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A RESOLVABLE OCTAHETEROHELICENE BASED ON THE 1,3,4,6-TETRAAZAPENTALENE RING SYSTEM†

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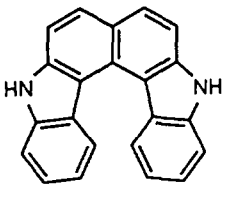
Abstract: The fluorescent octaheterohelicene, benzo[h]quinolino-[1'',2'':1',2']imidazo[4',5':4,5]imidazo[1,2-a]benzo[h]quinoline (7), has been resolved by radial chromatography on plates of silica to which (-)-TAPA and (+)-TAPA were covalently bound.

The first heterohelicene, proposed in 1927, was carbazolo[3,4-c]carbazole (1).[1] With the synthesis[2] and resolution[3] of the carbocyclic hexahelicene (2), interest in chiral compounds of the helicene and heterohelicene class developed rapidly and this area of research has been well reviewed.[4-10] In a continuing investigation in this Laboratory[11] of polycyclic compounds based on a central 1,3,4,6-tetraazapentalene moiety,[12] the hexaheterohelicene, quinolino[1'',2'':1',2']imidazo[4',5':4,5]imidazo-[1,2-a]quinoline (3), was prepared.[11a] A single crystal X-ray structure determination[11d] revealed that, at least in the solid state, compound 3 adopts a helical conformation although the terminal rings do not overlap as do those in 2. The difference is due to the larger external angles to the



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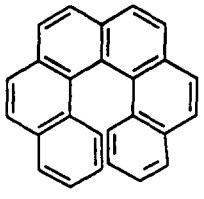

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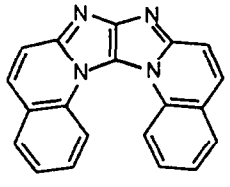

3

central five-membered rings in 3 compared with the external angles to the central six-membered rings in 2. Without clear overlap of the terminal rings, resolution of 3 would not be possible at room temperature due to the rate at which racemization would occur.

†Dedicated to the memory of Professor Roger Adams in the centennial year of his birth.

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An ORTEP drawing derived from an MMPMI[13] energy minimization of hexahelicene (2) is compared in Figure 1 with that of an octaheterohelicene formed by the extension of each of the terminal rings of 3 by one benzene ring. The overlap of the terminal rings indicates that the octaheterohelicene should be resolvable.

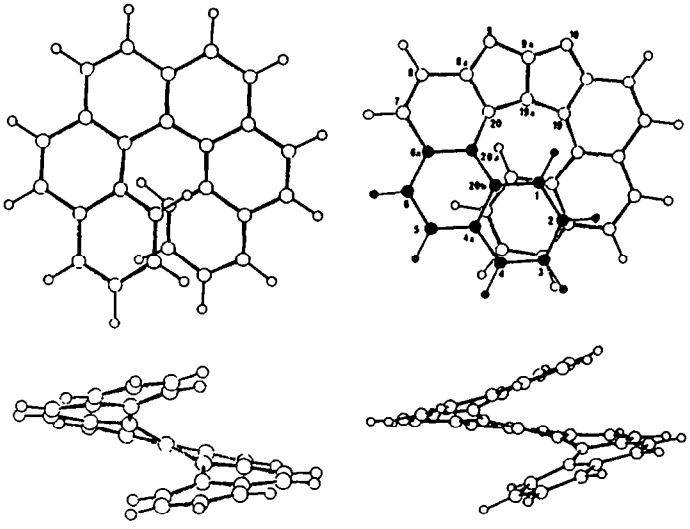
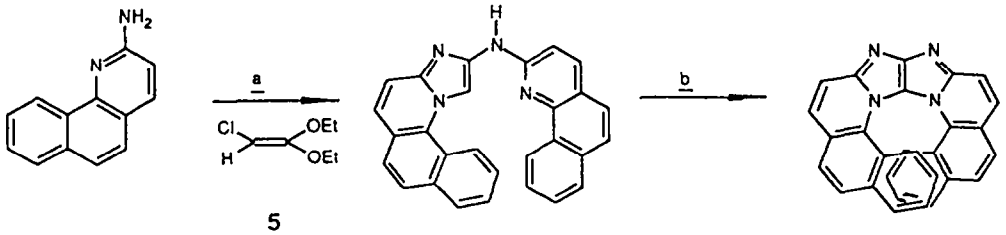


Figure 1. ORTEP drawings derived from MMPMI energy minimization of (left) hexahelicene 2 and (right) octaheterohelicene 7.

