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# Synthesis and Characterization of Platinum(II) Complexes with a Diazenecarboxamide-Appended Picolyl-Triazole Ligand

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**Keywords:** Platinum / N ligands / Chelates / Click chemistry

The coordination of the diazenecarboxamides, which were functionalized with the 1-(2-picolyl)-1*H*-1,2,3-triazole moiety **1**, to platinum(II) were studied, where $K_2[PtCl_4]$ and *cis*-$[PtCl_2(DMSO)_2]$ were used as the platinum sources. The picolyl-triazole (pictri) binding unit enabled chelation to the metal centre through the 1,2,3-triazole N2 and the pyridyl nitrogen atoms under mild reaction conditions. When *cis*-$[PtCl_2(DMSO)_2]$ was used, with $CH_2Cl_2$ or $CH_3CN$ as the reaction solvents, the pure, stable diamminedichloridoplatinum(II) complexes **2** were isolated by filtration in 39 to 83 % yield. The products were structurally characterized in solution by $^1H$, $^{13}C$ and $^{195}Pt$ NMR spectroscopy. The $^{195}Pt$ NMR chemical shifts for **2** appear in the region of –2203 to –2207 ppm. The structure of complex **2a** was confirmed by single-crystal X-ray crystallography. The formation of the platinum complexes **2** was monitored using NMR spectroscopy. The complexation with *cis*-$[PtCl_2(DMSO)_2]$ in $[D_7]$dmf proceeded through several intermediates, as indicated by the $^{195}Pt$ NMR spectra with resonances in the range of –3055 to –2907 ppm. Similarly, the reaction of *cis*-$[PtCl_2(DMSO)_2]$ with diazenecarboxamide, which was functionalized with the nonchelating 1-(2-aminoethyl)-1,2,3-triazole derivative, was examined by NMR spectroscopy.

## Introduction

Cisplatin [*cis*-diamminedichloridoplatinum(II)] is approved by the FDA to be used by itself or in combination with other drugs to treat bladder, ovarian, testicular, cervical and non-small-cell lung cancers, as well as squamous cell carcinoma and malignant mesothelioma.[1–3] Despite its high cure rates, there are several problems associated with cisplatin, which include the resistance that the tumour cells acquire after the initial treatment. Drug resistances are multifunctional processes[4] and it has been suggested that glutathione (GSH) and glutathione-S-transferase (GST) constitute the cellular defence.[5,6] To address this issue, cisplatin analogues that have bioactive carrier ligands that target GSH or GST have been developed.[7] This emerging approach is based on a multifunctional strategy, that is, the design of single chemical entities that are able to simultaneously modulate multiple targets.[8]

Our interest in exploring the oxidation of intracellular thiols has led to diazenecarboxamides, which can be abbreviated as diazenes.[9,10] We have shown that diazenes can decrease the intracellular GSH concentration and inhibit the growth of different tumour-cell lines.[11,12] These compounds also reduced the survival of cisplatin-resistant sublines and, in a combined treatment, acted synergistically with cisplatin.[10] Besides their GSH-depleting activity, some of the diazenes also activated alternative cell-death pathways.[11] Encouraged by the biological activity of diazenes and inspired by the recent advances in copper-catalyzed azide-alkyne 1,3-dipolar cycloaddition ("click chemistry"), we were prompted to design and synthesize a family of diazenes that were functionalized with the 1-(2-picolyl)-1*H*-1,2,3-triazole moiety (Figure 1).[13,14] We anticipated that this moiety would serve as a novel picolyl-triazole (pictri) ligand to platinum, since it offers a bidentate chelating system that involves the N2 atom of the 1,2,3-triazole ring and the pyridine nitrogen atom.

The potential of the triazole-containing ligands prepared by click chemistry is currently being extensively studied.[15] Recently, compounds that contain the pictri binding moiety have been explored as powerful click chelators for transition-metal ions.[16–18] By using a model compound, we have experimentally and theoretically explored the chelation of the pictri unit to $Cu^{II}$, $Ru^{II}$, $Pd^{II}$, $Ag^{I}$ and $Pt^{II}$.[17] In all of the above instances the chelation involved both the triazole N2 and the picolyl nitrogen atoms and formed a six-membered metallacycle, which was revealed by X-ray structural analysis.

We decided to explore the coordination properties of the pictri ligand, which was functionalized with diazenes, as part of our interest in the synthesis of organic-inorganic conjugates that have some potential in terms of biological activity.[19,20] Two different linkers were selected as the connectors between the diazene moiety and the pictri ligand: those that have an aromatic structure (Figure 1, a) and

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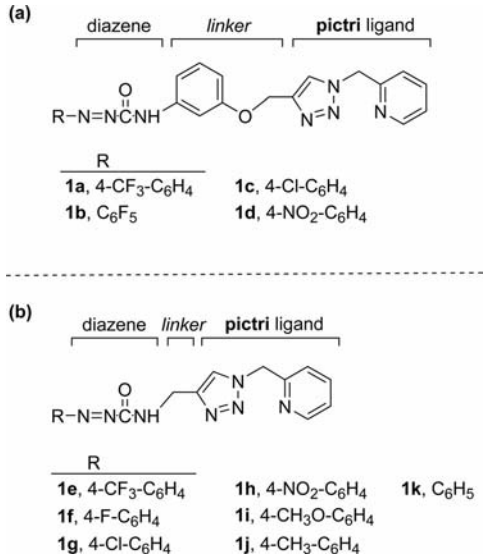


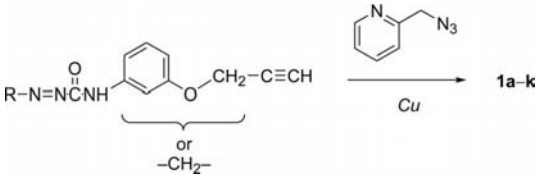

Figure 1. The diazene-appended pictri ligands with (a) an aromatic structure and (b) an aliphatic structure for the linker.

those that have an aliphatic structure (Figure 1, b). Various substituted phenyl rings were selected for R since the oxidative properties[9,10] of the diazenes depend on the electronic nature of the group attached directly to the –N=N– moiety. Our choice of the pictri ligand was also motivated by the literature reports on platinum complexes with 1,2,3-triazole[21] and pyridine,[2] as well as with those with di-2-pyridylmethane,[22] all of which exhibit cytotoxic properties.

## Results and Discussion

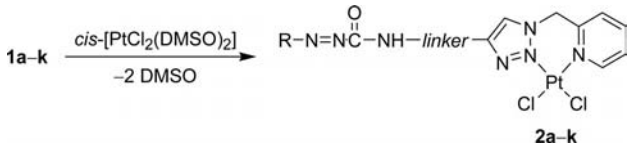
### Synthesis and Characterization

The diazene-modified pictri ligands selected for this study were easily prepared from the appropriate propargyl-appended diazenes and picolylazide by copper-catalyzed azide-alkyne 1,3-dipolar cycloaddition (click chemistry), as previously reported (Scheme 1).[13,14]




Scheme 1. The synthesis of ligands **1a**–**k**.

A general and convenient synthetic route to platinum(II) complexes involved *cis*-[$PtCl_2(DMSO)_2$] as the platinum source.[23,24] After stirring **1a**–**k** with one equivalent of *cis*-[$PtCl_2(DMSO)_2$] in $CH_2Cl_2$ or $CH_3CN$ for 1 to 8 d, the analytically pure products **2a**–**k** precipitated from the reaction mixtures and were isolated in 39 to 83% yield (Scheme 2, Table 1). In addition to $CH_2Cl_2$ and $CH_3CN$, EtOAc and acetone were also tested, but the first two solvents afforded the best results in terms of the chemical yield and the purity of the products **2a**–**k**.




Scheme 2. The synthesis of **2a**–**k** from **1a**–**k** and *cis*-[$PtCl_2(DMSO)_2$] in $CH_2Cl_2$ or $CH_3CN$ at room temperature. For details see Table 1.

