ELSEVIER

Journal of Organometallic Chemistry 658 (2002) 15–20

Journal of Organometallic Chemistry

www.elsevier.com/locate/jorganchem

Intramolecular C–N bond formation in the reductive elimination of *ortho*-palladated arylhydrazones of acetophenone

Aránzazu Carbayo, José V. Cuevas, Gabriel García-Herbosa *

Departamento de Química, Facultad de Ciencias, Universidad de Burgos, 09001 Burgos, Spain

Received 13 February 2002; received in revised form 21 March 2002; accepted 12 April 2002

Abstract

Carbonylation in dichloromethane at room temperature of the dimeric *ortho*-palladated complex $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_5\}(\mu\text{-}Cl)]_2$ yields in a first step the monocarbonyl $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_5\}Cl(CO)]$ which very slowly (days) undergoes in solution reductive elimination of palladium to give high yield of the isoindolinone derivative, 2-anilino-3-methylene-isoindolin-1-one. Addition of the stoichiometric amount of NaOMe to the monocarbonyl complex $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_5\}Cl(CO)]$ in solution leads instantaneously to reductive elimination and affords the indazole derivative, 3-methyl-1-phenyl-indazole, in high yield. Carbonylation of the related complex $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_4\text{-}p\text{-}NO_2\}(\mu\text{-}Cl)]_2$ yields in solution the monocarbonyl $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_4\text{-}p\text{-}NO_2\}Cl(CO)]$ which in minutes affords high yield of the isoindolinone derivative, 2-(4-nitroanilino)-3-methylene-isoindolin-1-one. Such different behaviour sheds light on the mechanistic grounds that govern the intramolecular C–N bond formation and the cyclization of *ortho*-palladated acetophenonearylhydrazones, and shows that the acidity of the N–H bond controls the rate of the reactions. The requirement of the formation of a palladium–nitrogen amido bond *cis* to a palladium–carbon bond is supported for these results. We suggest that a tautomeric equilibrium of the hydrazonato ligand accounts for the two alternate pathways.

Keywords: Metallacycles; Palladium(II); Carbonylation; Cyclization; Hydrazones

1. Introduction

Organometallic complexes of palladium are a group of chemicals of great interest as deduced from the huge number of references and books devoted to this subject. Particular attention is centred in their applications to organic synthesis [1]. Palladation reactions have been widely studied, and N-donor ligands capable of producing metallacycles have been thoroughly explored with regard to their synthesis, reactivity, structural and mechanistic aspects [2]. Most of the N-donor ligands, like tertiary amines, imines and azobenzenes only contain C–H bonds to activate and, in these cases, the products of their palladation reaction can be quite precisely anticipated [3]. However, when the ligands have also N–H bonds, C–H and N–H activations can occur simultaneously. In such cases, the presence of M–C(aryl) and M–N(amido) bonds on the same metal could lead to reductive elimination reactions and C–N bond formation. This is the case of acetophenonearylhydrazone ligands $PhC(CH_3)=NNHAr$ which have been used to prepare stable complexes containing both Pd–C(aryl) and Pd–N(amido) bonds [4,5]. The *trans*-arrangement of such bonds could account for the stability towards reductive elimination. In fact, *cis* arrangement for Pd–C and Pd–N(amido) bonds is uncommon. Those complexes containing such arrangement normally undergo reductive elimination and are models as intermediates in catalyzed C–N bond formation reactions and useful in organic synthesis [6].

