

# Organometallic Compounds of the Lanthanides. 22.<sup>1</sup> (Tetramethylethylenediamine)lithium Dimethyl Derivatives of Erbium and Lutetium

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Bis(cyclopentadienyl)erbium chloride and bis(cyclopentadienyl)lutetium chloride react with methyl lithium in tetrahydrofuran (THF) in the presence of tetramethylethylenediamine (tmed) to give the complexes  $Cp_2Ln(\mu-CH_3)_2Li(tmed)$  but in the presence of dimethoxyethane (dme) with formation of  $Cp_2Ln(\mu-CH_3)_2Li(THF)_2$  with  $Ln = Er$  and  $Lu$ . The structure of  $Cp_2Er(\mu-CH_3)_2Li(tmed)$  has been elucidated through complete X-ray analysis. The crystals are tetragonal of space group  $P4_32_12$  with  $a = 8.359$  (1) Å,  $c = 28.78$  (3) Å,  $V = 2011$  Å<sup>3</sup>,  $\rho_{calcd} = 1.488$  g cm<sup>-3</sup>, and  $Z = 4$ . The structure was solved by Patterson and Fourier techniques from 2359 reflections measured at 138 (2) K on an Enraf-Nonius CAD-4 automatic diffractometer using monochromated Mo  $K\alpha$  radiation. The final  $R$  value is 0.064 for the 1074 observed reflections ( $I \geq 3\sigma(I)$ ) included in the least-squares sums ( $R_w = 0.072$ ). Principal dimensions are as follows:  $Er-Cp_{cent} = 2.348$  (6) Å,  $Er-C_{br} = 2.458$  (19) Å, and  $Er \cdots Li = 3.01$  (4) Å.

## Introduction

The first bis(cyclopentadienyl)rare-earth methyl derivatives were described by Tsutsui in 1975.<sup>2,3</sup> Methylbis(cyclopentadienyl)gadolinium, -erbium, and -ytterbium have been prepared, but no structural data are available thus far. The compounds were described as monomers without coordinating solvent like methylbis(cyclopentadienyl)gadolinium.<sup>4</sup> Holton et al. demonstrated that methylbis(cyclopentadienyl)lanthanide derivatives are dimeric with an electron-deficient, three-center bond involving two lanthanide metals and a methyl bridge.<sup>5,6</sup> We found that methylbis(cyclopentadienyl)lutetium is monomeric in tetrahydrofuran, forming an 1:1 complex with this solvent, which can be detected by NMR spectroscopy below 0 °C, but decomposes on warming.<sup>7,8</sup>

Simple homoleptic methyl derivatives of the lanthanides like  $Ln(CH_3)_3$  are not known. However, permethylated complexes of the type  $[Li(tmed)]_3[Ln(CH_3)_6]$ , containing bridging methyl groups between the lanthanide metal and lithium are stable up to 142 °C.<sup>9-11</sup> An increase of the coordination number of the metal increases the stability of the methyl derivatives.

Now we have found that methylbis(cyclopentadienyl)lanthanide derivatives can be stabilized by using an excess

of methyl lithium. Single-crystal X-ray diffraction studies have been undertaken for one of these derivatives. <sup>1</sup>H and <sup>13</sup>C NMR spectra of the complexes have been recorded. The synthesis of the corresponding pentamethylcyclopentadienyl complexes of ytterbium and lutetium was published in the meantime.<sup>12,13</sup>

## Experimental Section

All reactions and preparations were performed by using Schlenk tubes in an atmosphere of dried, oxygen-free argon. The solvents used were dried and freed of oxygen by refluxing and keeping over NaH or potassium and distilling under argon prior to use. Anhydrous  $ErCl_3$  and  $LuCl_3$  were prepared from the pure oxides (Auer-Remy, Hamburg, West-Germany) by reaction with  $NH_4Cl$ .<sup>14</sup> Tetramethylethylenediamine (tmed) was dried and freed of oxygen by refluxing over KOH and distillation under argon. Melting points were determined in sealed, argon-filled capillaries. Elemental analyses were performed by a Perkin-Elmer CHN-Analyzer 240. Satisfactory analyses could be obtained by using a special Schlenk tube and small aluminum cans for weighing these extremely sensitive compounds. Metal analyses were carried out by complexometric titration against dithizone.<sup>15</sup>

