Synthesis and Circular Dichroism of some trans-5,5a,6,7,8,9,9a,10-Octahydrobenzo[g]quinoxalines (Octahydrobenzo[g]quinoxalines)

by

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Abstract - Starting from trans-decalone-2 several optically active pyrazine derivatives with chiral second sphere have been prepared. The cd of the parent compound, 5,5a,6,7,8,9,9a,10-octahydrobenzo[g]quinoxaline (+)-VII reveals four Cotton effects (in isooctane:band I at 327 nm, band II at 270 nm, band III at 228 nm, band IV at 210 nm)which could be assigned to transitions to the following excited states: $^1B_{3u}$, $^1B_{2u}$, $^1B_{2g}$, and $^1B_{1u}$. The signs of these Cotton effects can be correlated with those of related octahydroanthracenes and ketones with chiral second sphere. The cd spectra of the mono and diprotonated compound support this assignements. The cd spectra of several 2-substitution products are given.

1,2,3,4,4a,9,9a,10-trans-Octahydro anthracenes have been found to the particularly useful during our studies of

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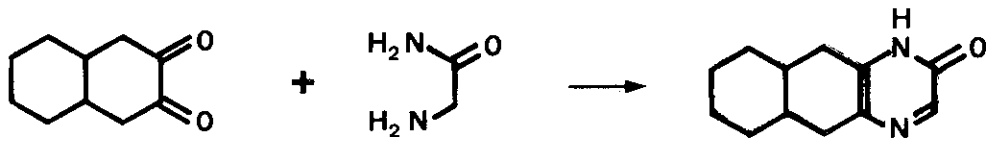
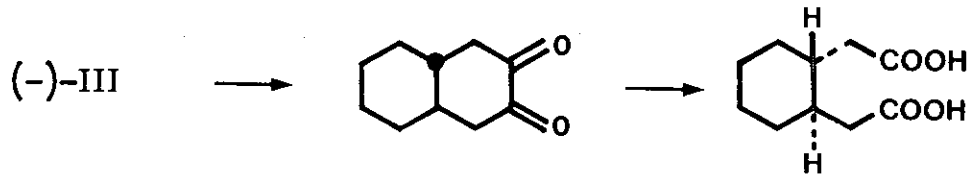
chiroptical properties of benzene derivatives with a chiral second sphere (1-4). We have now applied this same scheme to the pyrazine chromophore and describe here synthesis and cd of the parent compound and several of its derivatives.

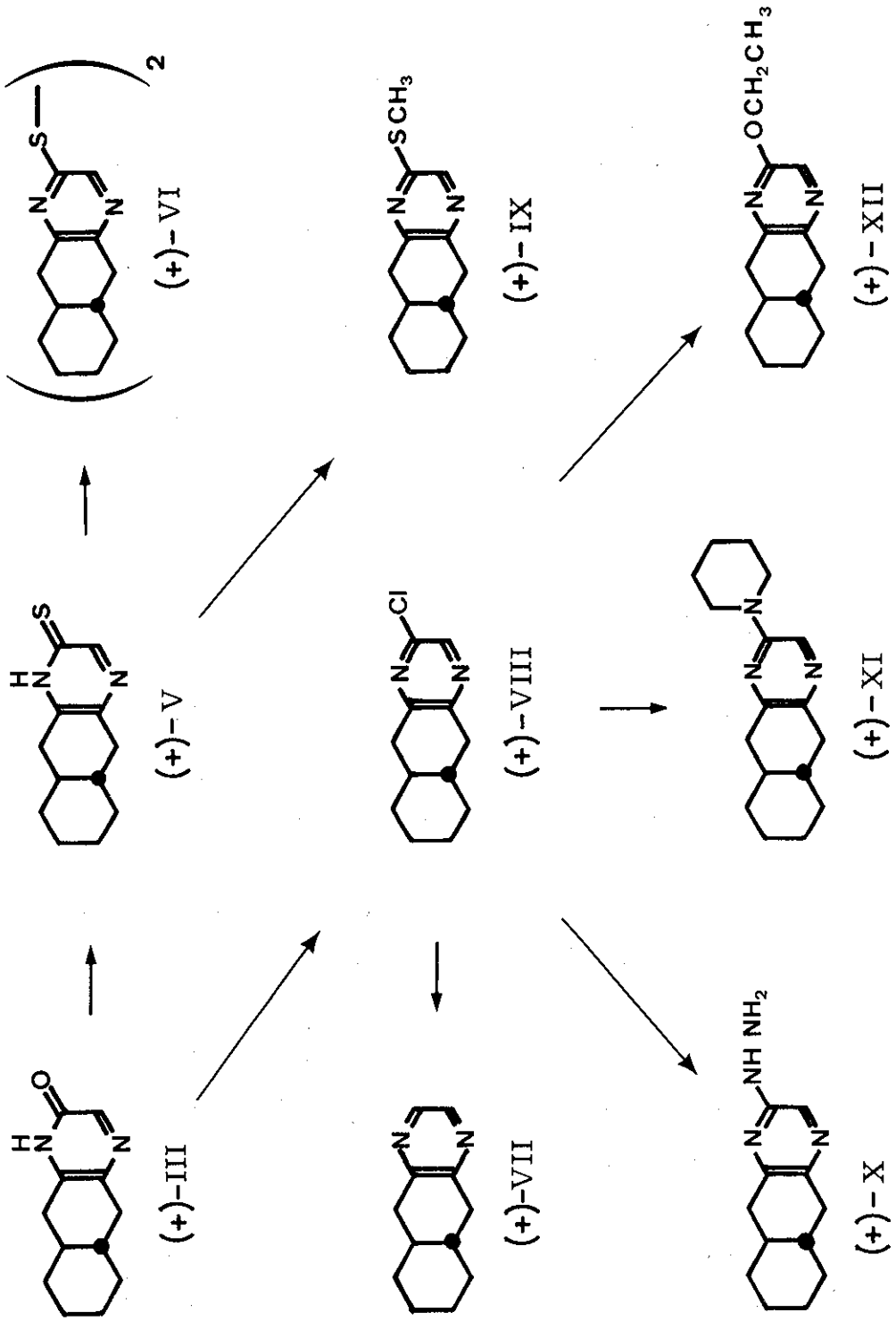
Synthesis. - rac-trans-Decalin-2,3-dione (I) was synthesized from rac-trans-decalone-2 according to Ganapathi (5) by oxidation with SeO_2. The decalone was obtained from rac-trans-decalol-2 with $K_2Cr_2O_7$ as described by Nikitin (6), and this in turn was prepared from commercial "decahydronaphthol" (Aldrich) by the Raney-nickel procedure published by Fernandez et al. (7). Reacting (±)-I with glycine amide in similar manner as described for analogous compounds (8) gave in very good yield the rac-trans-decahydrobenzo[g]quinoxalin-2-one (±)-III, which is basic enough to allow resolution via its salt with (+)-camphor-10-sulphonic acid. The (+)-enantiomer was thus prepared in optically pure state, and this



