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# Crystal structures of four indole derivatives as possible cannabinoid allosteric antagonists

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[a]Department of Chemistry, University of Aberdeen, Meston Walk, Aberdeen AB24 3UE, Scotland, and [b]Fundação Oswaldo Cruz, Instituto de Tecnologia em Fármacos-Far Manguinhos, 21041-250 Rio de Janeiro, RJ, Brazil. *Correspondence e-mail: l.trembleau@abdn.ac.uk, w.harrison@abdn.ac.uk

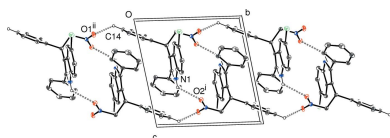The crystal structures of four indole derivatives with various substituents at the 2-, 3- and 5-positions of the ring system are described, namely, ethyl 3-(5-chloro-2-phenyl-1H-indol-3-yl)-3-phenylpropanoate, $C_{25}H_{22}ClNO_2$, (I), 2-bromo-3-(2-nitro-1-phenylethyl)-1H-indole, $C_{16}H_{13}BrN_2O_2$, (II), 5-methoxy-3-(2-nitro-1-phenylethyl)-2-phenyl-1H-indole, $C_{23}H_{20}N_2O_3$, (III), and 5-chloro-3-(2-nitro-1-phenylethyl)-2-phenyl-1H-indole, $C_{22}H_{17}ClN_2O_2$, (IV). The dominant intermolecular interaction in each case is an N—H⋯O hydrogen bond, which generates either chains or inversion dimers. Weak C—H⋯O, C—H⋯$\pi$ and $\pi$–$\pi$ interactions occur in these structures but there is no consistent pattern amongst them. Two of these compounds act as modest enhancers of CB1 cannabanoid signalling and two are inactive.

## 1. Chemical context

The indole ring system is an important element of many natural and synthetic molecules with important biological activities (Biswal *et al.*, 2012; Kaushik *et al.*, 2013; Sharma *et al.*, 2010). As part of our ongoing studies in this area, a group of indole derivatives with different substituents at the 2, 3 and 5-positions of the ring system were synthesised and tested as possible cannabinoid allosteric antagonists (Kerr, 2013). These compounds are analogues of 3-(2-nitro-1-phenylethyl)-2-phenyl-1H-indole (known as F087; see scheme), a positive allosteric modulator of CB1 (Adam *et al.*, 2007).
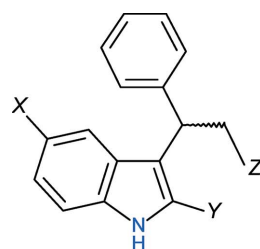


| | | | |
|---|---|---|---|
| F087 | X = H, | Y = Ph, | Z = NO₂ |
| (I) | X = Cl, | Y = Ph, | Z = CO₂Et |
| (II) | X = H, | Y = Br, | Z = NO₂ |
| (III) | X = OMe, | Y = Ph, | Z = NO₂ |
| (IV) | X = Cl, | Y = Ph, | Z = NO₂ |

We now report the crystal structures of four of the compounds from that study, *viz.* ethyl 3-(5-chloro-2-phenyl-1H-indol-3-yl)-3-phenylpropanoate, (I), 2-bromo-3-(2-nitro-1-phenylethyl)-1H-indole, (II), 5-methoxy-3-(2-nitro-1-phenylethyl)-2-phenyl-1H-indole, (III), and 5-chloro-3-(2-nitro-1-phenylethyl)-2-phenyl-1H-indole, (IV). Compounds (III) and (IV) were found to act as moderate enhancers of CB1 signalling at 1 µM concentration (Kerr, 2013) but compounds (I) and (II) were inactive.
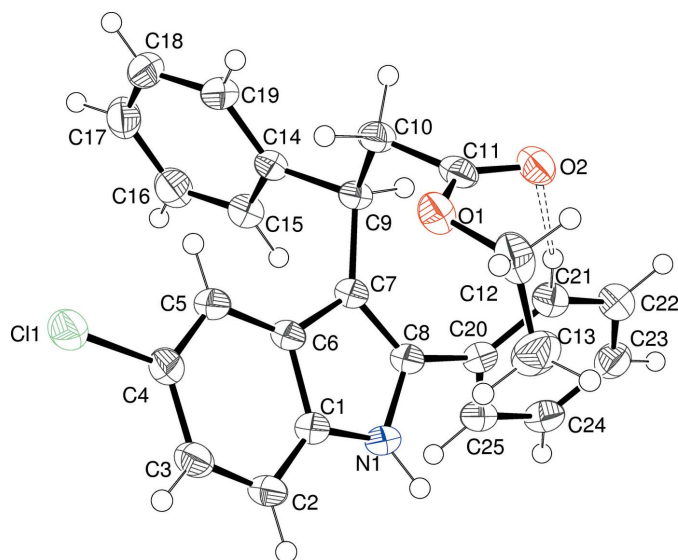
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**Figure 1**
The molecular structure of (I), showing 50% displacement ellipsoids. The double-dashed line indicates a weak C—H⋯O hydrogen bond.

## 2. Structural commentary

Each compound crystallizes in a centrosymmetric space group [*Pbcn* for (I), $P2_1/c$ for (II) and $P\bar{1}$ for (III) and (IV)] with one molecule in the asymmetric unit: in each structure, the stereogenic carbon atom (C9) was assigned an arbitrary *R* configuration. All the bond lengths and angles in these compounds lie within their expected ranges and full details are available in the CIF.

The molecular structure of (I) is illustrated in Fig. 1. The deviations of atoms Cl1, C9 and C20 from the mean plane
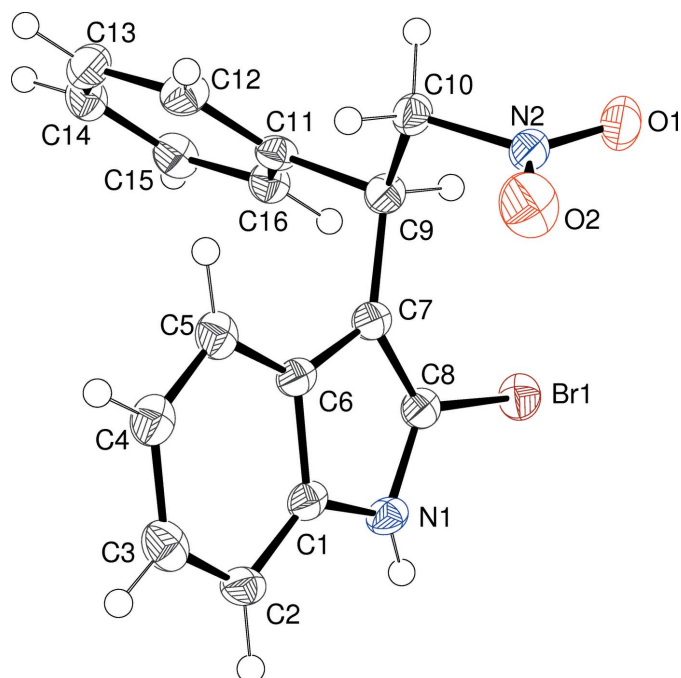


**Figure 2**
The molecular structure of (II), showing 50% displacement ellipsoids.
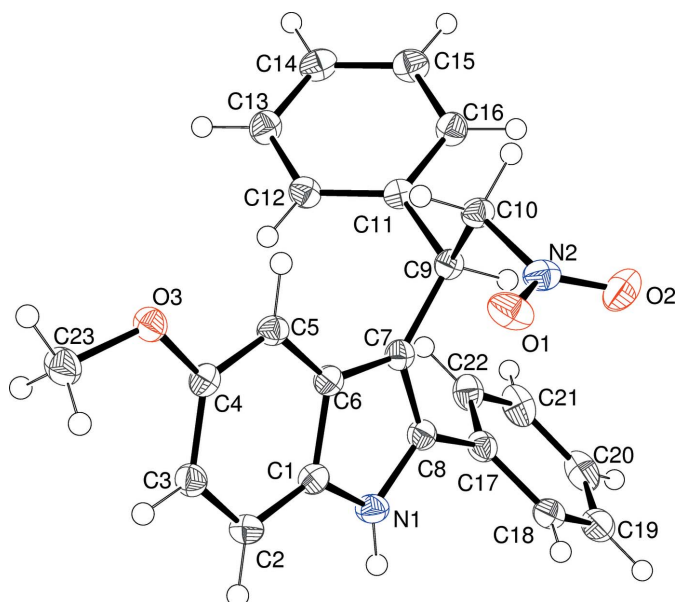


**Figure 3**
The molecular structure of (III), showing 50% displacement ellipsoids.

(r.m.s. deviation = 0.033 Å) of the indole ring system are 0.0293 (17), −0.156 (2) and −0.008 (2) Å, respectively. The larger deviation for C9 may arise from the steric crowding around it. The dihedral angle between the indole ring system and the C20-phenyl ring is 54.07 (4)° and the C7—C8—C20—C21 torsion angle is 53.7 (3)°. This twisting facilitates the formation of an intramolecular C—H⋯O interaction (Table 1), which generates an *S*(9) ring. Atom H9 is close to eclipsed with C8 (C8—C7—C9—H9 = 2°) and the C14 phenyl ring and the C10-bonded ester groups project to opposite sides of the indole ring, as quantified by the C8—C7—C9—C14 and C8—C7—C9—C10 torsion angles of 119.22 (17) and −115.32 (18)°, respectively. Looking down the C9—C7 bond with C8 facing upwards, the C14-phenyl group lies to the left of the indole ring system and the ester group to the right. With respect to the C9—C10 bond, atoms C11 and C14 have an anti disposition [C14—C9—C10—C11 = 175.39 (13)°]. The C11—O1—C12—C13 torsion angle is −81.27 (19)° and the dihedral angle between the indole ring system and the C14 phenyl ring is 86.55 (4)°.

The molecular structure of (II) is shown in Fig. 2. Atoms Br1 and C9 deviate from the mean plane of the indole ring system (r.m.s. deviation = 0.011 Å) by 0.073 (3) and 0.134 (4) Å, respectively. Again, the larger deviation of C9 can be ascribed to steric crowding. The substituents bonded to the 3-position of the ring in (II) are characterized by the C8—C7—C9—H9 torsion angle of −15° and the corresponding C8—C7—C9—C11 and C8—C7—C9—C10 angles of 101.0 (3)° and −134.3 (3)°, respectively. These indicate that the substituents attached to C9 are twisted by about 18° compared to the equivalent groups in (I), although the phenyl ring and nitro group still project in roughly opposite senses with respect to the indole ring. The N2—C10—C9—C11 torsion angle of −174.4 (3)° indicates that the nitro group and phenyl ring lie in an *anti* orientation about the C10—C9 bond.
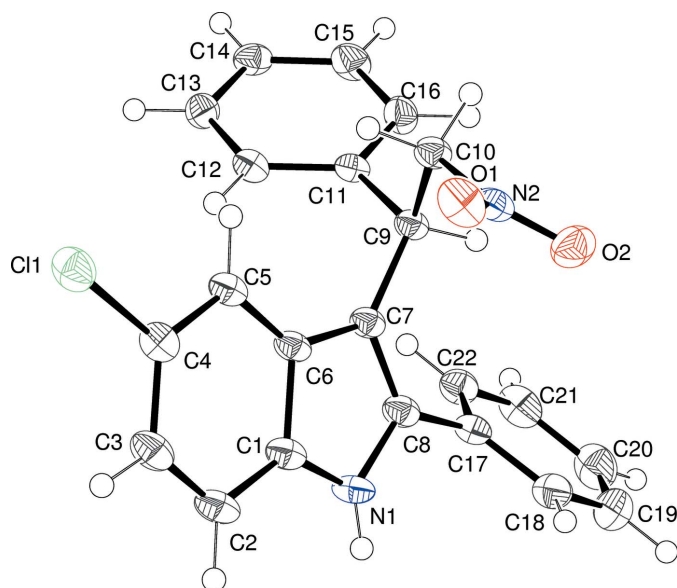
**Figure 4**
The molecular structure of (IV), showing 50% displacement ellipsoids.

The dihedral angle between the indole ring system and the phenyl ring is 81.69 (7)°.

Fig. 3 shows the molecular structure of (III). The r.m.s. deviation for the atoms making up the indole ring system is 0.013Å, and O3, C9 and C17 deviate from the mean plane by 0.0273 (12), −0.1302 (14), and 0.148 (1)Å, respectively. The dihedral angle between the indole ring plane and the C17-ring is 53.76 (3). This is similar to the equivalent value for (I), but the twist is in the opposite sense, as indicated by the C7—C8—C17—C22 torsion angle of −52.40 (15)°: in this case no intramolecular C—H···O bond is present. The dihedral angle between the indole ring and the C11 ring is 67.12 (3)°. The C8—C7—C9—H9, C8—C7—C9—C11 and C8—C7—C9—C10 torsion angles are −17, 102.46 (11) and −133.20 (10)°, respectively, which are almost identical to the corresponding values for (II). These indicate that the C9—H9 bond is twisted away from the indole plane to the same side of the molecule as the nitro group: looking down the C9—C7 bond, C9—H9 is rotated in a clockwise sense with respect to the ring. The disposition of N2 and C11 about the C10—C9 bond is *anti* [torsion angle = −171.63 (8)°]. The methyl C atom of the methoxy group deviates from the indole plane by −0.1302 (14) Å, *i.e.* slightly towards the side of the molecule occupied by the C11 phenyl ring.

A view of the molecular structure of (IV) can be seen in Fig. 4. The indole ring system has an r.m.s. deviation of 0.008 Å for its nine non-hydrogen atoms and Cl1, C9 and C17 deviate from the mean plane by 0.009 (1), 0.093 (1) and −0.044 (1)Å. Thus, the displacement of C9 is slightly smaller than in the other three structures presented here. In terms of the orientation of the substituents at the 3-position of the indole ring, the C8—C7—C9—H9, C8—C7—C9—C11 and C8—C7—C9—C10 torsion angles are −17, 102.42 (14) and −133.94 (12)°, respectively, which are very similar to the equivalent data for (II) and (III), again indicating that

**Table 1**
Hydrogen-bond geometry (Å, °) for (I).

$Cg2$ and $Cg4$ are the centroids of the C1–C6 and C20–C25 rings, respectively.

| $D$—H···$A$ | $D$—H | H···$A$ | $D$···$A$ | $D$—H···$A$ |
|---|---|---|---|---|
| C21—H21···O2 | 0.93 | 2.34 | 3.258 (2) | 169 |
| N1—H1···O2[i] | 0.91 (2) | 1.95 (2) | 2.8310 (18) | 163.0 (18) |
| C10—H10$A$···$Cg4$[ii] | 0.97 | 2.93 | 3.8022 (18) | 150 |
| C12—H12$A$···$Cg2$[iii] | 0.97 | 2.97 | 3.702 (2) | 133 |
| C16—H16···$Cg4$[iv] | 0.93 | 2.78 | 3.643 (2) | 154 |
| C19—H19···$Cg2$[i] | 0.93 | 2.96 | 3.7860 (18) | 149 |

Symmetry codes: (i) $-x+\frac{1}{2}, y-\frac{1}{2}, z$; (ii) $-x-\frac{1}{2}, y-\frac{1}{2}, z$; (iii) $-x+1, -y+1, -z$; (iv) $-x+1, y, -z+\frac{1}{2}$.

