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Tetracarbonyl[bis(diphenylphosphanyl)-tetramethyldisiloxane-κ^2P,P']-chromium(0)

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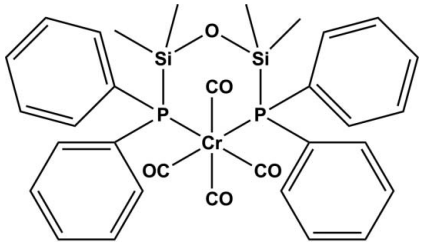
Key indicators: single-crystal X-ray study; T = 150 K; mean σ(C–C) = 0.003 Å; R factor = 0.035; wR factor = 0.059; data-to-parameter ratio = 17.2.

The title compound, $[Cr(C_{28}H_{32}OP_2Si_2)(CO)_4]$, was obtained by the ligand-exchange reaction of $Cr(CO)_6$ with $(Ph_2PSiMe_2)_2O$ in refluxing toluene. The CrC_4P_2 coordination geometry is distorted octahedral, with a P—Cr—P bite angle of 99.22 (4)°.

Related literature

For the synthesis of $(Ph_2PSiMe_2)_2O$, using $(SiMe_2Cl)_2O$ instead of $SiMe_2Cl_2$, see: Hassler & Seidl (1988). For the structures of complexes of group III metals with $(H_2PSi^iPr_2)_2O$, see: von Hänisch & Stahl (2006, 2007), and for group II metals, see: Kopecky *et al.* (2010). For the structure of a chromium complex with a silicon-bridged bisphosphine, see: Peulecke *et al.* (2010).



Experimental

Crystal data

$[Cr(C_{28}H_{32}OP_2Si_2)(CO)_4]$
M_r = 666.70
Monoclinic, *Cc*
a = 9.2722 (5) Å
b = 21.4148 (15) Å
c = 16.5695 (8) Å
β = 95.200 (4)°
V = 3276.5 (3) Å^3
Z = 4
Mo $K\alpha$ radiation
μ = 0.56 mm^{-1}
T = 150 K
0.30 × 0.21 × 0.12 mm

Data collection

Stoe IPDS II diffractometer
Absorption correction: numerical (*X-SHAPE* and *X-RED32*; Stoe & Cie, 2005)
T_{min} = 0.830, T_{max} = 0.952
21143 measured reflections
5756 independent reflections
4303 reflections with $I > 2\sigma(I)$
R_{int} = 0.071

Refinement

$R[F^2 > 2\sigma(F^2)]$ = 0.035
$wR(F^2)$ = 0.059
S = 0.79
5756 reflections
335 parameters
2 restraints
H-atom parameters constrained
$\Delta\rho_{max}$ = 0.32 e Å^{-3}
$\Delta\rho_{min}$ = −0.20 e Å^{-3}
Absolute structure: Flack (1983), 2799 Friedel pairs
Flack parameter: −0.021 (19)

Data collection: *X-AREA* (Stoe & Cie, 2005); cell refinement: *X-AREA*; data reduction: *X-AREA*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *XP* in *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXL97*.

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Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: YK2038).

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supporting information

Acta Cryst. (2012). E**68**, m119 [doi:10.1107/S1600536812000219]

Tetracarbonyl[bis(diphenylphosphanyl)tetramethyldisiloxane-κ^2P,P']chromium(0)

Normen Peulecke, Bernd H. Müller, Anke Spannenberg and Uwe Rosenthal

S1. Comment

Diphosphines (like diphenylphosphanylpropane) are widely used as chelating ligands for the complex formation. Among them the siloxane-bridged ligands and their complexes with transition metals are not known. The few examples were made for $(H_2PSi^iPr_2)_2O$ coordinated with Al, Ga or In yielding polycyclic structures (von Hänisch *et al.*, 2006, 2007) or with Mg, Ca, Sr or Ba yielding only in the case of Mg a monomeric structure (Kopecky *et al.*, 2010). During our studies on the selective oligomerization of ethene *via* transition metal-catalyzed tri- or tetramerization we became interested in chromium complexes with ligands of this class (*e.g.* $(Ph_2P)_2SiMe_2$: Peulecke *et al.*, 2010). In the present publication, we report the preparation and crystal structure of $C_{32}H_{32}CrO_5P_2Si_2$, which was observed to be the single product of a reaction of $(Ph_2PSiMe_2)_2O$ with $Cr(CO)_6$. The coordination geometry at the chromium centre is distorted octahedral. The observed bite-angle P—Cr—P is 99.22 (4)°.

