organic compounds

1*H*-Imidazol-1-yl 1,2,3,4-tetrahydro-isoquinolin-2-yl ketone

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In the crystal structure of the title compound, $C_{13}H_{13}N_3O$, the C—$N_{imidazole}$ bond length of 1.431 (3) Å is shorter than that observed [1.466 (6) Å] in the corresponding carbamoyl-imidazolium salt 3-methyl-1-(1,2,3,4-tetrahydroisoquinolin-2-ylcarbonyl)imidazolium iodide. A comparision of these compounds is used to highlight the structural differences that occur as a result of the imidazolium effect. Weak C—H···O hydrogen bonds link molecules into extended tapes in the *a* direction.

Comment

The increased reactivity of carbonylimidazolium salts, (II), over carbonylimidazoles, (I), has been demonstrated previously in several systems and is referred to as the imidazolium effect (Staab *et al.*, 1998). In 1971, Oakenfull *et al.* established that acylimidazolium salts react with nucleophiles faster than acylimidazoles. These compounds have subsequently been of considerable synthetic interest as reactive acylating agents (Kamijo *et al.*, 1982; Guibé-Jampel *et al.*, 1973; Watkins & Rapoport, 1982). The higher reactivity of carbonylimidazolium salts can be attributed to the positive charge on the imidazole (imid) ring, which diminishes the electron density on the C atom of the carbonyl group, facilitating both the addition and elimination steps involved in an acyl transfer mechanism.

Crystallographic analyses are known for compounds of type (I) (where R^1 is a C substituent), but a direct structural comparison between a carbonylimidazole and the corresponding carbonylimidazolium salt has not been reported to date. We have previously demonstrated the use of carbamoylimidazoles, (III), and carbamoylimidazolium salts, (IV), as carbamoyl transfer reagents, and used the salts (IV) for the formation of ureas, carbamates, thiocarbamates and amides (Batey *et al.*, 1998, 2002; Batey, Yoshina-Ishii *et al.*, 1999; Grzyb & Batey, 2003). We have also previously reported the X-ray crystal structure analysis of (VI) (Batey, Yoshina-Ishii & Lough, 1999). Carbamoylimidazolium salt (VI) is

prepared in two steps from 1,2,3,4-tetrahydroisoquinoline and *N,N′*-carbonyldiimidazole (CDI) in refluxing tetrahydrofuran to form the intermediate carbamoylimidazole, (V), in 79% yield. Methylation of (V) with iodomethane in acetonitrile at room temperature then furnishes the imidazolium salt, (VI), in 99% yield. We now report a crystal structure determination of the intermediate carbamoylimidazole, (V), and make a direct structural comparison with the imidazolium salt, (VI), providing a structural basis of the imidazolium effect.
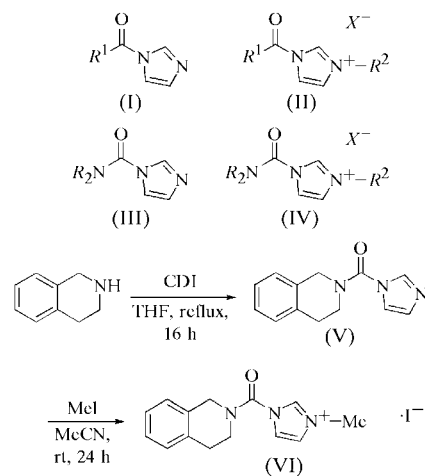
The C—$N_{isoquin}$ (isoquin is the tetrahydroisoquinoline ring) and C—N_{imid} bond lengths in (V) are 1.344 (3) and 1.431 (3) Å, respectively. In (VI), these distances are 1.327 (6) and 1.466 (6) Å, respectively. The C—$N_{isoquin}$ bond in both compounds is shorter than the C—N_{imid} bond, indicating that C—$N_{isoquin}$ has more double-bond character. However, while the C—$N_{isoquin}$ bond is longer in (V), the C—N_{imid} bond is shorter than in (VI).

