Preparation of Chiral Diphenyl-Substituted Polyether-Diester Compounds[1†]

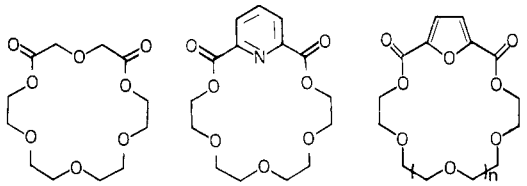
Jerald S. Bradshaw,* Scott T. Jolley, and Reed M. Izatt

Department of Chemistry, Brigham Young University, Provo, Utah 84602

Received September 29, 1981

A new series of chiral polyether-diester ligands has been prepared by reacting racemic and chiral diphenyl-substituted tetraethylene glycols with diglycolyl chloride (**5** and **6**), 2,5-furandicarbonyl chloride (**7** and **8**), 2,6-pyridinedicarbonyl chloride (**9–12**), and 4-methoxy-2,6-pyridinedicarbonyl chloride (**13**). The chiral diphenyl-substituted tetraethylene glycols were prepared from the *dl*-, (*S*)-, and (*R*)-mandelic acids.

The synthesis and cation complexing properties of macrocyclic polyether-diester ligands have been reported by us.[2-9] In general, the diester analogues of the crown compounds (i.e., **1–4**) are relatively easy to prepare and they do form weak complexes with the alkali, alkaline earth, and alkylammonium cations.[5] We now report the



1 **2** **3** n = 1 **4** n = 2

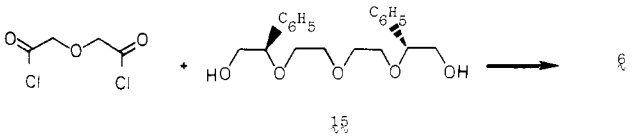
preparation of a series of chiral macrocyclic compounds in order to study complexes between chiral macrocyclic ligands and chiral alkylammonium salts. The chiral ligands include the dimethyl-substituted compounds reported previously[10] and the diphenyl ligands shown in Figure 1. Note that the diphenyl substituents are attached to the carbon atoms β to the ester groups, while the dimethyl substituents are located on the α-carbon atoms (compare Figures 1 and 2). This paper covers only the preparation of the diphenyl ligands. A detailed account of their complexation properties with chiral alkylammonium salts will be reported when that work is finished.

A recent review[11] has described the chiral macrocyclic ligands prepared by other workers. Some complexation studies with chiral macrocyclic ligands and chiral alkylammonium salts have also been performed. Stoddart and co-workers have prepared a variety of chiral ligands containing carbohydrate units.[12] They observed a modest amount of chiral recognition using the temperature-dependent ^{1}H NMR technique[13] when those chiral ligands were complexed with chiral alkylammonium salts.[14,15] Cram and co-workers have shown definite chiral recognition when complexing their chiral macrocyclic ligands containing binaphthyl units with chiral ammonium salts.[16,17]

Results and Discussion

The macrocyclic ligands shown in Figure 1 were prepared by reacting the appropriate diacid chloride and diphenyl-substituted tetraethylene glycol (Figure 1) in rapidly stirring benzene. For example, ligand **6** was prepared by reacting glycol **15** with diglycolyl chloride.

The structures proposed for the diphenyl-substituted macrocyclic compounds are consistent with data obtained



15 **6**

from IR, ^{1}H NMR spectra,[4,6,8,9] combustion analyses, and molecular weight determinations. Table I compares the physical properties of compounds **5–13** with the chiral dimethyl-substituted compounds[10] and other macrocyclic polyether-diester ligands. Figure 2 shows the other compounds listed in Table I.

The preparation of the starting diphenyl-substituted tetraethylene glycols (**14–17**, Figure 1) proved to be the most difficult part of the synthesis. We had determined previously that large alkyl groups attached to the first and last carbon atoms of tetraethylene glycol caused a significant decrease in the yield of the ring-closure reaction with the diacid chloride.[18] Therefore, we used a different approach for the synthesis of the chiral diphenyl-substituted glycols than that used for the chiral dimethyl glycols.[10,19] Scheme I shows the synthesis of (*S*,*S*)-**15** starting with (*S*)-mandelic acid, (*S*)-(+)-**29**. Stereospecificity for the

† Contribution No. 270 from the Institute for Thermochemical Studies.

