Syntheses and Properties of α-Alkyl-Substituted Bisdehydroaza[14]-annulenes and the Related Benzannelated Derivatives

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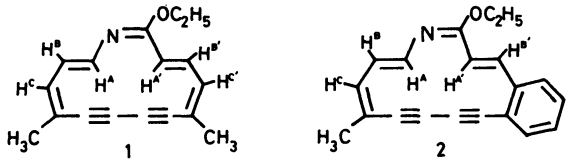
14-Ethoxy-2,5,10-trimethyl-6,8-bisdehydroaza[14]annulene, 14-ethoxy-2-ethyl-5,10-dimethyl-6,8-bisdehydroaza-[14]annulene, 2-ethoxy-3,11-dimethyl-5,6-benzo-7,9-bisdehydroaza[14]annulene, and 2-ethoxy-11,14-dimethyl-5,6-benzo-7,9-bisdehydroaza[14]annulene were synthesized. Influence of α-alkyl substitution and benzannelation upon the skeleton of the bisdehydroaza[14]annulene ring system is discussed on the basis of ^{1}H NMR and UV spectra of these azaannulenes and their α-alkyl unsubstituted ones.

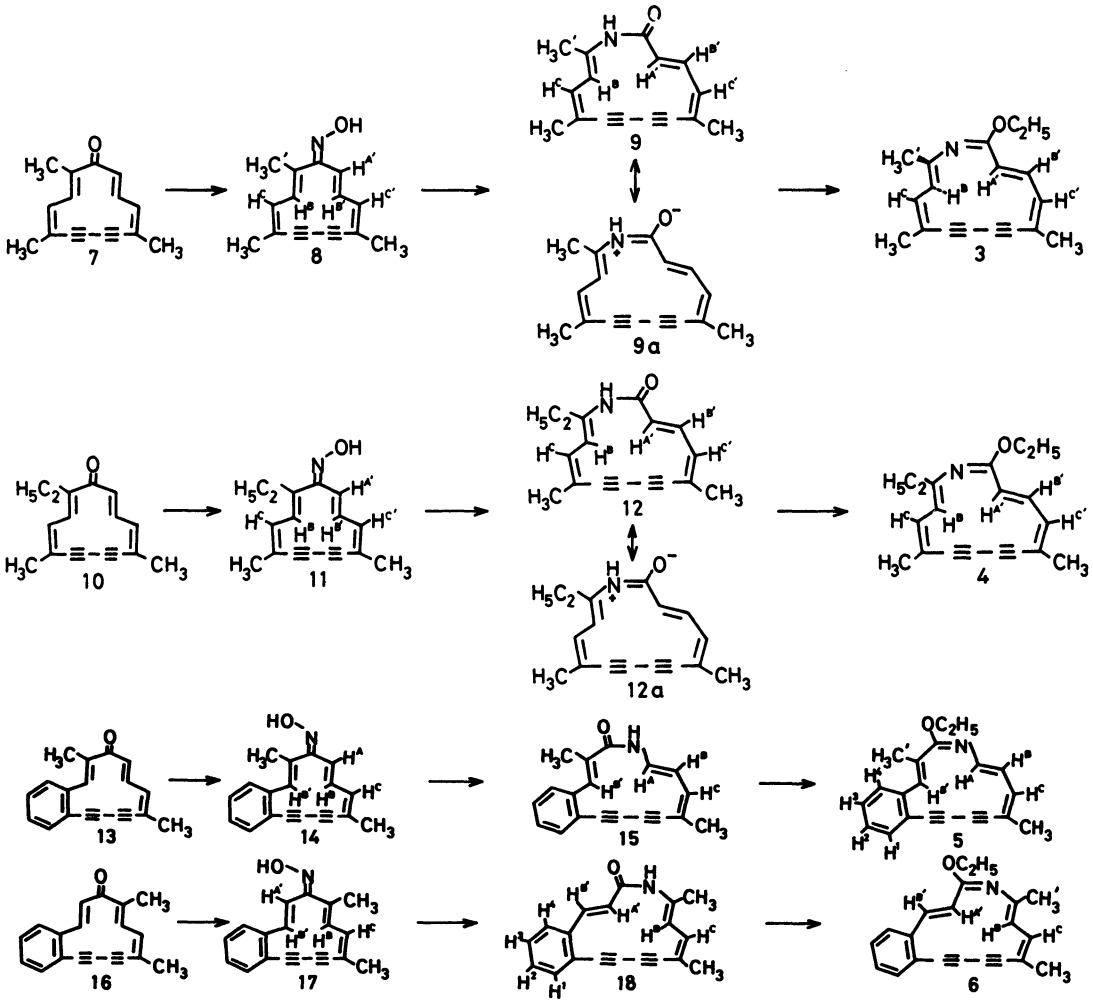
In a previous paper,[1] we reported the synthesis of the diatropic 14-ethoxy-5,10-dimethyl-6,8-bisdehydroaza-[14]annulene **1** and its benzannelated derivative **2** and showed that both the azaannulenes **1** and **2** proved to keep the conformations indicated between −60 to 60 °C, suggesting the rather high skeletal rigidity of **1** and **2**, in contrast to the cases of related 1,3-bisdehydro-[14]annulene series.[2]

This result as well as a prediction from molecular model led us to expect that the azaannulenes **1** and **2** might set α-alkyl substituent inside the ring properly. In order to investigate this possibility, it was decided to prepare α-alkyl derivatives of the compounds **1** and **2**. However, all the azaannulenes **3**—**6** obtained do not have α- or β-alkyl group inside the ring properly, by an analysis of their ^{1}H NMR spectra.[3]



Results and Discussion

Synthesis. Aza[14]annulenes **3**—**6** were prepared by the same procedure to that for synthesis of compounds **1** and **2**.[1] Treatment of the trimethylbisdehydro[13]-annulenone (**7**)[4] with a large excess of hydroxyl-



amine hydrochloride afforded only the isomer **8** of the two possible stereoisomeric oximes in 88% yield. The reaction of compound **8** with phosphorus pentachloride aroused Beckmann rearrangement to give the lactam **9** in 13% yield. The structure of compound **9** was determined by its ^{1}H NMR spectrum. Since Beckmann rearrangement is recognized to proceed usually in *anti*-migration with respect to hydroxyl group, the precursor of the lactam **9**, the oxime **8** should have the structure indicated.[5] The compound **9** reacted with a large excess of triethyloxonium tetrafluoroborate to yield the desired aza[14]annulene **3** in 38% yield. Similarly, the ethyldimethylbisdehydro[13]annulenone (**10**)[6] was led to the oxime **11** as a sole product in 52% yield, which was converted to the lactam **12** in 52% yield. Lactam **12** gave the azaannulene **4** in 14% yield. The dimethylbenzobisdehydro[13]annulenone (**13**)[4] was led to the oxime **14** (50%) as a sole product which was converted to the lactam **15** in 33% yield. The lactam **15** gave the benzazaannulene **5** in 10% yield. Thus, the formation of only the isomer **14** of the oxime from compound **13** prevented the possible preparation of an another α-methylated azaannulene, and instead led to the β-methylated one **5**. The oxime **17** (34%), obtained from the dimethylbenzobisdehydro[13]annulenone (**16**),[4] was led to the lactam **18** in 40% yield, which was

