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Inorganica Chimica Acta 342 (2003) 236–240
Inorganica Chimica Acta
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Transition metal complexes containing $P(C_6H_5)(C_6H_4Cl\text{-}2)_2$. The effect of added Lewis bases as a probe for substitution reactions occurring in ambient temperature Suzuki couplings catalyzed by Pd/$P(C_6H_5)(C_6H_4Cl\text{-}2)_2$

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Received 30 March 2002; accepted 21 May 2002

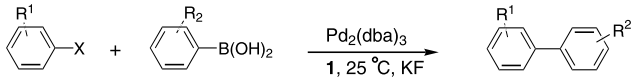
Abstract

The reactivity of the d^8 transition metal complexes, $[NiBr_2(CH_3OCH_2CH_2OCH_3)]$ and MCl_2L_2 (M = Pd, Pt; L = CH_3CN; L_2 = 1,5-cyclooctadiene), towards $P(C_6H_5)(C_6H_4Cl\text{-}2)_2$ (**1**) was investigated. While treatment of $[PdCl_2(cod)]$ with 2 equiv of **1** resulted in displacement of the weakly coordinating cyclooctadiene and formation of $[PdCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$, analogous reactions with $[PtCl_2(cod)]$ afforded the monosubstituted species $[PtCl_2(cod)(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)]$. The disubstituted complex $[PtCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$ was successfully obtained by treatment of $[PtCl_2(NCCH_3)_2]$ with 2 equiv of **1**. However, attempts to react **1** with $[NiBr_2(CH_3OCH_2CH_2OCH_3)]$ were unsuccessful. The chlorinated triphenyl phosphine is quite labile and is readily displaced from $[PdCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$ by various Lewis bases including nitrogen containing ligands such as 2,2′-bipyridine. The molecular structure of *trans*-$[PdCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$ was determined by X-ray diffraction and represents the first molecular structure determination of a transition metal complex containing **1**. This complex crystallizes in the monoclinic space group $P2_1/n$ with $a = 10.3928(3)$ Å, $b = 16.0102(4)$ Å, $c = 13.1884(4)$ Å, $\beta = 90.714(2)^\circ$, and $Z = 4$. Key geometric parameters include Pd–Cl(1) = 2.309(1) Å, Pd–P(1) = 2.334(1) Å; Pd–P(1)–C(7) = 118.3(2)°, Pd–P(1)–C(1) = 115.3(2)°, C(1)–C(6)–Cl(2) = 120.7(4)° and Cl(1)–Pd–P(1) = 85.86(4)°.

Keywords: Nickel; Palladium; Platinum; Phosphine; Substitution reactions

1. Introduction

Recently we observed that the chlorinated triphenylphosphine, $P(C_6H_5)(C_6H_4Cl\text{-}2)_2$ (**1**), is superior to PPh_3 when used as a supporting ligand in the palladium mediated Suzuki coupling of aryl bromides and chlorides with aryl boronic acids (Eq. (1)) [1]. Aryl bromides are successfully coupled at room temperature, while aryl chlorides required slight heating. Secondary reactions that plague Pd/PPh_3 catalyzed Suzuki couplings such as aryl–aryl exchange between PPh_3 and Pd–Ar and homocoupling of the aryl boronic acid were suppressed when **1** was used. To gain a greater understanding of the interaction between this ligand and transition metals, we have investigated the complexes formed between Group 10 metals and **1**. Furthermore, we have investigated the reaction of $[PdCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$ with various Lewis bases in order to study the coordinating ability of **1**.