(1) Presented in part at the 8th International Congress of Heterocyclic Chemistry, Graz, Austria, 23–28 Aug 1981.
(2) Izatt, R. M.; Lamb, J. D.; Maas, G. E.; Assay, R. E.; Bradshaw, J. S.; Christensen, J. J. *J. Am. Chem. Soc.* **1977**, *99*, 2365–2366.
(3) Izatt, R. M.; Lamb, J. D.; Asay, R. E.; Maas, G. E.; Bradshaw, J. S.; Christensen, J. J.; Moore, S. S. *J. Am. Chem. Soc.* **1977**, *99*, 6134–6136.
(4) Bradshaw, J. S.; Maas, G. E.; Lamb, J. D.; Izatt, R. M.; Christensen, J. J. *J. Am. Chem. Soc.* **1980**, *102*, 467–474.
(5) Lamb, J. D.; Izatt, R. M.; Swain, C. S.; Bradshaw, J. S.; Christensen, J. J. *J. Am. Chem. Soc.* **1980**, *102*, 479–482.
(6) Bradshaw, J. S.; Baxter, S. L.; Lamb, J. D.; Izatt, R. M.; Christensen, J. J. *J. Am. Chem. Soc.* **1981**, *103*, 1821–1827.
(7) Bradshaw, J. S.; Asay, R. E.; Baxter, S. L.; Fore, P. E.; Jolley, S. T.; Lamb, J. D.; Maas, G. E.; Thompson, M. D.; Izatt, R. M.; Christensen, J. J. *Ind. Eng. Chem. Prod. Res. Dev.* **1980**, *19*, 86–91.
(8) Maas, G. E.; Bradshaw, J. S.; Izatt, R. M.; Christensen, J. J. *J. Org. Chem.* **1977**, *42*, 3937–3941.
(9) Bradshaw, J. S.; Asay, R. E.; Maas, G. E.; Izatt, R. M.; Christensen, J. J. *J. Heterocycl. Chem.* **1978**, *15*, 825–831.
(10) Jones, B. A.; Bradshaw, J. S.; Izatt, R. M. *J. Heterocycl. Chem.* **1982**, in press.
(11) Jolley, S. T.; Bradshaw, J. S.; Izatt, R. M. *J. Heterocycl. Chem.* **1982**, in press.
(12) Stoddart, J. F. *Chem. Soc. Rev.* **1979**, *8*, 85–142.
(13) For a review, see Baxter, S. L.; Bradshaw, J. S. *J. Heterocycl. Chem.* **1981**, *18*, 233–245.
(14) Laidler, D. A.; Stoddart, J. F. *Tetrahedron Lett.* **1979**, 453–456.
(15) Andrews, D. G.; Ashton, P. R.; Laidler, D. A.; Stoddardt, J. F.; Wolstenholme, J. B. *Tetrahedron Lett.* **1979**, 2629–2632.
(16) Kyba, E. P.; Timko, J. M.; Kaplan, L. J.; deJong, F.; Gokel, G. W.; Cram, D. J. *J. Am. Chem. Soc.* **1978**, *100*, 4555–4568.
(17) Gokel, G. W.; Timko, J. M.; Cram, D. J. *J. Chem. Soc., Chem. Commun.* **1975**, 394–396.
(18) Jolley, S. T.; Bradshaw, J. S. *J. Org. Chem.* **1980**, *45*, 3554–3559.
(19) Cooper, K. D.; Walborsky, H. M. *J. Org. Chem.* **1981**, *46*, 2110–2113.

0022-3263/82/1947-1229$01.25/0

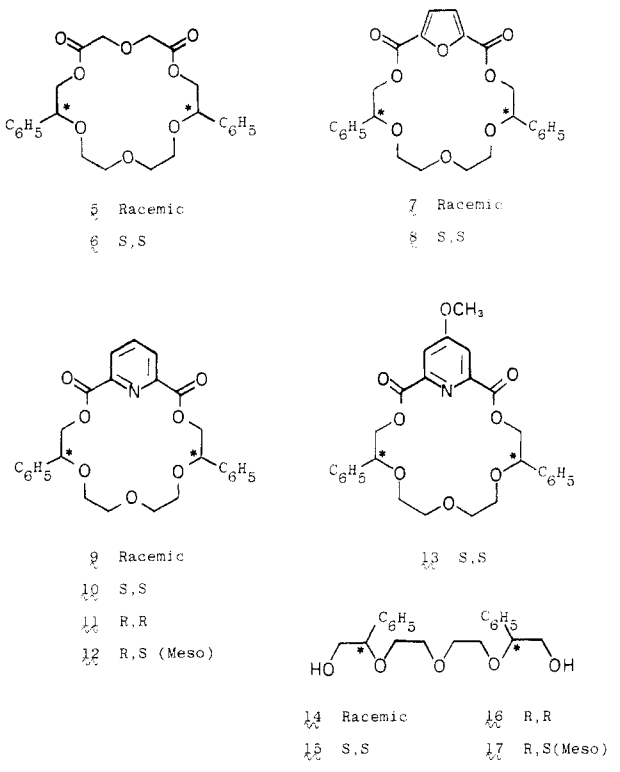


Figure 1. New compounds prepared in this study.

