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Ligand discrimination in the reaction of nitrones with $[PtCl_2(PhCN)_2]$. Selective formation of mono-oxadiazoline and mixed bis-oxadiazoline complexes under thermal and microwave conditions

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[2+3] Cycloaddition of nitrones to the nitrile ligands in the complexes *cis*- or *trans*-$[PtCl_2(PhCN)_2]$ occurs under ligand differentiation and allows for selective synthesis of complexes of the type *cis*- or *trans*-$[PtCl_2$(oxadiazoline)-(PhCN)]. Microwave irradiation enhances the reaction rates of the cycloaddition considerably and further favours the selectivity towards the mono-cycloadduct with respect to thermal conditions, because the first cycloaddition is accelerated to a higher extent than the second one. Reaction of the *trans*-substituted mono-oxadiazoline complexes with a nitrone different from the one used for the first cycloaddition step gives access to mixed bis-oxadiazoline compounds of the composition *trans*-[$PtCl_2$(oxadiazoline-a)(oxadiazoline-b)]. The corresponding *cis*-configured complexes, however, do not undergo further cycloaddition. All reactions described occur without isomerisation of the stereochemistry around the platinum center, independently of whether thermal or microwave heating is applied.

Introduction

Platinum compounds are used for medical purposes,[1] besides other applications as photochemical devices,[2] in molecular architecture,[3] or other fields of chemistry such as catalysis or metal-mediated organic synthesis.[4] Platinum complexes are typically prepared by ligand exchange, making use of the *trans*-effect[5] to overcome selectivity issues. Thus, the cancer drug *cis*-$[PtCl_2(NH_3)_2]$ is prepared from tetraiodoplatinate rather than tetrachloroplatinate to selectively introduce two ammonia ligands in *cis*-position to each other. Subsequent exchange of the iodo ligands in *cis*-$[PtI_2(NH_3)_2]$ requires the presence of a silver salt to produce the intermediate aquo complex, from which the aquo ligands are displaced by chloride.[6] Compared to the frequent application of ligand exchange reactions, surprisingly little use is made of selective ligand modification in the coordination sphere of the metal.[7] In particular, reactions leading to a differentiation between initially equivalent ligands are quite neglected up to now, although such effects are known to occur, as for example in the selective nucleophilic addition of hydroxide to Pt(II) bis-nitrile complexes to give mixed amide nitrile complexes.[8]

Previously, we showed that nitriles coordinated to Pt(IV) centers undergo [2+3] cycloaddition with aromatic and aliphatic nitrones under very mild conditions, and with this, the first Δ^4-1,2,4-oxadiazoline complexes were prepared.[9] The nitriles in the corresponding Pt(II) complexes exhibit a slightly lower reactivity, indicating that the Lewis acidity of the metal plays an important role.[10] When the cycloaddition is performed with nitriles bound to suitable chiral platinum compounds, the reaction is diastereoselective. Release of the Δ^4-1,2,4-oxadiazoline ligand from the resulting complexes allowed for the first enantioselective synthesis of this class of heterocycles.[11] Up to now, the platinum compounds were exhaustively reacted with nitrones, *i.e.* both ligands in bis-nitrile complexes of the type $[PtCl_x(RCN)_2]$ ($x = 2, 4$) were transformed into the oxadiazoline simultaneously. The resulting products are chemically stable and kinetically quite inert, and therefore, their suitability for medicinal purposes or any chemical application remains doubtful.

In the present work, we concentrated on the development of new routes for the synthesis of platinum complexes bearing only one oxadiazoline and another potentially labile and reactive ligand, *e.g.* a nitrile, which can be further derivatised or displaced. Such complexes might offer interesting opportunities for bonding to biologically relevant molecules or substrates in catalysis. Their synthesis might be achieved straightforwardly by cycloaddition of a nitrone to only one of the two equivalent nitriles in complexes of the type $[PtCl_2$-(nitrile)$_2]$ or $[PtCl_4$(nitrile)$_2]$, if the ligands were sufficiently different in reactivity. In the cycloaddition of nitrones to *trans*-$[PtCl_2$(cinnamonitrile)$_2]$, we did indeed observe for the first time that such discrimination takes place in the microwave-assisted reaction, although the reaction under thermal conditions was unselective.[12] The ability of the nitrone to differentiate between the two nitrile ligands was argued as either a microwave specific effect, favouring the first cycloaddition to a higher extent due to its more polar transition state, or a faster dissolution of the poorly soluble starting material under microwave irradiation and superheating of the solvent, leading to a homogenous reaction medium and stoichiometric reaction conditions. However, up to this stage, we were not able to distinguish between these two hypotheses. It was also unclear how generally applicable this mono-cycloaddition route would be if nitriles different from cinnamonitrile were to be used.

