

## The First Mononuclear Pt<sup>III</sup> Complex. Molecular Structures of (NBu<sub>4</sub>)[Pt<sup>III</sup>(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>] and of Its Parent Compound (NBu<sub>4</sub>)<sub>2</sub>[Pt<sup>II</sup>(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>]·2CH<sub>2</sub>Cl<sub>2</sub>

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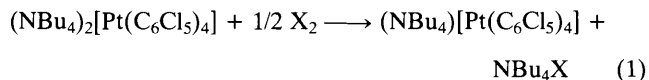
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(NBu<sub>4</sub>)[Pt<sup>III</sup>(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>], fully characterized by crystallographic, spectral, and magnetic measurements has been isolated by oxidation with halogens or TiCl<sub>3</sub> of the parent compound (NBu<sub>4</sub>)<sub>2</sub>[Pt<sup>II</sup>(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>], which has also been analysed by X-ray crystallography.

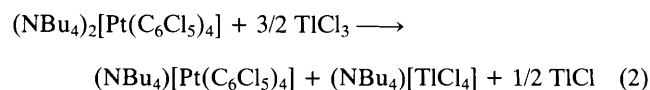
Several bi- or poly-nuclear complexes containing platinum formally in the Pt<sup>III</sup> oxidation state have been characterized.<sup>1</sup> All of them have Pt–Pt bonds. The preparation of Pt(NH<sub>3</sub>)<sub>2</sub>(SCN)<sub>2</sub>I, which according to its e.s.r. spectrum could be a Pt<sup>III</sup> compound, has been claimed.<sup>2</sup>

Now we report the preparation and structural characterization of the first well authenticated monomeric Pt<sup>III</sup> complex. A systematic study of the reactions between halogens and a series of anionic mono- or bi-nuclear pentafluoro- or pentachloro-phenyl derivatives of Pd or Pt, recently described by some of us,<sup>3</sup> has revealed that only the Pt<sup>II</sup> complex (NBu<sub>4</sub>)<sub>2</sub>[Pt(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>] can be oxidized to a stable M<sup>III</sup> complex. Thus, if Cl<sub>2</sub> or Br<sub>2</sub> (in CCl<sub>4</sub> solution) was added to the colourless dichloromethane solution of the Pt<sup>II</sup> complex, the instantaneous development of a deep-blue colour was observed and a blue Pt<sup>III</sup> complex, formed according to equation (1), was isolated in 90% yield.

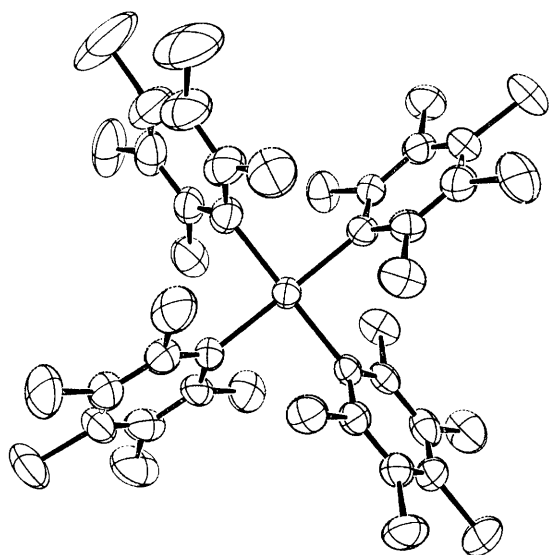


The same Pt<sup>III</sup> compound was obtained by treating the Pt<sup>II</sup> precursor with iodine or thallium(III) chloride, albeit in lower

yields. With iodine a brown solution was formed, which after evaporation to dryness and extraction with chloroform (in which the Pt<sup>III</sup> complex is only slightly soluble), gave blue (NBu<sub>4</sub>)[Pt(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>] (60% yield). With TiCl<sub>3</sub> [equation (2)], a blue solution was formed and the TiCl precipitated. Partial evaporation of the solution allowed separation of some of the Pt<sup>III</sup> complex (52% yield) from the co-soluble (NBu<sub>4</sub>)[TiCl<sub>4</sub>] complex.