The synthesis of the octaheterohelicene 7 (Scheme I) followed methods developed during the preparation of substituted 1,3,4,6-tetraazapenta-

Scheme I



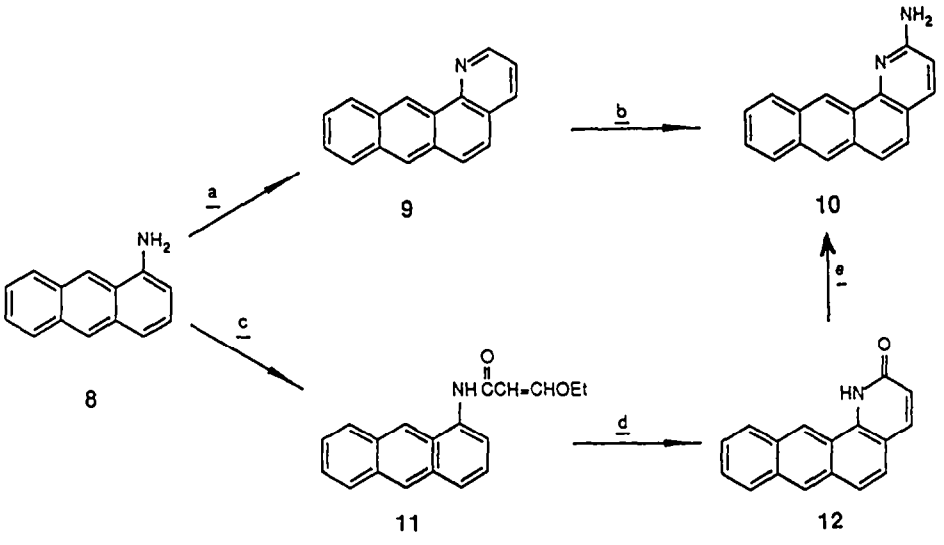
4 6 7

a, AcOH-Pyridine, 80 °C; b, $PhI(OAc)_2$, HFP-CH_3NO_2 (1:9 v/v).

lenes.[11] 2-Aminobenzo[h]quinoline (4)[14] was caused to react with chloroketene diethyl acetal (5) to provide the substituted imidazo[1,2-a]benzo[h]-quinoline 6 in 61% yield. The oxidative cyclization of 6 to the octaheterohelicene 7 was accomplished by the use of iodobenzene diacetate ((diacetoxyiodo)benzene). The best yield of 7 (47%) was achieved when a solvent combination of 1,1,1,3,3,3-hexafluoro-2-propanol and nitromethane in a ratio of 1:9 was used as the solvent.

Since the octaheterohelicene 7 was prepared with ease, we proceeded to the synthesis of the related bis-benzolog 14 (Schemes II, III), which should have overlapping anthracene moieties. The problem encountered initially lay in the synthesis of the starting amine, 2-aminonaphtho[2,3-h]quinoline (10), in sufficient amount. Compound 10 was first obtained by amination of naphtho[2,3-h]quinoline (9)[15] with sodium amide in N,N-dimethylaniline at 135-140 °C in 41% yield, and since compound 9 was obtained from the N-acetyl

Scheme II

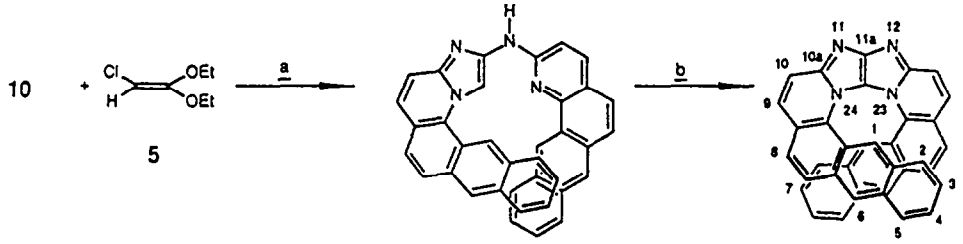


a, Skraup reaction conditions; b, $NaNH_2$, DMA; c, EtOCH=CHCOCl, toluene; d, conc. HCl, -10 °C; e, $PhOPO(NH_2)_2$, 240-250 °C.

derivative of 1-aminoanthracene (8) in only ∿ 25% yield in our hands, an alternative synthesis was sought. It was found that the amine 10 could be obtained directly from 12 by treatment with phenylphosphorodiamidate[16] in

40-50% yield, and compound **12** was available from **8**, via **11**, in an overall yield of 85% by application of the method of Effenberger and Hartmann.[17] Reaction of the amine **10** with chloroketene diethyl acetal (**5**) yielded the intermediate **13**,[18] which, on treatment with iodobenzene diacetate, underwent oxidative cyclization satisfactorily to naphtho[2,3-*h*]quinolino-[1'',2'':1',2']imidazo[4',5':4,5]imidazo[1,2-*a*]naphtho[2,3-*h*]quinoline (**14**).