(±)-trans-I II (±)-trans-III



(-)-I (+)-IV


(+)-III
(+)-V
(+)-VI
(+)-VII
(+)-VIII
(+)-IX
(+)-X
(+)-XI
(+)-XII

material was used for most of the further reactions. From the mother liquors of crystallization the (-)-enantiomer of appr. 25% enantiomeric purity was obtained, which was used to determine the absolute configuration by degradation to a known compound.

To this end (-)-III was hydrolized with 16% aqueous HBr to give (-)-I, which was oxidized according to Ganapathi (5) with alkaline H_2O_2 to the (+)-trans-cyclohexane diacetic acid (+)-IV of 6% enantiomeric purity (cf. 9). This (+)-diacid is known (9) to have (1R,2R)-chirality, so this settles the absolute configuration of (-)-III to be of (5aR,9aR)-configuration, furthermore laevorotatory trans-decalin-2,3-dione must be the S-isomer.

The amide grouping of (+)-III was transferred into the thiono analogue (+)-V with P_2S_5; its oxidation led to the disulphide (+)-VI, alkylation with CH_3I gave the methyl-mercapto derivative (+)-IX. The parent compound of this series could be obtained by reacting first (+)-III with PCl_5 to the chloro derivative (+)-VIII, which by catalytic hydrogenation over Pd/C gave (+)-VII . The chloro atom of (+)-VIII could also be exchanged by known procedures (8) for other groups, leading thus to the hydrazine derivative (+)-X, the N-piperidine compound (+)-XI, and the ethoxy derivative (+)-XII . The structures of these compounds follow from the mode of their preparation and their spectral characteristics.

Circular Dichroism. - The electronic spectra of pyrazine and its derivatives have been extensively investigated (e.g. 10-17) and several theoretical calculations have been published (e.g. 18-20). The best assignment of filled orbitals seems to be that of Gleiter et al. (21) which is based on the application of Koopman's theorem to the photoelectron spectrum. Not considering the low-lying σ-orbitals the following sequence (rising orbital energy) has been proposed: $\pi_1(b_{3u})$, $\pi_2(b_{2g})$, $n^-(b_{1u})$, $\pi_3(b_{1g})$, and $n^+(a_g)$. The LUMO is $\pi_4^*(b_{3u})$ (Fig. 1). For simplicity all symmetry labels used are those for point group D_{2h} even if the pyrazine molecule is substituted.

In a hydrocarbon solvent like isooctane the first band system with clearly visible fine structure around 320 nm has been called the "sharp system" and is ascribed to the $n^+ \rightarrow \pi_4^*$ ($^1A_g \rightarrow {}^1B_{3u}$) transition which is allowed and x-polarized (perpendicular to the plane of the ring). In more polar solvents the fine structure is washed out completely and the band is blueshifted, indicating its $n \rightarrow \pi^*$ nature. The second band system around 260 nm shows less pronounced fine structure and is called the "diffuse system". It is assigned the $\pi_3 \rightarrow \pi_4^*$ ($^1A_g \rightarrow {}^1B_{2u}$) transition and is scarcely depending on the choice of the solvent. A band at still shorter wavelengths (around 195 nm) has been assigned the $\pi_2 \rightarrow \pi_4^*$ ($^1A_g \rightarrow {}^1B_{1u}$) transition. Monoprotonation leads to a pyridine-like spectrum (10) whereas in conc. H_2SO_4 double protonation takes place and only one broad and very

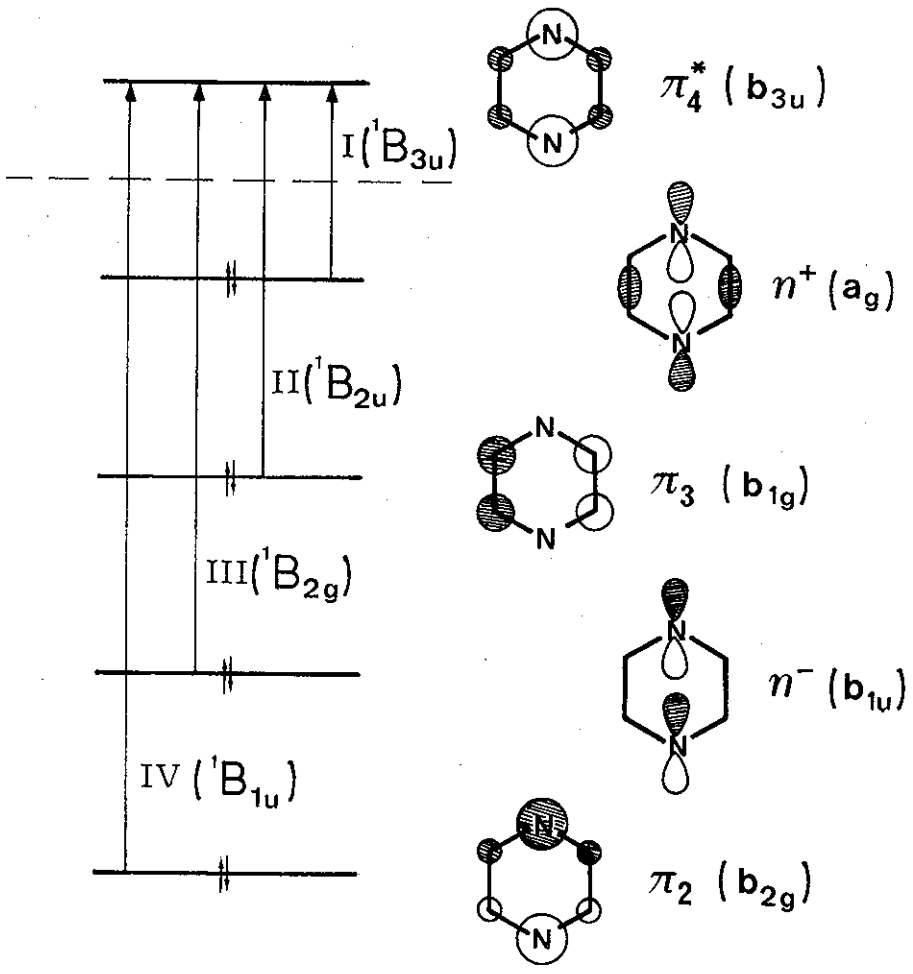
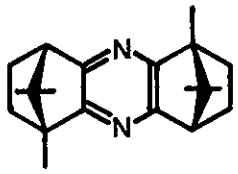
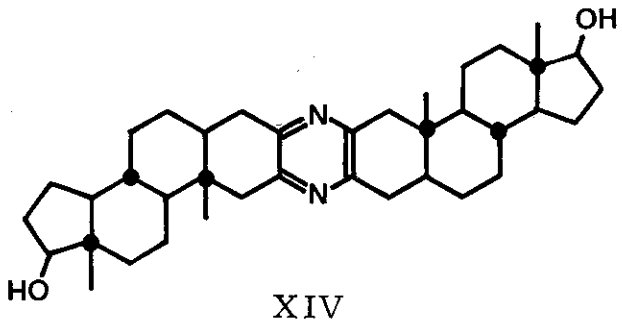


