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TETRAHEDRON

6-Chloro-spirocyclohexenindol-2-ones: an Unusual Ring Transformation to Ethyl 2-(Cyclohexa-1,4-dienyl)phenylcarbamates.

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Abstract: The Diels-Alder cycloaddition reaction of 3-chloromethylen-2-indolones **1** with a series of dienes **2** was studied in order to synthesize spirocyclohexenindolones **3** and **4**. The reaction proceeded with good diastereoselectivity and regioselectivity. Chloro-spirocyclohexenindolones **3** and **4** were transformed into 2-aminobiphenyl derivatives **5** by reacting with sodium ethoxide. Starting from the indolone **1c** and 2,3-dimethylbutadiene the spiro compounds **3f** and **4e** were obtained. On treatment with sodium ethoxide, **3f** was transformed into the phenanthridone derivatives **7** and **8**.

Keywords: Diels-Alder; chloromethylen-2-indolone; (cyclohexadienyl)phenylcarbamates; 2-aminobiphenyl; phenanthridone

INTRODUCTION

3-Yliden-2-indolones have been shown to be good starting materials to synthesize spirocyclohexenindolone derivatives owing to the reactivity in the Diels-Alder cycloaddition of their double bond substituted with an electron-withdrawing group.[1] Nevertheless, it was reported[1d] that this reaction was unsuccessful when 3-chloromethylenindolone **1** was reacted with several dienes.

The synthesis of spirocyclohexenindolones substituted with a chlorine atom on the cyclohexenyl ring attracted our attention for many reasons. It is known that spiroindolones are of general interest because they display different types of biological activities[2] and may also be used as starting materials for alkaloid syntheses.[3] However, chloro substituted representatives of this class of compounds are not known and it was expected that this reactive substituent could affect importantly the reactivity of the new class of the compounds.

In fact, a new and characteristic ring transformation of these spiro compounds was possible by virtue of the presence of the chlorine atom. 6-Chloro-spirocyclohex-3-en-1,3'-indol-2-ones **3** and **4** were easily transformed into ethyl 2-(cyclohexadienyl)phenylcarbamates **6**, which are the key intermediates in the formation of substituted 2-aminobiphenyls **5**. Compounds **5** are useful starting materials for the synthesis of heterocyclic compounds (phenanthridines, carbazoles)[4] and have many industrial uses.[5] This synthesis allows access to 2-aminobiphenyl derivatives with complete positional selectivity and different substitution patterns. Reactive substituents, suchas the ethoxycarbonyl group, are easily involved in cyclization reactions, leading to nitrogen-containing heterocycles, as in the case of synthesis of phenanthridone **8**.

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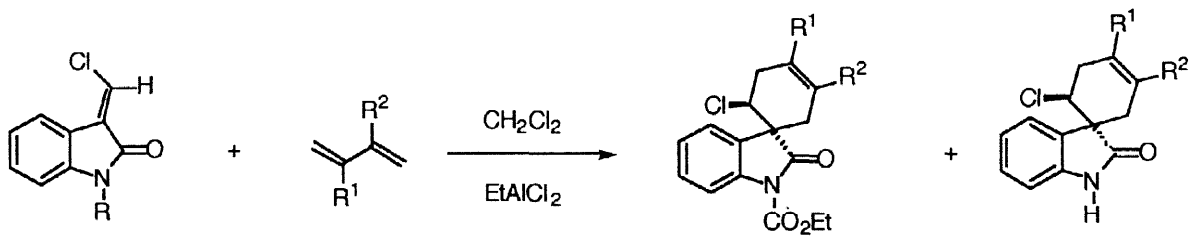
RESULTS AND DISCUSSION

Cycloaddition reactions of indolones 1 and dienes 2. The reaction of 3-chloromethylenindolones **1** with dienes **2** was possible only in presence of ethylaluminium dichloride as catalyst. Compound *E*-**1a** reacted with 2,3-dimethylbutadiene (**2a**) in dichloromethane at room temperature giving, after 2 h, a mixture of spiro compounds **3a** (75 %) and **4a** (22%). The latter product was derived from **3a**, which was partially deprotected at the nitrogen atom under the reaction conditions (Scheme 1).

