

Crystal Structure of (*E*)-2,3-Dihydro-2-(*R*-Phenylacylidene)-1,3,3-Trimethyl-1*H*-Indole (*R* = 4-CN, 4-Cl)

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Abstract Two new 1,3,3-trimethyl-2-methylene-2,3-dihydro-1*H*-indole derivatives, (*E*)-2,3-dihydro-2-(4-cyanophenylacylidene)-1,3,3-trimethyl-1*H*-indole, (**I**), and (*E*)-2,3-dihydro-2-(4-chlorophenylacylidene)-1,3,3-trimethyl-1*H*-indole, (**II**), have been synthesized and their crystal structure determined by single crystal X-ray diffraction. (**I**), C₂₀H₁₈N₂O, crystallizes in a monoclinic space group, *P*2₁/*c*, with unit cell parameters *a* = 9.882 (3), *b* = 15.614(4), *c* = 11.181(3) Å, β = 106.691(4)°, *Z* = 4. (**II**), C₁₉H₁₈Cl N O, crystallizes in a monoclinic space group, *P*2₁/*n*, with unit cell parameters *a* = 14.6722(19), *b* = 7.2597(9), *c* = 16.304 (2) Å, β = 111.249 (2)°, *Z* = 4. The molecules consist of an enaminoketone group formed by a Fischer base 1,3,3-trimethyl-2-methylene-2,3-dihydro-1*H*-indole bonded, at the exocyclic electron-rich β -carbon atom of the indole moiety, with the benzoyl chloride derivatives substituted at *para*-positions with cyano and chloro groups. The molecules adopt a *s-cis* conformation with respect to the C=O bond towards the C=C bond, and a *E* configuration about the latter indole exocyclic alkene C–C bond. Intermolecular arrangement of

the crystals show, for (**I**) an antiparallel stacking mode favored by the formation of weak C–H \cdots π interactions involving the phenyl ring attached to the carbonyl group and the phenyl of the indole fragment in a head-to-tail mode, whereas, (**II**) present an weak C–H \cdots Hal interaction.

Keywords Crystal structure · Fischer base · Enaminoketone · X-ray diffraction · *s-cis* Conformation

Introduction

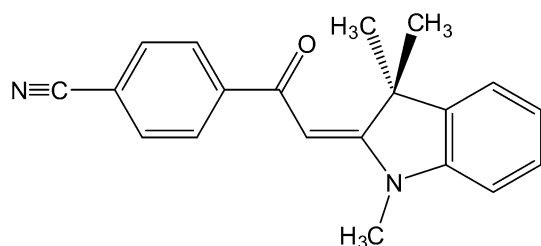
The Fischer base, 1,3,3-trimethyl-2-methylene-2,3-dihydro-1*H*-indole and its derivatives recently have been widely used in the organic synthesis related to prepare different types of chemical switches. Products with different photochromic and thermochromic properties have been reported in the literature because of the potential practical applications of these products to a variety of optoelectronics, molecular information devices and as organic electroluminescence materials [1–4], as well as, different products in the field of dyes [5]. Furthermore, indole enaminoketones derivatives represent another adequate route of synthesis, not only for photochromic derivatives of the Fischer Base [6], but also acetylenic products via indole enaminoketone fragmentation [7–9].

Some studies have reported the synthesis of 1,3,3-trimethyl-2-(phenylacylidene)-2,3-dihydro-1*H*-indole derivatives with different substituent in the phenyl ring [10]. Moreover, a spectroscopic study was carried out with Fischer base indole enaminoketone derivatives in order to establish the conformation of the enamino carbonyl fragment [11]. However, no similar derivatives have been reported previously using 1,3,3-trimethyl-2-methylene-2,3-dihydro-1*H*-indole in presence of the electrophiles

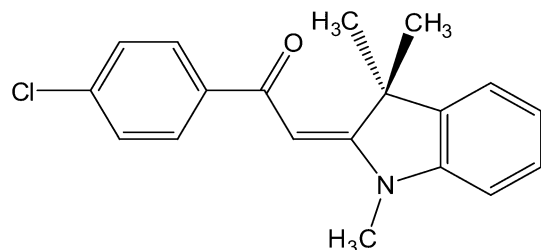
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Scheme 1 Structure of **(I)**



Scheme 2 Structure of **(II)**

p-cyanobenzoyl chloride and *p*-chlorobenzoyl chloride. Furthermore, single crystal structural studies of this type of derivatives do not appear in the reported literature.