Fig. 1. Schematic drawing of the four highest occupied MOs and the LUMO of pyrazine. Arrows indicate the transitions as assigned to cd bands I..IV. Orbital mixing is neglected.

intense band is found around 286 nm (10). Though transition energies and orbital energies do not parallel each other one nevertheless is tempted to place the $n^- \rightarrow \pi_4^*$ ($^1A_g \rightarrow {}^1B_{2g}$) transition also between 200 and 300 nm. This is, however, electrically dipole forbidden and there seems no chance to localize it in a spectrum in solution, though occasionally its direct or indirect identification in gas or matrix spectra (e.g. 22) has been claimed. As this transition on the other hand is magnetically dipole allowed it should be looked for in the cd spectrum.



XIII



XIV

The cd spectra of two simple optically active pyrazine derivatives XIII and XIV have been published (23). They have been recorded only in polar solvents and revealed two to three bands, which were assigned to the transitions to the $^1B_{3u}$, $^1B_{2u}$, and $^1B_{1u}$ states, resp. We have run the cd spectrum of (+)-VII in several solvents (Fig.2, Table 1) and find four band systems, three of which correspond to the uv bands mentioned above. In isooctane at 327 nm in both the cd and the uv spectrum (Fig. 3) the O-O band of the "sharp system" ($^1A_g \rightarrow {}^1B_{3u}$; band I) is found, followed by three

more fine structure peaks (splitting appr. 600 cm^{-1}). The "diffuse system" ($^1A_g \rightarrow {}^1B_{2u}$; band II) shows up around 270 nm (three fine structure peaks), and around 210 nm another cd band (band IV) is discernible, which corresponds to the 206 nm uv band and can be assigned the $^1A_g \rightarrow {}^1B_{1u}$ transition. In between these two latter bands another cd band (band III), actually the strongest one in the spectrum, appears at 228 nm, where the uv spectrum has just its minimum. Obviously this band corresponds to an electric dipole forbidden but magnetic dipole allowed transition, and so we assign it therefore the above mentioned $n^- \rightarrow \pi_4^*$ ($^1A_g \rightarrow {}^1B_{2g}$) transition. In more polar solvents band I looses its fine structure and is blueshifted as expected, whereas band II is scarcely influenced in its position and shape; also band III shows only slight hypsochromy. In the protic solvent hexafluoro acetone hydrate cd band I is so strongly blueshifted that it is seen only as some fine structure overlaying the long wavelength wing of cd band II; its shape suggests that even the sign has changed. This makes it difficult to compare our cd spectra with that of XIII (23) which was measured in methanol solution.

Monoprotonation (TFA in acetonitril) leads to complete loss of band I and also drastically reduces the rotational strength of band III, whereas band II is shifted bathochromically in agreement with the known uv behaviour (10). This band in cd reveals a shoulder which coincides with the maximum in the uv spectrum thus suggesting that one n-orbital is still available for an $n \rightarrow \pi^*$ transition. Double protonation

