organic compounds

1-Methylindole-3-carboxaldehyde oxime derivatives

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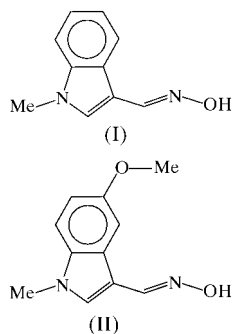Correspondence e-mail: r.w.janes@qmw.ac.uk

1-Methylindole-3-carboxaldehyde oxime, $C_{10}H_{10}N_2O$, (I), and (*E*)-5-methoxy-1-methylindole-3-carboxaldehyde oxime, $C_{11}H_{12}N_2O_2$, (II), were examined structurally to ascertain the geometry of the hydroxyimino function relative to the indole core. Oxime (I) exhibits *cis* geometry and there are two molecules in the asymmetric unit. In contrast, oxime (II) exhibits *trans* geometry and has four molecules in the asymmetric unit, with the geometry of the 5-methoxy group in one molecule differing from that in the other three. Both crystal structures are maintained by hydrogen bonding with no π-stacking of the indole moiety present.

Comment

Oxime derivatives (RR'CH=N—OH) are often the source of iminoxy radicals (RR'CH=N—O·) when oxidized chemically (Thomas, 1964), enzymatically (Lagercrantz, 1988) or by radical species (Brokenshire *et al.*, 1972). Based on electron-spin-resonance coupling constants of iminoxy radicals derived from alkyl/aryl oximes (which fall in a narrow range $a_N \sim 28$–32 G), these radicals were originally characterized as σ radi-

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cals (Gilbert & Norman, 1966). However, the impact of structure on the stability of iminoxy radicals became apparent when the bond dissociation energies (BDEs) for the O—H bonds in ketoximes were weakened dramatically by both resonance stabilization (implying that iminoxy radicals were acting as π radicals) and by increased steric congestion in the region of the hydroxyimino functionality (Bordwell & Zhang, 1995). We report herein the structural characterization of 1-methylindole-3-carboxyaldehyde oxime, (I), and the corresponding 5-methoxy derivative, (II), the geometry of which may influence the stability of their iminoxy radicals.

Oxime (I) contains two molecules (*A* and *B*) in the asymmetric unit. Fig. 1 presents a displacement ellipsoid plot of the labelled asymmetric unit. A pairwise comparison between these two molecules shows there to be no significant differences in their bond lengths or angles. Pairwise comparisons of the torsion angles show one significant difference between the molecules: the C7*A*—C6*A*—N9*A*—C10*A* torsion angle is 179.9 (4)°, while the C7*B*—C6*B*—N9*B*—C10*B* angle is 177.8 (4)°. The indole moiety in both molecules exhibits a high degree of planarity, with overall root-mean-square deviations (r.m.s.d.) for the ring atoms of 0.0069 and 0.0082 Å for molecules *A* and *B*, respectively. The six- and five-membered rings of the indole groups are ostensibly planar with each other. The
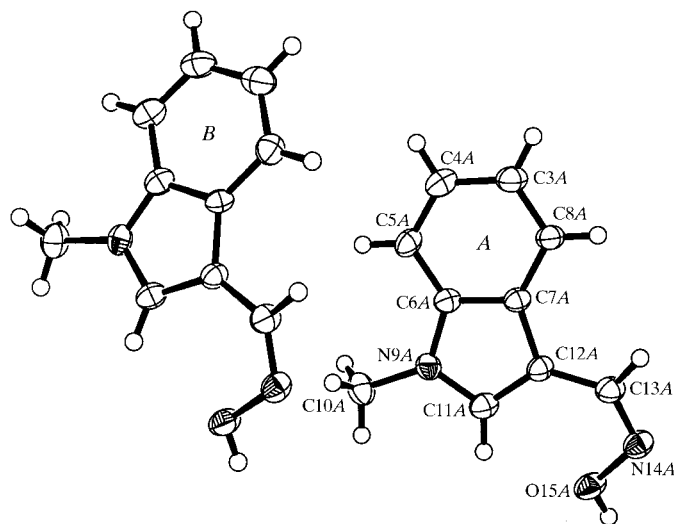

