## Reactions of Halogen(2,4,6-tri-*tert*-butylphenylimino)phosphine Complexes with Electrophiles and Nucleophiles: Abstraction or Substitution of the Halogen

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The structure of the first nickel halogeniminophosphine complex, *i.e.*  $(PEt_3)_2Ni(X-P=NAr)_2$  (Ar = 2,4,6-tri-*tert*-butylphenyl); X = CI is reported; reactions of this and related compounds with AICl<sub>3</sub> afford the cationic complexes **7–10**; the alkyliminophosphine complexes **12** and **13** are obtained by treatment of the chloroiminophosphine complexes **1a** and **4a** with Grignard reagent.

Recently, we described the first complexes of the 16-electron chloroiminophosphine complexes 1a-c and the 18-electron-species 4a-c.<sup>1</sup> Owing to the functionality at the low coordinated phosphorus atom these compounds are expected to show versatile reactivity. Here we report the first structure of these complexes and describe their reactions with Lewis acids and Grignard reagent. In order to gain an insight into the



Scheme 1 Reagents and conditions: i,  $[Ni(R_3P)_2(cod)]$  (1 equiv.), toluene, 0°C; ii,  $[Ni(R_3P)_2(cod)]$  (0.5 equiv.), toluene, 0°C, iii, [Ni(triphos)] or  $[Pt(Me_2PhP)(triphos)]$  (1 equiv.), toluene, 0°C

reaction behaviour we also report the synthesis of the bromoand iodo-analogues of compounds **1a–c**.

The single crystal X-ray analysis of complex  $4a^{\dagger}$  confirms the structure which was deduced from <sup>31</sup>P NMR data<sup>‡</sup> in which the nickel centre is surrounded by four phosphorus atoms in a nearly ideal tetrahedral arrangement. The molecular structure possesses crystallographic  $C_2$  symmetry with

† Crystal data for 4a: Red single crystals of 4a were grown from benzene at room temp. C<sub>48</sub>H<sub>88</sub>Cl<sub>2</sub>N<sub>2</sub>NiP<sub>4</sub>, M = 946.7, monoclinic, space group P2/n, a = 11.221(3), b = 15.953(4), c = 15.451(4) Å,  $\beta = 92.33(2)^\circ$ ; V = 2763.6(11) Å<sup>3</sup>; Z = 2;  $D_c = 1.14$  mg mm<sup>-3</sup>;  $\mu$ (Mo-Kα) = 0.59 mm<sup>-1</sup> F(000) = 1024;  $\lambda$ (Mo-Kα) = 0.71073 Å; R = 0.088 [ $R_w = 0.069$ ,  $w^{-1} = \sigma^2(F)$ ] [4904 unique reflections, 3363 data with  $F>4.0\sigma(F)$ ]. Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Notice to Authors, Issue No. 1.

‡ Selected NMR data for 4a: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>), δ 162.7 (t, 37.1 Hz), 13.3 (t, 37.1 Hz); <sup>1</sup>H (C<sub>6</sub>D<sub>6</sub>), δ 7.36 (b, 12H) PCH<sub>2</sub>CH<sub>3</sub>, 1.4 (s, 54H) Bu<sup>t</sup>, 1.2 (b, 18H) PCH<sub>2</sub>CH<sub>3</sub>, 2a: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>), δ 250.2 (t, 103.1 Hz), 22.4 (d, 103.1 Hz); 2b: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>), δ 251.6 (t, 107.3 Hz), 15.0 (d, 107.3 Hz); <sup>1</sup>H (C<sub>6</sub>D<sub>6</sub>), δ 7.33 (s, 2H) Ar, 2.0 (b, 12H) PCH<sub>2</sub>CCC, 1.5 (b, 27H) Bu<sup>t</sup>, 1.3 (b, 24H) PCCH<sub>2</sub>CH<sub>2</sub>C, 1.0 (b, 18H) PCCCCH<sub>3</sub>; 2c: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>), δ 229.0 (t, 109.7 Hz), 26.9 (d, 109.7 Hz); <sup>1</sup>H (C<sub>6</sub>D<sub>6</sub>), δ 7.0–7.8 (b, 32H) H<sub>arom</sub>, 1.36 (s, 9H) *p*-Bu<sup>t</sup>, 1.28 (m, 18H) *o*-Bu<sup>t</sup>; 5 two isoimers: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>) (a) δ 230.9 (t, 73.2 Hz; <sup>1</sup>J<sub>PtP</sub> 5581 Hz), -5.5 (d, 73.2 Hz; <sup>1</sup>J<sub>ptP</sub> 559 Hz); -27.2; (b) δ 227.9 (t, 73.2 Hz; <sup>1</sup>J<sub>PtP</sub> 5581 Hz), -4.0 (d, 73.2 Hz; <sup>1</sup>J<sub>PtP</sub> 5505 Hz); -27.2; 6: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>), δ 174.6 (q, 25.7 Hz), 13.9 (d, 25.7 Hz).