Scheme III



13 14

a, CH_3CN, p-TsOH, reflux; *b*, $PhI(OAc)_2$, $(CF_3)_2C(CH_3)OH$-CH_3NO_2 (1:4, v/v).

The ^1H NMR spectrum of the octaheterohelicene **7** in $CDCl_3$ included chemical shifts of the terminal ring protons at high field, similar to those of the carbocyclic heptahelicene,[19] due to shielding of the benzene ring over (under) which they lie (see Figure 1 for numbering): H-1, H-18, δ 7.06 ppm (d, J = 8.5 Hz); H-2, H-17, 6.29 (dd); H-3, H-16, 6.97 (dd); and H-4, H-15, 7.46 (d, J = 8.0 Hz). Through proton decoupling, $^1H/^{13}C$ short range[20] and long range[21,22] correlation studies, all of the ^1H and ^{13}C NMR assignments could be made (see Experimental). The ^1H NMR spectrum of the heterohelicene **14** revealed, *inter alia*, that the δ values for the singlet protons in **9**[15] and in **10** are shifted dramatically upfield in **14**, consistent with the overlap pictured for that compound (see also Figure 2).

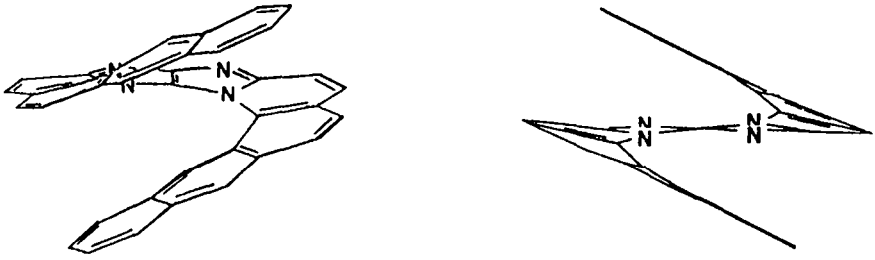


Figure 2. Drawings derived from MMPMI energy minimization of heterohelicene **14**. The structures are drawn as enantiomers to stress the potential resolvability of **14**.

As in the cases of dipyrido[1,2-a:2',1'-f]-1,3,4,6-tetraazapentalene[11b] and the hexaheterohelicene **3**,[11a] the octaheterohelicene **7** is strongly fluorescent (λ^{em}_{max} 462.5, 440 nm, Φ = 0.79, ethanol); by contrast, its extended bisbenzo derivative **14** is minimally fluorescent (λ^{em}_{max} 519.5, 494.5, Φ = 0.002, ethanol, λ^{ex}_{max} for both = 350 nm). The latter observation is consistent with the intramolecular stacking of the major portion of the ring system in **14** and suggests that the photochemistry may be worth investigating.

We have been able to resolve the racemic octaheterohelicene **7** by means of 2-(2,4,5,7-tetranitro-9-fluorenylideneaminooxy)propionic acid (TAPA).[2] It was not done by crystallographic separation of diastereomeric salts but by an adaptation of donor-acceptor complex chromatography.[23,24] 3-Aminopropyltriethoxysilane was first coupled to silica gel particles, and the free amino groups were then covalently linked with dicyclohexylcarbodiimide (DCC) to the chiral selector, either R(-)-TAPA or S(+)-TAPA.[25] Instead of using a column (HPLC)[25,26]of the treated silica, we used radial chromatography[27] for the effective separation of the enantiomers of **7**. Radial chromatography of the racemate on R(-)-TAPA bonded to silica, with hexane:methylene chloride:methanol (75:23:2) as eluent, first yielded fractions containing (-)-octaheterohelicene, followed by mixtures of (-) and (+), followed by fractions containing (+)-octaheterohelicene. The combined fractions of the (-)-isomer were rechromatographed on the R(-)-TAPA-bonded silica plate and finally on a fresh plate using the same system. The maximum (negative) specific rotation that was achieved after three stages was $[\alpha]_D^{25}$ -725° (c = 0.020, $CHCl_3$). Fractions containing the (+)-isomer were sequentially (a) combined and rechromatographed on the same R(-)-TAPA-bonded silica plate,

(b) chromatographed on an S(+)-TAPA-bonded silica plate, from which (+)-rotating fractions eluted first, and (c) purified finally by chromatography on a fresh R(-)-TAPA-bonded silica plate, from which the (+)-rotating isomer again eluted last. The maximum specific rotation that was achieved after three stages was $[\alpha]_D^{25}$ +730° (c = 0.046, $CHCl_3$).