In this paper we report the spontaneous intramolecular C–N bond formation between carbon monoxide and the *ortho*-palladated acetophenonephenylhydrazone complexes, $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_4\text{-}p\text{-}R\}(\mu\text{-}Cl)]_2$ (R = H, **A1**; R = NO_2, **A2**) leading to 2-anilino-3-methylene-isoindolin-1-one **1** and 2-(4-nitroa-

* Corresponding author. Present address: Quimica Inorganica, Pza. Misael Bañuelos s/n, 09001 Burgos, Spain. Tel.: +34-947-258-822; fax: +34-947-258-831

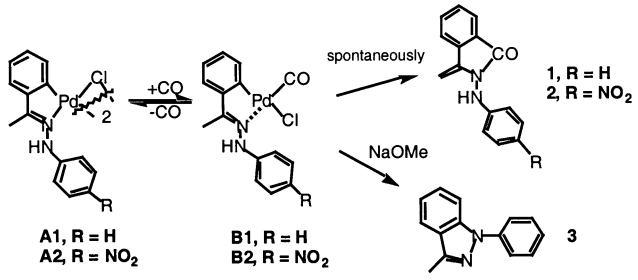
E-mail addresses: acarbayo@ubu.es (A. Carbayo), jvcv@ubu.es (J.V. Cuevas), gherbosa@ubu.es (G. García-Herbosa).

0022-328X/02/$ - see front matter
PII: S0022-328X(02)01466-3

nilino)-3-methylene-isoindolin-1-one **2**, two isoindolinone derivatives which, to our knowledge, have not been reported before [7,8]. These type of compounds is of current pharmacological interest [9,10]. The intramolecular C–N bond formation of the *ortho*-palladated acetophenonephenylhydrazone complex, $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_5\}(\mu\text{-}Cl)]_2$, in the presence of CO and sodium methoxide, leading to 3-methyl-1-phenyl-indazole **3** is also described. This can be a convenient way to prepare **3**, an apparently elusive molecule whose substitued derivatives are also of pharmacological interest [11–14]. These different results, depending on the reaction conditions, supply some clue about the mechanism of the reductive elimination in carbonylated complexes of *ortho*-palladated acetophenonearylhydrazones while opening a convenient way to synthesizing molecules of interest.

2. Results and discussion

As shown in Scheme 1, bubbling carbon monoxide through a suspension of the *ortho*-metallated dimer $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_5\}(\mu\text{-}Cl)]_2$ **A1** [4] affords a yellow solution characterized by a strong $\tilde{\nu}_{CO}$ band in the IR spectrum at 2127 cm^{-1} that is assigned to $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_5\}Cl(CO)]$ **B1**. Similar but stable monocarbonyls have been reported for *ortho*-palladated complexes of oximes [15]. However, monocarbonyl **B1** is only relatively stable in solution and concentration to vacuum or evaporation under CO atmosphere yields the starting dimer **A1** in a reversible carbonylation–decarbonylation reaction. Solutions of complex **B1** in dichloromethane are unstable and they decompose, after several hours at room temperature, affording palladium metal and 2-anilino-3-methylene-isoindolin-1-one **1**, the product of the intramolecular reductive elimination between the *ortho*-palladated hydrazone and the carbon monoxide. Bubbling carbon monoxide through a suspension of the related *ortho*-metallated dimer $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_4\text{-}p\text{-}NO_2\}(\mu\text{-}Cl)]_2$ [4] **A2** in dichloromethane at room temperature affords an unstable yellow solution that in a few minutes turns black due to palladium metal formed.