Table 1. The synthesis of the platinum(II) complexes **2a**–**k** from the diazene-conjugated pictri ligands (**1a**–**k**) and *cis*-[$PtCl_2(DMSO)_2$].

| Entry | Solvent | Time (days) | Prod. | R | Yield (%)[a] | δ $^{195}$Pt (ppm)[b] |
|---|---|---|---|---|---|---|
| Analogues with the aryl linker | | | | | | |
| 1 | $CH_2Cl_2$ | 3 | **2a** | 4-$CF_3$-$C_6H_4$ | 56 | –2207 |
| 2 | $CH_2Cl_2$ | 3 | **2b** | $C_6F_5$ | 83 | –2206 |
| 3 | $CH_2Cl_2$ | 1 | **2c** | 4-Cl-$C_6H_4$ | 39 | –2206 |
| 4 | $CH_2Cl_2$ | 3 | **2d** | 4-$NO_2$-$C_6H_4$ | 79 | –2207 |
| Analogues with the alkyl linker | | | | | | |
| 5 | $CH_3CN$ | 8 | **2e** | 4-$CF_3$-$C_6H_4$ | 51 | –2203 |
| 6 | $CH_3CN$ | 8 | **2f** | 4-F-$C_6H_4$ | 51 | –2203 |
| 7 | $CH_3CN$ | 6 | **2g** | 4-Cl-$C_6H_4$ | 55 | –2203 |
| 8 | $CH_2Cl_2$ | 8 | **2h** | 4-$NO_2$-$C_6H_4$ | 63 | –2204 |
| 9 | $CH_3CN$ | 8 | **2i** | 4-$CH_3$-$C_6H_4$ | 54 | –2203 |
| 10 | $CH_3CN$ | 8 | **2j** | 4-$CH_3O$-$C_6H_4$ | 69 | n.d.[c] |
| 11 | $CH_3CN$ | 8 | **2k** | $C_6H_5$ | 46 | n.d.[c] |

[a] Isolated pure product. [b] Measured in [$D_7$]dmf. [c] Not determined because of insufficient solubility.

Major changes in the $^1$H NMR spectra were observed for the resonances of the proton *ortho* to the nitrogen atom of the pyridine ring, the proton of the triazole unit and the bridging methylene protons of the picolyl group upon the coordination of **1a**–**k** to platinum(II) and the formation of **2a**–**k**. All of these signals shifted downfield (vide infra). The chemical shifts of the protons for group R, the diazene moiety and the linker remained virtually unchanged. For all of the products **2**, the geminal picolyl methylene protons resonated as a singlet, which suggested dynamic behaviour for the six-membered metallacycle that makes them equivalent on the NMR time scale. The $^{195}$Pt NMR chemical shifts for compounds **2a**–**i** appeared in the region of –2203 to –2207 ppm (Table 1). The downfield shift for the above-mentioned proton resonances and the $^{195}$Pt NMR chemical shifts are consistent with the literature reports for the platinum(II) coordination of the model pictri ligand.[17,18] NMR spectra could not be obtained for compounds **2j**–**k** because of insufficient solubility of the complexes. The complexes were further characterized by electrospray ionization mass spectrometry and micro-analysis.

The ligands (**1**) are red to yellow in colour because of the presence of the diazene moiety. The colour does not significantly change upon coordination to platinum(II). The UV/Vis spectra for complexes **2a** and **2e**, along with those of ligands **1a** and **1e**, were recorded in a dmf solution (Figures S1 and S2 in the Supporting Information). The corresponding complexes show strong absorptions at 280 to 300 nm in comparison to the absorptions for the ligands. Similar behaviour has been documented for 1-(2-picolyl)-4-phenyl-1*H*-1,2,3-triazole.[17,18]

Unfortunately, complexes **2a**–**k** were insoluble in water and in most common organic solvents, with the exception of *N*,*N*-dimethylformamide (dmf) and dimethyl sulfoxide (dmso). In deuterated *N*,*N*-dimethylformamide ([$D_7$]dmf) solutions, compounds **2a**–**k** were stable for several weeks. When **2a** was dissolved in deuterated dimethyl sulfoxide ([$D_6$]dmso) a rapid (within 24 h) ligand-exchange reaction took place with the formation of an uncoordinated pictri ligand, which was confirmed by $^1$H NMR spectroscopy. The propensity of dmso to interact with platinum(II) by ligand-substitution reactions has been documented.[18,25]

## X-ray Crystal Structure

In general, it proved extremely difficult to grow crystals for the complexes **2a**–**k** that were suitable for crystallographic studies, and only in one instance – that of **2a** – were we successful. Compound **2a** crystallized from boiling acetonitrile as monosolvate **2a**·$CH_3CN$ (see Exp. Section). The result of the single-crystal X-ray analysis confirmed the structural prediction depicted in Scheme 2.

The molecular structure for **2a** with selected bond lengths and angles is displayed in Figure 2. Ligand **1a** adopted a bidentate coordination mode through the triazole N2 atom and the nitrogen atom of the pyridine and formed a six-membered chelate ring, which adopted a boat-like conformation. The coordination at the platinum(II) centre is essentially square-planar. The largest deviation from the best plane that contained the coordination sphere is found for N2, which is 0.0670(12) Å out of the plane. The bond lengths for the coordination sphere are comparable to those found in other square-planar complexes of platinum(II).[26a] The sum of the platinum-containing angles equal 360°, with only minor deviations from the ideal 90° for the L–Pt–L (L = N, Cl) bond angles.

The only noteworthy intra- or intermolecular interactions in the solid state of **2a**·$CH_3CN$ that the crystal structure revealed was the presence of the intermolecular C–H···Pt contacts (Figure 3). In the boat conformation adopted by the six-membered chelate, the hydrogen atom (H6A) of the methylene carbon is oriented towards the platinum(II) centre of the contiguous molecule **2a**$^i$ and has a Pt···H distance of 2.699 Å and a C–H–Pt angle of 155.2°. Thus, in the solid state the two molecules are stabilized by a pair of intermolecular C–H···Pt contacts that form discrete associations. To the best of our knowledge, only a few similar examples of the intermolecular C–H···Pt interactions are found in the literature.[26b]

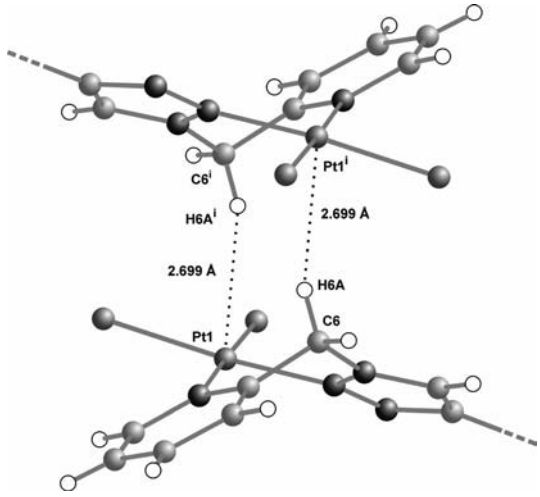



Figure 3. A diagram showing the intermolecular C–H···Pt interactions in **2a**·$CH_3CN$ [symmetry code: (i) $-x + 1$, $-y$, $-z + 1$].

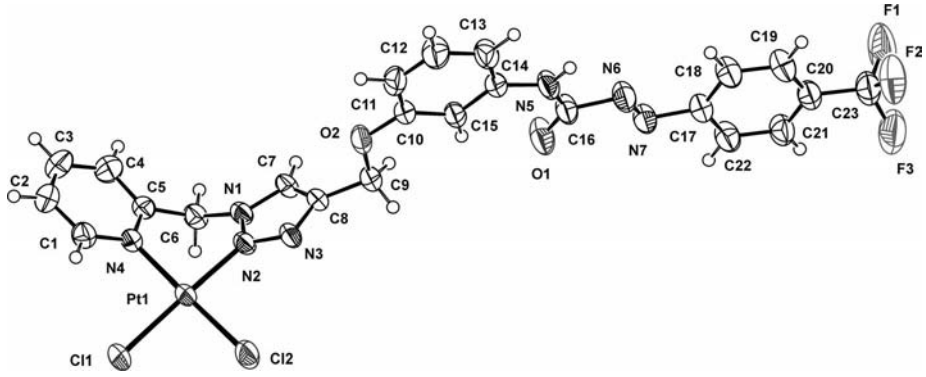


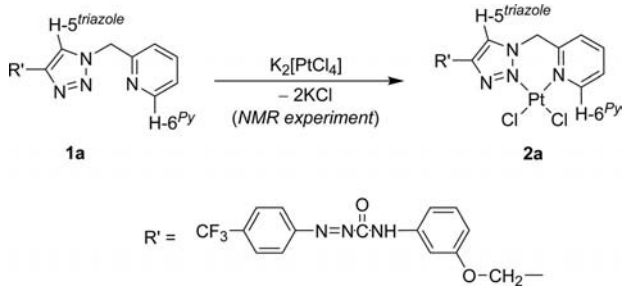

Figure 2. The ORTEP plot of **2a** from the X-ray crystal structure with the thermal ellipsoids at a 50% probability for the non-H atoms and open circles for H-atoms. The hydrogen atoms are not labelled. Selected bond lengths [Å]: Pt1–N2 2.005(3), Pt1–N4 2.040(3), Pt1–Cl1 2.2838(9), Pt1–Cl2 2.2899(8). Selected bond angles [°]: N2–Pt1–N4 89.30(10), N2–Pt1–Cl1 89.72(8), N2–Pt1–Cl2 175.34(8), N4–Pt1–Cl1 178.26(8), N4–Pt1–Cl2 90.75(8), Cl1–Pt1–Cl2 90.34(3).

