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Synthesis and characterization of novel thiosemicarbazone palladacycles†

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Abstract:
Since the appearance of the term palladacycle, as coined by Trofimenko[1], one of the most salient groups is the one comprising thiosemicarbazones.
Herein, the synthesis and characterization of several palladium cyclometallated compounds with thiosemicarbazone ligands is discussed. The ligands were synthesized by treatment of a ketone with four different thiosemicarbazides in acidified aqueous solution. Then, they were conveniently treated with a palladium salt to yield the corresponding palladacycle. All show a tetranuclear structure with [C, N, S] coordination of the ligands to the metal centers.

Keywords:

Cyclometallated, thiosemicarbazones, palladium

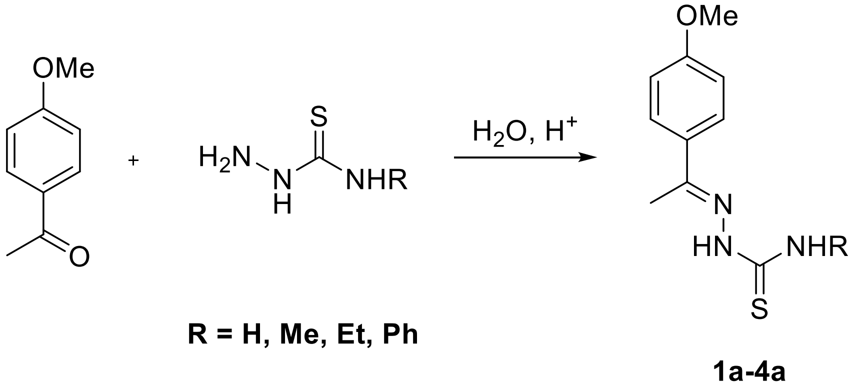
1. Introduction

Over the years, ligands such as thiosemicarbazones have been studied in cyclometallation reactions[2]. The main reason being they possess many donor atoms that can coordinate to the metal. Their applications have been widely studied; these compounds have catalytic properties in cross-coupling reactions[3,4].
They may also be used as cytotoxic and antitumoral species applicable in biological assays[5,6,7].

2. Experimental

2.1. Ligands

In an Erlenmeyer flask the thiosemicarbazide and hydrochloric acid (0,4 cm3) were added in water (20 cm3). After which the ketone was added. The mixture was stirred at room temperature for 8 h, after which a solid appeared, that was filtered, washed with water and dried under vacuum.



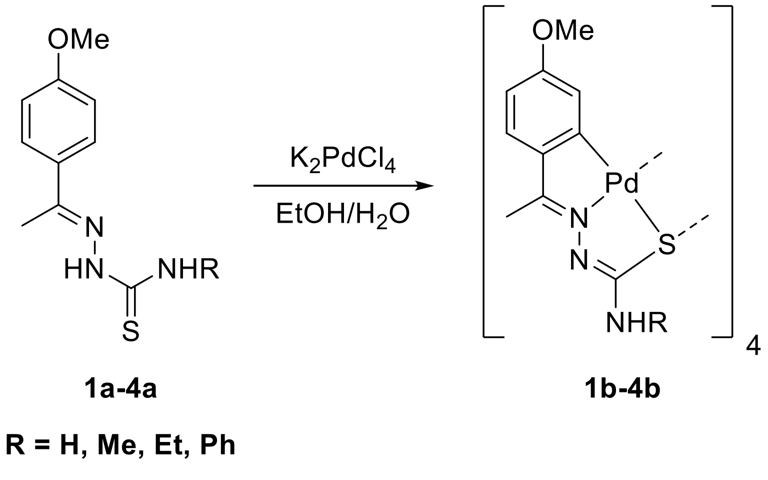
Scheme 1. Synthesized ligands

Ligand	R	Thiosemicarbazide (mg)	Ketone (mg)	Efficiency (%)
1a	H	250	412	90
2a	Me	250	357	98
3a	Et	250	315	88
4a	Ph	250	225	87

Chart 1. Quantities of reagents added

2.2. *Palladacycles*

In a Radley's tube potassium tetrachloropalladate was added in distilled water (6 cm^3). Then the thiosemicarbazone ligand was added in ethanol (40 cm^3). The resulting solution was stirred for 24 hours at room temperature. A suspension formed was centrifugated and the solid was dried under vacuum.



Scheme 2. Cyclometallated compounds synthesized

Compound	R	K_2PdCl_4 (mg)	Thiosemicarbazone (mg)	Efficiency (%)
1b	H	200	164	71
2b	Me	200	174	78
3b	Et	200	185	86
4b	Ph	200	275	89

Chart 2. Quantities of reagents added

3. Results and discussion

All the compounds were characterized by elemental analysis (C, H, N, S), IR and 1H NMR spectroscopy.

3.1. Elemental analysis

Theorical values appear in brackets.

Compound	Molecular formula	% C	% H	% N	% S
1a	$C_{10}H_{13}N_3OS$	51,7 (53,8)	5,9 (5,9)	18,1 (18,8)	17,7 (14,4)
2a	$C_{11}H_{15}N_3OS$	55,6 (55,7)	6,6 (6,4)	17,5 (17,7)	13,4 (13,5)
3a	$C_{12}H_{17}N_3OS$	57,4 (57,3)	6,8 (6,8)	16,7 (16,7)	13,0 (12,8)
4a	$C_{16}H_{13}N_3OS$	64,0 (64,2)	5,9 (5,7)	14,1 (14,0)	10,6 (10,7)
1b	$C_{40}H_{44}N_{12}O_4Pd_4S_4$	36,7 (36,7)	3,6 (3,4)	12,7 (12,8)	9,6 (9,8)
2b	$C_{44}H_{52}N_{12}O_4Pd_4S_4$	38,6 (38,7)	3,9 (3,8)	12,0 (12,3)	9,0 (9,4)
3b	$C_{48}H_{60}N_{12}O_4Pd_4S_4$	40,5 (40,5)	4,4 (4,3)	11,9 (11,8)	8,9 (9,0)
4b	$C_{64}H_{60}N_{12}O_4Pd_4S_4$	38,3 (47,6)	3,2 (3,7)	8,1 (10,4)	6,4 (7,9)

Chart 3. Elemental analysis characterization

The conclusion is that, with the exception of **4b**, the compounds are essentially pure.