C9—H9 is twisted towards the nitro group. The N2—C10—C9—C11 torsion angle of 179.61 (9)° shows that the anti orientation of N2 and C11 exactly mirrors that of the equivalent atoms in (II) and (III).

All-in-all, the conformations of (II), (III) and (IV) are very similar, especially in terms of the orientations of the substituents attached to C9 with respect to the indole ring. (I) differs slightly in that C9—H9 lies almost in the indole ring plane rather than being twisted away from it, which possibly correlates with the intramolecular C—H···O interaction noted above. Of course, in every case, crystal symmetry generates an equal number of molecules of the opposite chirality (*i.e.*, S configuration of C9), with an anticlockwise twist of C9—H9 with respect to the indole ring system.

## 3. Supramolecular features

As might be expected, the dominant supramolecular motif in all these compounds involve N—H···O hydrogen bonds, although the resulting topologies [chains for (I) and (II) and dimers for (III) and (IV)] are different. Various weak interactions also occur, as described below and listed in Tables 1–4, respectively.
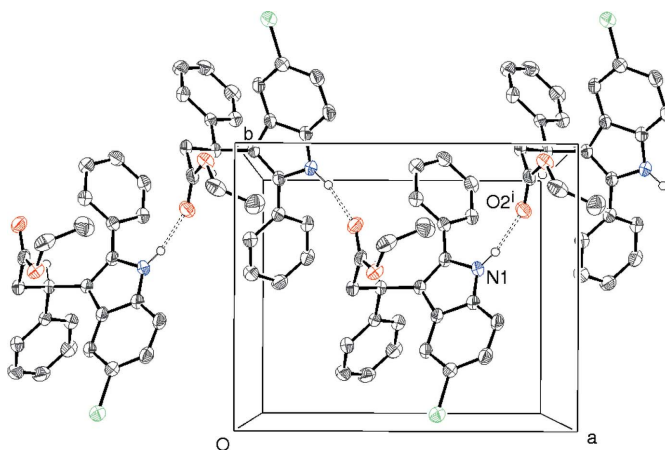


**Figure 5**
Partial packing diagram for (I), showing the formation of [100] chains linked by N—H···O hydrogen bonds (double-dashed lines). Symmetry code as in Table 1.

**Table 2**
Hydrogen-bond geometry (Å, °) for (II).

*Cg*2 and *Cg*4 are the centroids of the C1–C6 ring.

| $D$—H···$A$ | $D$—H | H···$A$ | $D$···$A$ | $D$—H···$A$ |
|---|---|---|---|---|
| N1—H1···O1$^i$ | 0.80 (4) | 2.32 (4) | 3.087 (3) | 161 (4) |
| C12—H12···$Cg$2$^{ii}$ | 0.95 | 2.75 | 3.500 (3) | 136 |

Symmetry codes: (i) $x, -y + \frac{1}{2}, z - \frac{1}{2}$; (ii) $-x + 1, y + \frac{1}{2}, -z + \frac{3}{2}$.

**Table 3**
Hydrogen-bond geometry (Å, °) for (III).

*Cg*2 and *Cg*4 are the centroids of the C1–C6 and C17–C22 rings, respectively.

| $D$—H···$A$ | $D$—H | H···$A$ | $D$···$A$ | $D$—H···$A$ |
|---|---|---|---|---|
| N1—H1···O1$^i$ | 0.867 (14) | 2.470 (14) | 3.1872 (13) | 140.5 (12) |
| C10—H10$A$···O3$^{ii}$ | 0.99 | 2.56 | 2.9934 (14) | 107 |
| C14—H14···O3$^{iii}$ | 0.95 | 2.51 | 3.4546 (14) | 173 |
| C18—H18···O1$^i$ | 0.95 | 2.59 | 3.2877 (14) | 131 |
| C21—H21···$Cg$2$^{iv}$ | 0.95 | 2.83 | 3.5297 (13) | 131 |
| C23—H23$C$···$Cg$4$^v$ | 0.98 | 2.76 | 3.5781 (13) | 141 |

Symmetry codes: (i) $-x, -y + 1, -z + 1$; (ii) $-x, -y, -z + 1$; (iii) $-x + 1, -y, -z + 1$; (iv) $-x + 1, -y + 1, -z + 1$; (v) $x, y, z + 1$.
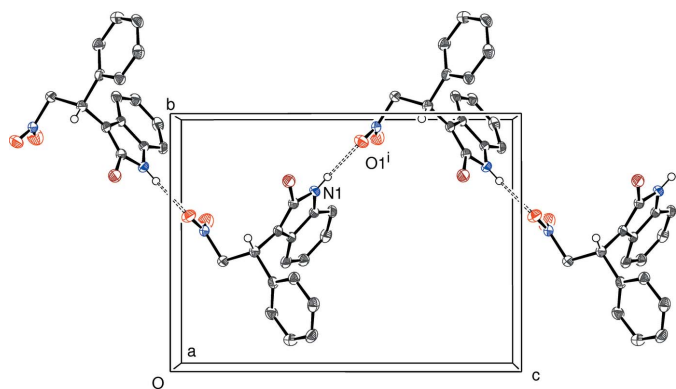
**Table 4**
Hydrogen-bond geometry (Å, °) for (IV).

| $D$—H···$A$ | $D$—H | H···$A$ | $D$···$A$ | $D$—H···$A$ |
|---|---|---|---|---|
| N1—H1···O2$^i$ | 0.814 (16) | 2.517 (16) | 3.0806 (15) | 127.4 (14) |
| C14—H14···O1$^{ii}$ | 0.95 | 2.60 | 3.1827 (17) | 120 |

Symmetry codes: (i) $-x + 1, -y + 1, -z + 1$; (ii) $x, y - 1, z$.

In (I), the N1—H1···O2$^i$ [(i) $= \frac{1}{2} - x, y - \frac{1}{2}, z$] bond links the molecules into [100] chains with a $C(8)$ chain motif (Fig. 5); adjacent molecules are related by b-glide symmetry. A *PLATON* (Spek, 2009) analysis of the packing in (I) indicated the presence of no fewer than four C—H···$\pi$ interactions, although the C10, C16 and C19 bonds must be very weak based on the long H···$\pi$ separation. Together, these links lead to a three-dimensional network in the crystal. There are no



**Figure 7**
An inversion dimer in the crystal of (III) linked by pairs of N—H···O and C—H···O hydrogen bonds (double-dashed lines). Symmetry code as in Table 3.

aromatic $\pi$–$\pi$ stacking interactions in (I), as the shortest ring centroid–centroid separation is greater than 4.6 Å.

The molecules of (II) are linked by N1—H1—O2$^i$ [(i) $= x, \frac{1}{2} - y, z - \frac{1}{2}$] hydrogen bonds into [001] chains (Fig. 6) characterized by a $C(8)$ motif: adjacent molecules are related by c-glide symmetry. Just one C—H···$\pi$ interaction occurs in the crystal of (II) but a $\pi$–$\pi$ stacking interaction involving inversion-related pairs of C1–C6 benzene rings is also observed: the centroid–centroid separation is 3.7122 (16) Å and the slippage is 1.69 Å. The weak links connect the chains into a three-dimensional network.

In (III), inversion dimers linked by N1—H1···O1$^i$ and N1$^i$—H1$^i$···O1 [(i) $= -x, 1 - y, 1 - z$] hydrogen bonds occur, which generate $R_2^2(16)$ loops. The dimer linkage is reinforced by a pair of C12—H12···O1 interactions (Fig. 7). The dimers are linked by several C—H···O and C—H···$\pi$ interactions, generating a three-dimensional network. The shortest ring centroid–centroid separation is over 4.7 Å.

In the crystal of (IV), the molecules associate into inversion dimers linked by N1—H1···O2$^i$ and N1$^i$—H1$^i$···O2 [(i) $= 1 - x, 1 - y, 1 - z$] hydrogen bonds (Fig. 8). Just one weak C—H···O hydrogen bond connects the dimers into [010] chains. The shortest ring centroid–centroid separation is over 4.5 Å.



**Figure 6**
Partial packing diagram for (II), showing the formation of [001] chains linked by N—H···O hydrogen bonds (double-dashed lines). Symmetry code as in Table 2.



**Figure 8**
Fragment of an [010] chain in the crystal of (IV) linked by N—H···O and C—H···O hydrogen bonds (double-dashed lines). Symmetry codes as in Table 4.

**Table 5**
Experimental details.

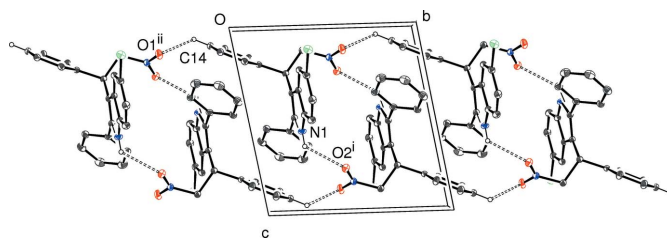| | (I) | (II) | (III) | (IV) |
|---|---|---|---|---|
| **Crystal data** | | | | |
| Chemical formula | $C_{25}H_{22}ClNO_2$ | $C_{16}H_{13}BrN_2O_2$ | $C_{23}H_{20}N_2O_3$ | $C_{22}H_{17}ClN_2O_2$ |
| $M_r$ | 403.89 | 345.19 | 372.41 | 376.83 |
| Crystal system, space group | Orthorhombic, $Pbcn$ | Monoclinic, $P2_1/c$ | Triclinic, $P\bar{1}$ | Triclinic, $P\bar{1}$ |
| Temperature (K) | 100 | 100 | 100 | 100 |
| $a, b, c$ (Å) | 10.1558 (7), 12.1446 (9), 33.605 (2) | 9.7223 (7), 10.2804 (7), 13.9652 (10) | 9.7561 (7), 10.0258 (7), 10.8942 (8) | 9.5830 (7), 9.7555 (7), 10.2307 (7) |
| $\alpha, \beta, \gamma$ (°) | 90, 90, 90 | 90, 91.238 (2), 90 | 116.415 (5), 91.843 (4), 97.963 (4) | 79.546 (6), 77.966 (6), 87.455 (7) |
| $V$ (Å$^3$) | 4144.8 (5) | 1395.48 (17) | 939.84 (12) | 919.87 (11) |
| $Z$ | 8 | 4 | 2 | 2 |
| Radiation type | Mo $K\alpha$ | Mo $K\alpha$ | Mo $K\alpha$ | Mo $K\alpha$ |
| $\mu$ (mm$^{-1}$) | 0.21 | 2.95 | 0.09 | 0.23 |
| Crystal size (mm) | $0.22 \times 0.19 \times 0.07$ | $0.22 \times 0.19 \times 0.05$ | $0.24 \times 0.21 \times 0.03$ | $0.48 \times 0.36 \times 0.16$ |
| | | | | |
| **Data collection** | | | | |
| Diffractometer | Rigaku Mercury CCD | Rigaku Mercury CCD | Rigaku Mercury CCD | Rigaku Mercury CCD |
| Absorption correction | – | Multi-scan (*SADABS*; Sheldrick, 1996) | – | Multi-scan (*SADABS*; Sheldrick, 1996) |
| $T_{min}, T_{max}$ | – | 0.563, 0.867 | – | 0.899, 0.965 |
| No. of measured, independent and observed [$I > 2\sigma(I)$] reflections | 27690, 4720, 3714 | 14919, 3213, 2911 | 12625, 4305, 3782 | 13253, 4138, 3363 |
| $R_{int}$ | 0.079 | 0.042 | 0.028 | 0.023 |
| $(\sin\theta/\lambda)_{max}$ (Å$^{-1}$) | 0.648 | 0.650 | 0.650 | 0.649 |
| | | | | |
| **Refinement** | | | | |
| $R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, $S$ | 0.053, 0.153, 1.05 | 0.040, 0.108, 1.07 | 0.035, 0.097, 1.06 | 0.031, 0.085, 1.06 |
| No. of reflections | 4720 | 3213 | 4305 | 4138 |
| No. of parameters | 266 | 193 | 257 | 247 |
| H-atom treatment | H atoms treated by a mixture of independent and constrained refinement | H atoms treated by a mixture of independent and constrained refinement | H atoms treated by a mixture of independent and constrained refinement | H atoms treated by a mixture of independent and constrained refinement |
| $\Delta\rho_{max}, \Delta\rho_{min}$ (e Å$^{-3}$) | 0.54, −0.25 | 1.26, −0.83 | 0.30, −0.22 | 0.27, −0.23 |

Computer programs: *CrystalClear* (Rigaku, 2012), *SHELXS97* and *SHELXL97* (Sheldrick, 2008), *ORTEP-3 for Windows* (Farrugia, 2012) and *publCIF* (Westrip, 2010).

## 4. Database survey

There are over 4000 indole derivatives with different substituents (including H) at the 2, 3 and 5 positions of the ring system reported in the Cambridge Structural Database (CSD; Groom & Allen, 2014). Narrowing the survey to indole derivatives with a C atom bonded to the 2-position of the ring and an $sp^3$-hybridized C atom with two further C atoms and one H atom bonded to it at the 3-position (as per C9 in the present structures) yielded 72 hits. An analysis of the dihedral angle in these structures corresponding to C8—C7—C9—H9 in the present structures showed a wide spread of values with no obvious overall pattern.

## 5. Synthesis and crystallization

A mixture of sodium chloride (219 mg, 3.75 mmol) and diethyl 2-([5-chloro-2-phenyl-1*H*-indol-3-yl]{phenyl}methyl)malonate (847 mg, 1.78 mmol), [prepared from diethyl benzylidenemalonate and 5-chloro-2-phenylindole in the presence of Cu(OTf)$_2$] in DMSO (10.8 ml) and water (150 ml) was stirred at 443K for 16 h. After cooling to room temperature, water was added until a precipitate formed (25 ml). The mixture was extracted into DCM (3 × 25 ml), washed with saturated NaCl(aq) (15 ml), dried over sodium sulfate, filtered and evaporated to leave a red oil. Flash chromatography (1:1 DCM, hexanes) afforded (I) as a colourless solid (638 mg, 89%), m.p. 464K. Colourless blocks were recrystallized from methanol solution at room temperature. IR (Nujol, cm$^{-1}$) 3391, 2911, 1738, 1629, 1581, 1556, 1445, 1399, 1283, 1271, 1215, 1208, 1145, 1113, 1077, 874, 852,761. HRMS (ESI) for $C_{25}H_{23}^{35}ClNO_2$ $[M + H]^+$ calculated 404.1418, found 404.1416.

