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Preparation and Structure of di-*exo*-Condensed Norbornane Heterocycles

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Summary. Cyclization of di-*exo*-aroylnorbornanecarboxylic acid with bidentate nucleophiles (hydrazine, *o*-phenylenediamine, *o*-aminophenol, alkylenediamines, and amino alcohols) yielded heterotri-, tetra-, and pentacycles. Their structures were established by means of NMR spectroscopy, with the application of HMQC, HMBC, DEPT, DIFFNOE, and COSY methods.

Key words. Heterocycles; Bicyclo[2.2.1]heptane derivatives; Cyclizations; Isoindolones.

Introduction

By reactions of di-*endo*-3-aroylbicyclo[2.2.1]heptane- or -heptene-2-carboxylic acids with bifunctional reagents (amino alcohols, diaminoalkanes, *o*-aminophenol, and *o*-aminothiophenol) a large number of condensed heterocycles have been synthesized [1–4]. The results show that the starting configurations of the norbornane amino acids are generally retained in the products. As the synthesis of the stereoisomeric di-*exo* derivatives has not been reported, the di-*endo* norbornene dicarboxylic anhydride **1** was now transformed to the known di-*exo* anhydride **2** by heating [5]. Only a few data were found in literature concerning the epimerization of di-*endo* norbornane derivatives [5–7]. The objective of this work was to prepare the previously unknown di-*exo* derivatives from **2** and to compare them with the di-*endo*-fused heterocycles [1].

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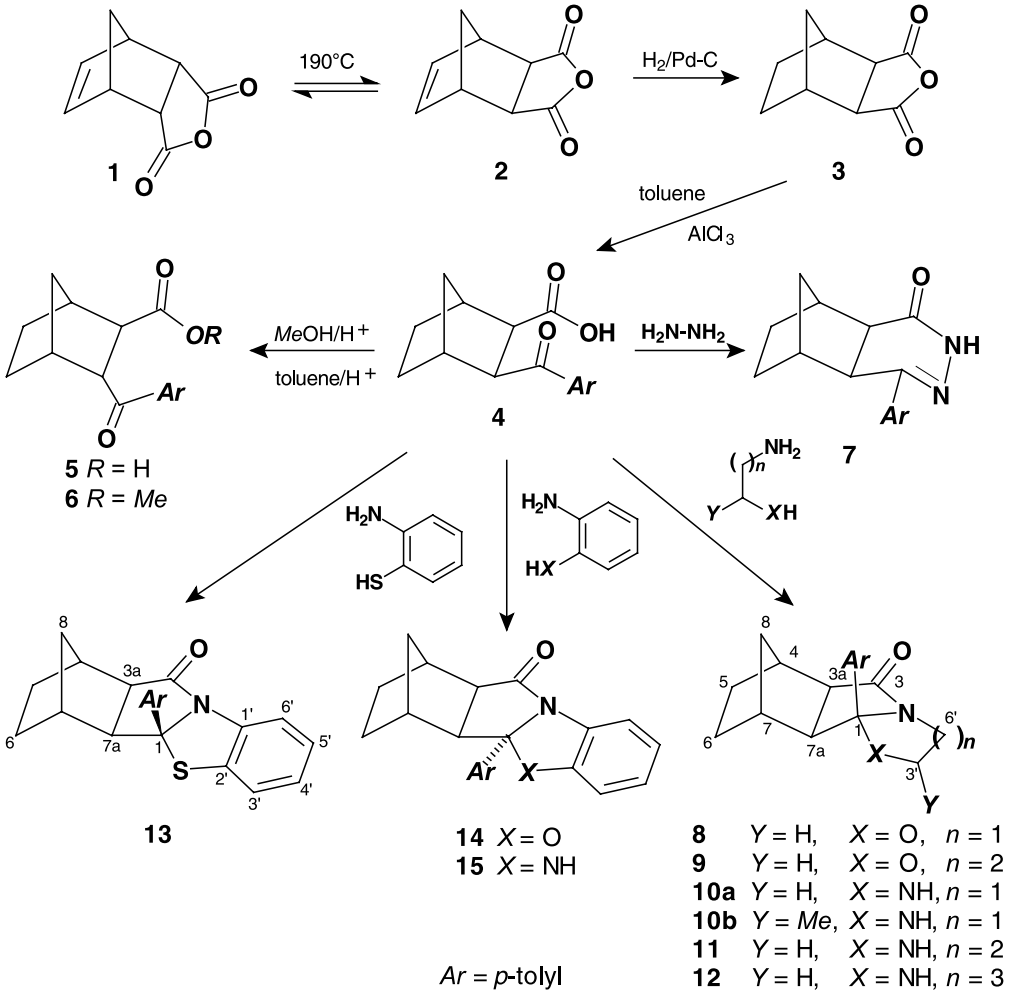
Results and Discussion