Figure 1
The asymmetric unit of oxime (I) drawn with ellipsoids at the 30% probability level. Molecules *A* and *B* are marked, and the numbering scheme used in the text is shown for molecule *A* (*ORTEP*-3; Farrugia, 1997).

oxime moieties are also planar, with r.m.s.d. values of 0.0011 and 0.0086 Å for molecules *A* and *B*, respectively. These oxime planes are not coplanar with the five-membered rings of the indole group, deviating by 15.82 and 14.96° for molecules *A* and *B*, respectively. The oxime groups of both molecules have *cis* geometries for the O15 atoms relative to the indole groups, and their deviations from planarity with the five-membered rings remove possible steric hindrances that would otherwise arise from this geometry.

Oxime (II) contains four molecules (A', B', C' and D') in the asymmetric unit. Minimal similarity restraints in *SHELXL* (Sheldrick, 1997) were applied to all atoms within these molecules with the exception of the methyl carbon of the 5-methoxy groups. Fig. 2 shows a displacement ellipsoid plot of the molecules of the asymmetric unit with labelling for molecule A' only, for ease of identification. Comparison of all four molecules shows that there are no differences for most of the corresponding bond lengths and angles, with a few notable exceptions. The methyl carbon of the 5-methoxy group of molecule A' is rotated towards the C8A atom side of the indole six-membered ring, while the remaining three methyl C atoms are rotated towards their C4 atom side, resulting in significant differences in bond lengths between C1A—O2A and the other methyl C—O bonds of the methoxy groups (Table 3). The C1A—O2A bond is significantly shorter than that usually associated with a methyl C—O bond in a methoxy group attached to an aromatic ring (1.424 Å; Allen *et al.*, 1987). Additionally, the C4A—C5A bond of the indole group is significantly shorter than the equivalent bond in the other three molecules. The bond angles associated with the methoxy group show significant differences. Unexpectedly, it is molecule B' that shows differences for the angle C3B—O2B—C1B when compared with molecules A' and D'. The methoxy groups of all four molecules are asymmetrically positioned on their respective six-membered rings. The larger of the two angles arises from distortion of the methyl group away from its ring (Table 3 and Fig. 2). The degree of asymmetry is least for molecule A' when compared with the other three molecules and might emanate from the overall difference in geometry of its methoxy group. Other bond-angle differences exist

between the four molecules (Table 3).

A number of significant differences exist between comparable torsion angles in the four molecules, many arising as a result of the difference in juxtaposition of the methoxy group in molecule A' with respect to its indole ring, in contrast to its position in the other three molecules. Further torsion-angle differences in these molecules can be implied from the least-squares deviations of the atoms in the different molecules from their indole ring planes. A table of this data is provided in the deposited material.

The different positions of the oxime groups in (II) are also illustrated by the angles between their planes and the planes of the adjacent five-membered rings. These relative angles are 4.46 (3), 0.82 (3), 4.86 (3) and 3.68 (3)° for molecules A', B', C' and D', respectively, all indicating a passing degree of planarity with the rest of the molecule for these groups with *trans* geometry. From these values, molecule B' differs significantly in geometry from the other three molecules, but D' also differs significantly from A' and C'. However, these values are all significantly lower than those for the two molecules of oxime (I), illustrating again the need to remove steric hindrance from around the oxime group in the molecules with *cis* geometries.