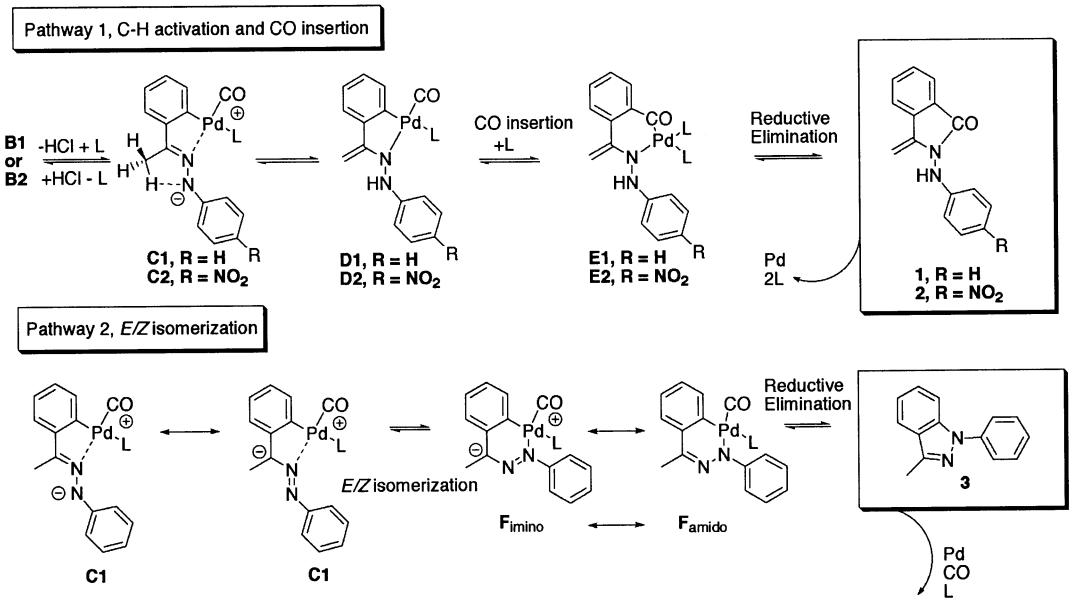


Scheme 1.

The unstable solution shows a strong $\tilde{\nu}_{CO}$ band in the IR spectrum at 2130 cm^{-1} that is assigned to $[Pd\{C_6H_4C(CH_3)=N-NHC_6H_4\text{-}p\text{-}NO_2\}Cl(CO)]$ **B2**. From stirred solutions of **B2** under CO, the compound 2-(4-nitroanilino)-3-methylene-isoindolin-1-one **2** can be recovered in high yield along with the palladium metal. The almost identical ν_{CO} value for the CO bands in both monocarbonyls **B1** and **B2** indicates that the coordination sphere of the metal complex must be both electronically and sterically equivalent in both complexes, showing independence with the substituents on the anilino group. Thus, the different reaction rates can be assigned to the acidity of the pendant N–H bond induced by the different substituents R in the *para*-position of the phenyl group. As shown in Scheme 2 pathway 1, the higher acidity of **B2** could supply higher concentrations of **C2**, and then the formation of **2** at room temperature takes less than 1 h whereas the formation of **1** under the same conditions takes 3 days.

The proposal of the deprotonation of the N–H bond as a necessary first step in the reductive elimination reaction to give **1** or **2**, is also supported by previous results exhibited by the related ligand 2-acetylpyridine-phenylhydrazone which, possessing deprotonable N–H bond, undergoes *ortho*-palladation reaction while 2-acetylpyridine-*N*-methyl-phenylhydrazone, with no N–H bonds, does not reacts under the same conditions [16]. Under such grounds, addition of the stoichiometric amount of NaOMe in MeOH to complete deprotonation of **B1** was carried out trying to accelerate the reaction but this led to a very different result. The indazole derivative 3-methyl-1-phenyl-indazole **3** (Scheme 2, pathway 2), the product of the intramolecular reductive elimination of *ortho*-palladated acetophenonephenylhydrazone, was formed in high yield while palladium metal was recovered from the reaction. In order to check if **B2** could lead to the nitro derivative of **3**, carbonylation of **A2** in dichloromethane was carried out in the presence of HCl gas. In these conditions **B2** appears to be stable while keeping the HCl atmosphere, as monitored by infrared spectroscopy. Addition of NaOMe in MeOH to this solution led to decomposition as the recovered product was mainly acetophenone-*p*-nitrophenylhydrazone. The reaction of **A1** with base in absence of CO leading to the binuclear complex $[Bu_4N][Pd\{C_6H_4C(CH_3)=N-NHPh\}\{\mu\text{-}N(Ph)=N-C(CH_3)C_6H_4\}(\mu\text{-}Cl)PdCl]$ has been recently reported [17].