### Monitoring the Coordination by NMR Spectroscopy

#### *The Reaction of the Pictri Ligand with $K_2[PtCl_4]$*

In our initial experiment directed towards the synthesis of **2**, the chelation of the pictri donor with $K_2[PtCl_4]$ as a platinum source was examined in an NMR spectroscopy experiment. A mixture of the selected ligand **1a** and $K_2[PtCl_4]$ (1.1 equiv.) was dissolved in a mixture of $[D_7]$dmf and $D_2O$ (7:4, v/v) at 60 °C in the presence of air (Scheme 3). The progress of the reaction was monitored at 60 °C by $^1$H NMR and $^{195}$Pt NMR spectroscopy. Within 3 h the $^1$H NMR spectra indicated an over 90% conversion of **1a** into a single product in which the resonances of the proton *ortho* to the nitrogen atom of the pyridine ring (H-$6^{Py}$), the proton of the triazole ring (H-$5^{triazole}$) and the bridging methylene protons (C$H_2$-Py) shifted downfield from 8.69, 8.54 and 5.94 ppm (in **1a**) to 9.31, 9.06 and 6.33 ppm, respectively (Figure 4). One $^{195}$Pt resonance was observed at $\delta$ = –2207 ppm, which is consistent with an $N_2Cl_2$ coordination environment.[27,28] These results, along with the fact that when **1a** was exposed to half an equiv. of $K_2[PtCl_4]$ in a similar experiment only half of **1a** was consumed, suggested bidentate platinum coordination for **2a** as shown in Scheme 3.




Scheme 3. The reaction of **1a** with $K_2[PtCl_4]$ to form **2a**, which was monitored by NMR spectroscopy (Figure 4).

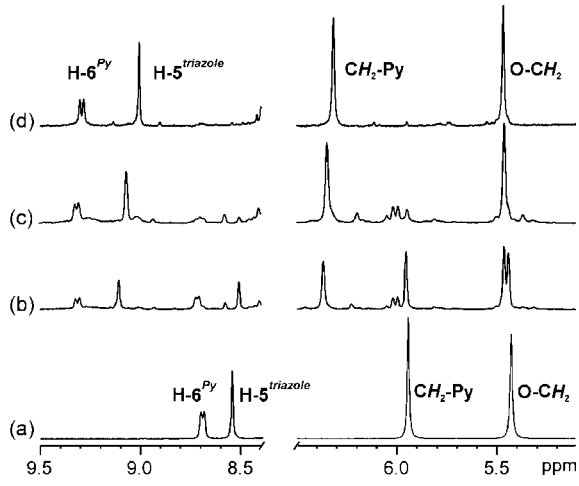
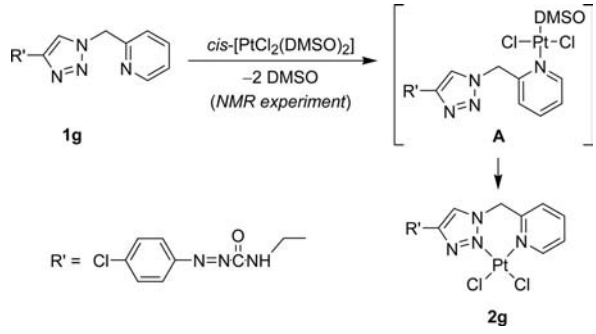



Figure 4. (a) Selected parts of the $^1$H NMR spectra of ligand **1a**. (b and c) The traces correspond to the reaction between **1a** (0.05 mmol) and $K_2[PtCl_4]$ (1.1 equiv.) in $[D_7]$dmf/$D_2O$ (0.7 mL/0.4 mL) at 60 °C after 1 h and 3 h, respectively. (d) The $^1$H NMR spectrum of an authentic sample of **2a**, which was independently prepared from **1a** and *cis*-$[PtCl_2(DMSO)_2]$ (see text).

Although $K_2[PtCl_4]$ has been extensively used for the preparation of different diamminedichloridoplatinum(II) chelates with bidentate ligands, including those that have a pictri structural unit,[18] this platinum source was less attractive for the preparation of **2a**–**k**. The desired complexation of **1a** to form **2a** was accompanied by the formation of unidentified byproducts as shown by traces b and c in Figure 4. The isolation of **2a** from the above NMR experiment by using solvent evaporation and/or precipitation with less-polar solvents gave impure material – attempts at purification of the latter by recrystallization failed and resulted in an even more complex mixture of products. This behaviour could be explained by the reactive nature of the diazene being incompatible with the specific reaction conditions used in the above NMR experiment. It is worth noting that the coordination of the diazene-appended propane-1,3-diamine ligand to platinum(II) with different platinum precursors and reaction conditions has also been reported to result in the decomposition of the ligand.[19]

#### *The Reaction of the Pictri Ligand with cis-$[PtCl_2(DMSO)_2]$*

In analogy to the above NMR experiment with $K_2[PtCl_4]$, a reaction between **1g** and *cis*-$[PtCl_2(DMSO)_2]$ (1 equiv.) was conducted in $[D_7]$dmf and monitored over several days by NMR spectroscopy (Scheme 4). In this case, overcrowded $^1$H NMR spectra with unresolved resonances were seen (data not shown), which indicated a complex transformation. The complexity of the reaction was illustrated by the $^{195}$Pt NMR spectroscopy (Figure 5). Within 20 min at 29 °C, compound **1g** was almost completely coordinated to the Pt centre, as is evident from the disappearance of the resonance at $\delta$ = –3466 ppm for *cis*-$[PtCl_2(DMSO)_2]$ and the concomitant appearance of the resonance at $\delta$ = –3050 ppm.




Scheme 4. The reaction of **1g** with *cis*-$[PtCl_2(DMSO)_2]$ to form **2g**, which was monitored by NMR spectroscopy (Figure 5).

The pictri donor can potentially offer three different nitrogen atoms for coordination to the metal, namely, N2 and N3 of the triazole unit and the pyridine nitrogen atom. Based on DFT calculations for 1-(2-picolyl)-4-phenyl-1*H*-1,2,3-triazole, the natural bonding orbital (NBO) charges follow the order N2 (–0.07) > N3 (–0.27) > pyridine nitro-

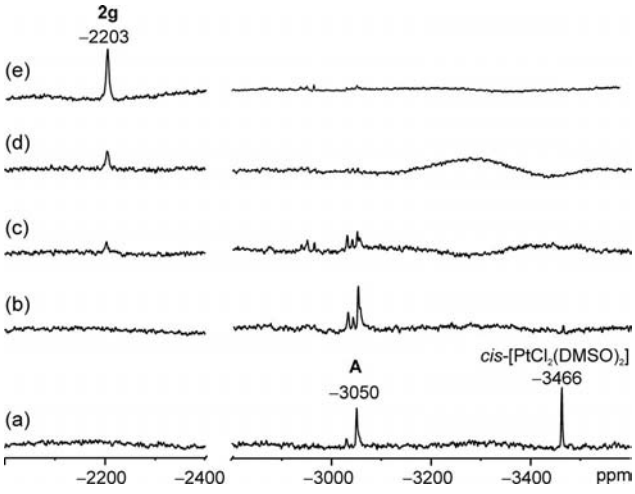
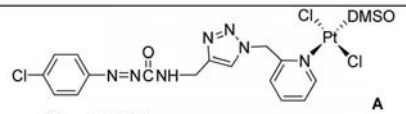
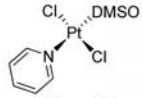
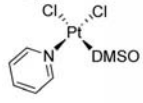
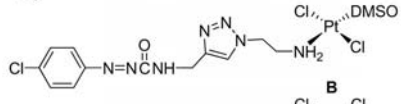
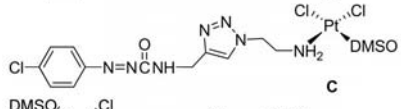
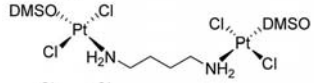
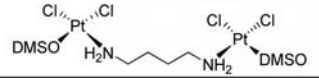



Figure 5. The course of the reaction between **1g** (0.1 mmol) and *cis*-[$PtCl_2(DMSO)_2$] (0.1 mmol) in [$D_7$]dmf (0.7 mL) at 29 °C was monitored by $^{195}$Pt NMR spectroscopy (Scheme 4). Only those parts of the spectra of interest are shown (from –2000 to –2400 ppm and from –2800 to –3600 ppm) after: (a) 2 min, (b) 20 min, (c) 1.5 d, (d) 4 d and (e) 17 d. The total spectral window measured spanned from –1800 to –4000 ppm.