A detailed analysis of the geometries associated with the oxime moiety reveals that the C13 atom is significantly asymmetrically positioned off the five-membered ring in both (I) and (II). This asymmetry is directly related to the geometry of the oxime moiety, notably whether it is *cis* or *trans* relative to the indole ring, and to the rotamer state of the oxime relative to the ring. In (I), where the oxime moiety is *cis* to the indole ring, the rotation of the group is such that the N14 atom
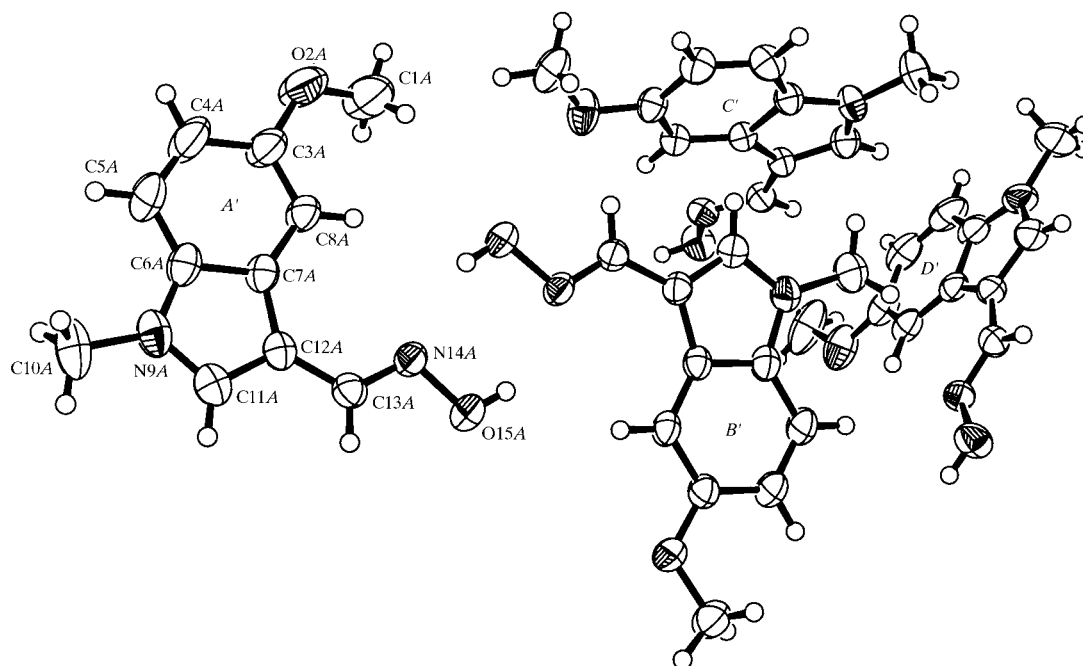
Figure 2
The asymmetric unit of oxime (II) drawn with ellipsoids at the 30% probability level. Molecules A', B', C' and D' are marked, and the numbering scheme used in the text is shown for molecule A' (*ORTEP*-3; Farrugia, 1997).

is towards the C11 atom. This juxtapositioning causes all the C7—C12—C13 angles to be smaller than the C11—C12—C13 angles. For oxime (II), the N14 atom is rotated towards the C7 side of the five-membered ring structure, and this results in the asymmetry being the opposite for the four molecules to that in the oxime (I) molecule. The need to reduce steric interaction in the *cis*-geometry oxime (I) opens out the C12—C13—N14 angles of molecules *A* and *B* compared with the *trans* geometry of oxime (II). In contrast, all six independent molecules of oximes (I) and (II) have C13—N14—O15 angles of ~110.5°. There are potential steric interactions in the *cis* geometry of oxime (I) between the oxime O atom and the ring. However, these are removed by the twist of the oxime groups away from planarity with the indole rings detailed earlier. The C13—N14 and N14—O15 bond lengths of the *cis*-geometry oxime (I) are, in the majority of comparisons, significantly shorter than the related bond lengths in the *trans* conformation in oxime (II) (Tables 1 and 3). These differences could also result from the *cis/trans* nature of the oxime group in these structures, but might reflect something of the electronic effect of adding a methoxy substituent to the indole ring.

The crystal structure of oxime (I) is maintained by hydrogen bonding, relating one molecule of the asymmetric unit to the other molecules of a symmetry-related asymmetric unit (Table 2). In contrast, while the structure of oxime (II) is also maintained by hydrogen bonding, the arrangement of hydrogen bonds within and between asymmetric units is noticeably different. Here, molecules *A′* and *B′* pseudo-heterodimerize across their oxime groups, while molecules *C′* and *D′* homodimerize to their own centrosymmetrically related mates. Both crystal structures exhibit a network of hydrogen bonds linking the molecules together, but there is no evidence of π-stacking arising from interactions between the indole rings.