S2. Experimental

$Cr(CO)_6$ (175 mg, 0.8 mmol) was added to a solution of $(Ph_2PSiMe_2)_2O$ (321 mg, 0.75 mmol) in 20 ml toluene and the resulting mixture was stirred at reflux temperature for 72 h. Subsequently, the formed yellow solution was cooled down to 0°C and filtered. Toluene was removed and the product was extracted with dichloromethane. The major part of dichloromethane was removed and the remaining solution was over-layered with *n*-hexane to get single crystals of the title compound, which were suitable for X-ray crystal structure analysis. The pale yellow compound was fully characterized by standard analytical methods, ^{31}P-NMR: (CD_2Cl_2): 5,9 p.p.m..

S3. Refinement

H atoms were placed in idealized positions with d(C—H) = 0.95 Å (CH) and 0.98 Å (CH_3) and refined using a riding model with U_{iso}(H) fixed at 1.2 U_{eq}(C) for CH and 1.5 U_{eq}(C) for CH_3.

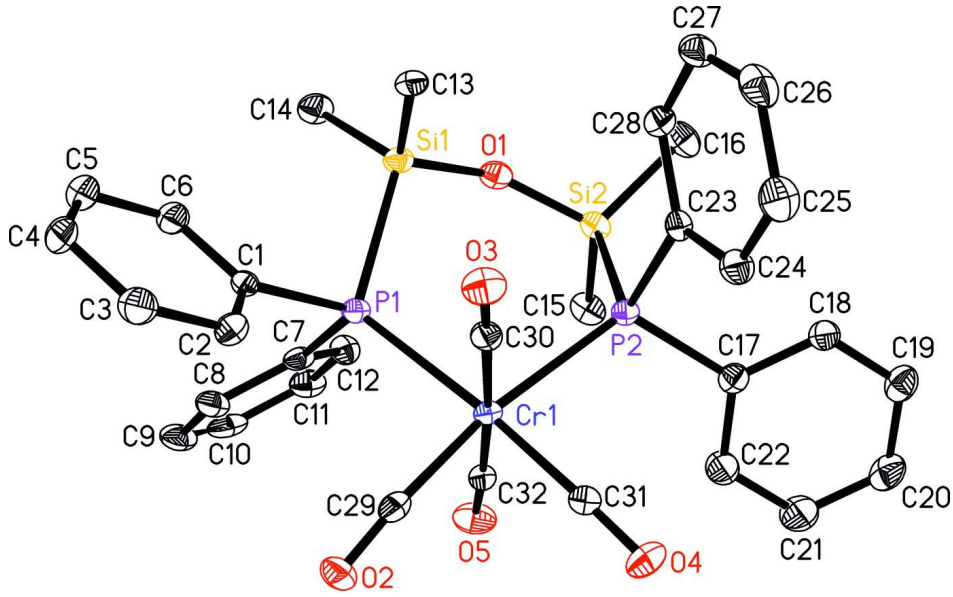

Figure 1

The molecular structure of the title compound with atom labels and 30% displacement ellipsoids. Hydrogen atoms are omitted for clarity.

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Crystal data

$[Cr(C_{28}H_{32}OP_2Si_2)(CO)_4]$
$M_r = 666.70$
Monoclinic, *Cc*
Hall symbol: C -2yc
$a = 9.2722\ (5)$ Å
$b = 21.4148\ (15)$ Å
$c = 16.5695\ (8)$ Å
$\beta = 95.200\ (4)°$
$V = 3276.5\ (3)$ Å^3
$Z = 4$
$F(000) = 1384$
$D_x = 1.352$ Mg m^{-3}
Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
Cell parameters from 4413 reflections
$\theta = 1.9–28.3°$
$\mu = 0.56$ mm^{-1}
$T = 150$ K
Prism, yellow
0.30 × 0.21 × 0.12 mm