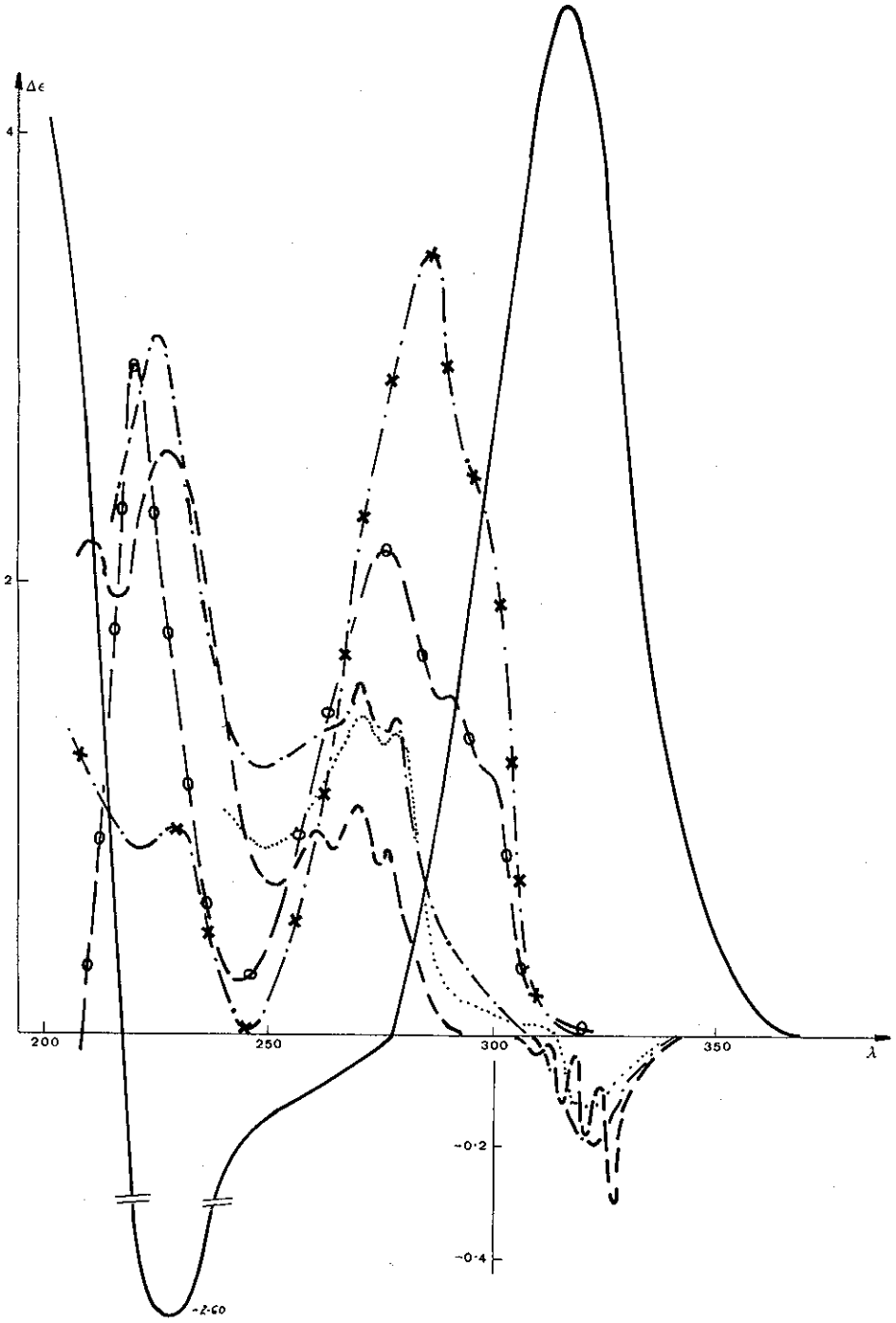


Fig. 2 cd spectra of (+)-VII in different solvents.

- - - - - - isooctane; -·-·-·-·- acetonitril;

✕·✕·✕·✕·✕ TFA in acetonitril; Θ - Θ - Θ hexafluoro-acetone hydrate; ····· chloroform;

_____ conc. H_2SO_4 . Enlarged scale valid only for negative bands above 300 nm.

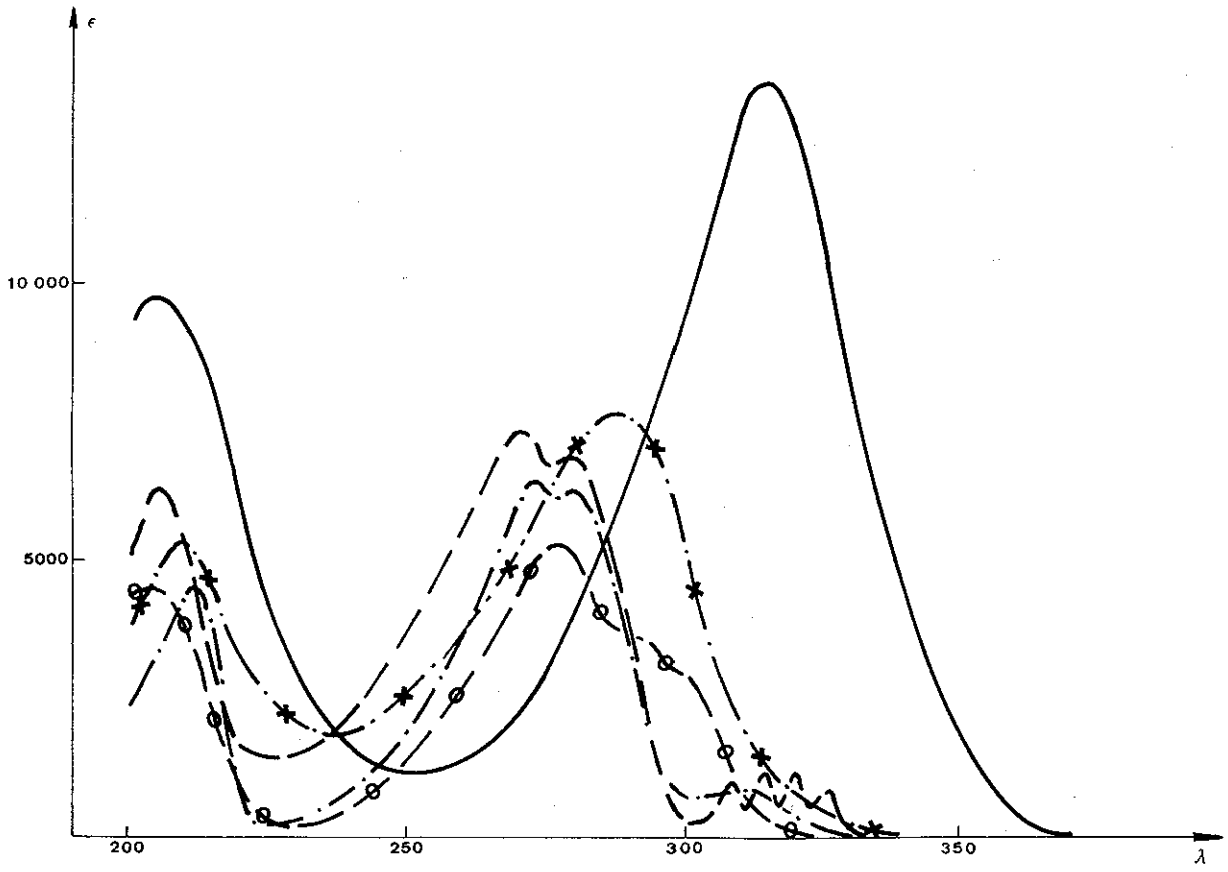


Fig. 3 uv spectra of (+)-VII in different solvents.