Results and discussion

In the present study, we addressed these questions by using *cis*- and *trans*-$[PtCl_2(PhCN)_2]$ as starting materials for reactions with the nitrones PhCH=N(Me)O (**2a**) and *p*-MeC_6H_4CH=N(Me)O (**2b**). The *trans*-isomer is well soluble in unpolar solvents such as $CHCl_3$ and thus allows for homogenous reactions and favourable conditions for a 1 : 1 stoichiometric reaction. Once the first cycloaddition has taken place, the second nitrile ligand still present in the molecule is expected to be different in reactivity because of the electronic interaction with the oxadiazoline in *trans*-position. Steric effects are not expected to play an important role because the ligands in question are at a maximum distance from each other. On the other hand, the *cis*-complex is less soluble in chloroform, although its reactivity can be assumed to be similar to the *trans*-compound. With ligands in a *cis*-arrangement, the second cycloaddition is not much influenced electronically by the first oxadiazoline ligand, but the approach of the nitrone might now suffer from steric repulsion. A comparision of the selectivity of these reactions with respect to mono-cycloaddition might thus allow a rational-

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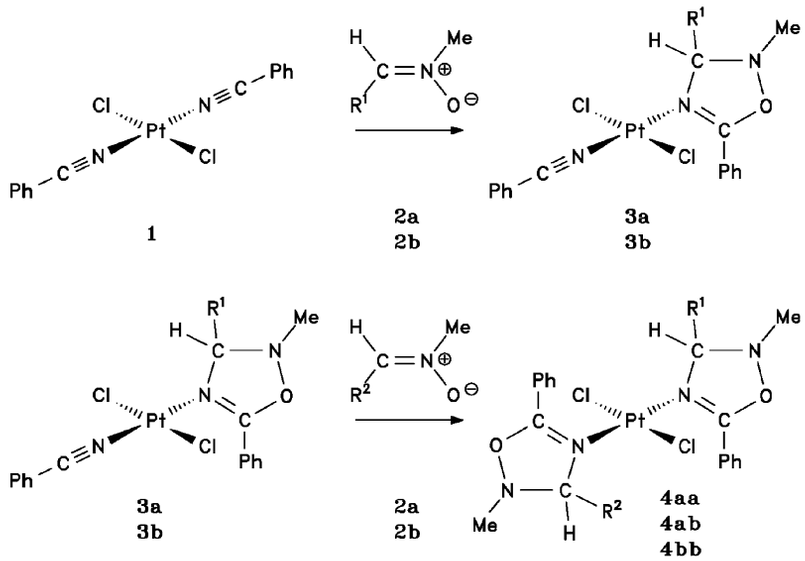


Scheme 1 a: R^1, R^2=Ph, b: R^1, R^2=*p*-MeC_6H_4.

isation of conditions under which a discrimination between two equivalent ligands can take place efficiently.

Reactions of *trans*-[$PtCl_2(PhCN)_2$]

The starting *trans*-[$PtCl_2(PhCN)_2$] complex was prepared from $PtCl_2$ and benzonitrile using Kharasch's method and purified by chromatography prior to use.[13,14] Cycloadditions were carried out on a 0.1 mmol scale with equimolar amounts of *trans*-[$PtCl_2(PhCN)_2$] **1** and nitrone **2a** or **2b**, in $CHCl_3$ (1 ml) as a solvent. The reaction mixtures were left at room temperature overnight. NMR of the crude mixture showed the presence of a new compound **3a** or **3b**, together with a small amount (2–4%) of the known diastereomeric bis-oxadiazoline complexes **4aa** or **4bb** as the only bypoducts. The new products **3a** and **3b** were isolated by chromatography and obtained as pale yellow solids in 68 and 72% yield. Characterisation of the products by elemental analysis, mass spectrometry, IR, ^1H, ^{13}C and ^{195}Pt NMR spectroscopy showed that the compounds contained both an oxadiazoline and a nitrile ligand, selective mono-cycloaddition had thus taken place. The FAB-MS spectra display a characteristic fragmentation pattern of loss of two Cl atoms and a PhCN ligand. In the IR spectra, both C≡N and C=N stretching bands are present. The C≡N vibration appears in the same range of wavenumbers as observed for the starting material **1** (2286 cm^{-1} for **3a**, 2283 cm^{-1} for **3b**, *vs.* 2285 cm^{-1} for **1**). The C=N vibrations are quite comparable with those of the bis-oxadiazoline complexes (1631 cm^{-1} for **3a**, 1630 cm^{-1} for **3b**, *vs.* 1645 and 1623 cm^{-1} for **4aa**, 1641 and 1627 cm^{-1} for **4bb**).

^1H and ^{13}C NMR spectra show the expected signals of the oxadiazoline and benzonitrile ligands. Compared to the bis-oxadiazoline complexes **4aa** and **4bb**, the C=NPh *ortho* protons are at significantly higher chemical shift, thus influenced by the Pt center more strongly. Also the C=N in ^{13}C NMR appears at higher chemical shift, reflecting the higher Lewis acidity of the Pt center. The signals of the benzonitrile ligand are practically unchanged, as compared to the starting material. The ^{195}Pt NMR resonance appears at −2236 to −2237 ppm, in a similar position as in the corresponding mono-oxadiazoline complex derived from cinnamonitrile,[12] and in between the resonances of the starting material *trans*-[$PtCl_2(PhCN)_2$] (−2350 ppm) and the *trans*-configured bis-oxadiazoline compounds (−2104 to −2121 ppm).