The results here presented supply some information about the mechanisms that control the C–N bond formation in reductive elimination reactions of *ortho*-palladated acetophenonearylhydrazone complexes. Support of the proposed intermediates **C** comes from the X-ray structurally characterized binuclear compounds of formula $[Pd\{C_6H_4C(CH_3)=N-NC_6H_4\text{-}p\text{-}R\}\{P(OMe)_3\}]_2$, where, R = H, NO_2, that were prepared by



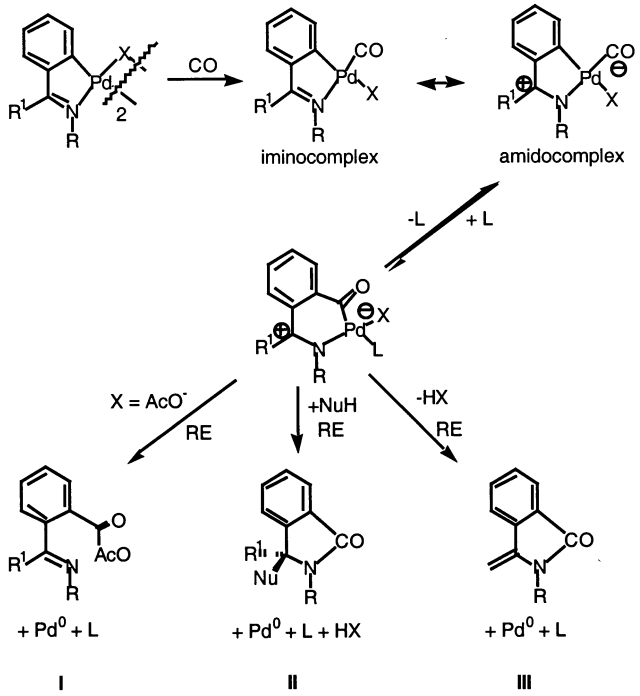
Scheme 2. L = any ligand available in the reaction.

treatment of [Pd{$C_6H_4C(CH_3)$=N–NHC_6H_4-*p*-R}Cl{$P(OMe)_3$}] (complexes analogous to **B** where CO has been substituted for trimethylphosphite) with sodium methoxide [4,5]. These complexes contain the hydrazonate anion proposed for **C**.

As shown in Scheme 2, pathway 1, **C1** or **C2** lead to the isoindolinones **1** or **2**, which are the products of the reductive elimination reactions of **E1** and **E2**, respectively. Intermediates **E**, not detected, contain a Pd–C bond *cis* to a Pd–N(amido) bond as it is required for C–N bond formation [6], are the result of carbon monoxide insertion in the palladium–phenyl bonds of **D.** Although intermediates **D** also contain a Pd–C bond *cis* to a Pd–N amido bond, the product of the reductive elimination at this point was not observed as the four-member ring expected must be highly strained. The steps **C** to **D** involve a proton migration from C–H to N–H. Such migration from the less to the more electronegative atom is similar to that observed in the well-known keto–enolic or en–amino–imino tautomers. When deprotonation is forced with NaOMe, complex **C1** follows a different pathway 2, leading to the *N*-phenylindazole derivative **3**, which is the product of the intramolecular reductive elimination of **F**, a six membered palladacycle showing, as in the case of intermediates **E**, Pd–C and Pd–N(amido) bonds in *cis* arrangement. The step **C1** to **F** is an *E* to *Z* isomerization around the C=N double bond. In pathway 1, the CO insertion into the Pd–C bond seems to be preferred over the *E*/*Z* isomerization that must occur in the pathway 2. The CO insertion on intermediate **F** should lead to a seven-membered palladacycle whose product of reductive elimination has not been observed. We suggest that the tautomeric equilibria between **C** and **D** are shifted to **D** in the absence of base and to **C** in the presence of base.