The N_{imid} [atom N2 in (V)] electron pair participates in the aromatic π system of the imidazolium ring and, as a result, is not as available to contribute to the C1—N2 bond. This effect is not as strong in (V) as it is in (VI), so this bond is shorter,
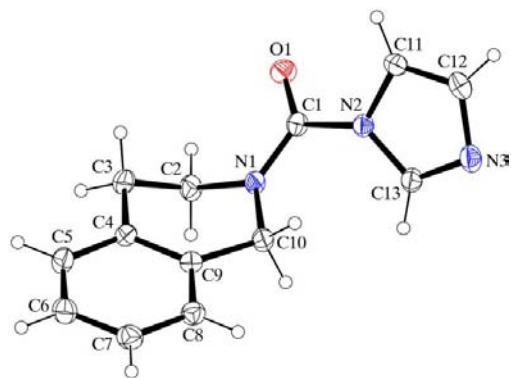

Figure 1
A view of the molecule of (V), showing the atom-numbering scheme. Displacement ellipsoids are drawn at the 30% probability level and H atoms are shown as small spheres of arbitrary radii.
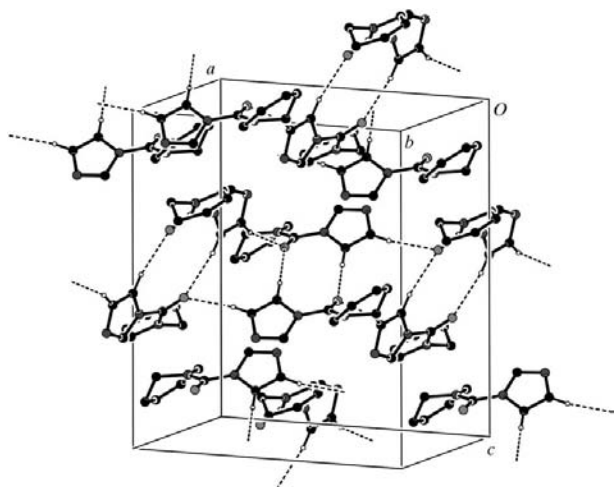
Figure 2
A partial packing diagram for (V), showing the C—H···O hydrogen bonds as dashed lines.

indicating a greater double-bond character. This stronger bond makes the imidazole in (V) a poorer leaving group.

The C=O bond length in (V) is 1.218 (3) Å, while in (VI) it is 1.211 (6) Å. While these distances are not statistically different, they correspond to the IR C=O stretch absorption frequencies, which are 1681 and 1711 cm^{-1} for (V) and (VI), respectively, indicative of a stronger C=O bond in (VI) compared with (V). We have also calculated the extent of the pyramidalization of atom N1, which represents the extent of sp^2/sp^3 hybridization. We have defined the angle ε, which is the angle in (V) that the C—N$_{isoquin}$ bond makes with the plane of atoms N1/C2/C10. For an ideally tetrahedral sp^3 N atom, the value of ε is 35.3° and for an sp^2-hybridized N atom ε is 0°. In the case of (V), the value of ε is 5.9°, while for (VI), the value of ε is 16.2°.

Interestingly, the orientation of the imidazole rings with respect to the carbamoyl C=O group is different in (V) and (VI). Compound (V) has an *s-trans* relationship about the C—N$_{imid}$ bond, whereas (VI) has an *s-cis* relationship. We were interested to see whether these conformational preferences were the thermodynamically preferred conformations (gas phase), and whether the same conformational preferences exist for compounds (I) and (II). *Ab initio* calculations (UHF/6-311G*) (*SPARTAN*02; Wavefunction, 2002) revealed almost identical energies (<0.1 kcal mol^{-1}; 1 kcal mol^{-1} = 4.184 kJ mol^{-1}) for the *s-cis* and *s-trans* conformations of (I) (R^1 = CH$_3$). In the case of the corresponding imidazolium salt, (II) (R^1 and R^2 = CH$_3$), the *s-cis* conformation was 1.9 kcal mol^{-1} lower in energy. Calculations on the carbamoylimidazole (III) [NR^2 = N(CH$_3$)$_2$] revealed the *s-cis* form to be only marginally lower in energy (0.2 kcal mol^{-1}) than the *s-trans* form. The solid-state structure of (V) shows the compound to be in the *s-trans* form. However, the *s-cis* form is significantly lower in energy (2.1 kcal mol^{-1}) for the carbamoylimidazolium salt (IV) [NR^2 = N(CH$_3$)$_2$ and R^2 = CH$_3$]. This latter result correlates with the X-ray crystal structure of (VI).