Table 1. ^{1}H NMR Chemical Shifts of **1**—**6** (in $CDCl_3$), and **1′**—**4′**, **6′** (CF_3COOD in $CDCl_3$) at 200 MHz, Determined at 21 °C (τ Value; internal standard, Me_4Si)

Compd	H^A	$H^{A'}$	H^B	$H^{B'}$	H^C	$H^{C'}$	$-OCH_2CH_3$	$-OCH_2CH_3$	CH_3	$CH_{3'}$	$-CH_2CH_3$	$-CH_2CH_3$	Benzenoid H
1[a]	6.25	7.06	2.99	2.19	2.62	2.70	5.40	8.51	7.49, 7.54				
1′[a]	(6.35)	(6.52)	(2.76)	(1.69)	(2.54)	(2.66)	(5.15)	(8.32)	(7.32), (7.52)				
3		4.99	6.04	2.55	2.93	3.22	5.74	8.63	7.79, 7.88	8.23			
3′		(4.29)	(4.18)	(2.36)	(3.19)	(3.19)	(5.29)	(8.45)	(7.76), (7.87)	(8.53)			
4		5.40	6.71	2.37	2.69	3.15	5.72	8.67	7.75, 7.85		7.65	9.01	
4′		(4.39)	(4.58)	(2.33)	(3.14)	(3.18)	(5.31)	(8.46)	(7.76), (7.87)		(8.07)	(9.16)	
2[a]	3.84	4.46	3.52	2.11	3.10		5.50	8.52	7.78				2.16—2.55
2′[a]	(3.12—3.20)	(4.14)	(3.12—3.20)	(1.53)	(4.16)		(5.17)	(8.30)	(7.73)				(1.98—2.24)
5[b]	2.09		3.85	3.38	3.58		5.67	8.62	8.04	8.21			2.48—2.74
6		3.24	4.80	2.43	3.36		5.74	8.60	8.02	8.24			2.51—2.74
6′		(2.95)	(3.74)	(1.95)	(3.48)		(5.26)	(8.35)	(7.94)	(8.23)			(2.33—2.45)

a) See Ref. 1. b) Addition of deuteriotrifluoroacetic acid to a solution of **5** in $CDCl_3$ resulted in decomposition of a sample.

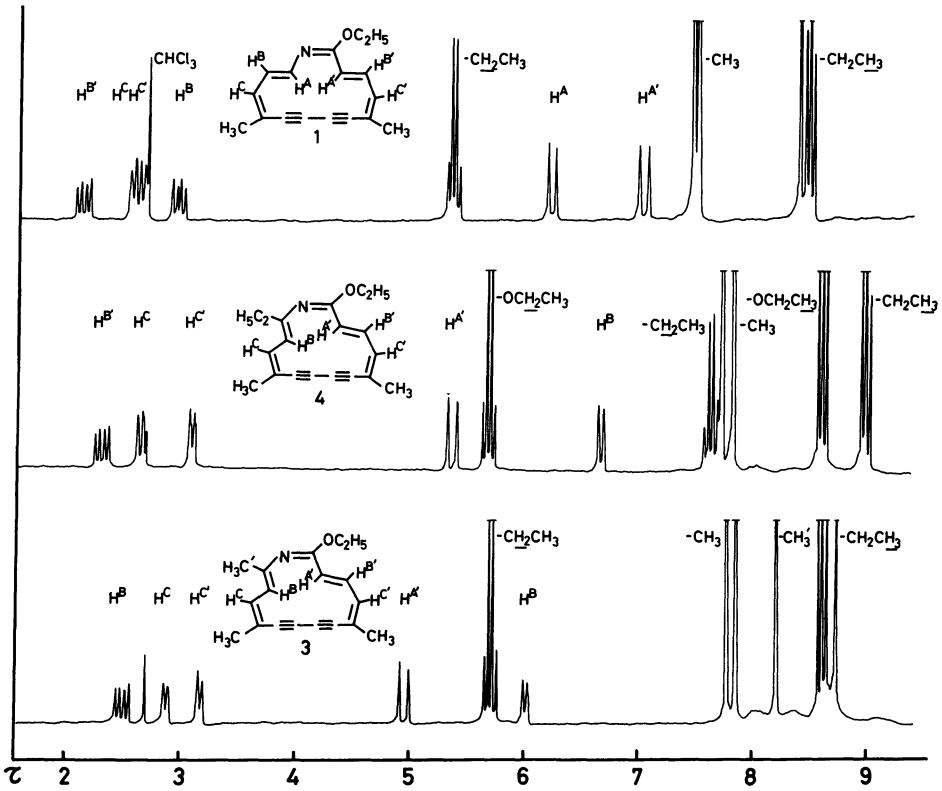


Fig. 1. The 200 MHz ^{1}H NMR spectra of **1**, **3**, and **4** in $CDCl_3$ (internal standard, TMS).

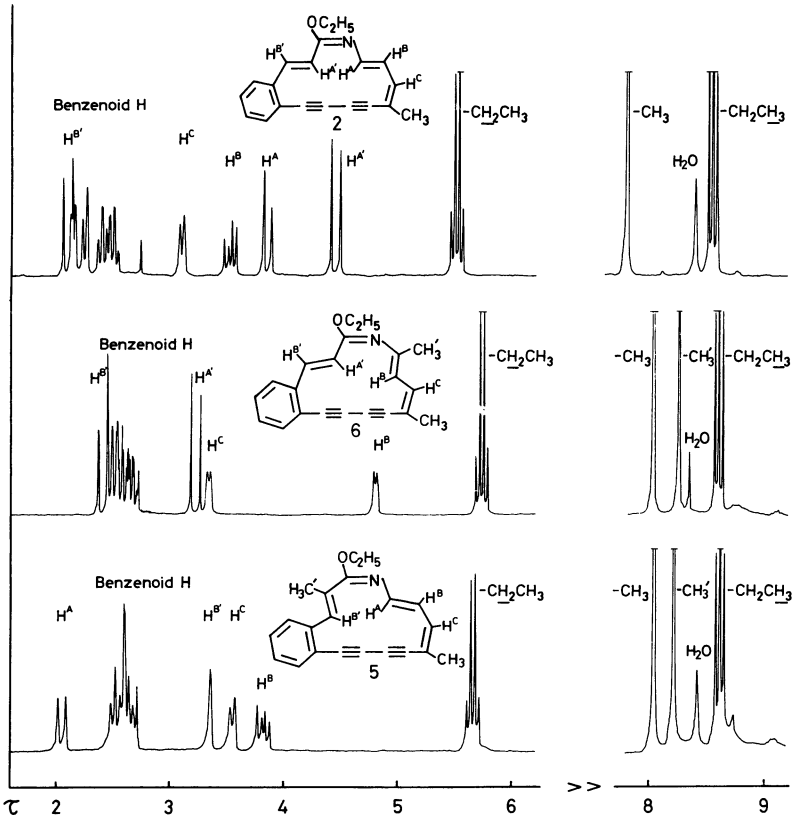
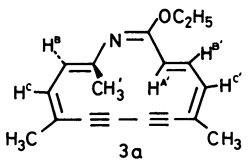


Fig. 2. The 200 MHz ^{1}H NMR spectra of **2**, **5**, and **6** in $CDCl_3$ (internal standard, TMS).

converted to the benzazaannulene **6** in 43% yield.