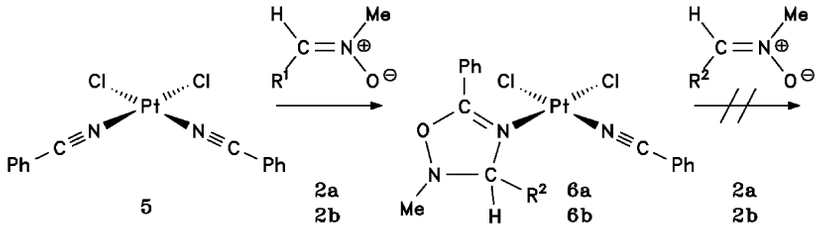
The mono-oxadiazoline complexes **3a** and **3b** can be converted into the known symmetric bis-oxadiazoline complexes **4aa** and **4bb** by reaction with a second equivalent of nitrone **2a** or **2b**. If a nitrone different from the one applied in the first cycloaddition is used (*e.g.* reaction of **3a** + **2b** or **3b** + **2a**), the mixed unsymmetric bis-oxadiazoline complex **4ab** is obtained. This second cycloaddition step was again completed at room temperature overnight, indicating that the difference in reactivity for the two cycloadditions is not drastically high, although sufficient to achieve a high selectivity.

The product was isolated as a pale yellow powder in 76% yield. All signals in IR, ^1H, ^{13}C and ^{195}Pt NMR are in their expected positions and highly similar to the ones obtained for the symmetric complexes **4aa** and **4bb**.[10] NMR data also show that the complex is formed as a 1 : 1 diastereomeric mixture, as expected. The aromatic groups of the oxadiazoline ligand facilitate the detection of these diastereoisomers because of their magnetic interaction with the ligand in *trans*-position on the metal. Still, their steric influence is not strong enough to induce any stereoselection in the cycloaddition to the *trans*-positioned ligand.

Under microwave irradiation in a sealed tube at a set temperature of 60 °C both cycloaddition steps were accelerated considerably. The first cycloaddition was complete within 20 min, providing similar yields and selectivities of the mono-cycloadducts **3a/b** as observed in the thermal reaction. Also the second cycloaddition was accelerated significantly and brought to completeness within 2.5 h. This is in agreement with results found by other groups and also by us that many cycloadditions, purely organic[15,16] and Lewis acid catalysed[17] or mediated ones,[12] benefit from microwave heating with respect to reaction rates.

Reactions of *cis*-[$PtCl_2(PhCN)_2$]

Pure *cis*-[$PtCl_2(PhCN)_2$] was obtained from reaction of benzonitrile with aqueous tetrachloroplatinate[18,14] and subsequent chromatographic purification of the product. The cycloaddition reactions were performed as described in the previous section for the corresponding *trans*-complex. However, due to the lower solubility of the *cis*-isomer, the reaction mixture is now a suspension with an unfavourable stoichiometry of the reagents present in the solution. Moreover, the oxadiazoline formed in the first step is now in *cis*-position to the remaining benzonitrile ligand. The two ligands are thus not able to communicate with each other electronically, and conversion of one nitrile into an oxadiazoline is not expected to change the reactivity of the second nitrile. If the reaction still distinguishes between the two nitriles, steric reasons should be made responsible for the result rather than electronic ones.



Scheme 2 a: R^1, R^2 = Ph, b: R^1, R^2 = *p*-MeC_6H_4.

The experiment showed that the *cis*-configured mono-cycloadduct formed selectively, in spite of the unfavourable conditions. The products **6a** and **6b** were isolated by crystallisation from $CHCl_3$ and diethyl ether. Mass spectra and elemental analysis are almost identical to those found for the *trans*-complexes **3a/b**. In the IR spectra, both C≡N and C=N stretching vibrations appear at slightly lower wavenumbers, compared to the analogous signals of the *trans*-compounds.

In the ^{1}H NMR spectra, the oxadiazoline N–CH–N and the *ortho*-protons of the N=CPh moiety appear at higher chemical shift than in the corresponding *trans*-compound. In contrast, the signals of the *meta*- and *para*-hydrogens of the CHPh group in **6a** emerge at lower chemical shifts (7.31 and 7.36 ppm, as compared to 7.45 ppm in **3a**). Accordingly in **6b**, the methyl group and the *ortho*-protons of the *p*-MeC_6H_4CH moiety are shifted similarly (2.19 and 7.14 ppm, as compared to 2.38 and 7.27 ppm in **3b**). An exceptionally low chemical shift is also found for the *ortho*-protons of the coordinated benzonitrile. In the *cis*-complexes, these protons appear at 7.17 ppm whereas the corresponding protons in the *trans*-complexes resonate at 7.68 ppm. In the ^{13}C NMR spectra, both C=N and C≡N are at lower chemical shift than in the analogous *trans*-complex.

As expected, the ^{195}Pt signal of the *cis*-complexes **6** is shifted downfield with respect to the *trans*-complexes **3**, as observed for many other *cis*/*trans*-isomeric Pt(II) compounds.[19] However, the effect is exceptionally small ($\Delta\delta \approx 10$ ppm). Compared to the ^{195}Pt chemical shift of the starting material *cis*-$[PtCl_2(PhCN)_2]$ of −2288 ppm, the resonance of the mono-oxadiazoline complex appears at higher ppm values (−2224 to −2228 ppm).

