Synthesis and chiroptical properties of optically active layer-block dendrimers

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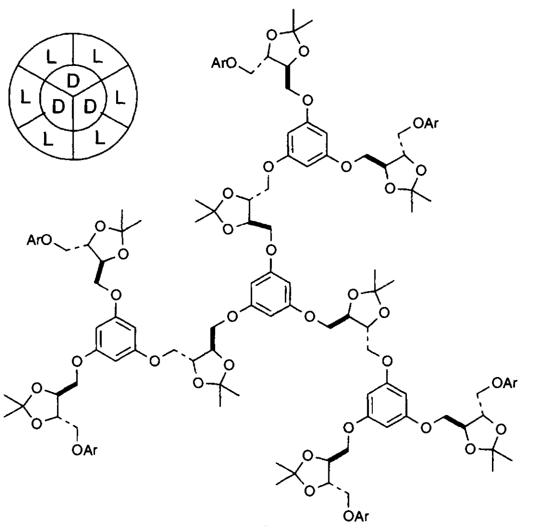
The syntheses of two different homochiral, layered-block dendrimers 1 and 2 are reported; the chiral units used in the construction of these two first-generation dendrimers are derivatives of (D)- and (L)-tartaric acid; for these low generation dendrimers, the optical rotation strength of the (D)-tartaric derived chiron cancels out that of its antipodal (L)-tartaric derived chiral unit.

Recent interest in the synthesis of optically active dendrimers stemmed from their potential applications in chiral recognition and asymmetric synthesis.[1] Recently, Seebach[2] and ourselves[3] independently disclosed that the optical activity of a low generation dendrimer was proportional to the number of chiral elements inside the dendritic structure. On the other hand, Meijer reported that a sterically congested dendrimer with optically active units located on the surface displayed a diminishing optical rotational property.[4] Here we report the syntheses and chiroptical properties of two different layer-block dendrimers **1** and **2**. These chiral dendrimers are made up of two different chiral elements which are derivatives of (D)- and (L)-tartaric acid and thus they are chiroptically enantiotopic to each other.

The first layer-block dendrimer **1** has an outer chiral layer made up of six (L)-chiral units derived from (L)-tartaric acid and an inner chiral layer made up of three antipodal (D)-chiral elements. The second layer-block dendrimer **2**, on the other hand, has an outer shell with three (D)- and three (L)-chiral units and an inner shell with three (D)-chiral units. Similar to the all (L)-tartrate dendritic series reported by us earlier,[3] the surface sector chosen was a 4-*tert*-butylphenoxy group and the branching juncture employed was a phloroglucinol unit.

The syntheses of these two dendrimers were similar to the methods described previously[3] with slight modifications. The C_2 symmetrical phenol **3**[3] was treated with 1 equiv. of linker



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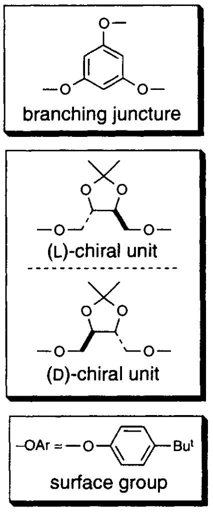

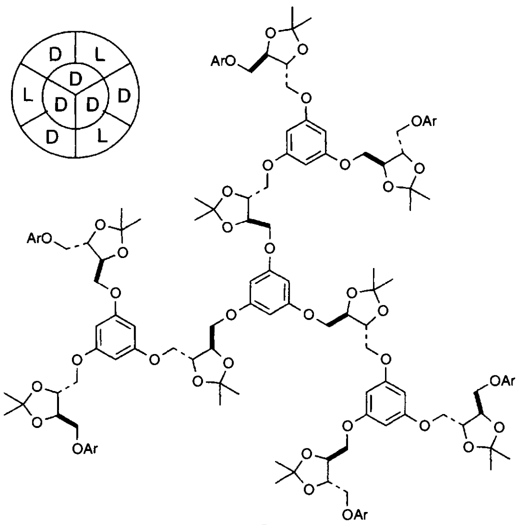

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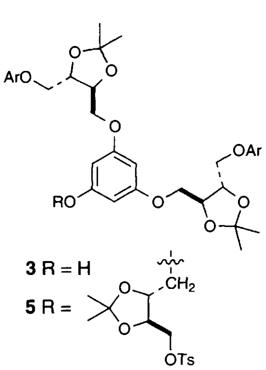
Table 1 Specific and molar rotations of dendritic molecules (23 °C, D line)

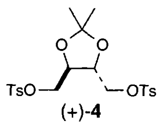
Compound	No. of (D)-tartrate units	No. of (L)-tartrate units	No. of (D)-units in excess[a]	Specific rotation [α][b]	Molar rotation[b]	Molar rotation per tartrate unit[c]
1	3	6	−3	−29	−748	−249
2	6	3	3	+23	+579	+193
5	1	2	−1	−29	−288	−288
7	2	4	−2	−17	−304	−152
8	2	4	−2	−22	−379	−190
10	0	1	−1	−33	−164	−164
11	0	2	−2	−55[d]	−425	−212
12	1	1	0	−3	−25	—
13	1	1	0	−3	−22	—
14	2	1	1	+8	+75	+75
15	4	2	2	+17	+314	+157
16	4	2	2	+18	+316	+158

[a] Negative values denote (L)-tartrate unit(s) is in excess. [b] Typical *c* values are in the range from 4.3 to 1.0. [c] Negative and positive values denote contributions from (L)- and (D)-tartrate unit(s), respectively. [d] Ref. 3.