^{1}H NMR Spectra. The ^{1}H NMR chemical shifts of the azaannulenes **1—6** are listed in Table 1, and the spectra of the azaannulenes **1**, **3**, and **4** are shown in Fig. 1 and the spectra of the benzannelated azaannulenes **2**, **5**, and **6** are shown in Fig. 2. The assignments of the resonances in these azaannulenes are based on the multiplicities and coupling constants. As is seen from both the Table 1 and Fig. 1, it is noted that comparison of the chemical shift differences between the olefinic outer and inner protons which can be regarded as an approximate measure of tropicity, or of the chemical shifts of $-OC\underline{H}_2CH_3$ and CH_3 protons that the diatropicity of these azaannulenes decreases in the order of the dimethyl- **1**>the α-ethyl- **4**>the α-methyl-substituted azaannulene **3**, demonstrating that the perturbation caused by the α-alkyl substitution for the aza[14]annulene **1** greatly reduces the planarity of the molecular skeleton and it is larger in the α-methyl substitution than in the α-ethyl one. This also permits the safe conclusion that both **3** and **4** do not set their α-alkyl groups inside the ring properly.

The similar observation is made from comparison of the ^{1}H NMR chemical shifts (Table 1 and Fig. 2) of the benzannelated azaannulenes **2**, **5**, and **6**. Comparison of the chemical shifts of $-OC\underline{H}_2CH_3$ and CH_3 protons again indicates that the tropicity decreases in the order of benzaza- **2**>β-methylated benzaza- **6**>α-methylated benzazaannulene **5**, suggesting that the α- or β-methyl substitution in **2** reduces the planarity of the molecular skeleton. It eliminates the weak diatropicity of **2**,[1] rendering both **5** and **6** to be atropic.



3a

Variable-temperature ^{1}H NMR spectra of these azaannulenes **1—6** were taken over the range of −60 to 60 °C and their chemical shifts are summarized in Table 2. As we see from Table 2, the spectra of **1** and **2** are essentially temperature-independent between these temperatures, although the resonances of the inner and outer protons of **1** and **2** move to a slightly higher and lower field, respectively, reflecting that the higher planarity of the azaannulene rings of **1** and **2** at lower temperature.[1] In contrast, the spectra of trimethylazaannulene **3** show temperature-dependency, as illustrated in Fig. 3. In particular, moving of the resonances of CH_3' and H^B proton toward higher and lower field, respectively, along with decreasing temperature, is notable. This fact as well as examination from molecular model leads us to believe the following. The molecule **3** exists in conformations such as **3** and **3a**, in which the vibrating CH_3'-C=CH^B

Table 2. ^{1}H NMR Chemical Shifts of Compounds **1**—**6** (In $CDCl_3$) at 90 MHz or 270 MHz (τ Value; internal standard, Me_4Si)

Compd	T/°C	H^A	$H^{A'}$	H^B	$H^{B'}$	H^C	$H^{C'}$	$-OCH_2CH_3$	$-OCH_2CH_3$	CH_3	CH_3'	$-CH_2CH_3$	$-CH_2CH_3$	H^4	H^1	H^2	H^3
1[a]	+60	6.18	6.97	3.03	2.24	2.64	2.72	5.38	8.52	7.50, 7.55							
	+23	6.25	7.06	3.02	2.20	2.63	2.71	5.41	8.52	7.50, 7.55							
	−30	6.35	7.16	3.01	2.16	2.62	2.69	5.45	8.51	7.50, 7.54							
	−60	6.40	7.21	3.02	2.15	2.61	2.68	5.48	8.51	7.48, 7.54							
2[a]	+60	3.78	4.37	3.53	2.12	3.11		5.48	8.53	7.79				2.16	2.27	2.39—2.55	
	+22	3.83	4.43	3.52	2.11	3.10		5.50	8.53	7.79				2.16	2.26	2.38—2.51	
	−30	3.91	4.50	3.52	2.09	3.09		5.54	8.52	7.79				2.14	2.24	2.36—2.51	
	−60	3.96	4.56	3.53	2.09	3.08		5.58	8.52	7.79				2.13	2.23	2.35—2.49	
3[b]	+60		5.01	6.11	2.55	2.93	3.24	5.73	8.64	7.81, 7.89	8.20						
	+22		5.00	6.06	2.55	2.94	3.23	5.74	8.63	7.80, 7.88	8.22						
	−30		4.86	5.77	2.58	2.98	3.22	5.77	8.60	7.79, 7.87	8.30						
	−60		4.73	5.52	2.63	3.12	3.24	5.78	8.58	7.79, 7.86	8.39						
4[b]	+60		5.38	6.71	2.38	2.71	3.16	5.71	8.64	7.77, 7.86		7.65	9.00				
	+23		5.41	6.71	2.37	2.71	3.15	5.72	8.63	7.75, 7.85		7.65	9.01				
	−30		5.37	6.62	2.39	2.69	3.13	5.74	8.61	7.74, 7.84		7.68	9.04				
	−60		5.28	6.50	2.39	2.75	3.13	5.76	8.59	7.74, 7.83		7.70	9.07				
5[b]	+60	2.07		3.87	3.43	3.59		5.67	8.64	8.06	8.22				2.51—2.87		
	+22	2.09		3.87	3.40	3.58		5.67	8.63	8.05	8.22				2.48—2.86		
	−30	2.13		3.85	3.28	3.54		5.68	8.59	8.02	8.23				2.45—2.82		
	−60	2.15		3.84	3.20	3.49		5.69	8.56	8.01	8.25				2.45—2.80		
6[b]	+60		3.25	4.84	2.40	3.35		5.72	8.60	8.02	8.22				2.44—2.80		
	+22		3.25	4.84	2.43	3.36		5.74	8.60	8.02	8.25				2.45—2.80		
	−30		3.24	4.72	2.50	3.42		5.78	8.60	8.03	8.31				2.45—2.80		
	−60		3.23	4.66	2.53	3.46		5.81	8.59	8.04	8.35				2.48—2.80		

a) At 270 MHz. b) At 90 MHz.

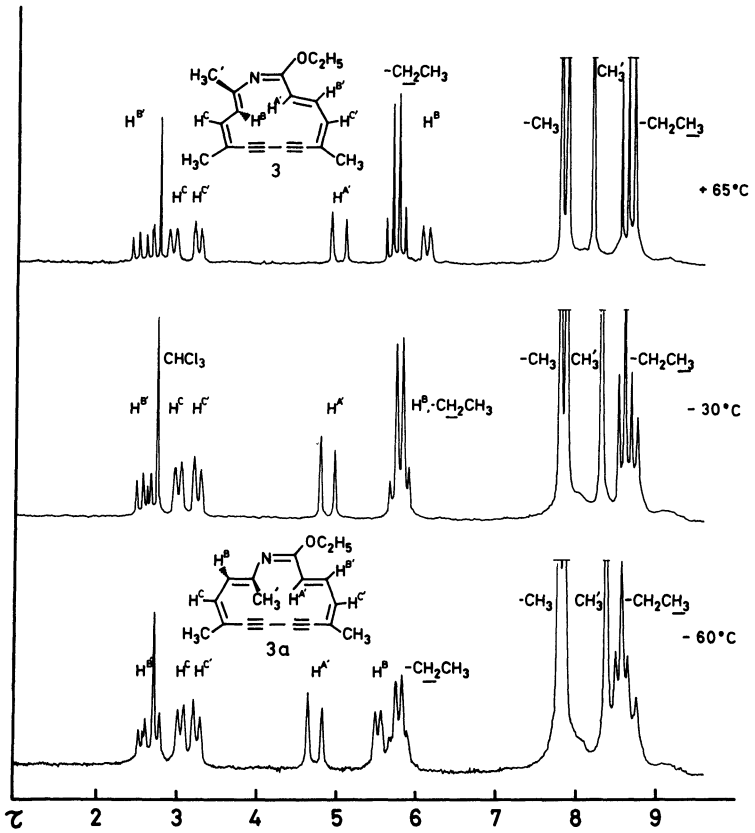


Fig. 3. The 90 MHz ^{1}H NMR spectra of **3** in $CDCl_3$ (internal standard, TMS).