In the present study, we report the synthesis of two new Fischer base enaminketone derivatives and their molecular structure were determined using the X-ray diffraction single crystal method to describe unambiguously the conformational arrangement. The structures of the Fischer base enaminketones are depicted in Schemes 1 and 2 for **(I)** and **(II)**, respectively.

Experimental

4-cyanobenzoic acid, 4-chlorobenzoic acid and triethylamine were purchased from Aldrich Chemical Co., 1,3,3-trimethyl-2-methylene indoline was purchased from Fluka and thionyl chloride was purchased from Alpha Aesar. All reagents were used without further purification. All other chemical substances were reagent grade commercial products. Benzene was dried over sodium benzophenone ketyl, distilled and stored over activated molecular sieve 4A.

Synthesis of (*E*)-2,3-Dihydro-2-(4-Cyanophenylacetylidene)-1,3,3-Trimethyl-1*H*-Indol (**I**)

The methodology has already been reported in the literature [8, 9]. In the present work, a mixture of 4-cyanobenzoic acid (2 g, 13.59 mmol) and thionyl chloride (2 eq., 3.23 g, 27.19 mmol) in 8 mL of dry benzene was refluxed for 1.5 h, afterward the excess thionyl chloride was evaporated under vacuum. For complete removal of the thionyl chloride, 8 mL of petroleum ether was added to the residue and then

eliminated under vacuum. The 4-nitrobenzoyl chloride obtained was dissolved in 15 mL of dry benzene, and this solution was added to a mixture of the Fischer base 1,3,3-trimethyl-2-methyleneindoline (1 eq., 2.35 g, 13.59 mmol) and triethylamine (1.2 eq., 1.65 g, 16.31 mmol) in 20 mL of dry benzene. The mixture was maintained at 40 °C for 2 h, after that it was allowed to stand overnight at room temperature. The final reaction mixture was first washed with water and the organic phase was separated and removed by vacuum. The resulting solid was washed successively with isopropyl alcohol. The yellow product was purified using a column chromatography with chloroform as a mobile phase. Suitable crystals for X-ray diffraction were obtained from toluene by slow evaporation. The yield was 2.94 g (71%); m. p.: 184–186 °C. Elemental analysis for C₂₀H₁₈N₂O: [found(calc.)]: C 79.74 (79.44)%; H 6.00 (6.15)%; N 9.26 (9.79)%. GCMS *m/z* 302 (M⁺), 301 (100%) 287.

Synthesis of (*E*)-2,3-Dihydro-2-(4-Chlorophenylacetylidene)-1,3,3-Trimethyl-1*H*-Indol (**II**)

The product was synthesized according to the procedure of **(I)**. The yield was 16.39 g (85%); m. p.: 146–148 °C. GCMS *m/z* 311 (M⁺), 310 (100%) 296, 278, 209.