For preparation of the di-*exo*-condensed norbornane heterocycles, we isomerized di-*endo*-bicyclo[2.2.1]hept-5-ene-2,3-dicarboxylic anhydride (**1**) to the di-*exo* analogue **2** by heating to 190°C (Scheme 1) [5]. To avoid the addition of the aromates to the double bond in the presence of $AlCl_3$ [2], **2** was saturated by catalytic hydrogenation to furnish **3** [6]. The *Friedel-Crafts* acylation of toluene with **3** led to di-*exo*-3-toluoylbicyclo[2.2.1]heptane-2-carboxylic acid **4**. As the oxocarboxylic acid **4** readily isomerizes to the *endo* aroyl derivative **5**, *e.g.* on boiling with HCl in toluene, and the esterification also affords the *endo*-aroyl-*exo*-methoxycarbonyl derivative **6**, **4** was reacted with hydrazine to yield the methylene-bridged di-*exo*-hexahydrophthalazin-4(3*H*)-one **7**. With alkanolamines, the methanooxazolo- **8** and -oxazinoisoindolones **9** were obtained. On cyclization with alkylenediamines **4** resulted in imidazo- **10a**, **10b**, pyrimido- **11**, and 1,3-diazepinoisoindolones **12**, while with *o*-aminothiophenol, *o*-aminophenol, and *o*-phenylenediamine, the pentacyclic benzthiazolo **13**, -oxazolo **14**, and -imidazo derivatives **15** were obtained.



Scheme 1

Table 1. [1]H NMR data of compounds **4–9**, **10a**, **10b**, and **11–15**[a]

	norbornane moiety									
	CH_2 $2 \times d$ $(2 \times 1H)$[b]		H-3a[c]	H-4[d]	H-5[e]		H-6[e]		H-7[d]	H-7a[f]
4	1.13	1.86	2.90	2.40	1.32[i]	1.53[k]	1.32[i]	1.53[k]	2.47	3.57
5	1.31[l]	1.69	4.02	2.63[i]	1.38	1.51	1.04	1.20	2.63[i]	3.20
6	1.36[m]	1.78[n]	3.22	2.63	1.43	1.57	1.12	1.26	2.71	4.11
7	1.18	~1.45[i]	3.06	2.85	~1.45[i]	1.54	~1.45[i]	1.67	2.45	2.67
8	0.86	1.24[i]	2.46	2.40	1.22[i]	1.44	1.09	1.30	1.34	2.57
9	0.75	1.07	2.57	2.37	~1.22[i]	1.41	1.00	~1.22[i]	1.12	2.11
10a	0.88	1.36	2.31	2.63	1.10	1.37	1.23	1.50	1.55	2.64
10b	0.80	1.20	~2.28[i]	2.55	1.00	1.30	1.17	1.44	1.48	2.64
11	0.82	1.23[i]	2.65[k]	2.63[k]	1.23[i]	1.50	1.03	~1.3[k]	1.32	1.98
12	0.69	0.98	2.53	2.58	~1.2	1.45	1.08	1.31	1.55	2.24
13	0.92[n]	1.24[n]	~3.0[i]	2.71	1.20	1.45	1.32	1.57	1.84	~3.0[i]
14	1.02	~1.15[i]	2.87[k]	2.64	~1.15[i] (2H)		1.52 (2H)		2.88[k]	2.46
15	~1.15[i]	1.21	2.78		~1.15[i] (2H)		1.51 (2H)		2.74	2.39

