Cl3—Cr—N3	174.02 (5)	C7—C8—C9	111.4 (3)
N1—Cr—N2	82.56 (7)	C8—C9—C10	115.4 (3)
N1—Cr—N3	82.02 (7)	N2—C11—C12	116.0 (2)
N2—Cr—N3	82.74 (9)	C11—C12—C13	112.8 (2)
C1—N1—C6	110.8 (2)	C12—C13—C14	112.8 (3)
C1—N1—C7	109.2 (2)	N3—C15—C16	116.9 (3)
C6—N1—C7	109.8 (2)	C15—C16—C17	110.8 (3)
C2—N2—C3	111.3 (2)	C16—C17—C18	114.9 (4)
C2—N2—C11	109.2 (2)		

C6—N1—C1—C2	134.1 (2)	C4—N3—C5—C6	133.3 (2)
C7—N1—C1—C2	−104.8 (3)	C15—N3—C5—C6	−104.2 (3)
C1—N1—C6—C5	−68.5 (3)	C4—N3—C15—C16	51.7 (3)
C7—N1—C6—C5	170.8 (2)	C5—N3—C15—C16	−70.4 (3)
C1—N1—C7—C8	−74.8 (3)	N1—C1—C2—N2	−49.2 (3)
C6—N1—C7—C8	46.9 (3)	N2—C3—C4—N3	−49.2 (3)
C3—N2—C2—C1	−65.4 (3)	N3—C5—C6—N1	−47.4 (3)
C11—N2—C2—C1	173.9 (2)	N1—C7—C8—C9	168.3 (3)
C2—N2—C3—C4	133.9 (2)	C7—C8—C9—C10	168.3 (3)
C11—N2—C3—C4	−105.3 (2)	N2—C11—C12—C13	124.9 (3)
C2—N2—C11—C12	60.0 (3)	C11—C12—C13—C14	174.7 (3)
C3—N2—C11—C12	−62.0 (3)	N3—C15—C16—C17	168.4 (3)
C5—N3—C4—C3	−67.3 (3)	C15—C16—C17—C18	172.9 (3)
C15—N3—C4—C3	171.0 (2)		

Isotropic displacement parameters for the ring H atoms range 2.4 (5)–4.2 (6) Å^2 and the C—H distances range 0.89 (2)–0.99 (2) Å. The H atoms of the butyl groups have *B* values in the range 2.9 (5)–19 (2) Å^2 and C—H distances in the range 0.86 (2)–1.08 (4) Å. Programs used include the Enraf–Nonius *SDP* system (Frenz, 1978) and *ORTEP* (Johnson, 1965).

Lists of structure factors, anisotropic displacement parameters and H-atom coordinates have been deposited with the IUCr (Reference: BK1036). Copies may be obtained through The Managing Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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Acta Cryst. (1995). C**51**, 20–23

cis-trans-[{N$_3$P$_3$Cl$_4$(C$_6$H$_5$)(PPh$_2$)}Mn(CO)$_2$(bipy){P(OPh)$_3$}]PF$_6$. A Cationic Manganese–Carbonyl Complex with a Phosphazenylphosphine Ligand

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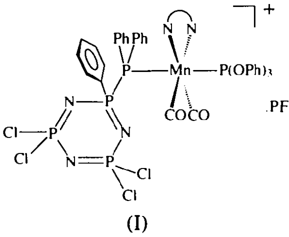
Abstract

The structure of *cis-trans*-(bipyridine-*N*,*N'*)dicarbonyl-[diphenyl(2-phenyl-4,4,6,6-tetrachloro-2-cyclotriphosphazenyl)phosphine-*P*](triphenyl phosphite-*P*)manganese(I) hexafluorophosphate, [Mn(C$_{18}$H$_{15}$O$_3$P)(C$_{10}$H$_8$N$_2$)(C$_{18}$H$_{15}$Cl$_4$N$_3$P$_4$)(CO)$_2$]PF$_6$, consists of discrete complex cations and PF$_6^-$ anions linked by several weak C—H···O and C—H···F interactions. The cation is a very distorted octahedral manganese–dicarbonyl fragment having *cis-trans* stereochemistry and bearing triphenylphosphite, bipyridine and phosphazenylphosphine [N$_3$P$_3$Cl$_4$(Ph)(PPh$_2$)] ligands. Analysis of the structure of the complex reveals that the coordination of the phosphazenylphosphine ligand to the cationic manganese–carbonyl fragment induces only minor changes in the phosphazene ring, affecting only the P5—P3 bond length.