Scheme 1



1a; R =CO_2 Et
1b; R = H

2a; $R^1 = R^2$ = Me
2b; R^1 = Me, R^2 = H

3a; $R^1 = R^2$ = Me
3b; R^1 = Me, R^2 = H
3c; R^1 = H, R^2 = Me

4a; $R^1 = R^2$ = Me
4b; R^1 = Me, R^2 = H

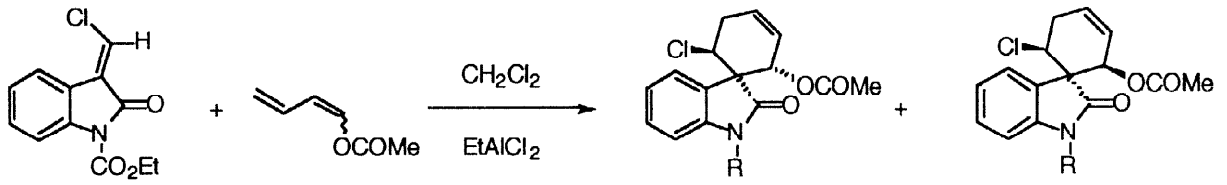
Compound **4a** was obtained as the sole reaction product in 76 % yield by using indolone **1b** and diene **2a** and operating under the same reaction conditions reported above. (Scheme 1) However, starting from the *N*-protected derivative **1a** the yield (total yield: 97 %) was better than starting from **1b**. Accordingly, in view of the transformation into biphenyl derivatives (see below), for which both compounds **3** and **4** are starting materials and can be used also in mixture, the *N*-protected indolones were always preferred for better overall yields.

The cycloaddition reaction appeared to be stereospecific because only one diastereoisomer was formed, in which the chlorine atom and the carbonyl group have the same *trans* relationship as in the starting olefin. The structure was confirmed as described below.

In order to evaluate both the possibility of changing the substituent pattern of the cyclohexenyl ring and the regiochemistry of the reaction, two different dienes were used: 2-methylbutadiene (**2b**) and 1-acetoxybutadiene (**2c**). The reaction of **1a** with **2b** resulted in the formation of two regioisomers **3b** and **3c**, in a 5:1 ratio, together with the *N*-deprotected indolone **4b** (Scheme 1). The structure of compounds **3b** and **4b** was assigned by their ^{1}H NMR spectra, in which the presence of a doublet of doublets at 2.21 and 2.17 ppm, respectively, corresponding to one of the two H-2, revealed the coupling of this proton with the vinyl one at C-3.

The diene **2c**, which was a mixture of *E/Z* isomers, reacted with **1a** giving in 7 h a mixture of diastereoisomers **3d** and **3e** and the corresponding *NH*-spiroindolones **4c**, **4d**. In this case the reaction proceeded with a good total yield (89 %) and a high regioselectivity (Scheme 2). The ^{1}H NMR analysis of the crude reaction mixture showed the presence of two diastereoisomers in a 1:1 ratio. Only trace amounts of a second regioisomer were detected. It is worth nothing that the observed regiochemistry is in good agreement with the results obtained when the diene **2c** was reacted with 3-(ethoxycarbonylmethylen)indolone.[1a]

Scheme 2



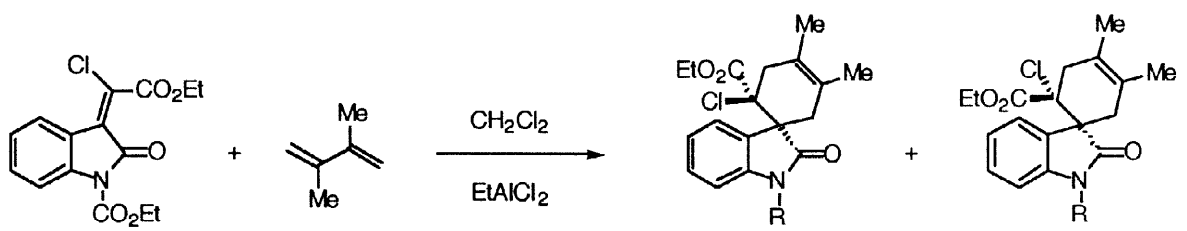
1a **2c** **3d**; R = CO_2Et **3e**; R = CO_2Et
4c; R = H **4d**; R = H

The configuration of the diastereoisomers **3d,e** was assigned by a NOESY experiment in which a positive Overhauser effect was observed between H-2 and H-6 only for compound **3e**, thus confirming the *cis* relationship between the chlorine atom and the acetoxy group. The ^1H NMR data were in agreement with those reported for similar compounds,[1a] confirming both the regiochemistry and diastereoselectivity observed.

Diene **2a** was reacted with indolone **1c** having double substitution at the double bond. The reaction was slower (36 h) than with **1a** and a mixture of diastereoisomers **3f** and **3g**, together with the corresponding *NH*-spiroindolones **4e** and **4f**, was obtained in 82 % total yield (Scheme 3). In this case a partial isomerization of the double bond occurred during reaction.

Compounds **3f,4e** were found as the major isomers and their configuration was demonstrated by the results reported below for their transformation into biphenyl berivatives.