	p-tolyl substituent[h]			
	CH_3[g]	*Ar*H-2′,6′		*Ar*H-3′,5′
4	2.34	7.79		7.27
5	2.34	7.84		7.20
6	2.41	7.92		7.27
7	2.31	7.52		7.13
8	2.31	~7.14[k]	7.27	~7.14[k] 7.34
9	2.33	7.05	7.32[k]	7.22 7.32[k]
10a	2.35	7.15	7.46	7.08 7.22
10b	2.28[i]	7.07	7.38[o]	7.00 7.16
11	2.39	7.06	7.58[o]	7.17 7.57
12	2.35	6.91	7.53	7.09 7.23
13	2.30	~6.95	~7.1	~7.2 ~7.5
14	2.24	7.31		7.08
15	2.23	7.18		7.07

[a] In $CDCl_3$ solution at 500 MHz; chemical shifts in ppm ($\delta_{TMS} = 0$ ppm), coupling constants in Hz; assignments were supported by HMQC and HMBC measurements, for **4**, **8**, **9**, **10b**, **12**, **13**, and **15** also by DIFFN*O*E, and for **10a**, **10b**, and **12** by COSY experiments; [b] *AB*-type spectrum: $2 \times d$, $J = 9.6$ (**4**), 10.0 (**5–9**), 10.5 (**10a**, **10b**, **11**, and **12**) Hz, δH(*exo*) < δH(*endo*) for **4–6**, **8**, **9**, **10b**, **12**, and **13**; [c] doublet, $J = 9.5$ (**4** and **7**), 5.0 (**5** and **6**), 8.0 (**8**, **9**, and **10a**), 8.2 (**11**), 8.7 (**12**), 7.3 (**15**) Hz; [d] ~*s* (1H); [e] 2–4 × *m* (4H), δH(*exo*) > δH(*endo*); [f] doublet, *J*: the same values as for H-3a (**4**, **7**, **8**, **9**, **10a**, **11**, **12**, and **15**), $J = 7.4$ (**13**), *dt*, $J = 5.0$ and 1.5 (**5** and **6**) Hz, broad coalesced signal of fine structure (**10b**); [g] *s* (3H); [h] rudimentary *AA′XX′*-type spectrum: $2 \times \sim d$ (2×2H), $J = 8.0$ (**4–7**, **14** and **15**) Hz, due to hindered rotation-separated *AB* and A_2-type spectra: $2 \times d$ (2×1H), $J = 8.0$ (**8** and **9**) Hz, and *s* (2H), $2 \times AB$ (approx.), $J = 7.8$ and 7.6 (**10a**, **10b**), 7.9 and 7.2 (**11**) Hz, $2 \times d$ and $2 \times dd$, $J = 7.8$, 1.9 and 8.0, 1.7 (**12**) Hz, four broad coalesced signals of fine structure (**13**); [i/k] overlapping signals; [l/m/n] further split to *dd*/*qad*/*td* due to ^4J long-range couplings; [o] broadened signal

In conclusion, the isomerization of di-*endo*-norbornenedicarboxylic anhydride **1** to the di-*exo* derivative **2**, followed by reduction and *Friedel-Crafts* acylation provides the di-*exo*-aroylnorbornane carboxylic acid **4**, which can be advantagously applied to the syntheses of di-*exo*-fused norbornane heterocycles: the condensed benzthiazolo, -oxazolo, and -imidazo compounds, *etc*.