the Ni atom lying on a twofold axis. As predicted by theoretical investigations<sup>2</sup> the chloroiminophosphine is  $\eta^{1}$ -bonded as a consequence of the carbene-like frontier orbital sequence. The bond length Ni–P(=N) (207 pm) is about 7% shorter than the Ni–PR<sub>3</sub> distance (222 pm) which can be attributed not only to the different hybridisation state of the phosphorus atoms but also to a back donation from the metal



Scheme 2 Reagents and conditions: i, AlCl<sub>3</sub> (1.1 equiv.), toluene, 0°C; ii, NaBPh<sub>4</sub> (1 equiv.), benzene, -70 °C, iii, L<sub>n</sub>{M} [7a-c: Ni(R<sub>3</sub>P)<sub>3</sub>, 8a: Pt(Et<sub>3</sub>P)<sub>3</sub>, 9: Ni(triphos), 10: Pt(Me<sub>2</sub>PhP)(triphos)] (1 equiv.), benzene, -70 C; iv, T > -70 °C



Scheme 3 Reagents and conditions: i, MeMgI (1 equiv. solution in diisopentyl ether), toluene,  $0^{\circ}$ C; ii, MeMgI (2 equiv. solution in diisopentyl ether), toluene,  $0^{\circ}$ C



Fig. 1 ORTEP view of the structure 4a, with ellipsoids drawn at the 30% probability level. Selected distances (Å) and angles (°) are: Ni-P(1) 2.069(2), Ni-P(2) 2.221(2), P(1)-Cl(1) 2.145(3). P(1)-N(1) 1.498(5); P(1)-Ni-P(2) 107.8(1), P(1)-Ni-P(1a) 109.4(1), P(2)-Ni-P(1a) 110.9(1), P(2)-Ni-P(2a) 110.3(1), Cl(1)-P(1)-N(1) 108.1(2), P(1)-N(1)-C(1) 142.1(5)

atom to the ligated P=N fragment. Compared with the free ligand the P–N–C(1) angle (142.1°) is reduced by 12.7° which correlates with a reduced s-character of the P=N double bond.

The 16-electron bromo- and iodo-iminophosphine complexes **2a–c** and **3a–c** can be obtained in good yields by treatment of Ni(R<sub>3</sub>P)<sub>2</sub>(cod) (cod = cycloocta-1,5-diene) with the halogenated iminophosphine (1 equiv.). Comparison of the chemical shift of the low-coordinated phosphorus atoms with the electronegativity of the attached halogen reveals that the nucleus becomes more shielded ( $\Delta\delta\sim$ 20 ppm) the lower the electronegativity of the halogen. This is opposite to the free ligands, reflecting that the chemical shift of the coordinated phosphorus is strongly influenced by back donation of the metal.

Compounds 5 and 6, which are with respect to the latter more sensitive towards thermal decomposition, were generated by reaction of the iminophosphine with  $Pt(Me_2PhP)(tri$ phos) or Ni(triphos) [triphos =  $(PPh_2CH_2)_3CMe$ ]. In solution two isomers of the platinum complex 5 exists.

Treatment of **1a**-c with AlCl<sub>3</sub> at 0 °C in the presence of the corresponding phosphine yields the cationic complexes **7a**-c.§ The presence of one  $[P=N]^+$  moiety and three phosphine groups is indicated by the AX<sub>3</sub> coupling pattern in the <sup>31</sup>P{<sup>1</sup>H}-NMR spectra. Both, the large <sup>2</sup>J<sub>PP</sub> (65-93 Hz) and the relatively large <sup>1</sup>J<sub>PtP</sub>-coupling constants (2817 Hz)<sup>3</sup> in **8a**§ give evidence for an η<sup>1</sup>-coordination of the cationic iminophosphine ligands, which is further confirmed by use of triphos as a ligand. The complexes **9** and **10**, made in the same way as compounds **7**, also show the AX<sub>3</sub> coupling pattern, while a side-on coordination would lead to an AX<sub>2</sub> pattern as a consequence of the loss of one ligand.<sup>36</sup> Furthermore, solid-state NMR spectra of the nickel compounds **7a** and **9** have been carried out and confirm that the structure in solution is the same as those in the solid state.

