Tricarbonylchromium Complexes of 2-Aminotetralin Derivatives. Hydride Displacement of Aromatic Methoxy Groups

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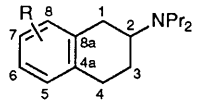
Tricarbonylchromium complexes of methoxy-substituted 2-propionamido- and 2-aminotetralins have been prepared and the stereochemistry of (2*S*)-*endo*-tricarbonyl[8-methoxy-2-(*N*-propylpropionamido)tetralin]chromium, (2*S*)-*endo*-**4c**, has been established by X-ray structure analysis. The complexes could be demethoxylated by treatment with $LiAlH_4$. This reaction occurred more readily with the *endo*- than with the *exo*-isomers. The fastest demethoxylation was observed with the tricarbonylchromium complex of 2-(2-methoxyphenyl)-*N*,*N*-dipropylethylamine.

The reactivity of an aromatic ring and its substituents may be modified by tricarbonylchromium complexation:[1] its tendency to undergo nucleophilic aromatic substitution will be enhanced[2] and the acidity of alkyl substituents will be increased.[3] In addition, arenechromium complexes are readily formed, are fairly stable, and may be decomplexed by oxidation of chromium or by ligand exchange. Thus, synthetic modifications of arenechromium complexes may offer useful alternatives to traditional manipulation of non-complexed rings and substituents.[4]

As part of a study of synthetic methods leading to various derivatives of 2-aminotetralin (2-amino-1,2,3,4-tetrahydronaphthalene), we have prepared chromium complexes of methoxy-substituted tetralins **1a–c** and of the corresponding amides **3a–c** (Scheme 1). The present paper describes the preparation and characterization of these complexes and their unexpected reactions with $LiAlH_4$.



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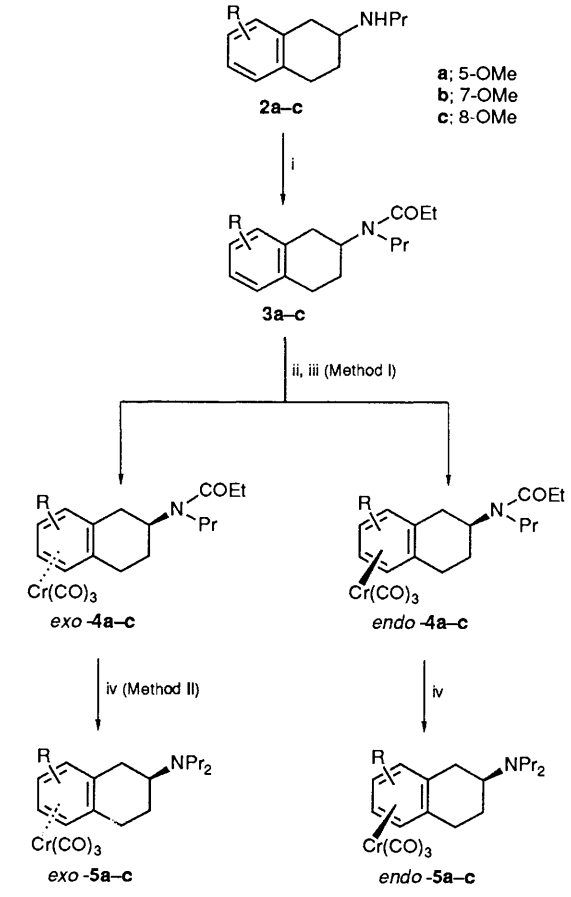
a; R = 5-OMe
b; R = 7-OMe
c; R = 8-OMe

Results and Discussion

Preparation of Chromium Complexes.—Racemic or optically pure methoxy-substituted 2-(propylamino)tetralins **2a–c** were converted into the corresponding propionamides **3a–c** by treatment with propionyl chloride and triethylamine (Scheme 1). Tricarbonylchromium complex formation was accomplished by heating a solution of the appropriate amide and hexacarbonylchromium in dibutyl ether–tetrahydrofuran (THF) (9:1) for 1–2 days. This procedure (Method I) produced mixtures of diastereoisomeric complexes **4a–c**. Preliminary experiments indicated that the isomer ratio obtained by complexation of compound **3b** could be modified by prolonged heating; *i.e.*, isomer ratios after short reaction times appeared to be kinetically controlled.[5] These observations were not utilized synthetically. Attempts to separate *endo* and *exo* tricarbonylchromium complexes **5a–c** failed since the isomers had similar chromatographic properties. However, the complexes of the precursor amides separated well on silica and the *endo* and *exo* stereoisomers could be purified by flash chromatography.[6] Throughout, the *exo* compounds had larger R_f-values on silica.[7] Stereochemically defined tricarbonylchromium complexes of aminotetralins, compounds **5a–c**, were prepared, in moderate to good yield, by reduction of the corresponding *exo* or *endo* amides with borane–dimethyl sulphide complex in THF (Method II; Scheme 1). Physical data of the new tricarbonylchromium complexes are presented in Table 1.



Scheme 1 Only relative stereochemistry is indicated. *Reagents and conditions*: i, EtCOCl; ii, $Cr(CO)_6$; iii, flash chromatography; iv, $Me_2S{\cdot}BH_3$.