Table 3. ^{1}H NMR Chemical Shifts of Lactams **9** and **12** at 200 MHz, Determined at 21 °C (τ Value; internal standard, Me_4Si)

Compd	$H^{A'}$	H^B	$H^{B'}$	H^C	$H^{C'}$	NH	CH_3	CH_3'	$-C\underline{H}_2CH_3$	$-CH_2C\underline{H}_3$
9	4.55	5.58	2.13	2.88	3.21	2.33	7.87, 7.91	7.79		
12	4.58	5.68	2.11	2.84	3.20	2.42	7.79, 7.91		5.01	8.85

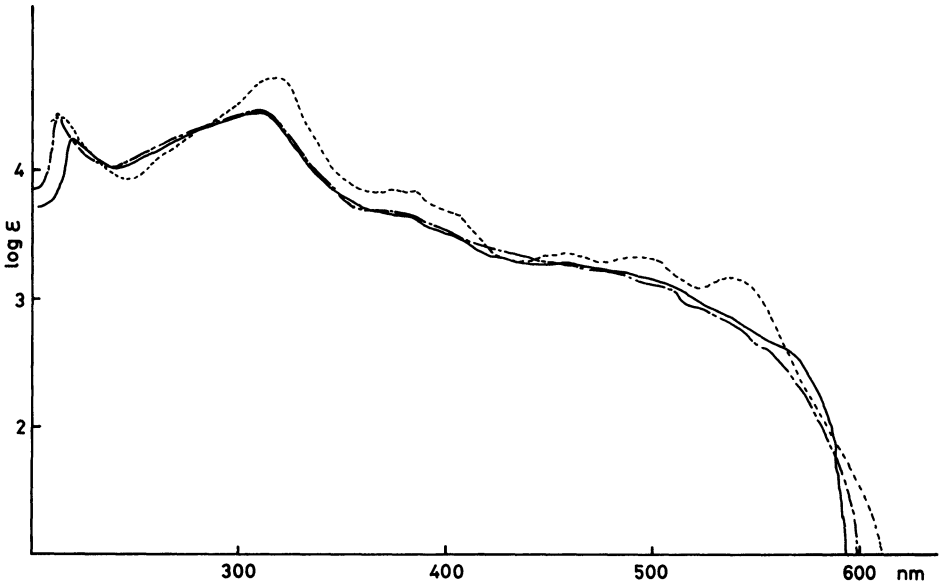
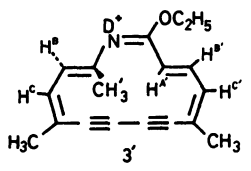
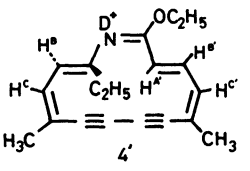


Fig. 4. Electronic spectra of **1** (------), **3** (—·—·—), and **4** (——) in THF.

moiety deviates from a molecular plane as depicted: The observed, relatively high-field, resonance of CH_3' protons and low-field resonance of H^B proton at −60 °C, suggests that the conformation **3a** is the preferred form at this temperature.

The similar behavior which is different from that for the cases of **1** and **2**, is observed in the variable-temperature spectra of **4**—**6** (Table 2), but the variation of their spectra is smaller than that of **3** between these temperatures. In the case of **4**, this might be attributable to the bulky α-ethyl group which hardly locates inside the ring, as compared with the case of **3**.





The ^{1}H NMR chemical shifts of the azaannulenes **1'**—**4'** and **6'**, taken in deuteriochloroform solution with a few drops of deuteriotrifluoroacetic acid, are also listed in Table 1. In these spectra, it is apparent that the resonances of almost all the protons including ethoxyl and methyl protons in these azaannulenes move to low field. This seems to be attributable to diminished π-electron perimeter, arising from withdrawal of electrons by deuteration. However, the movings of CH_3' and H^C protons in **3**, and of the CH_3, $-C\underline{H}_2CH_3$, and H^C protons in **4**, to high field, as compared with moving of the other protons in **3** and **4**, to low field, are rather large. This might also suggest that the CH_3'-C=CH^B-CH^C moiety in **3** and the C_2H_5-C=CH^B-CH^C one in **4** are mobile in their molecular perimeters. In particular, the high-field resonances of the CH_3' protons in the deuterated **3'** and the $-C\underline{H}_2CH_3$ and $-CH_2C\underline{H}_3$ protons in the deuterated **4'**, as compared with those of **3** and **4**, respectively, suggest that these deuterated species might exist in conformations indicated.

The ^{1}H NMR chemical shifts of the lactams **9** and **12**, which are the precursors of the azaannulenes **3** and **4**, respectively, are listed in Table 3. The fourteen-membered lactams **9** and **12** are also diatropic, since the inner $H^{A'}$ and H^B proton resonances appear at high field and the outer protons including CH_3, CH_3' protons in **9**, and $-C\underline{H}_2CH_3$, $-CH_2C\underline{H}_3$ protons in **12**, do at low field. Thus, the lactams **9** and **12** can be considered to exist in zwitter ionic forms **9a** and **12a**, as has been discussed previously.[1]

Electronic Spectra. The electronic absorption spectra, taken in tetrahydrofuran, of the bisdehydroaza-[14]annulenes **1**, **3**, and **4**, and of the benzannelated ones **2**, **5**, and **6** are illustrated in Figs. 4 and 5, respectively. As is seen from both Figs. 4 and 5, the longest wavelength band shift toward longer wavelength in the order of **1**>**4**>**3** (Fig. 4), **2**>**6**>**5** (Fig. 5), respectively, demonstrating the sequence for the degree of extended conjugation of π-electron system in these aza[14]annulene systems, conforming the results

