# IMPROVED SYNTHESIS OF 1-ADAMANTYL-PHOSPHINE AND ITS USE IN THE SYNTHESIS OF CYCLICPHOSPHINES CONTAINING 1-ADAMANTYL GROUP

**Atsushi Ohashi, Satoru Matsukawa, and Tsuneo Imamoto***

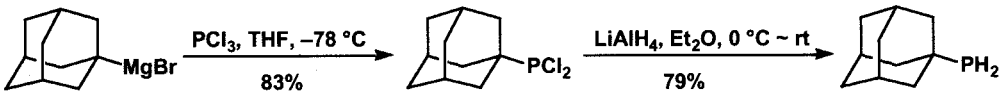
Department of Chemistry, Faculty of Science, Chiba University
Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

***Abstract*** – 1-Adamantylphosphine (**1**) was easily synthesized from 1-adamantylmagnesium bromide. Several new cyclic trialkylphosphines bearing 1-adamantyl group were prepared from compound (**1**).

Among chiral phosphines synthesized so far, cyclic ligands such as DuPHOS,[1] BPE,[1] PennPhos,[2] and 9-PBN[3] have been proved to exhibit excellent enantioselectivity in some catalytic asymmetric reactions. We found that the rhodium complexes with P-chiral bistrialkylphosphine ligands gave excellent enantioselectivity in the asymmetric hydrogenations of α-acylaminoacrylic acids.[4] In connection with this work, we planned to prepare cyclic trialkylphosphines from 1-adamantylphosphine (**1**) as a starting phosphine. These cyclic phosphine ligands containing the bulky 1-adamantyl group may have utility as chiral ligands in asymmetric catalysts.

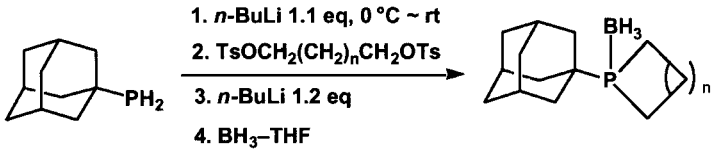
Compound (**1**) was previously synthesized by Setter and Last from 1-bromoadamantane *via* 1-adamantylphosphonyl dichloride.[5] Although the yield is satisfactory, toxic carbon tetrachloride is used in the procedure. We devised an alternative route to 1-adamantylphosphine through 1-adamantyldichlorophosphine as the intermediate. Herein we report a new synthetic procedure for the preparation of compound (**1**) together with synthesis of several cyclic phosphines containing 1-adamantyl group.

1-Adamantyldichlorophosphine was synthesized from 1-adamantylmagnesium bromide and phosphorus trichloride.[6] 1-Adamantylmagnesium bromide was allowed to react with phosphorus trichloride in THF at –78 °C to afford 1-adamantyldichlorophosphine in 83% yield. The reduction of this compound with $LiAlH_4$ in ether proceeded smoothly at 0 °C ~ room temperature to give the desired compound (**1**) in 79% yield



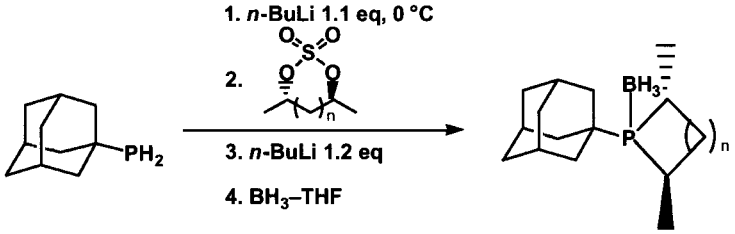
(Scheme 1). Compound (**1**) was not easily subjected to oxidation in air. It reacted with $BH_3$–THF to afford the corresponding alkylphosphine–borane adduct which was very labile and readily decomposed to liberate the parent phosphine.