Scheme 3



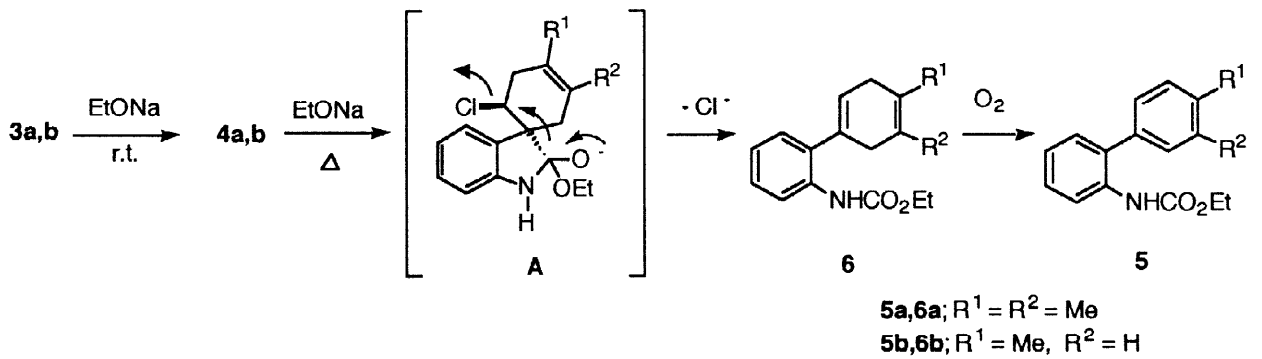
1c **2a** **3f**; R = CO_2Et **3g**; R = CO_2Et
4e; R = H **4f**; R = H

Rearrangement reaction of cycloadducts. The chlorospiroindolones **3** and **4** are starting materials for the preparation of 2-aminobiphenyl derivatives **5** through an unusual mechanism. The *trans* relationship between the chlorine atom and the carbonyl group is the steric requirement which allows this transformation.

By reacting **3a,b** in presence of an excess of sodium ethoxide in refluxing ethanol, *N*-ethoxycarbonyl-2-aminobiphenyl derivatives **6a,b** were obtained quantitatively. The same products were isolated starting from the *NH*-spiro compounds **4a,b**. It appeared that the first reaction step of this transformation was the deprotection of the nitrogen atom. In fact, reaction of **3a** with a single equivalent of sodium ethoxide at room temperature afforded **4a**. Compounds **4** were transformed into **6** by addition of ethoxide to the carbonyl group and ring

opening of intermediates **A** with loss of chloride ion. The 1,4-cyclohexadiene products **6** were isolated and underwent slow spontaneous oxidation to the biphenyl compounds **5a,b** (Scheme 4). The presence of an AA'XX' system in the ^{1}H NMR spectrum of compound **5b** confirmed both its structure and, indirectly, the regiochemistry of the cycloaddition reaction.

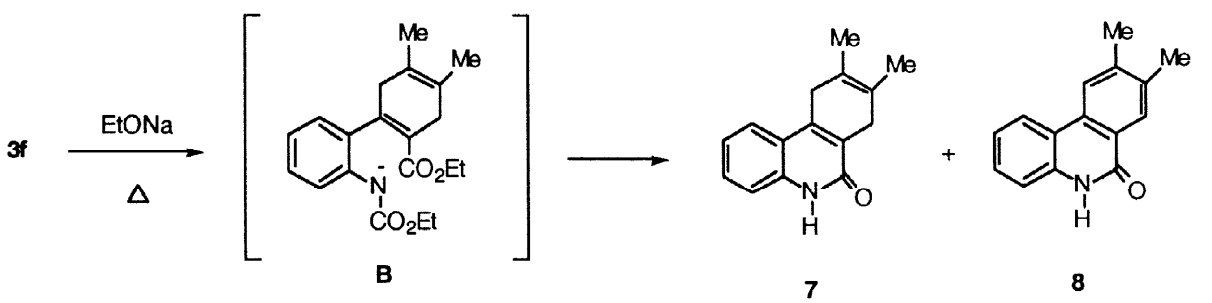
Scheme 4



Poor results were observed starting from **3d** and/or **3e**: only small amounts of the 2-hydroxy-2'-aminobiphenyl derivative were detected besides tarry compounds. However, a different and useful result was found when the spiro compound **3f** was treated with sodium ethoxide in refluxing ethanol: a mixture of the dihydrophenanthridone **7** and its aromatized product **8** was isolated in good yield (70 %) (Scheme 5). The key step in this reaction was the intramolecular condensation of the nitrogen anion of 2-(cyclohexadienyl)phenylcarbamate (intermediate **B**) with the ethoxycarbonyl group. Dihydrophenanthridone **7** was formed after deprotection of the nitrogen atom. Compound **7** underwent spontaneous oxidation to **8**.