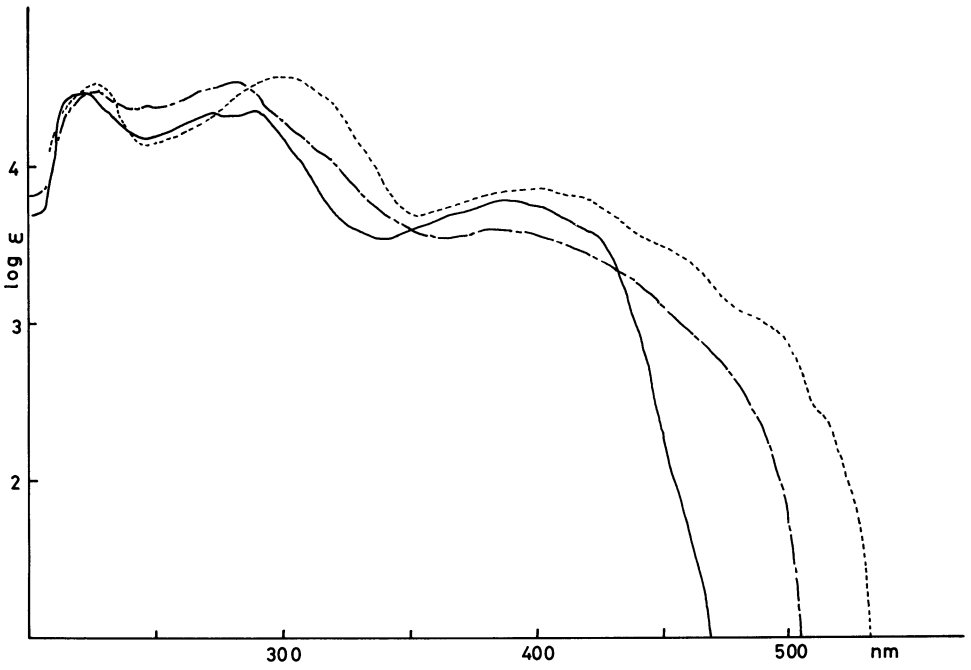


Fig. 5. Electronic spectra of **2** (------), **5** (——), and **6** (------) in THF.

from the ^{1}H NMR spectra.

All these results show that the conformation indicated for compound **1** is most appropriate for a conjugation of π-electrons in this bisdehydroaza[14]annulene system.

Experimental

All melting points are uncorrected. IR spectra were measured on Hitachi 260-50 spectrophotometer as KBr disk unless otherwise stated; only significant maxima are reported. Electronic spectra on Hitachi 220A spectrophotometer were measured in tetrahydrofuran solutions and recorded in nm. ε-Values are given in parentheses, shoulders being denoted by sh. Mass spectra were measured with JEOL JMS-200 spectrometer at 75 eV using a direct inlet system, ^{1}H NMR spectra were taken on JEOL FX-90Q (90 MHz) or Varian XL-200 spectrometer, and refer to solution in $CDCl_3$, unless otherwise specified, in τ-values with TMS as an internal standard. The coupling constants (J) are given in Hz. The individual assignments are made on the basis of multiplicities and coupling constants. Alumina (II–III) was used for column chromatography. Progress of most reactions was followed by TLC using Merck precoated alumina. Preparative TLC was carried out on 20×20 cm silica-gel plates (Merck, 0.5 or 2 mm thick). Dichloromethane was distilled over calcium hydride before use. Tetrahydrofuran (THF) was refluxed over potassium hydroxide pellets and distilled before use. Organic extracts with dichloromethane or chloroform were dried over anhyd calcium chloride prior to solvent removal.

1-Hydroxyimino-2,5,10-trimethylcyclotrideca-2,4,10,12-tetraene-6,8-diyne (8). To a stirred soln of the trimethylbisdehydro[13] annulenone (**7**)[4] (1.82 g, 8.20 mmol) in methanol (340 ml) and THF (85 ml) was added a soln of hydroxylamine hydrochloride (5.7 g, 82 mmol) in water (25 ml) at 38 °C in one portion. After stirring for further 3 h at the same temp, further quantities of hydroxylamine hydrochloride (each 5.7 g in water (25 ml)) were added after every 10 h. After stirring for a total of 27 h, the soln was poured into an aq sodium hydrogencabonate soln. The mixture was extracted with chloroform. The combined extracts were washed with aq sodium chloride soln, dried, and evaporated. The residue after solvent removal was chromatographed on alumina (3.7×7 cm). The early fractions eluted with benzene gave the recovered annulenone **7** (64 mg). The following fractions eluted with 5% ethanol in chloroform gave the oxime **8** (1.71 g, 88%) as a solid. Recrystallization from hexane–chloroform afforded orange needles: Mp 164—165 °C (decomp); MS m/z 237 (M^+, 89%) and 204 (100); mol wt 237.2; IR 3240 (-OH), 2170 (-C≡C-), and 980 cm^{-1} (trans C=C); UV_{max} 213 (29900), 275 (30900), and 350 nm sh (7740); ^{1}H NMR (90 MHz, DMSO-d_6) τ=−1.95 (s, 1H, OH, exchangeable with D_2O), 2.44 (d, 9, 1H, H^B), 2.45 (dd, 17, 9, 1H, $H^{B'}$), 2.99 (d, 10, 1H, $H^{C'}$), 3.23 (d, 10, 1H, H^C), 3.30 (d, 17, 1H, $H^{A'}$), 8.02 (s, 3H, CH_3'), and 8.18 (s, 6H, CH_3).

Found: C, 80.72; H, 6.22; N, 5.96%. Calcd for $C_{16}H_{15}NO$: C, 80.98; H, 6.37; N, 5.90%.

6,11,14-Trimethylazacyclotetradeca-3,5,11,13-tetraene-7,9-diyn-2-one (9). Phosphorus pentachloride (4.46 g, 21.4 mmol) was added in one portion to a stirred soln of the oxime **8** (1.01 g, 4.27 mmol) in THF (240 ml) at 1—3 °C. After stirring for 4 h at the same temp, the soln was poured into water, and an aq sodium hydrogencarbonate soln was added (pH 8). The soln was warmed on a steam-bath, and then the mixture was extracted with chloroform. The combined extracts were washed with aq sodium hydrogencarbonate soln, and aq sodium chloride soln, and dried. The dark red semi-solid obtained after solvent removal was chromatographed on alumina (3.7×7.0 cm). The fractions eluted with 2% chloroform in benzene afforded the lactam **9** (129 mg, 13%) as a solid. Recrystallization from hexane–chloroform afforded dark red cubes: Mp 186—188 °C (decomp); MS m/z 237 (M^+, 62%) and 194 (100); mol wt 237.2;

IR 3180, 3060 (NH), 2160 (-C≡C-), 1655 (C=O), 1605 and 1590 cm^{-1} (C=C); UV_{max} 298 sh (36700), 306 (38800), 365 sh (5330), and 436 nm (3280); ^1H NMR (200 MHz) τ=2.13 (dd, 15.5, 7.5, 1H, $H^{B'}$), 2.33 (br s, 1H, NH), 2.88 (d, 10, 1H, H^{C}), 3.21 (d, 7.5, 1H, $H^{C'}$), 4.55 (d, 15.5, 1H, $H^{A'}$), 5.58 (d, 10, 1H, H^{B}), 7.79 (s, 3H, CH_3'), 7.87 (s, 3H, CH_3), and 7.91 (s, 3H, CH_3).

Found: C, 81.09; H, 6.38; N, 5.93%. Calcd for $C_{16}H_{15}NO$: C, 80.98; H, 6.37; N, 5.90%.