The *cis*-configured mono-oxadiazoline complex does not react to the bis-oxadiazoline complex upon addition of a second equivalent of a nitrone, when similar conditions as in the synthesis of the corresponding *trans*-complexes are applied. We attribute this to steric hindrance rather than to electronic effects. Prolonged heating of the reaction mixture (60 °C, up to 6 days) leads to decomposition of **6a/b** to form a number of uncharacterised products. Isomerisation of *cis*-**6a/b** to *trans*-**3a/b** seems to play a minor role under the reaction conditions applied, since no formation of **3a/b** or the known *trans*-configured bis-oxadiazoline complexes **4** was detected.

Kinetic studies of the thermal and microwave-assisted reactions

In our previous study, the accelerating effect of microwave irradiation on the cycloaddition of nitrones to platinum-coordinated nitriles was observed but only discussed qualitatively because of solubility problems encountered with the cinnamonitrile complex used as starting material.[12] The reactions of the benzonitrile complexes described in the present work do not suffer from this problem to such an extent, and a more detailed investigation of the progress of the reaction, under thermal and microwave conditions, was thus possible. Still, rate constants on physical grounds were not determined because experimental error (*e.g.* in the temperature measurement in microwave experiments using an IR sensor) and differences in the reaction conditions (*e.g.* no possibility for online monitoring in the microwave reaction) would not allow numerically meaningful results to be produced.

(a) Thermal reaction of *trans*-$[PtCl_2(PhCN)_2]$. For the thermal reaction, a solution of 0.1 mmol of the platinum complex **1** and 0.1 mmol of the nitrone **2a** in 1 ml $CDCl_3$ was placed into an NMR tube and the reaction was followed at 40 °C by ^{1}H NMR spectroscopy. The composition of the mixture was evaluated from the integrals of the signals of the *ortho*-protons of the N=CPh group of the cycloaddition products **3a** and **4aa**, and the phenyl group of the nitrone **2a**. These signals were selected because they were well separated from each other and not affected by overlap by other signals. The starting $[PtCl_2(PhCN)_2]$ complex could not be monitored since no undisturbed signals were present.

Fig. 1 shows the progress of the reaction with time. The nitrone is consumed at the same rate that the mono-cycloaddition product is formed. After about 400 min the ratio **2a** : **3a** was practically constant over a period of 1 h, indicating that the reaction was complete. In the final mixture, 80% of the mono-cycloaddition product **3a** was present, and only 2.7% of the bis-cycloadduct **4aa** was formed. Thus, the thermal reaction is highly selective. The sample was further used to study the rate of the second cycloaddition of **2a** to the mono-cycloaddition product **3a** to give **4aa**. Another equivalent of the nitrone was added, and the reaction was again followed by ^{1}H NMR. Fig. 1 shows that now the nitrone and the mono-cycloadduct are consumed simultaneously, and the bis-cycloadduct is formed. However, the reaction is slower than in the first cycloaddition step. In terms of half-life times, formation of 50% of the mono-cycloaddition product requires approximately 75 min, whereas formation of 50% of the bis-cycloadduct takes approximately 450 min. The half life times thus differ by a factor of about 6.

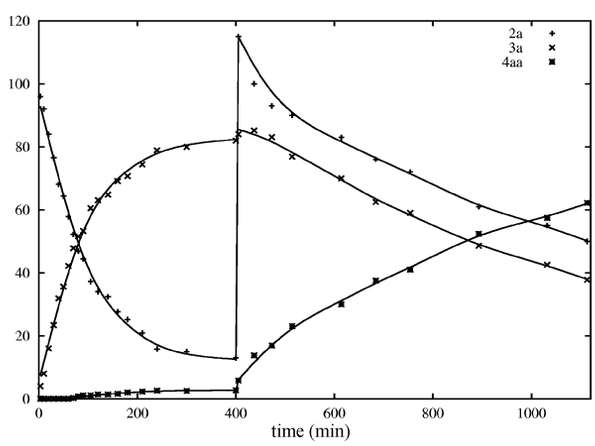


Fig. 1 Reaction of *trans*-$[PtCl_2(PhCN)_2]$ **1** and **2a** under thermal conditions.