gen atom (–0.48).[17] Thus, considering the fact that the pyridine nitrogen atom is a significantly more electron-rich donor, its participation in the initial monodentate coordination to form intermediate **A**, *trans*-[Pt(**1g**)$Cl_2$(DMSO)] (Scheme 4, Table 2, Entry 1), was assumed. This was supported by the literature reports that *cis*-[$PtCl_2(DMSO)_2$] reacts with sterically nondemanding heterocyclic nitrogen bases, L, to form *trans*-[$PtCl_2$(DMSO)L], which later isomerizes very slowly to the *cis* form.[29] The $^{195}$Pt NMR chemical shift of –3050 ppm (Table 2, Figure 5, a) also supported the proposed structure of the intermediate **A** as it is in good agreement with the chemical shift of –3023 ppm that was reported for *trans*-[$PtCl_2$(DMSO)(pyridine)], whereas the value for the *cis*- isomer is –2862 ppm (Table 2, Entries 2 and 3, respectively).[30] As evident from Figure 5, intermediate **A** quickly reacts to form a complex mixture of other unidentified intermediates that resonate in the range of –3055 to –2907 ppm. Over the course of several days the intensities of these resonances waned, while the peak at –2203 ppm that belongs to **2g** waxed. The isomerization of *trans*-[Pt(**1g**)$Cl_2$(DMSO)] (**A**) to the *cis*-isomer is expected from the reaction pathway, but its resonance in the $^{195}$Pt NMR spectra could not be identified.

Table 2. The structures and the $^{195}$Pt NMR spectroscopic data for some of the platinum(II) complexes.

| Entry | Structure | δ $^{195}$Pt (ppm)[a] |
|---|---|---|
| 1 |  | –3050[b] |
| 2 |  | –3023[c] |
| 3 |  | –2862[c] |
| 4 |  | –3129[b] |
| 5 |  | –3082[b] |
| 6 |  | –3102[d] |
| 7 |  | –3076[d] |

[a] Relative to $Na_2[PtCl_6]$. [b] This work (measured in [$D_7$]dmf). [c] Ref.[30] (measured in [$D_6$]dmso). [d] Ref.[31] (measured in [$D_6$]dmso).

## A Comparison between the 1-(2-Picolyl)-1,2,3-triazolyl and 1-(2-Aminoethyl)-1,2,3-triazolyl Ligands

The above results clearly demonstrate that 1,2,3-triazole, which is functionalized at position 1 with an appropriate pendant group (e.g. picolyl), can form stable chelates of platinum(II) with the triazole N2 atom being involved in the coordination. On the other hand, it has been previously reported that this is not the case for analogous compounds that have an aminoalkyl pendant group, as exemplified by 1-(2-aminoethyl)-1,2,3-triazole (**3**) (Figure 6).[21] The difference in the complexation affinity of the pyridyl versus the aminoalkyl functionalized triazoles has been recently addressed theoretically and was attributed to the distinct magnitude of the π-back-donation of the metal d electrons to the *anti*-bonding orbitals of the ligand.[17] In order to shed some light experimentally on the coordination of the 1-(2-aminoethyl)-1,2,3-triazole ligand to platinum(II), we reacted **4** (Figure 6), a closely related analogue of **1g**, with *cis*-[$PtCl_2(DMSO)_2$] in [$D_7$]dmf at 29 °C (Scheme 5). The progress of the reaction was monitored over several days by $^{195}$Pt NMR spectroscopy (Figure 7). An instant reaction was observed with the formation of a single species **B** resonating at $\delta$ = –3129 ppm, which later transformed very slowly into a new species **C** that showed a broad singlet at $\delta$ = –3082 ppm. Based on a similar consideration to that described above for intermediate **A**,[29] the structures of **B** and **C** were tentatively assigned to *trans*- and *cis*-[Pt(**4**)$Cl_2$(DMSO)], respectively. In these complexes compound **4** is monodentately coordinated to platinum(II) through the aminoalkyl nitrogen atom (Table 2, Entries 4 and 5, respectively). The $^{195}$Pt NMR chemical shifts and the line shape

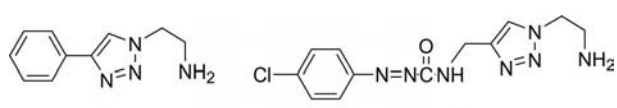
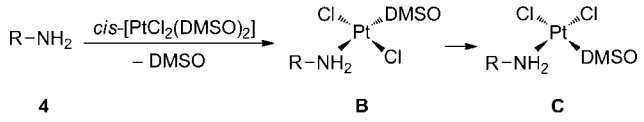


Figure 6. The structures of the 1-(2-aminoethyl)-1,2,3-triazolyl ligands **3** and **4**.

of the resonances for the *trans*- and *cis*-species, **B** and **C**, are consistent with those reported by Farrell and coworkers, who studied the isomerization of [*trans*-{$PtCl_2(DMSO)$}$_2NH_2(CH_2)_4NH_2$] to the dinuclear *cis*-derivative (Table 2, Entries 6 and 7).[28,31] Within 17 d no new $^{195}$Pt NMR peak appeared in the spectra, as shown in Figure 7. In comparison to the reaction with **1g** (vide supra), a remarkably clean reaction took place between *cis*-[$PtCl_2(DMSO)_2$] and ligand **4**, as can be inferred from the $^{195}$Pt NMR spectra.




4 B C

Scheme 5. The reaction of **4** with *cis*-[$PtCl_2(DMSO)_2$], which was monitored by NMR spectroscopy (Figure 7). For the complete structures of **B** and **C** see Table 2.

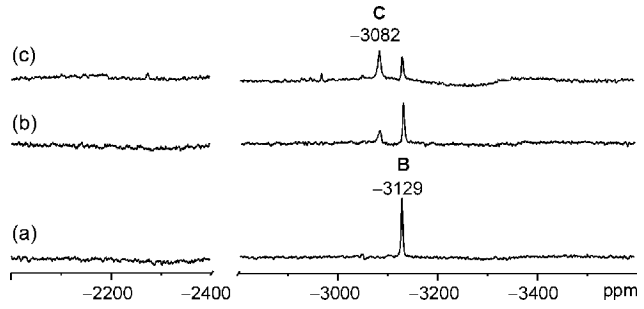



Figure 7. The course of the reaction (Scheme 5) between **4** (0.1 mmol) and *cis*-[$PtCl_2(DMSO)_2$] (0.1 mmol) in [$D_7$]dmf (0.7 mL) at 29 °C was monitored by $^{195}$Pt NMR spectroscopy. Only the parts of the spectra of interest are shown (from –2000 to –2400 ppm and from –2800 to –3600 ppm) after: (a) 2 min, (b) 1.5 d and (c) 17 d. The total spectral window measured spanned from –1800 to –4000 ppm.

All of the attempts to isolate species **B** and **C** failed, as illustrated by the following experiment: a mixture of **4** and *cis*-[$PtCl_2(DMSO)_2$] (1 equiv.) was stirred in $CH_2Cl_2$ in the presence of air for 20 min. During this time the reactants dissolved completely and formed a precipitate. As soon as the precipitate was collected by filtration it turned into a gummy, black material, which the $^1$H NMR spectral analysis indicated was a complex mixture of products. Unfortunately, these could not be identified.

## Conclusions

In continuation of our research on platinum(II) coordination with the model pictri ligand 1-(2-picolyl)-4-phenyl-1*H*-1,2,3-triazole,[17] we have applied this chemistry to more complex analogues, namely, pictri-appended diazenecarboxamides (**1**). We have demonstrated that the pictri unit in **1** allows bidentate coordination through the 1,2,3-triazole N2 and the pyridine nitrogen atom under mild reaction conditions to form stable diamminedichloridoplatinum(II) chelates (**2**). This is an important feature for reactive moieties such as diazenecarboxamides.[10,19] The coordination of **1** to platinum(II) was monitored by $^1$H and $^{195}$Pt NMR spectroscopy and indicated a complex reaction coordinate with the presence of several intermediates. Although some tentative explanations have been provided for a few of the observations, the in-depth mechanistic study of the platinum complexation by the pictri unit is beyond the scope of this work and will be the subject of another paper. The diamminedichloridoplatinum(II) structure of **2** was confirmed by single-crystal X-ray diffraction analysis for **2a**. Discrete associations were found in the solid state of **2a** where a pair of the complexes was stabilized by a pair of short intermolecular contacts (2.699 Å) between the methylene protons of the picolyl group and the platinum centre.