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PII: S0020-1693(02)01141-6

2. Experimental

2.1. General considerations

All reactions were performed under a nitrogen atmosphere on a vacuum line or in a nitrogen-filled drybox. THF was distilled from sodium–benzophenone. Diethyl ether was purified using a Grubbs-type solvent purification system. Dichloromethane was dried over CaH_2 and distilled. Nitrogen was purified by passage through purification columns (oxygen and moisture) from Chromatography Research Supplies. $[PdCl_2(cod)]$ (cod = 1,5-cyclooctadiene) [2], $[PdCl_2(NCCH_3)_2]$ [3] and $[PtCl_2(NCCH_3)_2]$ [4] were prepared as described previously. $P(C_6H_5)(C_6H_4Cl\text{-}2)_2$ (**1**) was prepared from 2-bromochlorobenzene in a manner similar to that described in the literature [5]. $[PtCl_2(cod)]$ and $[NiBr_2(DME)]$ (DME = $CH_3OCH_2CH_2OCH_3$), 2,2′-bipyridine, 1,10-phenanthroline, and 2,9-dimethyl-1,10-phenanthroline were obtained from Aldrich and used as received. Elemental analyses were performed by Midwest Microlabs. ^1H (300 MHz) and ^{31}P (121 MHz) NMR spectra were taken using a Bruker ARX-300 instrument and referenced to Me_4Si (0 ppm) and H_3PO_4 (85% aq. solution, 0 ppm), respectively. Quantitative $^{31}P\{^1H\}$ NMR spectra were obtained by turning off the decoupler during the pulse and delay and setting d1 to 30 s. Coupling constants are in given in Hertz.

2.2. Reaction of MX_2L_2 with *1*

2.2.1. Synthesis of trans-$[PdCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$ (*2*)

A flask was charged with $[PdCl_2(NCCH_3)_2]$ (100 mg, 0.39 mmol), **1** (260 mg, 0.79 mmol), CH_2Cl_2 (15 ml). The reaction was stirred at 25 °C, and a cloudy yellow–orange solution was evident after 30 min. After 24 h a fine yellow powder was obtained. After filtration and washing with diethyl ether, the residue was dried under vacuum to afford 300 mg (93%) of **2**. *Anal.* Calc. for $C_{36}H_{26}Cl_6P_2Pd$: C, 51.50; H, 3.12. Found: C, 52.20; H, 3.68%. ^1H NMR ($CDCl_3$, 25 °C): δ 7.10–7.78 (broad m, 22H, Ar–H), 6.68–6.70 (m, 4H, Ar–H). $^{31}P\{^1H\}$ NMR ($CDCl_3$, 25 °C): δ 21.6. Similar results were obtained using $[PdCl_2(cod)]$ (100 mg, 0.350 mmol) and **1** (232 mg, 0.700 mmol). A yellow solid was obtained from this reaction (280 mg, 96%).

2.2.2. Synthesis of $[PtCl_2(cod)(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)]$ (*3*)

A flask was charged with $[PtCl_2(cod)]$ (50.0 mg, 0.134 mmol), **1** (88.5 mg, 0.268 mmol), and THF (10 ml). The reaction was refluxed for 24 h. After filtration and drying under vacuum, a yellow solid was obtained. *Anal.* Calc. for $C_{26}H_{25}Cl_4PPt$: C, 44.27; H, 3.54. Found: C, 44.30; H, 3.68%. ^1H NMR ($CDCl_3$, 25 °C): δ 7.22–7.78 (broad m, 9H, Ar–H). 7.08–7.13 (m, 2H, Ar–H), 6.65–6.68 (m, 2H, Ar–H), 5.05 (m, 4H, =C*H*CH_2–), 2.10–2.16 (m, 8H, –CH_2–), $^{31}P\{^1H\}$ NMR ($CDCl_3$, 25 °C): δ 19.2 (br s, $^1J_{PtP}$ = nr).

2.2.3. Synthesis of $[PtCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$ (*4*)

A flask was charged with **1** (95 mg, 0.2 mmol), $[PtCl_2(NCCH_3)_2]$ (50 mg, 0.14 mmol), and THF (10 ml). This solution was refluxed for 24 h during which time a fine precipitate formed. After filtration a yellow powder was obtained (67.8 mg, 52%). *Anal.* Calc. for $C_{36}H_{26}Cl_6P_2Pt$: C, 46.58; H, 2.82. Found: C, 46.19; H 2.93%. ^1H NMR ($CDCl_3$, 25 °C): δ 7.22–7.45 (broad, m, 18H, Ar–H), 7.11–7.13 (m, 4H, Ar–H), 6.66–6.69 (m, 4H, Ar–H). $^{31}P\{^1H\}$ NMR ($CDCl_3$, 25 °C): δ 19.14 (s, $^1J_{PtP}$ = 2832).