Comment

The presence of phosphine in a phosphazene ring molecule, attached either directly to the ring P atoms or indirectly *via* pendant groups, is of interest because the resulting ligands and their complexes may be useful as models for high polymeric analogues (Allcock, Manners, Mang & Parvaez, 1990). The phosphazenylphosphine ligand N$_3$P$_3$Cl$_4$(C$_6$H$_5$)(PPh$_2$) has been coordinated previously to a neutral Cr(CO)$_5$ fragment and the X-ray structure determination of the resulting complex showed that no significant changes took place in the structure of the phosphazene ring upon coordination of the metal to the ligating PPh$_2$ group (Allcock, Manners, Mang & Parvaez, 1990). In order to determine the effect of a similar octahedral fragment, only this time with a positive charge, we prepared the title ionic complex, *cis-trans*-$[\{N_3P_3Cl_4(C_6H_5)(PPh_2)\}Mn(CO)_2(bipy)\{P(OPh)_3\}]PF_6$, (I), and determined its structure by X-ray diffraction.



(I)

The structure consists of discrete complex cations and octahedral PF_6^- anions (Fig. 1). The mean geometric parameters of the P environment are: P—N(ring) 1.580 (7), P—Cl 1.998 (3), P1—O 1.597 (5) Å, Mn—P1—O 116.5 (2), P—N—P(ring) 121.4 (4), N—P—N(ring) 117.7 (3) and Cl—P—Cl 100.5 (2)°. Although the position of the F atoms of the PF_6^- anion are affected by some dissorder, as suggested by the anisotropic displacement parameters, it is possible that in the crystal there are several weak H-atom interactions between the cation and the anion. Thus, the two mutually *cis* F atoms (F2 and F5) of the PF_6^- anion interact weakly with the C25—H25 and C13—H13 bonds of the bipyridine ligand. The shortest anion–cation separation is H13···F5 [2.1 (2) Å]. There are also weak cation–cation hydrogen-bond contacts between atoms C14, C24 and C25 of the bipyridine ligand and the O atoms of the carbonyl ligands. A few very weak intramolecular hydrogen-bond interactions can also be observed within the cation, the shortest of which are between the phosphazene ring N atoms, N3 and N5, and the C—H bonds of the phenyl rings attached to P2 and P3.