A mixture of indole (1.069 g, 9.13 mmol), trans-$\beta$-nitrostyrene (1.372 g, 9.20 mmol) and sulfamic acid (178 mg, 1.83 mmol) were refluxed in EtOH (45 ml) for 24 h. Removal of the solvent and flash chromatography (1:3 diethyl ether, hexanes) afforded 3-(2-nitro-1-phenylethyl)-1*H*-indole as a colourless solid (2.020 g, 83%). This was refluxed in ClCl$_4$ (40 ml) with NBS (1.505 g, 8.46 mmol) for 96 h, filtered and the solvent evaporated under reduced pressure to leave a red oily residue. Flash chromatography of the residue (1:5 EtOAc, hexanes) gave (II) as a peach-coloured solid (1.386 g, 53%). Pale-brown plates were recrystallized from methanol solution at room temperature; m.p. 436K; IR (KBr, cm$^{-1}$) 3353, 2987, 2923, 2856, 1548, 1452, 1337, 740 and 701; RMS (ESI) for $C_{16}H_{13}^{79}BrN_2O_2Na$ $[M + Na]^+$ calculated 367.0058, found 367.0049.

A mixture of trans-β-nitrostyrene (167 mg, 1.12 mmol), sulfamic acid (22 mg, 0.22 mmol) and 5-methoxy-2-phenyl-1*H*-indole (250 mg, 1.12 mmol), prepared from *p*-methoxyphenylhydrazine hydrochloride, acetophenone and PPA in EtOH (5 ml) was stirred at 323K for 40 h. The solvent was removed under reduced pressure and the residue was flash chromatographed (1:5 EtOAc, hexanes) to provide (III) as an orange solid (210 mg, 50%): Light-yellow blocks were recrystallized from methanol solution at room temperature; m.p. 434–436K; IR (KBr, cm$^{-1}$) 3407, 1629, 1600, 1581, 1534, 1369, 1200 and 1141; HRMS (ESI) for $C_{23}H_{21}N_2O_3$ $[M + H]^+$ calculated 373.1553, found 373.1544.

5-Chloro-2-phenyl-1*H*-indole (1.286 g, 5.65 mmol), trans-β-nitrostyrene (843 mg, 5.65 mmol) and sulfamic acid (110 mg, 1.13 mmol) were stirred in EtOH (80 ml) at reflux for 15 h. The solvent was removed under reduced pressure and the crude product was purified by flash chromatography (1:4 EtOAc, hexanes then 1:2 EtOAc, hexanes) to give the product as a yellow solid (1.105 g, 52%). $R_f$ 0.23 (1:4 EtOAc, hexanes); m.p. 457–459K; IR (KBr, cm$^{-1}$) 3396, 3034, 1740, 1598, 1510, 1318, 1055 and 839; HRMS (ESI) for $C_{22}H_{18}N_2O_2Cl$ $[M + H]^+$ calculated 377.1057, found 377.1054.

## 6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 5. The N-bound H atoms were located in difference maps and their positions freely refined. The C-bound H atoms were geometrically placed (C—H = 0.93–0.98 Å) and refined as riding atoms. The constraint $U_{iso}(H) = 1.2U_{eq}$(carrier) or $1.5U_{eq}$(methyl carrier) was applied in all cases. The methyl H atoms (if any) were allowed to rotate, but not to tip, to best fit the electron density.

## References

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# Crystal structures of four indole derivatives as possible cannabinoid allosteric antagonists

**Jamie R. Kerr, Laurent Trembleau, John M. D. Storey, James L. Wardell and William T. A. Harrison**

## Computing details

For all compounds, data collection: *CrystalClear* (Rigaku, 2012); cell refinement: *CrystalClear* (Rigaku, 2012); data reduction: *CrystalClear* (Rigaku, 2012); program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *ORTEP-3 for Windows* (Farrugia, 2012); software used to prepare material for publication: *publCIF* (Westrip, 2010).

## (I) Ethyl 3-(5-chloro-2-phenyl-1*H*-indol-3-yl)-3-phenylpropanoate

*Crystal data*

| | |
|---|---|
| $C_{25}H_{22}ClNO_2$ | $F(000) = 1696$ |
| $M_r = 403.89$ | $D_x = 1.294$ Mg m$^{-3}$ |
| Orthorhombic, *Pbcn* | Mo *Kα* radiation, $\lambda = 0.71075$ Å |
| Hall symbol: -P 2n 2ab | $\theta = 2.6–27.5°$ |
| $a = 10.1558 (7)$ Å | $\mu = 0.21$ mm$^{-1}$ |
| $b = 12.1446 (9)$ Å | $T = 100$ K |
| $c = 33.605 (2)$ Å | Block, colourless |
| $V = 4144.8 (5)$ Å$^3$ | $0.22 \times 0.19 \times 0.07$ mm |
| $Z = 8$ | |

*Data collection*

| | |
|---|---|
| Rigaku Mercury CCD diffractometer | 3714 reflections with $I > 2\sigma(I)$ |
| | $R_{int} = 0.079$ |
| Radiation source: fine-focus sealed tube | $\theta_{max} = 27.4°$, $\theta_{min} = 2.6°$ |
| Graphite monochromator | $h = -10 \rightarrow 13$ |
| *ω* scans | $k = -15 \rightarrow 15$ |
| 27690 measured reflections | $l = -27 \rightarrow 43$ |
| 4720 independent reflections | |

*Refinement*

| | |
|---|---|
| Refinement on $F^2$ | Primary atom site location: structure-invariant direct methods |
| Least-squares matrix: full | |
| $R[F^2 > 2\sigma(F^2)] = 0.053$ | Secondary atom site location: difference Fourier map |
| $wR(F^2) = 0.153$ | |
| $S = 1.05$ | Hydrogen site location: inferred from neighbouring sites |
| 4720 reflections | |
| 266 parameters | H atoms treated by a mixture of independent and constrained refinement |
| 0 restraints | |

$w = 1/[\sigma^2(F_o^2) + (0.0961P)^2 + 0.2647P]$

where $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{max} < 0.001$

$\Delta\rho_{max} = 0.54$ e Å$^{-3}$

$\Delta\rho_{min} = -0.24$ e Å$^{-3}$

*Special details*

**Geometry**. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

**Refinement**. Refinement of $F^2$ against ALL reflections. The weighted $R$-factor $wR$ and goodness of fit $S$ are based on $F^2$, conventional $R$-factors $R$ are based on $F$, with $F$ set to zero for negative $F^2$. The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating $R$-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. $R$-factors based on $F^2$ are statistically about twice as large as those based on $F$, and $R$- factors based on ALL data will be even larger.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å$^2$)*

|  | $x$ | $y$ | $z$ | $U_{iso}$*/$U_{eq}$ |
|---|---|---|---|---|
| C1 | 0.54948 (15) | 0.29890 (13) | 0.09779 (5) | 0.0311 (4) |
| C2 | 0.61955 (17) | 0.22877 (13) | 0.07259 (5) | 0.0348 (4) |
| H2 | 0.5861 | 0.1603 | 0.0654 | 0.042* |
| C3 | 0.73983 (18) | 0.26430 (14) | 0.05867 (5) | 0.0347 (4) |
| H3 | 0.7883 | 0.2201 | 0.0415 | 0.042* |
| C4 | 0.78952 (16) | 0.36789 (14) | 0.07051 (5) | 0.0326 (4) |
| C5 | 0.72080 (16) | 0.43914 (13) | 0.09457 (5) | 0.0302 (4) |
| H5 | 0.7557 | 0.5072 | 0.1016 | 0.036* |
| C6 | 0.59588 (16) | 0.40567 (12) | 0.10815 (5) | 0.0290 (3) |
| C7 | 0.49436 (15) | 0.45698 (12) | 0.13159 (5) | 0.0281 (3) |
| C8 | 0.39449 (16) | 0.38103 (13) | 0.13567 (5) | 0.0297 (3) |
| C9 | 0.49669 (15) | 0.57406 (12) | 0.14740 (5) | 0.0279 (3) |
| H9 | 0.4144 | 0.5860 | 0.1620 | 0.033* |
| C10 | 0.50018 (16) | 0.65784 (13) | 0.11262 (5) | 0.0313 (4) |
| H10A | 0.4879 | 0.7316 | 0.1231 | 0.038* |
| H10B | 0.5857 | 0.6550 | 0.0998 | 0.038* |
| C11 | 0.39491 (17) | 0.63402 (13) | 0.08240 (5) | 0.0318 (4) |
| C12 | 0.3469 (2) | 0.55713 (18) | 0.01910 (6) | 0.0457 (5) |
| H12A | 0.3883 | 0.5551 | −0.0069 | 0.055* |
| H12B | 0.2762 | 0.6108 | 0.0182 | 0.055* |
| C13 | 0.2900 (2) | 0.44405 (18) | 0.02866 (7) | 0.0514 (5) |
| H13A | 0.2238 | 0.4257 | 0.0094 | 0.077* |
| H13B | 0.2515 | 0.4452 | 0.0547 | 0.077* |
| H13C | 0.3590 | 0.3900 | 0.0278 | 0.077* |
| C14 | 0.61049 (16) | 0.59166 (12) | 0.17675 (5) | 0.0293 (4) |
| C15 | 0.62031 (17) | 0.52108 (14) | 0.20950 (5) | 0.0354 (4) |
| H15 | 0.5587 | 0.4651 | 0.2126 | 0.042* |
| C16 | 0.72023 (18) | 0.53266 (16) | 0.23754 (6) | 0.0408 (4) |
| H16 | 0.7253 | 0.4848 | 0.2591 | 0.049* |
| C17 | 0.81262 (18) | 0.61658 (16) | 0.23304 (6) | 0.0415 (4) |
| H17 | 0.8796 | 0.6250 | 0.2517 | 0.050* |
| C18 | 0.80455 (18) | 0.68715 (15) | 0.20092 (6) | 0.0403 (4) |

| | | | |
|---|---|---|---|
| H18 | 0.8664 | 0.7430 | 0.1980 | 0.048* |
| C19 | 0.70415 (17) | 0.67531 (14) | 0.17278 (5) | 0.0350 (4) |
| H19 | 0.6996 | 0.7234 | 0.1513 | 0.042* |
| C20 | 0.26765 (16) | 0.38379 (13) | 0.15729 (5) | 0.0312 (4) |
| C21 | 0.17591 (17) | 0.46826 (14) | 0.15152 (5) | 0.0355 (4) |
| H21 | 0.1954 | 0.5257 | 0.1342 | 0.043* |
| C22 | 0.05587 (17) | 0.46706 (15) | 0.17144 (6) | 0.0386 (4) |
| H22 | −0.0045 | 0.5234 | 0.1672 | 0.046* |
| C23 | 0.02557 (18) | 0.38227 (15) | 0.19767 (5) | 0.0368 (4) |
| H23 | −0.0548 | 0.3817 | 0.2109 | 0.044* |
| C24 | 0.11659 (17) | 0.29816 (14) | 0.20392 (5) | 0.0363 (4) |
| H24 | 0.0973 | 0.2416 | 0.2216 | 0.044* |
| C25 | 0.23610 (17) | 0.29836 (14) | 0.18378 (5) | 0.0339 (4) |
| H25 | 0.2957 | 0.2414 | 0.1879 | 0.041* |
| N1 | 0.42951 (14) | 0.28435 (11) | 0.11609 (5) | 0.0324 (3) |
| H1 | 0.3687 (19) | 0.2319 (17) | 0.1108 (6) | 0.039* |
| O1 | 0.44406 (12) | 0.59120 (10) | 0.04889 (4) | 0.0357 (3) |
| O2 | 0.27802 (12) | 0.65045 (10) | 0.08742 (4) | 0.0367 (3) |
| Cl1 | 0.94493 (4) | 0.40680 (4) | 0.052348 (14) | 0.04005 (16) |

*Atomic displacement parameters (Å²)*

| | $U^{11}$ | $U^{22}$ | $U^{33}$ | $U^{12}$ | $U^{13}$ | $U^{23}$ |
|---|---|---|---|---|---|---|
| C1 | 0.0296 (8) | 0.0234 (7) | 0.0403 (9) | 0.0003 (6) | −0.0034 (7) | −0.0012 (6) |
| C2 | 0.0384 (9) | 0.0222 (7) | 0.0438 (9) | 0.0028 (7) | −0.0050 (7) | −0.0056 (7) |
| C3 | 0.0378 (9) | 0.0279 (8) | 0.0384 (9) | 0.0066 (7) | −0.0033 (7) | −0.0055 (7) |
| C4 | 0.0291 (8) | 0.0288 (8) | 0.0400 (9) | 0.0027 (7) | −0.0020 (7) | 0.0033 (7) |
| C5 | 0.0322 (9) | 0.0218 (7) | 0.0368 (9) | 0.0001 (6) | −0.0032 (7) | −0.0004 (6) |
| C6 | 0.0305 (8) | 0.0203 (7) | 0.0362 (9) | 0.0024 (6) | −0.0034 (7) | −0.0002 (6) |
| C7 | 0.0284 (8) | 0.0205 (7) | 0.0353 (8) | 0.0014 (6) | −0.0024 (6) | 0.0001 (6) |
| C8 | 0.0305 (8) | 0.0214 (7) | 0.0371 (8) | 0.0015 (6) | −0.0038 (7) | −0.0013 (6) |
| C9 | 0.0282 (8) | 0.0193 (7) | 0.0361 (9) | 0.0007 (6) | 0.0006 (6) | −0.0003 (6) |
| C10 | 0.0333 (9) | 0.0211 (7) | 0.0393 (9) | 0.0001 (6) | 0.0021 (7) | 0.0021 (6) |
| C11 | 0.0368 (9) | 0.0208 (7) | 0.0378 (9) | 0.0050 (7) | 0.0013 (7) | 0.0033 (6) |
| C12 | 0.0416 (10) | 0.0577 (12) | 0.0379 (10) | 0.0153 (9) | −0.0057 (8) | −0.0072 (8) |
| C13 | 0.0528 (12) | 0.0515 (12) | 0.0500 (12) | −0.0075 (10) | −0.0030 (9) | −0.0182 (9) |
| C14 | 0.0277 (8) | 0.0225 (7) | 0.0377 (9) | 0.0033 (6) | 0.0010 (7) | −0.0047 (6) |
| C15 | 0.0336 (9) | 0.0286 (8) | 0.0439 (10) | 0.0017 (7) | −0.0009 (7) | −0.0007 (7) |
| C16 | 0.0403 (10) | 0.0397 (10) | 0.0423 (10) | 0.0072 (8) | −0.0026 (8) | −0.0012 (8) |
| C17 | 0.0316 (9) | 0.0462 (11) | 0.0466 (11) | 0.0064 (8) | −0.0068 (8) | −0.0120 (8) |
| C18 | 0.0313 (9) | 0.0345 (9) | 0.0551 (11) | −0.0032 (7) | 0.0005 (8) | −0.0108 (8) |
| C19 | 0.0352 (9) | 0.0257 (8) | 0.0441 (10) | −0.0017 (7) | 0.0003 (7) | −0.0033 (7) |
| C20 | 0.0303 (8) | 0.0251 (8) | 0.0382 (9) | −0.0029 (6) | −0.0030 (7) | −0.0034 (6) |
| C21 | 0.0337 (9) | 0.0290 (8) | 0.0439 (10) | 0.0004 (7) | −0.0009 (7) | 0.0020 (7) |
| C22 | 0.0347 (9) | 0.0342 (9) | 0.0468 (10) | 0.0034 (7) | −0.0016 (7) | −0.0022 (8) |
| C23 | 0.0316 (8) | 0.0375 (9) | 0.0414 (9) | −0.0049 (7) | 0.0034 (7) | −0.0071 (7) |
| C24 | 0.0414 (10) | 0.0283 (8) | 0.0392 (9) | −0.0064 (7) | 0.0024 (7) | −0.0013 (7) |
| C25 | 0.0354 (9) | 0.0245 (8) | 0.0419 (9) | −0.0013 (7) | 0.0002 (7) | −0.0026 (7) |

| | | | | | | |
|---|---|---|---|---|---|---|
| N1 | 0.0301 (7) | 0.0215 (6) | 0.0456 (8) | −0.0030 (6) | −0.0016 (6) | −0.0043 (6) |
| O1 | 0.0335 (7) | 0.0377 (7) | 0.0359 (7) | 0.0078 (5) | 0.0000 (5) | −0.0013 (5) |
| O2 | 0.0353 (7) | 0.0326 (6) | 0.0422 (7) | 0.0083 (5) | 0.0009 (5) | −0.0009 (5) |
| Cl1 | 0.0337 (3) | 0.0348 (3) | 0.0517 (3) | 0.00319 (17) | 0.00755 (18) | 0.00006 (18) |