The structure of phenanthridone **8** was confirmed both by spectroscopic data and by comparison with the literature.[6] A typical absorption at 1635 cm^{-1} (CO) in the IR spectrum and ^{1}H NMR signals in the 8.05-8.20 region were present.

Scheme 5



Interestingly, the reaction of the diastereoisomer **3g** resulted in a mixture of unidentified compounds in which compounds **7** and **8** were not detected. This result confirms that the *trans* relationship between the chlorine atom and the carbonyl group is necessary for the elimination process.

In conclusion, we have found that 3-chloromethylenindolones **1** reacted with several substituted dienes **2** giving 6-chloro-spirocyclohex-3-en-1,3'-indol-2-ones **3** and **4** with high diastereoselectivity and regioselectivity. The presence of the chlorine atom permitted, through the key intermediates **6**, an efficient and new synthesis of 2-aminobiphenyl derivatives **5** with different substituent patterns. A phenanthridone synthesis was also possible by using ethyl 2-chloro-spirocyclohex-4-en-1,3'-(2[1]-oxoindole)-2-carboxylate as starting compound.

EXPERIMENTAL

Melting points were determined using a Büchi 510 (capillary) and Electrothermal apparatus. IR spectra were recorded on a JASCO IR Report 100 spectrophotometer. NMR spectra were obtained with Bruker AC 200 and Varian Gemini 200 instruments. TLC: ready-to-use silica gel plates. Column chromatography: silica gel [Kieselgel 60-70 230 ASTM (Merck)] with the eluent indicated. Compound **1a-c** were prepared according to the known procedure.[3c] Anhydrous ethanol-free CH_2Cl_2 was used.

General Procedure for Cycloaddition Reaction

To a stirred solution of 3-methylenindolones **1a,c** (1 mmol) and of dienes **2a-c** (3 mmol) in anhydrous CH_2Cl_2 (5 ml), under nitrogen at room temp., $EtAlCl_2$ (21.7 μl, 0.2 eq.) was added. The solution turned from yellow to brown and after the time indicated the solvent was evaporated and the crude reaction mixture was chromatographed (pentane/CH_2Cl_2/Et_2O, 1 : 0 to 0 : 1) giving two fractions containing spiro compounds **3** and the corresponding *NH*-derivatives **4**.

6-Chloro-3,4-dimethyl-spirocyclohex-3-en-1,3'-[1'-ethoxycarbonyl]indol-2'-one (3a) and NH-Derivative (4a). Reaction time 2 h; **3a**: 256 mg (75 %); m.p. 118 °C (CH_2Cl_2/*i*-Pr_2O); IR (nujol) cm^{-1}: 1750, 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.46 (t, *J* = 7.1 Hz, 3H, Me), 1.65 (s, 3H, Me-4), 1.77 (s, 3H, Me-3), 2.56-2.70 (m, 2H, H-5), 2.07, 2.84 (two d, AX system, *J* = 17.1 Hz, 2H, H-2), 4.43-4.55 (m, 3H, H-6 and OCH_2), 7.15-7.42 (m, 3H, H_{arom}), 7.98 (d, *J* = 8.2 Hz, 1H, H-8'); ^{13}C NMR ($CDCl_3$) δ 14.3 (Me), 18.6, 18.7 (Me-3, Me-4), 38.7 (C-5), 40.9 (C-2), 53.5 (C-1), 59.1 (OCH_2), 63.6 (C-6), 115.5 (C-8'), 123.7, 124.6, (C-3, C-4), 128.7 (C_{arom}), 124.1, 124.9, 128.9 (CH_{arom}), 150.7 (CO_2Et), 176.6 (C-2'); Calcd. for $C_{18}H_{20}ClNO_3$ (333.8): C 64.77, H 6.04, N 4.20; found C 64.40, H 6.24, N 4.10; **4a**: 60 mg (22 %); m.p. 214 °C (CH_2Cl_2/*i*-Pr_2O); IR (nujol) cm^{-1}: 3150 (NH), 1700 (CO); ^1H NMR ($CDCl_3$) δ 1.66 (s, 3H, Me-4), 1.78 (s, 3H, Me-3), 2.65-2.75 (m, 2H, H-5), 2.03, 2.80 (two d, AX system, *J* = 17.9 Hz, 2H, H-2), 4.51 (t, *J* = 8.6 Hz, 1H, H-6), 6.94-7.32 (m, 4H, H_{arom}), 8.56 (s, 1H, NH exchangeable); Calcd. for $C_{15}H_{16}ClNO$ (261.7): C 68.83, H 6.16, N 5.35; found C 68.70, H 6.20, N 5.20.