The work presented herein could easily be adopted in the synthesis of other organic-inorganic conjugates of widespread interest owing to the mild and selective chemistry required for the introduction of the picolyl-triazole binding unit into the organic compounds and its affinity for several metal ions.

## Experimental Section

**General:** The reagents and solvents were used as purchased from Fluka, Aldrich or Alfa Aesar. Ligands **1a**–**d**,[13] **1e**–**k**,[14] 1-(2-aminoethyl)-4-phenyl-1*H*-1,2,3-triazole (**3**)[14] and *N*-{[1-(2-aminoethyl)-1*H*-1,2,3-triazol-4-yl]methyl}-2-(4-chlorophenyl)diazenecarboxamide (**4**),[14] as well as *cis*-[$PtCl_2(DMSO)_2$],[23] were prepared by known procedures. The NMR spectra were recorded at 302 K (unless otherwise indicated) with a Bruker Avance DPX 300 spectrometer operating at 300 MHz, 282 MHz, 75 MHz and 64 MHz for $^1$H, $^{19}$F, $^{13}$C and $^{195}$Pt, respectively. The $^1$H and $^{13}$C NMR spectra were referenced with respect to TMS as the internal standard. Some of the $^{13}$C NMR chemical shifts were determined relative to the upfield $^{13}$C NMR signal of the solvent [$D_7$]dmf at $\delta$ = 30.1 ppm. The $^{195}$Pt and $^{19}$F NMR spectra were referenced with respect to $Na_2[PtCl_6]$ (325 mg/0.65 mL $D_2O$, $T$ = 302 K)[32] and $CCl_3F$ as the external standards, respectively, at $\delta$ = 0 ppm. The $^{195}$Pt NMR spectra were recorded with a 75 kHz spectral width, 1000–70000 number of scans and a relaxation delay of 0.02 s between the acquisitions. A line broadening of 100 Hz was applied. The chemical shifts are given on the $\delta$ scale (ppm). The coupling constants ($J$) are given in Hertz. The multiplicities are indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet) and br (broadened). The high-resolution mass spectra were obtained with a Q-TOF Premier instrument. The infrared spectra were recorded with a BIO-RAD Excalibur Series spectrophotometer by using samples in potassium bromide disks. The far infrared spectra were recorded with a Perkin–Elmer System 2000 FTIR spectrophotometer by using samples in nujol. The UV/Vis spectra were recorded with a Varian Cary 50 UV/Vis Spectrophotometer. The elemental analyses (C, H, N) were performed with a Perkin–Elmer 2400 Series II CHNS/O Analyzer. The melting points were determined with a Kofler block.

**The NMR Spectroscopy Experiment for the Reaction of 1a with $K_2[PtCl_4]$ to form 2a:** Compound **1a** (24.1 mg, 0.050 mmol) was dissolved in a mixture of [$D_7$]dmf (0.7 mL) and $D_2O$ (0.4 mL) in an NMR tube and the $^1$H NMR spectrum was recorded (Figure 4, a). $K_2[PtCl_4]$ (22.8 mg, 0.055 mmol) was added and the reaction was monitored at 60 °C by $^1$H NMR spectroscopy (Figure 4, b and c) and by $^{195}$Pt NMR spectroscopy.

**The Synthesis and Characterization of Dichloridoplatinum(II) Complexes 2a–k**

**General Procedure:** Ligand **1** (0.30 mmol) and *cis*-[$PtCl_2(DMSO)_2$] (126.7 mg, 0.30 mmol) were mixed in dichloromethane (0.5 mL) or acetonitrile (1.5 mL) as indicated in Table 1. The reactants were completely dissolved after 1 h of stirring at room temperature. The reaction was stirred in the dark for the time indicated in Table 1. The precipitate was filtered off and washed with dichloromethane (0.5 mL) or acetonitrile (0.5 mL) and dried to give the analytically (CHN and NMR) pure complex **2**. The yields are given in Table 1. The NMR spectral and analytical data for **2** are listed below.

**Complex 2a:** Red solid, m.p. 201–203 °C. $^1$H NMR (300 MHz, [$D_7$]dmf): $\delta$ = 5.32 (s, 2 H, $CH_2$), 6.31 (s, 2 H, $CH_2$), 6.96 (dd, $J$ = 1.8, 8.0 Hz, 1 H, Ar-H), 7.39 (dd, $J$ = 8.1, 8.1 Hz, 1 H, Ar-H), 7.47 (br. d, $J$ = 8.4 Hz, 1 H, Ar-H), 7.60 (br. s, 1 H, Ar-H), 7.72 (dd, $J$ = 6.1, 6.1 Hz, 1 H, Ar-H), 7.97 (br. d, $J$ = 7.2 Hz, 1 H, Ar-H), 8.09 (d, $J$ = 8.6 Hz, 2 H, Ar-H), 8.15 (d, $J$ = 8.6 Hz, 2 H, Ar-H), 8.28 (ddd, $J$ = 1.4, 7.7, 7.7 Hz, 1 H, Ar-H), 8.97 (s, 1 H, triazole-H), 9.28 (br. d, $J$ = 4.9 Hz, 1 H, Ar-H), 11.07 (br. s, 1 H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 55.5, 61.7, 107.1, 111.0, 113.2, 124.5, 124.7 (q, $J$ = 273.0 Hz), 127.3, 127.4, 127.7 (q, $J$ = 3.8 Hz), 129.4, 130.8, 133.7 (q, $J$ = 23.2 Hz), 140.1, 141.3, 145.8, 151.4, 154.3, 154.4, 159.3, 160.4 ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2207 ppm. IR (KBr): $\tilde{\nu}$ = 3301, 1724, 1601, 1487, 1420, 1321, 1159, 1123, 1062, 849, 780, 687 $cm^{-1}$. IR (nujol): $\tilde{\nu}$ = 344 (Pt–Cl stretching) $cm^{-1}$. HRMS (ESI) calcd. for $C_{23}H_{19}{}^{35}Cl_2F_3N_7O_2{}^{194}Pt^+$ ([M + H]$^+$): 746.0556; found 746.0589. $C_{23}H_{18}Cl_2F_3N_7O_2Pt$ (747.41): calcd. C 36.96, H 2.43, N 13.12; found C 36.63, H 2.45, N 12.84.

**Crystallization of 2a (2a·$CH_3CN$):** Compound **2a** (160.0 mg) was dissolved in boiling acetonitrile (400 mL). The solution was filtered, cooled to room temperature and the solvent slowly evaporated over several weeks to approximately 100 mL. The yellow-orange crystals of **2a**·$CH_3CN$ (106.1 mg, 63% from **2a**) were collected by filtration: m.p. >350 °C. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2207 ppm. $C_{23}H_{18}Cl_2F_3N_7O_2Pt{\cdot}CH_3CN$ (788.47): calcd. C 38.08, H 2.68, N 14.21; found C 38.32, H 2.90, N 14.34.

**Complex 2b:** Orange solid, m.p. 240–243 °C. $^1$H NMR (300 MHz, [$D_7$]dmf): $\delta$ = 5.32 (s, 2 H, $CH_2$), 6.31 (s, 2 H, $CH_2$), 6.98 (dd, $J$ = 1.8, 8.0 Hz, 1 H, Ar-H), 7.39 (dd, $J$ = 8.1, 8.1 Hz, 1 H, Ar-H), 7.49 (br. d, $J$ = 8.0 Hz, 1 H, Ar-H), 7.60 (br. s, 1 H, Ar-H), 7.71 (dd, $J$ = 6.6, 6.6 Hz, 1 H, Ar-H), 7.96 (br. d, $J$ = 7.6 Hz, 1 H, Ar-H), 8.28 (ddd, $J$ = 1.4, 7.7, 7.7 Hz, 1 H, Ar-H), 8.96 (s, 1 H, triazole-H), 9.28 (br. d, $J$ = 5.7 Hz, 1 H, Ar-H), 11.37 (br. s, 1 H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 55.5, 61.8, 107.3, 111.4, 113.4, 127.3, 127.4, 127.5 (br), 129.4, 130.8, 137.3 (br), 140.0, 140.8 (br), 141.3, 144.3 (br), 145.8, 151.5, 154.4, 159.1, 159.4 ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2206 ppm. IR (KBr): $\tilde{\nu}$ = 3515, 3414, 3151, 1730, 1607, 1519, 1490, 1400, 1223, 1159, 1136, 1028, 974, 771 $cm^{-1}$. HRMS (ESI$^+$) calcd. for $C_{22}H_{14}{}^{35}Cl_2F_5N_7NaO_2{}^{194}Pt^+$ ([M + Na]$^+$): 790.0031; found 790.0034. $C_{22}H_{14}Cl_2F_5N_7O_2Pt$ (769.37): calcd. C 34.34, H 1.83, N 12.74; found C 34.04, H 2.06, N 12.36.