Table 2. ^{13}C NMR chemical shifts[a] of compounds **4**–**9**, **10a**, **10b**, and **11**–**15**[b, c]

	norbornane[e]							pyrrolidinone[e]	
	CH_2[d]	C-3a	C-4	C-5	C-6	C-7	C-7a	C-1	C=O
4	36.1	52.7	41.3	29.5	29.2	39.8	52.9	199.5	174.7
5	39.6	47.2	42.3[i]	28.9	24.0	42.4[i]	53.1	199.2	181.0
6	39.5	47.2	42.3	29.0	24.1	42.4	53.3	199.4	176.1
7	36.1	44.2	44.4	29.5	29.2	45.3	46.2	149.4	166.9
8	34.1	49.9	39.5	28.4	28.5	39.1	53.2	104.2	183.6
9	33.9	51.0	38.8	28.8	28.3	39.5	53.3	96.8	177.5
10a	34.2	50.4	39.6	28.7	28.8	39.7	54.5	91.3	182.3
10b	34.3	50.5	39.5	28.6	28.9	39.7	54.3	91.8	182.1
11	34.2	51.8	38.9	28.5	29.2	40.0	54.3	82.7	176.5
12	34.2	52.9	38.9	28.8	28.9	40.8	55.0	86.5	177.5
13	34.3	55.1	40.5	28.6[l]	28.6[l]	40.0	50.6	90.2	179.3
14	35.8	55.3	40.5	27.5	29.0	39.0	52.9	106.6	179.9
15	35.4	55.6	40.0	27.7	29.7	40.1	52.9	90.0	178.3

	$CH_2/CH/C_{Ar}$[h]		*p*-tolyl group				
	NC[f]	*X*C[g]	CH_3	C-1″	C-2″6″	C-3″5″	C-4‴″
4	–	–	21.9	135.6	128.9	129.9	143.6
5	–	–	22.0	134.8	129.1	129.7	144.3
6	–	–	22.0	134.9	129.1	129.7	144.2
7	–	–	21.7	133.3	126.5	129.6	140.0
8	44.3	63.2	21.6	135.5	126.3 130.5	127.5 129.1	138.2
9	37.9	62.6	21.5	135.0	127.7 128.3	129.6 130.9	138.1
10a	44.2	44.5	21.5	136.4	126.7 127.8	128.3 129.9	137.7
10b	51.6	53.0	21.5	~137[k]	126.4 127.6	128.4 130.0	137.7
11	38.7	41.5	21.5	136.0	128.2 128.3	128.8 130.3	137.6
12	41.8	42.6	21.4	139.2	125.9 128.3	128.4 130.1	137.7
13	133.5	139.5	21.5	138.5	124.9 128.4	128.0 129.5	137.7
14	128.9	152.4	21.5	141.6	124.7	129.6	138.7
15	129.7	142.7	21.4	144.7	123.7	130.0	138.1

[a] In ppm ($\delta_{TMS} = 0$ ppm) at 126 MHz; solvent: $CDCl_3$ or *DMSO*-d_6 (for **4**, **8**, and **9**); [b] assignments were supported by DEPT, HMQC, and HMBC measurements; [c] further lines, OCH_3: 52.2 (**6**); CCH_3: 19.8 (**10b**); CCH_2C-type carbon[h]: 27.1 (**11**), 24.7 and 33.1 (**12**); $C_{Ar}H$ (condensed benzene ring[m]), C-3′: 127.5 (**13**), 110.3 (**14**), and 111.2 (**15**); C-4′: 125.7 (**13**), 126.8 (**14**), and 126.1 (**15**); C-5′: 123.2 (**13**), 121.8 (**14**), and 120.6 (**15**), and C-6′: 120.6 (**13**), 117.4 (**14**), and 116.4 (**15**); [d] bridging methylene group; [e/m] numbering: see **8**–**12**/**13**–**15** (Scheme 1); [f] carbon bound to the amide nitrogen; [g] *X* = NH (**10a**, **10b**, **11**, **12**, and **15**), O (**8**, **9**, and **14**), S (**13**); [h] in hetero ring with two hetero atoms; [i] interchangeable assignments; [k] the line hidden by noise was identified from the HMBC spectrum; [l] two overlapping lines

The spectral data on the new compounds (**4**–**15**) (Tables 1–4) are proof of the presumed structures. Only a few additional remarks are necessary.