Crystallography.—In order to establish unambiguously the relative stereochemistry of the *endo*/*exo* isomers, we performed an X-ray structure analysis on one of the diastereoisomers of

Table 1 Physical data of tricarbonylchromium complexes of some 2-aminotetralins and related compounds

Compound (formula)	Preparation method[a]	Yield (%)	R_f	M.P. (°C)	Found (%) (Required) C	H	N
(2*R*)-*endo*-**4a**[b] ($C_{20}H_{25}CrNO_5$)	I	48	0.26[c]	127.5–129	58.4 (58.4)	6.2 (6.1)	3.3 (3.4)
(2*R*)-*exo*-**4a**[d] ($C_{20}H_{25}CrNO_5$)	I	36	0.50[c]	129–130.5	58.6 (58.4)	6.2 (6.1)	3.4 (3.4)
(±)-*endo*-**4b** ($C_{20}H_{25}CrNO_5$)	I	73	0.20[c]	*e*	58.6 (58.4)	6.2 (6.1)	3.3 (3.4)
(±)-*exo*-**4b** ($C_{20}H_{25}CrNO_5$)	I	18	0.44[c]	122.5–123	58.6 (58.4)	6.4 (6.1)	3.4 (3.4)
(±)-*endo*-**4c** ($C_{20}H_{25}CrNO_5$)	I	44	0.24[c]	146–148	58.1 (58.4)	6.1 (6.1)	3.5 (3.4)
(2*S*)-*endo*-**4c**[f] ($C_{20}H_{25}CrNO_5$)	I	13	0.24[c]	92.5–93.5	58.5 (58.4)	6.0 (6.1)	3.4 (3.4)
(±)-*exo*-**4c** ($C_{20}H_{25}CrNO_5$)	I	43	0.44[c]	136–137	58.5 (58.4)	6.4 (6.1)	3.4 (3.4)
(2*S*)-*exo*-**4c**[g] ($C_{20}H_{25}CrNO_5$)	I	9	0.44[c]	114.5–115.5	58.2 (58.4)	5.8 (6.1)	3.4 (3.4)
(2*R*)-*endo*-**5a**[h] ($C_{20}H_{27}CrNO_4$)	II	62	0.42[i]	*e*	60.6 (60.4)	7.1 (7.1)	3.5 (3.5)
(2*R*)-*exo*-**5a**[j] ($C_{20}H_{27}CrNO_4$)	II	59	0.60[i]	79–79.5	60.4 (60.4)	7.0 (7.1)	3.4 (3.5)
(±)-*endo*-**5b** ($C_{20}H_{27}CrNO_4$)	II	79	0.51[i]	45.5–46	60.5 (60.4)	7.0 (7.1)	3.5 (3.5)
(±)-*exo*-**5b** ($C_{20}H_{27}CrNO_4$)	II	89	0.46[i]	47.5–48	60.6 (60.4)	7.0 (7.1)	3.5 (3.5)
(±)-*endo*-**5c** ($C_{20}H_{27}CrNO_4$)	II	95	0.58[i]	83–83.5	60.6 (60.4)	6.8 (7.1)	3.3 (3.5)
(±)-*exo*-**5c** ($C_{20}H_{27}CrNO_4$)	II	85	0.60[i]	60.5–61	60.6 (60.4)	6.9 (7.1)	3.2 (3.5)
7 ($C_{14}H_{14}CrO_4$)	I	99	0.29[k]	109.5–110	56.6 (56.4)	4.8 (4.7)	
9 ($C_{18}H_{25}CrNO_4$)	I	95	0.43[i]	*e*	58.4 (58.2)	6.6 (6.8)	3.8 (3.8)
10 ($C_{17}H_{23}CrNO_3$)	I	99	0.63[i]	*e*	59.9 (59.8)	6.7 (6.8)	4.2 (4.1)

[a] See Experimental section. [b] $[\alpha]_D^{20}$ −45.8° (*c* 0.63, THF). [c] Silica gel; Et_2O. [d] $[\alpha]_D^{20}$ +126.4° (*c* 0.87, THF). [e] Oil. [f] $[\alpha]_D^{20}$ −257.2° (*c* 1.1, THF). [g] $[\alpha]_D^{20}$ +165.9° (*c* 0.98, THF). [h] $[\alpha]_D^{20}$ −79.3° (*c* 0.76, THF). [i] Alumina; diethyl ether–light petroleum. [j] $[\alpha]_D^{20}$ +143.8° (*c* 0.59, THF). [k] Silica gel; diethyl ether–light petroleum.

compound **4c**. Crystal data are given in Table 2 and atomic co-ordinates of the non-hydrogen atoms are listed in Table 3.* As shown in Fig. 1, the complex has the *endo* configuration. In the bicyclic tetralin moiety the benzene ring is flat within 0.026 Å and the cyclohexene ring adopts a near half-chair conformation as indicated by the ring-puckering parameters: $\varphi = 98(2)°$, $\theta = 52.1(7)°$ and $Q_{tot} = 0.557(8)$ Å, calculated according to Cremer and Pople.[8] The methoxy substituent at C(8) is slightly bent out of the benzene-ring plane: the torsion angles τ[C(7)–C(8)–O(8)–C(81)] and τ[C(8a)–C(8)–O(8)–C(81)] are 10(2) and −169.1(8)°, respectively. The C(2) substituent adopts a pseudoequatorial position, τ[C(8a)–C(1)–C(2)–N(9)] being −173.0(6)°. The amide group adopts the *S-trans* geometry.

The tricarbonylchromium moiety has the expected pyramidal shape. The Cr atom is equidistant from the aromatic-ring plane [1.735(1) Å] and the base of the pyramid formed by the three carbonyl oxygen atoms [1.731(1) Å]. These two planes are slightly tilted with a dihedral angle of 2.0(2)°. The Cr atom is somewhat displaced from the benzene ring axis having a shorter distance to C(4a), C(5) and C(6) (mean distance 2.20 Å) than to C(7), C(8) and C(8a) (mean distance 2.28 Å). The bond lengths and the bond angles within the organic ligand and also within the $Cr(CO)_3$ moiety generally conform to the expected values.