**Complex 2c:** Orange solid, m.p. 229–232 °C. $^1$H NMR (300 MHz, [$D_7$]dmf): $\delta$ = 5.31 (s, 2 H, $CH_2$), 6.32 (s, 2 H, $CH_2$), 6.94 (br. d, $J$ = 6.5 Hz, 1 H, Ar-H), 7.37 (dd, $J$ = 8.1, 8.1 Hz, 1 H, Ar-H), 7.48 (br. d, $J$ = 8.4 Hz, 1 H, Ar-H), 7.61 (br. s, 1 H, Ar-H), 7.67–7.81 (m, 3 H, Ar-H), 7.93–8.05 (m, 3 H, Ar-H), 8.28 (dd, $J$ = 7.2, 7.2 Hz, 1 H, Ar-H), 8.98 (s, 1 H, triazole-H), 9.27 (br. d, $J$ = 5.4 Hz, 1 H, Ar-H), 10.98 (br. s, 1 H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 55.5, 61.8, 107.1, 110.9, 113.2, 125.6, 127.3, 127.4, 129.4, 130.6, 130.7, 139.4, 140.4, 141.3, 145.8, 150.8, 151.5, 154.4, 159.3, 160.6 ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2206 ppm. IR (KBr): $\tilde{\nu}$ = 3420, 3119, 1727, 1608, 1490, 1189, 1156, 1088, 842, 771 $cm^{-1}$. HRMS (ESI$^+$) calcd. for $C_{22}H_{18}{}^{35}Cl_3N_7NaO_2{}^{194}Pt^+$ ([M + Na]$^+$): 734.0112; found 734.0139. $C_{22}H_{18}Cl_3N_7O_2Pt$ (713.86): calcd. C 37.01, H 2.54, N 13.73; found C 37.24, H 2.17, N 13.34.

**Complex 2d:** Orange solid, m.p. 206–210 °C. $^1$H NMR (300 MHz, [$D_7$]dmf): $\delta$ = 5.32 (s, 2 H, $CH_2$), 6.32 (s, 2 H, $CH_2$), 6.97 (br. d, $J$ = 8.0 Hz, 1 H, Ar-H), 7.39 (dd, $J$ = 8.1, 8.1 Hz, 1 H, Ar-H), 7.48 (br. d, $J$ = 8.2 Hz, 1 H, Ar-H), 7.61 (br. s, 1 H, Ar-H), 7.73 (br. dd, $J$ = 6.3 Hz, 1 H, Ar-H), 7.98 (d, $J$ = 7.5 Hz, 1 H, Ar-H), 8.18 (d, $J$ = 8.9 Hz, 2 H, Ar-H), 8.29 (br. dd, $J$ = 7.7 Hz, 1 H, Ar-H), 8.57 (d, $J$ = 8.9 Hz, 2 H, Ar-H), 8.97 (br. s, 1 H, triazole-H), 9.28 (br. d, $J$ = 5.3 Hz, 1 H, Ar-H), 11.11 (br. s, 1 H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 55.5, 61.8, 107.1, 111.1, 113.2, 124.8, 125.9, 127.3, 127.4, 129.4, 130.8, 140.1, 141.3, 145.8, 150.9, 151.5, 154.4, 155.3, 159.4, 160.2, 163.1 ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]-dmf): $\delta$ = –2207 ppm. IR (KBr): $\tilde{\nu}$ = 3449, 1725, 1609, 1525, 1346, 1193, 1159, 864, 767 $cm^{-1}$. HRMS (ESI$^-$) calcd. for $C_{22}H_{17}N_8O_4{}^{35}Cl_2{}^{194}Pt^-$ ([M – H]$^-$): 721.0377; found 721.0365. $C_{22}H_{18}Cl_2N_8O_4Pt$ (724.41): calcd. C 36.48, H 2.50, N 15.47; found C 36.87, H 2.16, N 15.09.

**Complex 2e:** Orange solid, m.p. >300 °C. $^1$H NMR (300 MHz, [$D_7$]dmf): $\delta$ = 4.73 (d, $J$ = 6.0 Hz, 2 H, $CH_2$), 6.29 (s, 2 H, $CH_2$), 7.72 (dd, $J$ = 6.1 Hz, 1 H, Ar-H), 7.95 (d, $J$ = 7.3 Hz, 1 H, Ar-H), 8.05 (s, 4 H, Ar-H), 8.28 (ddd, $J$ = 1.2, 7.7, 7.7 Hz, 1 H, Ar-H), 8.81 (s, 1 H, triazole-H), 9.27 (d, $J$ = 5.1 Hz, 1 H, Ar-H), 9.35 (br. t, $J$ = 5.7 Hz, 1 H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 36.3, 55.4, 124.3, 124.7 (q, $J$ = 272 Hz), 127.3, 127.6 (q, $J$ = 3.8 Hz), 128.5, 133.6 (q, $J$ = 32.5 Hz), 141.3, 147.0, 151.6, 154.3, 154.4, 163.5, 163.5 ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2203 ppm. IR (KBr): $\tilde{\nu}$ = 3345, 1720, 1324, 1130, 1065 $cm^{-1}$. HRMS (ESI$^-$) calcd. for $C_{17}H_{15}{}^{35}Cl_2F_3N_7O{}^{194}Pt^-$ [M + 2H – H]$^-$: 654.0294; found 654.0325. $C_{17}H_{14}Cl_2F_3N_7OPt$ (655.32): calcd. C 31.16, H 2.15, N 14.96; found C 31.18, H 2.08, N 14.79.

**Complex 2f:** Yellow solid, m.p. >300 °C. $^1$H NMR (300 MHz, [$D_7$]-dmf): $\delta$ = 4.71 (d, $J$ = 5.9 Hz, 2 H, $CH_2$), 6.29 (s, 2 H, $CH_2$), 7.42–7.53 (m, 2 H, Ar-H), 7.70 (ddd, $J$ = 1.3, 7.5, 7.5 Hz, 1 H, Ar-H), 7.88–8.20 (m, 3 H, Ar-H), 8.27 (ddd, $J$ = 1.4, 7.7, 7.7 Hz, 1 H, Ar-H), 8.80 (s, 1 H, triazole-H), 9.18–9.34 (m, 2 H, Ar-H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 36.3, 55.4, 117.2, 117.5, 126.3, 126.4, 127.3, 128.5, 141.3, 147.2, 148.9, 149.0, 151.6, 154.5, 163.6, 164.4, 167.8 ppm. $^{19}$F NMR (282 MHz, [$D_7$]dmf): $\delta$ = –107.9 (m) ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2203 ppm. IR (KBr): $\tilde{\nu}$ = 3358, 3119, 1717, 1501, 1227, 1140, 851, 772 $cm^{-1}$. HRMS (ESI$^-$) calcd. for $C_{16}H_{15}{}^{35}Cl_2FN_7O{}^{194}Pt^-$ [M + 2H – H]$^-$: 604.0326; found 604.0338. $C_{16}H_{14}Cl_2FN_7OPt$ (605.31): calcd. C 31.75, H 2.33, N 16.20; found C 31.37, H 2.43, N 15.83.

**Complex 2g:** Ochre solid, m.p. >300 °C. $^1$H NMR (300 MHz, [$D_7$]-dmf): $\delta$ = 4.70 (d, $J$ = 5.9 Hz, 2 H, $CH_2$), 6.30 (s, 2 H, $CH_2$), 7.70 (d, $J$ = 8.7 Hz, 2 H, Ar-H), 7.85 (d, $J$ = 8.7 Hz, 2 H, Ar-H), 7.95 (d, $J$ = 7.3 Hz, 1 H, Ar-H), 8.30 (dd, $J$ = 7.7, 7.7 Hz, 1 H, Ar-H), 8.80 (s, 1 H, triazole-H), 9.22–9.34 (m, 2 H, Ar-H, N-H) ppm. $^{13}$C NMR (75 MHz, [$D_7$]dmf): $\delta$ = 36.3, 55.4, 125.4, 127.3, 128.4, 130.5, 139.1, 141.3, 147.1, 150.7, 151.5, 154.4, 163.5 ppm. $^{195}$Pt NMR (64 MHz, [$D_7$]dmf): $\delta$ = –2203 ppm. IR (KBr): $\tilde{\nu}$ = 3360, 1721, 1489, 1152, 843 $cm^{-1}$. HRMS (ESI$^-$) calcd. for $C_{16}H_{15}{}^{35}Cl_3N_7O{}^{194}Pt^-$ [M + 2H – H]$^-$: 620.0030; found 620.0050. $C_{16}H_{14}Cl_3N_7OPt$ (621.77): calcd. C 30.91, H 2.27, N 15.77; found C 30.53, H 2.42, N 15.39.