Data collection

Stoe IPDS II diffractometer
Radiation source: fine-focus sealed tube
Graphite monochromator
ω scans
Absorption correction: numerical (*X-SHAPE* and *X-RED32*; Stoe & Cie, 2005)
$T_{min} = 0.830$, $T_{max} = 0.952$
21143 measured reflections
5756 independent reflections
4303 reflections with $I > 2\sigma(I)$
$R_{int} = 0.071$
$\theta_{max} = 25.3°$, $\theta_{min} = 1.9°$
$h = -11\rightarrow11$
$k = -25\rightarrow25$
$l = -19\rightarrow19$

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.035$
$wR(F^2) = 0.059$
$S = 0.79$
5756 reflections
335 parameters
2 restraints
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map

Hydrogen site location: inferred from neighbouring sites
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0178P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max} = 0.32$ e Å^{-3}
$\Delta\rho_{min} = -0.20$ e Å^{-3}
Absolute structure: Flack (1983), **2799 Friedel pairs**
Absolute structure parameter: −0.021 (19)

Special details

Geometry. All s.u.'s (except the s.u. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell s.u.'s are taken into account individually in the estimation of s.u.'s in distances, angles and torsion angles; correlations between s.u.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell s.u.'s is used for estimating s.u.'s involving l.s. planes.

Refinement. Refinement of F^2 against ALL reflections. The weighted *R*-factor *wR* and goodness of fit *S* are based on F^2, conventional *R*-factors *R* are based on *F*, with *F* set to zero for negative F^2. The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating *R*-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. *R*-factors based on F^2 are statistically about twice as large as those based on *F*, and *R*- factors based on ALL data will be even larger.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	x	*y*	*z*	U_{iso}*/U_{eq}
C1	0.7971 (2)	0.47102 (10)	0.89997 (14)	0.0260 (8)
C2	0.9455 (2)	0.46252 (10)	0.91594 (14)	0.0323 (9)
H2	0.9816	0.4315	0.9534	0.039*
C3	1.04124 (19)	0.49949 (13)	0.87708 (16)	0.0404 (11)
H3	1.1427	0.4937	0.8880	0.048*
C4	0.9885 (3)	0.54495 (12)	0.82225 (15)	0.0464 (12)
H4	1.0539	0.5702	0.7957	0.056*
C5	0.8400 (3)	0.55345 (11)	0.80628 (14)	0.0445 (11)
H5	0.8039	0.5845	0.7688	0.053*
C6	0.7443 (2)	0.51649 (12)	0.84514 (15)	0.0358 (10)
H6	0.6428	0.5223	0.8342	0.043*
C7	0.5653 (2)	0.48049 (10)	1.00308 (14)	0.0284 (9)
C8	0.6274 (2)	0.53733 (11)	1.02723 (14)	0.0339 (9)
H8	0.7233	0.5468	1.0154	0.041*
C9	0.5493 (3)	0.58024 (9)	1.06870 (15)	0.0424 (10)
H9	0.5917	0.6191	1.0852	0.051*
C10	0.4089 (3)	0.56631 (11)	1.08601 (15)	0.0433 (12)
H10	0.3555	0.5956	1.1144	0.052*
C11	0.3468 (2)	0.50947 (13)	1.06186 (16)	0.0407 (11)
H11	0.2509	0.4999	1.0737	0.049*
C12	0.4249 (2)	0.46656 (10)	1.02039 (16)	0.0330 (9)
H12	0.3825	0.4277	1.0039	0.040*
C13	0.6284 (4)	0.36230 (18)	0.7687 (2)	0.0311 (9)
H13A	0.5700	0.3395	0.7261	0.047*
H13B	0.6998	0.3340	0.7963	0.047*
H13C	0.6784	0.3969	0.7445	0.047*
C14	0.3937 (4)	0.45715 (19)	0.7988 (2)	0.0378 (10)
H14A	0.3678	0.4848	0.8424	0.057*
H14B	0.3055	0.4396	0.7706	0.057*