Structure Determination and Refinement

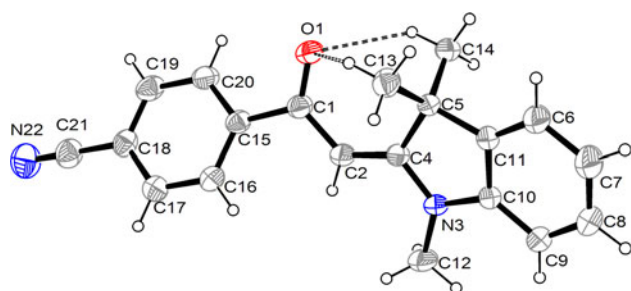
Suitable crystals for X-ray diffraction were mounted in random orientation on glass fibers. The X-ray intensity data were measured at 298 K on a Bruker SMART APEX CCD-based three-circle X-ray diffractometer system using graphite mono-chromated Mo-K α radiation ($\lambda = 0.71073$ Å). The crystal structures were solved by direct methods and refined by using SHELXS-97 and SHELXL-97 crystallographic software packages [12–14]. All non-hydrogen atoms were refined anisotropically using reflections $I > 2\sigma(I)$. Hydrogen atoms were located in ideal positions. Geometric calculations and visualizations were done using PLATON [15], MERCURY [16] and DIAMOND [17]. Crystal and experimental data of **(I)** and **(II)** are listed in Table 1. Scheme 1 shows the molecular structures of **(I)** and **(II)**, respectively. Ortep diagrams [18] of the asymmetric units and crystal packing of **(I)** and **(II)** are displayed in Figs. 1, 2, 3 and 4, respectively. Selected geometric parameters for **(I)** and **(II)** are listed in Table 2. The geometric parameters associated with intra and intermolecular D–H...A interactions are listed in Table 3.

Results and Discussion

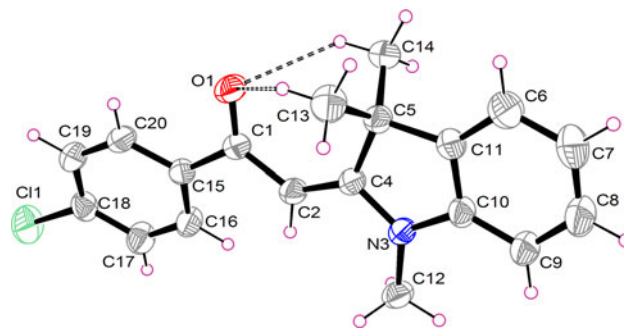
The molecules **(I)** and **(II)** adopt a *s-cis* conformation with respect to the C=O bond towards the C=C bond, and an

Table 1 Crystal and experimental data for **(I)** and **(II)**

	(I)	(II)
Empirical formula	C ₂₀ H ₁₈ N ₂ O	C ₁₉ H ₁₈ Cl N O
Formula weight	302.36	311.79
Temperature	298(2) K	298(2) K
Wavelength	0.71073 Å	0.71073 Å
Crystal system	Monoclinic	Monoclinic
Space group	P 2 ₁ /c	P 2 ₁ /n
<i>a</i> (Å)	9.882(3)	14.6722(19)
<i>b</i> (Å)	15.614(4)	7.2597(9)
<i>c</i> (Å)	11.181(16)	16.304(2)
β (°)	106.691(4)	111.249(2)
Volume (Å ³)	1652.4(7)	1618.5(4)
Z	4	4
Density (calculated) (Mg m ⁻³)	1.215	1.280
Absorption coefficient (mm ⁻¹)	0.076	0.237
F(000)	640	656
Crystal size	0.34 × 0.31 × 0.07 mm	0.36 × 0.16 × 0.10 mm
Theta range for data collection	2.15°–25.38°	2.34°–25.35°
Index ranges	–11 ≤ <i>h</i> ≤ 11 –18 ≤ <i>k</i> ≤ 18 –13 ≤ <i>l</i> ≤ 13	–17 ≤ <i>h</i> ≤ 17 –8 ≤ <i>k</i> ≤ 8 –19 ≤ <i>l</i> ≤ 19
Reflections collected	13055	12891
Independent reflections	3019 [R(int) = 0.0649]	2964 [R(int) = 0.0713]
Data/parameters	3019/211	2964/203
Max. and min. Transmission	0.9774 and 0.9948	0.956 and 0.977
Final R indices [I > 2sigma(I)]	R1 = 0.0637, wR2 = 0.1408	R1 = 0.0466, wR2 = 0.1074
Goodness-of-fit on F ²	1.03	0.86
Largest diff. peak and hole	0.146 and –0.137 e Å ⁻³	0.168 and –0.189 e Å ⁻³