- - - - - isooctane; -·-·-·-·-·-acetonitril;

✕·-·✕·-·✕ TFA in acetonitril; ⊖ - ⊖ - ⊖ hexafluoro-

acetone hydrate; ———— conc. H_2SO_4.

Table 1.

cd of optically active pyrazine derivatives

Compound	solvent	λ_{max} ($\Delta\varepsilon$)
(+)-III	ethanol	341 (+0.58), 309 (+0.78), 237 (+1.51), 205 (+1.98)
	ethanol + NaOH	333 (+1.10), 226 (+1.96), 210 (+2.03)
	ethanol +TFA	336 (+0.58), 310 (+0.77), 237 (+1.54), 203 (+1.9)
(+)-V	ethanol	430 (+0.52), 321 (-0.11), 296 (+1.00), 250 (+0.70)
	ethanol + NaOH	366 (+0.87), 283 (+1.19)
(+)-VI	acetonitril	321 (+1.26), 309 (+1.28), 299 (+1.34), 226 (+3.47)
	acetonitril +TFA	316 (+1.87), 311 (+1.90), 297 (+2.08), 228 (+3.76)
(+)-VII	isooctane	327 (-0.30), 321 (-0.17), 316 (-0.12), 309 (-0.04), 277 (+0.82), 270 (+1.00), 261 (+0.86), 227 (+2.58), 211 (+2.19)
	acetonitril	324 (-0.20), 277 (+2.51), 270 (+2.76), 263sh (+2.30), 226 (+5.55)
	acetonitril +TFA	305sh (+1.92), 286 (+3.75), 227 (+1.0)
	chloroform	326 (-0.14), 322 (-0.12), 295sh (+0.2), 279 (+1.32), 272 (+1.38)
	hexafluoroacetone hydrate	300sh (+1.13), 291 (+1.51), 275 (+2.14), 220 (+2.98)
	conc. H_2SO_4	316 (+4.64), 227 (-2.60)

(Table 1, continued)

(+)-VIII	isooctane	316 (-0.16), 303 (+0.48), 296 (+0.57) 281 (+1.28), 218 (+3.87)
	acetonitril	317 (-0.07), 281 (+1.48), 221 (+4.00)
	acetonitril + TFA	296 (+1.13), 282 (+1.35), 221 (+3.13)
(+)-IX	isooctane	327 (+0.93), 251 (+1.01), 222 (+2.58), 206 (-0.7)
	acetonitril	327 (+0.88), 298 (+0.30), 247 (+0.64), 224 (+1.83)
	acetonitril + TFA	368 (+0.62), 306 (+0.51), 246 (+0.81)
(+)-X	acetonitril	333 (+0.98), 328 (+0.99), 215 (+3.67)
	acetonitril + TFA	341 (+0.57), 297 (+0.71), 237sh (+0.18), 218 (+1.4)
	ethanol	336 (+0.91), 237sh (+0.34), 214 (+3.40)
(+)-XI	isooctane	342 (+1.00), 243 (+1.63), 220 (+4.20)
	acetonitril	354 (+0.88), 246 (+1.47), 220 (+4.09)
	acetonitril + TFA	353 (+0.75), 245 (+1.17), 222 (+3.31)
(+)-XII	acetonitril	306 (+1.32), 285sh (+0.90), 213 (+3.85)
	acetonitril +TFA	321 (+1.79), 296sh (+1.46), appr. 208 (+2.23)

in conc. H_2SO_4 increases not only ε but also $\Delta\varepsilon$ for the strongly redshifted band II, again in agreement with known similar shifts recorded for pyrazine (10) and the optically active compounds XIII and XIV (23). A band at 227 nm in this solvent corresponds most probably to a higher energy transition not accessable in the neutral solution.

The sign of the cd band I is negative, all other three cd bands have positive $\Delta\varepsilon$ values, and these correlation between chirality of the second sphere and the sign of the Cotton effects can be explained on the basis of the following simple symmetry arguments. (+)-VII is comparable to a p-disubstituted octahydroanthracene as shown in Fig. 4. Bands II and IV of a pyrazine correspond to the $^1B_{2u}$ and $^1B_{1u}$ bands of benzene, the chromophore of the carbocyclic reference compound.With the same absolute configuration these two cd bands are indeed positive in both compounds (1).

The other two transitions (bands I and III) commence at n-orbitals and can thus be compared with the carbonyl $n\rightarrow\pi^*$ transition. Actually the point group of VII is C_2, so one has to compare its cd with that of a cycloalkanone in the twist conformation with the C=O in the "point" of the twist (Fig. 4). The n^--orbital has the same symmetry as the n-orbital of the carbonyl, and π_4^*belongs to the same irreducible representation as the π^*-orbital of the ketone. With the absolute configuration of the second spheres identical (Fig. 4) the corresponding cd bands should have the same sign, and exactly this is found: cd band III is positive for (+)-VII and positive for a twisted