In accord with the ''splitting rule'' [8, 9][a], the di-*exo* structure of **4** and **7**–**15** is obvious from the 8.4 ± 1.1 Hz doublet split of the H-3a and H-7a signals. This high splitting value is in accord with the dihedral angle of 0°; further splits (from the 3a,4 and 7,7a vicinal H,H interactions) are not observed also as expected from the *Karplus* relation [10]: the dihedral angles are ~90°. The H-7a signal for **5** and **6** is split into a double triplet by 5.0, 1.5, and 1.5 Hz [H-3a,7a, 7,7a, and 7a,8(*exo*) interactions], which confirms the *endo* position of the tolyl group, while the H-3a signal (in accord with the *endo* position of this H) exhibits an unaltered doublet. (For comparison of the spectroscopic data, the numbering in the Scheme is applied in this part and in Tables 1–4.)

As rotation of the tolyl group in **8**–**13** is hindered, the *Ar*H-2′,6′ and *Ar*H-3′,5′ signals appear separately in the ^{1}H and ^{13}C NMR spectra. The condensed planar benzene ring in **14** and **15** leads to a change in the C-1 configuration, and the *endo* situation of the tolyl group (as proved by DIFFN*O*E experiments, which demonstrate the close-lying position of H-7 and H-7a to the *ortho*-hydrogens of the tolyl group in **15**) allows free rotation (Table 4). The C-1 configuration in **13** is unaltered relative to **8**–**12**, and the more bulky S atom distorting the whole tetra-

Table 3. Characteristic IR wavenumbers (cm^{-1}) of compounds **4**–**9**, **10a**, **10b**, and **11**–**15**, in KBr discs

	νOH[a] or νNH band	νC=O band[b]	Amide-I band[c]	νC–O band ester or ether group	γ-C_{Ar}H band	
					p-di-subst. benzene ring	*o*-di-subst. benzene ring
4	3500–2500	1705	1673	–	824	–
5	3250–2250	1699	1668	–	851	–
6	–	1727	1671	1179, 1233	817	–
7	3250–2000	–	1664	–	813, 824	–
8	–	–	1716	1008	826	–
9	–	–	1697	1026	821	–
10a	3276	–	1679	–	816, 825	–
10b	3244	–	1676	–	827	–
11	3293	–	1673	–	826	–
12	3305	–	1660	–	808, 825	–
13	–	–	1717	–	849	744, 756
14	–	–	1716	1225	822	744
15	3300	–	1693	–	819	736

[a] νOH band (**4** and **5**); [b] COOH (**4** and **5**) or COOMe group (**6**); [c] νC=O band of conjugated ketone group (**4**–**6**)

[a] Due to the ~90° dihedral angles, for the di-*exo* compounds, the vicinal H-3a,4 and H-7,7a interactions cause no double splits of the H-3a and H-7a signals, while these couplings lead to the split by 2-4 Hz in the di-*endo*-molecules where the dihedral angles are about 30°. As a consequence, the H-3a, H-7a atoms have a doublet in the di-*exo* derivatives and double doublet signals in the di-*endo* analogues

Table 4. Results of DIFFN*O*E experiments with compounds **8**, **9**, **10b**, **12**, **13**, and **15**[a]

Saturated signal	Responding signals				
	H-8(*endo*)[b]	H-6′(*ax*)[c]	H-3′	H-7	H-7a
ArH-2,6[d]	**8**, **9**, **10b**, **12**, **13**	**8**, **9**, **12**	**10b**	**15**	**15**

[a] Interacting pairs showing only trivial effects (N*O*E between geminal or vicinal hydrogens) are not included in this table; responses relevant for stereostructures are exclusively given; all experiments were also executed in opposite sence (in the complementary measurements, the responding signals of the first experiments were irradiated, when intensity enhancements were observed for all signal saturated previously); [b] *endo*-H of the bridging group; [c] *exo*-H of the NCH_2 group; [d] the ArH-2 and ArH-6 signals of the tolyl group appear separated in case of **12** and both give mutual N*O*Es with the H-8(*endo*) and H-6′(*ax*) signals

cyclic skeleton forces the tolyl group close to the bridging CH_2. Hence, between these moieties, the tolyl group is unable to rotate freely, similarly as in **8**–**12**. In **8**–**13**, the aromatic ring is situated near to the bridging CH_2 and its anisotropic shielding results in an upfield shift of the signals of this CH_2 (0.69–0.92 and 0.98–1.36 ppm for **8**–**13**, and 1.02–1.36 and 1.15–1.78 ppm for **5**–**7**, **14**, and **15**).