The CD spectra of the (+)- and (-)-heterohelicenes are in mirror-image relationship (Figure 3). They exhibit up to fourteen CD bands (including inflections and shoulders) between 190 and 500 nm.

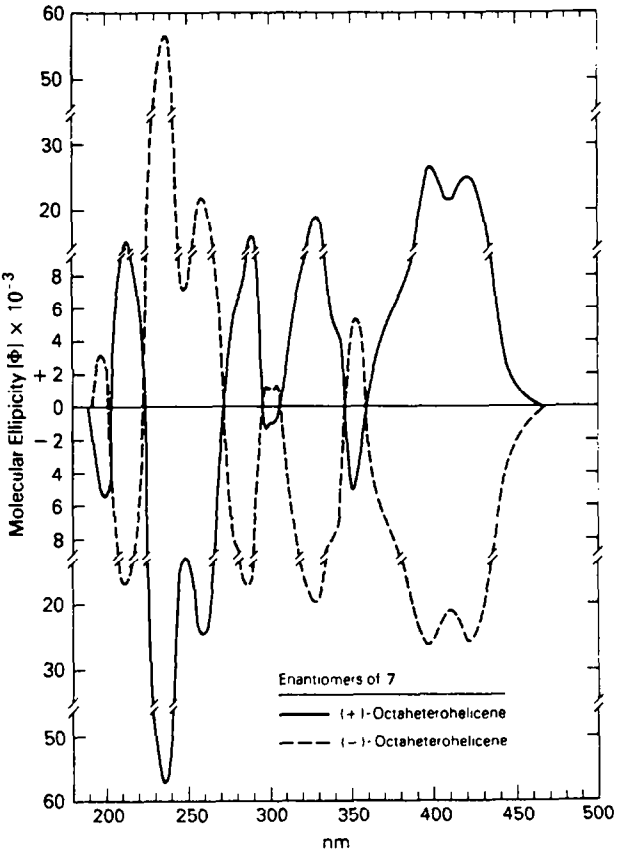


Figure 3. CD Spectra of the enantiomers of the octaheterohelicene **7** in ethanol solution.

It is tempting to regard the (-)-enantiomer of the octaheterohelicene **7** as having left-handed (M)[28] chirality and the (+)-enantiomer of **7** as having right-handed (P)[28] chirality. Such a tentative assignment of absolute configuration is based upon experimental and theoretical data that have found no exceptions to this stereochemical relationship among the helicenes and heterohelicenes that that have been studied thus far.[4,8,29-41]

It is of special interest to note that a resolvable heterohelicene can be obtained in only two steps, condensation and oxidative cyclization (Scheme I), from available starting materials, 2-aminobenzo[h]quinoline and chloroketene diethyl acetal. This sequence is illustrative of further generality. In addition to compound **14**, other heterohelicenes in the series, where there is sufficient ring overlap, are approachable by this facile route of synthesis and resolution.

EXPERIMENTAL

Instrumentation. Melting points were determined on a Büchi melting point apparatus and are uncorrected. ^{1}H NMR spectra were recorded on a General Electric QE-300 (300.15 MHz) or a Varian XL-200 (200.06 MHz) Fourier-transform spectrometer using tetramethylsilane as an internal standard. Ultraviolet/visible spectra were obtained on a Beckman Acta MVI spectrophotometer. Fluorescence excitation and emission spectra were recorded on a Spex Fluorolog IIIC spectrofluorometer coupled with a Datamate microprocessor. Mass spectra were obtained on a Varian MAT CH-5 instrument in the Mass Spectrometry Laboratory, School of Chemical Sciences. Elemental analyses were performed by Thomas McCarthy and his staff at the University of Illinois. The optical rotations were recorded on a JASCO model DIP 360 digital spectropolarimeter. The CD spectra were recorded in ethanol at normal temperature on a JASCO model J-500A recording spectropolarimeter equipped with a Model DP-500N data processor and an IBM BC-XT computer. The results, obtained at Hoffmann-LaRoche, Inc., Nutley, New Jersey, are summarized in Figure 3.