H14C	0.4463	0.4810	0.7604	0.057*
C15	0.2877 (4)	0.3024 (2)	1.0248 (3)	0.0391 (10)
H15A	0.2035	0.3285	1.0080	0.059*
H15B	0.3546	0.3257	1.0628	0.059*
H15C	0.2557	0.2645	1.0512	0.059*
C16	0.2766 (4)	0.2188 (2)	0.8767 (3)	0.0420 (11)
H16A	0.3063	0.2172	0.8215	0.063*
H16B	0.1730	0.2283	0.8748	0.063*
H16C	0.2956	0.1784	0.9033	0.063*
C17	0.5663 (3)	0.19242 (10)	1.05885 (13)	0.0303 (9)
C18	0.5334 (3)	0.13181 (12)	1.03342 (11)	0.0312 (9)
H18	0.5345	0.1210	0.9779	0.037*
C19	0.4989 (3)	0.08701 (9)	1.08926 (16)	0.0406 (11)
H19	0.4764	0.0456	1.0719	0.049*
C20	0.4973 (3)	0.10283 (12)	1.17053 (14)	0.0457 (11)
H20	0.4737	0.0722	1.2087	0.055*
C21	0.5302 (3)	0.16344 (14)	1.19597 (11)	0.0542 (12)
H21	0.5291	0.1742	1.2515	0.065*
C22	0.5646 (3)	0.20824 (10)	1.14013 (15)	0.0443 (11)
H22	0.5871	0.2497	1.1575	0.053*
C23	0.6851 (2)	0.20647 (11)	0.90486 (12)	0.0255 (9)
C24	0.8044 (2)	0.16907 (12)	0.92776 (11)	0.0345 (9)
H24	0.8388	0.1655	0.9833	0.041*
C25	0.8732 (2)	0.13685 (11)	0.86935 (16)	0.0436 (11)
H25	0.9547	0.1113	0.8850	0.052*
C26	0.8228 (3)	0.14204 (12)	0.78803 (14)	0.0438 (11)
H26	0.8698	0.1200	0.7481	0.053*
C27	0.7035 (3)	0.17944 (12)	0.76513 (10)	0.0371 (10)
H27	0.6691	0.1830	0.7096	0.045*
C28	0.6347 (2)	0.21165 (11)	0.82354 (13)	0.0310 (9)
H28	0.5532	0.2372	0.8079	0.037*
C29	0.9060 (4)	0.39081 (19)	1.0826 (2)	0.0300 (9)
C30	0.8865 (4)	0.31736 (18)	0.9509 (2)	0.0273 (9)
C31	0.8607 (4)	0.27757 (19)	1.0996 (2)	0.0337 (9)
C32	0.6494 (4)	0.36119 (18)	1.1135 (2)	0.0284 (9)
Cr1	0.76936 (6)	0.33701 (3)	1.03423 (4)	0.02284 (14)
O1	0.4032 (2)	0.34064 (12)	0.87633 (15)	0.0311 (6)
O2	0.9939 (3)	0.42194 (14)	1.11716 (16)	0.0440 (8)
O3	0.9613 (3)	0.30592 (13)	0.90084 (16)	0.0384 (7)
O4	0.9272 (3)	0.24106 (14)	1.14056 (18)	0.0548 (9)
O5	0.5824 (3)	0.37908 (14)	1.16462 (17)	0.0469 (8)
P1	0.66695 (9)	0.42154 (5)	0.95043 (6)	0.0236 (2)
P2	0.60852 (10)	0.25311 (5)	0.98419 (6)	0.0247 (2)
Si1	0.50981 (10)	0.39322 (5)	0.84235 (6)	0.0283 (3)
Si2	0.38082 (10)	0.28057 (5)	0.93478 (6)	0.0288 (3)