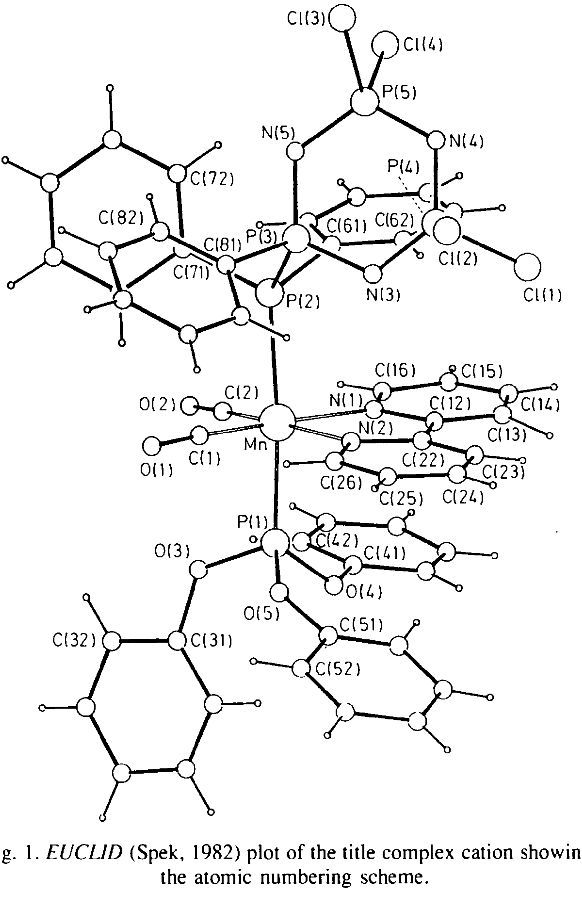


Fig. 1. *EUCLID* (Spek, 1982) plot of the title complex cation showing the atomic numbering scheme.

The complex cation consists of an Mn atom bonded to two mutually *cis* carbonyl ligands, two N atoms of a chelated bipyridine ligand and two P atoms, one of the phosphite $P(OPh)_3$ and the other of the PPh_2 group of the phosphazenylphosphine ligand. There are no intramolecular interactions between the Mn atom and the N or Cl atoms of the phosphazene ring. The stereochemistry around the Mn atom is only approximately octahedral and there are many distortions from ideal geometry. Thus the angles between the P2→Mn vector and the equatorial Mn—N2 [98.2 (2)°] and Mn—C2 [86.0 (2)°] bonds are significantly different from 90°. The large P2—Mn—N2 angle appears to be due mainly to the position in the molecule of the sterically demanding $—P(C_6H_5)N_3P_3Cl_4$ moiety relative to the Mn—N2 internuclear distance. The reason this bond is the more affected can be understood by considering that the torsion angle N2—Mn—P2—P3 is only −24.5 (2)° while N1—Mn—P2—P3 is −102.6 (2) and Mn—P2—P3—N3 is 47.7 (2)°. The same explanation may be given for the deviation from linearity of the C2—Mn—N2 angle [171.4 (3)°]. Other deviations from octahedral geometry, such as the angle N1—Mn—N2 [78.3 (2)°], are due to the geometrical demands of the bidentate bipyridine ligand and are normal. The Mn—P2 bond distance [2.362 (3) Å] is rather large (Orpen, Brammer, Allen, Kennard, Watson & Taylor, 1989). This is similar to the corresponding Cr—P distance of 2.387 Å in the Cr analogue $[\{N_3P_3Cl_4(C_6H_5)(PPh_2)\}Cr(CO)_5]$ (Allcock, Manners, Mang & Parvaez, 1990). However, in the case of the manganese complex cation an important *trans* influence is expected due to the presence of the $P(OPh)_3$ ligand [P2—Mn—P1 is 174.34 (7)° and the $^2J_{PMnP}$ coupling constant is 122 Hz].

The dimensions and angles of the $P_3N_3Cl_4$ ring (Table 2) are very close to those observed in both the free phosphazenylphosphine $N_3P_3Cl_4(C_6H_5)(PPh_2)$ and in the chromium complex $[\{N_3P_3Cl_4(C_6H_5)(PPh_2)\}Cr(CO)_5]$ (Allcock, Manners, Mang & Parvaez, 1990). The N_3P_3 phosphazene ring is approximately planar, the largest deviation from the least-squares plane being 0.123 (7) Å for the atom N3. The angle between this plane and and the plane of the bipyridine ligand is 68.3 (2)°. The bipyridine ligand is also planar with a maximum deviation from the ideal least-squares plane of −0.0336 (9) Å for atom C14. Also, as in the chromium analogue, the

P3—P2 bond length in the cationic manganese complex [2.245 (2) Å] is significantly longer than in the free phosphine [2.199 (2) Å]. This suggests that the effect of the $Cr(CO)_5$ fragment on the P3—P5 bond is nearly the same as that of the cationic $Mn(CO)_2(bipy)\{P(OPh)_3\}^+$ fragment.