6-Chloro-4-methyl-spirocyclohex-3-en-1,3'-[1'-ethoxycarbonyl]indol-2'-one (3b), 6-Chloro-3-methyl-spirocyclohex-3-en-1,3'-[1'-ethoxycarbonyl]indol-2'-one (3c) and NH-Derivative (4b). Reaction time 2 h; **3**: 156 mg (57 %) (mixture of **3b,c**, 5 : 1); **3b**: m.p. 116 °C (Et_2O/pentane); IR (nujol) cm^{-1}: 1750, 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.47 (t, *J* = 7.1 Hz, 3H, Me), 1.83 (s, 3H, Me-4), 2.21 (dd, *J* = 17.5, 5.3 Hz, 1H, H-2), 2.50-2.74 (m, 2H, H-5), 2.75-2.92 (m, 1H, H-2), 4.49 (q, *J* = 7.1 Hz, 2H, OCH_2), 4.55 (dd, *J* = 10.2, 6.9 Hz, 1H, H-6), 5.51-5.54 (m, 1H, H-3), 7.17-7.43 (m, 3H, H_{arom}), 7.98 (d, *J* = 8.1 Hz, 1H, H-8'); Calcd. for $C_{17}H_{18}ClNO_3$ (319.8): C 63.85, H 5.67, N 4.38; found C 63.70, H 5.73, N 4.22. **3c** (mixture with **3b**): ^1H NMR ($CDCl_3$) δ 1.45 (t, *J* = 7.1 Hz, 3H, Me), 1.79 (s, 3H, Me-3), 5.35-5.45 (m, 1H, H-4); **4b**: 60 mg (23 %); m.p. 214 °C(CH_2Cl_2/*i*-Pr_2O); IR (nujol) cm^{-1}: 3150 (NH), 1700 (CO); ^1H NMR ($CDCl_3$) δ 1.83 (s, 3H, Me-4), 2.17 (dd, *J* = 16.4, 5.4 Hz, 1H, H-2), 2.55-2.88 (m, 3H, H-5 and H-2), 4.54 (dd, *J* = 9.9, 7.1 Hz, 1H,

H-6), 5.50-5.57 (m, 1H, H-3), 6.93-7.32 (m, 4H, H_{arom}), 8.23 (s, 1H, NH exchangeable); Calcd. for $C_{14}H_{14}ClNO$ (247.7): C 67.88, H 5.70, N 5.65; found C 67.80, H 5.75, N 5.51.

*2-Acetoxy-6-chloro-spirocyclohex-3-en-1,3'-[1'-ethoxycarbonyl]indol-2'-ones (**3d,e**) and NH-Derivatives (**4c,d**).* Reaction time 7 h; Flash column chromatography: EtOAc/cyclohexane, 1 / 5. **3d**: 16 **mg** (5 %); m.p. 131 °C (Et_2O); IR (nujol) cm^{-1}: 1780, 1740, 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.47 (t, *J* = 7.1 Hz, 3H, Me), 1.74 (s, 3H, MeCO), 2.68-2.82 (m, 2H, H-5), 4.49 (q, *J* = 7.1 Hz, 2H, OCH_2), 4.55 (dd, *J* = 6.4, 10.3 Hz,1H, H-6), 5.79-6.03 (m, 3H, H-2, H-3, H-4), 7.16-7.46 (m, 3H, H_{arom}), 8.00 (d, *J* = 8.1 Hz, 1H, H-8'); **3e**: 134 mg (37 %); m.p. 119 °C (Et_2O); IR (nujol) cm^{-1}: 1780, 1740, 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.44 (t, *J* = 7.1 Hz, 3H, Me), 2.11 (s, 3H, MeCO), 2.61-2.79, 2.93-3.09 (two m, 2H, H-5), 4.46 (q, *J* = 7.1 Hz, 2H, OCH_2), 4.76 (dd, *J* = 9.9, 6.2 Hz, 1H, H-6), 5.39 (d, *J* = 5.0 Hz, 1H, H-2), 5.79-5.89 (m, 1H, H-3), 6.16-6.24 (m, 1H, H-4), 7.12-7.45 (m, 3H, H_{arom}), 7.99 (d, *J* = 8.1 Hz, 1H, H-8'); ^{13}C NMR ($CDCl_3$) δ 14.2 (Me), 21.1 (MeCO), 33.0 (C-5), 55.1 (C-1), 55.3 (C-6), 63.5 (OCH_2), 69.3 (C-2), 115.3 (C-8'), 123.6 (C-3), 124.6-129.7 (CH_{arom}), 131.5 (C-4), 140.1, (C_{arom}), 150.6 (CO_2Et), 170.4, 172.1, (C-2', COMe); Calcd. for $C_{18}H_{18}ClNO_5$ (363.8): C 59.43, H 4.99, N 3.85; found C 59.38, H 5.05, N 3.80; **4c,d**: 140 mg (47 %); **4c** (mixture with **4d**): ^1H NMR ($CDCl_3$) δ 1.77 (s, 3H, Me), 2.68-2.85 (m, 2H, H-5), 4.55 (dd, *J* = 10.4, 6.6 Hz, 1H, H-6), 5.75-6.04 (m, 3H, H-2, H-3, H-4), 6.90-7.40 (m, 4H, H_{arom}), 8.13 (s, 1H, NH exchangeable); **4d**: m.p. 195 °C (Et_2O); IR (nujol) cm^{-1}: 3150 (NH), 1720, 1700 (CO); ^1H NMR ($CDCl_3$) δ 2.12 (s, 3H, Me), 2.65-2.80, 2.95-3.12 (two m, 2H, H-5), 4.75 (dd, *J* = 9.9, 6.1 Hz, 1H, H-6), 5.45 (d, *J* = 5.3 Hz, 1H, H-2), 5.82-5.92, 6.15-6.23 (two m, 2H, H-3, H-4), 6.90-7.34 (m, 4H, H_{arom}), 7.76 (s, 1H, NH exchangeable); Calcd. for $C_{15}H_{13}ClNO_3$ (290.7): C 61.97, H 4.51, N 4.82; found C 62.12, H 4.55, N 4.95.