Carbonylation reactions of *ortho*-palladated Schiff base complexes are well known and a putative mechanism was proposed in the past to explain the products of the reactions [18].

In light of the results reported here we propose in Scheme 3 an alternate mechanism for the carbonylation of *ortho*-palladated Schiff base complexes by accepting



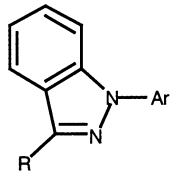
Scheme 3. Proposed mechanism for the carbonylation of *ortho*-palladated imines. NuH: nucleophile, RE: reductive elimination.

the importance of Pd–N (amido) bonds [6]. First, CO coordinates to palladium in position *cis* to the Pd–C(aryl) bond following the 'transphobia' arguments according to which soft ligands coordinate *cis* and hard ligands *trans* to Pd–C bonds [19,20]. Then, the influence of the coordinated CO on the *trans*-nitrogen atom induces the iminocomplex to change to the amidocomplex which undergoes CO insertion into the Pd–C bond. Three pathways are now possible to explain the products of the carbonylations: (1) reductive elimination to **I**, (2) nucleophilic attack and reductive elimination affording **II**, and (3) γ-proton elimination followed by reductive elimination affording **III**.

In summary, formation of C–N bonds seems to be associated to the ability of the strong π-acceptor ligand CO to modify the electronic properties of the nitrogen donor atom of the ligand in *trans*-position. Such nitrogen can participate in reductive elimination reactions when it behaves as amidocomplex but no as iminocomplex. In both pathways the final step is the reductive elimination of a six-member palladacycle containing a Pd–C bond *cis* to a Pd–N(amido) bond.

The synthesis of isoindolinones analogous to **1** and **2**, containing the anilino groups 2,4-dinitroanilino, 4-nitroanilino or 2-nitroanilino was reported many years ago [7,8]. The procedures are based in multistep synthesis and the use of high temperatures. To our knowledge, compound **1**, that contains an unsubstituted anilino group, has not been described yet. Taking into account the recent interest [9,10] in such kind of molecules we consider that the procedure reported here can be a more convenient way to synthesize isoindolinone derivatives in some cases. Although the synthesis of *N*-aryl-indazoles has been carried out from different approaches, we have not found in the literature any efficient synthetic procedure for compound **3**. Related derivatives with the formula shown in Scheme 4 have been published. Thus, high yields have been reported for the synthesis of the compound in which Ar = Ph and R = Ph [21], but not when R = Me and Ar = Ph.

When R = $COOC_2H_5$ and Ar = Ph a 85% of yield has been reported [21]. It seems to be clear that the synthesis (or the stability) of *N*-aryl-indazoles is affected by the nature of R, although in that paper the authors did not mention it. The synthesis of the indazolium hexaclor-oantimonate where, the substituted indazole is that with



Generic N-arylindazoles

Scheme 4.

Ar = 2,4,6-$C_6H_2Cl_3$ and R = Me has also been reported [22,23]. In this case the activated group is the Ar group. Compound **3** appears reported with a yield of < 5% among a group of related derivatives, which were obtained with 39–90% yields, in which R = Me and the position of Ar is occupied by alkyl substituents [24]. The synthesis of 1-phenyl-1*H*-indazole (i.e. R = H, Ar = Ph) has been recently reported via the palladium-catalyzed cyclization of [*N*-aryl-*N*′-(*o*-bromophenyl)hydrazinato-*N*′]-triphenylphosphonium bromide [25]. In short, the synthetic procedures for arylindazoles seem to be strongly dependent on the nature of substituents R and Ar on the generic formula shown in Scheme 4. Here we report a convenient high yield synthesis at room temperature of compound **3**. Although obtained in high yield, compound **3** is unstable and must be kept cold and under nitrogen to avoid fast decomposition. It likely undergoes oxidation via radicals that polymerize giving insoluble material.