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
C1	0.038 (2)	0.021 (2)	0.019 (2)	0.0002 (17)	0.0021 (16)	−0.0045 (16)
C2	0.036 (2)	0.035 (3)	0.026 (2)	−0.0021 (19)	0.0065 (17)	0.0034 (19)
C3	0.038 (2)	0.049 (3)	0.035 (3)	−0.009 (2)	0.0054 (19)	−0.002 (2)
C4	0.069 (3)	0.043 (3)	0.029 (2)	−0.021 (2)	0.015 (2)	0.004 (2)
C5	0.063 (3)	0.033 (3)	0.036 (3)	−0.004 (2)	−0.003 (2)	0.007 (2)
C6	0.044 (2)	0.030 (2)	0.032 (2)	0.003 (2)	−0.0028 (19)	0.0019 (19)
C7	0.033 (2)	0.031 (2)	0.020 (2)	0.0103 (18)	−0.0037 (16)	0.0010 (17)
C8	0.038 (2)	0.035 (2)	0.027 (2)	0.0046 (19)	−0.0038 (17)	−0.0067 (19)
C9	0.056 (3)	0.041 (3)	0.029 (2)	0.009 (2)	−0.004 (2)	−0.012 (2)
C10	0.059 (3)	0.051 (3)	0.019 (2)	0.029 (2)	−0.001 (2)	−0.003 (2)
C11	0.040 (2)	0.051 (3)	0.031 (2)	0.010 (2)	0.0019 (19)	−0.003 (2)
C12	0.036 (2)	0.032 (2)	0.032 (2)	0.0053 (18)	0.0060 (18)	−0.0047 (19)
C13	0.037 (2)	0.034 (2)	0.021 (2)	0.0009 (18)	−0.0046 (17)	0.0011 (17)
C14	0.032 (2)	0.043 (3)	0.036 (2)	0.0092 (19)	−0.0067 (18)	0.001 (2)
C15	0.027 (2)	0.048 (3)	0.043 (3)	−0.003 (2)	0.0073 (18)	−0.009 (2)
C16	0.028 (2)	0.043 (3)	0.055 (3)	−0.004 (2)	0.0000 (19)	−0.012 (2)
C17	0.027 (2)	0.032 (2)	0.031 (2)	−0.0007 (18)	0.0014 (17)	0.0025 (18)
C18	0.030 (2)	0.034 (2)	0.029 (2)	−0.0039 (18)	0.0021 (17)	0.0017 (18)
C19	0.034 (2)	0.041 (3)	0.047 (3)	−0.004 (2)	0.0019 (19)	0.011 (2)
C20	0.041 (2)	0.051 (3)	0.045 (3)	−0.014 (2)	0.006 (2)	0.018 (2)
C21	0.074 (3)	0.057 (3)	0.033 (3)	−0.012 (3)	0.014 (2)	0.005 (2)
C22	0.061 (3)	0.041 (3)	0.032 (3)	−0.012 (2)	0.011 (2)	−0.001 (2)
C23	0.026 (2)	0.022 (2)	0.029 (2)	−0.0021 (16)	0.0024 (16)	−0.0007 (16)
C24	0.038 (2)	0.032 (2)	0.034 (2)	0.0066 (19)	0.0033 (17)	−0.0038 (19)
C25	0.039 (2)	0.040 (3)	0.052 (3)	0.010 (2)	0.009 (2)	−0.004 (2)
C26	0.049 (3)	0.039 (3)	0.047 (3)	−0.004 (2)	0.024 (2)	−0.012 (2)
C27	0.046 (2)	0.038 (3)	0.028 (2)	−0.002 (2)	0.0095 (19)	−0.0052 (19)
C28	0.035 (2)	0.031 (2)	0.027 (2)	−0.0007 (18)	0.0044 (17)	0.0023 (18)
C29	0.035 (2)	0.032 (2)	0.023 (2)	0.004 (2)	0.0045 (17)	0.0058 (18)
C30	0.025 (2)	0.026 (2)	0.030 (2)	0.0028 (17)	−0.0065 (18)	0.0000 (18)
C31	0.042 (2)	0.032 (2)	0.026 (2)	−0.003 (2)	−0.0026 (18)	−0.001 (2)
C32	0.032 (2)	0.027 (2)	0.025 (2)	−0.0029 (19)	−0.0030 (19)	0.0018 (18)
Cr1	0.0245 (3)	0.0260 (3)	0.0177 (3)	0.0008 (3)	0.0004 (2)	0.0006 (3)
O1	0.0225 (13)	0.0387 (16)	0.0310 (15)	0.0027 (13)	−0.0036 (11)	−0.0031 (13)
O2	0.0440 (17)	0.0467 (19)	0.0393 (18)	−0.0202 (15)	−0.0076 (14)	−0.0015 (15)
O3	0.0333 (15)	0.0500 (19)	0.0332 (17)	0.0070 (13)	0.0097 (13)	−0.0023 (14)
O4	0.066 (2)	0.047 (2)	0.047 (2)	0.0058 (16)	−0.0199 (16)	0.0163 (16)
O5	0.0479 (18)	0.067 (2)	0.0275 (17)	0.0013 (16)	0.0121 (14)	−0.0112 (16)
P1	0.0252 (5)	0.0252 (5)	0.0201 (5)	0.0034 (5)	0.0005 (4)	−0.0011 (4)
P2	0.0271 (5)	0.0257 (5)	0.0213 (5)	−0.0002 (5)	0.0032 (4)	−0.0007 (4)
Si1	0.0296 (6)	0.0309 (6)	0.0234 (6)	0.0046 (5)	−0.0030 (5)	−0.0015 (5)
Si2	0.0241 (5)	0.0326 (6)	0.0298 (6)	0.0001 (5)	0.0023 (5)	−0.0048 (5)