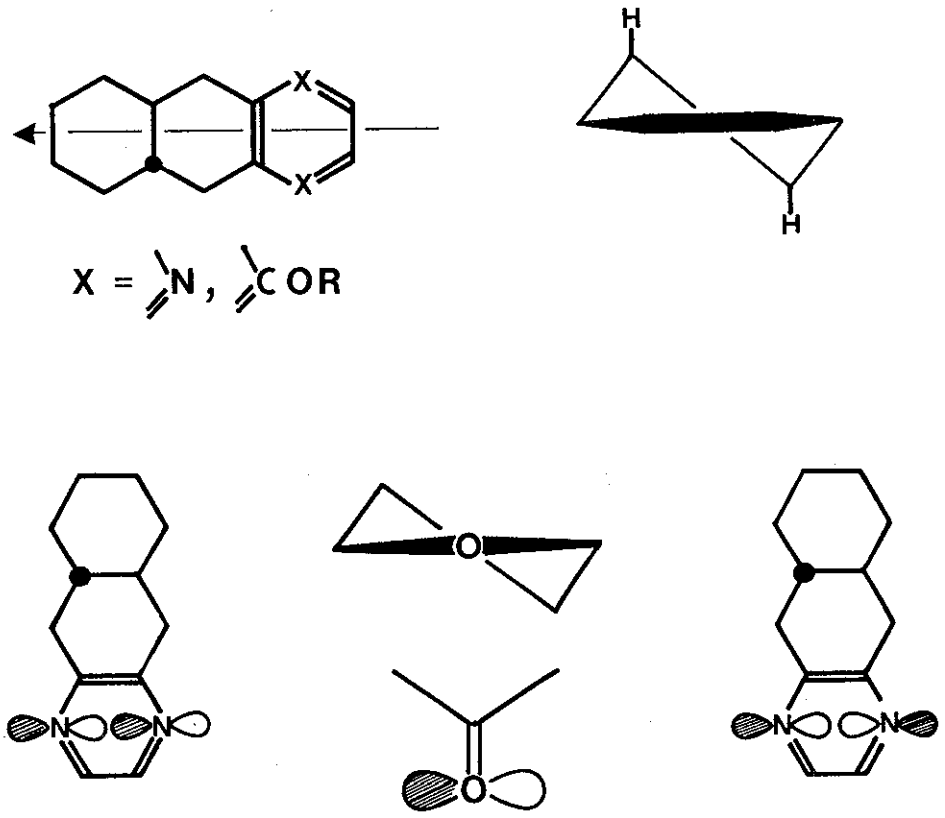


Fig. 4. Correlation between chirality of second sphere and signs of Cotton effects of (+)-VII.

Top: projection of (+)-VII and a p-disubstituted octahydroanthracene along the arrow. The thick bar represents the double bond of the middle cyclohexene ring.

Bottom: Comparison of the symmetries (point group C_{2v}) of n-orbitals. Left: $n^{-}(b_2)$-orbital of (+)-VII. Middle: $n(b_2)$-orbital of a ketone (projection along O towards C for a twisted alkanone (above)). Right: $n^{+}(a_1)$-orbital of (+)-VII. The π_4^*-orbital of (+)-VII and the π^*-orbital of a ketone belong to the irreducible representation b_1 in C_{2v}.

cycloalkanone of same chirality of the second sphere (24). Because of the sum rule for cd bands (25) the other $n\rightarrow\pi^*$ band, terminating at the same π^*-orbital, should have opposite sign, i.e. a negative one, as is indeed found for (+)-VII.

It is interesting now to compare the transition energies as obtained experimentally for (+)-VII in isooctane with those calculated for the unsubstituted pyrazine (Table 2). One calculation places indeed the $^1A_g\rightarrow{}^1B_{2g}$ transition higher than the $^1A_g\rightarrow{}^1B_{2u}$ transition as assigned here. Another transition calculated of similar energy, viz. $n^+\rightarrow\pi_5^*(^1A_g \rightarrow {}^1A_u)$ cannot correspond to the observed strong cd band III as it lacks both an electric and a magnetic transition moment.

Table 2.

Transition energies for pyrazines

State	Transition energy (eV)		
	calc. (20) (for pyrazine)	calc. (19) (for pyrazine)	found for (+)-VII in cd
$^1B_{3u}$ $(n^+\rightarrow\pi_4^*)$	3.91	4.22	3.79 (band I)
$^1B_{2u}$ $(\pi_3\rightarrow\pi_4^*)$	5.26	5.29	4.47 (band II)
^1A_u $(n^+\rightarrow\pi_5^*)$	4.90	5.22	
$^1B_{2g}$ $(n^-\rightarrow\pi_4^*)$	5.12	5.65	5.46 (band III)
$^1B_{1u}$ $(\pi_2\rightarrow\pi_4^*)$	9.31	9.10	5.89 (band IV)

In chloroform solution cd band I starts to become bisignated, and this may be explained by assuming the presence of (at least) two vibrational series within the same electronic transition (26). In the vapour uv spectrum of pyrazine at least five series have been identified (13); one is therefore not forced from cd to assume the presence of one more transition in this area (cf. also the similar discussion in (23)). For XIV in chloroform the published (23) cd between 350 and 280 nm is very similar to that of (+)-VII as it should be, as both molecules have identical chiral second spheres.

Monochlorination of pyrazine shifts the "sharp system" to the blue,the "diffuse" one to the red. The same is found in the uv and cd spectra of the optically active chloro compound (+)-VIII. The cd of band I is clearly bisignated in both isooctane and acetonitril solution. Though the two n-orbitals are not any more degenerate they still will couple with each other in a similar manner as in pyrazine itself and therefore the signs of the bands are still the same. The cd and uv maxima do not strictly coincide around 220 nm, from these spectra it nevertheless cannot be deduced unequivocally whether one or two cd bands are present in this range.

With the stronger perturber OEt in (+)-XII cd band I (acetonitril) merges together with the strong cd band II, but the overall shape of the curve is still similar to that of (+)-VII and (+)-VIII, resp. All other substituents introduced into the 2-position of the ring system (compounds VI, IX, X,

and XI) are still more powerful perturbers and most of these cd and uv spectra are therefore more complex than those mentioned hitherto. The amide (II) and thioamide chromophore (IV) differs appreciable from that of a simple substituted pyrazine as long as the tautomer depicted in the formulae scheme prevails. The appearance of a new medium strong cd band above 350 nm clearly indicates that in (ethanolic) solution indeed these forms are preponderant in agreement with general experience (8).