14-Ethoxy-2,5,10-trimethyl-6,8-bisdehydroaza[14]annulene (3). To a stirred soln of the lactam **9** (93.4 mg, 0.394 mmol) in dichloromethane (50 ml) was added dropwise a soln of triethyloxonium tetrafluoroborate (2.2 g, 12 mmol) in dichloromethane (30 ml) during 30 min at room temp under argon. After stirring for 1 h, further quantities of the oxonium salt (each 1.5 g in dichloromethane (20 ml)) were added every day, and stirring was continued for 3 d. Then the soln was cooled in an ice-bath and aq 50% potassium carbonate soln (50 ml) was cautiously added. Then the mixture was poured into water and extracted with dichloromethane. The residue after solvent removal was chromatographed on alumina (3.7×6.0 cm). The initial fractions eluted with 5% ether in hexane gave the azaannulene **3** (39.2 mg, 37.5%) as a red liquid: MS *m/z* 265 (M^+, 54%) and 208 (100); mol wt 265.3; IR (neat) 2150 (-C≡C-), 1575 (C=C), 1290, 1255, and 1055 cm^{-1} (-O-); UV_{max} 277 sh (19200), 307 (26100), 386 sh (4030), 470 sh (1760), 511 sh (1160), and 553 nm sh (520), and see Fig. 4; ^1H NMR (200 MHz) τ=2.55 (dd, 16, 7, 1H, $H^{B'}$), 2.93 (d, 8, 1H, H^{C}), 3.22 (d, 7.5, 1H, $H^{C'}$), 4.99 (d, 16, 1H, $H^{A'}$), 5.74 (q, 7, 2H, $-OC\underline{H}_2CH_3$), 6.04 (d, 7.5, 1H, H^{B}), 7.79 (s, 3H, CH_3), 7.88 (s, 3H, CH_3), 8.23 (s, 3H, CH_3'), and 8.63 (t, 7, 3H, $-OCH_2C\underline{H}_3$), and see Figs. 1 and 3; **3'** (200 MHz, CF_3COOD in $CDCl_3$) τ=2.36 (dd, 16, 8, 1H, $H^{B'}$), 3.19 (d, 7.5, 2H, H^{C} and $H^{C'}$), 4.18 (s, 1H, H^{B}), 4.29 (d, 16, 1H, $H^{A'}$), 5.29 (q, 7, 2H, $-OC\underline{H}_2CH_3$), 7.76 (s, 3H, CH_3), 7.87 (s, 3H, CH_3), 8.45 (t, 7, 3H, $-OCH_2C\underline{H}_3$), and 8.53 (s, 3H, CH_3').

Found: C, 81.64; H, 7.50; N, 5.00%. Calcd for $C_{18}H_{19}NO$: C, 81.47; H, 7.22; N, 5.28%.

The later fractions eluted with chloroform gave the recovered lactam **9** (40 mg).

2-Ethyl-1-hydroxyimino-5,10-dimethylcyclotrideca-2,4,10,12-tetraene-6,8-diyne (11). To a stirred soln of the ethyldimethylbisdehydro[13]annulenone (**10**)[6] (1.24 g, 5.27 mmol) in methanol (150 ml) was added in one portion a soln of hydroxylamine hydrochloride (4.0 g, 5.8 mmol) in water (20 ml) was added. Then after stirring for 16 h, further quantities of hydroxylamine hydrochloride (each 4.0 g in water (20 ml)) were added after every 4 h. After stirring for a total of 34 h, the soln was worked up as in the preparation of **8**. The residue after solvent removal was chromatographed on alumina (4.0×7.5 cm). The early fractions eluted with benzene gave the recovered annulenone **10** (26 mg). The following fractions eluted with 2% ethanol in chloroform gave the oxime **11** (692 mg, 52%) as a solid. Recrystallization from hexane-chloroform afforded orange needles: Mp 155—156 °C (decomp); MS *m/z* 251 (M^+, 84%) and 204 (100); mol wt 251.3; IR 3250 (-OH), 2170 (-C≡C-), 1000, and 990 cm^{-1} (trans C=C); UV_{max} 217 (20100), 274 (31000), and 351 nm sh (7200); ^1H NMR (90 MHz, DMSO-d_6) τ=−1.89 (s. 1H, OH, exchangeable with D_2O), 2.49 (dd, 17, 8.5, 1H, $H^{B'}$), 2.60 (d, 11, 1H, H^{B}), 3.03 (d, 10.3, 1H, H^{C}), 3.26 (d, 8.5, 1H, $H^{C'}$), 3.29 (d. 17, 1H, $H^{A'}$), 7.50 (q, 7.4, 2H, $-C\underline{H}_2CH_3$), 8.17 (s, 6H, CH_3), and 9.03 (t, 7.4, 3H, $-CH_2C\underline{H}_3$).

Found: C, 81.17; H, 6.92; N, 5.64%. Calcd for $C_{17}H_{17}NO$: C, 81.24; H, 6.82; N, 5.57%.

14-Ethyl-6,11-dimethylazacyclotetradeca-3,5,11,13-tetraene-7,9-diyn-2-one (12). A soln of phosphorus pentachloride (4.85 g, 23.3 mmol) in THF (330 ml) was added dropwise during 40 min to a stirred soln of the oxime **11** (1.17 g, 4.66 mmol) in THF (200 ml) under ice-bath. The soln was allowed to rise to room temp and stirring was continued for 3.5 h at same temp. Then the mixture was worked up as in the preparation of **9**. The residue after solvent removal was chromatographed on alumina (3.7×8.0 cm). The early fractions eluted with benzene-chloroform (2:3) gave the lactam **12** (610 mg, 52%) as a solid. Recrystallization from hexane-chloroform afforded red necdles: Mp 189—191 °C (decomp); MS *m/z* 251 (M^+, 75%) and 222 (100); mol wt 251.3; IR 3170, 3060 (NH), 2155 (-C≡C-), 1655 (C=O), 1600, and 1590 cm^{-1} (C=C); UV_{max} 218 (13800), 299 sh (28200), 307 (29900), and 441 nm sh (2500); ^1H NMR (200 MHz) τ=2.11 (dd, 15, 7, 1H, $H^{B'}$), 2.42 (br s, 1H, NH), 2.84 (d, 10, 1H, H^{C}), 3.20 (d, 6.4, 1H, $H^{C'}$), 4.58 (d, 15.7, 1H, $H^{A'}$), 5.68 (d, 10, 1H, H^{B}), 5.01 (q, 7.5, 2H, $-C\underline{H}_2CH_3$), 7.79 (s, 3H, CH_3), 7.91 (s, 3H, CH_3), and 8.85 (t, 7.5, 3H, $-CH_2C\underline{H}_3$).

Found: C, 81.31; H, 6.78; N, 5.33%. Calcd for $C_{17}H_{17}NO$: C, 81.24; H, 6.82; N, 5.57%.

The later fractions eluted with 5% ethanol in chloroform afforded the recovered oxime **11** (139 mg).