<sup>1</sup>H NMR spectra were obtained in sealed 5-mm tubes and <sup>13</sup>C NMR spectra in sealed 10-mm tubes on a Bruker WP 80 SI instrument. We thank M. Dettlaff for recording the spectra. (*N,N,N',N'*-Tetramethylethylenediamine)lithium Dimethylbis(cyclopentadienyl)erbate(III) (1). A 23.4-mmol sample of  $NaC_5H_5$  in 10 mL of tetrahydrofuran was added at room temperature to a slurry of 3.2 g (11.7 mmol) of  $ErCl_3$  in 50 mL of tetrahydrofuran. The mixture was stirred for 3 h and subsequently cooled to -78 °C. A 1.4-g (11.7-mmol) sample of tmed and 14.6 mL of a 1.6 M solution of methyl lithium in diethyl ether were added. The solution was stirred for 3 h at -78 °C and then warmed to room temperature. After the mixture was stirred at room temperature for 30 min, volatile materials were removed and the oily residue was diluted in diethyl ether. After filtration the clear solution was cooled to -30 °C over night. Pink crystals

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Table I. Crystal and Data Collection Parameters for  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)^a$ 

formula	$C_{18}H_{32}ErLiN_2$
fw	450.65
space group <sup>b</sup>	$P4_22_1$
$a, c$ , Å	8.359 (1)
$b$ , Å	28.78 (3)
$V$ , Å <sup>3</sup>	2011
$F(000)$	900
$\rho$ calcd, g·cm <sup>-3</sup>	1.488
$\mu$ , cm <sup>-1</sup>	48.0
$Z$	4
cryst size, mm	$0.43 \times 0.43 \times 0.50$
diffractometer	Enraf-Nonius CAD-4
radiatn $\lambda$ , Å	Mo $K\alpha$ , 0.710 69
temp, K	$138 \pm 2$
scan technique	$\theta - 2\theta$
$2\theta$ limits, deg	$3 \leq 2\theta \leq 52$
scan speed	variable, max scan time 45 s
no. of unique data	1114
no. of observed data	1074 ( $I_o \geq 3\sigma(I)$ )
$R = \sum   F_o  -  F_c   / \sum  F_o $	0.064
no. of parameters	104

<sup>a</sup> Estimated standard deviations for the last significant digit are in parentheses. <sup>b</sup> Based upon systematic absences;  $0k0$ ,  $k = 2n + 1$ ,  $00l$ ,  $l = 4n + 1, 2, 3$ . <sup>c</sup> Final lattice parameters were determined from a least-squares refinement of the angular settings of 48 reflections measured with Mo  $K\alpha_1$  radiation ( $\lambda = 0.709 26$  Å).

were obtained the next day by decanting the solvent and careful drying in vacuo: yield 2.7 g (52%) of 1; decomp pt 108–112 °C. Anal. Calcd for  $C_{18}H_{32}ErLiN_2$ : C, 47.97; H, 7.16; N, 6.22; Er, 37.11. Found: C, 47.93; H, 7.27; N, 6.02; Er, 37.60.

(*N,N,N',N'*-Tetramethylethylenediamine)lithium Dimethylbis(cyclopentadienyl)lutetate(III) (2). This compound was prepared from 3.1 g (11 mmol) of  $LuCl_3$ , 22 mmol of  $NaC_5H_5$ , 1.2 g (11 mmol) of tmed, and 13.7 mL of an 1.6 M solution of methylolithium in diethyl ether by using the method described above. Colorless crystals of 2 were obtained: yield 2.87 g (56%); decomp pt 118–122 °C. Anal. Calcd for  $C_{18}H_{32}LiLuN_2$ : C, 47.17; H, 7.04; N, 6.11; Lu, 38.17. Found: C, 47.11; H, 7.20; N, 6.01; Lu, 37.68.