Experimental

Oximes (I) (Hiremath *et al.*, 1984) and (II) were prepared from commercially available indoles by *N*-methylation and formylation, followed by reaction with hydroxylamine. Crystals of (I) were grown by slow evaporation from methanol at room temperature, while crystals of (II) were also grown from methanol at room temperature but after initial nucleation were cooled to complete their growth at 277 K.

Oxime (I)

Crystal data

$C_{10}H_{10}N_2O$
$M_r = 174.20$
Monoclinic, $P2_1$
$a = 13.462\ (4)$ Å
$b = 5.079\ (4)$ Å
$c = 14.127\ (4)$ Å
$\beta = 111.53\ (4)°$
$V = 898.4\ (8)$ Å^3
$Z = 4$

$D_x = 1.288$ Mg m^{-3}
Cu $K\alpha$ radiation
Cell parameters from 25 reflections
$\theta = 11.3–38.7°$
$\mu = 0.693$ mm^{-1}
$T = 293\ (2)$ K
Needle, colourless
$0.30 \times 0.20 \times 0.15$ mm

Data collection

Enraf–Nonius CAD-4 diffractometer
ω–2θ scans
3706 measured reflections
2045 independent reflections
1039 reflections with $I > 2\sigma(I)$
$R_{int} = 0.052$

$\theta_{max} = 74.24°$
$h = 0 \to 16$
$k = -6 \to 0$
$l = -17 \to 16$
3 standard reflections
every 200 reflections
intensity decay: none

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.049$
$wR(F^2) = 0.129$
$S = 1.001$
2045 reflections
240 parameters
H-atom parameters constrained

$w = 1/[\sigma^2(F_o{}^2) + (0.0453P)^2]$
where $P = (F_o{}^2 + 2F_c{}^2)/3$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 0.17$ e Å^{-3}
$\Delta\rho_{min} = -0.20$ e Å^{-3}
Extinction correction: *SHELXL*97
Extinction coefficient: 0.0043 (7)

Table 1
Selected geometric parameters (Å, °) for (I).

C3A—C8A	1.372 (6)	N9A—C11A	1.355 (6)
C3A—C4A	1.398 (7)	N9A—C10A	1.459 (6)
C4A—C5A	1.361 (7)	C11A—C12A	1.357 (7)
C5A—C6A	1.388 (6)	C12A—C13A	1.437 (7)
C6A—N9A	1.380 (6)	C13A—N14A	1.292 (6)
C6A—C7A	1.390 (6)	N14A—O15A	1.392 (6)
C7A—C8A	1.395 (7)	C13B—N14B	1.288 (6)
C7A—C12A	1.438 (6)	N14B—O15B	1.402 (6)
C11A—C12A—C7A	105.9 (4)	C11B—C12B—C13B	129.3 (5)
C11A—C12A—C13A	129.7 (5)	C11B—C12B—C7B	106.1 (4)
C7A—C12A—C13A	124.4 (5)	C13B—C12B—C7B	124.6 (5)
N14A—C13A—C12A	130.4 (5)	N14B—C13B—C12B	132.2 (5)
C13A—N14A—O15A	110.1 (5)	C13B—N14B—O15B	111.2 (4)

Table 2
Hydrogen-bonding geometry (Å, °) for (I).

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
O15A—H15A$\cdots$N14B^i	0.82	1.89	2.709 (5)	176
O15B—H15B$\cdots$N14A^i	0.82	2.11	2.895 (6)	162

Symmetry code: (i) $1 - x, \frac{1}{2} + y, -z$.

Oxime (II)

Crystal data

$C_{11}H_{12}N_2O_2$
$M_r = 204.23$
Triclinic, $P\bar{1}$
$a = 8.2351\ (2)$ Å
$b = 15.8892\ (7)$ Å
$c = 17.8070\ (11)$ Å
$\alpha = 71.148\ (4)°$
$\beta = 81.245\ (4)°$
$\gamma = 75.124\ (3)°$
$V = 2125.02\ (17)$ Å^3