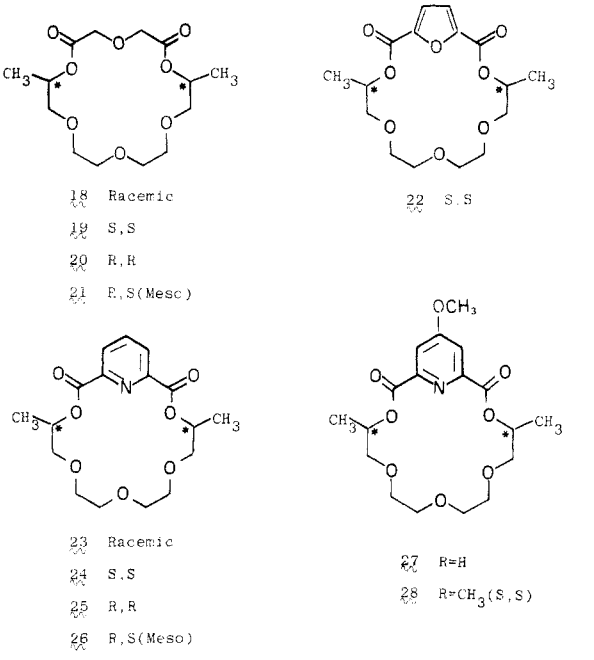


Figure 2. Other ligands listed in Table I.

reduction of (*S*)-(+)-**29** was shown by Dale and Mosher.[20] Some of the intermediate compounds could not be purified and characterized (see Experimental Section); however, the final glycols **14** and **15** were found to be pure compounds.

Meso glycol **17** was prepared by the method shown in Scheme II. In this case an excess of diethylene glycol ditosylate was added to the *R* monoblocked glycol **31**. The resulting phenyl-substituted triethylene glycol derivative [(*R*)-**33**] was then reacted with the sodium salt of the *S*

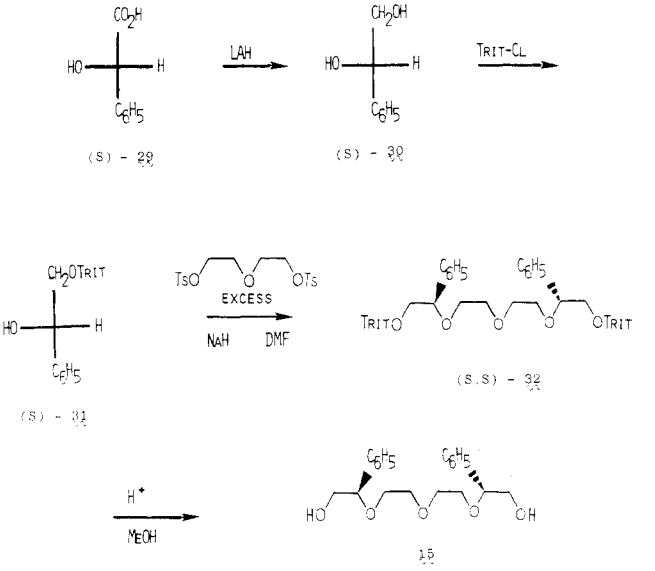
(20) Dale, J. A.; Mosher, H. S. *J. Org. Chem.* **1970**, *35*, 4002–4003.
(21) Bradshaw, J. S.; Jolley, S. T. *J. Heterocycl. Chem.* **1979**, *16*, 1157–1161.

Table I. A Comparison of the Physical Properties for the Diphenyl Ligands and Other Chiral and Achiral Macrocyclic Polyether-Diester Compounds[a]

compd	% yield	mp (bp), °C	$[\alpha]_D$	ref
1	35	78.5-79.5		8
18	32	(170-172/1 mm)		21
19	22	(170-172/1 mm)	+46.5	10
20	17	63-66[b]	−46.1	10
21	24	liquid		10
5	36	liquid		
6	43	76-78[b]	+90.7	
3	60	117-118		6
22	23	80	−27.3	10
7	40	186.5-187.5		
8	26	130-132	+90.4	
2	78	86.5-87.5		9
23	19	81-83		21
24	49	94	−13.7	10
25	24	91-92	+13.2	10
26	38	102-103		10
9	21	164.5-166		
10	51	126-128	+87	
11	44	127-128	−91	
12	49	100-102		
27	54	116-117		4
28	17	98-99	−6.9	10
13	28	140-142	+80.9	

[a] Compound structures are given in the text and Figures 1 and 2. [b] Melting point of the hydrate.