Bis(tetrahydrofuran)lithium Dimethylbis(cyclopentadienyl)erbate(III) (3). The compound was prepared according to 1 from 4.0 g (14.6 mmol) of  $ErCl_3$ , 29.2 mmol of  $NaC_5H_5$ , 1.35 g (15 mmol) of dme, and 18.25 mL of an 1.6 M solution of methylolithium in diethyl ether. The reaction was carried out in 100 mL of THF. Pink crystals of 3 were obtained: yield 3.8 g (55%); decomp pt 104–106 °C. Anal. Calcd for  $C_{20}H_{32}ErLiO_2$ : C, 50.18; H, 6.74; Er, 34.94. Found: C, 50.09, H, 6.74; Er, 35.05.

Bis(tetrahydrofuran)lithium Dimethylbis(cyclopentadienyl)lutetate(III) (4). This compound was prepared from 3.0 g (10.65 mmol) of  $LuCl_3$ , 21.3 mmol of  $NaC_5H_5$ , 0.9 g (10 mmol) of dme, and 13.3 mL of an 1.6 M solution of methylolithium in diethyl ether and 80 mL of tetrahydrofuran by using the method described above. Colorless crystals of 4 were obtained: yield 2.75 g (53%); decomp pt 108–110 °C. Anal. Calcd for  $C_{20}H_{32}LiLuO_2$ : C, 49.39; H, 6.63; Lu, 35.97. Found: C, 49.25; H, 6.69; Lu, 35.54.

**Crystal Structure of 1.** A suitable crystal of 1 with the dimensions 0.43 mm  $\times$  0.43 mm  $\times$  0.50 mm was inspected under a microscope and placed in the nitrogen beam of the diffractometer as we have described earlier.<sup>16</sup> The cell dimensions were determined by least squares from the  $+2\theta$  and  $-2\theta$  values of 48 reflections spaced throughout reciprocal space and measured at 138 K. All measurements were performed on an Enraf-Nonius CAD-4 automatic counter diffractometer controlled by a PDP 8/e computer and fitted with a low-temperature device.

Applying  $\theta - 2\theta$  scan techniques and Mo  $K\alpha$  radiation, 2359 intensity data were collected at 138 (2) K to a maximum  $2\theta$  of

Table II. Final Positional Parameters for  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed) (\times 10^4)^a$ 

atom	x	y	z
Er <sup>b</sup>	2028.0 (7)	2028.0 (7)	0.0
Li	-519 (31)	-519 (31)	0.0
N	-1972 (18)	-1611 (15)	501 (5)
C1 <sup>c</sup>	3576 (19)	3775 (14)	-613 (5)
C2	4563 (19)	2423 (14)	-528 (5)
C3	3778 (19)	1054 (14)	-711 (5)
C4	2306 (19)	1560 (14)	-908 (5)
C5	2181 (19)	3241 (14)	-848 (5)
C6	2123 (21)	-876 (23)	132 (7)
C7	-2557 (24)	-3016 (22)	260 (7)
C8	-3262 (20)	-522 (24)	629 (7)
C9	-1212 (25)	-2159 (23)	933 (6)

<sup>a</sup> Estimated standard deviations for the last significant digit are in parentheses. <sup>b</sup> Er and Li lie on a special position (Wyckoff position *a*), on the twofold axis which passes through the midpoint of the C7-C7' bond. One asymmetric unit contains  $1/2$  molecule of 1. <sup>c</sup> Atoms C1-C5 were refined as ideal pentagon,  $d(C-C) = 1.42$  Å.

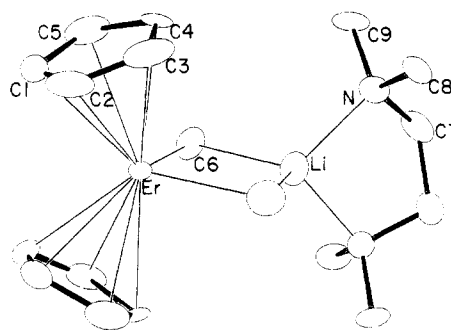


Figure 1. ORTEP drawing of one molecule  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)$ . The content of one asymmetric unit is labeled with the employed numbering scheme.