Chemicals. 2-Aminoanthracene, 7,8-benzoquinoline (benzo[h]quinoline), (-)-TAPA, (+)-TAPA, and TLC grade silica gel (ave. particle size 5-25 μ) were purchased from Aldrich Chemical Company, Milwaukee, Wisconsin. Phenylphosphorodiamidate was purchased from Alfa Products, Danvers, Massachusetts. 1,1,1,3,3,3-Hexafluoro-2-propanol (HFP) and 1,1,1,3,3,3-hexafluoro-2-methyl-2-propanol from SCM Specialty Chemicals.

N-(2-Benzo[h]quinolinyl)imidazo[1,2-a]benzo[h]quinolin-2-amine (**6**). 2-Aminobenzo[h]quinoline (1.0 g, 5.15 mmol), prepared by the direct amina-

tion of 7,8-benzoquinoline,[14] in pyridine-acetic acid (40 mL, 1:1) was heated to 80 °C. Chloroketene diethyl acetal (0.40 g, 2.6 mmol) was added, and heating at 80 °C was continued for 8.5 h, followed by cooling to 0 °C. (CAUTION! Chloroketene diethyl acetal is a mutagen and should be handled with caution in a well ventilated hood, with suitable trapping.) The yellow precipitate was collected by filtration, was washed with water followed by methanol, and was dried to give 0.64 g (61%) of **6**. The reaction was repeated on a larger scale. An analytical sample was obtained by recrystallization from DMF-H_2O, mp > 250 °C. ^1H NMR ($(CD_3)_2SO$) δ 10.63 (s, 1), 10.06 (s, 1), 9.53 (d, J = 8.4 Hz, 1), 9.33 (m, 1), 8.32 (d, J = 7.5 Hz, 1), 8.26 (d, J = 8.7 Hz, 1), 7.95-8.08 (m, 5), 7.70-7.83 (m, 6), 7.45 (d, J = 8.7 Hz, 1); UV λ_{max} nm: (EtOH) 400, 326, 280, 240, 224; EI-Mass spectrum (70 eV) m/z (rel intensity) 411 (21), 410 (M^+, 67), 409 (12), 206 (14), 205 (25), 194 (100), 178 (14), 167 (33), 140 (12), 139 (12). Calcd for $C_{28}H_{18}N_4$: C, 81.93; H, 4.42; N, 13.65. Found: C, 82.07; H, 4.38; N, 13.72.

Benzo[h]quinolino[1'',2'':1',2']imidazo[4',5':4,5]imidazo[1,2-a]benzo-[h]quinoline (7). Iodobenzene diacetate ((diacetoxyiodo)benzene) (1.6 g, 5 mmol) in 25 mL of a solution of HFP-CH_3NO_2 (1:9, v/v) was added dropwise to a suspension of **6** (2.0 g, 5 mmol) in 75 mL of HFP-CH_3NO_2 (1:9, v/v) and the reaction mixture was stirred at 25 °C for 1.5 h. The solvent was removed, and crude **7** was obtained by column chromatography on silica gel, with $CHCl_3$ and $CHCl_3$:MeOH (95:5) as eluents. Pure **7** (0.94 g, 47% yield) was obtained by column chromatography[27] on silica gel using $CHCl_3$:MeOH (98:2) and (90:10) as eluent, followed by recrystallization from $CHCl_3$:hexane, mp > 250 °C. ^1H and corresponding ^{13}C NMR ($(CD_3)_2SO$) δ H-1, H-18 (7.06, d, J = 8.5 Hz; C1, C18, 120.5); H-2, H-17 (6.29, dd; 123.2); H-3, H-16 (6.97, dd; 125.9); H-4, H-15 (7.46, d, J = 8.0 Hz; 126.5); H-5, H-14 (7.69, d, J = 8.5 Hz; 125.2); H-6, H-13 (7.86, d, J = 8.5 Hz; 124.3); H-7, H-12 (7.90, d, J = 9.2 Hz; 126.1); H-8, H-11 (8.10, d, J = 9.2 Hz; 116.7). The quarternary carbons were assigned as follows: 4a, 14a (131.3); 6a, 12a (120.6); 8a, 10a (147.1); 9a (154.6); 18a, 20b (125.6); 18b, 20a (130.5); 19a (123.6). UV λ_{max} nm (ε x 10^3, L mol^{-1} cm^{-1}): (EtOH) 420 (8.5), 397 (8.5), 354 (10.1), 328 (16.0), 309 (19.2), 290 (23.2), 256 (30.2), 238 (33.0), 211 (41.8). EI-Mass spectrum (70 eV) m/z (rel intensity) 409 (31), 408 (M^+, 100), 407 (6); fluorescence λ^{em}_{max} 462.5, 440.0, Φ = 0.79 (absolute ethanol) (relative to coumarin in absolute ethanol, Φ = 0.51 at λ^{ex} 350 nm, measured relative to the reported value of Φ = 0.64 at λ^{ex} 366[42]) (all excitations at 350 nm). Calcd for $C_{28}H_{16}N_4$: C, 82.34; H, 3.95; N, 13.72. Found: C, 82.32; H, 4.02; N, 13.78.