Experimental Part

The silica used for column chromatography had 50-100 µ (Gebr. Herrmann, Köln), melting points were determined on a Kofler micro melting point apparatus, optical rotations were measured in tubes of 1 dm length with a Perkin-Elmer model 141, uv spectra were run on a CARY 17, ir spectra (in KBr pellets) on a Shimadzu IR 400, nmr spectra were taken on a Varian A-60, T-60 or NV-14, using TMS as internal reference. Values are quoted in the δ-scale (δ_{TMS} = 0 ppm). Mass spectra were done on a Varian-MAT CH-5 fitted with a direct inlet system at 70 eV. The cd spectra were run on a Jobin-Yvon dichrograph Mark III at room temperature in cells of 2.00 to 0.01 cm path length and concentrations of appr. 1 mg/g. Microanalysis by Dr. Pascher, Bonn.

rac-trans-1,2,5,5a,6,7,8,9,9a,10-Decahydro-benzo[g]quinoxalin-2-one (Compound (±)-III) . - To a stirred solution of 0.93g glycine amide hydrochloride (II) (cooled in an ice bath) in a mixture of 30 ml methanol and 10 ml water, 2.8g trans-decalin-2,3-dione (I) were added, then 6.6 ml of a 10% aqueous NaOH solution was added dropwise. The slurry was slowly brought to room temperature and stirred for another 2h, resulting in a clear solution. After acidification with hydrochloric acid the product precipitated and was recrystallized from ethanol yielding 2.9g (81%) of mp 265-67°C, λ_{max} (ethanol) 340 (7300), 227 nm (ε 9100), ν_{max} 3100-2400 (broad, NH), 1650 cm^{-1}, nmr (DMSO-d_6) 7.8 (H-3), 2.5 - 0.9 (14H). (Found: C, 70.33; H, 7.77; N, 13.85; M^+, 204, other prominent fragments 176 and 94 m/e. $C_{12}H_{16}N_2O$ requires C, 70.55; H, 7.90; N, 13.72%;

M, 204.27).

Resolution of (±)-III . - To a suspension of 17.7 g (±)-III in 200 ml methylene chloride 21.7 g (+)-camphor-10-sulphonic acid were added, then the suspension was intensely shaken until a yellow solution resulted. The salt was precipitated with 400 ml ether and recrystallized from methylene chloride/ether mixtures (1:2 at the beginning, later 1:1) until the mp of the corresponding free base did not rise any more (appr. 20 times). The mother liquors of the first five recrystallizations were worked up again and the resulting material was added to the main batches. The free base was obtained by treating the salt with a mixture of ethanol and excess of $NaHCO_3$ solution under vigorous stirring. Crystallization from ethanol yielded optically pure (+)-III of mp 268-70°C, $[\alpha]_D^{23}$ +140° (acetic acid; c 0.8). Spectral data and R_f values were identical with those of the racemate. From the combined mother liquors appr. 8g of the (-)-enantiomer (25% enantiomeric purity) could be obtained by direct crystallization.

Degradation of (-)-III to (+)-(R)-trans-1,2-Cyclohexanediacetic acid (IV) . - 2.0 g (-)-III of 25% enantiomeric purity were hydrolyzed over night by boiling in 50 ml 16% aqueous HBr. The reaction mixture was then extracted with methylene chloride and the resulting material chromatographed on silica with petrol ether/ether (2:3). The first fractions were recrystallized twice from n-hexane yielding 120 mg of a material of $[\alpha]_D^{23}$ -22.6° (ethanol; c 9.0), being identical with trans-decalin-2,3-dione.

80 mg of this material were oxidized with alkaline

H_2O_2 exactly as described (5) and yielded 30 mg (+)-IV of mp 163-67° and $[\alpha]_D^{23}$ +3.0° (ethanol; c 6.0). Optically pure (+)-IV is reported to have $[\alpha]_D$ +49.4° (9).

(+)-(5aS,9aS)-1,2,5,5a,6,7,8,9,9a,10-Decahydrobenzo[g]quinoxalin-2-thione (Compound (+)-V) . - A solution of 2.7 g (+)-III and 2.95 g P_2S_5 in 40 ml pyridine was refluxed for 4h, then treated with ice water and extracted with methylene chloride. After recrystallization from ethanol 1.6 g (55%) yellow crystals of mp 188-90°C, $[\alpha]_D^{23}$ +167° (ethanol; c 1.7), λ_{max} (ethanol) 409 (8500), 286 nm (ε 15000), ν_{max} 3000-2400 (broad, NH), 1600 cm^{-1}, nmr ($CDCl_3$) 8.5 (H-3), 3.3 - 0.7 ppm (14H). (Found: C, 65.28; H, 7.19; S, 14.67; M^+, 220, other prominent fragments at 176 and 94 m/e. $C_{12}H_{16}N_2S$ requires C, 65.41; H, 7.32; S, 14.55; M, 220.33).

(+)-Bis-(5aS,9aS)-5,5a,6,7,8,9,9a,10-octahydrobenzo[g]quinoxalin-2-yl disulphide (Compound (+)-VI). - To a solution of 100 mg (+)-V in 2 ml 7% aqueous NH_3 was added a solution of 200 mg $K_3[Fe(CN)_6]$ in 2 ml water. The precipitate was crystallized from ethyl acetate/n-hexane (1:1) yielding 70 mg (70%) of glittering platelets, mp 141-43°C, $[\alpha]_D^{23}$ +130° (ethanol; c 3.5), λ_{max} (acetonitril) 314sh (7300), 300 (7900), 234 nm (ε 7800), ν_{max} 1550, 1460, 1440 cm^{-1}, nmr ($CDCl_3$), 8.6 (H-3), 3.5 - 0.8 ppm (14H). (Found: C, 65.40; H, 6.88; S, 14.66; M^+, 438. $C_{24}H_{30}N_4S_2$ requires C, 65.71; H, 6.89; S, 14.62; M, 438.64).

(+)-(5aS,9aS)-2-Methylthio-trans-5,5a,6,7,8,9a,10-octahydrobenzo[g]quinoxaline (Compound (+)-IX). - 80 mg (+)-V were dissolved in 4 ml 5% aqueous NaOH solution and shaken

15 min with 0.2 ml methyl iodide. After extraction with methylene chloride an oil resulted which was chromatographed on silica with ether. Crystallization at-8°C from n-hexane yielded 45 mg (53%) of mp 65-66°C, $[\alpha]_D^{23}$ +130° (ethanol; c 0.6), λ_{max} (acetonitril) 327 (5700), 304sh (3500), 250 nm (ε 6500), ν_{max} 1510, 1450, 1430 cm^{-1}, nmr ($CDCl_3$) 8.2 (H-3) 2.5 (SCH_3), 3.1 - 1.0 ppm (14H). (Found: C, 66.78; H 7.78; N, 11.96; S, 13.74; M^+, 234. $C_{13}H_{18}N_2S$ requires C, 66.62; H, 7.74; N, 11.96; S, 13.68; M, 234.35).