**Complex 2h:** Ochre solid, m.p. >300 °C. $^1$H NMR (300 MHz, [$D_7$]-dmf): $\delta$ = 4.75 (d, $J$ = 6.0 Hz, 2 H, $CH_2$), 6.42 (s, 2 H, $CH_2$), 7.72 (dd, $J$ = 6.4 Hz, 1 H, Ar-H), 7.95 (d, $J$ = 7.3 Hz, 1 H, Ar-H), 8.08

(d, $J$ = 8.9 Hz, 2 H, Ar-H), 8.31 (dd, $J$ = 7.6, 7.6 Hz, 1 H, Ar-H), 8.52 (d, $J$ = 8.9 Hz, 2 H, Ar-H), 8.90 (s, 1 H, triazole-H), 9.30 (d, $J$ = 5.5 Hz, 1 H, Ar-H), 9.44 (br. t, $J$ = 4.9 Hz, 1 H, N-H) ppm. $^{13}$C NMR (75 MHz, [D$_7$]dmf): $\delta$ = 36.4, 55.4, 124.6, 125.9, 127.4, 128.5, 141.4, 147.0, 150.7, 151.6, 154.5, 155.3, 163.3 ppm. $^{195}$Pt NMR (64 MHz, [D$_7$]dmf): $\delta$ = –2204 ppm. IR (KBr): $\tilde{\nu}$ = 3314, 3268, 3128, 1724, 1525, 1347, 866, 768 cm$^{-1}$. HRMS (ESI$^-$) calcd. for $C_{16}H_{14}{}^{35}Cl_2N_8O_3{}^{194}Pt^-$ [M + 2H – H]$^-$: 631.0271; found 631.0290. $C_{16}H_{14}Cl_2N_8O_3Pt$ (632.32): calcd. C 30.39, H 2.23, N 17.72; found C 30.19, H 2.32, N 17.42.

**Complex 2i:** Ochre solid, m.p. >300 °C. $^1$H NMR (300 MHz, [D$_7$]dmf): $\delta$ = 2.43 (s, 3 H, $CH_3$), 4.70 (d, $J$ = 5.9 Hz, 2 H, $CH_2$), 6.29 (s, 2 H, $CH_2$), 7.45 (d, $J$ = 8.1 Hz, 2 H, Ar-H), 7.65–7.74 (m, 3 H, Ar-H), 7.95 (d, $J$ = 6.9 Hz, 1 H, Ar-H), 8.27 (ddd, $J$ = 1.4, 7.7, 7.7 Hz, 1 H, Ar-H), 8.79 (s, 1 H, triazole-H), 9.15 (br. t, $J$ = 5.4 Hz, 1 H, N-H), 9.18 (d, $J$ = 4.8 Hz, 1 H, Ar-H) ppm. $^{13}$C NMR (75 MHz, [D$_7$]dmf): $\delta$ = 21.4, 36.3, 55.4, 123.8, 127.3, 128.41, 128.42, 130.8, 141.3, 145.1, 147.3, 150.3, 151.6, 154.4, 163.8 ppm. $^{195}$Pt NMR (64 MHz, [D$_7$]dmf): $\delta$ = –2204 ppm. IR (KBr): $\tilde{\nu}$ = 3360, 3336, 3127, 1717, 1505, 1153, 831, 766 cm$^{-1}$. HRMS (ESI$^-$) calcd. for $C_{17}H_{18}{}^{35}Cl_2N_7O^{194}Pt^-$ [M + 2H – H]$^-$: 600.0577; found 600.0600. $C_{17}H_{17}Cl_2N_7OPt$ (601.35): calcd. C 33.95, H 2.85, N 16.30; found C 33.57, H 2.93, N 15.98.

**Complex 2j:** Ochre solid, m.p. >300 °C. IR (KBr): $\tilde{\nu}$ = 3350, 3117, 1708, 1503, 1143, 1022, 841, 770 cm$^{-1}$. The NMR spectra could not be obtained because the complex was insufficiently soluble. HRMS (ESI$^-$) calcd. for $C_{17}H_{18}{}^{35}Cl_2N_7O_2{}^{194}Pt^-$ [M + 2H – H]$^-$: 616.0526; found 616.0498. $C_{17}H_{17}Cl_2N_7O_2Pt$ (617.35): calcd. C 33.07, H 2.78, N 15.88; found C 32.75, H 2.93, N 15.56.

**Complex 2k:** Yellow solid, m.p. >300 °C. IR (KBr): $\tilde{\nu}$ = 3354, 3118, 1717, 1493, 768 cm$^{-1}$. The NMR spectra could not be obtained because the complex was insufficiently soluble. HRMS (ESI$^-$) calcd. for $C_{16}H_{16}{}^{35}Cl_2N_7O^{194}Pt^-$ [M + 2H – H]$^-$:586.0420; found 586.0439. $C_{16}H_{15}Cl_2N_7OPt$ (587.32): calcd. C 32.72, H 2.57, N 16.69; found C 32.35, H 2.63, N 16.44.

**X-ray Structure Determination of 2a·CH$_3$CN:** Crystal data: $C_{23}H_{18}Cl_2F_3N_7O_2Pt{\cdot}CH_3CN$, $M$ = 788.49, triclinic, space group $P\bar{1}$, $a$ = 8.33230(10) Å, $b$ = 10.0246(2) Å, $c$ = 18.7318(4) Å, $\alpha$ = 95.3617(11)°, $\beta$ = 90.1259(12)°, $\gamma$ = 113.7736(11)°, $V$ = 1424.23(5) Å$^3$, $Z$ = 2, $D_c$ = 1.839 g cm$^{-3}$, $\mu$ = 5.172 mm$^{-1}$. A yellow block of compound **2a**·CH$_3$CN with dimensions of 0.10 × 0.05 × 0.05 mm$^3$ was glued to a glass thread. The diffraction data were collected with a Nonius Kappa CCD diffractometer with an area detector at room temperature. A graphite monochromated Mo-$K_\alpha$ radiation source ($\lambda$ = 0.71072 Å) was employed. A total of 10993 reflections were measured, 6408 were independent and 5749 [$I > 2\sigma(I)$] were considered observed. The structure was solved by direct methods using SIR-92[33] and refined with a full-matrix least-squares procedure based on $F^2$ using SHELXL-97.[34] All of the non-hydrogen atoms were refined anisotropically. All of the C–H hydrogen atoms were included in the model at geometrically calculated positions and refined using a riding model. The hydrogen atom bonded to nitrogen N5 was visible in the last stages of the refinement and was refined with the constrained N–H bond length (0.86 Å) and isotropic thermal parameters (1.2 times the thermal parameter of the attached nitrogen atom). The final $R$ indices [$I > 2\sigma(I)$] $R1$ = 0.0249, $wR_2$ = 0.0561, and (all data) $R1$ = 0.0313, $wR_2$ = 0.0561 were found.

CCDC-692994 contains the supplementary crystallographic data for **2a·CH$_3$CN**. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

**Supporting Information** (see footnote on the first page of this article): The UV/Vis spectra for compounds **1a**, **1e**, **2a** and **2e**.