Synthesis of 2-Aminonaphtho[2,3-*h*]quinoline (**10**). Method A (**8** → **9** → **10**). 1-Acetylaminoanthracene (**8**-Ac), mp 210-211 °C, prepared by acetylation of 1-aminoanthracene, was subjected to Skraup reaction conditions to yield (25%) naphtho[2,3-*h*]quinoline (**9**), mp 131-132 °C (lit.[16] 132-133 °C), obtained anhydrous (Calcd for $C_{17}H_{11}N$: C, 89.05; H, 4.84; N, 6.11. Found: C, 88.91; H, 4.86; N, 6.07). Compound **9** (3.0 g, 13 mmol) was combined with sodium amide (2.8 g, 72 mmol) and added to *N*,*N*-dimethylaniline (25 mL). The stirred mixture was heated at 135-140 °C for 20 h, cooled, poured onto 50 g of ice, and extracted with toluene (4 x 20 mL). The combined extracts were evaporated to dryness under reduced pressure, and the residue was dry-loaded onto 100 g of silica gel. The amine was eluted with petroleum ether-ether (0-50%), appropriate fractions were combined, evaporated to dryness, and recrystallized from EtOH-H_2O to give **10** (1.3 g, 41%), mp 162-163 °C. ^1H NMR ($CDCl_3$) δ 9.65 (s, 1), 8.35 (s, 1), 8.18 (m, 1), 8.04 (m, 1), 7.91 (d, *J* = 8.4 Hz, 1), 7.66 (d, *J* = 8.7 Hz, 1), 7.54 (m, 1), 7.49 (d, *J* = 9.0 Hz, 1), 6.81 (d, *J* = 8.4 Hz, 1), 4.83 (s, 2, NH_2). UV λ_{max} nm (ε x 10^3. L mol^{-1} cm^{-1}): (EtOH) 408 (2.5), 364 (8.2), 318 (36.9), 304 (26.2), 294 (22.9), 264 (sh) (55.7), 255 (62.8), 220 (42.6). EI-Mass spectrum (70 eV) *m/z* (rel intensity) 245 (20), 244 (M^+, 100), 85 (48), 83 (75). Calcd for $C_{17}H_{12}N_2$: C, 83.58; H, 4.95; N, 11.47. Found: 83.50; H, 4.93; N, 11.47.

Method B (**8** → **11** → **12** → **10**). The intermediates **11** and **12** were mentioned by Effenberger and Hartmann,[17] but no experimental details were provided. N-(1-Anthryl)-3-ethoxy-2-propenoylamide (**11**). Cooled solutions of 3-ethoxypropenoyl cholride and 1-aminoanthracene (**8**) in toluene were combined and stirred at 25 °C for 24 h. The precipitate was collected by filtration, washed with ether, H_2O, and dried at 70 °C under vacuum to give **11** in 98% yield, pure enough to be used in the next step. An analytical sample was obtained by a single recrystallization from EtOH-H_2O, mp 209-210 °C. Calcd for $C_{19}H_{17}NO_2$: C, 78.33; H, 5.88; N, 4.81. Found: C, 78.28; H, 5.74; N, 4.75.

Naphtho[2,3-*h*]quinolin-2-one (**12**). Compound **11** (12.0 g, 41 mmol) was ground to a fine powder and added to 200 mL of conc. HCl that was precooled to -10 °C. The mixture was kept at -10 °C for 2 h, then allowed to warm to room temperature. After an additional 24 h, the solid was collected by filtration, washed with H_2O (5 x 100 mL), and dried to yield **12** (9.1 g, 91%), mp 260 °C. An analytical sample was obtained by one recrystallization from $CHCl_3$-hexane; ^1H NMR ($(CD_3)_2SO$) δ 9.64 (s, 1), 8.59 (s, 1), 8.11 (m, 3), 7.79 (m, 1), 7.64 (m, 4), 6.70 (d, 1, *J* = 9.1); FT IR (KBr) 3080, 3050, 1655, 1620, 1580, 1530, 1420, 1285, 1190 cm^{-1}; UV λ_{max} nm (ε x 10^3, L mol^{-1}

cm^{-1}): (EtOH) 421 (3.9), 398 (4.5), 376 (4.5), 376 (4.5), 321 (64.3), 307 (33.8), 266 (46.1), 256 (46.1), 248 (43.9), 210 (29.2). EI-Mass spectrum (70 eV) m/z (rel intensity) 246 (20), 245 (M^+, 100), 217 (15). Calcd for $C_{17}H_{11}NO$: C, 83.24; H, 4.52; N, 5.71. Found: C, 83.29; H, 4.28; N, 5.53.