Table 2 Crystal data and selected experimental details from the determination of the crystal structure of (2*S*)-*endo*-tricarbonyl[8-methoxy-2-(*N*-propylpropionamido)-1,2,3,4-tetrahydronaphthalene]-chromium, (2*S*)-*endo*-**4c**. Where given, esds are in parentheses.

Formula	$C_{20}H_{25}CrNO_5$
M_w	411.42
Crystal colour	yellow
Approximate crystal size (mm)	0.51 × 0.36 × 0.32
Space group	$C222_1$
a (Å)	10.232(1)
b (Å)	16.039(1)
c (Å)	24.782(1)
$\alpha = \beta = \gamma$ (°)	90.0
V_c (Å^3)	4066.9(3)
Z	8
ρ_c (g cm^{-3})	1.34
F(000)	1728
$\mu_{Mo\text{-}K\alpha}$(cm^{-1})	5.76
N_{obs}(unique, non-zero)	2582
N_{ref}	$1508_{[F > 2\sigma(F)]}$
No. of variables	255
$R = \Sigma\|\Delta F\|/\Sigma\|F_o\|$	0.073
$R_w = [\Sigma w\|\Delta F\|^2/\Sigma w\|F_o\|^2]^{\frac{1}{2}}$	0.049
Weighting	$w = 1.5\,[\sigma^2(F) + 0.003F^2]^{-1}$

The X-ray crystallographic determination of (2*S*)-*endo*-**4c** also establishes the stereochemistry of the 8-methoxy-substituted chromium complexes (±)-*exo*- and (±)-*endo*-**5c** since they were prepared from the amides (±)-*exo*- and *endo*-**4c**,

* Lists of hydrogen co-ordinates, bond lengths, bond angles and anisotropic thermal parameters are deposited at the Cambridge Crystallographic Data Centre. See section 5.6.3 of Instructions for Authors, *J. Chem. Soc., Perkin Trans. 1*, 1991, issue 1.

Table 3 Fractional co-ordinates of the non-hydrogen atoms of (2*S*)-*endo*-**4c**

Atom	*x*	*y*	*z*
Cr	0.1457(2)	0.1916(1)	0.4223(1)
C(1)	0.1165(7)	−0.0145(5)	0.3816(3)
C(2)	0.2433(9)	−0.0584(5)	0.3674(3)
C(3)	0.3542(9)	0.0062(5)	0.3602(4)
C(4)	0.3805(8)	0.0439(5)	0.4168(5)
C(4a)	0.2566(9)	0.0768(5)	0.4430(4)
C(5)	0.2651(10)	0.1356(5)	0.4857(4)
C(6)	0.1524(14)	0.1677(5)	0.5090(3)
C(7)	0.0254(11)	0.1419(5)	0.4915(4)
C(8)	0.0172(11)	0.0823(5)	0.4508(3)
C(8a)	0.1344(8)	0.0504(4)	0.4255(3)
O(8)	−0.0951(6)	0.0517(4)	0.4323(3)
C(81)	−0.2155(11)	0.0905(7)	0.4483(5)
N(9)	0.2262(7)	−0.1130(4)	0.3206(3)
C(10)	0.2163(8)	−0.1965(5)	0.3295(4)
O(10)	0.2283(8)	−0.2246(3)	0.3745(3)
C(11)	0.1904(11)	−0.2519(6)	0.2813(4)
C(12)	0.1627(16)	−0.3389(6)	0.2963(5)
C(13)	0.1946(9)	−0.0761(6)	0.2658(4)
C(14)	0.3094(9)	−0.0758(7)	0.2290(5)
C(15)	0.2607(12)	−0.0514(6)	0.1720(4)
C(16)	0.0944(7)	0.2985(5)	0.4351(3)
O(16)	0.0635(6)	0.3667(4)	0.4437(3)
C(17)	0.0618(9)	0.1940(6)	0.3586(4)
O(17)	0.0093(8)	0.1920(6)	0.3159(3)
C(18)	0.2859(11)	0.2315(6)	0.3878(5)
O(18)	0.3811(8)	0.2565(5)	0.3663(4)

respectively. The relative stereochemistries of the stereoisomers of amides **4a** and **4b** and those of the corresponding amino derivatives **5a** and **5b** were assigned based on indirect spectroscopic evidence.

NMR Spectroscopy.—Relevant ^{1}H and ^{13}C NMR data are presented in Tables 4 and 5. $CDCl_3$ solutions of non-complexed amides **3a–c** produced ^{1}H NMR spectra in which almost all signals were doubled, probably due to the presence of interconverting *S-trans* and *S-cis* amide rotational isomers. Integration over the two signals due to 2-H, which had a chemical-shift difference >0.7 ppm, revealed that these rotational isomers were present in about equal amounts. Also, the ^{13}C NMR spectra of amides **3a–c** exhibited doubling of the majority of signals.

^{1}H NMR spectroscopy of the *exo* isomers of chromium complexes **4a–c** indicated that the amide isomers were present in a 1:1 ratio in **4a** and in a 1:2 ratio in **4b** and **4c**. The spectra of *endo* derivatives **4a–c** differed considerably from those of the corresponding *exo* isomers. The most apparent difference was seen in the ratio of amide isomers; in the *endo* derivatives, this ratio varied from 1:4 in **4b** and **4c** to 1:5 in **4a**. In addition, the chemical shifts of the signals due to 2-H appeared considerably more downfield in the *endo* than in the *exo* isomers. These differences were used to assign relative stereochemistries of the diastereoisomers of complexes **4a** and **4b**. No spectral differences between the diastereoisomers of amine complexes **5a–c** appeared to be of diagnostic value for assigning relative stereochemistry.