*Ethyl 2-Chloro-4,5-dimethyl-spirocyclohex-4-en-1,3'-[1'-ethoxycarbonyl-2'-oxo]indole-2-carboxylates (**3f,g**) and NH-Derivatives (**4e,f**).* Reaction time 36 h; **3f,g**: 191 mg (47 %), **4e,f**: 117 (35%); **3f**: m.p. 93 °C (CH_2Cl_2/*i*-Pr_2O); IR (nujol) cm^{-1}: 1770, 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.07 (t, *J* = 7.1 Hz, 3H, Me), 1.45 (t, *J* = 7.0 Hz, 3H, Me), 1.68 (s, 3H, Me-5), 1.77 (s, 3H, Me-4), 2.17, 2.77 (two d, AX system, *J* = 17.1 Hz, 2H, H-6), 2.55, 3.53 (two d, AX system, *J* = 17.7 Hz, 2H, H-3), 3.97-4.09 (m, 2H, OCH_2), 4.48 (q, *J* = 7.0 Hz, 2H, OCH_2), 7.11-7.35 (m, 2H, H_{arom}), 7.80 (d, *J* = 7.7 Hz, 1H, H-5'), 7.91 (d, *J* = 7.9 Hz, 1H, H-8'); Calcd. for $C_{21}H_{24}ClNO_5$ (405.9): C 62.14, H 5.96, N 3.45; found C 62.10, H 6.03, N 3.21; **3g** (mixture with **3f**): ^1H NMR ($CDCl_3$) δ 1.06 (t, *J* = 7.1 Hz, 3H, Me), 1.44 (t, *J* = 7.0 Hz, 3H, Me), 1.67, 1.82 (two s, 6H, Me-4 and Me-5), 1.99 (d, *J* = 16.5 Hz, 1H, H-6), 2.63, 3.30 (m, 3H, H-3, H-6), 3.98 (q, *J* = 7.0 Hz, 2H, OCH_2), 4.41-4.54 (m, 2H, OCH_2), 7.07-7.37 (m, 3H, H_{arom}), 7.96 (d, *J* = 8.2 Hz, 1H, H-8'); **4e**: m.p. 111 °C (Et_2O/pentane); IR (nujol) cm^{-1}: 3350 (NH), 1750, 1710 (CO); ^1H NMR ($CDCl_3$) δ 1.10 (t, *J* = 7.1 Hz, 3H, Me), 1.68 (s, 3H, Me-5), 1.78 (s, 3H, Me-4), 2.18, 2.75 (two d, AX system, *J* = 18.1 Hz, 2H, H-6), 2.55, 3.57 (two d, AX system, *J* = 17.3 Hz, 2H, H-3), 4.01-4.10 (m, 2H, OCH_2), 6.79-7.26 (m, 3H, H_{arom}), 7.37 (s, 1H, NH exchangeable), 7.69 (d, *J* = 7.5 Hz, 1H, H-5'); ^{13}C NMR ($CDCl_3$) δ 13.7 (Me), 18.4, 18.9 (Me-4, Me-5), 40.1 (C-6), 42.3 (C-3), 52.7 (C-1), 62.4 (OCH_2), 72.2 (C-2), 109.4 (C-5'), 121.2, 122.6 (C-4, C-5), 122.2, 125.4, 128.5 (CH_{arom}), 131.8, 140.8 (C_{arom}), 169.2 (C-2'), 178.1 (CO_2Et); Calcd. for $C_{18}H_{20}ClNO_3$ (333.8): C 64.77, H 6.04, N 4.20; found C 64.47, H 6.23, N 4.18; **4f** (mixture with **4e**): ^1H NMR ($CDCl_3$) δ 1.08 (t, *J* = 7.1 Hz, 3H, Me), 1.69 (s, 3H, Me-5), 1.83 (s, 3H, Me-4), 1.95, 3.06 (two d, AX system, *J* = 17.4 Hz, 2H, H-6), 2.80, 3.24 (two d, AX system, *J* = 19.1 Hz, 2H, H-3), 3.94-4.14 (m, 2H, OCH_2), 6.88-7.25 (m, 4H, H_{arom}), 8.41 (s, 1H, NH exchangeable), 7.69 (d, *J* = 7.5 Hz, 1H, H-5').