This primary phosphine was used for the preparation of cyclic phosphines having 1-adamantyl group. At first, we tried to synthesize 1-adamantylphosphetane–borane (**2a**) and 1-adamantylphospholane–borane (**2b**) by the reaction of compound (**1**) with 1,3-propanediol ditosylate or 1,4-butanediol ditosylate. *n*-Butyllithium was used for the cyclization in THF at 0 °C ~ room temperature to give compounds (**2a** and **2b**) in 27% and




**2a** n = 1 : 27%
**2b** n = 2 : 39%

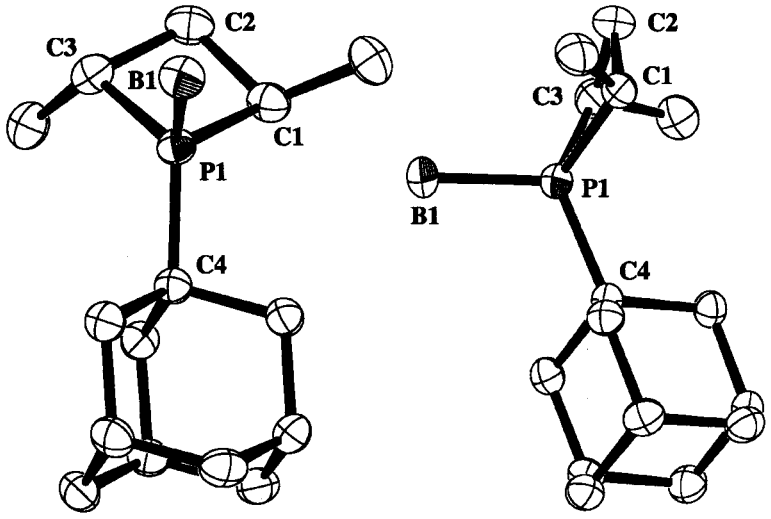
**Scheme 2**




**3a** n = 1 : 63%
**3b** n = 2 : 49%

**Scheme 3**

39% yields, respectively (Scheme 2).[7] Based on this result, preparation of optically active cyclic phosphines was examined using cyclic sulfate of (*S*,*S*)-2,4-pentanediol or (*S*,*S*)-2,5-haxanediol. The reaction proceeded smoothly to afford (2*R*,4*R*)-2,4-dimethyl(1-adamantyl)phosphetane–borane (**3a**) and (2*R*,5*R*)-2,5-dimethyl(1-adamantyl)-phospholane–borane (**3b**) in 63% and 49% yields, after recrystallization from hexane (Scheme 3). These compounds were characterized by IR, NMR, and HRMS. The structure of **3a** was unequivocally determined by X-Ray crystallography. The crystal structure was shown in Figure 1. The ORTEP drawing clearly indicates that this compound




(A) Top View (B) Side View

**Figure 1.** ORTEP drawing of (*R*,*R*)-**3a**. Crystal Data: $C_{15}H_{28}BP$, orthorhombic, space group $P2_12_12$; bond lengths P1–B1 1.922(5) Å, P1–C1 1.838(4) Å, P1–C3 1.851(5) Å, P1–C4 1.840(4) Å; bond angles C1–P1–C3 79.3(2)°, C1–C2–C3 99.4(3)°, P1-C1-C2 88.5(3)°,

adamantyl group and the boranato group at the pseudo equatorial position and at the pseudo axial position, respectively (see Side View). Another characteristic feature of this crystal structure is exhibited in the bond angles. Namely, the C1–P1–C3 bond angle is remarkably small (79.3 °) and the C1–C2–C3 bond angle is relatively large (99.4 °) to form a strained four membered ring.

Subsequent removal of the boranato group was efficiently carried out by the method of McKinstry and Livinghouse.[8] The reactions with trifluoromethanesulfonic acid in toluene, followed by treatment with aqueous KOH, provided the desired phosphines in high yields.[9] These phosphines were converted to cationic Rh-complexes by the reactions with [Rh(nbd = 2,5-norbornadiene)$_2$]$BF_4$.[10] The structure of [Rh((*R*,*R*)-2,5-dimethyl(1-adamantyl)phosphetane)$_2$(nbd)]$BF_4$ (**4a**) was determined by X-Ray crystallography. The crystal structure was shown in Figure 2. The ORTEP drawing apparently shows that two monodentate phosphine ligands are coordinated to the rhodium atom. This complex does not form a $C_2$-symmetric structure. Another characteristic of this crystal structure is the considerable wide bond angle of P–Rh–P (100.6 °). It is also noted that the unit cell has unusually long length of *c*-axis (57 Å). These characteristics of the crystal structure may be ascribed to the steric hindrance of the 1-adamantyl group.