In the present series of compounds, the signals due to 2-H were insufficiently resolved to permit their detailed analysis. However, the observation that the widths of these signals were always ≥40 Hz indicates that 2-H adopts a pseudoaxial conformation in all the derivatives studied (this would be consistent with two large diaxial couplings and two couplings of smaller magnitude between equatorial and axial hydrogens).[9]

As expected,[10] signals due to the aromatic hydrogens and carbons were shifted upfield upon complexation. In addition, the signal due to the protons of the methoxy group was shifted upfield and that due to the methoxy carbon was shifted downfield. Throughout, the three carbonyl ligands appeared as one signal in the ^{13}C NMR spectra.

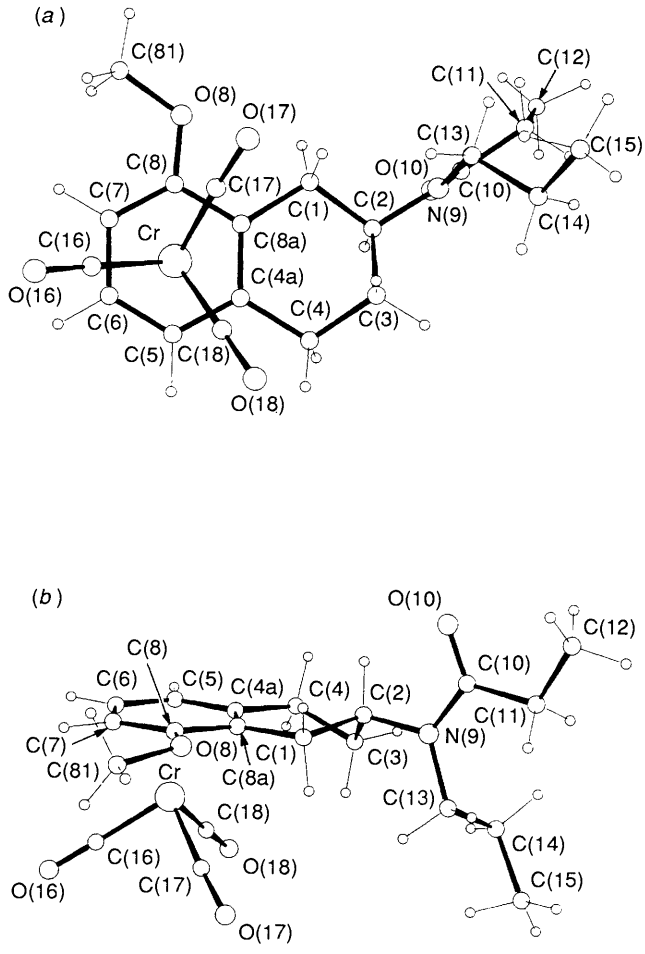
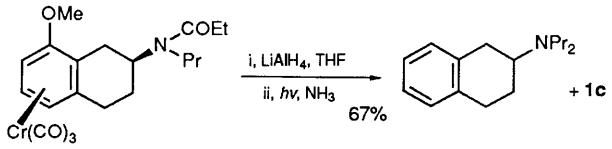


Fig. 1 Perspective views of the molecular structure of (2*S*)-**4c**. The atoms are labelled as in the text.

The complexes were also studied by IR spectroscopy and by fast-atom bombardment mass spectrometry (FAB-MS) but these spectroscopic techniques did not help in the assignment of relative stereochemistries.*

Reactions with Lithium Tetrahydridoaluminate.—In preliminary attempts to prepare *endo*-**5c**, the *endo* isomer of amide complex **4c** was treated with lithium tetrahydridoaluminate in boiling THF. The resulting mixture was decomplexed (*hv*, NH_3). Surprisingly, the product mixture consisted of demethoxylated amine **6** in addition to the expected product **1c**.



endo-**4c** **6**

To the best of our knowledge, no-one has previously obtained evidence that hydride is capable of replacing a methoxy

* Tables with selected IR and FAB-MS spectroscopic data of the tricarbonylchromium complexes have been deposited at the British Library Document Supply Centre (Boston Spa) [Sup. No.: 56818 (3 pp.)].

See Instructions for Authors, *J. Chem. Soc., Perkin Trans. 1*, 1991, for details of the Supplementary Publications Scheme.

Table 4 Selected ^{1}H NMR data of tricarbonylchromium complexes of some 2-aminotetralins and related compounds