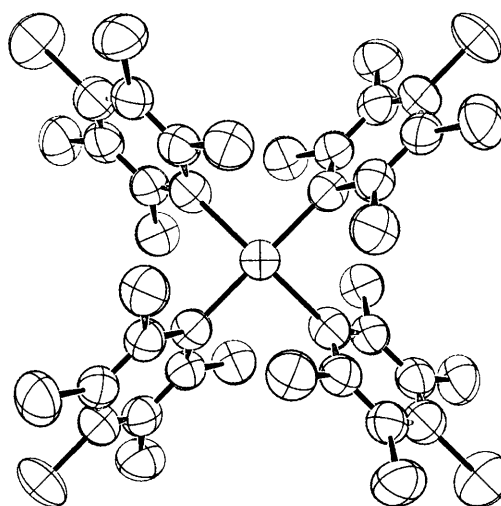
At room temperature (NBu<sub>4</sub>)[Pt(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>] is air- and moisture-stable, both as a solid and in solution. It melts (with decomposition) at 210 °C. In acetone solution it behaves as a 1:1 electrolyte (Λ<sub>m</sub> = 125 Ω<sup>-1</sup> cm<sup>2</sup> mol<sup>-1</sup>).<sup>4</sup> The i.r. spectrum of the compound (Nujol) shows the absorptions due to C<sub>6</sub>Cl<sub>5</sub> shifted 10–15 cm<sup>-1</sup> towards higher energies relative to the corresponding ones of the Pt<sup>II</sup> parent complex (NBu<sub>4</sub>)<sub>2</sub>[Pt(C<sub>6</sub>Cl<sub>5</sub>)<sub>4</sub>]. A single absorption at 830 cm<sup>-1</sup> (X-sensitive mode<sup>5</sup>) along with another at 602 cm<sup>-1</sup> [assignable to ν(Pt–C)<sup>6</sup>] are in agreement with the square-planar



**Figure 1.** The molecular geometry of the  $[\text{Pt}(\text{C}_6\text{Cl}_5)_4]^-$  anion in the  $\text{Pt}^{\text{III}}$  complex  $(\text{NBu}_4)[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$ . Average Pt-C, C-C, and C-Cl distances in the anion are 2.094(8), 1.388(12), and 1.725(9) Å, respectively.

symmetry of the anion ( $D_{4h}$ ,  $E_u$  mode). The  $\text{Pt}^{\text{III}}$  compound is paramagnetic: two independent magnetic susceptibility measurements<sup>7</sup> yield  $\mu_{\text{eff}}$  2.4–2.5  $\mu_{\text{B}}$  at low temperature ( $T = 6$ –80 K), consistent with a spin 1/2 system with a large orbital contribution. This observation is also consistent with a  $d^7$  electronic configuration for the  $[\text{Pt}(\text{C}_6\text{Cl}_5)_4]^-$  anion.

The crystal structures of both  $(\text{NBu}_4)[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$  (Figure 1)<sup>†</sup> and its parent complex  $(\text{NBu}_4)_2[\text{Pt}(\text{C}_6\text{Cl}_5)_4] \cdot 2\text{CH}_2\text{Cl}_2$  (Figure 2)<sup>†</sup> show virtually identical square-planar geometries. The average Pt-C, C-C, and C-Cl distances, and interatomic angles of the two anions, all agree within experimental error. {For  $(\text{NBu}_4)[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$ , Pt-C 2.094(8), C-C 1.388(12), C-Cl 1.725(9) Å; for  $(\text{NBu}_4)_2[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$ , Pt-C 2.086(14), C-C 1.393(16), C-Cl 1.731(12) Å.} Even the average tilt angles (*i.e.*, the angles between the  $\text{C}_6\text{Cl}_5$  rings and the central PtC<sub>4</sub> square plane) are essentially the same: 63.0° for the dark-blue  $\text{Pt}^{\text{III}}$  anion,  $[\text{Pt}(\text{C}_6\text{Cl}_5)_4]^-$  (Figure 1), and 63.1° for the pale yellow (nearly colourless)  $\text{Pt}^{\text{II}}$  precursor,  $[\text{Pt}(\text{C}_6\text{Cl}_5)_4]^{2-}$  (Figure 2). The  $[\text{Pt}(\text{C}_6\text{Cl}_5)_4]^-$  anions in the crystal structure of  $(\text{NBu}_4)[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$  are widely separated