The direct proof of this C-1 configuration is provided, for instance, by the DIFFN*O*E measurements on **9** and also on **13**, which demonstrate the steric closeness of the H(*endo*) atom of the bridging CH_2 and the *ortho*-hydrogens of the tolyl group: upon saturation of the signal of one of these two types of hydrogens the other responded. Such an effect is absent in case of **15**, while a strong DIFFN*O*E on the H_{Ar}-2′,6′ signals was observed when H-7a was irradiated.

The different C-1 configuration in **13** and **14**, **15** follows directly from the dramatic difference, for example, in the ^1H chemical shifts of H-7 (1.84 ppm for **13**, but 2.88 for **14** and 2.74 ppm for **15**).

The presumed hindered rotation in **8**–**13** was confirmed by the temperature dependence of the ^1H NMR spectrum of **10a**.

Experimental

IR spectra were run in KBr disks on a Bruker IFS-55 FT-spectrometer controlled by Opus 3.0 software. The ^1H and ^{13}C NMR spectra were recorded in $CDCl_3$ solution in 5 mm tubes at RT on a Bruker DRX-500 spectrometer at 500.13 (^1H) and 125.76 (^{13}C) MHz, with the D signal of the solvent as the lock and *TMS* as internal standard. The VT-NMR measurements were carried out in *DMSO*-d_6 from 298 to 353 K on Bruker AM 300 equipment. The standard Bruker microprogram N*O*EMULT was used to generate N*O*E [11] and to acquire DIFFN*O*E spectra [12, 13] with a selective pre-irradiation time. DEPT spectra [14] were run in a standard manner [15], using only a $\Theta = 135°$ pulse to separate the CH/CH_3 and CH_2 lines phased "up" and "down". The 2D-COSY [16a, 17a], HMQC [16b, 17b] and HMBC [18, 19] spectra were obtained by using the standard Bruker pulse programs COSY-45 INV4GSSW and INV4GSLRNDSW. The results of elemental analyses agreed satisfactorily with the calculated values.

di-exo-Bicyclo[2.2.1]heptane-2,3-dicarboxylic anhydride (**3**, $C_9H_{10}O_3$)

In an autoclave, a mixture of 65.66 g of **2** (Acros 32059) and 2 g of 5% Pd–C in 1000 cm^3 of dry *THF* was stirred for 24 h at $4 * 10^3$ kPa with H_2. The solid was then removed by filtration and the filtrate was

evaporated. On crystallization from Et_2O/*n*-hexane, the residue gave 58.5 g (88%) of **3**. Mp 78–79°C. NMR data correspond with those given in Ref. [6].

3-exo-p-Toluoylbicyclo[2.2.1]heptane-2-exo-carboxylic acid (**4**, $C_{16}H_{18}O_3$)

Anhydride **3** (16.6 g) was dissolved in 100 cm^3 of dry toluene and 30.66 g of powdered anhydrous $AlCl_3$ were added slowly with continuous stirring at RT. Stirring was continued for 4 h, and the mixture was kept at RT overnight. The mixture was next decomposed with 100 g of ice and 20 cm^3 of 36% HCl and extracted with 3×50 cm^3 of CH_2Cl_2. The extract was washed with H_2O, dried (Na_2SO_4), and evaporated. The residue was crystallized from *Et*OA*c*/*n*-hexane [20]. Yield 16.3 g (63%); mp 164–166°C.