**Fig. 1** The molecular structure and atom numbering of **(I)**. Displacements ellipsoidal of non-H atom are drawn at the 30% of probability level. Intramolecular hydrogen bonds are depicted by dashed lines

E configuration about the indole exocyclic alkene C–C bond. The bond distances and angles of the indole moiety for both crystals are similar to the reported by other crystal indole derivatives [4, 19]. The bond distance of N3–C10 for **(I)** and **(II)** are 1.402(4) and 1.404(3) Å, respectively. These distance values are longer than those reported in the literature for a N_{sp}³–C_{ar} indole bond with 1.372 Å [20], and consequently are similar to the N–C bonds of the Fisher base structure derivative reported by Rok and coworkers [4].

**Fig. 2** The molecular structure and atom numbering of **(II)**. Displacements ellipsoidal of non-H atom are drawn at the 30% of probability level. Intramolecular hydrogen bonds are depicted by dashed lines

Due to the compounds reported here present N3–C4 bond lengths of 1.368(3) Å for **(I)** and 1.366(2) Å for **(II)**, C4=C2 bond length of 1.370(4) Å for **(I)** and 1.364(3) Å for **(II)** and C1=O1 bond of 1.239(3) Å for **(I)** and 1.231(3) Å for **(II)** (Table 2), a push–pull conjugation is present and the distance values are characteristic in enaminketone molecular frameworks [21]. These bond distances are different with the corresponding ones reported

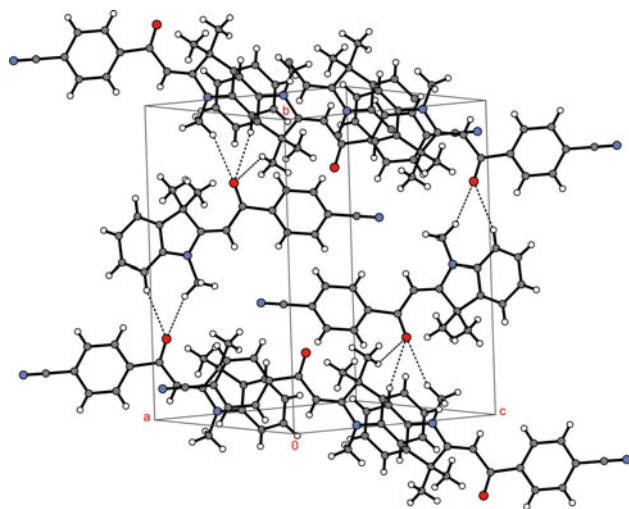


Fig. 3 The crystal packing of compound **(I)** and visualization of intermolecular C–H...O hydrogen bond interactions

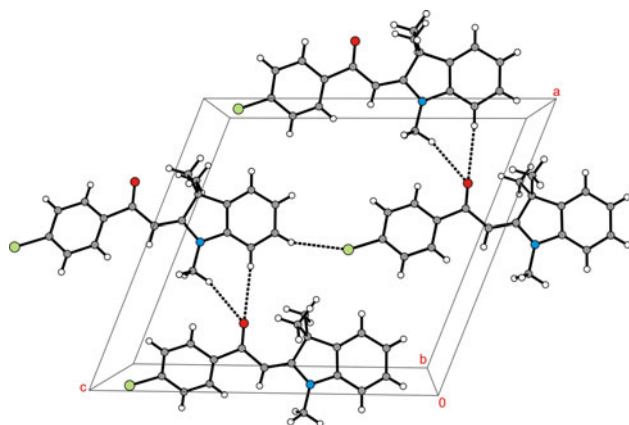


Fig. 4 The crystal packing of compound **(II)** and visualization of intermolecular C–H...O hydrogen bond interactions viewed down the *b* axis