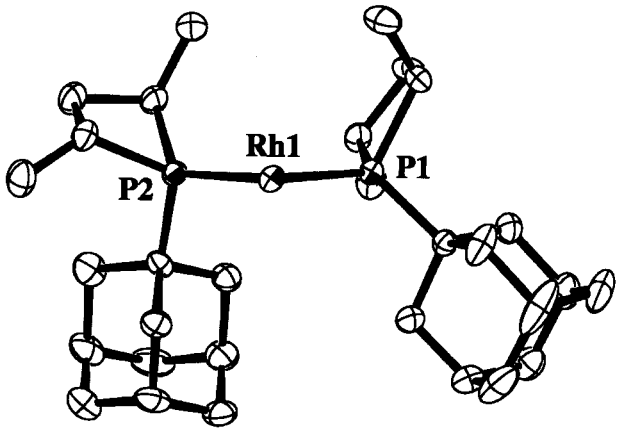



**Figure 2.** ORTEP drawing of rhodium complex [Rh((*R*,*R*)-2,5-dimethyl(1-adamantyl)phosphetane)$_2$ (nbd)]$BF_4$ (**4a**) : the NBD and the $BF_4^-$anion are omitted for clarity. Crystal Data: $C_{37}H_{58}BF_4P_2Rh$; hexagonal; space group $P6_5$; $a$ = 11.140(1) Å, $c$ = 57.234(9) Å; bond lengths P1–Rh1 2.370(2) Å, P2–Rh1 2.331(2) Å, Rh1–nbd *ca.* 2.2 Å; bond angle P1–Rh1–P2 100.6°.

In summary, we have shown that 1-adamantylphosphine can be easily synthesized from phosphorous trichloride and 1-adamantylmagnesium bromide. Furthermore, compound (**1**) was found to be a good starting material for the synthesis of achiral and chiral cyclic trialkyl monophosphines.

## EXPERIMENTAL

**1-Adamantyldichlorophosphine.** To a stirred solution of phosphorus trichloride (6.4 mL, 73 mmol) in dry THF (100 mL) was slowly added 1-adamantylmagnesium bromide (180 mL of 0.37 M ether solution, 67 mmol) at –78 °C under Ar atmosphere over a period of 1 h, and the mixture was allowed to warm to rt. After stirring overnight, it was filtered through a glass filter. The solvent was evaporated under reduced pressure. The residue was distilled *in vacuo* (1.0 mmHg) at 110–130 °C (bath temperature) to give pure 1-adamantyldicholorophosphine as colorless solid (13.2 g, 83%) : mp 70–72 °C. Anal. Calcd for $C_{10}H_{15}Cl_2P$: C, 50.66; H, 6.38, Found: C, 50.42; H, 6.55.

**1-Adamantylphosphine (1).** To a stirred solution of $LiAlH_4$ (239 mg, 6.3 mmol) in ether (40 mL) was

over a period of 30 min. The mixture was then allowed to warm to ambient temperature and stirred for 1 h. Degassed water (*ca.* 40 mL) was added dropwise by the use of the syringe to the flask. After the reaction mixture was stirred for 30 min, the organic layer was separated, and was passed through neutral alumina column. The filtrate was concentrated on an evaporator and the residual oil was distilled under reduced pressure to give pure **1** as colorless oil (962 mg, 79%) : bp 80 °C (1.0 mmHg); (lit.,[5] 75 °C, 0.1 mmHg).

**1-Adamantylphosphetane–Borane (2a).** To a stirred solution of **1** (1.0 g, 6 mmol) in THF (20 mL) was slowly added *n*-butyllithium (5 mL of 1.54 M *n*-hexane solution, 7.7 mmol) at 0 °C under Ar atmosphere over a period of 30 min. After the mixture was stirred for 30 min, 1,3-propanediol ditosylate (2.3 g, 6.6 mmol) was added. The mixture was then allowed to warm to ambient temperature and stirred for 1 h. The flask was again cooled to 0 °C and *n*-butyllithium (5.8 mL of 1.54 M *n*-hexane solution, 8.9 mmol) was added. After the reaction mixture was stirred for 30 min at rt, the flask was immersed in an ice-bath and $BH_3$–THF complex (7.7 mL of 1.0 M THF solution, 7.7 mmol) was added. The mixture was stirred for 30 min and it was slowly added to vigorously stirred ice-water (*ca.* 150 mL) containing 30 mL of conc. HCl. The organic layer was separated and the aqueous layer was extracted with EtOAc (3 × 50 mL). The combined extracts were washed with brine, dried over $Na_2SO_4$, and evaporated under reduced pressure. The residue was loaded on a silica gel column, eluting with toluene / hexane (2 : 1) to give colorless solid. The crude product was recrystallized from hexane to give pure **2a** as colorless crystal (360 mg, 27%) : mp 110–113 °C; $^1$H NMR (400 MHz, $CDCl_3$) δ 0.65 (br q, $J_{HP}$ = 344 Hz, 3H), 1.74–1.76 (m, 6H), 1.77 (t, 6H), 1.78–2.00 (m, 2H), 2.15 (s, 3H), 2.25 (m, 2H), 2.26 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$) δ 16.5 (d, $J_{CP}$ = 40 Hz), 18.7 (d, $J_{CP}$ = 18 Hz), 27.5 (d, $J_{CP}$ = 9 Hz), 31, 35.3 (d, $J_{CP}$ = 20 Hz), 36.4; IR (KBr) 2900, 2360, 1450, 1340, 1170, 1060, 950, 700, 530; FAB MS (rel intensity) 221 ($M^+$–2H, 59), 209 ($M^+$–$BH_3$, 26); HRMS calcd for $C_{13}H_{24}BP$ 222.1183, found 221.1627. Anal. Calcd for $C_{13}H_{24}BP$: C, 70.30; H, 10.89, Found: C, 70.51; H, 11.03.