2.2.4. Reaction of $[NiBr_2(DME)]$ with *1*

A flask was charged with $[NiBr_2(DME)]$ (50 mg, 0.162 mmol), **1** (107.3 mg, 0.325 mmol), and THF (10 ml). The reaction was refluxed for 24 h. Upon removing the solvent, a green solid was obtained. Analysis of the ^1H and ^{31}P NMR spectra of the material revealed that no uptake of **1** had occurred.

2.2.5. Treatment of *2* with Lewis bases

An NMR tube was charged with $[PdCl_2(cod)]$ (3 mg, 10 μmol), **1** (6.9 mg, 20 μmol), $P(O)Ph_3$ (2.9 mg, 10.4 μmol; internal standard), Lewis base (20.8 μmol for monodentate ligands; 10.4 μmol for bidentate ligands), and $CDCl_3$ (0.5 ml). The sample was heated to 90 °C for 10 min in the sealed NMR tube. Due to the insolubility of many of the products, the progress of the reaction was monitored by the integration of the internal standard $P(O)Ph_3$ versus free **1**. The results of these experiments are summarized in Tables 3 and 4.

2.2.6. Molecular structure determination of *2*·2$CDCl_3$

A crystal suitable for X-ray diffraction studies was grown by slow evaporation of a $CDCl_3$ solution. The data collection was performed using a Bruker SMART diffractometer (Mo radiation, 0.71073 Å) equipped with a CCD detector at 218 K Preliminary cell determination was done using a set of 45 narrow frames (0.3°, 15 s exposure). The data sets consisted of 4790 independent reflections. Crystal data and structure refinement parameters are listed in Table 1. Structure solution and refinement were carried out using the SHELXTL-PLUS software package [6]. The C–Cl bond distances were restrained to be within 0.05 deviation, while the thermal parameters of the chlorines were restrained to be similar. Due to partially twinned crystals, it was not possible to obtain a reasonable solution from SMART. The triclinic cell suggested by SMART resulted in extremely poor data reduction parameters and no chemically reasonable solution could be obtained based on this cell. Therefore,

Table 1
Crystal data and structure refinement for **2**·2CDCl$_3$

Empirical formula	$Pd_{0.5}PCl_6H_{13}DC_{19}$
Formula weight (g mol^{-1})	540.17
Crystal system	monoclinic
Space group	$P2_1/n$
a (Å)	10.3928(3)
b (Å)	16.0102(4)
c (Å)	13.1884(4)
β (°)	90.714(2)
V (Å^3)	2194.3(1)
Z	4
D_{calc} (mg m^{-3})	1.632
Absorption coefficient (mm^{-1})	1.255
$F(000)$	1072
Crystal size (mm)	0.36 × 0.33 × 0.28
β Range for data collection (°)	2.00–27.00
Reflections collected	29786
Independent reflections (R_{int})	4790 (0.041)
Completeness to $\theta = 27°$	99.70%
Max/min transmission	0.7201/0.6607
Refinement method	full-matrix least-squares on F^2
Data/restraints/parameters	4790/21/269
Goodness-of-it on F^2	1.302
Final R indices [$I > 2\sigma(I)$]	$R_1 = 0.0646$, $wR_2 = 0.1165$
R indices (all data)	$R_1 = 0.0740$, $wR_2 = 0.1197$
$\Delta\rho_{max}/\Delta\rho_{min}$, (e Å^{-3})	0.625/−0.693

GEMINI (Bruker-AXS, 2000) program was used to find out all possible cell choices of which a monoclinic cell was chosen to be the correct cell choice for this compound. The structure was solved and refined in the monoclinic space group $P2_1/n$.

The compound crystallizes with a molecule of $CDCl_3$ as solvent of crystallization. The solvent molecule is disordered around the C atom. The disorder was resolved with two sets of Cl atoms in 48:52% ratio.

3. Results and discussion

3.1. Treatment of L_2MCl_2 with $P(C_6H_5)(C_6H_4Cl\text{-}2)_2$

Treatment of [$PdCl_2$(cod)] or [$PdCl_2(CH_3CN)_2$] with 2 equiv. of **1** resulted in the displacement of the weakly coordinating cyclooctadiene or acetonitrile and formation of *trans*-[$PdCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2$] (**2**). This reaction was complete within seconds at room temperature and prolonged stirring resulted in the formation of a fine yellow powder. Complex **2** was quite stable to air and moisture, but exhibited poor solubility in most common organic solvents. The $^{31}P\{^1H\}$ NMR spectrum ($CDCl_3$, 25 °C) of **2** contained a singlet, consistent with rapid rotamer interconversion.