in the literature for a $N_{sp^3}-C_{sp^2}$ bond with 1.416 Å, a $C_{sp^2}-C_{sp^2}$ bond with 1.317 Å and $C_{sp^2}=O$ bond with 1.210 Å [20, 22]. The aforementioned geometrical parameters for **(I)** and **(II)** are present because the conjugative delocalization of the nitrogen lone pair of the amino group with the α,β -unsaturated carbonyl moiety, consequently, the amino group presents a planar geometry for the reason that the sum of the angles around the indole N3 atom is 360.0(6)° for **(I)** and 360.0(5)° for **(II)**, indicating the ideal sp^2 hybridization in each compound [23]. All of the other geometric parameters are within expected ranges [20].

The molecule presents a virtually planar conformation in the indole moiety, showed by its interplanar angle of the fused rings (C6–11 and N3–C4–C5–C10–C11) of 2.81° for **(I)** and almost 1° for **(II)**. Nevertheless, the exocyclic carbon chain presents a distortion of the indole plane with

Table 2 Selected bond distances (Å), bond and torsion angles (°) for **(I)** and **(II)**

Parameter	(I)	(II)
O1–C1	1.239(3)	1.230(3)
C1–C2	1.434(4)	1.437(3)
C1–C15	1.507(5)	1.508(4)
C2–C4	1.370(4)	1.365(3)
N3–C4	1.368(3)	1.365(2)
N3–C10	1.402(4)	1.404(3)
N3–C12	1.458(3)	1.454(3)
C4–C5	1.531(4)	1.528(3)
C5–C11	1.511(4)	1.512(3)
C11–C10	1.385(3)	1.379(3)
C18–C11		1.732(4)
C18–C21	1.439(5)	
C21–N22	1.140(5)	
O1–C1–C2	125.7(3)	125.1(2)
O1–C1–C15	116.5(3)	117.6(2)
C1–C2–C4	127.9(2)	129.5(2)
C2–C1–C15	117.8(2)	117.3(2)
C2–C4–C5	129.9(2)	131.0(2)
N3–C4–C2	122.3(2)	121.2(2)
N3–C4–C5	107.7(2)	107.8(2)
C4–N3–C10	112.0(2)	112.1(2)
C4–N3–C12	125.0(2)	124.8(2)
C12–N3–C10	123.0(2)	123.1(2)
C17–C18–C11	120.6(2)	
C19–C18–C11	118.9(2)	
O1–C1–C2–C4	15.7(5)	−0.6(4)
O1–C1–C15–C20	21.8(4)	17.2(3)
C1–C3–C4–N3	−178.7(3)	179.8(2)
C1–C2–C4–C5	4.8(5)	0.1(4)
C2–C4–N3–C12	2.2(4)	−2.0(3)

Table 3 Intra-intermolecular hydrogen bond distances (Å) and bond angles (°)

	D–H...A	d(D–H)	d(H...A)	d(D...A)	<(DHA)
I	C13–H13B...O1 ^a	0.96	2.337	3.094(4)	135.3
	C14–H14B...O1 ^a	0.96	2.300	3.068(4)	136.5
	C9–H9...O1 ⁱ	0.93	2.642	3.487(3)	151.4
	C12–H12B...O1 ⁱ	0.96	2.780	3.656(3)	152.1
	C14–H14C...O1 ⁱⁱ	0.96	2.723	3.446(3)	132.6
II	C13–H13B...O1 ^a	0.96	2.328	3.092(3)	136.0
	C14–H14B...O1 ^a	0.96	2.362	3.113(3)	135.1
	C9–H9...O1 ⁱⁱⁱ	0.93	2.787	3.713(3)	173.4
	C12–H12B...O1 ⁱⁱⁱ	0.96	2.672	3.603(2)	163.8
	C8–H8...C11 ^{iv}	0.93	2.995	3.802(3)	152.0