*Geometric parameters (Å, º)*

| | | | |
|---|---|---|---|
| C1—N1 | 1.376 (2) | C12—H12B | 0.9700 |
| C1—C2 | 1.396 (2) | C13—H13A | 0.9600 |
| C1—C6 | 1.423 (2) | C13—H13B | 0.9600 |
| C2—C3 | 1.377 (3) | C13—H13C | 0.9600 |
| C2—H2 | 0.9300 | C14—C19 | 1.398 (2) |
| C3—C4 | 1.413 (2) | C14—C15 | 1.398 (2) |
| C3—H3 | 0.9300 | C15—C16 | 1.392 (3) |
| C4—C5 | 1.375 (2) | C15—H15 | 0.9300 |
| C4—Cl1 | 1.7569 (18) | C16—C17 | 1.394 (3) |
| C5—C6 | 1.408 (2) | C16—H16 | 0.9300 |
| C5—H5 | 0.9300 | C17—C18 | 1.381 (3) |
| C6—C7 | 1.439 (2) | C17—H17 | 0.9300 |
| C7—C8 | 1.378 (2) | C18—C19 | 1.398 (3) |
| C7—C9 | 1.518 (2) | C18—H18 | 0.9300 |
| C8—N1 | 1.392 (2) | C19—H19 | 0.9300 |
| C8—C20 | 1.479 (2) | C20—C21 | 1.399 (2) |
| C9—C14 | 1.535 (2) | C20—C25 | 1.404 (2) |
| C9—C10 | 1.550 (2) | C21—C22 | 1.391 (2) |
| C9—H9 | 0.9800 | C21—H21 | 0.9300 |
| C10—C11 | 1.503 (2) | C22—C23 | 1.390 (3) |
| C10—H10A | 0.9700 | C22—H22 | 0.9300 |
| C10—H10B | 0.9700 | C23—C24 | 1.393 (3) |
| C11—O2 | 1.216 (2) | C23—H23 | 0.9300 |
| C11—O1 | 1.337 (2) | C24—C25 | 1.390 (2) |
| C12—O1 | 1.465 (2) | C24—H24 | 0.9300 |
| C12—C13 | 1.524 (3) | C25—H25 | 0.9300 |
| C12—H12A | 0.9700 | N1—H1 | 0.91 (2) |
| | | | |
| N1—C1—C2 | 130.09 (15) | C12—C13—H13B | 109.5 |
| N1—C1—C6 | 107.52 (14) | H13A—C13—H13B | 109.5 |
| C2—C1—C6 | 122.38 (16) | C12—C13—H13C | 109.5 |
| C3—C2—C1 | 117.83 (15) | H13A—C13—H13C | 109.5 |
| C3—C2—H2 | 121.1 | H13B—C13—H13C | 109.5 |
| C1—C2—H2 | 121.1 | C19—C14—C15 | 118.16 (16) |
| C2—C3—C4 | 120.02 (16) | C19—C14—C9 | 123.52 (15) |
| C2—C3—H3 | 120.0 | C15—C14—C9 | 118.31 (14) |
| C4—C3—H3 | 120.0 | C16—C15—C14 | 121.52 (17) |
| C5—C4—C3 | 123.02 (16) | C16—C15—H15 | 119.2 |
| C5—C4—Cl1 | 119.41 (13) | C14—C15—H15 | 119.2 |
| C3—C4—Cl1 | 117.56 (13) | C15—C16—C17 | 119.43 (17) |
| C4—C5—C6 | 117.79 (15) | C15—C16—H16 | 120.3 |

| | | | |
|---|---|---|---|
| C4—C5—H5 | 121.1 | C17—C16—H16 | 120.3 |
| C6—C5—H5 | 121.1 | C18—C17—C16 | 119.92 (17) |
| C5—C6—C1 | 118.83 (15) | C18—C17—H17 | 120.0 |
| C5—C6—C7 | 134.25 (14) | C16—C17—H17 | 120.0 |
| C1—C6—C7 | 106.92 (14) | C17—C18—C19 | 120.54 (17) |
| C8—C7—C6 | 106.98 (14) | C17—C18—H18 | 119.7 |
| C8—C7—C9 | 127.13 (14) | C19—C18—H18 | 119.7 |
| C6—C7—C9 | 125.86 (14) | C18—C19—C14 | 120.43 (17) |
| C7—C8—N1 | 109.24 (14) | C18—C19—H19 | 119.8 |
| C7—C8—C20 | 132.44 (15) | C14—C19—H19 | 119.8 |
| N1—C8—C20 | 118.27 (14) | C21—C20—C25 | 118.54 (16) |
| C7—C9—C14 | 111.54 (12) | C21—C20—C8 | 121.89 (15) |
| C7—C9—C10 | 110.58 (13) | C25—C20—C8 | 119.56 (15) |
| C14—C9—C10 | 112.09 (13) | C22—C21—C20 | 120.60 (17) |
| C7—C9—H9 | 107.5 | C22—C21—H21 | 119.7 |
| C14—C9—H9 | 107.5 | C20—C21—H21 | 119.7 |
| C10—C9—H9 | 107.5 | C23—C22—C21 | 120.47 (17) |
| C11—C10—C9 | 111.53 (13) | C23—C22—H22 | 119.8 |
| C11—C10—H10A | 109.3 | C21—C22—H22 | 119.8 |
| C9—C10—H10A | 109.3 | C22—C23—C24 | 119.46 (17) |
| C11—C10—H10B | 109.3 | C22—C23—H23 | 120.3 |
| C9—C10—H10B | 109.3 | C24—C23—H23 | 120.3 |
| H10A—C10—H10B | 108.0 | C25—C24—C23 | 120.31 (16) |
| O2—C11—O1 | 123.06 (16) | C25—C24—H24 | 119.8 |
| O2—C11—C10 | 124.70 (16) | C23—C24—H24 | 119.8 |
| O1—C11—C10 | 112.24 (14) | C24—C25—C20 | 120.62 (16) |
| O1—C12—C13 | 111.45 (16) | C24—C25—H25 | 119.7 |
| O1—C12—H12A | 109.3 | C20—C25—H25 | 119.7 |
| C13—C12—H12A | 109.3 | C1—N1—C8 | 109.21 (13) |
| O1—C12—H12B | 109.3 | C1—N1—H1 | 127.3 (13) |
| C13—C12—H12B | 109.3 | C8—N1—H1 | 120.8 (13) |
| H12A—C12—H12B | 108.0 | C11—O1—C12 | 115.72 (14) |
| C12—C13—H13A | 109.5 | | |
| | | | |
| N1—C1—C2—C3 | −179.31 (17) | C10—C9—C14—C19 | 1.3 (2) |
| C6—C1—C2—C3 | 2.3 (3) | C7—C9—C14—C15 | −54.82 (19) |
| C1—C2—C3—C4 | 1.1 (3) | C10—C9—C14—C15 | −179.43 (14) |
| C2—C3—C4—C5 | −2.6 (3) | C19—C14—C15—C16 | −0.2 (2) |
| C2—C3—C4—Cl1 | 178.83 (13) | C9—C14—C15—C16 | −179.44 (15) |
| C3—C4—C5—C6 | 0.7 (3) | C14—C15—C16—C17 | 0.2 (3) |
| Cl1—C4—C5—C6 | 179.22 (12) | C15—C16—C17—C18 | −0.1 (3) |
| C4—C5—C6—C1 | 2.6 (2) | C16—C17—C18—C19 | 0.1 (3) |
| C4—C5—C6—C7 | −176.81 (18) | C17—C18—C19—C14 | −0.1 (3) |
| N1—C1—C6—C5 | 177.11 (14) | C15—C14—C19—C18 | 0.1 (2) |
| C2—C1—C6—C5 | −4.2 (2) | C9—C14—C19—C18 | 179.36 (15) |
| N1—C1—C6—C7 | −3.36 (18) | C7—C8—C20—C21 | 53.7 (3) |
| C2—C1—C6—C7 | 175.36 (16) | N1—C8—C20—C21 | −129.19 (18) |
| C5—C6—C7—C8 | −178.78 (18) | C7—C8—C20—C25 | −127.7 (2) |

| | | | |
|---|---|---|---|
| C1—C6—C7—C8 | 1.79 (18) | N1—C8—C20—C25 | 49.4 (2) |
| C5—C6—C7—C9 | 3.1 (3) | C25—C20—C21—C22 | −0.4 (3) |
| C1—C6—C7—C9 | −176.37 (15) | C8—C20—C21—C22 | 178.19 (16) |
| C6—C7—C8—N1 | 0.44 (18) | C20—C21—C22—C23 | 0.5 (3) |
| C9—C7—C8—N1 | 178.56 (15) | C21—C22—C23—C24 | 0.0 (3) |
| C6—C7—C8—C20 | 177.73 (17) | C22—C23—C24—C25 | −0.7 (3) |
| C9—C7—C8—C20 | −4.1 (3) | C23—C24—C25—C20 | 0.8 (3) |
| C8—C7—C9—C14 | 119.22 (17) | C21—C20—C25—C24 | −0.3 (2) |
| C6—C7—C9—C14 | −63.0 (2) | C8—C20—C25—C24 | −178.90 (15) |
| C8—C7—C9—C10 | −115.32 (18) | C2—C1—N1—C8 | −174.90 (18) |
| C6—C7—C9—C10 | 62.5 (2) | C6—C1—N1—C8 | 3.69 (19) |
| C7—C9—C10—C11 | 50.25 (17) | C7—C8—N1—C1 | −2.61 (19) |
| C14—C9—C10—C11 | 175.39 (13) | C20—C8—N1—C1 | 179.66 (14) |
| C9—C10—C11—O2 | 72.6 (2) | O2—C11—O1—C12 | −4.3 (2) |
| C9—C10—C11—O1 | −106.83 (15) | C10—C11—O1—C12 | 175.18 (14) |
| C7—C9—C14—C19 | 125.93 (16) | C13—C12—O1—C11 | −81.27 (19) |

*Hydrogen-bond geometry (Å, º)*

Cg2 and Cg4 are the centroids of the C1–C6 and C20–C25 rings, respectively.

| $D$—H···$A$ | $D$—H | H···$A$ | $D$···$A$ | $D$—H···$A$ |
|---|---|---|---|---|
| C21—H21···O2 | 0.93 | 2.34 | 3.258 (2) | 169 |
| N1—H1···O2[i] | 0.91 (2) | 1.95 (2) | 2.8310 (18) | 163.0 (18) |
| C10—H10$A$···Cg4[ii] | 0.97 | 2.93 | 3.8022 (18) | 150 |
| C12—H12$A$···Cg2[iii] | 0.97 | 2.97 | 3.702 (2) | 133 |
| C16—H16···Cg4[iv] | 0.93 | 2.78 | 3.643 (2) | 154 |
| C19—H19···Cg2[i] | 0.93 | 2.96 | 3.7860 (18) | 149 |

Symmetry codes: (i) −$x$+1/2, $y$−1/2, $z$; (ii) −$x$−1/2, $y$−1/2, $z$; (iii) −$x$+1, −$y$+1, −$z$; (iv) −$x$+1, $y$, −$z$+1/2.

## (II) 2-Bromo-3-(2-nitro-1-phenylethyl)-1*H*-indole

*Crystal data*

| | |
|---|---|
| $C_{16}H_{13}BrN_2O_2$ | $F(000) = 696$ |
| $M_r = 345.19$ | $D_x = 1.643$ Mg m$^{-3}$ |
| Monoclinic, $P2_1/c$ | Mo $K\alpha$ radiation, $\lambda = 0.71075$ Å |
| Hall symbol: -P 2ybc | Cell parameters from 14875 reflections |
| $a = 9.7223$ (7) Å | $\theta = 2.9$–27.5° |
| $b = 10.2804$ (7) Å | $\mu = 2.95$ mm$^{-1}$ |
| $c = 13.9652$ (10) Å | $T = 100$ K |
| $\beta = 91.238$ (2)° | Slab, pale brown |
| $V = 1395.48$ (17) Å$^3$ | 0.22 × 0.19 × 0.05 mm |
| $Z = 4$ | |

*Data collection*

| | |
|---|---|
| Rigaku Mercury CCD diffractometer | Absorption correction: multi-scan (*SADABS*; Sheldrick, 1996) |
| Radiation source: fine-focus sealed tube | $T_{min} = 0.563$, $T_{max} = 0.867$ |
| Graphite monochromator | 14919 measured reflections |
| $\omega$ scans | 3213 independent reflections |
| | 2911 reflections with $I > 2\sigma(I)$ |

$R_{int} = 0.042$
$\theta_{max} = 27.5°$, $\theta_{min} = 2.9°$
$h = -12 \rightarrow 12$

$k = -13 \rightarrow 13$
$l = -18 \rightarrow 17$

*Refinement*

Refinement on $F^2$
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.040$
$wR(F^2) = 0.108$
$S = 1.07$
3213 reflections
193 parameters
0 restraints
Primary atom site location: structure-invariant
    direct methods

Secondary atom site location: difference Fourier
    map
Hydrogen site location: inferred from
    neighbouring sites
H atoms treated by a mixture of independent
    and constrained refinement
$w = 1/[\sigma^2(F_o^2) + (0.0534P)^2 + 2.3689P]$
    where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 1.26$ e Å$^{-3}$
$\Delta\rho_{min} = -0.82$ e Å$^{-3}$