In the isoquinoline group, an analysis of the puckering (Cremer & Pople, 1975) in the six-membered ring N1/C2/C3/C4/C9/C10 gives $Q_T = 0.485$ (3). The conformational analysis of that ring (Duax *et al.*, 1976) shows that the conformation is half-chair, with a local psuedo-twofold axis running through the mid-points of the C2—C3 and C9—C10 bonds.

In the crystal structure of (V), molecules related by centres of symmetry are linked by C—H···O hydrogen bonds into pairs forming $R_2^2(10)$ rings (Bernstein *et al.*, 1995). These pairs are, in turn, linked by futher C—H···O hydrogen bonds through 2_1 screw axes to form molecular tapes in the *a* direction. This secondary interaction involves the formation of $R_4^2(10)$ rings. Details of the hydrogen-bonding geometry and motif are given in Table 2 and Fig. 2.

Experimental

Crystal data

C$_{13}$H$_{13}$N$_3$O	Mo $K\alpha$ radiation
M_r = 227.26	Cell parameters from 3967
Monoclinic, $I2/a$	reflections
a = 13.3571 (12) Å	θ = 2.6–27.5°
b = 10.7473 (10) Å	μ = 0.09 mm^{-1}
c = 15.7604 (15) Å	T = 150 (1) K
β = 90.914 (4)°	Plate, colourless
V = 2262.2 (4) Å^3	0.10 × 0.10 × 0.02 mm
Z = 8	
D_x = 1.335 Mg m^{-3}	

Data collection

Nonius KappaCCD area-detector diffractometer	R_{int} = 0.087
	θ_{max} = 25.0°
φ scans, and ω scans with κ offsets	$h = -15 \rightarrow 15$
6905 measured reflections	$k = -11 \rightarrow 12$
1992 independent reflections	$l = -18 \rightarrow 18$
1221 reflections with $I > 2\sigma(I)$	

Refinement

Refinement on F^2	$(\Delta/\sigma)_{max} < 0.001$
$R[F^2 > 2\sigma(F^2)] = 0.049$	$\Delta\rho_{max} = 0.21$ e Å^{-3}
$wR(F^2) = 0.122$	$\Delta\rho_{min} = -0.27$ e Å^{-3}
S = 1.03	Extinction correction:
1992 reflections	*SHELXTL/PC* (Sheldrick,
155 parameters	2001)
H-atom parameters constrained	Extinction coefficient: 0.0026 (4)
$w = 1/[\sigma^2(F_o^2) + (0.0463P)^2]$	
where $P = (F_o^2 + 2F_c^2)/3$	

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Table 1
Selected geometric parameters (Å, °).

O1—C1	1.218 (3)	N2—C11	1.383 (3)
N1—C1	1.344 (3)	N2—C1	1.431 (3)
N1—C10	1.462 (3)	N3—C13	1.308 (3)
N1—C2	1.467 (3)	N3—C12	1.384 (3)
N2—C13	1.365 (3)		
C1—N1—C10	126.47 (18)	C13—N3—C12	104.6 (2)
C1—N1—C2	118.61 (19)	O1—C1—N1	125.1 (2)
C10—N1—C2	114.72 (18)	O1—C1—N2	118.7 (2)
C13—N2—C11	105.99 (19)	N1—C1—N2	116.1 (2)
C13—N2—C1	130.0 (2)	N1—C2—C3	110.1 (2)
C11—N2—C1	123.2 (2)		

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

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
C11—H11$A\cdots$O1^i	0.95	2.56	3.480 (3)	164
C12—H12$A\cdots$O1^{ii}	0.95	2.31	3.227 (3)	161

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

All H atoms were placed in calculated positions, with methylene C—H = 0.99 Å and C—H = 0.95 Å for all others. They were included in the refinement in the riding-model approximation, with U_{iso}(H) = $1.2U_{eq}$(C). In the standard setting, the space group of the crystal structure is $C2/c$, with a β angle of 129.749 (4)°; the space group was converted to $I2/a$ to reduce correlation between x- and z-related parameters.

Data collection: *COLLECT* (Nonius, 1998); cell refinement: *DENZO–SMN* (Otwinowski & Minor, 1997); data reduction: *DENZO–SMN*; program(s) used to solve structure: *SHELXTL/PC* (Sheldrick, 2001); program(s) used to refine structure: *SHELXTL/PC*; molecular graphics: *SHELXTL/PC*; software used to prepare material for publication: *SHELXTL/PC*.

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