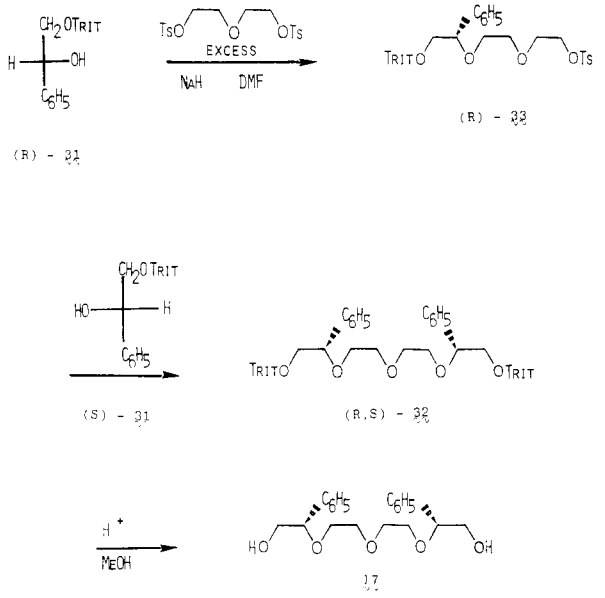
Scheme I



monoblocked glycol **31** to give the diblocked tetraethylene glycol compound [(*R,S*)-**32**]. An added bonus of the reaction sequence shown in Scheme II is that some *R,R*-diblocked tetraethylene glycol compound [(*R,R*)-**32**, see Scheme I] was also isolated with the (*R*)-**33** in the first step. Compound **16** was produced from the (*R,R*)-**32** byproduct by the procedure shown in Scheme I. It is important to note that all four glycols (**14–17**) gave IR and ^{1}H NMR spectra consistent with the proposed structures and that glycols **15** and **16** exhibited nearly the same specific rotations only opposite in sign (+105° vs. −103°, respectively).

In general, the diphenyl-substituted macrocyclic compounds had higher melting points than the unsubstituted or dimethyl-substituted compounds (compare compounds **3** and **22** with **7** and **8** and **2** and **23–26** with **9–12** in Table I). Normally one expects the racemic compound to have the lower melting point. This is the case with the dimethyl compounds **23–26**. The racemic diphenyl compound (**9**),

Scheme II



on the other hand, had the highest melting point (see Table I).

We are now starting a study of the complexation of these chiral diphenyl-substituted ligands as well as the dimethyl analogues (18–28, Figure 2) with chiral alkylammonium salts. The full details of this study will be reported at a future time.

Experimental Section

All infrared (IR) spectra were obtained with a Perkin-Elmer 457 or a Beckman Acculab 2 spectrophotometer. Proton nuclear magnetic resonance spectra (^{1}H NMR) were obtained on a Varian EM-390 or a JEOL FX-90Q spectrometer. All ^{1}H NMR spectra were run in deuteriochloroform, using tetramethylsilane as an internal standard. ^{13}C NMR spectra were obtained on a JEOL FX-90Q spectrometer using deuteriochloroform as the solvent. Molecular-weight determinations were done by osmometry on a Hitachi Perkin-Elmer Model 115 molecular-weight apparatus. Melting points were determined on a Thomas-Hoover capillary-type melting-point apparatus and are uncorrected. Optical rotations were determined with a Perkin-Elmer Model 141 polarimeter. Elemental analyses were performed by MHW Laboratories, Phoenix, AZ.

All starting acid chlorides were prepared in our laboratory as we have reported previously.[8,9] The starting diphenyl-substituted glycols were prepared as outlined below.

(*S*,*S*)-(+)-2,10-Diphenyl-3,6,9-trioxaundecane-1,11-diol (15; Scheme I). (*S*)-(+)-Mandelic acid [(*S*)-(+)-**29**; Aldrich; 50 g, 0.42 mol] was reduced by treatment with 16 g (0.42 mol) of lithium aluminium hydride in anhydrous diethyl ether to give 31 g (68%) of (*S*)-(+)-phenyl-1,2-ethanediol [(*S*)-(+)-**30**]: mp 66–68 °C (lit.[20] value, 63–65 °C); $[\alpha]^{25}_D$ +37.5° (*c* 3.37, 95% ethanol) (lit. value,[20] −39.7° for the *R* isomer); IR same as that found in Sadtler. Compound (*S*)-(+)-**30** (30 g, 0.217 mol) was stirred with 60.4 g (0.217 mol) of triphenylmethyl chloride in 200 mL of pyridine at room temperature for 16 h. The crude product was dissolved in ether and washed with water to remove the excess pyridine. The ether solution was dried, filtered, and evaporated under reduced pressure. The resulting solid (mp 82–84 °C) was found to contain 1 equiv of pyridine. The pyridine was removed as an azeotrope with toluene and the resulting (*S*)-(+)-1,4,4,4-tetraphenyl-3-oxa-1-butanol [(*S*)-(+)-**31**] could not be further purified: $[\alpha]^{25}_D$ +7.5° (*c*, 1.94, $CHCl_3$); ^{1}H NMR δ 2.99 (s, 1 H, OH), 3.33 (d, 2 H, *J* = 6 Hz, OCH_2), 4.69 (t, 1 H, *J* = 6 Hz, CH), 7.19 (m, 15 H), 7.35 (m, 5 H).