3. Conclusions

Ortho-palladated acetophenonephenylhydrazones react with carbon monoxide and, depending on conditions, undergo cyclization giving isoindolinone derivatives or *N*-phenylindazole that contain new carbon–nitrogen bonds. These results supply information about the reductive elimination mechanisms of palladacycles containing palladium–carbon σ bonds arranged *cis* to palladium–nitrogen amido bonds.

4. Experimental

4.1. General considerations

^{1}H-NMR spectra were recorded on a Bruker AC 80 instrument and a Varian XL-400 instrument. ^{13}C-NMR was recorded on a Varian XL-400 instrument. ^{1}H chemical shifts were measured with TMS as internal reference at 25 °C. ^{13}C chemical shifts were measured with reference to the residual solvent resonances. All chemical shifts are reported in δ units, parts per million (ppm). Solid IR spectra were recorded as KBr disk (in the range 4000–400 cm^{-1}) on a Nicolet Impact 410 instrument. Solution IR spectra were recorded (in the range 2200–1700 cm^{-1}) on a Perkin–Elmer 843 spectrometer. Mass spectra were obtained with a Hewlett Packard II mass spectrometer with a Hewlett Packard 5791 A Mass Selective Detector. Microanalyses were performed by the SCAI (Servicios Centrales de Apoyo a la Investigacion de la Universidad de Burgos) with sulfanilamide and acetanilide as patrons.

Complexes [Pd{$C_6H_4C(CH_3)$=N–NHC_6H_4*p*-R}(μ-Cl)]$_2$ (R = H, **A1**; R = NO_2, **A2**) where, prepared

according to published procedures [4]. All reactions were carried out using Schlenk techniques. Solvents were distilled and dried over calcium dihydride (hexane and methylene chloride) and degassed by standard methods prior to use.

4.2. Identification in solution of [Pd{$C_6H_4C(CH_3)$=N–NHC_6H_5}Cl(CO)] (**B1**)

When carbon monoxide was bubbled through a suspension of [Pd{$C_6H_4C(CH_3)$=N–NHC_6H_5}(μ-Cl)]$_2$ (**A1**) (500 mg, 0.71 mmol) in dichloromethane (100 ml) at room temperature (r.t.), a yellow solution, that slowly turned black, was formed. The solution showed a strong $\tilde{\nu}_{CO}$ band in the infrared at 2127 cm^{-1} that was assigned to **B1**. Concentration to isolate the solid under CO atmosphere afforded the starting dimer **A1**.

4.3. Identification in solution of [Pd{$C_6H_4C(CH_3)$=N–$NHC_6H_4pNO_2$}Cl(CO)]$_2$ (**B2**)

When carbon monoxide was bubbled through a suspension of [Pd{$C_6H_4C(CH_3)$=N–$NHC_6H_4pNO_2$}-(μ-Cl)]$_2$ (**A2**) (500 mg, 0.63 mmol) in dichloromethane (100 ml) at r.t., an unstable yellow solution, that slowly turned black (Section 2), was formed. The solution showed a strong $\tilde{\nu}_{CO}$ band in the infrared at 2130 cm^{-1} that was assigned to **B2**.