*Special details*

**Geometry**. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

**Refinement**. Refinement of $F^2$ against ALL reflections. The weighted $R$-factor $wR$ and goodness of fit $S$ are based on $F^2$, conventional $R$-factors $R$ are based on $F$, with $F$ set to zero for negative $F^2$. The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating $R$-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. $R$-factors based on $F^2$ are statistically about twice as large as those based on $F$, and $R$- factors based on ALL data will be even larger.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å$^2$)*

|  | *x* | *y* | *z* | $U_{iso}*/U_{eq}$ |
| --- | --- | --- | --- | --- |
| C1 | 0.4952 (3) | 0.3822 (3) | 0.59411 (18) | 0.0218 (5) |
| C2 | 0.3700 (3) | 0.3784 (3) | 0.54275 (19) | 0.0261 (6) |
| H2 | 0.3510 | 0.3120 | 0.4970 | 0.031* |
| C3 | 0.2753 (3) | 0.4750 (3) | 0.5611 (2) | 0.0297 (6) |
| H3 | 0.1888 | 0.4745 | 0.5281 | 0.036* |
| C4 | 0.3051 (3) | 0.5740 (3) | 0.6280 (2) | 0.0281 (6) |
| H4 | 0.2376 | 0.6386 | 0.6395 | 0.034* |
| C5 | 0.4299 (3) | 0.5801 (3) | 0.6776 (2) | 0.0257 (6) |
| H5 | 0.4492 | 0.6489 | 0.7213 | 0.031* |
| C6 | 0.5274 (3) | 0.4817 (2) | 0.66142 (18) | 0.0210 (5) |
| C7 | 0.6650 (3) | 0.4559 (3) | 0.69787 (18) | 0.0215 (5) |
| C8 | 0.7066 (3) | 0.3462 (3) | 0.65211 (19) | 0.0223 (5) |
| C9 | 0.7553 (3) | 0.5367 (3) | 0.76399 (19) | 0.0229 (5) |
| H9 | 0.8379 | 0.4833 | 0.7817 | 0.027* |
| C10 | 0.6852 (3) | 0.5750 (3) | 0.85699 (19) | 0.0248 (6) |
| H10A | 0.7475 | 0.6310 | 0.8960 | 0.030* |
| H10B | 0.6003 | 0.6249 | 0.8420 | 0.030* |
| C11 | 0.8057 (3) | 0.6574 (3) | 0.70989 (18) | 0.0219 (5) |
| C12 | 0.7453 (3) | 0.7795 (3) | 0.7152 (2) | 0.0284 (6) |
| H12 | 0.6706 | 0.7933 | 0.7568 | 0.034* |
| C13 | 0.7938 (3) | 0.8824 (3) | 0.6596 (2) | 0.0313 (6) |

| H13 | 0.7520 | 0.9657 | 0.6639 | 0.038* |
| C14 | 0.9025 (3) | 0.8638 (3) | 0.5982 (2) | 0.0294 (6) |
| H14 | 0.9354 | 0.9338 | 0.5607 | 0.035* |
| C15 | 0.9624 (3) | 0.7418 (3) | 0.5922 (2) | 0.0281 (6) |
| H15 | 1.0363 | 0.7278 | 0.5499 | 0.034* |
| C16 | 0.9147 (3) | 0.6396 (3) | 0.6479 (2) | 0.0247 (5) |
| H16 | 0.9570 | 0.5566 | 0.6436 | 0.030* |
| N1 | 0.6058 (3) | 0.2984 (2) | 0.59133 (16) | 0.0230 (5) |
| H1 | 0.623 (4) | 0.242 (3) | 0.554 (3) | 0.028* |
| N2 | 0.6503 (3) | 0.4554 (2) | 0.91218 (16) | 0.0271 (5) |
| O1 | 0.7431 (2) | 0.3967 (2) | 0.95513 (16) | 0.0339 (5) |
| O2 | 0.5300 (3) | 0.4220 (3) | 0.91282 (19) | 0.0464 (6) |
| Br1 | 0.87595 (3) | 0.26053 (3) | 0.66349 (2) | 0.02856 (12) |

*Atomic displacement parameters (Å²)*

|  | $U^{11}$ | $U^{22}$ | $U^{33}$ | $U^{12}$ | $U^{13}$ | $U^{23}$ |
|---|---|---|---|---|---|---|
| C1 | 0.0294 (13) | 0.0189 (12) | 0.0174 (11) | −0.0045 (10) | 0.0064 (10) | 0.0008 (9) |
| C2 | 0.0357 (15) | 0.0257 (13) | 0.0169 (12) | −0.0090 (11) | 0.0020 (11) | −0.0003 (10) |
| C3 | 0.0280 (14) | 0.0373 (16) | 0.0237 (14) | −0.0035 (12) | 0.0021 (11) | 0.0056 (12) |
| C4 | 0.0321 (15) | 0.0271 (14) | 0.0255 (14) | 0.0026 (11) | 0.0075 (12) | 0.0026 (11) |
| C5 | 0.0289 (14) | 0.0279 (14) | 0.0205 (13) | −0.0011 (11) | 0.0059 (11) | 0.0042 (10) |
| C6 | 0.0279 (13) | 0.0190 (12) | 0.0164 (11) | −0.0039 (10) | 0.0062 (10) | 0.0002 (9) |
| C7 | 0.0286 (13) | 0.0206 (12) | 0.0155 (11) | −0.0043 (10) | 0.0058 (10) | 0.0007 (9) |
| C8 | 0.0266 (13) | 0.0222 (12) | 0.0184 (12) | −0.0009 (10) | 0.0058 (10) | 0.0005 (10) |
| C9 | 0.0272 (13) | 0.0219 (12) | 0.0198 (12) | −0.0006 (10) | 0.0053 (10) | −0.0005 (10) |
| C10 | 0.0336 (15) | 0.0199 (12) | 0.0210 (13) | 0.0006 (11) | 0.0041 (11) | 0.0007 (10) |
| C11 | 0.0238 (12) | 0.0246 (13) | 0.0172 (12) | −0.0053 (10) | 0.0016 (10) | −0.0021 (10) |
| C12 | 0.0313 (15) | 0.0280 (14) | 0.0263 (14) | −0.0014 (12) | 0.0078 (11) | −0.0037 (12) |
| C13 | 0.0379 (16) | 0.0232 (14) | 0.0329 (15) | 0.0001 (12) | 0.0020 (13) | −0.0002 (12) |
| C14 | 0.0319 (15) | 0.0314 (15) | 0.0250 (14) | −0.0079 (12) | 0.0010 (11) | 0.0074 (11) |
| C15 | 0.0242 (13) | 0.0368 (16) | 0.0235 (14) | −0.0051 (11) | 0.0044 (11) | 0.0029 (11) |
| C16 | 0.0249 (13) | 0.0267 (13) | 0.0226 (13) | −0.0024 (11) | 0.0024 (10) | 0.0012 (11) |
| N1 | 0.0310 (12) | 0.0192 (11) | 0.0191 (11) | −0.0020 (9) | 0.0053 (9) | −0.0030 (8) |
| N2 | 0.0453 (15) | 0.0204 (11) | 0.0158 (10) | −0.0012 (10) | 0.0063 (10) | 0.0003 (9) |
| O1 | 0.0419 (12) | 0.0265 (10) | 0.0335 (11) | 0.0044 (9) | 0.0015 (9) | 0.0070 (9) |
| O2 | 0.0381 (13) | 0.0549 (16) | 0.0463 (15) | −0.0109 (12) | 0.0043 (11) | 0.0110 (12) |
| Br1 | 0.03170 (18) | 0.02778 (17) | 0.02638 (18) | 0.00571 (11) | 0.00434 (12) | 0.00019 (10) |

*Geometric parameters (Å, º)*

| C1—N1 | 1.379 (4) | C9—H9 | 1.0000 |
|---|---|---|---|
| C1—C2 | 1.399 (4) | C10—N2 | 1.495 (3) |
| C1—C6 | 1.419 (4) | C10—H10A | 0.9900 |
| C2—C3 | 1.382 (4) | C10—H10B | 0.9900 |
| C2—H2 | 0.9500 | C11—C12 | 1.388 (4) |
| C3—C4 | 1.408 (4) | C11—C16 | 1.395 (4) |
| C3—H3 | 0.9500 | C12—C13 | 1.400 (4) |

| | | | |
|---|---|---|---|
| C4—C5 | 1.385 (4) | C12—H12 | 0.9500 |
| C4—H4 | 0.9500 | C13—C14 | 1.388 (4) |
| C5—C6 | 1.408 (4) | C13—H13 | 0.9500 |
| C5—H5 | 0.9500 | C14—C15 | 1.387 (4) |
| C6—C7 | 1.445 (4) | C14—H14 | 0.9500 |
| C7—C8 | 1.363 (4) | C15—C16 | 1.392 (4) |
| C7—C9 | 1.510 (4) | C15—H15 | 0.9500 |
| C8—N1 | 1.373 (4) | C16—H16 | 0.9500 |
| C8—Br1 | 1.871 (3) | N1—H1 | 0.80 (4) |
| C9—C10 | 1.531 (4) | N2—O2 | 1.219 (4) |
| C9—C11 | 1.538 (4) | N2—O1 | 1.231 (3) |
| | | | |
| N1—C1—C2 | 129.7 (2) | N2—C10—C9 | 109.6 (2) |
| N1—C1—C6 | 107.9 (2) | N2—C10—H10A | 109.7 |
| C2—C1—C6 | 122.5 (3) | C9—C10—H10A | 109.7 |
| C3—C2—C1 | 117.4 (3) | N2—C10—H10B | 109.7 |
| C3—C2—H2 | 121.3 | C9—C10—H10B | 109.7 |
| C1—C2—H2 | 121.3 | H10A—C10—H10B | 108.2 |
| C2—C3—C4 | 121.0 (3) | C12—C11—C16 | 118.7 (3) |
| C2—C3—H3 | 119.5 | C12—C11—C9 | 124.3 (2) |
| C4—C3—H3 | 119.5 | C16—C11—C9 | 117.0 (2) |
| C5—C4—C3 | 122.0 (3) | C11—C12—C13 | 120.4 (3) |
| C5—C4—H4 | 119.0 | C11—C12—H12 | 119.8 |
| C3—C4—H4 | 119.0 | C13—C12—H12 | 119.8 |
| C4—C5—C6 | 118.2 (3) | C14—C13—C12 | 120.5 (3) |
| C4—C5—H5 | 120.9 | C14—C13—H13 | 119.7 |
| C6—C5—H5 | 120.9 | C12—C13—H13 | 119.7 |
| C5—C6—C1 | 118.9 (3) | C15—C14—C13 | 119.3 (3) |
| C5—C6—C7 | 134.1 (3) | C15—C14—H14 | 120.4 |
| C1—C6—C7 | 106.9 (2) | C13—C14—H14 | 120.4 |
| C8—C7—C6 | 105.6 (2) | C14—C15—C16 | 120.2 (3) |
| C8—C7—C9 | 124.6 (3) | C14—C15—H15 | 119.9 |
| C6—C7—C9 | 129.5 (2) | C16—C15—H15 | 119.9 |
| C7—C8—N1 | 111.7 (2) | C15—C16—C11 | 121.0 (3) |
| C7—C8—Br1 | 128.3 (2) | C15—C16—H16 | 119.5 |
| N1—C8—Br1 | 120.0 (2) | C11—C16—H16 | 119.5 |
| C7—C9—C10 | 113.4 (2) | C8—N1—C1 | 107.8 (2) |
| C7—C9—C11 | 109.3 (2) | C8—N1—H1 | 121 (3) |
| C10—C9—C11 | 111.2 (2) | C1—N1—H1 | 130 (3) |
| C7—C9—H9 | 107.6 | O2—N2—O1 | 123.5 (3) |
| C10—C9—H9 | 107.6 | O2—N2—C10 | 117.6 (3) |
| C11—C9—H9 | 107.6 | O1—N2—C10 | 118.8 (3) |
| | | | |
| N1—C1—C2—C3 | 178.9 (3) | C6—C7—C9—C11 | −71.6 (3) |
| C6—C1—C2—C3 | −1.3 (4) | C7—C9—C10—N2 | 62.0 (3) |
| C1—C2—C3—C4 | 0.9 (4) | C11—C9—C10—N2 | −174.4 (2) |
| C2—C3—C4—C5 | 0.6 (4) | C7—C9—C11—C12 | 97.6 (3) |
| C3—C4—C5—C6 | −1.6 (4) | C10—C9—C11—C12 | −28.4 (4) |

| C4—C5—C6—C1 | 1.2 (4) | C7—C9—C11—C16 | −78.9 (3) |
| C4—C5—C6—C7 | 179.5 (3) | C10—C9—C11—C16 | 155.2 (2) |
| N1—C1—C6—C5 | −179.9 (2) | C16—C11—C12—C13 | −0.3 (4) |
| C2—C1—C6—C5 | 0.2 (4) | C9—C11—C12—C13 | −176.7 (3) |
| N1—C1—C6—C7 | 1.3 (3) | C11—C12—C13—C14 | 0.2 (5) |
| C2—C1—C6—C7 | −178.5 (2) | C12—C13—C14—C15 | 0.2 (5) |
| C5—C6—C7—C8 | −178.4 (3) | C13—C14—C15—C16 | −0.6 (4) |
| C1—C6—C7—C8 | 0.0 (3) | C14—C15—C16—C11 | 0.5 (4) |
| C5—C6—C7—C9 | −4.7 (5) | C12—C11—C16—C15 | 0.0 (4) |
| C1—C6—C7—C9 | 173.8 (2) | C9—C11—C16—C15 | 176.6 (3) |
| C6—C7—C8—N1 | −1.4 (3) | C7—C8—N1—C1 | 2.3 (3) |
| C9—C7—C8—N1 | −175.6 (2) | Br1—C8—N1—C1 | −177.72 (18) |
| C6—C7—C8—Br1 | 178.61 (19) | C2—C1—N1—C8 | 177.6 (3) |
| C9—C7—C8—Br1 | 4.5 (4) | C6—C1—N1—C8 | −2.2 (3) |
| C8—C7—C9—C10 | −134.3 (3) | C9—C10—N2—O2 | −105.5 (3) |
| C6—C7—C9—C10 | 53.0 (4) | C9—C10—N2—O1 | 75.3 (3) |
| C8—C7—C9—C11 | 101.0 (3) | | |

*Hydrogen-bond geometry (Å, º)*

Cg2 and Cg4 are the centroids of the C1–C6 ring.

| $D$—H⋯$A$ | $D$—H | H⋯$A$ | $D$⋯$A$ | $D$—H⋯$A$ |
|---|---|---|---|---|
| N1—H1⋯O1[i] | 0.80 (4) | 2.32 (4) | 3.087 (3) | 161 (4) |
| C12—H12⋯Cg2[ii] | 0.95 | 2.75 | 3.500 (3) | 136 |

Symmetry codes: (i) $x$, $−y+1/2$, $z−1/2$; (ii) $−x+1$, $y+1/2$, $−z+3/2$.