14-Ethoxy-2-ethyl-5,10-dimethyl-6,8-bisdehydroaza[14]annulene (4). To a stirred soln of the lactam **12** (703 mg, 2.80 mmol) in dichloromethane (250 ml) was added dropwise a soln of triethyloxonium tetrafluoroborate (7.97 g, 42 mmol) in dichloromethane (80 ml) during 1 h at room temp. After stirring for a further 2.5 h, further quantities of the oxonium salt (each 10 g in dichloromethane (50 ml)) was added every 15 h. After stirring for a total of 48 h, the mixture was worked up as in the preparation of **3**. The residue after solvent removal was chromatographed on alumina (3.7×8.0 cm). The early fractions eluted with 3% ether in hexane gave a red liquid, which was further purified by preparative TLC. The fast moving, red band on evaporation afforded the azaannulene **4** (111 mg, 14.2%) as a red liquid: MS *m/z* 279 (M^+, 51%) and 222 (100); mol wt 279.3; IR (neat) 2140 (-C≡C-), 1575 (C=C), 1290, 1250, and 1050 cm^{-1} (-O-); UV_{max} 219 (17100), 298 sh (27700), 308 (30900), 383 sh (4200), and 422 nm sh (1940), and see Fig. 4; ^1H NMR (200 MHz) τ=2.37 (dd, 15.5, 7.5, 1H, $H^{B'}$), 2.69 (d, 9, 1H, H^{C}), 3.15 (d, 7.5, 1H, $H^{C'}$), 5.40 (d, 15.5, 1H, $H^{A'}$), 5.72 (q, 7, 2H, $-OC\underline{H}_2CH_3$), 6.71 (d, 9, 1H, H^{B}), 7.65 (q, 7.5, 2H, $-C\underline{H}_2CH_3$), and 7.75 (s, 3H, CH_3), 7.85 (s, 3H, CH_3), 8.67 (t, 7, 3H, $-OCH_2C\underline{H}_3$), and 9.01 (t, 7.5, 3H, $-CH_2C\underline{H}_3$), and see Fig. 1; **4'** (200 MHz, CF_3COOD in $CDCl_3$) τ=2.33 (dd, 16, 8, 1H, $H^{B'}$), 3.14 (d, 5.5, 1H, H^{C}), 3.18 (d, 8, 1H, $H^{C'}$), 4.39 (d, 15.5, 1H, $H^{A'}$), 4.58 (d, 5.5, 1H, H^{B}), 5.31 (q, 7, 2H, $-OC\underline{H}_2CH_3$), 7.76 (s, 3H, CH_3), 7.87 (s, 3H, CH_3), 8.07 (q, 7.5, 2H, $-C\underline{H}_2CH_3$), 8.46 (t, 7, 3H, $-OCH_2C\underline{H}_3$), and 9.16 (t, 7.5, 3H, $-CH_2C\underline{H}_3$).

Found: C, 81.55; H, 7.88; N, 4.94%. Calcd for $C_{19}H_{21}NO$: C, 81.68; H, 7.58; N, 5.01%.

The later fractions eluted with chloroform gave the recovered lactam **12** (425 mg).

1-Hyroxyimino-2,10-dimethyl-4,5-benzocyclotrideca-2,10,12-triene-6,8-diyne (14). To a stirred soln of bisdehydrobenz-[13]annulenone (**13**)[4] (2.63 g, 10.2 mmol) in methanol (350 ml) and THF (200 ml) was added in one portion a soln of

hydroxylamine hydrochloride (14.2 g, 0.204 mmol) in water (30 ml) at room temp. After stirring for 13 h, further quantities of hydroxylamine hydrochloride (each 7.1 g in water (30 ml)) were added after every 5 h. After for a total of 27 h at 40 °C, the mixture was worked up as in the preparation of **8**. The residue after solvent removal was chromatographed on alumina (4.5×7.0 cm). The early fractions eluted with benzene gave the recovered annulenone **13** (26 mg). The following fractions eluted with benzene–chloroform (1:1) gave the oxime **14** (1.64 g, 59%) as a solid. Recrystallization from hexane–chloroform afforded yellow plates: Mp 160—162 °C (decomp); MS *m/z* 273 (M^+, 40%) and 258 (100); mol wt 273.2; IR 3250 (-OH), 2180 (-C≡C-), and 975 cm^{-1} (trans C=C); UV_{max} 225 (34100), 253 sh (25000), 266 (37800), 279 (47100), 328 sh (5820), 350 sh (7650), 371 (9460), and 392 nm sh (7520); ^1H NMR (90 MHz, DMSO-d_6) τ=−1.44 (s, 1H, OH, exchangeable with D_2O), 2.50 (dd, 16, 11, 1H, H^B), 2.42—2.80 (m, 4H, benzenoid H), 3.09 (d, 10, 1H, H^C), 3.49 (s, 1H, $H^{B'}$), 3.57 (d, 16, 1H, H^A), and 8.20 (s, 6H, CH_3).

Found: C, 83.47; H, 5.54; N, 5.41%. Calcd for $C_{19}H_{15}NO$: C, 83.49; H, 5.53; N, 5.13%.

3,11-Dimethyl-5,6-benzazacyclotetradeca-3,5,11,13-tetraene-7,9-diyn-2-one (15). A soln of phosphorus pentachloride (2.20 g, 10.6 mmol) in THF (120 ml) was added dropwise to a stirred soln of the oxime **14** (580 mg, 2.1 mmol) in THF (60 ml) during 40 min at 5 °C. After stirring for 3 h at room temp a soln of phosphorus pentachloride (0.35 g, 2.0 mmol) in THF (8 ml) was further added and the soln was stirred for a further 2 h. Then the soln was worked up as in the preparation of **9**. The residue after solvent removal was chromatographed on alumina (4.0×8.0 cm). The early fractions eluted with benzene–chloroform (1:1) gave the lactam **15** (195 mg, 33%) as a solid. Recrystallization from hexane–chloroform afforded yellow needles: Mp 220—222 °C (decomp); MS *m/z* 273 (M^+, 55%) and 230 (100); mol wt 273.3; IR 3180, 3070 (NH), 2220 (-C≡C-), 1650 (C=O), and 960 cm^{-1} (trans C=C); UV_{max} 257 sh (20900), 272 (28800), 286 (30700), 326 sh (4650), 388 (6980), and 422 nm sh (4650); ^1H NMR (200 MHz, DMSO-d_6) τ=−0.20 (d, 11, 1H, NH), 2.25 (dd, 14, 11, 1H, H^A), 2.37—2.61 (m, 4H, benzenoid H), 3.18 (s, 1H, $H^{B'}$), 3.58 (d, 8, 1H, H^C), 4.31 (dd, 14, 8, 1H, H^B), 8.13 (s, 3H, CH_3), and 8.24 (s, 3H, CH_3).

Found: C, 83.40; H, 5.44; N, 5.41%. Calcd for $C_{19}H_{15}NO$: C, 83.49; H, 5.53; N, 5.13%.

The later fractions eluted with chloroform gave the recovered oxime **14** (22 mg).

2-Ethoxy-3,11-dimethyl-5,6-benzo-7,9-bisdehydroaza[14]-annulene (5). A soln of triethyloxonium tetrafluoroborate (2.43 g, 12.8 mmol) in dichloromethane (30 ml) was added during 30 min dropwise to a soln of the lactam **15** (349 mg, 1.28 mmol) in dichloromethane (50 ml) at room temp under argon. After stirring for 15 h, the soln was worked up as in the preparation of **3**. The residue after solvent removal was chromatographed on alumina (3.7×7.0 cm). The fractions eluted with 10% ether in hexane gave the azaannulene **5** (39.8 mg, 10.3%) as a solid. Recrystallization from benzene afforded pale yellow needles: Mp 86.0—86.5 °C; MS *m/z* 301 (M^+, 64%) and 244 (100); mol wt 301.3; IR 2195 (-C≡C-), 1615, 1595 (C=C), 1295, 1270, and 1020 cm^{-1} (-O-); UV_{max} 260 sh (17700), 274 (21500), 288 (21800), 364 sh (4670), 387 (5420), and 418 nm sh (3940), and see Fig. 5; ^1H NMR (200 MHz) τ=2.09 (d, 13, 1H, H^A), 2.53 (d, 7.3, 1H, H^4), 2.59—2.74 (m, 3H, H^1, H^2, and H^3), 3.38 (s, 1H, $H^{B'}$), 3.58 (d, 8, 1H, H^C), 3.85 (dd, 13.5, 8, 1H, H^B), 5.67 (q, 7, 2H, $-OCH_2CH_3$), 8.04 (s, 3H, CH_3), 8.21 (s, 3H, CH_3'), and 8.62 (t, 7, 3H, $-OCH_2CH_3$).