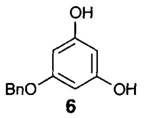


3 R = H
5 R =

Ar = 4-*tert*-butylphenyl



(+)-**4**



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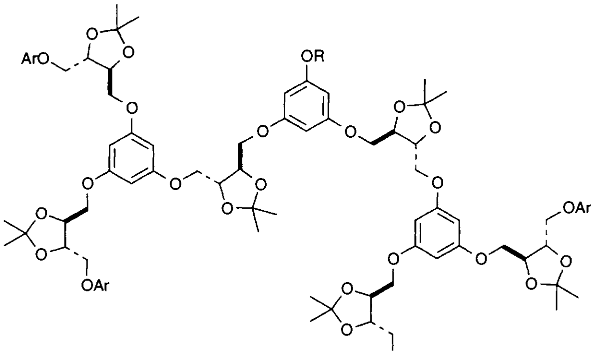
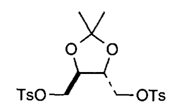
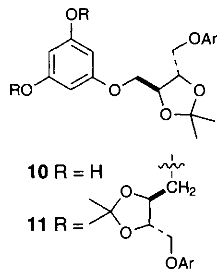


7 R = Bn
8 R = H

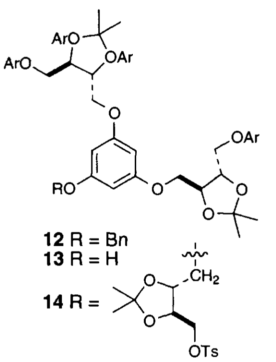


(−)-**9**

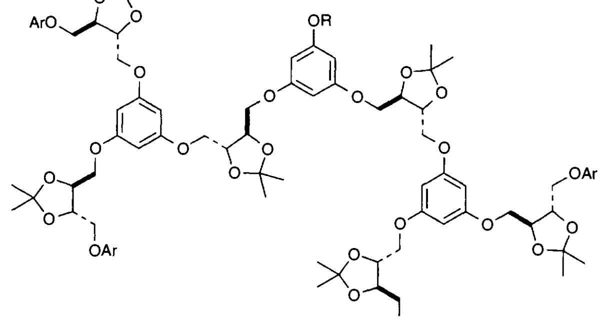


10 R = H
11 R =

Ar = 4-*tert*-butylphenyl



12 R = Bn
13 R = H
14 R =



15 R = Bn
16 R = H

(D)-(+)-**4**[5] (K_2CO_3 in DMF, 90 °C) to give layer-block sector **5**† in 57% yield. Attachment of two equivalents of sector **5** to 5-benzyloxyresorcinol **6**[3] (Cs_2CO_3, DMF) furnished the bis-*O*-alkylated benzyl ether **7**† in 55% yield. Subsequent hydrogenolysis (10% Pd–C, EtOH–EtOAc) followed by attachment (Cs_2CO_3, DMF) of a third layer-block sector **5** to the resulting phenol **8** gave the layer-block dendrimer **1**† in an overall 46% yield as a white foam.

Preparation of the other layer-block first generation dendrimer **2** proved to be problematic. The bottleneck was the inefficient mono-*O*-alkylation (Cs_2CO_3, DMF) of 5-benzyloxyresorcinol **6** with the tosylate (−)-**9**[3] to give the mono-*O*-alkylated compound **10**.† In all conditions tried, the bis-*O*-alkylation product **11**[3] was always isolated in substantial amounts even when a large excess of **6** was used. In the end, we could only isolate the desired product **10** in 34% yield together with 28% of **11**. Reaction (Cs_2CO_3, DMF) of the mono-*O*-alkylated compound **10** with 1 equivalent of linker (D)-(+)-**9**[3] gave the C_{2v} symmetrical benzyl ether **12**† as a white foam in 89%. After hydrogenolysis (10% Pd–C, EtOH–EtOAc) and further mono-*O*-alkylation (K_2CO_3, DMF) of the phenol **13** with excess (D)-(+)-**4**, the dendritic 'wedge' **14**† could be obtained in 54% yield. This dendritic wedge was then transformed to the phenol **16**† of the next generation and finally to the layer-block dendrimer **2** in an overall 14% yield as a white foam following the procedures described for **5**.

The optical rotational properties of these compounds were noteworthy (Table 1). It was noted that the chiroptical effect of the (L)-tartrate chiral unit cancelled that of the (D)-tartrate unit on a one to one basis. As a consequence, the overall molar rotation of the dendritic fragment was proportional to the number of (D)- or (L)-tartrate units in excess. Thus, each individual chiral tartaric unit, irrespective of its position inside the dendritic matrix, contributed to the overall molar rotation to the same absolute extent with the sign of rotation depending on its absolute configuration. This result further suggested that these lower generation dendritic molecules had a highly ordered three dimensional structure. Compounds **12** and **13**, having C_{2v} symmetry, in principle should be devoid of optical activity, but they do have very small specific rotational values. This could be due to the presence of a very small amount of chiral impurities.

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Footnote

† All compounds gave satisfactory ^1H and ^{13}C NMR spectral and elemental analysis results.

References

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5 Compound (D)-(+)-**4** was prepared from (D)-tartaric acid by the methods described for its antipode, see E. A. Mash, K. A. Nelson, S. van Deusen and S. B. Hemperly, *Org. Synth.*, 1990, **68**, 92; T. Morimoto, M. Chiba and K. Achiwa, *Tetrahedron*, 1993, **49**, 1793.

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