## (III) 5-Methoxy-3-(2-nitro-1-phenylethyl)-2-phenyl-1*H*-indole

*Crystal data*

| | |
|---|---|
| $C_{23}H_{20}N_2O_3$ | $Z = 2$ |
| $M_r = 372.41$ | $F(000) = 392$ |
| Triclinic, $P\overline{1}$ | $D_x = 1.316$ Mg m$^{-3}$ |
| Hall symbol: -P 1 | Mo $K\alpha$ radiation, $\lambda = 0.71075$ Å |
| $a = 9.7561$ (7) Å | Cell parameters from 12105 reflections |
| $b = 10.0258$ (7) Å | $\theta = 2.9–27.5°$ |
| $c = 10.8942$ (8) Å | $\mu = 0.09$ mm$^{-1}$ |
| $\alpha = 116.415$ (5)° | $T = 100$ K |
| $\beta = 91.843$ (4)° | Slab, light yellow |
| $\gamma = 97.963$ (4)° | $0.24 \times 0.21 \times 0.03$ mm |
| $V = 939.84$ (12) Å$^3$ | |

*Data collection*

| | |
|---|---|
| Rigaku Mercury CCD diffractometer | 3782 reflections with $I > 2\sigma(I)$ |
| | $R_{int} = 0.028$ |
| Radiation source: fine-focus sealed tube | $\theta_{max} = 27.5°$, $\theta_{min} = 2.9°$ |
| Graphite monochromator | $h = −12\rightarrow12$ |
| $\omega$ scans | $k = −13\rightarrow13$ |
| 12625 measured reflections | $l = −14\rightarrow14$ |
| 4305 independent reflections | |

*Refinement*

| | |
|---|---|
| Refinement on $F^2$ | Secondary atom site location: difference Fourier map |
| Least-squares matrix: full | |
| $R[F^2 > 2\sigma(F^2)] = 0.035$ | Hydrogen site location: inferred from neighbouring sites |
| $wR(F^2) = 0.097$ | |
| $S = 1.06$ | H atoms treated by a mixture of independent and constrained refinement |
| 4305 reflections | |
| 257 parameters | $w = 1/[\sigma^2(F_o^2) + (0.0492P)^2 + 0.1954P]$ |
| 0 restraints | where $P = (F_o^2 + 2F_c^2)/3$ |
| Primary atom site location: structure-invariant direct methods | $(\Delta/\sigma)_{max} = 0.001$ |
| | $\Delta\rho_{max} = 0.30$ e Å$^{-3}$ |
| | $\Delta\rho_{min} = -0.22$ e Å$^{-3}$ |

*Special details*

**Geometry**. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

**Refinement**. Refinement of $F^2$ against ALL reflections. The weighted $R$-factor $wR$ and goodness of fit $S$ are based on $F^2$, conventional $R$-factors $R$ are based on $F$, with $F$ set to zero for negative $F^2$. The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating $R$-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. $R$-factors based on $F^2$ are statistically about twice as large as those based on $F$, and $R$- factors based on ALL data will be even larger.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)*

| | $x$ | $y$ | $z$ | $U_{iso}$*/$U_{eq}$ |
|---|---|---|---|---|
| C1 | 0.19835 (10) | 0.50476 (11) | 0.67418 (11) | 0.0204 (2) |
| C2 | 0.17538 (11) | 0.56338 (12) | 0.81213 (11) | 0.0230 (2) |
| H2 | 0.1769 | 0.6686 | 0.8661 | 0.028* |
| C3 | 0.15006 (11) | 0.46425 (12) | 0.86931 (11) | 0.0218 (2) |
| H3 | 0.1334 | 0.5015 | 0.9633 | 0.026* |
| C4 | 0.14906 (10) | 0.30892 (11) | 0.78826 (11) | 0.0199 (2) |
| C5 | 0.17195 (10) | 0.25007 (11) | 0.65095 (10) | 0.0196 (2) |
| H5 | 0.1709 | 0.1448 | 0.5979 | 0.024* |
| C6 | 0.19683 (10) | 0.34839 (11) | 0.59073 (10) | 0.0191 (2) |
| C7 | 0.22732 (10) | 0.33046 (11) | 0.45606 (10) | 0.0191 (2) |
| C8 | 0.24758 (10) | 0.47341 (11) | 0.46426 (10) | 0.0203 (2) |
| C9 | 0.22632 (10) | 0.18956 (11) | 0.32343 (10) | 0.0191 (2) |
| H9 | 0.2138 | 0.2182 | 0.2473 | 0.023* |
| C10 | 0.10313 (10) | 0.06333 (11) | 0.29937 (11) | 0.0209 (2) |
| H10A | 0.1067 | −0.0259 | 0.2104 | 0.025* |
| H10B | 0.1097 | 0.0324 | 0.3736 | 0.025* |
| C11 | 0.35712 (10) | 0.11774 (11) | 0.30199 (11) | 0.0197 (2) |
| C12 | 0.45009 (11) | 0.13848 (12) | 0.41090 (11) | 0.0222 (2) |
| H12 | 0.4337 | 0.2004 | 0.5031 | 0.027* |
| C13 | 0.56717 (11) | 0.06865 (12) | 0.38520 (12) | 0.0246 (2) |
| H13 | 0.6302 | 0.0831 | 0.4601 | 0.030* |
| C14 | 0.59239 (11) | −0.02169 (12) | 0.25117 (12) | 0.0258 (2) |
| H14 | 0.6726 | −0.0687 | 0.2342 | 0.031* |
| C15 | 0.49987 (12) | −0.04312 (12) | 0.14192 (12) | 0.0263 (2) |

| | | | | |
|---|---|---|---|---|
| H15 | 0.5166 | −0.1049 | 0.0498 | 0.032* |
| C16 | 0.38279 (11) | 0.02591 (12) | 0.16739 (11) | 0.0238 (2) |
| H16 | 0.3195 | 0.0104 | 0.0923 | 0.029* |
| C17 | 0.29178 (11) | 0.52239 (11) | 0.36018 (11) | 0.0216 (2) |
| C18 | 0.21895 (12) | 0.61533 (12) | 0.32766 (11) | 0.0263 (2) |
| H18 | 0.1360 | 0.6427 | 0.3682 | 0.032* |
| C19 | 0.26838 (14) | 0.66735 (13) | 0.23588 (12) | 0.0324 (3) |
| H19 | 0.2195 | 0.7313 | 0.2146 | 0.039* |
| C20 | 0.38861 (14) | 0.62652 (13) | 0.17520 (12) | 0.0333 (3) |
| H20 | 0.4218 | 0.6627 | 0.1126 | 0.040* |
| C21 | 0.46049 (12) | 0.53318 (14) | 0.20555 (12) | 0.0309 (3) |
| H21 | 0.5424 | 0.5046 | 0.1632 | 0.037* |
| C22 | 0.41268 (11) | 0.48128 (13) | 0.29814 (11) | 0.0255 (2) |
| H22 | 0.4623 | 0.4177 | 0.3193 | 0.031* |
| C23 | 0.13008 (14) | 0.25934 (13) | 0.98450 (11) | 0.0301 (3) |
| H23A | 0.1179 | 0.1737 | 1.0062 | 0.045* |
| H23B | 0.0556 | 0.3185 | 1.0194 | 0.045* |
| H23C | 0.2204 | 0.3235 | 1.0280 | 0.045* |
| N1 | 0.22919 (10) | 0.57768 (10) | 0.59438 (9) | 0.02257 (19) |
| H1 | 0.2353 (14) | 0.6738 (16) | 0.6209 (14) | 0.027* |
| N2 | −0.03129 (9) | 0.11860 (10) | 0.29782 (10) | 0.0245 (2) |
| O1 | −0.09938 (8) | 0.14343 (9) | 0.39586 (9) | 0.0325 (2) |
| O2 | −0.06497 (9) | 0.13940 (10) | 0.19906 (10) | 0.0348 (2) |
| O3 | 0.12460 (8) | 0.20475 (8) | 0.83947 (7) | 0.02322 (17) |

*Atomic displacement parameters (Å²)*

| | $U^{11}$ | $U^{22}$ | $U^{33}$ | $U^{12}$ | $U^{13}$ | $U^{23}$ |
|---|---|---|---|---|---|---|
| C1 | 0.0195 (5) | 0.0209 (5) | 0.0220 (5) | 0.0045 (4) | 0.0026 (4) | 0.0104 (4) |
| C2 | 0.0250 (5) | 0.0197 (5) | 0.0228 (5) | 0.0063 (4) | 0.0036 (4) | 0.0075 (4) |
| C3 | 0.0213 (5) | 0.0246 (5) | 0.0191 (5) | 0.0062 (4) | 0.0039 (4) | 0.0088 (4) |
| C4 | 0.0161 (4) | 0.0225 (5) | 0.0229 (5) | 0.0030 (4) | 0.0022 (4) | 0.0120 (4) |
| C5 | 0.0178 (5) | 0.0188 (4) | 0.0216 (5) | 0.0037 (3) | 0.0025 (4) | 0.0085 (4) |
| C6 | 0.0156 (4) | 0.0207 (5) | 0.0204 (5) | 0.0038 (3) | 0.0020 (4) | 0.0087 (4) |
| C7 | 0.0165 (4) | 0.0208 (5) | 0.0201 (5) | 0.0031 (3) | 0.0021 (4) | 0.0094 (4) |
| C8 | 0.0186 (5) | 0.0212 (5) | 0.0205 (5) | 0.0037 (4) | 0.0012 (4) | 0.0088 (4) |
| C9 | 0.0172 (4) | 0.0207 (5) | 0.0200 (5) | 0.0036 (4) | 0.0026 (4) | 0.0098 (4) |
| C10 | 0.0173 (5) | 0.0199 (5) | 0.0251 (5) | 0.0045 (4) | 0.0029 (4) | 0.0093 (4) |
| C11 | 0.0180 (4) | 0.0196 (4) | 0.0227 (5) | 0.0030 (3) | 0.0046 (4) | 0.0104 (4) |
| C12 | 0.0199 (5) | 0.0217 (5) | 0.0229 (5) | 0.0022 (4) | 0.0022 (4) | 0.0086 (4) |
| C13 | 0.0184 (5) | 0.0256 (5) | 0.0292 (6) | 0.0018 (4) | −0.0007 (4) | 0.0126 (5) |
| C14 | 0.0191 (5) | 0.0258 (5) | 0.0353 (6) | 0.0062 (4) | 0.0074 (4) | 0.0153 (5) |
| C15 | 0.0271 (5) | 0.0277 (5) | 0.0256 (5) | 0.0085 (4) | 0.0100 (4) | 0.0120 (5) |
| C16 | 0.0235 (5) | 0.0275 (5) | 0.0221 (5) | 0.0061 (4) | 0.0044 (4) | 0.0122 (4) |
| C17 | 0.0233 (5) | 0.0191 (5) | 0.0204 (5) | −0.0008 (4) | −0.0005 (4) | 0.0086 (4) |
| C18 | 0.0343 (6) | 0.0205 (5) | 0.0218 (5) | 0.0052 (4) | 0.0003 (4) | 0.0074 (4) |
| C19 | 0.0514 (7) | 0.0217 (5) | 0.0236 (6) | 0.0034 (5) | −0.0024 (5) | 0.0111 (4) |
| C20 | 0.0446 (7) | 0.0286 (6) | 0.0234 (6) | −0.0094 (5) | −0.0017 (5) | 0.0136 (5) |

| | | | | | | |
|---|---|---|---|---|---|---|
| C21 | 0.0266 (5) | 0.0369 (6) | 0.0249 (6) | −0.0061 (5) | 0.0013 (4) | 0.0135 (5) |
| C22 | 0.0220 (5) | 0.0283 (5) | 0.0253 (5) | −0.0006 (4) | −0.0006 (4) | 0.0129 (5) |
| C23 | 0.0429 (7) | 0.0261 (5) | 0.0213 (5) | 0.0033 (5) | 0.0039 (5) | 0.0117 (5) |
| N1 | 0.0283 (5) | 0.0177 (4) | 0.0223 (4) | 0.0047 (3) | 0.0042 (4) | 0.0093 (4) |
| N2 | 0.0186 (4) | 0.0191 (4) | 0.0321 (5) | 0.0024 (3) | 0.0020 (4) | 0.0087 (4) |
| O1 | 0.0209 (4) | 0.0300 (4) | 0.0343 (5) | 0.0038 (3) | 0.0078 (3) | 0.0036 (4) |
| O2 | 0.0278 (4) | 0.0361 (5) | 0.0484 (5) | 0.0061 (3) | −0.0020 (4) | 0.0265 (4) |
| O3 | 0.0286 (4) | 0.0217 (4) | 0.0199 (4) | 0.0019 (3) | 0.0031 (3) | 0.0106 (3) |

*Geometric parameters (Å, º)*

| | | | |
|---|---|---|---|
| C1—N1 | 1.3791 (13) | C13—C14 | 1.3860 (16) |
| C1—C2 | 1.3880 (14) | C13—H13 | 0.9500 |
| C1—C6 | 1.4174 (14) | C14—C15 | 1.3883 (16) |
| C2—C3 | 1.3891 (14) | C14—H14 | 0.9500 |
| C2—H2 | 0.9500 | C15—C16 | 1.3889 (15) |
| C3—C4 | 1.4060 (14) | C15—H15 | 0.9500 |
| C3—H3 | 0.9500 | C16—H16 | 0.9500 |
| C4—C5 | 1.3814 (14) | C17—C22 | 1.3986 (15) |
| C4—O3 | 1.3846 (12) | C17—C18 | 1.3999 (15) |
| C5—C6 | 1.4072 (14) | C18—C19 | 1.3891 (16) |
| C5—H5 | 0.9500 | C18—H18 | 0.9500 |
| C6—C7 | 1.4428 (13) | C19—C20 | 1.3865 (19) |
| C7—C8 | 1.3811 (14) | C19—H19 | 0.9500 |
| C7—C9 | 1.5042 (14) | C20—C21 | 1.3853 (18) |
| C8—N1 | 1.3728 (14) | C20—H20 | 0.9500 |
| C8—C17 | 1.4768 (14) | C21—C22 | 1.3914 (15) |
| C9—C11 | 1.5250 (14) | C21—H21 | 0.9500 |
| C9—C10 | 1.5421 (13) | C22—H22 | 0.9500 |
| C9—H9 | 1.0000 | C23—O3 | 1.4198 (13) |
| C10—N2 | 1.4951 (13) | C23—H23A | 0.9800 |
| C10—H10A | 0.9900 | C23—H23B | 0.9800 |
| C10—H10B | 0.9900 | C23—H23C | 0.9800 |
| C11—C12 | 1.3901 (15) | N1—H1 | 0.867 (14) |
| C11—C16 | 1.3954 (15) | N2—O1 | 1.2243 (12) |
| C12—C13 | 1.3933 (15) | N2—O2 | 1.2267 (13) |
| C12—H12 | 0.9500 | | |
| | | | |
| N1—C1—C2 | 129.92 (9) | C14—C13—H13 | 119.8 |
| N1—C1—C6 | 107.75 (9) | C12—C13—H13 | 119.8 |
| C2—C1—C6 | 122.32 (9) | C13—C14—C15 | 119.66 (10) |
| C1—C2—C3 | 118.32 (9) | C13—C14—H14 | 120.2 |
| C1—C2—H2 | 120.8 | C15—C14—H14 | 120.2 |
| C3—C2—H2 | 120.8 | C14—C15—C16 | 119.93 (10) |
| C2—C3—C4 | 120.11 (9) | C14—C15—H15 | 120.0 |
| C2—C3—H3 | 119.9 | C16—C15—H15 | 120.0 |
| C4—C3—H3 | 119.9 | C15—C16—C11 | 120.75 (10) |
| C5—C4—O3 | 115.49 (9) | C15—C16—H16 | 119.6 |