Anal. Calcd for $C_{27}H_{24}O_2$: mol wt, 380.5. Found: mol wt, 358.

Compound (*S*)-(+)-**31** (80 g, 0.21 mol) in 200 mL of rapidly stirring dry dimethylformamide was reacted with 15 g (0.31 mol) of 50% sodium hydride. The reaction temperature rose to 60 °C and some foaming occurred. After hydrogen ceased to be evolved (about 2 h), 43.5 g (0.105 mol) of diethylene glycol ditosylate in 200 mL of dry dimethylformamide was added at a slow rate to minimize foaming. The resulting mixture was stirred overnight at 80 °C. After the mixture was cooled, 200 mL of cold water was added to destroy the excess sodium hydride. The reaction mixture was then extracted 4 times with 100-mL portions of ether. The combined ether extracts were washed with water, dried, and evaporated under reduced pressure. The crude (*S*,*S*)-(+)-1,1,1,4,12,15,15,15-octaphenyl-2,5,8,11,14-pentaoxapentadecane [(*S*,*S*)-(+)-**32**], thus obtained [about 60%; $[\alpha]^{25}_D$ +14° (*c* 2.75, $CHCl_3$)], was used in the next step without further purification.

A 30-fold excess of methanol was added to compound (*S*,*S*)-(+)-**32** in a 500-mL round-bottom flask. The stirred mixture was heated to reflux temperature and 2 mL of concentrated aqueous hydrochloric acid was added. The solid (*S*,*S*)-(+)-**32** dissolved within 10 min. The solution was refluxed overnight. The reaction mixture was then cooled to −20 °C, whereupon most of the methyl triphenylmethyl ether separated as a solid. The residue, after the solid was filtered and the methanol removed, was purified by chromatography on silica gel, using a 2:1 mixture of ether and acetone as the eluant. (*S*,*S*)-(+)-Diphenyl-3,6,9-trioxaundecane-1,11-diol (**15**) was recrystallized from hexane: mp 85.5–87.5 °C; $[\alpha]^{25}_D$ +105° (*c* 0.475, $CHCl_3$); IR 3500 (sharp), 3100–3400 (br), 1100 (sharp) cm^{-1}; ^{1}H NMR δ 3.67 (s, 12 H, OCH_2), 4.50 (m, 4 H), 7.34 (s, 10 H).

Anal. Calcd for $C_{20}H_{26}O_5$: C, 69.34; H, 7.57; mol wt, 346.4. Found: C, 69.14; H, 7.42; mol wt, 340.

Racemic diol **14** was prepared in the same manner as reported above for racemic mandelic acid. This product was an oil which gave the same ^{1}H NMR and IR spectra.

Anal. Calcd for $C_{20}H_{26}O_5$: C, 69.34; H, 7.57; mol wt, 346.4. Found: C, 69.12; H, 7.52; mol wt, 347.

(*R*,*S*)-2,10-Diphenyl-3,6,9-trioxaundecane-1,11-diol (17) and (*R*,*R*)-(−)-2,10-Diphenyl-3,6,9-trioxaundecane-1,11-diol (16; Scheme II). Compound (*R*)-(−)-**31**, $[\alpha]^{25}_D$ −7.5° (*c* 2.01, $CHCl_3$), prepared as described above for (*S*)-(+)-**31** (80 g, 0.21 mol), was treated with 15 g (0.31 mol) of sodium hydride in 200 mL of dimethyl formamide. Diethylene glycol ditosylate (140 g, 0.34 mol) in 100 mL of benzene was added and the reaction mixture was stirred at room temperature for 2 days. The mixture was added to cold water and extracted with ether to give a mixture of crude (*R*)-(−)-**33** and (*R*,*R*)-(−)-**32**. These compounds were separated on silica gel, using a 2:1 mixture of hexane and ethyl ether as eluant. Compound (*R*)-(−)-**33** was eluted first as a thick syrup: 76 g (58%); $[\alpha]^{25}_D$ −10.5° (*c* 1.2, $CHCl_3$); IR (neat) 1360, 1190, 1175 cm^{-1}; ^{1}H NMR δ 2.31 (s, 3 H, CH_3), 3.0–3.6 (m, 8 H, OCH_2), 4.09 (m, 2 H, SO_3CH_2), 4.39 (t, 2 H, *J* = 6.0 Hz, CH), 7.26 (m, 22 H), 7.73 (m, 2 H). This material was used without further purification in the next step in the preparation of (*R*,*S*)-**32**.