**1-Adamantylphospholane–Borane (2b).** This compound was prepared in 3 mmol scale according to a similar procedure for the preparation of **2a**. Thus, **1** (507 mg, 3 mmol) was allowed to react sequentially with *n*-butyllithium (3.6 mmol), 1,4-butanediol ditosylate (1.3 g, 3.6 mmol), *n*-butyllithium (4.5 mmol), and $BH_3$–THF (3.9 mmol). The crude product was recrystallized from hexane to give pure **2b** as colorless crystal (39%) : mp 140–142 °C; $^1$H NMR (400 MHz, $CDCl_3$) δ 0.45 (br q, $J_{HP}$ = 264 Hz, 3H), 1.6 (m, 4H), 1.74–1.76 (m, 6H), 1.77 (t, $J_{HP}$ = 11.6 Hz, 6H), 1.80–1.90 (m, 4H), 2.15 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$) δ 19.3 (d, $J_{CP}$ = 34 Hz), 27.3, 27.5 (d, $J_{CP}$ = 9 Hz), 30 (d, $J_{CP}$ = 30 Hz), 36.3, 36.4; IR (KBr) 2900, 2365, 1445, 1340, 1055, 885, 705, 600; FAB MS (rel intensity) 235 ($M^+$–H, 100), 223 ($M^+$–$BH_3$, 32); HRMS calcd for $C_{14}H_{26}BP$ 236.1452, found 235.1792. Anal. Calcd for $C_{14}H_{26}BP$: C, 71.21; H, 11.10, Found: C, 71.13; H, 11.18.

**(2*R*,4*R*)-2,4-Dimethyl(1-adamantyl)phosphetane–Borane (3a).** To compound (**1**) (1.38 g, 8.2 mmol) in THF (120 mL) was added *via* syringe *n*-butyllithium (5.9 mL of a 1.52 M solution in *n*-hexane, 9 mmol) at

mL) of (2*S*,4*S*)-2,4-pentanediol cyclic sulfate (1.5 g, 9 mmol). After the solution was stirred for 2 h, *n*-butyllithium (6.6 mL of a 1.52 M solution in *n*-hexane, 10 mmol) was again added dropwise via syringe in ice-bath. Initially, gelatinous precipitates formed. After the reaction mixture was stirred for 30 min, the flask was immersed in an ice-bath and $BH_3$–THF complex (11 mL of 1.0 M THF solution, 11 mmol) was added. The mixture was stirred for 30 min at rt and it was slowly added to vigorously stirred ice-water (*ca.* 150 mL) containing 30 mL of conc. HCl. The organic layer was separated and the aqueous layer was extracted with EtOAc (3 × 50 mL). The combined extracts were washed with brine, dried over $Na_2SO_4$, and evaporated under reduced pressure. The crude product was recrystallized from hexane to give pure **3a** as colorless crystals (1.3 g, 63%) : mp 128–130 °C; $[\alpha]^{27}_D$ –8.1° (*c* 0.90, $CHCl_3$); $^1$H NMR (400 MHz, $CDCl_3$) δ 0.64 (br q, $J_{HP}$ = 190 Hz, 3H), 1.23–1.29 (m, 3H), 1.36–1.41 (m, 3H), 1.75 (s, 6H), 1.80–2.00 (m, 9H), 2.15–2.36 (m, 2H), 2.69–2.80 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$) δ 15.9, 16.5 (d, $J_{CP}$ = 5.7 Hz), 22.2 (d, $J_{CP}$ = 39 Hz), 27.7 (d, $J_{CP}$ = 8.2 Hz), 31.0 (d, $J_{CP}$ = 37 Hz), 34.3 (d, $J_{CP}$ = 15 Hz), 36.75 (d, $J_{CP}$ = 53 Hz), 36.8 (d, $J_{CP}$ = 16 Hz); IR(KBr) 2910, 2360, 1450, 1340, 1070, 690; FAB MS (rel intensity) 249 ($M^+$–H, 51), 237 ($M^+$–$BH_3$, 22); HRMS calcd for $C_{15}H_{28}BP$ 250.1720, found 249.1944. Anal. Calcd for $C_{15}H_{28}BP$: C, 72.02; H, 11.28, Found: C, 71.98; H, 11.15.