**Figure 2.** The molecular geometry of the  $[\text{Pt}(\text{C}_6\text{Cl}_5)_4]^{2-}$  anion in the  $\text{Pt}^{\text{II}}$  complex  $(\text{NBu}_4)_2[\text{Pt}(\text{C}_6\text{Cl}_5)_4] \cdot 2\text{CH}_2\text{Cl}_2$ . Note that this is essentially identical to that of the  $\text{Pt}^{\text{III}}$  complex shown in Figure 1. Average Pt-C, C-C, and C-Cl distances in this anion are 2.086(14), 1.393(16), and 1.731(12) Å, respectively.

and show no evidence for the presence of  $\text{Pt} \cdots \text{Pt}$  stacking interactions (the closest  $\text{Pt} \cdots \text{Pt}$  distance is 9.7 Å).

Both the dark blue (almost black) crystals and the solutions of  $(\text{NBu}_4)[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$  show notable stability, which is probably unique to the  $\text{C}_6\text{Cl}_5$  ligand since oxidation with halogens of other  $[\text{Pt}^{\text{II}}\text{X}_4]^{2-}$  precursors did not lead to similar  $\text{Pt}^{\text{III}}$  complexes. A steric shielding of the  $\text{Pt}^{\text{III}}$  atom by the bulky  $\text{C}_6\text{Cl}_5$  ligands cannot be invoked since the geometries of the  $\text{Pt}^{\text{II}}$  and  $\text{Pt}^{\text{III}}$  complexes are virtually identical. However, a steric barrier could be responsible for the lack of any observable dimerisation and therefore for the paramagnetic behaviour of the complex.

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<sup>†</sup> Crystal data for  $(\text{NBu}_4)[\text{Pt}(\text{C}_6\text{Cl}_5)_4]$ ,  $\text{C}_{40}\text{H}_{36}\text{Cl}_{20}\text{NPt}$ ,  $M = 1434.88$ , triclinic, space group  $P1$  (No. 2),  $a = 9.747(8)$ ,  $b = 16.170(8)$ ,  $c = 17.675(8)$  Å,  $\alpha = 104.95(3)$ ,  $\beta = 92.09(5)$ ,  $\gamma = 77.67(5)^\circ$ ,  $U = 2629(2)$  Å<sup>3</sup>,  $D_c = 1.79$  g cm<sup>-3</sup>,  $Z = 2$ . X-Ray data were collected on a Nicolet/Syntex P21 diffractometer using  $\text{Mo-K}\alpha$  radiation. The structure was solved by standard heavy-atom techniques and refined to a final  $R$  factor of 3.3% for 4786 reflections.  $(\text{NBu}_4)_2[\text{Pt}(\text{C}_6\text{Cl}_5)_4] \cdot 2\text{CH}_2\text{Cl}_2$ ,  $\text{C}_{58}\text{H}_{76}\text{Cl}_{24}\text{N}_2\text{Pt}$ ,  $M = 1847.22$ , tetragonal, space group  $P4/nnc$  (No. 126),  $a = b = 14.407(6)$ ,  $c = 19.929(8)$  Å,  $U = 4135(3)$  Å<sup>3</sup>,  $D_c = 1.49$  g cm<sup>-3</sup>,  $Z = 2$ . X-Ray data were collected as in the previous case, and the structure refined to a final  $R$  factor of 4.6% for 951 reflections. The structure determination of this compound was complicated by disorder effects, not only in the *n*-butyl groups of the cations but also in the  $\text{CH}_2\text{Cl}_2$  molecules of crystallization. The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Laboratory, Lensfield Road, Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.