Experimental

The phosphine $[N_3P_3Cl_4(C_6H_5)(PPh_2)]$ (Allcock, Manners, Mang & Parvaez, 1990) and the complex $[MnI(CO)_2(bipy)\{P(OPh)_3\}]$ (Carriedo, Crespo, Riera, Valín, Moreiras & Solans, 1986) were prepared following the published procedures. The title compound was prepared by stirring a mixture of the phosphine (0.1 g, 0.185 mmol) with the complex (0.09 g, 0.128 mmol) and $TlPF_6$ (0.1 g) in CH_2Cl_2 (15 ml) for 2.5 h at room temperature, filtering the resulting mixture, concentrating it *in vacuo* and adding diethyl ether to give a yellow precipitate (0.1 g, 60%). The product was crystallized from CH_2Cl_2/ether (slow diffusion). Relevant spectroscopic data: FTIR spectrum (cm^{-1}): ν(CO) absorptions (in CH_2Cl_2 solution), 1971(*s*), 1905(*s*); other bands (nujol mull), 1197(*vs*) [ν(PN), with shoulders of medium intensity corresponding to the $P(OPh)_3$ ligand], 952(*w*), 932(*m*), 907(*w*) [$P(OPh)_3$], 842(*vs*) [ν(PF) of PF_6^-]. ^{31}P NMR (in CH_2Cl_2, measured with reference to down-field external aqueous H_3PO_4): 18.0 (dd, $^2J_{PNP}$ = 16 Hz, $^3J_{PPNP}$ = 8 Hz, PCl_2); 31.9 [ddt, $^1J_{PP}$ = 85 Hz, $^2J_{PNP}$ = 16 Hz, $^3J_{PPMnP}$ = 8 Hz, P(Ph)], 50.3 (dd, $^1J_{PP}$ = 85 Hz, $^2J_{PMnP}$ = 122 Hz, the signal is too broad to see the $^3J_{PPNP}$ of 8 Hz, PPh_2), 154 [d, broad, $^2J_{PMnP}$ = 122 Hz, $P(OPh)_3$].

Crystal data

$[Mn(C_{18}H_{15}O_3P)(C_{10}H_8N_2)(C_{18}H_{15}Cl_4N_3P_4)(CO)_2]PF_6$
$M_r = 1261.39$
Triclinic
$P\bar{1}$
$a = 10.563\ (2)$ Å
$b = 10.603\ (3)$ Å
$c = 12.250\ (3)$ Å
$\alpha = 97.68\ (4)°$
$\beta = 99.34\ (3)°$
$\gamma = 93.11\ (2)°$
$V = 1337.6\ (5)$ Å^3
$Z = 1$
$D_x = 1.566$ Mg m^{-3}

Mo $K\alpha$ radiation
$\lambda = 0.71073$ Å
Cell parameters from 25 reflections
$\theta = 15–20°$
$\mu = 0.698$ mm^{-1}
$T = 293$ K
Prismatic plate
0.13 × 0.13 × 0.07 mm
Yellow

Data collection

Enraf–Nonius CAD-4 diffractometer
$\omega–2\theta$ scans
Absorption correction: semi-empirical (*DIFABS*; Walker & Stuart, 1983)
$T_{min} = 0.28$, $T_{max} = 0.31$
10 470 measured reflections
7302 independent reflections
5057 observed reflections [$I > 2\sigma(I)$]

$R_{int} = 0.050$
$\theta_{max} = 24.97°$
$h = -10 \rightarrow 12$
$k = -12 \rightarrow 12$
$l = -14 \rightarrow 14$
3 standard reflections monitored every 200 reflections
frequency: 60 min
intensity variation: 12.00%

Refinement

Refinement on F^2
$R(F) = 0.0442$
$wR(F^2) = 0.1082$
$S = 0.957$
7302 reflections
682 parameters
H atoms refined as riding with common isotropic U

$w = 1/[\sigma^2(F_o^2) + (0.0665P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.055$
$\Delta\rho_{max} = 0.68$ e Å^{-3}
$\Delta\rho_{min} = -0.30$ e Å^{-3}
Atomic scattering factors from *International Tables for Crystallography* (1992, Vol. C, Tables 4.2.6.8 and 6.1.1.4)