**X-Ray Crystallography of 3a.** Crystal data for $C_{15}H_{28}BP$: orthorhombic, space group $P2_12_12$; $a$ = 19.23(1), $b$ = 23.08(2), $c$ = 6.730(3) Å; $V$ = 2986(2) Å$^3$; $z$ = 8; $d_{calc}$ = 1.113 g/cm$^{-3}$; $F$(000) = 1104; μ(Mo Kα) = 1.62 cm$^{-1}$; λ(Mo Kα) = 0.71070 Å; 2872 reflections measured; 2755 observed ($I$>2.9σ($I$)); 308 variables; $R$ = 0.056; $R$w = 0.071; GOF = 1.59.

**(2*R*,5*R*)-2,5-Dimethyl(1-adamantyl)phospholane–Borane (3b).** This compound was prepared in 3.1 mmol scale according to the procedure for the preparation of **3a**. Thus, **1** (512 mg, 3.1 mmol) was allowed to react sequentially with *n*-butyllithium (3.4 mmol), (2*S*,5*S*)-2,5-hexanediol cyclic sulfate (616 mg, 3.4 mmol), *n*-butyllithium (3.7 mmol), and $BH_3$–THF (4 mmol). The crude product was recrystallized from hexane to give pure **3b** as colorless crystals (49%) : mp 156–157 °C; $[\alpha]^{27}_D$ –23° (*c* 0.79, $CHCl_3$); $^1$H NMR (400 MHz, $CDCl_3$) δ 0.46 (br q, $J_{HP}$ = 315 Hz, 3H), 1.20–1.26 (m, 3H), 1.41–1.46 (m, 3H), 1.74 (s, 6H), 1.85–1.99 (m, 11H), 2.04–2.19 (m, 2H), 2.25–2.38 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$) δ 14.5, 16.0 (d, $J_{CP}$ = 65 Hz), 26.7 (d, $J_{CP}$ = 33 Hz), 27.7 (d, $J_{CP}$ = 8.2 Hz), 33.6 (d, $J_{CP}$ = 25 Hz), 35.2 (d, $J_{CP}$ = 109 Hz), 36.7 (d, $J_{CP}$ = 21 Hz), 37.8 (d, $J_{CP}$ = 32 Hz); IR (KBr) 2905, 2360, 1450, 1065, 685; FAB MS (rel intensity) 263 ($M^+$+H, 93), 251 ($M^+$–$BH_3$, 41); HRMS calcd for $C_{16}H_{30}BP$ 264.1989, found 263.2107. Anal. Calcd for $C_{17}H_{33}BP$: C, 73.12; H, 11.91, Found: C, 72.83; H, 11.65.

## ACKNOWLEDGMENT

This paper is decade to Professor Teruaki Mukaiyama in commemoration of his 73rd birthday. The authors thank Mr. Masayoshi Nishiura for X-Ray analysis. This work was supported by the Grant-in-Aid from The Ministry of Education, Sport and Culture, Japan Government.