Compound	Rotational isomer[a]	^{1}H NMR chemical shifts (δ_H) 2-H	5-H	6-H	7-H	8-H	OMe	A:B
3a	A	4.00		6.70	7.13	6.67	3.82	1:1
	B	4.63		6.69	7.08	6.65	3.81	
3b	A	4.03	7.0	6.7		6.6	3.77	1:1
	B	4.65						
3c	A	3.99	6.69	7.13	6.73		3.82	1:1
	B	4.68	6.65	7.09	6.71		3.80	
exo-**4a**	A	3.63		5.07	5.40	4.81	3.76	1:2
	B	4.22		5.02	5.39	4.77	3.74	
endo-**4a**	A	3.92		4.94	5.50	4.77	3.74	1:5
	B	≈4.8					3.73	
exo-**4b**	A	4.20	5.55	5.19		4.97	3.68	1:1.8
	B	3.60	5.53	5.16		4.93	3.66	
endo-**4b**	A	3.95	5.52	5.05		4.95	3.71	1:4
	B	4.80					3.69	
exo-**4c**	A	3.65	4.85	5.52	4.97		3.74	1:1
	B	4.07	4.83	5.45	4.95		3.70	
endo-**4c**	A	3.92	4.86	5.37	5.06		3.75	1:4
	B	4.76					3.72	
exo-**5a**		*b*		5.01	5.38	4.81	3.74	
endo-**5a**		≈2.4		4.91	5.47	4.80	3.71	
exo-**5b**		*b*	5.50	5.14		4.97	3.71	
endo-**5b**		*b*	5.49	5.05		4.99	3.69	
exo-**5c**		2.37	4.83	5.44	4.94		3.73	
endo-**5c**		≈2.5	4.84	5.35	5.03		3.74	
1a		≈2.5		6.71	7.09	6.65	3.81	
1b		2.98	6.98	6.68		6.64	3.77	
1c		*b*	6.66	7.08	6.71		3.82	

[a] Arbitrarily assigned. [b] Obscured.

Table 5 Selected ^{13}C NMR data of tricarbonylchromium complexes of some 2-aminotetralins and related compounds

Compound	Rotational isomer[a]	^{13}C NMR chemical shifts (δ_C) CrCO	C-8a	C-8	C-7	C-6	C-5	C-4a	C-2	OMe
1a			138.42	121.65	126.13	106.86	143.18	126.53	56.64	55.19
1b			137.93	113.90	157.51	111.95	129.40	128.69	56.80	55.19
1c			125.60[b]	157.63	106.73	125.91	120.85	137.96[b]	56.89	55.19
3a	A		136.94	121.28	126.25	106.98	157.20	124.43	51.02	55.19
	B		136.17		126.62	107.29		124.03	53.37	
3b	A		136.72	113.68	157.63	112.79	129.65	127.18	53.77	55.19
	B		135.89		157.85	112.29	129.53	127.77	51.51	
3c	A		124.43[b]	157.32	106.89	126.19	120.79	136.44[b]	51.20	55.19
	B		123.69[b]		106.98	126.62		136.94[b]	53.83	
exo-**4a**	A	233.39	110.22	86.63	93.21	73.47	140.36	97.59	55.81[b]	55.68[b]
	B	233.76	112.23		93.42	73.04	140.86	98.58		
endo-**4a**		234.07	110.19	86.57	93.14	72.58	141.79	99.35	49.01	55.84
exo-**4b**	A	233.48	109.27	78.51[b]	142.13	77.73[b]	95.24	99.29	55.56[b]	55.78[b]
	B	233.85	111.12		142.22		95.74	100.53		
endo-**4b**		234.85	109.08	78.26[b]	142.65	77.92[b]	95.40	101.88	49.17	55.65
exo-**4c**	A	233.94	100.19	141.17	73.01	92.31	87.03	110.28	55.34	55.90
	B	233.57	98.21	141.54	72.58	93.11	86.23	109.39	52.62	
endo-**4c**	A	233.26	97.31	140.06	73.26	92.68	87.75	110.04	52.81	55.87
	B	233.67	98.49	140.27	73.47		87.06	110.87	49.14	
exo-**5a**		233.76	112.54	87.06	93.14	73.01	140.68	99.53	55.03	55.81
endo-**5a**		234.14	111.58	87.12	92.93	72.58	141.76	100.56	56.21	55.81
exo-**5b**		233.82	111.49	78.51[b]	142.03	78.07[b]	95.43	101.11	55.10	55.56
endo-**5b**		234.13	110.32	78.60[b]	142.37	78.14[b]	95.21	103.00	56.39	55.59
exo-**5c**		233.98	100.59	141.51	72.82	92.44	86.81	110.96	55.47	55.84
endo-**5c**		233.76	99.82	140.55	73.16	92.56	86.97	111.92	56.24	55.84

[a] Arbitrarily assigned. [b] May be reversed across a row.

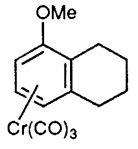
group in arene(carbonyl)chromium complexes.[11] In order to study this reaction, we performed experiments in which *endo*- and *exo*-complexes **5a–c** were treated with lithium tetrahydridoaluminate (Table 6). Throughout, the demethoxylation reaction occurred more readily in the *endo*- than in the *exo*-derivatives. Thus, a C-2 nitrogen substituent, which is located *syn* to the tricarbonylchromium moiety, appears to promote the demethoxylation. We also prepared tricarbonylchromium complex **7**, which lacks a C-2 substituent, and submitted it to the same reaction conditions. As expected, only a minor amount of demethoxylated product was formed.

Since the above results indicated that a properly positioned co-ordinating nitrogen was able to facilitate the demethoxylation reactions, we prepared the conformationally flexible

Table 6 Demethoxylation of tricarbonylchromium complexes of some 2-aminotetralin derivatives, and a related compound, when treated with $LiAlH_4$

Compound	Reaction time (h)[a]	Yield (%)[b] of demethoxylated product
(2*R*)-*endo*-**5a**	24	39
(2*R*)-*exo*-**5a**	24	10
(±)-*endo*-**5b**	20	54
(±)-*exo*-**5b**	20	4
(±)-*endo*-**5c**	17	75
(±)-*exo*-**5c**	17	17
7	24	8

[a] Reactions were performed in boiling THF and 10 equivalents of $LiAlH_4$ were used. [b] Yields were determined by gas chromatography after decomplexation (*hν*, NH_3).