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[1] http://www.cancer.gov/.
[2] L. Kelland, *Nat. Rev. Cancer* **2007**, *7*, 573–584.
[3] a) B. Lippert (Ed.), *Cisplatin: Chemistry and Biochemistry of a Leading Anticancer Drug*, Wiley-VCH, Zürich, **1999**; b) Y. Jung, S. Lippard, *Chem. Rev.* **2007**, *107*, 1387–1407; c) A. V. Klein, T. W. Hambley, *Chem. Rev.* **2009**, *109*, 4911–4920; d) J. Reedijk, *Eur. J. Inorg. Chem.* **2009**, 1303–1312; e) B. W. Harper, A. M. Krause-Heuer, M. P. Grant, M. Manohar, K. B. Garbutcheon-Singh, J. R. Aldrich-Wright, *Chem. Eur. J.* **2010**, *16*, 7064–7077.
[4] a) L. R. Kelland, *Drugs* **2000**, 1–8; b) M. A. Fuertes, C. Alonso, J. M. Pérez, *Chem. Rev.* **2003**, *103*, 645–662.
[5] a) P. Mistry, L. R. Kelland, G. Abel, S. Sidhar, K. R. Harrap, *Br. J. Cancer* **1991**, *64*, 215–220; b) A. Casini, A. Scozzafava, C. T. Supuran, *Environ. Health Perspect.* **2002**, *110*, 801–806; c) G. K. Balendiran, R. Dabur, D. Fraser, *Cell Biochem. Funct.* **2004**, *22*, 343–352.
[6] D. Gibson, *Dalton Trans.* **2009**, 10681–10689.
[7] a) R. Millet, S. Urig, J. Jacob, E. Amtmann, J.-P. Moulinoux, S. Gromer, K. Becker, E. Davioud-Charvet, *J. Med. Chem.* **2005**, *48*, 7024–7039; b) W. H. Ang, I. Khalaila, C. S. Allardyce, L. Juillerat-Jeanneret, P. J. Dyson, *J. Am. Chem. Soc.* **2005**, *127*, 1382–1383.
[8] a) R. Morphy, Z. Rankovic, *J. Med. Chem.* **2005**, *48*, 6523–6543; b) A. Cavalli, M. L. Bolognesi, *J. Med. Chem.* **2009**, *52*, 7339–7359; c) B. Meunier, *Acc. Chem. Res.* **2008**, *41*, 69–77.
[9] J. Košmrlj, M. Kočevar, S. Polanc, *J. Chem. Soc. Perkin Trans. 1* **1998**, 3917–3919.
[10] J. Košmrlj, M. Kočevar, S. Polanc, *Synlett* **2009**, 2217–2235.
[11] S. Jakopec, K. Dubravčić, S. Polanc, J. Košmrlj, M. Osmak, *Toxicol. vitro* **2006**, *20*, 217–226.
[12] a) M. Osmak, T. Bordukalo, J. Košmrlj, M. Kvajo, Z. Marijanović, D. Eljuga, S. Polanc, *Neoplasma* **1999**, *46*, 201–206; b) M. Osmak, T. Bordukalo, B. Jernej, J. Košmrlj, S. Polanc, *Anti-Cancer Drugs* **1999**, *10*, 853–859; c) M. Osmak, T. Bordukalo, A. Ambriović Ristov, B. Jernej, J. Košmrlj, S. Polanc, *Neoplasma* **2000**, *47*, 390–395; d) L. Pieters, J. Košmrlj, R. Lenaršič, M. Kočevar, S. Polanc, *Arkivoc* **2001**, *5*, 42–50; e) D. Moskatelo, A. Benjak, V. Laketa, S. Polanc, J. Košmrlj, M. Osmak, *Chemotherapy* **2002**, *48*, 36–41; f) D. Moskatelo, S. Polanc, J. Košmrlj, L. Vuković, M. Osmak, *Pharmacol. Toxicol.* **2002**, *91*, 258–263; g) T. Čimbora-Zovko, S. Bombek, J. Košmrlj, L. Kovačič, S. Polanc, A. Katalinić, M. Osmak, *Drug Dev. Res.* **2004**, *61*, 95–100; h) S. Jakopec, K. Dubravčić, A. Brozović, S. Polanc, M. Osmak, *Cell Biol. Toxicol.* **2006**, *22*, 61–71; i) I. Martin-Kleiner, S. Bombek, J. Košmrlj, B. Čupić, T. Čimbora-Zovko, S. Jakopec, S. Polanc, M. Osmak, J. Gabrilovac, *Toxicol. vitro* **2007**, *21*, 1453–1459.
[13] D. Urankar, J. Košmrlj, *J. Comb. Chem.* **2008**, *10*, 981–985.
[14] D. Urankar, M. Steinbücher, J. Kosjek, J. Košmrlj, *Tetrahedron* **2010**, *66*, 2602–2613.
[15] a) T. L. Mindt, H. Struthers, L. Brans, T. Anguelov, C. Schweinsberg, V. Maes, D. Tourwé, R. Schibli, *J. Am. Chem. Soc.* **2006**, *128*, 15096–15097; b) H. Struthers, T. L. Mindt, R. Schibli, *Dalton Trans.* **2010**, *39*, 675–696.

  

[16] a) W. S. Brotherton, H. A. Michaels, J. T. Simmons, R. J. Clark, N. S. Dalal, L. Zhu, *Org. Lett.* **2009**, *11*, 4954–4957; b) J. D. Crowley, P. H. Bandeen, L. R. Hanton, *Polyhedron* **2010**, *29*, 70–83; c) Y. Fu, Y. Liu, C. Zhong, H. Li, X. G. Chen, J. G. Qin, *Chin. J. Inorg. Chem.* **2010**, *26*, 1133–1140; d) G.-C. Kuang, H. A. Michaels, J. T. Simmons, R. J. Clark, L. Zhu, *J. Org. Chem.* **2010**, *75*, 6540–6548; e) S.-Q. Bai, S. Leelasubcharoen, X. Chen, L. L. Koh, J.-L. Zuo, T. S. A. Hor, *Cryst. Growth Des.* **2010**, *10*, 1715–1720; f) J. D. Crowley, P. H. Bandeen, *Dalton Trans.* **2010**, *39*, 612–623; g) S.-Q. Bai, J. Y. Kwang, L. L. Koh, D. J. Young, T. S. A. Hor, *Dalton Trans.* **2010**, *39*, 2631–2636; h) D. Urankar, A. Pevec, I. Turel, J. Košmrlj, *Cryst. Growth Des.* **2010**, *10*, 4920–4927.
[17] D. Urankar, B. Pinter, A. Pevec, F. De Proft, I. Turel, J. Košmrlj, *Inorg. Chem.* **2010**, *49*, 4820–4829.
[18] K. J. Kilpin, J. D. Crowley, *Polyhedron* **2010**, *29*, 3111–3117.
[19] D. Urankar, J. Košmrlj, *Inorg. Chim. Acta* **2010**, *363*, 3817–3822.
[20] S. Grabner, J. Košmrlj, N. Bukovec, M. Čemažar, *J. Inorg. Biochem.* **2003**, *95*, 105–112.
[21] a) A. Maisonial, P. Serafin, M. Traïkia, E. Debiton, V. Théry, D. J. Aitken, P. Lemoine, B. Viossat, A. Gautier, *Eur. J. Inorg. Chem.* **2008**, 298–305; b) A. Chevry, M.-L. Teyssot, A. Maisonial, P. Lemoine, B. Viossat, M. Traïkia, D. J. Aitken, G. Alves, L. Morel, L. Nauton, A. Gautier, *Eur. J. Inorg. Chem.* **2010**, 3513–3519.
[22] a) A. Canty, E. A. Stevens, *Inorg. Chim. Acta* **1981**, *55*, L57–L59; b) N. Moeller, B. S. Kangarloo, I. Puscasu, C. Mock, B. Krebs, J. E. A. Wolff, *Anticancer Res.* **2000**, *20*, 4435–4440.
[23] R. Romeo, L. M. Scolaro, *Inorg. Synth.* **1998**, *32*, 153–158.
[24] I. Eryazici, C. N. Moorefield, G. R. Newkome, *Chem. Rev.* **2008**, *108*, 1834–1895.
[25] a) S. J. S. Kerrison, P. J. Sadler, *J. Chem. Soc., Chem. Commun.* **1977**, 861–863; b) W. I. Sundquist, K. J. Ahmed, L. S. Hollis, S. J. Lippard, *Inorg. Chem.* **1987**, *26*, 1524–1528; c) J. Yoo, J.-H. Kim, Y. S. Sohn, Y. Do, *Inorg. Chim. Acta* **1997**, *263*, 53–60.
[26] a) Cambridge Structural Database (version 5.31.1, update May 2010); b) Search for platinum(II) complexes that have a square planar environment with C–H···Pt separations in the range of 2.0 to 2.8 Å.
[27] a) C. Tessier, F. D. Rochon, *Inorg. Chim. Acta* **1999**, *295*, 25–38; b) E. Monti, M. Gariboldi, A. Maiocchi, E. Marengo, C. Cassino, E. Gabano, D. Osella, *J. Med. Chem.* **2005**, *48*, 857–866.
[28] B. M. Still, P. G. A. Kumar, J. R. Aldrich-Wright, W. S. Price, *Chem. Soc. Rev.* **2007**, *36*, 665–686.
[29] G. Annibale, M. Bonivento, L. Cattalini, M. L. Tobe, *J. Chem. Soc., Dalton Trans.* **1992**, 3433–3438.
[30] A. P. S. Fontes, A. Oskarsson, K. Lövqvist, N. Farrell, *Inorg. Chem.* **2001**, *40*, 1745–1750.
[31] Y. Qu, S. G. de Almeida, N. Farrell, *Inorg. Chim. Acta* **1992**, *201*, 123–129.
[32] T. G. Appleton, F. B. Ross, *Inorg. Chim. Acta* **1996**, *252*, 79–89.
[33] A. Altomare, G. Cascarano, C. Giacovazzo, A. Guagliardi, *J. Appl. Crystallogr.* **1994**, *27*, 435–435.
[34] G. M. Sheldrick, *Acta Crystallogr., Sect. A* **2008**, *64*, 112–122.
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