52°. The intensities of three standard reflections were measured every 2 h of X-ray exposure. No significant changes in the intensity of the check reflections were observed.

The raw data were corrected for Lorentz and polarization effects and merged. A total of 1114 unique reflections were obtained, 1074 of which were considered observed ( $I \geq 3\sigma(I)$ ) and used for subsequent calculations. No absorption correction was made. The extreme sensitivity toward air and moisture as well as the facile loss of tmed from the crystals forced us to apply a mounting procedure<sup>16</sup> where the crystals are not sealed in capillaries. The crystal was completely covered with ice at the end of the data collection. Attempts to deice the crystal in order to measure the faces resulted in the loss of the crystal and hence the lack of an absorption correction. Crystal and data collection details are summarized in Table I.

From the systematic absent reflections the space group was determined to be either  $P4_22_1$  or its enantiomorphic space group  $P4_12_1$ . The position of the erbium atom was calculated from a three-dimensional Patterson map. The positional parameters of the erbium atom were refined, and a difference Fourier map was calculated using the heavy-atom phases. All other non-hydrogen atoms were located in this difference Fourier map. These atoms were refined in stages by using first isotropic and later anisotropic thermal parameters. The hydrogen atoms were introduced at calculated positions with a constant isotropic temperature factor of  $U = 0.08$  Å<sup>2</sup>. Refinement was carried out in both the enantiomorphic space groups with  $P4_22_1$  giving the better *R* value and being assumed the correct choice.

A difference Fourier map calculated from the final structure factors showed no unusual features. The strongest peaks in this map were located in the immediate vicinity of the erbium atom ( $\pm 3.5$  e/Å<sup>3</sup>, 0.88 Å from Er,  $\pm 3.1$  e/Å<sup>3</sup>, 0.87 Å from Er, and  $\pm 2.3$  e/Å<sup>3</sup>, 1.55 Å from Er). All calculations were performed by using the program SHELX.<sup>17</sup> Atomic scattering factors for Er and Li

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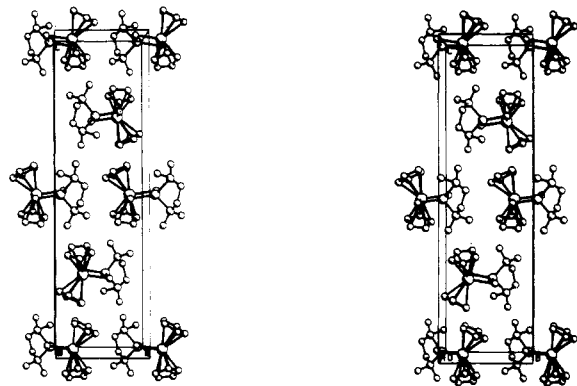


Figure 2. A stereoview of the packing.

Table III. Interatomic Distances (Å) for  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)^a$ 

Er-C1	2.631 (13)	Er...Li	3.01 (4)
Er-C2	2.629 (15)	Li-C6	2.26 (3)
Er-C3	2.643 (14)	Li-N	2.10 (3)
Er-C4	2.654 (13)	N-C7	1.45 (2)
Er-C5	2.646 (14)	N-C8	1.46 (2)
Er-C(mean) <sup>b</sup>	2.641 (11)	N-C9	1.47 (2)
Er-Cp <sup>c</sup>	2.348 (14)	C7-C7' <sup>d</sup>	1.59 (3)
Er-C6	2.458 (19)		

<sup>a</sup> Estimated standard deviations for the last significant digit are in parentheses. <sup>b</sup> This is the averaged value for the distance between the erbium atom and the carbon atoms of the cyclopentadienyl group. <sup>c</sup> Cp denotes the centroid of the cyclopentadienyl group. <sup>d</sup> Primed atoms represent transformed coordinates of the type  $y, x, -z$ .