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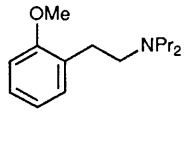

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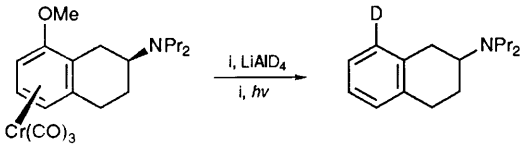


endo-**5c** **11**

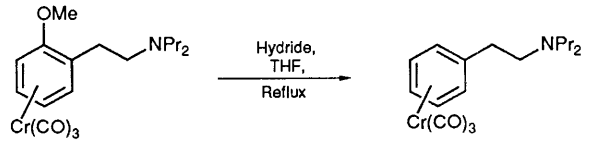
tricarbonylchromium complex of 2-(2-methoxyphenyl)-*N*,*N*-dipropylethylamine **8**. Upon reaction with lithium tetrahydridoaluminate, under the standard conditions, the complex **9** gave an almost quantitative yield of demethoxylated product **10** (Table 7).

It is noteworthy that treatment of complex *endo*-**5c** with lithium tetradeuteridoaluminate in THF produced, after decomplexation, the deuteriated and demethoxylated derivative **11** in 66% yield. The deuteride had replaced the methoxy group in an apparently regiospecific manner since only one deuteriated product was observed.

Reactions with Other Reagents.—Complex **9** was treated with some other hydride reagents (Table 7). Lithium or sodium borohydride produced very low yields of demethoxylated product despite prolonged reaction times. Similarly, lithium hydride, even in combination with the Lewis acids boron trifluoride–diethyl ether or aluminium chloride, was ineffective as a demethoxylating reagent. When *N*,*N*,*N*′,*N*′-tetramethylethylenediamine (TMEDA) was added to the reaction mixture, the yield of demethoxylated product was slightly decreased.

In conclusion, the demethoxylation reaction appears to require the presence of lithium tetrahydridoaluminate to proceed optimally.

Table 7 Effects of various hydride reagents on the demethoxylation of tricarbonyl[2-(2-methoxyphenyl)-*N*,*N*-dipropylethylamine]chromium **9**



9 **10**

Reagent	Reaction time (h)	Yield (%) of demethoxylated product[a]
LiH	24	0
LiH–$AlCl_3$	38	7
LiH–BF_3·OEt_2	48	0
$LiBH_4$	100	2
$NaBH_4$[b]	80	2
$LiAlH_4$	20	96
$LiAlH_4$–TMEDA	48	82

[a] Yields were determined by GLC after decomplexation. [b] 1,2-Dimethoxyethane was used instead of THF.

Experimental

Routine ^1H and ^{13}C NMR spectra were recorded at 90 and 22.5 MHz, respectively, on a JEOL FX 90Q spectrometer and were referenced to internal tetramethylsilane. *J*-Values are given in Hz. High-resolution 400 MHz ^1H NMR spectra were obtained on a Varian VXR 400 spectrometer, and fast-atom bombardment mass spectra (FAB-MS) were obtained on a Finnigan MAT-90 spectrometer using a glycerol matrix. IR spectra were obtained on a Perkin-Elmer 298 IR spectrophotometer. Optical rotations were obtained on a Perkin-Elmer 241 polarimeter. Capillary GLC was performed on a Carlo Erba 4200, by use of an SE 52 column (25 m), equipped with a flame ionization detector (FID-40) and a Milton Roy CI-10B integrator. M.p.s (uncorrected) were determined in open glass capillaries on a Thomas-Hoover apparatus. Elemental analyses were performed by Mikro Kemi AB, Uppsala, Sweden. Light petroleum refers to the fraction boiling in the range 40–60°C.

Preparation of Amides **3a–c**.—Propionyl chloride (7.6 cm^3, 86 mmol) was added dropwise to a suspension of finely ground 8-methoxy-2-propylaminotetralin hydrochloride **2c**[12] (20.05 g, 78.4 mmol) and triethylamine (21.5 cm^3, 150 mmol) in diethyl ether (1 dm^3). The reaction mixture, which was immersed in an ice-bath, was stirred overnight at room temperature. The precipitate was removed by filtration, the filtrate was concentrated, and the oily residue was purified by flash chromatography with diethyl ether as eluent to give pure 8-methoxy-2-(*N*-propylpropionamido)-1,2,3,4-tetrahydronaphthalene **3c** as an oil (20 g, 93%). (2*R*)-5-Methoxy-2-(*N*-propylpropionamido)-1,2,3,4-tetrahydronaphthalene, (2*R*)-**3a** (yield 96%), (±)-7-methoxy-2-(*N*-propylpropionamido)-1,2,3,4-tetrahydronaphthalene (±)-**3b** (yield 94%), and (2*S*)-8-methoxy-2-(*N*-propylpropionamido)-1,2,3,4-tetrahydronaphthalene, (2*S*)-**3c** (yield 100%) were prepared similarly from (2*R*)-5-methoxy-(2*R*)-(**2a**,[13] (±)-7-methoxy- (±)-**2b**,[13] and (2*S*)-8-methoxy-2-propylaminotetralin (2*S*)-**2c**,[14] respectively.