(b) Thermal reaction of *cis*-$[PtCl_2(PhCN)_2]$. The complex *cis*-$[PtCl_2(PhCN)_2]$ converts selectively into the corresponding *cis*-configured mono-cycloaddition product **6a** upon reaction with one equivalent of the nitrone **2a**, as shown in Fig. 2. Under the same experimental conditions as described for the analogous reaction of the *trans*-complex, approximately 300 min are required to reach 50% conversion. The reaction is thus a factor of 4 slower than in the case of the *trans*-complex. Taking into

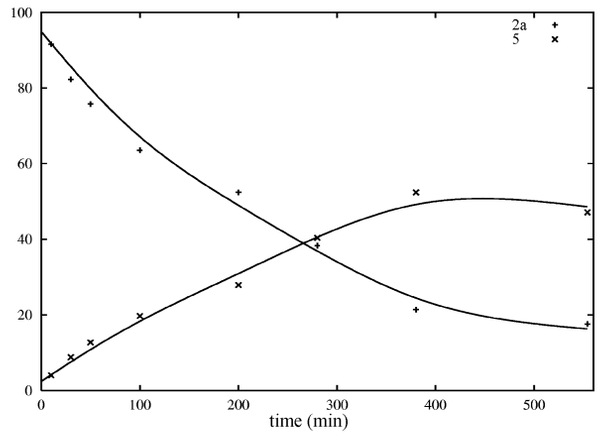


Fig. 2 Reaction of *cis*-[$PtCl_2(PhCN)_2$] **5** and **2a** under thermal conditions.

account that the starting material is not completely dissolved at the beginning of the reaction, the difference in reaction rate may be partially attributed to concentration effects rather than a reduced reactivity of the coordinated nitrile.

Formation of the mono-cycloadduct **6a** passes a maximum yield of about 52% after 380 min. At more prolonged reaction times, degradation of **6a** to a number of uncharacterised compounds becomes noticeable. From the ^{1}H NMR spectra, no evidence was found for an isomerisation of *cis*-**6a** to *trans*-**3a**.

Addition of a second equivalent of the nitrone **2a** and continuation of the reaction produces an increasing amount of unidentified products. No signals at the expected positions for a bis-oxadiazoline complex were detected in the ^{1}H NMR spectra.

(c) Microwave reaction of *trans*-[$PtCl_2(PhCN)_2$]. The microwave-assisted reaction was performed in CH_2Cl_2 because of its higher microwave-susceptibility as compared to $CHCl_3$, under otherwise similar conditions. Pulsed microwave irradiation of 100 W was applied over a period of 1 min, giving rise to an increase of temperature from room temperature to 55 °C. Every minute, a 25 µl sample was taken from the reaction mixture, the solvent was evaporated in a stream of nitrogen, and the residual oil was analysed immediately by ^{1}H NMR in $CDCl_3$ solution. Meanwhile, the bulk sample was stored on ice to prevent thermal reaction. Once the formation of the mono-cycloadduct was found complete, a second equivalent of the nitrone was added and microwave irradiation at a set temperature of 60 °C was continued. Every 10 min, a sample was taken and analysed by ^{1}H NMR as described above.

The progress of the reaction with time is shown in Fig. 3. Both cycloaddition steps were significantly accelerated with

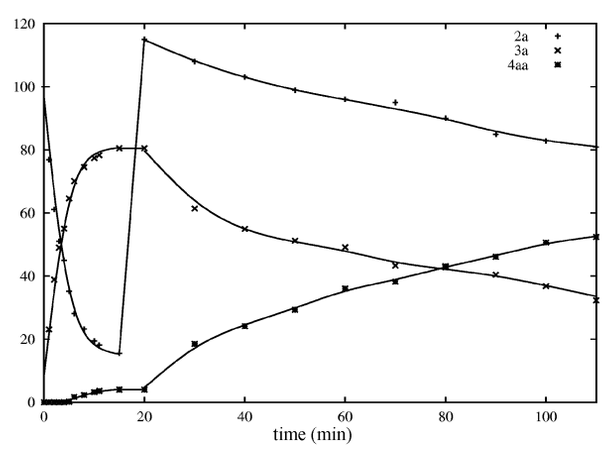


Fig. 3 Reaction of *trans*-[$PtCl_2(PhCN)_2$] **1** and **2a** under microwave irradiation.

respect to thermal conditions (see Fig. 1). The mono-cycloaddition achieves a 50% conversion after 3 min already, the reaction is thus a factor 25 faster than the thermal reaction. Subsequent production of 50% of the bis-cycloadduct requires approximately 65 min under microwave heating, the second cycloaddition step is thus accelerated by only a factor of 7 relative to the thermal reaction. Comparing these values and the reaction profiles of the thermal and microwave-assisted reaction, it becomes evident that the difference in reaction rates of first and second cycloaddition is much more pronounced in microwave conditions. This supports our initial assumption that microwave irradiation has a much stronger effect on the first step of the reaction.

It is commonly accepted that reactions occuring *via* more polar transition states are more susceptible to microwaves.[20] Our previous quantum chemical calculations showed this might indeed apply to the reactions described here. It was found that coordination of the nitrile to a Lewis acid changes the reaction mechanism from a concerted one involving an unpolar transition state to a two-step reaction, in which transition states and the intermediate are zwitterionic, highly polar species.[21] Thus, the stronger the Lewis acid, the more polar the transition states would be. In the initial bis-nitrile complex, all ligands are electron withdrawing and with this, the platinum center is expected to be more Lewis-acidic than in the mono-oxadiazoline complex, in which the oxadiazoline ligand rather acts as an electron donating ligand.