Table IV. Interatomic Angles (deg) for  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)^a$ 

Cp <sup>b</sup> -Er-Cp' <sup>c</sup>	131.4 (5)	Li-N-C7	103 (1)
Cp-Er-C6	104.9 (5)	Li-N-C8	109 (1)
Cp-Er-C6'	107.4 (6)	Li-N-C9	118 (1)
C6-Er-C6'	95.0 (6)	C7-N-C8	112 (2)
C6-Li-N	113 (1)	C7-N-C9	107 (1)
C6-Li-N'	118 (1)	C8-N-C9	107 (1)
C6-Li-C6'	107 (1)	Er-C6-Li	79.2 (9)
N-Li-N'	88 (1)	N-C7-C7'	110 (1)

<sup>a</sup> Estimated standard deviations for the last significant digit are in parentheses. <sup>b</sup> Cp denotes the centroid of the cyclopentadienyl group. <sup>c</sup> Primed atoms represent transformed coordinates of the type  $y, x, -z$ .

and the  $\Delta f'$  and  $\Delta f''$  components of anomalous dispersion for Er were taken from ref 18.

Final atomic positional parameters are listed in Table II. The atomic numbering scheme followed in these listings is identified in Figure 1. Figure 2 shows a stereoview of the packing. Each asymmetric unit contains  $1/2$  molecule of 1. Er and Li lie on a special position (Wyckoff position a) on the twofold axis which passes through the midpoint of the C7-C7' bond. Interatomic distances and angles are listed in Tables III and IV, respectively.

## Results and Discussion

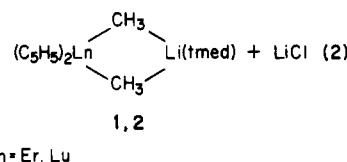
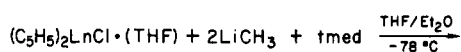
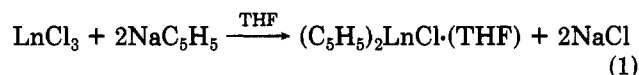
**Synthesis of Lithium Dimethylbis(cyclopentadienyl)lanthanide Complexes.** Erbium trichloride and lutetium trichloride react in tetrahydrofuran with sodium cyclopentadienide in the molar ratio 1:2 with formation of bis(cyclopentadienyl)erbium chloride or bis(cyclopentadienyl)lutetium chloride. The reaction of these compounds with the double amount of methyllithium in diethyl ether in the presence of tmed at  $-78^\circ C$  gave the appropriate (*N,N,N',N'*-tetramethylethylenediamine)lith-

Table V.  $^1H$  and  $^{13}C$  NMR Spectral Data for 2 and 4 in  $C_6D_6$ <sup>a</sup>

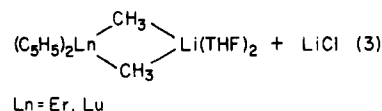
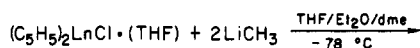
		$(C_5H_5)_2Lu(\mu-CH_3)_2Li(tmed)$	$(C_5H_5)_2Lu(\mu-CH_3)_2Li(THF)_2$
$^1H$	$\delta(C_5H_5)$	6.26 (s)	6.31 (s)
	$\delta(CH_3)$	-0.89 (s)	-0.77 (s)
	$\delta(NCH_3)$	1.84 (s)	
	$\delta(NCH_2)$	1.57 (s)	
	$\delta(CH_2(THF))$		3.52 (t)
$^{13}C$	$\delta(CH_2(THF))$		1.39 (t)
	$\delta(C_5H_5)$	108.49	108.53
	$\delta(CH_3)$	15.77	15.21
	$\delta(NCH_3)$	45.94	
	$\delta(NCH_2)$	56.53	
	$\delta(CH_2(THF))$		68.22
	$\delta(CH_2(THF))$		25.38

<sup>a</sup> Chemical shifts are reported in ppm from  $Si(CH_3)_4$ ; s = singlet and t = triplet.

ium dimethylbis(cyclopentadienyl)lanthanide(III) derivatives (eq 1 and 2).  $(C_5H_5)_2ErCl \cdot (THF)$  and  $(C_5H_5)_2LuCl$



(THF) react with 2 equiv of methyllithium in the presence of dimethoxyethane (dme) instead of tmed with formation of methyl-bridged lithium dimethyldi(cyclopentadienyl)lanthanide complexes, but coordinated with two molecules of tetrahydrofuran at the lithium atom and not with one dme (eq 3).