Geometric parameters (Å, º)

C1—C2	1.3900	C16—H16C	0.9800
C1—C6	1.3900	C17—C18	1.3900
C1—P1	1.860 (2)	C17—C22	1.3900
C2—C3	1.3900	C17—P2	1.860 (2)
C2—H2	0.9500	C18—C19	1.3900
C3—C4	1.3900	C18—H18	0.9500
C3—H3	0.9500	C19—C20	1.3900
C4—C5	1.3900	C19—H19	0.9500
C4—H4	0.9500	C20—C21	1.3900
C5—C6	1.3900	C20—H20	0.9500
C5—H5	0.9500	C21—C22	1.3900
C6—H6	0.9500	C21—H21	0.9500
C7—C8	1.3900	C22—H22	0.9500
C7—C12	1.3900	C23—C24	1.3900
C7—P1	1.8419 (19)	C23—C28	1.3900
C8—C9	1.3900	C23—P2	1.8437 (19)
C8—H8	0.9500	C24—C25	1.3900
C9—C10	1.3900	C24—H24	0.9500
C9—H9	0.9500	C25—C26	1.3900
C10—C11	1.3900	C25—H25	0.9500
C10—H10	0.9500	C26—C27	1.3900
C11—C12	1.3900	C26—H26	0.9500
C11—H11	0.9500	C27—C28	1.3900
C12—H12	0.9500	C27—H27	0.9500
C13—Si1	1.838 (4)	C28—H28	0.9500
C13—H13A	0.9800	C29—O2	1.163 (4)
C13—H13B	0.9800	C29—Cr1	1.841 (4)
C13—H13C	0.9800	C30—O3	1.155 (4)
C14—Si1	1.847 (4)	C30—Cr1	1.881 (4)
C14—H14A	0.9800	C31—O4	1.173 (4)
C14—H14B	0.9800	C31—Cr1	1.829 (4)
C14—H14C	0.9800	C32—O5	1.161 (4)
C15—Si2	1.849 (4)	C32—Cr1	1.869 (4)
C15—H15A	0.9800	Cr1—P1	2.4223 (11)
C15—H15B	0.9800	Cr1—P2	2.4322 (11)
C15—H15C	0.9800	O1—Si1	1.632 (3)
C16—Si2	1.854 (4)	O1—Si2	1.635 (3)
C16—H16A	0.9800	P1—Si1	2.2856 (13)
C16—H16B	0.9800	P2—Si2	2.2716 (13)
C2—C1—C6	120.0	C21—C20—H20	120.0
C2—C1—P1	120.76 (14)	C19—C20—H20	120.0
C6—C1—P1	119.24 (14)	C20—C21—C22	120.0
C1—C2—C3	120.0	C20—C21—H21	120.0
C1—C2—H2	120.0	C22—C21—H21	120.0
C3—C2—H2	120.0	C21—C22—C17	120.0