*Transformation of **3a** into **4a**.* The cycloadduct **3a** (333 mg, 1 mmol) was dissolved in a solution of

EtOH/EtONa (23 mg of Na, 1 mmol in 10 ml of EtOH) and stirred at room temperature for 2 days. After solvent evaporation the crude reaction mixture was taken up with CH_2Cl_2 (10 ml) and washed with HCl (10 ml, 10 %). The organic layer was dried giving compound **4a** in quantitative yield (260 mg).

*General Procedure for Preparation of Ethyl 2-(Cyclohexa-1,4-dienyl)phenylcarbamates (**6a,b**):* a) The cycloadducts **3a,b** (1 mmol) were dissolved in a solution of EtOH/EtONa (92 mg of Na, 4 mmol in 10 ml of EtOH) and refluxed for 2 h. After the reaction work up as described before, compounds **6a,b** were isolated in quantitative yield. b) The cycloadduct **4a** (260 mg, 1 mmol) was dissolved in a solution of EtOH/EtONa (46 mg of Na, 2 mmol, in 10 ml of EtOH) and refluxed for 2 h. After the reaction work up as described before, compounds **6a** was isolated in quantitative yield (270 mg).

*Ethyl 2-(4,5-Dimethylcyclohexa-1,4-dienyl)phenylcarbamate (**6a**).* Oil; IR (nujol) cm^{-1}: 3400 (NH), 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.32 (t, J = 7.1 Hz, 3H, Me), 1.70, 1.72 (two s, 6H, Me-4, Me-5), 2.70-2.90 (m, 4H, H-3, H-6), 4.25 (q, J = 7.1 Hz, 2H, OCH_2), 5.72 (dd, J = 1.7, 3.4 Hz, 1H, H-2), 6.96 (s, 1H, NH exchangeable), 6.98-7.30 (m, 3H, H_{arom}), 8.10 (d, J = 6.0 Hz, 1H, H_{arom}-6); ^{13}C NMR ($CDCl_3$) δ 15.0 (Me), 18.6, 18.8 (Me-4, Me-5), 34.3, 37.5 (C-3, C-6), 61.5 (OCH_2), 118.6 (CH_{arom}-6), 123.5 (C-2), 123.1, 123.7, 132.7, 133.4 (C-1, C-4, C-5, C_{arom}), 118.6-128.9 (CH_{arom}), 154.0 (CO); Calcd. for $C_{17}H_{21}NO_2$ (271.4): C 75.25, H 7.80, N 5.16; found C 75.05, H 7.93, N 5.03.

*Ethyl 2-(4-Methylcyclohexa-1,4-dienyl)phenylcarbamate (**6b**).* Oil; IR (nujol) cm^{-1}: 3400 (NH), 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.32 (t, J = 7.1 Hz, 3H, Me), 1.76 (s, 3H, Me-4), 2.70-2.95 (m, 4H, H-3, H-6), 4.25 (q, J = 7.1 Hz, 2H, OCH_2), 5.51 (dd, J = 1.5, 1.7 Hz, 1H, H-5), 5.73 (dd, J = 1.7, 1.9 Hz, 1H, H-2), 6.90 (s, 1H, NH exchangeable), 7.01-7.29 (m, 3H, H_{arom}), 8.06 (d, J = 8.3 Hz, 1H, H_{arom}-6); Calcd. for $C_{16}H_{19}NO_2$ (257.3): C 74.68, H 7.44, N 5.44; found C 74.50, H 7.53, N 5.28.

*Oxidation of **6a,b** to **5a,b**.* Compounds **6** (1 mmol) were dissolved in CH_2Cl_2 (10 ml) and exposed to air for the time indicated. The aminobiphenyl derivatives **5** were isolated in quantitative yield.