Dimethoxyethane is therefore a weaker base together with methyl-bridged lithium dimethylbis(cyclopentadienyl)lanthanide complexes than tetrahydrofuran. The formation of the dme complex is not possible in tetrahydrofuran solution, but it should be possible in diethyl ether solution, as shown with the isolation of tris[(dimethoxyethane)lithium] hexamethyl derivatives of some lanthanides from ethereal solutions.<sup>16</sup>

The air-sensitive complexes are pink (1 and 3) or colorless (2 and 4). They are soluble in benzene, toluene, diethyl ether, and tetrahydrofuran but insoluble in saturated hydrocarbon solvents.

**Spectroscopic Characterization.** The erbium compounds 1 and 3 are paramagnetic, and therefore, we could not obtain acceptable NMR spectra. The diamagnetic lutetium compounds 2 and 4 show in benzene-*d*<sub>6</sub> the expected  $^1H$  and  $^{13}C$  signals for the methyl groups and the tmed or THF ligands (Table V).

**Molecular Structure of  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)$  (1).**<sup>19</sup> X-ray structure investigations have been carried

(18) "International Tables for Crystallography"; Kynoch Press; Birmingham, England, 1974; Vol. IV, Tables 2.2B and 2.3.1.

(19) Schumann, H., Lauke, H., Hahn, E., presented at the: "11th International Conference on Organometallics Chemistry, Pine Mountain, GA, Oct 1983.

out for various bridged dinuclear bis(cyclopentadienyl)-lanthanide compounds. Molecular structures are known for the dilanthanide compounds of the type  $R_2Ln(\mu-X)_2LnR_2$  with halogen,<sup>20-22</sup> carbon,<sup>6,23</sup> and hydrogen bridges.<sup>24,25</sup> Structures of dinuclear complexes containing a lanthanide metal and a group 3A element with different bridging groups are also known.<sup>26,27</sup> We report herein an example of a dinuclear lanthanide-lithium complex with two methyl bridges between the metal centers.

The crystal structure of  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)$  consists of discrete molecules which show no unusually short intermolecular distances. There are four molecules per unit cell. The  $(C_5H_5)_2Er$  moiety is bonded through two methyl bridges to a lithium cation, which in turn is bonded to a molecule of tmed as shown in Figure 1.

The Er-Cp distance (Cp denotes the centroid of the cyclopentadienyl group) of 2.348 (14) Å falls within the expected range based on earlier observations for erbium compounds (2.325 (20) and 2.345 (20) Å for  $[(C_5H_5)_2Er-CC(CH_3)_3]_2$ ,<sup>23</sup> 2.389 (3) Å for  $(C_5H_5)ErCl_2(THF)_3$ <sup>28</sup>). However, the Er-C bond length for the methyl carbon (Er-C6 = 2.458 (19) Å) is significantly shorter than in the permethylated complex  $[Li(tmed)]_3[Er(CH_3)_6]$  (2.57 (2) Å).<sup>10,11</sup> This is not surprising, since the permethylated complex contains six electron-deficient methyl bridges.

Previous studies for nonbridged f complexes showed that alkynide-metal bond lengths are shorter than alkyl-metal bond lengths (2.33 (2) Å in  $(C_5H_5)_3UCCC_6H_5$ <sup>29</sup> vs. 2.43 (3) Å in  $(C_5H_5)_3U(n-Bu)$ <sup>30</sup>). It was predicted that this trend