Preparation of (±)-exo-*Tricarbonyl*[*8-methoxy*-2-(N-*propylpropionamido*)-1,2,3,4-*tetrahydronaphthalene*]*chromium* [(±)-exo-**4c**] *and* (±)-endo-*Tetracarbonyl*[*8-methoxy*-2-(N-*propylpropionamido*)-1,2,3,4-*tetrahydronaphthalene*]*chromium* [(±)-endo-**4c**]. *Method I.*—A mixture of $Cr(CO)_6$ (9.3 g, 42.26 mmol), (±)-**3c** (6.14 g, 22.30 mmol), and Bu_2O–THF (9:1; 1.2 dm^3) was purged with nitrogen for 2 min and was then heated to reflux for 42 h. The reaction mixture was filtered (Celite) and the THF was evaporated off. The resulting solution was added on a silica column and purified by flash chromatography by use of gradient elution [diethyl ether–light petroleum (1:1) ⟶ diethyl ether]. Repeated flash chromatography gave (±)-exo-**4c** (3.93 g, 43%) and (±)-endo-**4c** (4.04 g, 44%) as yellow oils which crystallized in a freezer.

(±)-endo-*Tricarbonyl*[2-(*dipropylamino*)-8-*methoxy*-1,2,3,4-*tetrahydronaphthalene*]*chromium* [(±)-endo-**5c**].—*Method II.*—Compound (±)-*endo*-**4c** (7.25 g, 17.6 mmol) was dissolved in dry THF (5 cm^3). The solution was heated to 60 °C and a 2 mol dm^{-3} solution of borane–dimethyl sulphide in THF (15.0 cm^3, 30.0 mmol) was added dropwise during 20 min. Dimethyl sulphide was distilled off during the reaction. After 2 h the solution was quenched with aq. HCl (5 mol dm^{-3}; 3.6 cm^3, 18 mmol) and the mixture was heated to reflux for 15 min. Sodium hydroxide pellets were added to the cooled reaction mixture. The resulting mixture was partitioned between aq. NaOH and diethyl ether. The dried (K_2CO_3) and concentrated organic layer was purified on an alumina column by gradient elution [diethyl ether–light petroleum (1:4) ⟶ diethyl ether–light petroleum (1:1)] to give (±)-*endo*-**5c** as a yellow oil (5.93 g, 85%) which solidified in a freezer. The resulting crystals could be recrystallized from diethyl ether–light petroleum.

Demethoxylation of Chromium Complexes: General Procedure.—A solution of (±)-*endo*-Tricarbonyl[2-(dipropylamino)-8-methoxytetralin]chromium, (±)-*endo*-**5c** (0.91 g, 2.28 mmol) in dry THF (10 cm^3) was added dropwise to a solution of $LiAlH_4$ (1.02 g, 26.88 mmol) in THF (125 cm^3). The mixture was heated to reflux for 20 h. The reaction was quenched by successive additions of aq. NaOH (5 mol dm^{-3}) and water. The precipitate was filtered off and the filtrate was partitioned between water and diethyl ether. The ether was evaporated off and the residue was dissolved in THF (20 cm^3) containing aq. ammonia (1 cm^3). The solution was stirred and exposed to UV irradiation from a Hanovia 6515-34 photochemical immersion lamp. When the decomplexation was complete (TLC) the resulting solution was purified by acid–base extraction followed by chromatography on an alumina column by use of gradient elution (light petroleum ⟶ diethyl ether). Repeated chromatography gave 0.37 g (70%) of pure (±)-2-(dipropylamino)tetralin (±)-**6**.[15]

2-(2-*Methoxyphenyl*)-N,N-*dipropylethylamine* **8**.—A solution of 2-methoxyphenylacetic acid (3.0 g, 17.7 mmol) in thionyl dichloride (10 cm^3, 138 mmol) was stirred for 4 h and excess of reagent was distilled off. The residue was dissolved in diethyl ether (100 cm^3). The reaction vessel was immersed in an ice-bath and a solution of dipropylamine (2.7 cm^3, 20 mmol) and triethylamine (4.8 cm^3, 34 mmol) in diethyl ether (15 cm^3) was added dropwise. The mixture was stirred overnight at room temperature. The precipitate was filtered off, the filtrate was concentrated, and the oily residue was purified on silica gel with diethyl ether–light petroleum (1:1) as eluent. The resulting amide (13.0 g, 12.2 mmol) was reduced with $LiAlH_4$ (1.1 g, 27.8 mmol) in boiling THF (100 cm^3). The mixture was quenched by successive additions of aq. NaOH (5 mol dm^{-3}) and water. The product was purified on alumina with diethyl ether–light petroleum (1:4) as eluent to give the free base (2.4 g, 56%). The HCl *salt* of the amine was recrystallized from acetone–light petroleum; m.p. 118.0–118.5 °C; $\delta_H(CDCl_3$; free base) 7.14 (3 H, s), 4.00–2.80 (9 H, m), 2.50–1.50 (6 H, m) and 1.04 (γ-H); $\delta_C(CDCl_3$; free base) 157.54 (C-2′), 130.30 (C-6′), 129.28 (C-1′), 127.09 (C-4′), 120.38 (C-5′), 110.19 (C-3′), 56.21 (C-α), 55.16 (OMe), 54.05 (C-1), 27.61 (C-2), 20.48 (C-β) and 12.01 (C-γ); *m/z* 235 (M^+) and 114 (100) (Found: C, 65.4; H, 9.8; N, 5.2. $C_{15}H_{25}NO{\cdot}HCl{\cdot}\frac{1}{4}H_2O$ requires C, 65.2; H, 9.7; N, 5.1%).