Table 1. *Fractional atomic coordinates and equivalent isotropic displacement parameters* (Å^2)

$$U_{eq} = (1/3)\Sigma_i\Sigma_j U_{ij}a_i^*a_j^*\mathbf{a}_i.\mathbf{a}_j.$$

	x	y	z	U_{eq}
Mn1	0.0000	0.0000	0.0000	0.0295 (2)
Cl1	−0.4009 (2)	−0.4136 (2)	−0.2245 (2)	0.0591 (5)
Cl2	−0.2239 (2)	−0.5486 (2)	−0.3713 (2)	0.0771 (7)
Cl3	−0.3004 (3)	−0.2937 (2)	−0.6486 (2)	0.0756 (7)
Cl4	−0.4416 (2)	−0.0979 (2)	−0.5158 (2)	0.0705 (6)
P1	0.0908 (2)	0.0135 (2)	0.1773 (2)	0.0373 (4)
P2	−0.0858 (2)	0.0050 (2)	−0.1897 (2)	0.0290 (4)
P3	−0.1010 (2)	−0.1726 (2)	−0.3148 (2)	0.0299 (4)
P4	−0.2821 (2)	−0.3748 (2)	−0.3271 (2)	0.0393 (4)
P5	−0.3084 (2)	−0.2227 (2)	−0.4901 (2)	0.0398 (4)
P6	−0.5638 (2)	−0.5400 (2)	−0.9677 (2)	0.0669 (6)
F1	−0.4183 (7)	−0.5677 (8)	−0.9821 (8)	0.155 (3)
F2	−0.6994 (6)	−0.5224 (8)	−0.946 (2)	0.203 (5)
F3	−0.5973 (8)	−0.6842 (7)	−0.989 (1)	0.169 (4)
F4	−0.5930 (9)	−0.552 (2)	−1.0960 (8)	0.190 (4)
F5	−0.521 (1)	−0.4030 (8)	−0.9504 (13)	0.235 (6)
F6	−0.520 (1)	−0.542 (2)	−0.8444 (8)	0.233 (6)
O1	0.2605 (5)	−0.0284 (5)	−0.0491 (5)	0.069 (2)
O2	0.0296 (5)	0.2814 (5)	0.0241 (5)	0.060 (2)
O3	0.2038 (5)	0.1263 (5)	0.2105 (4)	0.052 (2)
O4	0.0095 (5)	0.0287 (4)	0.2772 (4)	0.046 (2)
O5	0.1699 (5)	−0.1026 (5)	0.2091 (4)	0.056 (2)
N1	−0.1835 (5)	−0.0043 (5)	0.0354 (4)	0.029 (2)
N2	−0.0391 (5)	−0.1909 (4)	0.0028 (4)	0.035 (2)
N3	−0.1656 (5)	−0.2856 (5)	−0.2601 (5)	0.036 (2)
N4	−0.3641 (6)	−0.3313 (6)	−0.4320 (5)	0.050 (2)
N5	−0.1757 (5)	−0.1483 (5)	−0.4326 (5)	0.040 (2)
C1	0.1590 (7)	−0.0146 (6)	−0.0316 (6)	0.037 (2)
C2	0.0189 (6)	0.1727 (7)	0.0131 (5)	0.035 (2)
C12	−0.2360 (6)	−0.1209 (7)	0.0464 (6)	0.044 (2)
C13	−0.3598 (7)	−0.1367 (8)	0.0713 (7)	0.054 (2)
C14	−0.4305 (7)	−0.0337 (9)	0.0807 (7)	0.061 (2)
C15	−0.3798 (7)	0.0855 (8)	0.0708 (6)	0.049 (2)
C16	−0.2548 (6)	0.0955 (7)	0.0490 (5)	0.039 (2)
C22	−0.1533 (7)	−0.2281 (6)	0.0289 (6)	0.042 (2)
C23	−0.1885 (8)	−0.3503 (7)	0.0377 (8)	0.059 (2)
C24	−0.1024 (9)	−0.4425 (8)	0.0228 (8)	0.070 (2)
C25	0.0136 (9)	−0.4092 (7)	−0.0029 (7)	0.061 (2)
C26	0.0442 (7)	−0.2827 (7)	−0.0111 (6)	0.049 (2)
C31	0.2781 (6)	0.1700 (7)	0.3148 (6)	0.047 (2)
C32	0.3497 (7)	0.2833 (7)	0.3180 (7)	0.053 (2)
C33	0.4257 (8)	0.3347 (8)	0.4163 (8)	0.068 (2)
C34	0.4355 (8)	0.2757 (9)	0.5110 (8)	0.067 (2)
C35	0.3622 (9)	0.1629 (9)	0.5024 (7)	0.066 (2)
C36	0.2841 (8)	0.1107 (8)	0.4073 (6)	0.063 (2)
C41	−0.0797 (7)	0.1206 (7)	0.2916 (6)	0.046 (2)
C42	−0.0562 (7)	0.2442 (7)	0.2725 (6)	0.049 (2)
C43	−0.1499 (9)	0.3265 (7)	0.2878 (6)	0.056 (2)
C44	−0.261 (1)	0.2914 (9)	0.3220 (7)	0.069 (2)
C45	−0.2809 (8)	0.1674 (9)	0.3437 (7)	0.064 (2)
C46	−0.1910 (7)	0.0804 (7)	0.3287 (6)	0.051 (2)
C51	0.1579 (7)	−0.2105 (6)	0.2613 (5)	0.043 (2)
C52	0.2609 (9)	−0.2807 (8)	0.2678 (8)	0.075 (3)
C53	0.260 (2)	−0.388 (1)	0.319 (2)	0.103 (4)