$Z = 8$
$D_x = 1.277$ Mg m^{-3}
Cu $K\alpha$ radiation
Cell parameters from 21 reflections
$\theta = 20.8–42.1°$
$\mu = 0.734$ mm^{-1}
$T = 293\ (2)$ K
Needle, colourless
$0.60 \times 0.20 \times 0.03$ mm

Data collection

Enraf–Nonius CAD-4 diffractometer
ω–2θ scans
Absorption correction: ψ scan (North *et al.*, 1968)
$\quad T_{min} = 0.755, T_{max} = 0.854$
10 056 measured reflections
7107 independent reflections
4302 reflections with $I > 2\sigma(I)$

$R_{int} = 0.025$
$\theta_{max} = 66.10°$
$h = -9 \to 5$
$k = -18 \to 17$
$l = -21 \to 20$
3 standard reflections
every 200 reflections
intensity decay: none

Refinement

Table 3
Selected geometric parameters (Å, °) for (II).

C1A—O2A	1.375 (4)	C12A—C13A	1.430 (3)
O2A—C3A	1.371 (3)	C13A—N14A	1.270 (3)
C3A—C8A	1.375 (3)	N14A—O15A	1.415 (2)
C3A—C4A	1.407 (3)	C1B—O2B	1.418 (3)
C4A—C5A	1.350 (3)	C13B—N14B	1.270 (3)
C5A—C6A	1.386 (3)	N14B—O15B	1.422 (2)
C6A—N9A	1.382 (3)	C1C—O2C	1.421 (3)
C6A—C7A	1.405 (3)	C13C—N14C	1.271 (2)
C7A—C8A	1.394 (3)	N14C—O15C	1.417 (2)
C7A—C12A	1.443 (3)	C1D—O2D	1.423 (4)
N9A—C11A	1.352 (3)	C13D—N14D	1.268 (3)
N9A—C10A	1.455 (3)	N14D—O15D	1.418 (2)
C11A—C12A	1.368 (3)		
C11A—C12A—C13A	123.4 (2)	C11C—C12C—C13C	123.1 (2)
C11A—C12A—C7A	106.5 (2)	C11C—C12C—C7C	106.3 (2)
C13A—C12A—C7A	130.1 (2)	C13C—C12C—C7C	130.5 (2)
N14A—C13A—C12A	124.0 (2)	N14C—C13C—C12C	123.0 (2)
C13A—N14A—O15A	110.9 (2)	C13C—N14C—O15C	111.0 (2)
C11B—C12B—C13B	122.9 (2)	C11D—C12D—C13D	122.7 (2)
C11B—C12B—C7B	106.3 (2)	C11D—C12D—C7D	106.5 (2)
C13B—C12B—C7B	130.8 (2)	C13D—C12D—C7D	130.8 (2)
N14B—C13B—C12B	124.4 (2)	N14D—C13D—C12D	123.3 (2)
C13B—N14B—O15B	110.3 (2)	C13D—N14D—O15D	110.9 (2)

Table 4
Hydrogen-bonding geometry (Å, °) for (II).

D—H⋯A	D—H	H⋯A	D⋯A	D—H⋯A
O15A—H15A⋯N14B	0.82	2.16	2.882 (3)	147
O15B—H15B⋯N14A	0.82	2.04	2.786 (3)	151
O15C—H15C⋯N14C^i	0.82	2.02	2.755 (3)	149
O15D—H15D⋯N14D^{ii}	0.82	2.03	2.765 (3)	149

Symmetry codes: (i) $1 - x, -y, 2 - z$; (ii) $1 - x, 1 - y, 2 - z$.

All H atoms for both crystal structures were initially located in differences maps, but were then placed geometrically in riding positions and refined isotropically with U_{iso} set to 1.2U_{eq} of the associated atom.

For both compounds, data collection: *CAD*-4 *Software* (Enraf–Nonius, 1989); cell refinement: *CAD*-4 *Software*; data reduction: *CAD*-77 and *CADRAL* (Korber, 1982), and *CADSHEL* (Cooper, 1990); program(s) used to solve structure: *SHELXS*97 (Sheldrick, 1997); program(s) used to refine structure: *SHELXL*97 (Sheldrick, 1997); molecular graphics: *ORTEP*-3 (Farrugia, 1997).

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