2-Aminonaphtho[2,3-*h*]quinoline (**10**). Phenylphosphorodiamidate (9.0 g, 52 mmol) and compound **12** (5.0 g, 20 mmol) were ground to a fine powder and transferred to a 100-mL round-bottomed flask. The flask was placed into a Wood's metal bath preheated to 160 °C. The temperature was raised slowly to 240 °C while the mixture was stirred, then heated for 2 h at 240-250 °C. After cooling, the melt was treated with 60 mL of n-butylamine, and this mixture was heated at reflux for 45 min. After filtration, the filtrate was evaporated to dryness. The black residue was extracted with ether (3 x 100 mL), and the combined extracts were treated with charcoal, filtered through Celite, and treated with HCl gas. The resulting solid was isolated, washed with MeOH (100 mL), and suspended in 50 mL MeOH. A solution of 2 N NaOH was added dropwise until the yellow solid had dissolved and only a brown residue remained. The solution was filtered, and the filtrate was diluted with 200-300 mL of water. The yellow precipitate was collected by filtration, washed with 100 mL of water, and dried to give **10** (2.0 g, 40%), mp 162-163 °C.

N-(2-Naphtho[2,3-*h*]quinolinyl)imidazo[1,2-*a*]naphtho[2,3-*h*]quinolin-2-amine (**13**). Compound **10** (1.0 g, 4.0 mmol), chloroketene diethyl acetal (**5**) (0.62 g, 4.0 mmol) (CAUTION!) and *p*-toluenesulfonic acid (0.10 g) were combined in 200 mL of dry CH_3CN and stirred under nitrogen for 6 h. Additional **10** (2.0 g, 8 mmol) was added, and the solution was heated for 48 h. The solid collected by filtration was heated with 50 mL of dilute $NaHCO_3$, and the resulting solid was collected by filtration, dried, and then washed with 100 mL of hot CH_2Cl_2. The solid was dried to give **13** (0.65 g, 32%). The filtrates were combined, evaporated to dryness, and recrystallized from EtOH-H_2O to give 0.70 g of recovered **10**. An analytical sample of **13** was obtained by one recrystallization from DMF-H_2O, mp > 250 °C. ^1H NMR ($(CD_3)_2SO$) δ 10.62 (s, 1), 10.53 (s, 1), 10.05 (s, 1), 9.58 (s, 1), 8.92 (s, 1), 8.53 (s, 1), 8.40 (d, 2), 8.18 (d, 1), 7.95 (m, 3), 7.86 (m, 2), 7.73 (d, 1), 7.42 (m, 3), 7.34 (dd, 2); UV λ_{max} nm (EtOH) 376, 310, 261, 240. EI-Mass spectrum (70 eV) m/z (rel intensity) 512 (15), 511 (40), 510 (M^+, 100), 245 (22), 244 (97). Calcd for $C_{36}H_{22}N_4 \cdot 0.25H_2O$: C, 83.94; H, 4.40; N, 10.88. Found: C, 83.65; H, 4.26; N, 10.80.