C54	0.151 (2)	−0.4236 (9)	0.3609 (9)	0.093 (3)
C55	0.0486 (9)	−0.3518 (8)	0.3561 (8)	0.073 (3)
C56	0.0511 (8)	−0.2443 (7)	0.3044 (8)	0.064 (2)
C61	−0.2531 (6)	0.0461 (6)	−0.2080 (5)	0.032 (2)
C62	−0.3509 (6)	−0.0415 (7)	−0.2045 (5)	0.040 (2)
C63	−0.4779 (7)	−0.0079 (9)	−0.2029 (6)	0.057 (2)
C64	−0.4983 (8)	0.118 (2)	−0.2022 (7)	0.069 (3)
C65	−0.4033 (9)	0.2075 (9)	−0.2059 (7)	0.066 (2)
C66	−0.2812 (7)	0.1734 (7)	−0.2091 (6)	0.045 (2)
C71	−0.0081 (6)	0.1185 (6)	−0.2636 (5)	0.031 (2)
C72	−0.0666 (7)	0.1461 (6)	−0.3651 (6)	0.042 (2)
C73	−0.0110 (8)	0.2333 (7)	−0.4209 (6)	0.049 (2)
C74	0.1086 (8)	0.2957 (7)	−0.3725 (7)	0.056 (2)
C75	0.1695 (7)	0.2703 (7)	−0.2728 (7)	0.056 (2)
C76	0.1127 (7)	0.1825 (7)	−0.2157 (6)	0.045 (2)
C81	0.0608 (6)	−0.2053 (6)	−0.3295 (6)	0.033 (2)
C82	0.1279 (7)	−0.1356 (7)	−0.3911 (6)	0.045 (2)
C83	0.2509 (7)	−0.1675 (8)	−0.4045 (7)	0.059 (2)
C84	0.3022 (7)	−0.2665 (8)	−0.3614 (7)	0.060 (2)
C85	0.2386 (7)	−0.3369 (7)	−0.2979 (7)	0.055 (2)
C86	0.1148 (7)	−0.3060 (7)	−0.2831 (7)	0.053 (2)

Table 2. *Selected geometric parameters* (Å, °)