(±)-8-*Deuterio*-2-(*dipropylamino*)-1,2,3,4-*tetrahydronaphthalene* [(±)-**11**].—Compound (±)-**11** was prepared in 67% yield from (±)-*endo*-**5c** (0.21 g, 0.52 mmol) and $LiAlD_4$ (0.32 g, 7.53 mmol) by the procedure described for the preparation of compound **6**. The product was isolated as the hydrochloride. (±)-**11**·HCl showed m.p. 153.5–154 °C; $\delta_H(CD_3OD)$ 7.14 (3 H, s), 4.00–2.80 (9 H, m), 2.50–1.50 (6 H, m) and 1.04 (γ-H); $\delta_C(CD_3OD)$ 136.01, 133.51, 130.29, 129.43, 127.24 (aromatic Cs), 61.61 (C-2), 53.83 (C-α), 30.51, 29.25, 25.14 (cyclohexene Cs), 19.70 (C-β) and 11.33 (C-γ); *m/z* 232 (M^+), 203 and 132 (Found: C, 70.8; H, 9.4; N, 5.2. $C_{16}H_{24}DN{\cdot}HCl{\cdot}\frac{1}{4}H_2O$ requires C, 70.6; H, 9.8; N, 5.1%).

NMR Data on tricarbonylchromium complexes not presented in Tables 3 and 4 are given below.

Tricarbonyl-(5-*methoxy*-1,2,3,4-*tetrahydronaphthalene*)*chromium* **7**. $\delta_H(CDCl_3)$ 5.40 (t, 7-H), 4.98 (d, 6-H), 4.81 (d, 8-H), 3.73 (s, OMe), 2.83–2.50 (4 H, m) and 1.90–1.10 (4 H, m); $\delta_C(CDCl_3)$ 234.07 (CrCO), 141.17 (C-5), 112.29 (C-8a), 100.65 (C-4a), 92.68 (C-7), 87.22 (C-8), 72.98 (C-6), 55.78 (OMe), 28.41, 22.98 and 21.68 (aliphatic Cs).

Tricarbonyl[2-(2′-*methoxyphenyl*)-N,N-*dipropylethylamine*]-*chromium* **9**. $\delta_H(CDCl_3)$ 5.57 (dd, 6′-H), 5.44 (dt, 4′-H), 5.05 (d, 3′-H), 4.88 (t, 5′-H), 3.74 (s, OMe), 2.71–2.57 (m, 1-H_2), 2.79 (m, one rotamer, 2-H), 2.4–2.32 (m, other rotamer, partially obscured, 2-H), 2.42 (t, one rotamer, α-H), 2.42 (t, other rotamer, α-H), 1.45 (m, β-H) and 0.87 (t, γ-H); $\delta_H(CDCl_3)$ 233.64 (CrCO), 141.63 (C-2′), 100.77 (C-1′), 97.31 (C-6′), 93.30 (C-4′), 85.83 (C-5′), 74.43 (C-3′), 55.96 (C-α), 55.74 (OMe), 54.26 (C-1), 27.12 (C-2), 20.35 (C-β) and 11.92 (C-γ).

Tricarbonyl(2-*phenyl*-N,N-*dipropylethylamine*)*chromium* **10**. $\delta_H(CDCl_3)$ 5.50–5.05 (5 H, m), 2.80–2.20 (8 H, m), 1.60–1.20 (m, β-H) and 0.85 (t, γ-H); $\delta_C(CDCl_3)$ 233.21 (CrCO), 112.63, 93.79, 93.27 and 90.52 (aromatic Cs), 55.47 and 33.05 (ethylene chain), 56.05 (C-α), 20.44 (C-β) and 11.92 (C-γ).

X-Ray Crystallography. Data Collection and Processing.—Crystals of (2*S*)-*endo*-**4c**, suitable for single-crystal X-ray diffraction studies, were obtained by storage of a solution of the complex in dibutyl ether–light petroleum in a freezer. The intensity data were collected at room temperature on a Siemens STOE/AED2 diffractometer equipped with a graphite monochromator and Mo-Kα radiation (λ 0.71069 Å, θ_{max} 30°) using the ω–2θ scan technique. Five reference reflections were measured approximately every 60 min. No systematic variation was detected. Data reduction included corrections for background, Lorentz, and polarization effects, but the rather low absorption effects (Table 2) were ignored. The unit-cell parameters were refined by least-squares using the angular settings (θ-values) of 69 strong reflections, carefully centred within the range $14.5 < 2\theta < 26.6°$.

Structure Analysis and Refinement.—The structure was solved by direct methods (SHELXS)[16] and refined by the full-matrix least-squares method of the SHELX system.[17] The positions of the non-hydrogen atoms were refined together with their anisotropic thermal parameters. The hydrogen atomic sites were calculated at assumed positions (C–H 1.08 Å) after each cycle of refinement. The methyl groups were treated as rigid groups with three rotational parameters refined for each of them. Two isotropic temperature factors were refined for the hydrogens: one for the methyl H atoms and one for the remaining hydrogens. This structural model was refined with both (*S*) and (*R*) absolute configuration assumed for the chiral C-2 atom. The refinement with (*S*) configuration resulted in the final agreement factors shown in Table 2, while the calculation for the (*R*) enantiomer converged to the values $R = 0.077$ and $R_w = 0.055$. Accordingly, the X-ray study confirmed the absolute configuration of the chiral C-2 atom as (*S*), as previously assigned on the basis of the known stereochemistry of the starting material (*S*)-**2c**.[18] Table 3 lists the final atomic co-ordinates referring to the correct enantiomer.

The atomic scattering factor for the Cr-atom was taken from Cromer and Waber,[19] those for the C-, O- and N-atoms from

Cromer and Mann,[20] and those for the H-atoms from Stewart, Davidson and Simpson.[21] The corrections for the anomalous dispersion of the non-hydrogen atoms were taken from Cromer and Liberman.[22]

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