3-endo-p-Toluoylbicyclo[2.2.1]heptane-2-exo-carboxylic acid (**5**, $C_{16}H_{18}O_3$)

A mixture of 1.29 g of di-*exo*-3-*p*-toluoylbicyclo[2.2.1]heptane-2-carboxylic acid (**4**) and 2 drops of 36% HCl in 10 cm^3 of toluene was refluxed for 3 h. After evaporation, the residue was crystallized. Yield 0.95 g (74%); mp 129–131°C (Et_2O/petroleum ether, bp 40–60°C).

Methyl 3-endo-p-toluoylbicyclo[2.2.1]heptane-2-exo-carboxylate (**6**, $C_{17}H_{20}O_3$)

A mixture of 1.29 g of **4** and 0.20 cm^3 of conc. H_2SO_4 in 20 cm^3 of *Me*OH was refluxed for 2 h. After evaporation of the solvent, 30 cm^3 of H_2O were added and the mixture was extracted with 3×10 cm^3 of diethyl ether. The extract was dried (Na_2SO_4) and, after removal of the solvent, the residue was crystallized. Yield 1.06 g (78%); mp 67–68°C (Et_2O/petroleum ether, bp 40–60°C).

5,8-Methano-4-p-tolyl-4a,5,6,7,8,8a-hexahydro-2H-phthalazin-1-one (**7**, $C_{16}H_{18}N_2O$)

A solution of 1.29 g of **4** and 0.5 g of hydrazine hydrate in 10 cm^3 of *Et*OH was refluxed for 4 h and was concentrated under vacuum to half of its volume. On standing, the product **7** separated and was removed by filtration. Yield 0.91 g (72%); mp 208–210°C (*Et*OH).

General Procedure for the Preparation of ***8***, ***9***, ***10a***, ***10b***, ***11***, ***12***, ***13***, ***14***, *and* ***15***

A mixture of 1.29 g of **4**, 0.46 g of ethanolamine, or 0.56 g of 1-amino-2-propanol, or 0.56 g of 1-amino-3-propanol, or 0.45 g of ethylenediamine, or 0.56 g of 1,2-diaminopropane, or 0.56 g of 1,3-diaminopropane, or 0.66 g of 1,4-diaminobutane, or 0.93 g of 2-aminothiophenol, or 0.82 g of 2-aminophenol, or 0.81 g of 1,2-diaminobenzene, and 0.05 g of *PTSA* in 10 cm^3 of dry chlorobenzene was refluxed for 10 h. The solvent was evaporated, the residue was dissolved in 5 cm^3 of $CHCl_3$, and the solution was transferred to an Al_2O_3 column (Acros, basic, 50-200 μ) and eluted with *n*-hexane: *Et*OA*c* (2:1) for **8**, **9**, **13**, **14**, and **15** or with *Et*OA*c*:*n*-hexane (2:1) for **10a**, **10b**, **11**, and **12**.

6,9-Methano-9b-p-tolyl-2,3,5a,6,7,8,9,9a-octahydrooxazolo[2,3-a]isoindol-5-one
(**8**, $C_{18}H_{21}NO_2$)

Yield 0.68 g (48%); mp 162–163°C (*i-Pr*$_2$O).

7,10-Methano-10b-p-tolyl-3,4,6a,7,8,9,10,10a-octahydro-2H-[1,3]
oxazino[2,3-a]isoindol-6-one (**9**, $C_{19}H_{23}NO_2$)

Yield 0.56 g (38%); mp 163–164°C (*i-Pr*$_2$O).

6,9-Methano-9b-p-tolyl-2,3,5a,6,7,8,9,9a-octahydroimidazo[2,3-a]isoindol-5-one (**10a**, $C_{18}H_{22}N_2O$)

Yield 0.75 g (53%); mp 183–184°C (*Et*OAc/*i-Pr*$_2$O).

6,9-Methano-2-methyl-9b-p-tolyl-2,3,5a,6,7,8,9,9a-octahydroimidazo[2,3-a]isoindol-5-one (**10b**, $C_{19}H_{24}N_2O$)

Yield 0.72 g (49%); mp 181–183°C (*i-Pr*$_2$O).