*Ethyl (3,4-Dimethylbiphenyl -2-yl)carbamate (**5a**).* Reaction time: 1 week; Oil; IR (nujol) cm^{-1}: 3400 (NH), 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.26 (t, J = 7.2 Hz, 3H, Me), 2.32 (s, 6H, Me-4, Me-5), 4.16 (q, J = 7.2 Hz, 2H, OCH_2), 6.70 (s, 1H, NH exchangeable), 7.05-7.38 (m, 6H, H_{arom}), 8.14 (d, J = 8.1 Hz, 1H, H-6); Calcd. for $C_{17}H_{19}NO_2$ (269.3): C 75.81, H 7.11, N 5.20; found C 75.70, H 6.98, N 5.23.

*Ethyl (4-Methylbiphenyl -2-yl)carbamate (**5b**).* Reaction time: 2 weeks; Oil; IR (nujol) cm^{-1}: 3400 (NH), 1720 (CO); ^1H NMR ($CDCl_3$) δ 1.26 (t, J = 7.3 Hz, 3H, Me), 2.43 (s, 3H, Me-4), 4.17 (q, J = 7.3 Hz, 2H, OCH_2), 6.90 (s, 1H, NH exchangeable), 7.00, 7.15 (AA'XX' system, J = 7.9 Hz, 4H, H_{arom}), 7.10-7.39 (m, 3H, H_{arom}), 8.13 (d, J = 8.1 Hz, 1H, H-6); Calcd. for $C_{16}H_{17}NO_2$ (255.3): C 75.27, H 6.71, N 5.49; found C 75.40, H 6.73, N 5.40.

*8,9-Dimethyl-7,10-dihydro-5H-phenanthridin-6-one (**7**) and 8,9-Dimethyl-5H-phenanthridin-6-one (**8**).* Compound **3f** (405 mg, 1 mmol) was dissolved in a solution of EtOH/EtONa (92 mg of Na, 4 mmol in 10 ml of EtOH) and refluxed for 7 h. After reaction work up as described before, the reaction mixture was chromatographed (CH_2Cl_2/Et_2O 1 : 0 to 0 : 1) giving two fractions containing the dihydroderivative **7** (42 mg, 20 %), and the aromatic compound **8** (112 mg, 50 %), respectively. **7**: m.p. 291 °C (CH_2Cl_2/*i*-Pr_2O); IR (nujol) cm^{-1}: 3300, 1640 (CO); ^1H NMR ($CDCl_3$) δ 1.56, 1.83 (two s, 6H, Me-8, Me-9), 3.20-3.30 (two m, 4H, CH_2), 7.20-7.70 (m, 4H, H_{arom}), 9.90 (s, 1H, NH exchangeable); Calcd. for $C_{15}H_{15}NO$ (225.3): C 79.97, H 6.71, N 6.22; found C 80.10, H 6.83, N 6.08; **8**: m.p. 297 °C (CH_2Cl_2); IR (nujol) cm^{-1}: 3250, 1635 (CO); ^1H NMR (DMSO-d_6) δ 2.38, 2.42 (two s, 6H, Me-8, Me-9), 7.12-7.25, 7.30-7.41 (m, 3H, H_{arom}), 8.05 (s, 1H,

H_{arom}), 8.10 (s, 1H, H_{arom}), 8.20 (d, J = 1.5 Hz, 1H, H_{arom}), 11.5 (s, 1H, NH exchangeable); Calcd. for $C_{15}H_{13}NO$ (223.3): C 80.69, H 5.87, N 6.27; found C 80.46, H 5.84, N 8.10.

REFERENCES

1. a) Okada, K.; Kondo, M.; Tanino, H.; Kakoi, H.; Inoue, S. *Heterocycles* **1992**, *34*, 589 and references cited therein. b) Wenkert, E.; Liu, S. *Synthesis* **1992**, 323. c) Grigg, R.; Stevenson, P.; Worakun, T. *Tetrahedron* **1988**, *44*, 2049. d) Richards, C. G.; Thurston, D. E. *Tetrahedron* **1983**, *39*, 1817. e) Okada, K.; Sakuma, H.; Kondo, M.; Inoue; S. *Chemistry Letters* **1979**, 213. f) Richards, C. G.; Ross, M. S. F. *Tetrahedron Lett.* **1968**, 4391.
2. Joshi, K.; Jain, R.; Chand, P. *Heterocycles* **1985**, *23*, 957 and references cited therein.
3. Flann, C. J.; Overman, L. E.; Sarkar, A. K. *Tetrahedron Lett.* **1991**, *32*, 6993 and references cited therein.
4. Sivasubramanian, S.; Muthusubramanian, S.; Ramasamy, S.; Arumugam, N. *Indian J. Chem.* **1981**, *20B*, 552 and references cited therein.
5. Avenoza, A.; Busto, J. H.; Cativiela, C.; Peregrina, J. M. *Synthesis*, **1995**, 671, and references cited therein.
6. Lamba, J. J. S; Tour, J. *J. Am. Chem. Soc.*, **1994**, *116*, 11723.