4.4. Synthesis of 2-anilino-3-methylene-isoindolin-1-one (**1**)

Carbon monoxide was bubbled during 72 h through a suspension of complex [Pd{$C_6H_4C(CH_3)$=N–NHC_6H_5}(μ-Cl)]$_2$ (**A1**) (500 mg, 0.71 mmol) in dichloromethane (100 ml) at r.t. The mixture was filtered and the black solid formed was removed. The resulting yellow solution was concentrated under vacuum and the product **1** was precipitated by the addition of hexane (25 ml). The product **1** was collected as a pale yellow solid by filtration to yield 238 mg (1.01 mmol, 71%). ^{1}H-NMR (400 MHz, $CDCl_3$): $\delta = 5.22$ (dd, 2H, AB system, ^2J(H–H) = 1.90 Hz), 6.54–7.86 (m, 9H, aromatics), 6.54 (s, 1H, NH) ppm; $^{13}C\{^1H\}$-NMR (400 MHz, $CDCl_3$): $\delta = 165.3$ (CO), 151.7, 139.6, 134.0, 133.2, 133.0, 130.1, 128.6, 125.8, 125.7, 123.7, 120.7, 112.0, 111.8, 90.9 (CH_2) ppm; IR: $\tilde{\nu} = 3278$ cm^{-1}(NH), $\tilde{\nu} = 1706$ cm^{-1} (C=O); Anal. Calc. (%) for $C_{15}H_{12}N_2O$ (236.29): C, 76.24; H, 5.12; N, 11.85. Found: C, 76.60; H, 5.09; N, 11.91%.

4.5. Synthesis of 2-(4-nitroanilino)-3-methylene-isoindolin-1-one (**2**)

Carbon monoxide was bubbled during 1h through a suspension of [Pd{$C_6H_4C(CH_3)$=N–$NHC_6H_4pNO_2$}(μ-Cl)]$_2$ (**A2**) (500 mg, 0.63 mmol) in dichloromethane (100 ml) at r.t. The mixture was filtered and the black solid formed was removed. The orange solution was partially pumped and hexane (25 ml) was added to induce precipitation of **2**. Yield: 220 mg, 62%. ^{1}H-NMR (400 MHz, $CDCl_3$): $\delta = 5.28$ (dd, 2H, AB system, ^2J(H–H) = 1.99 Hz), 6.82–8.20 (m, 8H, aromatics), 6.70 (s, 1H, NH) ppm; $^{13}C\{^1H\}$-NMR (400 MHz, $CDCl_3$): $\delta =$ 165.3 (CO), 146.3, 140.4, 134.1, 132.5, 129.6, 129.2, 128.2, 125.4, 123.5, 121.3, 120.3, 113.2, 113.1, 90.5 (CH_2) ppm; IR: $\tilde{\nu} = 3264$ cm^{-1}(NH), $\tilde{\nu} = 1712$ cm^{-1} (C=O), $\tilde{\nu} = 1600cm^{-1}$ ($\tilde{\nu}_{as}$ NO_2), $\tilde{\nu} = 1328cm^{-1}$ ($\tilde{\nu}_{sym}$ NO_2); Anal. Calc. (%) for $C_{15}H_{11}N_3O_3$ (281.29): C, 64.04; H, 3.94; N, 14.94. Found: C, 63.91; H, 4.03; N, 15.09%.

4.6. Synthesis of 3-methyl-1-phenyl-indazole (**3**)

Carbon monoxide was bubbled during 1 h through a suspension of 500 mg (0.71 mmol) of [Pd{$C_6H_4C(CH_3)$=N–NHC_6H_5}(μ-Cl)]$_2$ (**A1**) in dichloromethane (100 ml) at r.t. The mixture was filtered and 1.78 ml of a 0.8 M solution of NaOMe in MeOH were added (equivalent to 1.4 mmol of NaOMe). The mixture was stirred for 1 h and the black solid was removed by filtration. The resulting orange–brown solution was pumped and hexane (25 ml) was added to induce precipitation of **3** (250 mg, 1.2 mmol, 85%). ^{1}H-NMR (80 MHz, $CDCl_3$): $\delta = 2.70$ (s, 3H, CH_3), 7.11–8.29 (m, 9H, aromatics) ppm; MS (70 eV, EI): *m/z* (%): 208 (100); Anal. Calc. (%) for $C_{14}H_{12}N_2$ (208.28): C, 80.72; H, 5.81; N, 13.45. Found: C, 80.57; H, 5.83; N, 13.69%.