C4—C3—C2	120.0	C21—C22—H22	120.0
C4—C3—H3	120.0	C17—C22—H22	120.0
C2—C3—H3	120.0	C24—C23—C28	120.0
C3—C4—C5	120.0	C24—C23—P2	117.76 (13)
C3—C4—H4	120.0	C28—C23—P2	122.03 (13)
C5—C4—H4	120.0	C23—C24—C25	120.0
C6—C5—C4	120.0	C23—C24—H24	120.0
C6—C5—H5	120.0	C25—C24—H24	120.0
C4—C5—H5	120.0	C24—C25—C26	120.0
C5—C6—C1	120.0	C24—C25—H25	120.0
C5—C6—H6	120.0	C26—C25—H25	120.0
C1—C6—H6	120.0	C27—C26—C25	120.0
C8—C7—C12	120.0	C27—C26—H26	120.0
C8—C7—P1	121.32 (14)	C25—C26—H26	120.0
C12—C7—P1	118.66 (14)	C26—C27—C28	120.0
C7—C8—C9	120.0	C26—C27—H27	120.0
C7—C8—H8	120.0	C28—C27—H27	120.0
C9—C8—H8	120.0	C27—C28—C23	120.0
C10—C9—C8	120.0	C27—C28—H28	120.0
C10—C9—H9	120.0	C23—C28—H28	120.0
C8—C9—H9	120.0	O2—C29—Cr1	175.5 (3)
C9—C10—C11	120.0	O3—C30—Cr1	178.3 (3)
C9—C10—H10	120.0	O4—C31—Cr1	175.9 (4)
C11—C10—H10	120.0	O5—C32—Cr1	175.3 (3)
C12—C11—C10	120.0	C31—Cr1—C29	85.09 (17)
C12—C11—H11	120.0	C31—Cr1—C32	92.86 (17)
C10—C11—H11	120.0	C29—Cr1—C32	87.19 (16)
C11—C12—C7	120.0	C31—Cr1—C30	90.68 (17)
C11—C12—H12	120.0	C29—Cr1—C30	92.24 (16)
C7—C12—H12	120.0	C32—Cr1—C30	176.35 (18)
Si1—C13—H13A	109.5	C31—Cr1—P1	174.94 (13)
Si1—C13—H13B	109.5	C29—Cr1—P1	90.02 (12)
H13A—C13—H13B	109.5	C32—Cr1—P1	88.19 (12)
Si1—C13—H13C	109.5	C30—Cr1—P1	88.20 (12)
H13A—C13—H13C	109.5	C31—Cr1—P2	85.67 (13)
H13B—C13—H13C	109.5	C29—Cr1—P2	170.75 (12)
Si1—C14—H14A	109.5	C32—Cr1—P2	93.36 (12)
Si1—C14—H14B	109.5	C30—Cr1—P2	87.78 (12)
H14A—C14—H14B	109.5	P1—Cr1—P2	99.22 (4)
Si1—C14—H14C	109.5	Si1—O1—Si2	149.42 (16)
H14A—C14—H14C	109.5	C7—P1—C1	101.72 (12)
H14B—C14—H14C	109.5	C7—P1—Si1	103.63 (9)
Si2—C15—H15A	109.5	C1—P1—Si1	101.09 (9)
Si2—C15—H15B	109.5	C7—P1—Cr1	115.56 (9)
H15A—C15—H15B	109.5	C1—P1—Cr1	116.54 (8)
Si2—C15—H15C	109.5	Si1—P1—Cr1	116.09 (5)
H15A—C15—H15C	109.5	C23—P2—C17	102.33 (12)
H15B—C15—H15C	109.5	C23—P2—Si2	106.78 (9)

Si2—C16—H16A	109.5	C17—P2—Si2	100.11 (9)
Si2—C16—H16B	109.5	C23—P2—Cr1	112.29 (9)
H16A—C16—H16B	109.5	C17—P2—Cr1	116.68 (9)
Si2—C16—H16C	109.5	Si2—P2—Cr1	116.92 (5)
H16A—C16—H16C	109.5	O1—Si1—C13	113.43 (16)
H16B—C16—H16C	109.5	O1—Si1—C14	107.24 (16)
C18—C17—C22	120.0	C13—Si1—C14	111.74 (18)
C18—C17—P2	120.29 (14)	O1—Si1—P1	106.01 (10)
C22—C17—P2	119.69 (14)	C13—Si1—P1	103.80 (12)
C19—C18—C17	120.0	C14—Si1—P1	114.63 (14)
C19—C18—H18	120.0	O1—Si2—C15	111.88 (17)
C17—C18—H18	120.0	O1—Si2—C16	110.00 (17)
C18—C19—C20	120.0	C15—Si2—C16	109.82 (19)
C18—C19—H19	120.0	O1—Si2—P2	104.67 (10)
C20—C19—H19	120.0	C15—Si2—P2	105.15 (14)
C21—C20—C19	120.0	C16—Si2—P2	115.21 (14)