The much larger  ${}^{1}J_{PtP=N}$  value in **10** with respect to **8a** is in agreement with earlier investigations<sup>4,5</sup> and results from the division of s-character in the Pt hybrids used to bind to the ligands. Thus, the geometry of triphos leads to an increased p-character of the Pt triphos bond (angle P-Pt-P~95°); as a consequence the Pt P=N bond has more s-character and therefore shows an increased coupling constant.<sup>5</sup> However, the  ${}^{1}J_{PtP=N}$  values in both complexes are smaller than expected. This is due to the positive charge of the iminophosphine ligand which results in a decreased electron density at the phosphorus atom and finally in a reduced coupling constant.<sup>6</sup>

Treatment of the compounds 1a-3a with NaBPh<sub>4</sub> yields the expected cation 7a only with the bromo- or iodo-complexes while the chloroiminophosphine complex 1a remains unaffected. A more direct synthetic route is to prepare the free iminophosphine-cation first followed by complexation. However, this reaction has to be carried out below -70 °C, otherwise a substitution reaction of the halogen by a phenyl group from the BPh<sub>4</sub><sup>-</sup> results in the formation of the phenyliminophosphine 11.7 Treatment of the compounds 1a or 4a with MeMgI leads to a substitution reaction yielding the

<sup>§</sup> Selected spectroscopic data for **7a**: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  209.9 (q, 64.7 Hz), 18.6 (d, 64.7 Hz); <sup>1</sup>H (C<sub>6</sub>D<sub>6</sub>),  $\delta$  7.4 (s, 2H) Ar, 1.44 (m, 18H) PCH<sub>2</sub>C, 1.4 (s, 18H) *o*-Bu<sup>t</sup>, 1.38 (s, 9H) *p*-Bu<sup>t</sup>, 1.24 (s, 27H) PCCH<sub>3</sub>; <sup>27</sup>Al (C<sub>6</sub>D<sub>6</sub>),  $\delta$  102.9 (s); MS [FAB/meta-nitrobenzyl alcohol (mNBA)]: *m*/z (%) = 702.2 (3.4) [M<sup>+</sup>], 584.2 (68.2) [M<sup>+</sup>-PEt<sub>3</sub>], 466.2 (76.4) [M<sup>+</sup>-2PEt<sub>3</sub>], 290.0 (56.4) [M<sup>+</sup>-Ni(PEt<sub>3</sub>)<sub>3</sub>]; **7b**: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  211.1 (q, 67.6 Hz), 11.5 (d, 67.6 Hz); <sup>1</sup>H (C<sub>6</sub>D<sub>6</sub>),  $\delta$  7.38 (s, 2H) Ar, 1.55 (b, 18H) PCH<sub>2</sub>CCC, 1.48 (b, 36H) PCCH<sub>2</sub>CH<sub>2</sub>C, 1.34 (b, 36H) Bu<sup>t</sup>, 0.94 (s, 27) PCCCCH<sub>3</sub>; <sup>27</sup>Al (C<sub>6</sub>D<sub>6</sub>),  $\delta$  102.6 (s); MS (FAB/mNBA): *m*/z(%) = 752.5 (50.9) [M<sup>+</sup> - PBu<sub>3</sub>], 550.3 (49.1) [M<sup>+</sup> - 2PBu<sub>3</sub>], 462.3(45.5) [M<sup>+</sup> - P=N-Ar], 290.2 (56.4) [M<sup>+</sup> - Ni(PBu<sub>3</sub>)<sub>3</sub>]; **7c**: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  210.6 [m(b)]; 27.7 (d(b) 69.2 Hz)]; **8a**: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  192.7 (q, 34.2 Hz), 22.9 (d, 34.2 Hz); **10**: <sup>31</sup>P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  138.1 (q, 97.7 Hz, <sup>1</sup>/<sub>PtP</sub> 6250 Hz), -3.9 (d, 97.7 Hz; <sup>1</sup>/<sub>PtP</sub> 3123 Hz).

complexes 12¶ and 13. These complexes are of particular interest, because the free methyl-iminophosphine is unstable towards dimerisation.<sup>8</sup>

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¶ Selected NMR data of 12:  ${}^{31}$ P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  289.1 (q, 41.2 Hz), 9.5 (d, 41.5 Hz); 13:  ${}^{31}$ P (C<sub>6</sub>D<sub>6</sub>),  $\delta$  313.7 (t, 15.3 Hz), 16.5 (t, 15.3 Hz);  ${}^{13}$ C (C<sub>6</sub>D<sub>6</sub>),  $\delta$  14.1 (d, 103.1 Hz) Me-P=N.

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