3.2. IR spectroscopy

The IR spectra show that the ν(N-H) and ν(C=S) stretches are absent in the cyclometallated compounds. This confirms that the deprotonation and the loss of C=S double bond character is needed for the formation of the palladacycle.

Ligand	ν(N-H)	ν(C=S)	Compound	ν(N-H)
1a	3154/3243/3375	826	1b	3159/3292
2a	3193/3366	836	2b	3353
3a	3201/3299	829	3b	3341
4a	3230/3296	834	4b	3289

Chart 4. IR spectroscopy characterization

3.3. ^{1}H NMR spectroscopy

The disappearance of the ortho aromatic proton resonance and the hydrazinic proton resonance ensures cyclometallation.

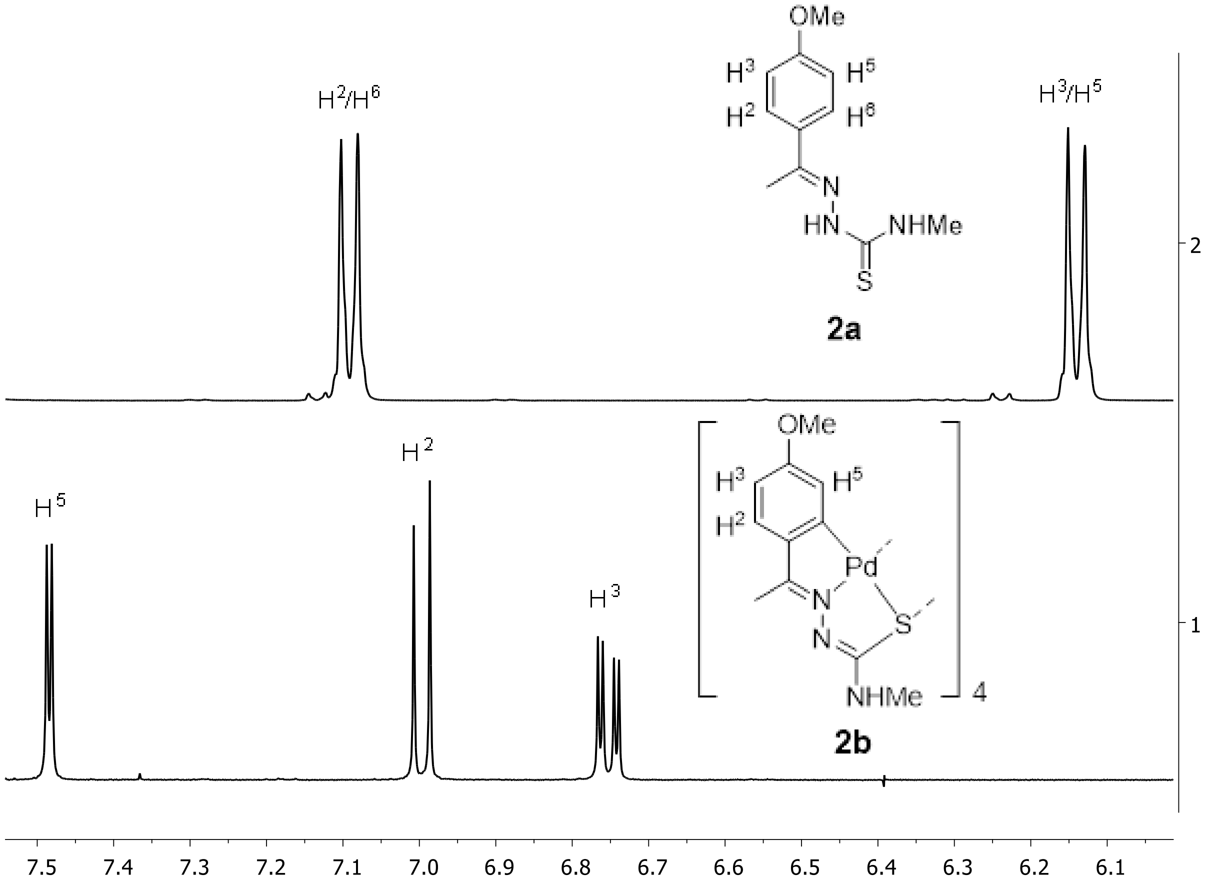


Figure 1. ^{1}H NMR stacked spectrum (400 MHz, DMSO-d_6) for compounds 2a and 2b

4. Conclusions

- Coordination to the metal center occurs in the thiol form of the thiosemicarbazone, approved by IR spectroscopy.
- ^{1}H NMR spectroscopy confirms cyclometallation, with the thiosemicarbazone ligand as tridentate [*C*, *N*, *S*].
- The cyclometallated compounds show a tetranuclear structure, with two type of bonds between palladium and sulfur: Pd-S$_{\text{chelate}}$ and Pd-S$_{\text{bridging}}$.
- Elemental analysis confirms the purity of the compounds, except for **4b**.

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Conflicts of Interest: “The authors declare no conflict of interest”

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