Single crystals of **2**·2$CDCl_3$ were grown by slow evaporation of $CDCl_3$ solution. The molecular structure was determined by X-ray diffraction (Fig. 1) and

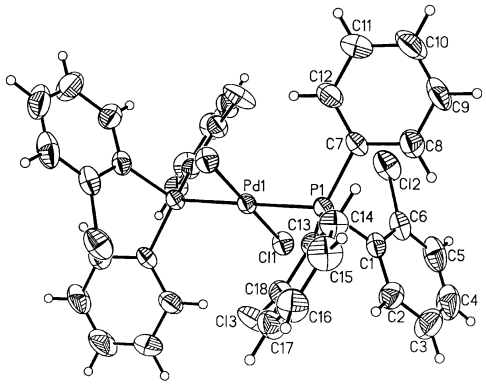


Fig. 1. Molecular structure (ORTEP) of **2**·2$CDCl_3$. Thermal ellipsoids shown at 50% probability. The solvent of crystallization ($CDCl_3$) has been omitted for clarity.

selected bond distances and angles are listed in Table 2. The molecule exhibits crystallographically imposed inversion symmetry about the Pd center. The Pd–P(1) bond distance was determined to be 2.334(1) Å, while the Pd–Cl(1) bond distance was measured to be 2.309(1) Å. Both of these bond distances are within the normal range for such complexes [7]. The bond angles of Pd–P(1)–C(1), Pd–P(1)–C(7) and Pd–P(1)–C(13) were all found to be within normal ranges as well. The angle between Cl(1)–Pd–P(1) was found to be 94.14(4)° while the complementary angle was 85.86(4)°. The compression of the bond angle is attributed to a steric interaction between chlorines on palladium and the Ar–Cl groups.

While treatment of [$PdCl_2$(cod)] with 2 equiv. of **1** rapidly formed **2**, analogous reactions with [$PtCl_2$(cod)] did not form [$PtCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2$]. Monitoring the reaction by ^1H NMR spectroscopy ($CDCl_3$) revealed that free cyclooctadiene was not produced upon addition of 2 equiv. of **1**. The ^1H NMR spectrum of the reaction contained peaks at δ 5.05 and 2.10–2.16 ppm (free cyclooctadiene δ 5.52 and 2.31 ppm), suggesting incomplete displacement of the cyclooctadiene and formation of [$PtCl_2$(cod)($P(C_6H_5)(C_6H_4Cl\text{-}2)_2$)] (**3**, Eq. (2)). The $^{31}P\{^1H\}$ NMR spectrum contained peaks in a

Table 2
Selected bond lengths (Å) and angles (°) for **2**·2$CDCl_3$

Bond lengths	
Pd–Cl(1)	2.309(1)
Pd–P(1)	2.334(1)
P(1)–C(1)	1.818(5)
P(1)–C(7)	1.830(4)
Bond angles	
Pd–P(1)–C(1)	115.3(2)
Pd–P(1)–C(7)	118.5(2)
Pd–P(1)–C(13)	110.5(1)
Cl(1)–Pd(1)–P(1)	85.86(4)
Cl(1)′–Pd(1)–P(1)	94.14(4)

1:1 ratio at δ 19.1 and −16.5 (free **1**). The elemental analysis was also consistent with this.

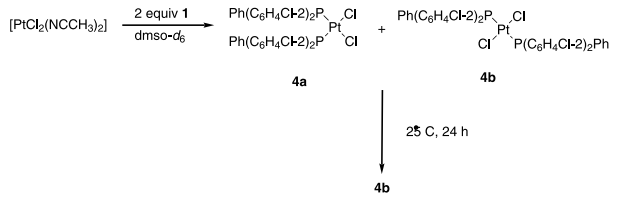
$$[PtCl_2(cod)] + 2 \text{ equiv. } \mathbf{1} \rightarrow [PtCl_2(cod)(P(C_6H_5)(C_6H_4Cl2)_2)] + 1 \text{ equiv. } \mathbf{1} \quad (2)$$