(+)-(5aS,9aS)-2-Chloro-trans-5,5a,6,7,8,9,9a,10-octahydrobenzo[g]quinoxaline (Compound (+)-VIII). A suspension of 1.5 g (+)-III in a mixture of 1.8 g PCl_5 and 20 ml $POCl_3$ was heated to 90-100°C and intensely stirred. After 30 - 40 min the material had dissolved completely and stirring was continued for 30 min. Then ice was added and the product was extracted with methylene chloride and purified by chromatography over silica with methylene chloride. The first fractions contained the bulk of the material which was 3 times crystallized from n-hexane at -5°C, yielding 0.7 g (43%) of mp 71-73°C, $[\alpha]_D^{23}$ +158° (ethanol; c 0.3), ν_{max} 1520, 1440, 1420 cm^{-1}, nmr ($CDCl_3$) 8.3 (H-3), 3.3 - 1.0 (14H); in presence of a saturated solution of $Eu(tfc)_3$ the optically pure (+)-VIII shows only one signal for H-3, whereas the racemate gives two singlets. The signal of the (+)-enantiomer appears at lower field. (Found: C, 64.50; H, 6.72; Cl, 16.07; N, 12.57; M^+, 222, other prominent fragments at 207, 193, 178, 165, 153, and 142 m/e. $C_{12}H_{15}ClN_2$ requires C, 64.71; H, 6.79; Cl, 15.92; N, 12.58; M, 222.71).

(+)-(5aS,9aS)-trans-5,5a,6,7,8,9,9a,10-Octahydrobenzo[g]quinoxaline (Compound (+)-VII). - A solution of 100 mg (+)-VIII in 5 ml 95% ethanol and 0.5 ml triethyl amine was hydrogenated at room temperature over 10% Pd/C (appr. 1h). After filtration the material was precipitated with water and purified by chromatography in ether solution over silica. After two recrystallizations from n-hexane the yield was 52 mg (62%) of mp 86-87°C, $[\alpha]_D^{23}$ +168° (ethanol; c 0.5), λ_{max} (acetonitril) 312 (800), 279 (6200), 273 (6300), 206 nm (ε 4500), ν_{max} 1460, 1440, 1420 cm^{-1}, nmr ($CDCl_3$) 8.3 (H-2,H-3), 3.4 - 1.1 ppm (14H). (Found: C, 76.78; H, 8.50; N, 14.81; M^+, 188, other prominent fragments at 173, 159, 145, 131, 119, and 108 m/e. $C_{12}H_{16}N_2$ requires C, 76.55; H, 8.57; N, 14.87; M, 188.27).

(+)-(5aS,9aS)-2-Hydrazino-trans-5,5a,6,7,8,9,9a,10-octahydrobenzo[g]quinoxaline (Compound (+)-X). - A solution of 100 mg (+)-VIII in 2 ml 100% hydrazine hydrate and 2 ml ethanol was refluxed over night in an oilbath (100°C). Precipitation with 10 ml water in the cold gave a voluminous material which was five times recrystallized from methanol yielding 38 mg (39%) of mp 155-57°C, $[\alpha]_D^{23}$ +138° (ethanol; c 0.3), λ_{max} (acetonitril) 330 (5600), 236 nm (ε 8600), ν_{max} 1630, 1580, 1500, 1440 cm^{-1}, nmr (DMSO-d_6) 7.9 (H-3), 7.5 ($NHNH_2$), 3.0 - 1.0 ppm (14H). (Found: C, 65.82; H, 8.19; N, 25.49; M^+, 218. $C_{12}H_{18}N_4$ requires C, 66.02; H, 8.31; N, 25.67; M, 218.30).

(+)-(5aS,9aS)-2-(N-Piperidino)-trans-5,5a,6,7,8,9,9a,10-octahydrobenzo[g] quinoxaline (Compound (+)-XI) . - A solution of 110 mg (+)-VIII in 5 ml piperidine was refluxed over night in an oil bath (120°C). After cooling water was added and the precipitate was chromatographed on silica with

methylene chloride. Two crystallizations from n-hexane yielded 90 mg (67%) of mp 121-22°C, $[\alpha]_D^{23}$ +96° (ethanol; c 0.5), λ_{max} (acetonitril) 346 (6700), 301(2000), 260 nm (ε 14200), ν_{max} 1570, 1520, 1480, 1440 cm^{-1}, nmr ($CDCl_3$) 7.9 (H-3), 3.6-3.3 (m, 4 H), 3.2 - 1.0 ppm (14 H). (Found: C, 75.40; H, 9.25; N, 15.46; M^+, 271, other prominent fragments at 242, 228, 215, 203, and 188 m/e. $C_{17}H_{25}N_3$ requires C, 75.23; H, 9.29; N, 15.49; M, 271.41).

(+)-(5aS,9aS)-2-Ethoxy-trans-5,5a,6,7,8,9,9a,10-octahydrobenzo[g]quinoxaline (Compound (+)-XII). - To a solution of 60 mg metallic Na in 4 ml abs. ethanol 140 mg (+)-VIII were added, then the solution was refluxed under continuous stirring for 4h (oil bath 90 - 100°C). After cooling the solution was poured into water, the product was extracted with methylene chloride and chromatographed on silica with ether. After two crystallizations from n-hexane 90 mg (62%) of mp 68-69°C, $[\alpha]_D^{23}$ +130° (ethanol; c 0,4), λ_{max} (acetonitril) 304 (8100), 287sh (6300), 217 nm (ε 8400), ν_{max} 1560, 1520, 1440 cm^{-1}, nmr ($CDCl_3$) 7.9 (H-3), 4.3 (q, $OC\underline{H}_2CH_3$), 1.3 ppm (t, $OCH_2C\underline{H}_3$). (Found: C, 72.50; H, 8.66; N, 12.05; M^+, 232, other prominent fragments at 217 and 204 m/e. $C_{14}H_{20}N_2O$ requires C, 72.37; H, 8.68; N, 12.06; M, 232.32).

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