Concluding remarks

The results of this work indicate that ligand differentiation might have a much wider application range in the selective synthesis of coordination compounds than initially assumed, and both electronic and steric effects can be used to induce a selective reaction. Thus, the nitrile ligands in the soluble complex *trans*-[$PtCl_2(PhCN)_2$] are different in reactivity towards cycloaddition with nitrones, under both thermal and microwave conditions. This can be explained by a higher Lewis acidity of the metal center in the starting bis-nitrile complex with respect to the mono-oxadiazoline complex. A rather subtle differentiation between the initially equivalent ligands is thus possible, on the grounds of electronic communication of the ligands in *trans*-position to each other. Cycloaddition of nitrones with *cis*-[$PtCl_2(PhCN)_2$] equally occurs under ligand discrimination, to produce the mono-cycloadduct as the sole product. The selectivity of this reaction can be attributed to steric effects rather than electronic ones.

Microwave irradiation generally enhances the reaction rates of the cycloadditions and also renders the reaction with the symmetric transition metal complex *trans*-[$PtCl_2$(nitrile)$_2$] significantly more selective, because the first cycloaddition appears to be accelerated to a higher extent than the second one. Microwave heating is therefore advantageous for the preparation of the unsymetrically substituted complexes in cases where ligand differentiation under thermal conditions is not much pronounced.

The complexes [$PtCl_2$(oxadiazoline)(PhCN)] obtained in this study can be used for further chemistry due to the presence of one labile and reactive nitrile ligand. Thus, reaction with a nitrone different from the one used in the first cycloaddition gives easy access to complexes bearing two different oxadiazolines. Other promising applications, as for example in medicinal chemistry, can be envisaged since the labile nitrile ligand present in the molecule might allow the platinum center to interact with biological environments. Additionally, such complexes are suitable for use in combinatorial chemistry to generate platinum libraries, or for anchoring platinum compounds to biologically relevant carrier molecules. Further studies in these directions are ongoing in our group.

Experimental section

Materials and instrumentation

Solvents were obtained from commercial sources and used as received. *trans*-[$PtCl_2(PhCN)_2$],[13,14] *cis*-[$PtCl_2(PhCN)_2$][14, 18] and nitrones **2a** and **2b**[22] were prepared according to published methods. Microwave experiments were performed in a Smith Creator™ microwave reactor (Personal Chemistry, Uppsala) in 0.5 to 2 ml septum sealed pyrex glass tubes. An IR detector was used for the measurement of the reaction temperature. C, H and N elemental analyses were carried out on a Leeman CE 440 automatic analyser. Infrared spectra (4000–400 cm^{-1}) were recorded on Perkin Elmer 2000 FTIR and Nicolet Avatar 320 FT-IR spectrometers in KBr pellets. Positive FAB-MS spectra of the samples in 3-nitrobenzyl alcohol (NBA) matrices were obtained on a Thermoquest MAT 95XL instrument. ^1H, ^{13}C and ^{195}Pt NMR experiments were acquired on a Bruker DRX 500 spectrometer at ambient temperature. Signals in ^1H and ^{13}C were assigned with the help of COSY, NOESY and HMQC spectra. ^{195}Pt chemical shifts are given relative to aqueous $K_2[PtCl_4]$ = −1630 ppm, with half height line widths in parentheses.

Preparation of complexes *cis*- and *trans*-[$PtCl_2$(PhCN)-(oxadiazole)]

A solution of *trans*-[$PtCl_2(PhCN)_2$] (42 mg, 0.1 mmol) and nitrone **2a** or **2b** (0.1 mmol) in CH_2Cl_2 (1 ml) was left at room temperature overnight. The reaction mixture was filtered through a plug of silica gel. Evaporation of the solvent provided the products **3a** or **3b** as pale yellow solids.

Analytical data for *trans*-**3a**: Yield is 68%. Anal. Calcd for $C_{22}H_{19}Cl_2N_3OPt$: C, 43.50; H, 3.15; N, 6.92. Found: C, 43.71; H, 3.30; N, 6.93. FAB$^+$-MS, *m*/*z*: 571 [M – HCl]$^+$, 535 [M – 2 HCl]$^+$, 506 [M – PhCN]$^+$, 432 [M – 2 HCl – PhCN]$^+$. IR spectrum (selected bands), cm^{-1}: 2286 w *ν*(C≡N), 1631 s *ν*(C=N). ^1H NMR (500 MHz, $CDCl_3$) *δ*(ppm) 3.06 (s, 3H, NMe), 6.00 (s, 1H, N–CH–N), 7.45 (m, 3H) and 7.73 (d, 7.4 Hz, 2H)(CH–Ph), 7.60 (t, 7.8 Hz, 2H), 7.66 (m, 1H) and 9.00 (d, 8.0 Hz, 2H)(N=C–Ph), 7.49 (t, 7.8 Hz, 2H) and 7.68 (m, 3H)(N≡CPh). ^{13}C NMR (125.7 MHz, $CDCl_3$) *δ*(ppm) 46.1 (NMe), 94.5 (N–CH–N), 109.7 (C_q, N≡CPh), 116.5 (N≡C), 122.5 (C_q, N=CPh), 128.6 (CH, N=CPh), 128.6 (CH, CHPh), 128.7 (CH, CHPh), 129.2 (CH, N≡CPh), 129.8 (CH, CHPh), 130.6 (CH, N=CPh), 133.4 (CH, N≡CPh), 134.2 (CH, N≡CPh), 134.7 (CH, N=CPh), 135.5 (C_q, CHPh), 164.6 (C=N). ^{195}Pt NMR (107.3 MHz, $CDCl_3$) *δ*(ppm) −2237 (750 Hz).