Although **1** was unsuccessful in completely displacing cyclooctadiene from $[PtCl_2(cod)]$, treatment of *trans*-$[PtCl_2(NCCH_3)_2]$ with 2 equiv. of **1** afforded $[PtCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)_2]$. The $^{31}P\{^1H\}$ NMR spectrum of the reaction mixture revealed the presence of two peaks (δ 19.14 and 26.46 ppm) during the early stages of the reaction. This observation was consistent with the initial formation of both *cis* and the *trans* isomers (**4a**, **4b**) of $[PtCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)]$. Upon standing, the conversion to a single product was complete after 24 h (Scheme 1). This species exhibited a peak at δ 29.1 ppm in the ^{31}P NMR spectrum (DMSO-d_6), and was assigned to **4b**.

Treatment of $NiCl_2 \cdot 6H_2O$ in boiling propanol with PPh_3 is a successful method for the preparation of $[NiCl_2(PPh_3)_2]$ [8]. However, analogous reactions carried out using **1** were unsuccessful in generating $[NiCl_2(P(C_6H_5)(C_6H_4Cl\text{-}2)_2)]$. Upon standing, these solutions afforded crystals of **1**. Since the treatment of $[NiBr_2(DME)]$ (DME = $CH_3OCH_2CH_2OCH_3$) with various Lewis bases has been shown to be successful in displacing the DME [9], 2 equiv. of **1** was added to solutions ($CDCl_3$) of $[NiBr_2(DME)]$. Upon addition of **1**, free DME was not observed in the ^1H NMR spectrum. Heating this solution (70 °C, 24 h) was also unsuccessful in displacing the DME.

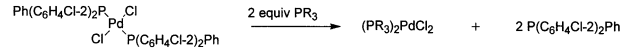
3.2. Addition of Lewis bases to 2

The inability of **1** to displace cyclooctadiene from $[PtCl_2(cod)]$ or DME from $[NiBr_2(DME)]$ prompted us to investigate the relative lability of **1** from Group 10 metal centers. Additionally, the ease of displacement of **1** from palladium is a critical concern in the Suzuki coupling of aryl halides with aryl boronic acids catalyzed by Pd/**1**. These reactions were carried out by the addition of the Lewis base to a solution ($CDCl_3$) of **2**. Due to the low solubility of **2**, it was prepared in situ ($CDCl_3$) from $[PdCl_2(cod)]$ and 2 equiv. of **1**. The results of this study are listed in Table 3. In all cases, a monodentate or bidentate phosphine donor completely displaced **1** from **2**. Of particular interest are entries 3



Scheme 1.

Table 3
Treatment of **2** with phosphine ligands



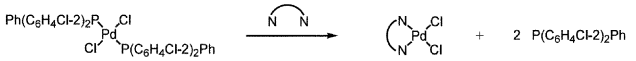
	PR_3	% conversion [a]
1	1,2-bis(diphenylphosphino)ethane [b]	97
2	triphenyl phosphine	98
3	tris(4-fluorophenyl)phosphine	98
4	tris(4-chlorophenyl)phosphine	97
5	tris(2,4,6-trimethoxyphenyl)phosphine	95

[a] $CDCl_3$ solutions at 90 °C for 1 h in a sealed NMR tube using $P(O)Ph_3$ as an internal standard.
[b] 1 equivalent of 1,2-bis(diphenylphosphino) ethane was used.

and 4. In these cases, triarylphosphines containing the halogen in the fourth-position completely displaced **1** from **2.** Since all of the phosphine donors investigated were successful, we examined nitrogen-based ligands (Table 4). Treatment of a solution ($CDCl_3$) of **2** with nitrogen donors such as 2,2′-bipyridine and 1,10-phenanthroline completely displaced **1** from **2**. Only the sterically hindered α-diimine and 2,9-dimethyl-1,10-phenanthroline were unsuccessful in this reaction. These results suggested that displacement of **1** from palladium by pyridyl containing aryl halides in ambient temperature Suzuki couplings of these substrates with aryl boronic acids could occur in significant amounts.

Substitution reactions of four-coordinate square-planar complexes have been studied extensively [10]. These reactions proceed by associative attack of an incoming ligand to afford a square-pyramidal intermediate followed by rearrangement to a trigonal-bipyramidal intermediate. Reversal of this process accompanied by loss of the leaving ligand generates the new four-coordinate square-planar complex. For Ni(II) it is believed that the mechanism proceeds via a tetrahedral intermediate [11]. These processes are repeated twice when disubstitution occurs.