Found: C, 83.73; H, 6.60; N, 4.72%. Calcd for $C_{21}H_{19}NO$: C, 83.69; H, 6.35; N, 4.65%.

1-Hydroxyimino-10,13-dimethyl-4,5-benzotrideca-2,10,12-triene-6,8-diyne (17). To a stirred soln of bisdehydrobenzo-[13]annulenone (**16**)[4] (1.62 g, 6.27 mmol) in methanol (180 ml) and THF (100 ml) was added in one portion a soln of hydroxylamine hydrochloride (4.50 g, 65 mmol) in water (10 ml) at room temp. After stirring for 13 h at the same temp, a further quantity of hydroxylamine hydrochloride (13.5 g) in water (30 ml) was added, and stirring was continued for further 15 h. The soln was then warmed to 38—39 °C and was stirred for further 7 h. Then the soln was worked up as in the preparation of **8**. After solvent removal, the residue was chromatographed on alumina (4.2×8.0 cm). The early fractions eluted with 3% ethanol in chloroform gave the oxime **17** (577 mg, 34%) as a solid. Recrystallization from hexane–chloroform afforded yellow needles: Mp 204—206 °C (decomp); MS *m/z* 273 (M^+, 88%) and 256 (100); mol wt 273.2; IR 3250 (-OH), 2180 (-C≡C-), and 980 cm^{-1} (trans C=C); UV_{max} 225 (30300), 272 (36300), 281 sh (35800), 380 (5460), and 412 nm sh (4140); ^1H NMR (90 MHz, DMSO-d_6) τ=−1.87 (s, 1H, OH, exchangeable with D_2O), 2.45 (d, 10.5, 1H, H^B), 2.61 (d, 17, 1H, $H^{B'}$), 2.52—2.75 (m, 4H, benzenoid H), 2.90 (d, 10.5, 1H, H^C), 3.15 (d, 17, 1H, $H^{A'}$), 7.98 (s, 3H, CH_3), and 8.16 (s, 3H, CH_3).

Found: C, 83.28; H, 5.42; N, 5.20%. Calcd for $C_{19}H_{15}NO$: C, 83.49; H, 5.53; N, 5.13%.

11,14-Dimethyl-5,6-benzazacyclotetradeca-3,5,11,13-tetraene-7,9-diyn-2-one (18). A soln of phosphorus pentachloride (2.63 g, 2.23 mmol) in THF (210 ml) was added to a stirred soln of the oxime **17** (869 mg, 3.18 mmol) in THF (150 ml) during 1 h under ice-bath. After stirring for 5 h at room temp the mixture was worked up as in the preparation of **9**. The residue after solvent removal was chromatographed on alumina (4.2×7.0 cm). The early fractions eluted with benzene–chloroform (1:1) gave the lactam **18** (346 mg, 39.8%) as a solid. Recrystallization from hexane–chloroform afforded orange needles: Mp 210—212 °C (decomp); MS *m/z* 273 (M^+, 84%) and 244 (100); mol wt 273.3; IR 3190, 3060 (NH), 2190 (-C≡C-), 1660 (C=O), and 980 cm^{-1} (trans C=C); UV_{max} 227 (28600), 268 sh (26200), 281 (32300), 295 sh (26300), 300 sh (23900), and 379 nm (7160); ^1H NMR (200 MHz, DMSO-d_6) τ=0.37 (s, 1H, NH), 1.90 (d, 16, 1H, $H^{B'}$), 2.21 (d, 7.7, 1H, H^4), 2.31 (d, 7.3, 1H, H^1), 2.30—2.48 (m, 2H, H^2 and H^3), 2.88 (d, 8.5, 1H, H^C), 3.53 (d, 16, 1H, $H^{A'}$), 4.77 (d, 8.5, 1H, H^B), 8.02 (s, 3H, CH_3), and 8.03 (s, 3H, CH_3).

Found: C, 83.19; H, 5.51; N, 5.25%. Calcd for $C_{19}H_{15}NO$: C, 83.49; H, 5.53; N, 5.13%.

The later fractions eluted with chloroform gave the recovered oxime **17** (166 mg).

2-Ethoxy-11,14-dimethyl-5,6-benzo-7,9-bisdehydroaza[14]-annulene (6). To a stirred soln of the lactam **18** (336 mg, 1.23 mmol) in dichloromethane (50 ml) was added dropwise a soln of triethyloxonium tetrafluoroborate (2.33 g, 12.3 mmol) in dichloromethane (30 ml) during 1 h at room temp under argon. After stirring for 2 h, a further quantity of the oxonium salt (1.2 g) in dichloromethane (20 ml) was added, and stirring was continued for further 8.5 h at room temp. Then the reaction mixture was worked up as in the preparation of **3**. The residue after removal of solvent was chromatographed on alumina (3.7×6.5 cm). The ini-

tial fractions eluted with 2% ether in hexane gave the azaannulene **6** (159 mg, 43%) as a solid. Recrystallization from hexane–benzene afforded orange plates: Mp 100—101 °C; MS *m/z* 301 (M^+, 75%) and 244 (100); mol wt 301.3; IR 2190, 2110 (-C≡C-), 1595 (C=C), 1250, 1050 (-O-), 975, and 960 cm^{-1} (trans C=C); UV_{max} 228 (29400), 245 sh (23800), 271 sh (30800), 281 (34200), 322 sh (9860), and 386 nm (3830), and see Fig. 5; ^1H NMR (200 MHz) τ=2.43 (d, 16, 1H, $H^{B'}$), 2.51—2.74 (m, 4H, benzenoid H), 3.24 (d, 16, 1H, $H^{A'}$), 3.36 (d, 5.5, 1H, H^C), 4.80 (d, 5.5, 1H, H^B), 5.74 (q, 7, 2H, $-OC\underline{H}_2CH_3$), 8.02 (s, 3H, CH_3), 8.24 (s, 3H, CH_3'), and 8.60 (t, 7, 3H, $-OCH_2C\underline{H}_3$), (200 MHz, CF_3COOD in $CDCl_3$) τ=1.95 (d, 16, 1H, $H^{B'}$), 2.33—2.45 (m, 4H, benzenoid H), 2.95 (d, 16, 1H, $H^{A'}$) 3.48 (s, 1H, H^C), 3.74 (s, 1H, H^B), 5.26 (q, 7, 2H, $-OC\underline{H}_2CH_3$), 7.94 (s, 3H, CH_3), 8.23 (s, 3H, CH_3), and 8.35 (t, 7, 3H, $-OCH_2C\underline{H}_3$).

Found: C, 83.91; H, 6.42; N, 4.76%. Calcd for $C_{21}H_{19}NO$: C, 83.69; H, 6.35; N, 4.65%.

The later fractions eluted with 5% ethanol in chloroform gave the recovered lactam **18** (192 mg).

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