| C5—C4—C3 | 121.77 (9) | C11—C16—H16 | 119.6 |
| O3—C4—C3 | 122.74 (9) | C22—C17—C18 | 119.44 (10) |
| C4—C5—C6 | 119.03 (9) | C22—C17—C8 | 119.24 (9) |
| C4—C5—H5 | 120.5 | C18—C17—C8 | 121.24 (10) |
| C6—C5—H5 | 120.5 | C19—C18—C17 | 119.78 (11) |
| C5—C6—C1 | 118.44 (9) | C19—C18—H18 | 120.1 |
| C5—C6—C7 | 134.84 (9) | C17—C18—H18 | 120.1 |
| C1—C6—C7 | 106.69 (9) | C20—C19—C18 | 120.42 (11) |
| C8—C7—C6 | 106.53 (9) | C20—C19—H19 | 119.8 |
| C8—C7—C9 | 122.90 (9) | C18—C19—H19 | 119.8 |
| C6—C7—C9 | 130.34 (9) | C21—C20—C19 | 120.20 (10) |
| N1—C8—C7 | 109.81 (9) | C21—C20—H20 | 119.9 |
| N1—C8—C17 | 120.54 (9) | C19—C20—H20 | 119.9 |
| C7—C8—C17 | 129.53 (9) | C20—C21—C22 | 119.95 (11) |
| C7—C9—C11 | 116.98 (8) | C20—C21—H21 | 120.0 |
| C7—C9—C10 | 113.02 (8) | C22—C21—H21 | 120.0 |
| C11—C9—C10 | 106.58 (8) | C21—C22—C17 | 120.20 (11) |
| C7—C9—H9 | 106.5 | C21—C22—H22 | 119.9 |
| C11—C9—H9 | 106.5 | C17—C22—H22 | 119.9 |
| C10—C9—H9 | 106.5 | O3—C23—H23A | 109.5 |
| N2—C10—C9 | 109.91 (8) | O3—C23—H23B | 109.5 |
| N2—C10—H10A | 109.7 | H23A—C23—H23B | 109.5 |
| C9—C10—H10A | 109.7 | O3—C23—H23C | 109.5 |
| N2—C10—H10B | 109.7 | H23A—C23—H23C | 109.5 |
| C9—C10—H10B | 109.7 | H23B—C23—H23C | 109.5 |
| H10A—C10—H10B | 108.2 | C8—N1—C1 | 109.21 (9) |
| C12—C11—C16 | 119.01 (9) | C8—N1—H1 | 124.8 (9) |
| C12—C11—C9 | 122.66 (9) | C1—N1—H1 | 126.0 (9) |
| C16—C11—C9 | 118.32 (9) | O1—N2—O2 | 124.00 (10) |
| C11—C12—C13 | 120.17 (10) | O1—N2—C10 | 118.40 (9) |
| C11—C12—H12 | 119.9 | O2—N2—C10 | 117.58 (9) |
| C13—C12—H12 | 119.9 | C4—O3—C23 | 118.32 (8) |
| C14—C13—C12 | 120.48 (10) | | |
| | | | |
| N1—C1—C2—C3 | −178.02 (10) | C10—C9—C11—C16 | 75.88 (11) |
| C6—C1—C2—C3 | −0.03 (16) | C16—C11—C12—C13 | 0.21 (15) |
| C1—C2—C3—C4 | 0.44 (15) | C9—C11—C12—C13 | 179.28 (9) |
| C2—C3—C4—C5 | −0.41 (16) | C11—C12—C13—C14 | 0.17 (15) |
| C2—C3—C4—O3 | 179.94 (9) | C12—C13—C14—C15 | −0.27 (15) |
| O3—C4—C5—C6 | 179.63 (8) | C13—C14—C15—C16 | 0.00 (16) |
| C3—C4—C5—C6 | −0.04 (15) | C14—C15—C16—C11 | 0.38 (16) |
| C4—C5—C6—C1 | 0.44 (14) | C12—C11—C16—C15 | −0.48 (15) |
| C4—C5—C6—C7 | 178.27 (10) | C9—C11—C16—C15 | −179.60 (9) |
| N1—C1—C6—C5 | 177.97 (9) | N1—C8—C17—C22 | 123.13 (11) |
| C2—C1—C6—C5 | −0.42 (15) | C7—C8—C17—C22 | −52.40 (15) |
| N1—C1—C6—C7 | −0.42 (11) | N1—C8—C17—C18 | −53.62 (14) |
| C2—C1—C6—C7 | −178.81 (9) | C7—C8—C17—C18 | 130.85 (12) |
| C5—C6—C7—C8 | −177.12 (11) | C22—C17—C18—C19 | −0.89 (16) |

| | | | |
|---|---|---|---|
| C1—C6—C7—C8 | 0.88 (11) | C8—C17—C18—C19 | 175.85 (10) |
| C5—C6—C7—C9 | 8.44 (19) | C17—C18—C19—C20 | 0.67 (17) |
| C1—C6—C7—C9 | −173.56 (10) | C18—C19—C20—C21 | 0.07 (17) |
| C6—C7—C8—N1 | −1.04 (11) | C19—C20—C21—C22 | −0.58 (17) |
| C9—C7—C8—N1 | 173.92 (9) | C20—C21—C22—C17 | 0.34 (17) |
| C6—C7—C8—C17 | 174.87 (10) | C18—C17—C22—C21 | 0.39 (16) |
| C9—C7—C8—C17 | −10.17 (17) | C8—C17—C22—C21 | −176.42 (10) |
| C8—C7—C9—C11 | 102.46 (11) | C7—C8—N1—C1 | 0.80 (12) |
| C6—C7—C9—C11 | −83.89 (13) | C17—C8—N1—C1 | −175.54 (9) |
| C8—C7—C9—C10 | −133.20 (10) | C2—C1—N1—C8 | 178.01 (10) |
| C6—C7—C9—C10 | 40.46 (14) | C6—C1—N1—C8 | −0.21 (11) |
| C7—C9—C10—N2 | 58.52 (11) | C9—C10—N2—O1 | −108.24 (10) |
| C11—C9—C10—N2 | −171.63 (8) | C9—C10—N2—O2 | 70.21 (11) |
| C7—C9—C11—C12 | 24.35 (13) | C5—C4—O3—C23 | 166.65 (9) |
| C10—C9—C11—C12 | −103.20 (10) | C3—C4—O3—C23 | −13.68 (14) |
| C7—C9—C11—C16 | −156.57 (9) | | |

*Hydrogen-bond geometry (Å, °)*

Cg2 and Cg4 are the centroids of the C1–C6 and C17–C22 rings, respectively.

| $D$—H⋯$A$ | $D$—H | H⋯$A$ | $D$⋯$A$ | $D$—H⋯$A$ |
|---|---|---|---|---|
| N1—H1⋯O1[i] | 0.867 (14) | 2.470 (14) | 3.1872 (13) | 140.5 (12) |
| C10—H10$A$⋯O3[ii] | 0.99 | 2.56 | 2.9934 (14) | 107 |
| C14—H14⋯O3[iii] | 0.95 | 2.51 | 3.4546 (14) | 173 |
| C18—H18⋯O1[i] | 0.95 | 2.59 | 3.2877 (14) | 131 |
| C21—H21⋯$Cg$2[iv] | 0.95 | 2.83 | 3.5297 (13) | 131 |
| C23—H23$C$⋯$Cg$4[v] | 0.98 | 2.76 | 3.5781 (13) | 141 |

Symmetry codes: (i) −$x$, −$y$+1, −$z$+1; (ii) −$x$, −$y$, −$z$+1; (iii) −$x$+1, −$y$, −$z$+1; (iv) −$x$+1, −$y$+1, −$z$+1; (v) $x$, $y$, $z$+1.

## (IV) 5-Chloro-3-(2-nitro-1-phenylethyl)-2-phenyl-1*H*-indole

*Crystal data*

| | |
|---|---|
| $C_{22}H_{17}ClN_2O_2$ | $V = 919.87\ (11)$ Å³ |
| $M_r = 376.83$ | $Z = 2$ |
| Triclinic, $P\overline{1}$ | $F(000) = 392$ |
| Hall symbol: -P 1 | $D_x = 1.360$ Mg m⁻³ |
| $a = 9.5830\ (7)$ Å | Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å |
| $b = 9.7555\ (7)$ Å | $\mu = 0.23$ mm⁻¹ |
| $c = 10.2307\ (7)$ Å | $T = 100$ K |
| $\alpha = 79.546\ (6)°$ | Block, colourless |
| $\beta = 77.966\ (6)°$ | $0.48 \times 0.36 \times 0.16$ mm |
| $\gamma = 87.455\ (7)°$ | |

*Data collection*

| | |
|---|---|
| Rigaku Mercury CCD diffractometer | Absorption correction: multi-scan (*SADABS*; Sheldrick, 1996) |
| Radiation source: fine-focus sealed tube | $T_{min} = 0.899$, $T_{max} = 0.965$ |
| Graphite monochromator | 13253 measured reflections |
| $\omega$ scans | 4138 independent reflections |
| | 3363 reflections with $I > 2\sigma(I)$ |

$R_{int} = 0.023$

$\theta_{max} = 27.5°$, $\theta_{min} = 2.1°$

$h = -12 \rightarrow 12$

$k = -11 \rightarrow 12$

$l = -13 \rightarrow 13$

*Refinement*

| | |
|---|---|
| Refinement on $F^2$ | Secondary atom site location: difference Fourier map |
| Least-squares matrix: full | |
| $R[F^2 > 2\sigma(F^2)] = 0.031$ | Hydrogen site location: inferred from neighbouring sites |
| $wR(F^2) = 0.085$ | |
| $S = 1.06$ | H atoms treated by a mixture of independent and constrained refinement |
| 4138 reflections | |
| 247 parameters | $w = 1/[\sigma^2(F_o^2) + (0.044P)^2 + 0.1384P]$ where $P = (F_o^2 + 2F_c^2)/3$ |
| 0 restraints | |
| Primary atom site location: structure-invariant direct methods | $(\Delta/\sigma)_{max} = 0.002$ |
| | $\Delta\rho_{max} = 0.27$ e Å$^{-3}$ |
| | $\Delta\rho_{min} = -0.23$ e Å$^{-3}$ |

*Special details*

**Geometry**. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

**Refinement**. Refinement of $F^2$ against ALL reflections. The weighted $R$-factor $wR$ and goodness of fit $S$ are based on $F^2$, conventional $R$-factors $R$ are based on $F$, with $F$ set to zero for negative $F^2$. The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating $R$-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. $R$-factors based on $F^2$ are statistically about twice as large as those based on $F$, and $R$-factors based on ALL data will be even larger.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å$^2$)*

| | $x$ | $y$ | $z$ | $U_{iso}*/U_{eq}$ |
|---|---|---|---|---|
| C1 | 0.30134 (13) | 0.30487 (13) | 0.47178 (13) | 0.0244 (3) |
| C2 | 0.15631 (13) | 0.33679 (14) | 0.49919 (14) | 0.0293 (3) |
| H2 | 0.1067 | 0.3398 | 0.5893 | 0.035* |
| C3 | 0.08662 (13) | 0.36395 (14) | 0.39233 (14) | 0.0293 (3) |
| H3 | −0.0124 | 0.3858 | 0.4077 | 0.035* |
| C4 | 0.16322 (13) | 0.35909 (14) | 0.26078 (13) | 0.0259 (3) |
| C5 | 0.30654 (12) | 0.32723 (13) | 0.23105 (13) | 0.0232 (3) |
| H5 | 0.3547 | 0.3250 | 0.1404 | 0.028* |
| C6 | 0.37928 (12) | 0.29823 (12) | 0.33886 (12) | 0.0213 (2) |
| C7 | 0.52344 (12) | 0.26002 (12) | 0.35141 (12) | 0.0208 (2) |
| C8 | 0.52687 (13) | 0.24560 (13) | 0.48676 (13) | 0.0234 (3) |
| C9 | 0.65601 (12) | 0.24850 (13) | 0.24431 (12) | 0.0206 (2) |
| H9 | 0.7395 | 0.2586 | 0.2863 | 0.025* |
| C10 | 0.66676 (13) | 0.36530 (13) | 0.12008 (12) | 0.0230 (3) |
| H10A | 0.7613 | 0.3610 | 0.0593 | 0.028* |
| H10B | 0.5927 | 0.3523 | 0.0689 | 0.028* |
| C11 | 0.67609 (12) | 0.11141 (13) | 0.19138 (12) | 0.0205 (2) |
| C12 | 0.56223 (13) | 0.03868 (13) | 0.17345 (12) | 0.0232 (3) |
| H12 | 0.4676 | 0.0721 | 0.1988 | 0.028* |
| C13 | 0.58560 (13) | −0.08258 (13) | 0.11871 (13) | 0.0253 (3) |
| H13 | 0.5070 | −0.1314 | 0.1065 | 0.030* |

| | | | |
|---|---|---|---|
| C14 | 0.72269 (14) | −0.13258 (13) | 0.08191 (13) | 0.0260 (3) |
| H14 | 0.7385 | −0.2150 | 0.0435 | 0.031* |
| C15 | 0.83681 (14) | −0.06224 (14) | 0.10125 (15) | 0.0300 (3) |
| H15 | 0.9311 | −0.0971 | 0.0774 | 0.036* |
| C16 | 0.81368 (13) | 0.05913 (14) | 0.15540 (14) | 0.0275 (3) |
| H16 | 0.8925 | 0.1072 | 0.1681 | 0.033* |
| C17 | 0.64585 (13) | 0.20526 (14) | 0.55687 (12) | 0.0243 (3) |
| C18 | 0.68391 (14) | 0.28733 (15) | 0.64173 (14) | 0.0308 (3) |
| H18 | 0.6360 | 0.3733 | 0.6516 | 0.037* |
| C19 | 0.79159 (16) | 0.24370 (18) | 0.71180 (16) | 0.0402 (4) |
| H19 | 0.8166 | 0.2994 | 0.7704 | 0.048* |
| C20 | 0.86283 (16) | 0.11925 (18) | 0.69676 (16) | 0.0414 (4) |
| H20 | 0.9364 | 0.0898 | 0.7453 | 0.050* |
| C21 | 0.82741 (14) | 0.03761 (16) | 0.61152 (15) | 0.0355 (3) |
| H21 | 0.8768 | −0.0476 | 0.6011 | 0.043* |
| C22 | 0.71956 (13) | 0.08033 (14) | 0.54118 (13) | 0.0278 (3) |
| H22 | 0.6956 | 0.0245 | 0.4821 | 0.033* |
| N1 | 0.39365 (11) | 0.27288 (12) | 0.55865 (11) | 0.0263 (2) |
| H1 | 0.3714 (16) | 0.2700 (17) | 0.6404 (17) | 0.032* |
| N2 | 0.64715 (11) | 0.50447 (11) | 0.16313 (11) | 0.0258 (2) |
| O1 | 0.55567 (10) | 0.58312 (10) | 0.12206 (11) | 0.0354 (2) |
| O2 | 0.72277 (11) | 0.53298 (10) | 0.23676 (10) | 0.0357 (2) |
| Cl1 | 0.07128 (3) | 0.39630 (4) | 0.12679 (3) | 0.03265 (10) |