Table 4
Treatment of **2** with nitrogen ligands



	$N^{\frown}N$	% conversion [a]
1	2,2-bipyridine	99
2	4,4-dimethyl-2,2-bipridine	94
3	1,10-phenanthroline	97
4	$\{(C_6H_3{}^iPr_2\text{-}2,6)N{=}C(Me)\}_2$	0
5	2,9-dimethyl-1,10-phenanthroline	0

[a] $CDCl_3$ solutions at 90 °C for 1 h in a sealed NMR tube with $P(O)Ph_3$ as an internal standard.

4. Summary

Upon reacting our ligand with each of the three d^8 metals under investigation it was determined that substitution of the acetonitrile or cyclooctadiene ligands on the Pd complex occurred with relative ease, leading to **2** as the sole product. Substitution of the $[PtCl_2(NCCH_3)_2]$ complex resulted in a mixture of *cis* and *trans* isomers, while treatment of $[PtCl_2(cod)]$ with **1** afforded the monosubstituted species **3**. Compound **1** was insufficiently basic to displace DME from $[NiBr_2(DME)]$, even under rigorous conditions. The displacement of **1** from **2** by added Lewis bases was successful for numerous phosphorus and nitrogen based ligands. The results of this investigation suggest that displacement of **1** from palladium could occur in significant amounts in the ambient temperature Suzuki coupling of heteroatom containing aryl halides with aryl boronic acids catalyzed by Pd/**1**.

5. Supplementary material

The molecular structure information for **2** including atomic coordinates, anisotropic displacement parameters, and geometrical parameters have been deposited in the Cambridge Structural Database. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: +44-1223-336-033, e-mail: deposit@ccdc.cam.ac.uk or http://www.ccdc.cam.ac.uk).

References

[1] S.A. Rosemeier, M.R. Pramick, S.B. Nickse, R.A. Stockland, Jr., J.J. Stone, S.M. Baldwin, Organometallics, in preparation.
[2] J. Chatt, L. Vallarino, L.M. Venanzi, J. Chem. Soc. A (1957) 3413.
[3] L. Hegedus, in: M. Schlosser (Ed.), Organometallics in Synthesis, Wiley, New York, 1994, p. 448.
[4] (a) F.P. Fanizzi, F.P. Intini, L. Maresca, G. Natile, J. Chem. Soc., Dalton Trans. (1990) 199;
(b) D. Fraccarollo, R. Bertani, M. Mozzon, Inorg. Chim. Acta 201 (1992) 15.
[5] (a) The procedure followed was that of Davis and Mann. M. Davis, G. Mann, J. Chem. Soc. A (1964) 3770;
(b) N.A.A. Al-Jabar, A.G. Massey, J. Organomet. Chem. 288 (1985) 145;
(c) M.C.J.M. Van Hooijdonk, G. Gerritsen, L. Brandsma, Phosphorous Sulfur Silicon Relat. Elem. 162 (2000) 39.
[6] G.M. Sheldrick, Bruker AXS, Bruker Analytical X-ray Division, Madison, WI, (1998).
[7] (a) N.D. Kolosova, A.N. Sobolev, T.E. Kron, E.S. Petrov, V.K. Bel'skii, Koord. Him. 12 (1986) 393;
(b) G. Ferguson, R. McCrindle, A.J. McAlees, M. Parvez, Acta Crystallogr., B 38 (1982) 2679;
(c) M. Weigelt, D. Becher, E. Poetsch, C. Bruhn, D. Steinborn, Z. Anorg. Allg. Chem. 625 (1999) 1542.
[8] I.P. Parkin, in: J.D. Woolins (Ed.), Inorganic Experiments, VCH, New York, 1994, p. 101.
[9] C.M. Killian, L.K. Johnson, M. Brookhart, Organometallics 16 (1997) 2005.
[10] A. Yamamoto, Organotransition Metal Chemistry, Wiley, New York, 1986, pp. 199–206.
[11] (a) C.G. Grimes, R.G. Pearson, Inorg. Chem. 13 (1974) 970;
(b) P. Favre, C.W. Schlaepfer, Chem. Phys. Lett. 139 (1987) 250.