Analytical data for *trans*-**3b**: Yield is 72%. Anal. Calcd for $C_{23}H_{21}Cl_2N_3OPt$: C, 44.45; H, 3.41; N, 6.76. Found: C, 45.27; H, 3.44; N, 6.66. FAB$^+$-MS, *m*/*z*: 585 [M – Cl]$^+$, 549 [M – 2 HCl]$^+$, 520 [M – PhCN]$^+$, 482 [M – Cl – PhCN]$^+$, 446 [M – 2 HCl – PhCN]$^+$. IR spectrum (selected bands), cm^{-1}: 2283 w *ν*(C≡N), 1630 s *ν*(C=N and C=C). ^1H NMR (500 MHz, $CDCl_3$) *δ*(ppm) 2.38 (s, 3H, C_6H_4 *Me*), 3.04 (s, 3H, NMe), 5.95 (s, 1H, N–CH–N), 7.27 (d, 8.0 Hz, 2H) and 7.61 (d, 8.1 Hz, 2H)(C_6 *H*$_4$Me), 7.60 (t, 7.9 Hz, 2H), 7.66 (m, 1H) and 8.99 (d, 7.5 Hz, 2H)(N=C–Ph), 7.48 (t, 7.9 Hz, 2H) and 7.68 (m, 3H)(N≡CPh). ^{13}C NMR (125.7 MHz, $CDCl_3$) *δ*(ppm) 21.8 (C_6H_4 *Me*), 46.0 (NMe), 94.6 (N–CH–N), 109.8 (C_q, N≡CPh), 116.5 (C≡N), 122.2 (C_q, N=CPh), 128.6 (CH, C_6H_4Me), 128.7 (CH, N=CPh), 129.1 (CH) and 129.3 (CH)(C_6H_4Me and N≡CPh), 130.4 (CH, N=CPh), 133.0 (C_q, C_6H_4Me), 133.5 (CH, N≡CPh), 134.0 (CH, N≡CPh), 134.7 (CH, N=CPh), 139.8 (C_q, C_6H_4Me),164.3 (C=N). ^{195}Pt NMR (107.3 MHz, $CDCl_3$) *δ*(ppm) −2236 (750 Hz).

A suspension of *cis*-[$PtCl_2(PhCN)_2$] (42 mg, 0.1 mmol) and nitrone **2a** or **2b** (0.1 mmol) in CH_2Cl_2 (1 ml) was left at room temperature overnight. Evaporation of the solvent and recrystallisation from $CHCl_3$/diethyl ether provided the products *cis*-**6a** or *cis*-**6b** as pale yellow solids.

Analytical data for *cis*-**6a**: Yield is 43%. Anal. Calcd for $C_{22}H_{19}Cl_2N_3OPt$: C, 43.50; H, 3.15; N, 6.92. Found: C, 43.22; H, 3.01; N, 6.88. FAB$^+$-MS, *m*/*z*: 607 [M]$^+$, 571 [M – HCl]$^+$, 535 [M – 2 HCl]$^+$, 506 [M – PhCN]$^+$, 432 [M – 2 HCl – PhCN]$^+$. IR spectrum (selected bands), cm^{-1}: 2280 w *ν*(C≡N), 1625 s *ν*(C=N). ^1H NMR (500 MHz, $CDCl_3$) *δ*(ppm) 3.08 (s, 3H, NMe), 6.13 (s, 1H, N–CH–N), 7.31 (t, 7.5 Hz, 1H), 7.36 (m, 2H) and 7.78 (d, 7.6 Hz, 2H)(CH–Ph), 7.60 (t, 7.6 Hz, 2H), 7.71 (t, 7.8Hz, 1H) and 9.07 (d, 7.9 Hz, 2H)(N=C–Ph), 7.16 (d, 8.2 Hz, 2H), 7.40 (t, 7.8 Hz, 2H) and 7.63 (m, 1H)(N≡CPh). ^{13}C NMR (125.7 MHz, $CDCl_3$) *δ*(ppm) 46.9 (NMe), 94.3 (N–CH–N), 109.3 (C_q, N≡CPh), 114.3 (N≡C), 121.8 (C_q, N=CPh), 127.8 (CH, CHPh), 128.9 (CH, CHPh), 129.0 (CH, N=CPh), 129.1 (CH, N≡CPh), 129.6 (CH, CHPh), 130.0 (CH, N=CPh), 133.0 (CH, N≡CPh), 134.4 (CH, N=CPh), 134.7 (CH, N≡CPh), 136.7 (C_q, CHPh), 163.6 (C=N). ^{195}Pt NMR (107.3 MHz, $CDCl_3$) *δ*(ppm) −2228 (650 Hz).