Naphtho[2,3-h]quinolino[1'',2'':1',2']imidazo[4',5':4,5]imidazo[1,2-a]-naphtho[2,3-h]quinoline (**14**). A suspension of **13** (100 mg, 0.2 mmol) in 5 mL of a solution of 1,1,1,3,3,3-hexafluoro-2-methyl-2-propanol and CH_3NO_2 (1:4) was added to a solution of iodobenzene diacetate (300 mg, 0.9 mmol) in 15 mL of the same solvent heated at reflux. After the addition of **13**, the mixture was maintained at reflux for an additional 20 min, then stirred at 25 °C for 40 min. The solvent was evaporated to dryness, and the residue was placed on a 1 x 18 cm column of Florisil. Compound **14** was eluted with $CHCl_3$-MeOH (25:1). The fractions containing **14** were combined, evaporated to dryness, and rechromatographed using radial chromatography[27] (silica gel) with $CHCl_3$-MeOH (50:1) as the eluent. The yield of **14** was 25 mg (25%), mp > 250 °C. ^1H NMR ($CDCl_3$) δ 8.15 (d, J = 9.1 Hz, 2), 7.86 (d, J = 9.2 Hz, 2), 7.51 (d, J = 9.1 Hz, 2), 7.35 (m, 6) 7.26 (dd, 2), 7.03 (m, 4), 6.65 (d, J = 8.5 Hz, 2); UV λ_{max} nm (ε x 10^3, L mol^{-1} cm^{-1}) (EtOH) 450 (4.4), 420 (8.0), 394 (8.0), 340 (22.5), 320 (22.9), 300 (25.8), 264 (sh) (42.9), 242 (sh) (57.5), 232 (66.2). Low-resolution EI-mass spectrum (70 eV) m/z (rel intensity) 509 (41), 508 (M^+, 100), 280 (29), 270 (11), 244 (27); high-resolution EI-mass spectrum obsd. 508.16789 ($C_{36}H_{20}N_4$ requires 508.16879); fluorescence λ^{em}_{max} 519.5, 494.5, Φ = 0.002 (absolute ethanol) (relative to coumarin in absolute ethanol, Φ = 0.51 at λ^{ex} = 350 nm (measured relative to the reported value of Φ = 0.64 at λ^{ex} = 366 nm[42])).

Resolution of Benzo[h]quinolino[1'',2'':1',2']imidazo[4',5':4,5]imidazo-[1,2-a]benzo[h]quinoline (**7**). A Chromatotron[27] plate for radial chromatography was prepared as follows from TLC-grade silica gel without binder (30 g) combined with 3-aminopropyltriethoxysilane (15 g, 68 mmol) in 250 mL of dry toluene, according to the general methodology of Mikeš et al.[25] The mixture was heated at reflux under nitrogen for 8-10 h, filtered, and washed with toluene (3 x 150 mL), acetone (3 x 150 mL), and methanol (3 x 150 mL). The silica gel was dried under vacuum at 110 °C for 2 h, then added to a solution of (-)-TAPA[2] (3.8 g, 8.5 mmol) and DCC (2.0 g, 10.0 mmol) in anhydrous chloroform. The mixture was stirred at 25 °C for 4 h. The dark brown silica gel was collected by filtration, washed with chloroform (3 x 150 mL), acetone (3 x 150 mL), and methanol (3 x 150 mL), dried overnight in vacuum, and ground with $CaSO_4 \cdot 2H_2O$ (23 g) that had been dried at 300 °C for 24 h. Water (80 mL, 5 °C) was combined with 45 g of the silica gel-$CaSO_4$ mixture and poured onto a Chromatotron plate. The plate was allowed to stand at 25 °C for 24 h, was then heated at 70 °C for 4 h before use.

The (+)- and (-)-enantiomers of the octaheterohelicene **7** were separated by radial chromatography on the silica/(-)-TAPA plate in five batches of 60 mg each of racemic **7**, using hexane:methylene chloride:methanol (75:23:2) as

the eluent. Fractions were collected and analyzed by their optical rotation. The first fractions obtained rotated plane polarized light in the negative direction. The rotational order of elution is the same as that observed for the carbohelicenes[25] and the heterohelicenes[26] using an HPLC system consisting of silica/(-)-TAPA.

The negative-rotating fractions were combined and concentrated to yield (-)-7. These fractions were followed by some containing mixtures of (-)-and (+)-7, and lastly by fractions containing (+)-7, which were combined and concentrated. The (-)-7 was rechromatographed on the same plate using the same eluent system, and (-)-7 of higher negative rotation was obtained by pooling fractions and concentrating. Further elution gave additional (+)-7. The final purification of (-)-7 was carried out on a fresh plate of (-)-TAPA bonded to silica, $[\alpha]_D^{25}$ -725 °C (c = 0.020, $CHCl_3$).

The combined late fractions, (+)-rotating, from the first two chromatographic separations were concentrated and purified by radial chromatography on a silica/(+)-TAPA plate using the same eluent system. The (+)-enantiomer eluted first. Fractions with high positive rotation were combined and concentrated. The final purification of (+)-7 was carried out on a fresh plate of silica/(-)-TAPA, from which it was eluted among the last fractions, $[\alpha]_D^{25}$ +730 ° (c = 0.046, $CHCl_3$). The coincidence of the values of negative and positive specific rotation led us to believe that we had achieved satisfactory separation of the enantiomers. If the coincidence is fortuitous, we recognize that higher numerical values of $[\alpha]_D^{25}$ may be obtained in the future. Nevertheless, the molecular ellipicity curves (Figure 3) for (+)- and (-)-7 offer convincing evidence for the success of the resolution.

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