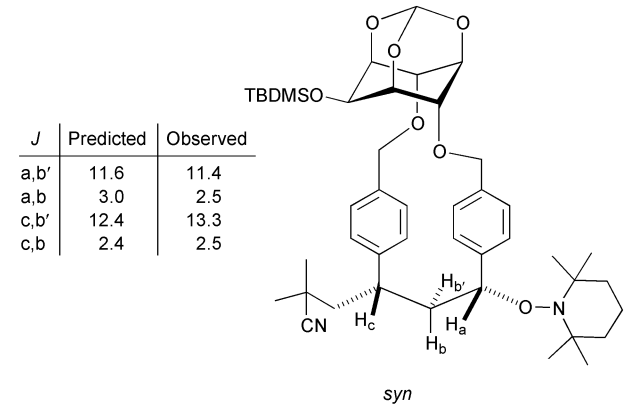
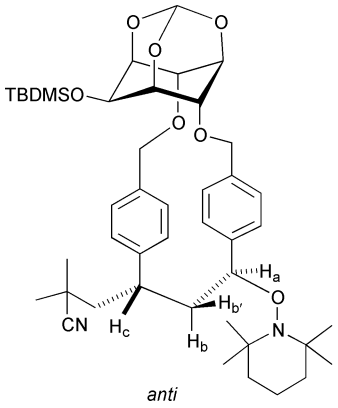


J	Predicted	Observed
a,b′	11.6	11.4
a,b	3.0	2.5
c,b′	12.4	13.3
c,b	2.4	2.5

syn



J	Predicted	Observed
a,b′	11.6	11.4
a,b	2.4	2.5
c,b′	4.0	13.3
c,b	3.1	2.5

anti

Fig. 2 Two possible diastereoisomeric structures for the trapped product **8**.

solution of the monomer **4** in the presence of AIBN **6** (28 mM) and TEMPO **7** (10 mM) to give the alkoxyamine **8** in 5% yield (the mass balance was mainly starting material) (Scheme 3). The low yield of product arises from competing reaction of the cyanoisopropyl radical with the aminoxyl agent.[8] To our knowledge this is the first example of trapping of the cyclic intermediate in a styrenic radical cyclopolymerisation, and may offer important opportunities to study the kinetics of the early propagation steps of such processes.

The structure determination of the cyclic product **8** was performed by ^{1}H NMR TOCSY and NOE experiments. Selective 1-D TOCSY experiments assisted in determining the connectivity sequence of atoms. Mutual NOE effects were observed between H_a and H_c in compound **8**, indicating that the methine protons are part of the same cyclic structure. The observed ^{1}H NMR coupling constant (13.3 Hz) between H_c and $H_{b'}$ is more consistent with the *syn* diastereoisomer (predicted 12.4 Hz) than the *anti* (predicted *J* 4.0 Hz) (Fig. 2).§

In conclusion we have confirmed the existence of a cyclopolymerisation by trapping the reactive radical intermediate. Furthermore, interatomic bond distances between the vinyl groups in both **3** and **4**, as established in the solid state, favour the formation of a cyclic structure. Hence, the monomers based on *myo*-inositol orthoformate show interesting opportunities to prepare a rigid scaffold with oriented functionality.

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Notes and references

† *Crystal data* for **3**: Colourless needle-shaped crystals, mp 136 °C, of $C_{25}H_{26}O_6$ were monoclinic, space group $P2_1/c$, with a = 6.072(6), b = 24.506(6), c = 14.217(3) Å, α = 90, β = 99.35(4), γ = 90°, V = 2087(2) Å^3, Z = 4, T = 180 (2) K, μ = 0.96 mm^{-1}, ρ_{calc} = 1.344 Mg m^{-3}, M = 422.46. One of the vinyl groups, C(24) and C(25), appears to be disordered about two orientations. The final $R_w(F^2)$ = 0.1037 with a goodness of fit = 1.014, while the conventional $R(F)$ = 0.0559 for 7948 reflections with $F_o > 4[\sigma(F_o)]$. CCDC 182/1833. See http://www.rsc.org/suppdata/cc/b0/b007057m/ for crystallographic files in .cif format.

‡ Further details of the cyclopolymerisation (see following Communication, DOI: 10.1039/b007058k) will be described in a full paper.

§ Molecular modelling[12] of **8** using the MM2 force field in MacroModel v5.5® indicated that the distance between the methine hydrogens H_a and H_c in either the *syn* or *anti* isomers was 2.43–3.74 Å, within the NOE experimental range. It is impossible to distinguish the two alternative *syn*-diastereoisomers (relative to the 2-TBDMSO substituent).

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