^a Intramolecular. ⁱ $-x, y - 1/2, 1/2 - z$; ⁱⁱ $x, 1/2 - y, z + 1/2$; ⁱⁱⁱ $1/2 + x, 3/2 - y, 1/2 + z$; ^{iv} $x, y, z - 1$

respect the carbonyl group O1–C1 when observed the torsion angle C1–C2–C4–C5 with $4.8(5)^\circ$ for (**I**), this denotes that the molecule shows a tendency to twist around the formal double bond. However, (**II**) does not present the behavior mentioned, since the same dihedral angle is coplanar (Table 2). Additionally, the dihedral angle O1–C1–C2–C4 of $15.7(5)^\circ$ shows the similar behavior of deviation of C=C plane in molecule (**I**), whereas, molecule (**II**) maintains planar geometry. Furthermore, the phenyl ring (C15–C20) is twisted away with respect of the carbonyl C=O plane indicated by the torsion angle O1–C1–C15–C20 with $21.8(4)^\circ$ for compound (**I**), and $17.2(3)^\circ$ for compound (**II**). The short C21–N22 triple bond in (**I**) is in the range of a normal cyano bond, as well as, chloro atom in (**II**) is for a C_{ar} –Cl bond [20].

No classic hydrogen bonds are present, neither intra nor intermolecular for both molecules (**I**) and (**II**). However, according with the literature [24, 25], not only weak C–H...O contacts, which are depicted in the supramolecular assembly (Fig. 3), but also C–H... π interactions govern intra and intermolecular crystal packing for (**I**). On the other hand, crystal of (**II**) presents weak interactions of the types C–H...O and C–H...Hal.

Compound (**I**) and (**II**) present weak C–H...O hydrogen bonds in a bifurcated fashion with C13 and C14 as the donor atoms and the oxygen of carbonyl group O1 as the acceptor (Fig. 4). For compound (**I**), weak intermolecular hydrogen bond are involved with the atom of the carbonyl group O1 as acceptor in a trifurcated fashion with the donor atoms C9 and C12 to form a ring $R_2^1(7)$ in graph notation [26], and with atom C14, which helps link the molecules to form a chain $C(7)$; these motifs propagate along the 110 plane. Since the interplanar angle between the rings (C6–C11) and (C15–C20) is 41.56° , the structure is supported by a weak C–H... π -ring interaction involving $Cg1$ at $-x, -y, -z$, [$Cg1$ = center of gravity for the group (C6–C11) within the indole ring, C17–H17... $Cg1$, H17... $Cg1$ = 2.850 Å, C17... $Cg1$ = 3.608 Å, C17–H17... $Cg1$ = 139°], and gives support to molecular packing stability in the unit cell.

Intermolecular weak hydrogen bonds in (**II**), involves the atom of the carbonyl group O1 as acceptor in a bifurcated fashion with the donor atoms C9 and C12 to form a centrosymmetric ring $R_2^1(7)$ in graph notation. In the same manner, a weak C–H...Hal hydrogen bond is present with the C8 as donor atom and Cl1 as acceptor atom. For (**II**), since the interplanar angle between the rings (C6–C11) and (C15–C20) is 17.31° , additional packing interaction is present in the crystalline environment. Intermolecular π -ring interactions occurs between $Cg1$ and $Cg2$ [$Cg1$... $Cg2$ = 3.9941 Å ($-x, -y, 1 - z$); where $Cg1$ (C15–C20) and $Cg2$ (C6–C11) = center of gravity for the two groups, the phenyl ring and within the indole ring, respectively].

Supplementary Material

CCDC 783910 and 784274 contain the supplementary crystallographic data for this paper. These data can be obtained free of charge via <http://www.ccdc.cam.ac.uk/conts/retrieving.html> (or from the Cambridge Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033).

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