Mn1—C1	1.793 (7)	P1—O4	1.603 (5)
Mn1—C2	1.814 (7)	P1—O3	1.606 (5)
Mn1—N2	2.050 (5)	P2—P3	2.245 (2)
Mn1—N1	2.053 (5)	P3—N5	1.588 (6)
Mn1—P1	2.210 (2)	P3—N3	1.621 (5)
Mn1—P2	2.362 (2)	P4—N3	1.556 (5)
Cl1—P4	1.979 (3)	P4—N4	1.566 (7)
Cl2—P4	2.008 (2)	P5—N4	1.569 (6)
Cl3—P5	2.004 (3)	P5—N5	1.579 (6)
Cl4—P5	2.000 (3)	O1—C1	1.141 (7)
P1—O5	1.581 (5)	O2—C2	1.139 (7)
C2—Mn1—N2	171.4 (3)	O4—P1—Mn1	122.4 (2)
C1—Mn1—N1	173.8 (3)	O3—P1—Mn1	111.3 (2)
C1—Mn1—P1	86.2 (2)	P3—P2—Mn1	120.1 (1)
C2—Mn1—P1	88.9 (2)	N5—P3—N3	115.5 (3)
N2—Mn1—P1	87.2 (2)	N3—P4—N4	119.2 (3)
N1—Mn1—P1	93.6 (2)	Cl1—P4—Cl2	101.0 (2)
C1—Mn1—P2	91.5 (2)	N4—P5—N5	118.5 (3)
C2—Mn1—P2	86.0 (2)	Cl4—P5—Cl3	100.0 (2)
N2—Mn1—P2	98.2 (2)	P4—N3—P3	121.1 (3)
N1—Mn1—P2	89.2 (2)	P4—N4—P5	120.3 (4)
P1—Mn1—P2	174.3 (1)	P5—N5—P3	122.8 (3)
O5—P1—Mn1	115.8 (2)		
N2—Mn1—P2—P3	−24.5 (2)	Mn1—P2—P3—N3	47.7 (2)
N1—Mn1—P2—P3	−102.6 (2)		

Data were collected (Enraf–Nonius, 1989) with profile analysis over all reflections (Lehmann & Larsen, 1974; Grant & Gabe, 1978). Friedel pairs were measured from 0 to 20° (θ). Standard drift corrections were applied. Cell refinement was performed using *DIRDIF CRYSDA* (Beurskens *et al.*, 1992). *DATAR* (Van der Maelen Uría, 1991) was used for data reduction. The structure was completed by the *DIRDIF* phase-expansion procedure. Isotropic least-squares refinement used a local version of *SHELX*76 (Sheldrick, 1976; Van der Maelen Uría, 1991). Final refinement used *SHELXL*93 (Sheldrick, 1993). The absolute configuration was checked with a new version of the *BIJVOET* program (Beurskens, Noordik & Beurskens, 1980) giving a Bijvoet coefficient of 0.933 (2) for the strongest 100 Friedel pairs. Further geometrical calculations were made with *PARST* (Nardelli, 1983) and Fig. 1 was produced using the *EUCLID* package (Spek, 1982).

We thank the Spanish DGICYT for support (project PB91-0664).

Lists of structure factors, anisotropic displacement parameters, H-atom coordinates, complete geometry and hydrogen-bonding geometry have been deposited with the IUCr (Reference: HR1019). Copies may be obtained through The Managing Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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Acta Cryst. (1995). C**51**, 23–26

$[MoH_4(dppe)_2]$.thf (dppe = $Ph_2PCH_2CH_2PPh_2$; thf = Tetrahydrofuran)

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(*Received* 19 *May* 1994; *accepted* 28 *June* 1994)

Abstract

The structure of tetrahydridobis[1,2-bis(diphenylphosphino)ethane-*P*,*P*′]molybdenum(IV), $[MoH_4(dppe)_2]$ (dppe = $Ph_2PCH_2CH_2PPh_2$), is reported as

Acta Crystallographica Section C
ISSN 0108-2701 © 1995