should persist for bridged f-element systems.<sup>23</sup> We found, however, that for alkyl and alkynide bridges in dinuclear erbium complexes there exists no difference in the erbium-carbon (br) bond length ( $[(C_5H_5)_2ErCCC(CH_3)_3]_2$ , Er-C<sub>br</sub> = 2.42 (2) and 2.47 (2) Å;<sup>23</sup>  $(C_5H_5)_2Er(\mu-CH_3)_2Li(tmed)$ , Er-C<sub>br</sub> = 2.458 (19) Å). The metal-carbon (br) distance in the two complexes above is significantly longer than the Ln-C<sub>br</sub> distance in ylide complexes (2.344 (15) and 2.378 (15) for  $((CH_3)_5C_5)_2Lu(CH_2)_2P(CH_3)_2$ ).<sup>1</sup> The Li-C and Li-N distances show no abnormality and are within the range observed for the permethylated erbium complex stabilized with tmed.<sup>11</sup>

In 1, both metals are surrounded in a distorted tetrahedral fashion. The angle involving the metal and the two carbon bridges is the smallest for erbium (C6-Er-C6' = 95.0 (6)°), whereas the angle Cp-Er-Cp' (131.4 (5)°) is the largest and shows the greatest deviation from the ideal tetrahedral geometry. This behavior is not unusual and has been observed for other bridged cyclopentadienyl-lanthanide compounds ( $(C_5H_5)_2Ln(\mu-CH_3)_2Ln(C_5H_5)_2$ ; Ln = Y, C-Ln-C = 92.3 (3)°, Cp-Ln-Cp = 128.9 (5)°; Ln = Yb, C-Ln-C = 93.4 (5)°, Cp-Ln-Cp = 128.2 (5)°<sup>6</sup>). The tetrahedral geometry at lithium is less distorted with the angle N-Li-N' (88 (1)°) being the smallest. The angle at the bridging carbon (Er-C6-Li = 79.2 (9)°) is much smaller than the Ln-C-Ln angle for the dilanthanide compounds (Ln = Y, 87.7 (3)°; Ln = Yb, 86.8 (5)°<sup>6</sup>; Ln = Er, 96.6 (7)°<sup>23</sup>), but in the range of this angle for the permethylated complex (77 (2)°<sup>11</sup>).

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**Registry No.** 1, 93895-51-3; 2, 93895-53-5; 3, 93895-54-6; 4, 93895-55-7;  $(C_5H_5)_2ErCl(THF)$ , 93895-56-8;  $(C_5H_5)_2LuCl(THF)$ , 82293-69-4;  $ErCl_3$ , 10138-41-7;  $LuCl_3$ , 10099-66-8.

**Supplementary Material Available:** Tables of thermal parameters (Table VI), and hydrogen parameters (Table VII), and the least-squares planes (Table VIII) and a listing of observed and calculated structure factors for 1 (8 pages). Ordering information is given on any current masthead page.

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## Yttrium-89 NMR Spectra of Organoyttrium Complexes

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The <sup>89</sup>Y NMR spectra of the following organoyttrium complexes are reported:  $(CH_3C_5H_4)_3Y(THF)$ ,  $[(CH_3C_5H_4)_2Y(\mu-Cl)]_2$ ,  $(CH_3C_5H_4)_2YCl(THF)$ ,  $[(CH_3C_5H_4)_2Y(\mu-CH_3)]_2$ ,  $(CH_3C_5H_4)_2YCH_3(THF)$ ,  $\{(CH_3C_5H_4)_2Y[\mu-C\equiv CC(CH_3)_3]\}_2$ ,  $[(CH_3C_5H_4)_2Y(\mu-H)(THF)]_2$ ,  $\{(C_5H_5)_2Y(\mu-H)\}_3(\mu_3-H)\{Li(THF)_4\}$ , and  $(C_5Me_5)_2Y(\mu-Cl)_2K(THF)_2$ . Chemical shifts relative to  $YCl_3$  vary over a 400 ppm range. A 27-Hz <sup>89</sup>Y-<sup>1</sup>H coupling was resolved in the spectrum of  $[(CH_3C_5H_4)_2Y(\mu-H)(THF)]_2$ .

As part of a general investigation of the organometallic chemistry of the lanthanide elements,<sup>2-4</sup> we have studied

the chemistry of organometallic yttrium complexes.<sup>4-7</sup> Although yttrium is not formally a lanthanide element, it