Compound (*R*,*R*)-(−)-**32**, $[\alpha]^{25}_D$ −13° (*c* 0.434, $CHCl_3$), was eluted after (*R*)-(−)-**33**. This material was treated with acidified methanol as in the preparation of **15** to give (*R*,*R*)-(−)-2,10-diphenyl-3,6,9-trioxaundecane-1,11-diol (**16**): 4.2 g (5%); mp 82–84 °C; $[\alpha]^{25}_D$ −103° (*c* 0.442, $CHCl_3$); IR and ^{1}H NMR were the same as above for compound **15**.

Anal. Calcd for $C_{20}H_{26}O_5$: C, 69.34; H, 7.57; mol wt, 346.4. Found: C, 69.06; H, 7.65; mol wt, 358.

Compound (*R*,*R*)-(−)-**33** was added to an equimolar amount of (*S*)-(+)-**31** which had been treated with sodium hydride. The resulting mixture was treated as above for the preparation of (*S*,*S*)-(+)-**32** to give (*R*,*S*)-**32**. This material was hydrolyzed in acidified methanol as reported above for compound **15** and chromatographed on silica gel, using ether as the eluant, to give a poor yield of (*R*,*S*)-2,10-diphenyl-3,6,9-trioxaundecane-1,11-diol (**17**) as an oil: IR and ^{1}H NMR were the same as reported for **15**.

Anal. Calcd for $C_{20}H_{26}O_5$: C, 69.34; H, 7.57; mol wt, 346.4. Found: C, 68.91; H, 7.60; mol wt, 344.

General Procedure for the Synthesis of Macrocyclic Compounds. The glycol and acid chloride in separate 250-mL portions of benzene (25 mL of tetrahydrofuran was also used with 2,6-pyridinedicarbonyl chloride) were simultaneously added to 1 L of rapidly stirring benzene at 50 °C. After the hydrogen chloride had ceased to be evolved (usually 2 days), the solvent was removed under reduced pressure. The product was isolated

from the crude polymer–monomer mixture by vacuum distillation, recrystallization, or a hot hexane extraction technique.[8,9] Specific details will be given for each compound.

9,17-Diphenyl-1,4,7,10,13,16-hexaoxacyclooctadecane-2,6-dione (5). Diglycolyl dichloride (1.71 g, 0.01 mol) and 3.5 g (0.01 mol) of glycol **14** were reacted together. The crude mixture was purified by a hot hexane extraction to give 1.6 g (36%) of a yellow liquid: IR (neat) 1750 cm^{-1}; ^1H NMR δ 3.62 (m, 8 H, OCH_2), 4.28 (m, 4 H, $COOCH_2$), 4.40 (m, 4 H, $COCH_2$), 4.63 (m, 2 H, $COOCH_2CH$), 7.33 (s, 10 H).

Anal. Calcd for $C_{24}H_{30}O_8$: C, 64.85; H, 6.35; mol wt, 444.5. Found: C, 65.00; H, 6.43; mol wt, 450.

(*S*,*S*)-(+)-9,17-Diphenyl-1,4,7,10,13,16-hexaoxacyclooctadecane-2,6-dione (6). Diglycolyl dichloride (6.32 g, 0.037 mol) and 12.8 g (0.037 mol) of glycol **15** were reacted. A thick yellow liquid (7.0 g, 42.7%) was isolated by a hot hexane extraction. This liquid crystallized in the presence of water to form a hydrate: mp 76–78 °C; $[\alpha]_D$ +90.7° (*c* 0.357, $CHCl_3$); IR (neat) 1745 cm^{-1}; IR (KBr) 1720, 1745 cm^{-1}; ^1H NMR δ 3.60 (s, 8 H, OCH_2), 4.27 (m, 4 H, $COOCH_2$), 4.40 (s, 4 H, $COCH_2$), 4.65 (m, 2 H, $COOCH_2CH$), 7.34 (s, 10 H).

Anal. Calcd for $C_{24}H_{20}O_8$ (dried over P_2O_5): C, 64.85; H, 6.35; mol wt, 444.5. Found: C, 64.76; H, 6.36; mol wt, 443.