*Atomic displacement parameters (Å²)*

| | $U^{11}$ | $U^{22}$ | $U^{33}$ | $U^{12}$ | $U^{13}$ | $U^{23}$ |
|---|---|---|---|---|---|---|
| C1 | 0.0251 (6) | 0.0227 (7) | 0.0221 (6) | 0.0022 (5) | 0.0018 (5) | −0.0036 (5) |
| C2 | 0.0257 (6) | 0.0306 (7) | 0.0269 (7) | 0.0039 (5) | 0.0054 (5) | −0.0059 (6) |
| C3 | 0.0212 (6) | 0.0281 (7) | 0.0343 (7) | 0.0043 (5) | 0.0023 (5) | −0.0051 (6) |
| C4 | 0.0243 (6) | 0.0230 (7) | 0.0285 (6) | 0.0019 (5) | −0.0038 (5) | −0.0020 (5) |
| C5 | 0.0224 (6) | 0.0215 (6) | 0.0224 (6) | 0.0005 (5) | 0.0016 (5) | −0.0029 (5) |
| C6 | 0.0214 (5) | 0.0182 (6) | 0.0216 (6) | 0.0012 (4) | 0.0025 (4) | −0.0043 (5) |
| C7 | 0.0209 (5) | 0.0189 (6) | 0.0210 (6) | 0.0012 (4) | 0.0004 (4) | −0.0046 (5) |
| C8 | 0.0239 (6) | 0.0205 (6) | 0.0233 (6) | 0.0012 (4) | 0.0012 (5) | −0.0046 (5) |
| C9 | 0.0195 (5) | 0.0210 (6) | 0.0199 (6) | 0.0006 (4) | −0.0001 (4) | −0.0044 (5) |
| C10 | 0.0242 (6) | 0.0207 (6) | 0.0222 (6) | 0.0007 (5) | 0.0007 (5) | −0.0055 (5) |
| C11 | 0.0223 (5) | 0.0198 (6) | 0.0170 (5) | 0.0007 (4) | 0.0002 (4) | −0.0023 (5) |
| C12 | 0.0212 (5) | 0.0223 (6) | 0.0235 (6) | 0.0013 (4) | −0.0010 (4) | −0.0017 (5) |
| C13 | 0.0277 (6) | 0.0227 (7) | 0.0248 (6) | −0.0037 (5) | −0.0048 (5) | −0.0028 (5) |
| C14 | 0.0337 (7) | 0.0197 (6) | 0.0229 (6) | 0.0004 (5) | −0.0003 (5) | −0.0056 (5) |
| C15 | 0.0243 (6) | 0.0281 (7) | 0.0357 (7) | 0.0049 (5) | 0.0016 (5) | −0.0106 (6) |
| C16 | 0.0211 (6) | 0.0267 (7) | 0.0354 (7) | 0.0000 (5) | −0.0015 (5) | −0.0120 (6) |
| C17 | 0.0235 (6) | 0.0269 (7) | 0.0190 (6) | −0.0017 (5) | 0.0011 (4) | −0.0010 (5) |
| C18 | 0.0306 (7) | 0.0329 (8) | 0.0275 (7) | −0.0015 (5) | −0.0004 (5) | −0.0075 (6) |
| C19 | 0.0373 (8) | 0.0517 (10) | 0.0345 (8) | −0.0071 (7) | −0.0100 (6) | −0.0105 (7) |
| C20 | 0.0312 (7) | 0.0536 (10) | 0.0386 (8) | −0.0008 (7) | −0.0132 (6) | 0.0009 (7) |
| C21 | 0.0293 (7) | 0.0344 (8) | 0.0379 (8) | 0.0037 (6) | −0.0047 (6) | 0.0026 (6) |

| C22 | 0.0286 (6) | 0.0260 (7) | 0.0263 (6) | 0.0001 (5) | −0.0023 (5) | −0.0021 (5) |
| N1 | 0.0257 (5) | 0.0324 (6) | 0.0179 (5) | 0.0043 (4) | 0.0025 (4) | −0.0055 (5) |
| N2 | 0.0279 (5) | 0.0211 (6) | 0.0242 (5) | −0.0030 (4) | 0.0049 (4) | −0.0039 (4) |
| O1 | 0.0314 (5) | 0.0234 (5) | 0.0466 (6) | 0.0044 (4) | −0.0006 (4) | −0.0034 (4) |
| O2 | 0.0465 (6) | 0.0291 (6) | 0.0326 (5) | −0.0025 (4) | −0.0066 (4) | −0.0100 (4) |
| Cl1 | 0.02364 (15) | 0.0386 (2) | 0.03372 (18) | 0.00338 (12) | −0.00654 (12) | −0.00124 (14) |

*Geometric parameters (Å, º)*

| | | | |
|---|---|---|---|
| C1—N1 | 1.3683 (17) | C12—C13 | 1.3885 (18) |
| C1—C2 | 1.3921 (17) | C12—H12 | 0.9500 |
| C1—C6 | 1.4197 (16) | C13—C14 | 1.3817 (18) |
| C2—C3 | 1.3766 (19) | C13—H13 | 0.9500 |
| C2—H2 | 0.9500 | C14—C15 | 1.3828 (19) |
| C3—C4 | 1.4002 (18) | C14—H14 | 0.9500 |
| C3—H3 | 0.9500 | C15—C16 | 1.3862 (19) |
| C4—C5 | 1.3775 (16) | C15—H15 | 0.9500 |
| C4—Cl1 | 1.7556 (13) | C16—H16 | 0.9500 |
| C5—C6 | 1.4044 (17) | C17—C18 | 1.3922 (19) |
| C5—H5 | 0.9500 | C17—C22 | 1.3991 (19) |
| C6—C7 | 1.4404 (16) | C18—C19 | 1.385 (2) |
| C7—C8 | 1.3734 (17) | C18—H18 | 0.9500 |
| C7—C9 | 1.5096 (15) | C19—C20 | 1.384 (2) |
| C8—N1 | 1.3751 (15) | C19—H19 | 0.9500 |
| C8—C17 | 1.4724 (17) | C20—C21 | 1.382 (2) |
| C9—C11 | 1.5216 (17) | C20—H20 | 0.9500 |
| C9—C10 | 1.5344 (17) | C21—C22 | 1.3866 (19) |
| C9—H9 | 1.0000 | C21—H21 | 0.9500 |
| C10—N2 | 1.4941 (16) | C22—H22 | 0.9500 |
| C10—H10A | 0.9900 | N1—H1 | 0.814 (16) |
| C10—H10B | 0.9900 | N2—O2 | 1.2213 (14) |
| C11—C12 | 1.3881 (17) | N2—O1 | 1.2291 (14) |
| C11—C16 | 1.3929 (16) | | |
| | | | |
| N1—C1—C2 | 129.73 (12) | C11—C12—C13 | 120.50 (11) |
| N1—C1—C6 | 107.57 (10) | C11—C12—H12 | 119.8 |
| C2—C1—C6 | 122.70 (12) | C13—C12—H12 | 119.8 |
| C3—C2—C1 | 118.29 (12) | C14—C13—C12 | 120.29 (11) |
| C3—C2—H2 | 120.9 | C14—C13—H13 | 119.9 |
| C1—C2—H2 | 120.9 | C12—C13—H13 | 119.9 |
| C2—C3—C4 | 119.30 (11) | C13—C14—C15 | 119.74 (12) |
| C2—C3—H3 | 120.4 | C13—C14—H14 | 120.1 |
| C4—C3—H3 | 120.4 | C15—C14—H14 | 120.1 |
| C5—C4—C3 | 123.55 (12) | C14—C15—C16 | 120.03 (12) |
| C5—C4—Cl1 | 118.42 (10) | C14—C15—H15 | 120.0 |
| C3—C4—Cl1 | 118.03 (10) | C16—C15—H15 | 120.0 |
| C4—C5—C6 | 117.99 (11) | C15—C16—C11 | 120.73 (12) |
| C4—C5—H5 | 121.0 | C15—C16—H16 | 119.6 |

| | | | |
|---|---|---|---|
| C6—C5—H5 | 121.0 | C11—C16—H16 | 119.6 |
| C5—C6—C1 | 118.18 (10) | C18—C17—C22 | 119.25 (12) |
| C5—C6—C7 | 135.24 (11) | C18—C17—C8 | 121.17 (12) |
| C1—C6—C7 | 106.59 (11) | C22—C17—C8 | 119.56 (12) |
| C8—C7—C6 | 106.72 (10) | C19—C18—C17 | 120.07 (14) |
| C8—C7—C9 | 122.33 (11) | C19—C18—H18 | 120.0 |
| C6—C7—C9 | 130.71 (11) | C17—C18—H18 | 120.0 |
| C7—C8—N1 | 109.55 (11) | C20—C19—C18 | 120.24 (14) |
| C7—C8—C17 | 129.83 (11) | C20—C19—H19 | 119.9 |
| N1—C8—C17 | 120.61 (11) | C18—C19—H19 | 119.9 |
| C7—C9—C11 | 115.84 (10) | C21—C20—C19 | 120.30 (14) |
| C7—C9—C10 | 112.82 (10) | C21—C20—H20 | 119.8 |
| C11—C9—C10 | 106.89 (9) | C19—C20—H20 | 119.8 |
| C7—C9—H9 | 106.9 | C20—C21—C22 | 119.85 (14) |
| C11—C9—H9 | 106.9 | C20—C21—H21 | 120.1 |
| C10—C9—H9 | 106.9 | C22—C21—H21 | 120.1 |
| N2—C10—C9 | 110.47 (10) | C21—C22—C17 | 120.27 (13) |
| N2—C10—H10A | 109.6 | C21—C22—H22 | 119.9 |
| C9—C10—H10A | 109.6 | C17—C22—H22 | 119.9 |
| N2—C10—H10B | 109.6 | C1—N1—C8 | 109.57 (11) |
| C9—C10—H10B | 109.6 | C1—N1—H1 | 124.3 (11) |
| H10A—C10—H10B | 108.1 | C8—N1—H1 | 126.1 (11) |
| C12—C11—C16 | 118.70 (11) | O2—N2—O1 | 124.12 (11) |
| C12—C11—C9 | 122.24 (10) | O2—N2—C10 | 118.09 (11) |
| C16—C11—C9 | 119.02 (11) | O1—N2—C10 | 117.78 (11) |
| | | | |
| N1—C1—C2—C3 | −179.28 (14) | C7—C9—C11—C16 | −145.63 (12) |
| C6—C1—C2—C3 | −0.5 (2) | C10—C9—C11—C16 | 87.68 (13) |
| C1—C2—C3—C4 | −0.2 (2) | C16—C11—C12—C13 | −1.00 (18) |
| C2—C3—C4—C5 | 0.5 (2) | C9—C11—C12—C13 | 176.86 (11) |
| C2—C3—C4—Cl1 | −179.27 (11) | C11—C12—C13—C14 | 0.26 (18) |
| C3—C4—C5—C6 | 0.0 (2) | C12—C13—C14—C15 | 0.75 (19) |
| Cl1—C4—C5—C6 | 179.72 (10) | C13—C14—C15—C16 | −1.0 (2) |
| C4—C5—C6—C1 | −0.66 (18) | C14—C15—C16—C11 | 0.2 (2) |
| C4—C5—C6—C7 | 179.07 (13) | C12—C11—C16—C15 | 0.75 (19) |
| N1—C1—C6—C5 | 179.96 (11) | C9—C11—C16—C15 | −177.17 (12) |
| C2—C1—C6—C5 | 0.96 (19) | C7—C8—C17—C18 | 127.05 (15) |
| N1—C1—C6—C7 | 0.16 (14) | N1—C8—C17—C18 | −54.28 (17) |
| C2—C1—C6—C7 | −178.84 (12) | C7—C8—C17—C22 | −54.79 (19) |
| C5—C6—C7—C8 | −179.77 (14) | N1—C8—C17—C22 | 123.88 (14) |
| C1—C6—C7—C8 | −0.02 (14) | C22—C17—C18—C19 | −1.4 (2) |
| C5—C6—C7—C9 | 5.8 (2) | C8—C17—C18—C19 | 176.80 (12) |
| C1—C6—C7—C9 | −174.44 (12) | C17—C18—C19—C20 | 0.7 (2) |
| C6—C7—C8—N1 | −0.13 (14) | C18—C19—C20—C21 | 0.2 (2) |
| C9—C7—C8—N1 | 174.87 (11) | C19—C20—C21—C22 | −0.3 (2) |
| C6—C7—C8—C17 | 178.65 (13) | C20—C21—C22—C17 | −0.4 (2) |
| C9—C7—C8—C17 | −6.4 (2) | C18—C17—C22—C21 | 1.24 (19) |
| C8—C7—C9—C11 | 102.42 (14) | C8—C17—C22—C21 | −176.96 (12) |

| | | | |
|---|---|---|---|
| C6—C7—C9—C11 | −83.90 (16) | C2—C1—N1—C8 | 178.66 (14) |
| C8—C7—C9—C10 | −133.94 (12) | C6—C1—N1—C8 | −0.25 (14) |
| C6—C7—C9—C10 | 39.74 (17) | C7—C8—N1—C1 | 0.24 (15) |
| C7—C9—C10—N2 | 51.15 (13) | C17—C8—N1—C1 | −178.67 (11) |
| C11—C9—C10—N2 | 179.61 (9) | C9—C10—N2—O2 | 53.52 (14) |
| C7—C9—C11—C12 | 36.52 (16) | C9—C10—N2—O1 | −126.47 (11) |
| C10—C9—C11—C12 | −90.17 (13) | | |

*Hydrogen-bond geometry (Å, º)*

| *D*—H⋯*A* | *D*—H | H⋯*A* | *D*⋯*A* | *D*—H⋯*A* |
|---|---|---|---|---|
| N1—H1⋯O2[i] | 0.814 (16) | 2.517 (16) | 3.0806 (15) | 127.4 (14) |
| C14—H14⋯O1[ii] | 0.95 | 2.60 | 3.1827 (17) | 120 |

Symmetry codes: (i) −*x*+1, −*y*+1, −*z*+1; (ii) *x*, *y*−1, *z*.