1. M. J. Burk, J. E. Feaster, and R. L. Harlow, *Organometallics*, **1990**, *9*, 2653; M. J. Burk, *J. Am. Chem. Soc.*, **1991**, *113*, 8518; M. J. Burk, J. E. Feaster, W. A. Nugent, and R. L. Harlow, *J. Am. Chem. Soc.*, **1993**, *115*, 10125; M. J. Burk, J. E. Feaster, and R. L. Harlow, *Organometallics*, **1990**, *9*, 2653; M. J. Burk, J. R. Lee, and J. P. Martinez, *J. Am. Chem. Soc.*, **1994**, *116*, 10847.
2. Z. Chen, Q. Jiang, G. Zhu, D. Xiao, P. Cap, and C. Guo, X. Zhang, *J. Org. Chem.*, **1997**, *62*, 4521; Q. Jiang, Y. Jiang, D. Xiao, and P. Cao, X. Zhang, *Angew. Chem., Int. Ed. Eng.*, **1998**, *37*, 1100.
3. Y. Hamada, N. Seto, H. Ohmori, and K. Hatano, *Tetrahedron Lett.*, **1996**, *37*, 7565.
4. T. Imamoto, J. Watanabe, Y. Wada, H. Masuda, H. Yamada,H. Tsuruta, S. Matsukawa, and K. Yamaguchi, *J. Am. Chem. Soc.*, **1998**, *120*, 1635.
5. H. Stetter and W. D. Last, *Chem. Ber.*, **1969**, *102*, 3364.
6. One-pot synthesis of compound (**1**) was attempted. Thus, phosphorus trichloride was treated with 1-adamantylmagnesium bromide in THF, followed by reaction with $LiAlH_4$. The yield obtained by this procedure was 40% yield.
7. The reaction of (1-adamantyl)dichlorophosphine with $BrMg(CH_2)_4MgBr$ was also attempted for the synthesis of 1-adamantyldichlorophosphine. However, the yield of the product was very low (4% yield).
8. L. McKinstry and T. Livinghouse, *Tetrahedron Lett.*, **1994**, *35*, 9319; L. McKinstry and T. Livinghouse, *Tetrahedron*, **1994**, *50*, 6145.
9. To a stirred, cooled (0 °C) solution of cyclic phosphine–borane (0.2 mmol) in dry toluene (2 mL) was slowly added trifluoromethanesulfonic acid (85 μL, 1 mmol) under Ar atmosphere. After 30 min, the ice-bath was removed and the mixture was stirred at ambient temperature by monitoring the reaction by TLC until monophosphine–borane disappeared. A solution of KOH (200 mg, 3.6 mmol) in 1.5 mL of degassed EtOH was slowly added with stirring. The mixture was stirred at 70 °C for 1 h and cooled to rt. Freshly distilled $Et_2O$ (5 mL) was added with syringe and the mixture was settled. The upper layer was collected using a syringe. This ether extraction was repeated twice and the combined extracts were dried over $Na_2SO_4$. The solution was passed through a column of basic alumina using degassed ether. The eluent was evaporated *in vacuo* to leave practically pure desired phosphine ligands as colorless solid or oil.
10. A solution of (2*R*,4*R*)-2,4-dimethyl(1-adamantyl)phosphetane (120 mg, 0.51 mmol) in freshly distilled THF (6 mL) was added to a stirred suspension of $[Rh(nbd)_2]BF_4$ (83 mg, 0.22 mmol) in THF (6 mL) under Ar atmosphere. The suspension gradually turned to an almost clear solution during 2 h, which was filtrated under Ar to remove a small amount of precipitates. The filtrate was evaporated *in vacuo* and the residual solid was washed with hexane to give orange powder, which was dried *in vacuo*. The Rh-complex was recrystallized from THF to give dark red prisms. The crystal structure of [(Bis((2*R*,5*R*)-2,5-dimethyl(1-adamantyl)phosphetane))rhodium(nbd)]tetrafluoroborate was determined by single crystal X-Ray analysis. Crystal data for $C_{37}H_{58}BF_4P_2Rh$ 754.52, hexagonal, space group $P6_5$; $a$ = 11.14(1), $c$ = 57.234(9) Å; $V$ = 6151(1) $Å^3$; $z$ = 6; $d_{calc}$ = 1.222 $g/cm^{-3}$; $F(000)$ = 2376; μ(Mo Kα) = 5.34 $cm^{-1}$; λ(Mo Kα) = 0.71069 Å; 27200 reflections measured; 3332 observed ($I$>1.50σ($I$)); 405 variables; $R$ = 0.048; $Rw$ = 0.065; GOF = 1.05.
11. A. Marinetti,V. Kruger, and F. X. Buzin, *Tetrahedron Lett.*, **1997**, *38*, 2947.

Received, 27th April, 1999