5,13-Diphenyl-3,6,9,12,15,20-hexaoxobicyclo[15.2.1]eicosa-17,19-diene-2,16-dione (7). 2,5-Furandicarbonyl chloride (1.55 g, 0.008 mol) and glycol **14** (2.75 g, 0.008 mol) were used. The crude material was dissolved in acetone and a white crystalline material (1.5 g, 40%) with a broad melting point (162–180 °C) separated. Recrystallization from benzene and then from acetone gave large crystals, mp 186.5–187.5 °C, and some finer crystals, mp 167–170 °C, which could not be purified further: IR (KBr) 1705 cm^{-1}; ^1H NMR δ 3.73 (s, 8 H, OCH_2), 4.24 (m, 2 H, $COOCH_2CH$), 4.70 (m, 4 H, $COOCH_2$), 7.30 (s, 2 H, furano H), 7.38 (s, 10 H).

Anal. Calcd for $C_{26}H_{28}O_8$: C, 66.94; H, 5.62; mol wt, 466.5. Found: C, 66.81; H, 5.62; mol wt, 470.

(*S*,*S*)-(+)-5,13-Diphenyl-3,6,9,12,15,20-hexaoxabicyclo-[15.2.1]eicosa-17,19-diene-2,6-dione (8). 2,5-Furandicarbonyl chloride (6.8 g, 0.035 mol) and 12.1 g (0.035 mol) of glycol **15** were reacted. The product was purified by a hot hexane extraction to give 4.2 g (25.8%) of a white crystalline material: mp 130–132 °C; $[\alpha]^{25}_D$ +90.4° (*c* 0.397, $CHCl_3$); IR (KBr) 1710 cm^{-1}; ^1H NMR δ 3.72 (s, 8 H, OCH_2), 4.24 (m, 2 H, $COOCH_2CH$), 4.69 (m, 4 H, $COOCH_2$), 7.30 (s, 2 H, furano H), 7.37 (s, 10 H).

Anal. Calcd for $C_{26}H_{28}O_8$: C, 66.94; H, 5.62; mol wt, 466.5. Found: C, 67.07; H, 5.59; mol wt, 471.

5,13-Diphenyl-3,6,9,12,15-pentaoxa-21-azabicyclo[15.3.1]-heneicosa-1(21),17,19-triene-2,16-dione (9). 2,6-Pyridinedicarbonyl chloride (4.08 g, 0.02 mol) and 6.9 g (0.02 mol) of glycol **14** were reacted. The product was separated by a hot hexane extraction followed by recrystallization from acetone to give 2.0 g (21%) of fine white crystals: mp 164.5–166 °C; IR (KBr) 1725 cm^{-1}; ^1H NMR δ 3.75 (s, 8 H, OCH_2), 4.6 (m, 6 H, $COOCH_2CH$), 7.43 (s, 10 H), 7.8–8.4 (m, 3 H).

Anal. Calcd for $C_{27}H_{27}NO_7$: C, 67.91; H, 5.70; mol wt, 477.5. Found: C, 68.17, H, 5.78; mol wt, 461.

(*S*,*S*)-(+)-5,13-Diphenyl-3,6,9,12,15-pentaoxa-21-azabicyclo[15.3.1]heneicosa-1(21),17,19-triene-2,16-dione (10). 2,6-Pyridinedicarbonyl chloride (8.16 g, 0.04 mol) and 13.8 g (0.04 mol) of glycol **15** were reacted. The macrocycle was initially isolated by a hot hexane extraction as a liquid (9.8 g, 51%). The liquid was dissolved in acetone and cooled to give chunky white crystals: mp 126–128 °C; $[\alpha]^{25}_D$ +87° (*c* 1.85, $CHCl_3$); IR (KBr) 1720 cm^{-1}; ^1H NMR δ 3.75 (s, 8 H, OCH_2), 4.2–4.7 (m, 4 H, $COOCH_2$), 4.83 (m, 2 H, $COOCH_2CH$), 7.40 (m, 10 H), 7.9–8.4 (m, 3 H).

Anal. Calcd for $C_{27}H_{27}NO_7$: C, 67.91; H, 5.70; mol wt, 477.5. Found: C, 67.68; H, 5.91; mol wt, 473.