Acknowledgements

The authors gratefully acknowledge to the Spanish Dirección General de Enseñanza Superior (PB97-0470-C02) and the Junta de Castilla y León (BU08/99) for financial support. We also acknowledge to the Servicios Centrales de Apoyo a la Investigación (SCAI) de la Universidad de Burgos for technical support.

References

[1] J. Tsuji, Palladium Reagents and Catalysts, Wiley, Chichester, 1996.
[2] A.D. Ryabov, Chem. Rev. 90 (1990) 403.
[3] I. Omae, Coord. Chem. Rev. 83 (1988) 137.
[4] P. Espinet, G. García-Herbosa, F.J. Herrero, Y. Jeannin, M. Philoche-Levisalles, Inorg. Chem. 28 (1989) 4207.
[5] P. Espinet, M.Y. Alonso, G. García-Herbosa, J.M. Ramos, Y. Jeannin, M. Philoche-Levisalles, Inorg. Chem. 31 (1992) 2501.
[6] (A) J.F. Hartwig, Angew. Chem. Int. Ed. 37 (1998) 2046; (b) J.F. Hartwig, Angew. Chem. Int. Ed. 37 (1998) 2090.
[7] F.M. Rowe, W. Osborn, J. Chem. Soc. (1947) 829.

[8] F.M. Rowe, D.A.W. Adams, A.T. Peters, A.E. Gillam, J. Chem. Soc. (1937) 90.
[9] S.M. Allin, C.J. Northfield, M.I. Page, A.M.Z. Slawin, J. Chem. Soc. Perkin Trans. 1 (2000) 1715.
[10] T.R. Belliotti, W.A. Brink, S.R. Kesten, J.R. Rubin, D.J. Wustrow, K.T. Zoski, S.Z. Whetzel, A.E. Corbin, T.A. Pugsley, T.G. Heffner, L.D. Wise, Bioorg. Med. Chem. Lett. 8 (1998) 1499.
[11] L. Mosti, L. Sansebastiano, P. Fossa, P. Schenone, F. Mattioli, Farmaco 47 (1992) 357.
[12] L. Mosti, G. Menozzi, P. Schenone, L. Molinario, F. Conte, C. Montanario, E. Marmo, Farmaco-Edizione Sci. 43 (1988) 763.
[13] Y. Fujimura, Y. Ikeda, I. Matsunaga, Yakugaku Zasshi J. Pharm. Soc. Jpn. 106 (1986) 995.
[14] T. Koide, H. Matsushita, Neuropharmacology 20 (1981) 285.
[15] H. Onoue, K. Nakagawa, I. Moritani, J. Organomet. Chem. 35 (1972) 217.
[16] G. García-Herbosa, A. Muñoz, D. Miguel, S. García-Granda, Organometallics 13 (1994) 1775.
[17] A. Carbayo, J.V. Cuevas, G. García-Herbosa, S. García-Granda, D. Miguel, Eur. J. Inorg. Chem. (2001) 2361.
[18] J.M. Thompson, R.F. Heck, J. Org. Chem. 40 (1975) 2667.
[19] J. Vicente, A. Arcas, D. Bautista, P.G. Jones, Organometallics 16 (1997) 2127.
[20] J. Vicente, J.A. Abad, A.D. Frankland, M.C.R. de Arellano, Chem. Eur. J. 5 (1999) 3066.
[21] P. DallaCroce, C. LaRosa, Synthesis, (1984) 982.
[22] Q. Wang, A. Amer, S. Mohr, E. Ertel, J.C. Jochims, Tetrahedron (1993) 9973.
[23] A.M. Amer, M.A. Mostafa, M.S. Amer, Afinidad 54 (1997) 305.
[24] C.P.A. Kunka, J. Warkentin, Can. J. Chem. 68 (1990) 575.
[25] J.J. Song, N.K. Yee, Tetrahedron Lett. 42 (2001) 2937.