Analytical data for *cis*-**6b**: Yield is 48%. Anal. Calcd for $C_{23}H_{21}Cl_2N_3OPt$: C, 44.45; H, 3.41; N, 6.76. Found: C, 44.15; H, 3.37; N, 6.93. FAB$^+$-MS, *m*/*z*: 585 [M – Cl]$^+$, 549 [M – 2 HCl]$^+$, 520 [M – PhCN]$^+$, 446 [M – 2 HCl – PhCN]$^+$. IR spectrum (selected bands), cm^{-1}: 2276 w *ν*(C≡N), 1627 s *ν*(C=N and C=C). ^1H NMR (500 MHz, $CDCl_3$) *δ*(ppm) 2.19 (s, 3H, C_6H_4 *Me*), 3.07 (s, 3H, NMe), 6.08 (s, 1H, N–CH–N), 7.13 (d, 7.8 Hz, 2H) and 7.61 (d, 7.8 Hz, 2H)(C_6 *H*$_4$Me), 7.60 (m, 2H), 7.72 (t, 7.5 Hz, 1H) and 9.09 (d, 7.6 Hz, 2H)(N=C–Ph), 7.17 (d, 7.4 Hz, 2H), 7.40 (t, 7.9 Hz, 2H) and 7.61 (m, 1H)(N≡CPh). ^{13}C NMR (125.7 MHz, $CDCl_3$) *δ*(ppm) 21.1 (C_6H_4 *Me*), 46.9 (NMe), 94.2 (N–CH–N), 109.3 (C_q, N≡CPh), 114.2 (C≡N), 121.8 (C_q, N=CPh), 127.8 (CH, C_6H_4Me), 129.0 (CH, N=CPh), 129.1 (CH, N≡CPh), 129.6 (CH, C_6H_4Me), 129.9 (CH, N=CPh), 133.0 (CH, N≡CPh), 133.9 (C_q, C_6H_4Me), 134.4 (CH, N=CPh), 134.6 (CH, N≡CPh), 139.2 (C_q, C_6H_4Me), 163.5 (C=N). ^{195}Pt NMR (107.3 MHz, $CDCl_3$) *δ*(ppm) −2224 (650 Hz).

Preparation of complexes *trans*-[$PtCl_2$(oxadiazoline-a)-(oxadiazoline-b)]

A solution of the mono-oxadiazoline complex **3a** or **3b** (0.1 mmol) and nitrone **2a** or **2b** (0.1 mmol) in CH_2Cl_2 (1 ml) was left at room temperature overnight. The reaction mixture was filtered through a plug of silica gel. The products **4aa**, **4ab** or **4bb** were obtained as pale yellow solids after evaporation of the solvent.

Analytical data for **4aa** and **4bb** correspond to those given in the literature.[10]

Analytical data for **4ab**: two diastereoisomers in a ratio 1 : 1. Yield is 76%. Anal. Calcd for $C_{31}H_{30}Cl_2N_4O_2Pt$: C, 49.21; H, 4.00; N, 7.41. Found: C, 48.65; H, 3.90; N, 7.15. FAB$^+$-MS, *m*/*z*: 756 [M]$^+$, 684 [M – 2 HCl]$^+$, 549 [M – 2 HCl – PhCH=N(Me)O]$^+$, 535 [M – 2 HCl – PhCH=N(Me)O]$^+$. IR spectrum (selected bands), cm^{-1}: 1641 and 1625 s *ν*(C=N). ^1H NMR (500 MHz, $CDCl_3$) *δ*(ppm) 2.40 and 2.43 (s, 3H each, C_6H_4 *Me*), 2.94 (s, 9H) and 2.96 (s, 3H)(NMe), 5.83 (s, br., 1H), 5.87 (s, br., 2H) and 5.92 (s, br., 1H)(N–CH–N), 7.27 (m, 4H), 7.46 (m, 2H) and 7.53 (m, 2H)(C_6 *H*$_4$Me), 7.33–7.38 (m, 8H), 7.56–7.61 (m, 4H), 8.66 (m. 4H) and 8.88 (s, br., 4H)(N=C–Ph), 7.47 (m, 6H), 7.58 (m, 2H) and 7.61 (m, 2H)(CHPh). ^{13}C NMR (125.7 MHz, $CDCl_3$) *δ*(ppm) 21.4 (C_6H_4 *Me*), 46.0, 46.1 and 46.3 (NMe), 94.7 (N–CH–N), 122.3, 122.4, 122.5 and 122.6 (C_q, N=CPh), 128.2, 128.5, 128.58, 128.62 and 128.7 (2 CH C_6H_4Me, 4 CH CHPh, 4 CH N=CPh), 129.2 and 129.3 (CH, C_6 *H*$_4$Me), 129.6 and 129.7 (CH, CHPh), 130.4, 130.5, 130.6 and 130.7 (CH, N=CPh), 133.0 (br., C_q, C_6H_4Me), 133.31, 133.36, 133.47 and 133.50 (CH, N=CPh), 136.1 (br., C_q, CHPh), 139.3 and 139.5 (C_q, C_6H_4Me), 163.4 and 164.0 (C=N). ^{195}Pt NMR (107.3 MHz, $CDCl_3$) *δ*(ppm) −2111 (620 Hz) and −2121 (620 Hz).

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