(*R*,*R*)-(−)-5,13-Diphenyl-3,6,9,12,15-pentaoxa-21-azabicyclo[15.3.1]heneicosa-1(21),17,19-triene-2,16-dione (11). 2,6-Pyridinedicarbonyl chloride (1.4 g, 6.8×10^{-3} mol) and 2.35 g (6.8×10^{-3} mol) of glycol **16** were reacted. Pure macrocycle (1.4 g, 44%) was obtained by crystallization: mp 127–128 °C; $[\alpha]^{25}_D$ −91° (*c* 0.398, $CHCl_3$); IR (KBr) 1720 cm^{-1}; ^1H NMR δ 3.70 (s, 8 H, OCH_2), 4.2–5.65 (ABC, 4 H, $COOCH_2$, 4.80 (m, 2 H, $COOCH_2CH$), 7.38 (m, 10 H), 7.8–8.4 (m, 3 H).

Anal. Calcd for $C_{27}H_{27}NO_7$: C, 67.91; H, 5.70; mol wt, 477.5. Found: C, 67.71; H, 5.78; mol wt, 487.

(*R*,*S*)-5,13-Diphenyl-3,6,9,12,15-pentaoxa-21-azabicyclo-[15.3.1]heneicosa-1(21),17,19-triene-2,16-dione (12). 2,6-Pyridinedicarbonyl chloride (2.35 g, 0.0115 mol) and 4.0 g (0.0115 mol) of glycol **17** were reacted. Pure macrocycle was obtained by a hot hexane extraction followed by recrystallization from methanol: 2.7 g (49%); mp 100–102 °C; IR (KBr) 1725 cm^{-1}; ^1H NMR δ, 3.66 (m, 8 H, OCH_2), 4.48 (m, 4 H, $COOCH_2$), 4.95 (m, 2 H, $COOCH_2CH$), 7.37 (m, 10 H), 7.8–8.4 (m, 3 H).

Anal. Calcd for $C_{27}H_{27}NO_7$: C, 67.91; H, 5.70; mol wt, 477.5. Found: C, 68.10; H, 5.71; mol wt, 471.

(*S*,*S*)-(+)-5,13-Diphenyl-19-methoxy-3,6,9,12,15-pentaoxa-21-azabicyclo[15.3.1]heneicosa-1(21),17,19-triene-2,16-dione (13). 4-Methoxy-2,6-pyridinedicarbonyl chloride (4.1 g, 0.0176 mol) and 6.1 g (0.0176 mol) of glycol **15** were used in this reaction. The product was purified by a hot hexane extraction followed by recrystallization from acetone to gave a solid: 2.5 g (28%); mp 140–142 °C; $[\alpha]^{25}_D$ +80.9° (*c* 0.414, $CHCl_3$); IR (KBr) 1720 cm^{-1}; ^1H NMR δ 3.71 (s, 8 H, OCH_2), 3.94 (s, 3 H, OCH_3), 4.2–4.65 (m, 4 H, $COOCH_2$), 4.80 (m, 2 H, $COOCH_2CH$), 7.38 (m, 10 H), 7.82 (s, 2 H).

Anal. Calcd for $C_{28}H_{29}NO_8$: mol wt, 507.5. Found: mol wt, 526.

Acknowledgment. This work was supported by National Science Foundation Grant CHE 80000059. We thank Mr. Brian A. Jones for his helpful discussions.

Registry No. *dl*-**5**, 80595-08-0; (*S*,*S*)-(+)-**6**, 80656-05-9; *dl*-**7**, 80595-09-1; (*S*,*S*)-(+)-**8**, 80656-06-0; *dl*-**9**, 80595-10-4; (*S*,*S*)-(+)-**10**, 80656-07-1; (*R*,*R*)-(−)-**11**, 80656-08-2; *meso*-**12**, 80595-11-5; (*S*,*S*)-(+)-**13**, 80595-12-6; *dl*-**14**, 80595-13-7; (*S*,*S*)-(+)-**15**, 80657-40-5; (*R*,*R*)-(−)-**16**, 80656-09-3; *meso*-**17**, 80595-14-8; (*R*)-(−)-**29**, 611-71-2; (*S*)-(+)-**29**, 17199-29-0; *dl*-**29**, 611-72-3; (*S*)-(+)-**30**, 25779-13-9; (*R*)-(−)-**31**, 80595-15-9; (*S*)-(+)-**31**, 80595-16-0; (*R*,*R*)-(−)-**32**, 80595-17-1; (*S*,*S*)-(+)-**32**, 80595-18-2; (*R*,*S*)-**32**, 80595-19-3; (*R*)-(−)-**33**, 80595-20-6; diethylene glycol ditosylate, 7460-82-4; triphenylmethyl chloride, 76-83-5; diglycolyl dichloride, 21062-20-4; 2,5-furandicarbonyl chloride, 10375-34-5; 2,6-pyridinedicarbonyl chloride, 3739-94-4; 4-methoxy-2,6-pyridinedicarbonyl chloride, 71045-38-0.