7,10-Methano-10b-p-tolyl-1,2,3,4,6a,7,8,9,10,10a-decahydropyrimido[2,3-a]isoindol-6-one (**11**, $C_{19}H_{24}N_2O$)

Yield 0.83 g (56%); mp 205–206°C (*i-Pr*$_2$O).

8,10-Methano-11b-p-tolyl-2,3,4,5,7a,8,9,10,11,11a-decahydro[1,3]diazepino[2,3-a]isoindol-7-one (**12**, $C_{20}H_{26}N_2O$)

Yield 0.64 g (41%); mp 171–173°C (*i-Pr*$_2$O).

6,9-Methano-9b-p-tolyl-5a,6,7,8,9,9a-hexahydrobenzthiazolo[2,3-a]isoindol-5-one (**13**, $C_{22}H_{21}NOS$)

Yield 0.62 g (36%); mp 171–172°C (*i-Pr*$_2$O).

6,9-Methano-9b-p-tolyl-5a,6,7,8,9,9a-hexahydrobenzoxazolo[2,3-a]isoindol-5-one (**14**, $C_{22}H_{21}NO_2$)

Yield 0.70 g (42%); mp 145–147°C (*i-Pr*$_2$O).

6,9-Methano-9b-p-tolyl-5a,6,7,8,9,9a-hexahydrobenzimidazo[2,3-a]isoindol-5-one (**15**, $C_{22}H_{22}N_2O$)

Yield 0.78 g (47%); mp 232–234°C (*Et*OAc).

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References

[1] Stájer G, Csende F, Bernáth G, Sohár P, Szúnyog J (1994) Monatsh Chem **125**: 933
[2] Sohár P, Frimpong-Manso S, Stájer G, Bernáth G (1994) Magn Reson Chem **32**: 705
[3] Sohár P, Nagy K, Bernáth G, Stájer G (1995) Magn Reson Chem **33**: 329
[4] Miklós F, Stájer G, Sohár P, Böcskei Zs (2000) Synlett 67
[5] Craig D (1951) J Am Chem Soc **73**: 4889
[6] Canonne P, Belanger D, Lemay G (1982) J Org Chem **47**: 3953
[7] Pandey B, Athawale AA, Reddy RS, Dalvy PV, Kumar P (1991) Chem Lett 1173
[8] Sohár P, Stájer G, Bernáth G (1983) Org Magn Reson **21**: 512

[9] Sohár P, Pelczer I, Stájer G, Bernáth G (1987) Magn Reson Chem **25**: 584
[10] Karplus M (1959) J Chem Phys **30**: 11; (1960) **33**: 1842
[11] Noggle JH, Schirmer RE (1971) The Nuclear Overhauser Effect. Academic Press, New York
[12] Sohár P (1983) Nuclear Magnetic Resonance Spectroscopy, vol 1. CRC Press, Boca Raton, Florida, pp 194–196
[13] Sanders JKM, Mersch JD (1982) Prog Nucl Magn Reson **15**: 353
[14] Pegg DT, Doddrell DM, Bendall MR (1982) J Chem Phys **77**: 2745
[15] Bendall MR, Doddrell DM, Pegg DT, Hull WE (1982) High Resolution Multipulse NMR Spectrum Editing and DEPT. Bruker, Karlsruhe
[16] Ernst RR, Bodenhausen G, Wokaun A (1987) Principles of Nuclear Magnetic Resonance in One and Two Dimensions. Clarendon Press, Oxford, UK: a) p 400; b) p 471
[17] Sanders JKM, Hunter BK (1987) Modern NMR Spectroscopy. A Guide for Chemists. University Press, Oxford, U K: a) p 108; b) p 94 and p 100
[18] Bax A, Morris G (1981) J Magn Reson **42**: 501
[19] Kessler H, Griesinger C, Zarboch J, Loosli H (1984) J Magn Reson **57**: 331
[20] Morgan MS, Tipson RS, Lowy A, Baldwin WE (1942) J Am Chem Soc **66**: 404