

5-Acetyl-2-amino-6-methyl-4-phenyl-4*H*-pyran-3-carbonitrile and 2-amino-5-benzoyl-6-methyl-4-phenyl-4*H*-pyran-3-carbonitrile acetonitrile solvate

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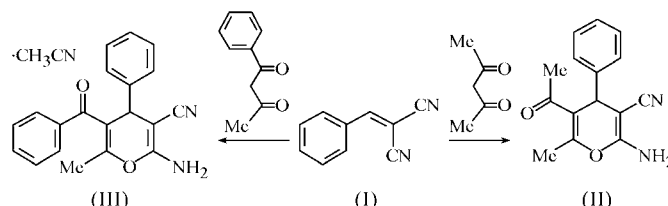
The syntheses, X-ray structural investigations and calculations of the conformational preferences of the carbonyl substituent with respect to the pyran ring have been carried out for the two title compounds, *viz.* C₁₅H₁₄N₂O₂, (II), and C₂₀H₁₆N₂O₂·C₂H₃N, (III), respectively. In both molecules, the heterocyclic ring adopts a flattened boat conformation. In (II), the carbonyl group and a double bond of the heterocyclic ring are *syn*, but in (III) they are *anti*. The carbonyl group forms a short contact with a methyl group H atom in (II). The dihedral angles between the pseudo-axial phenyl substituent and the flat part of the pyran ring are 92.7 (1) and 93.2 (1)° in (II) and (III), respectively. In the crystal structure of (II), intermolecular N—H···N and N—H···O hydrogen bonds link the molecules into a sheet along the (103) plane, while in (III), they link the molecules into ribbons along the *a* axis.

Comment

The present investigation of the title compounds, (II) and (III), is a continuation of our work that includes the syntheses and structural studies of heterocyclic compounds, such as 4*H*-pyran derivatives (Nesterov & Viltchinskaia, 2001; Nesterov *et al.*, 2004, 2005), that can be obtained starting from different unsaturated nitriles (Nesterov *et al.*, 2001*a,b*). Some 4*H*-pyran derivatives are potential bioactive compounds, such as calcium antagonists (Suarez *et al.*, 2002) and potent apoptosis inducers (Kemnitzer *et al.*, 2004; Zhang *et al.*, 2005).

X-ray analysis shows that the molecules of (II) and (III) have slightly different structures (Figs. 1 and 2). In both molecules, the pyran ring adopts a flattened boat conformation: atoms O1 and C4 are displaced out of the C2/C3/C5/C6 plane [planar to within 0.026 (1) and 0.021 (1) Å in compounds (II) and (III), respectively] by 0.060 (1) and

0.023 (1) Å, respectively, in (II), and by −0.110 (1) and −0.174 (1) Å in (III). The bending of the heterocycle along the lines O1···C4, C2···C6 and C3···C5 is 4.1 (1), 5.1 (1) and 1.9 (1)°, respectively, in (II), compared with 13.2 (1), 9.3 (1) and 11.6 (1)° in (III). The dihedral angle between the pseudo-axial phenyl substituent and the flat part of the pyran ring is 92.7 (1)° in (II) and 93.2 (1)° in (III).



The C=O group has interesting orientational preferences relative to the C5=C6 double bond. In compound (II), the groups are *syn* ('*cisoid*') [torsion angle C6—C5—C8—O2 = 38.0 (2)°], while in (III) they are *anti* ('*transoid*') [torsion angle C6—C5—C8—O2 = −141.4 (2)°]. In the first case, a short intramolecular contact (O2···H7A = 2.31 Å) is present. In the latter case, there is a short steric intramolecular contact [C7···C20 = 3.298 (2) Å] which is shorter than the sum of the van der Waals radii of two C atoms (Rowland & Taylor, 1996). Probably, the C···C contact plays a role in the orientation of the bulky phenyl substituent in the molecule of (III) relative to the heterocycle [torsion angle C5—C8—C9—C20 = 29.9 (2)°].

Similar to related compounds (Nesterov *et al.*, 2004), both (II) and (III) display a conjugation between the donor NH₂ and the acceptor CN groups *via* the C2=C3 double bond. In addition, the H atoms of the NH₂ group participate in inter-

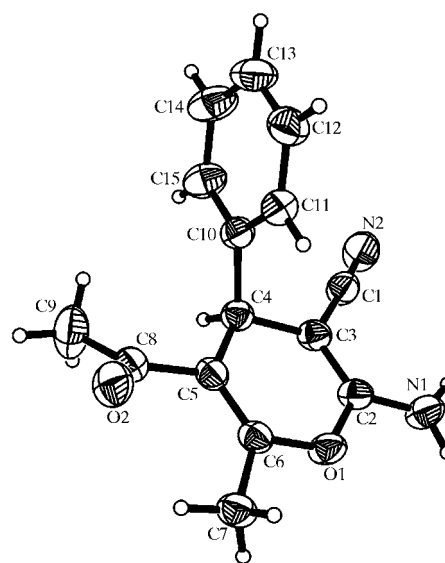


Figure 1

A view of compound (II), showing the atom numbering used. Displacement ellipsoids are drawn at the 50% probability level and H atoms are shown as small spheres of arbitrary radii.

molecular $\text{N}-\text{H}\cdots\text{N}$ and $\text{N}-\text{H}\cdots\text{O}$ hydrogen bonds. In (II), these interactions link the molecules into a sheet along the (103) plane (Fig. 3), while in (III) they link the molecules into ribbons along the a axis (Fig. 4). In (III), the acetonitrile solvent molecules do not participate in hydrogen bonds and do not form any short intermolecular contacts. Most of the geometric parameters in the molecules are very similar to standard values (Allen *et al.*, 1987) and previous results on related compounds (Nesterov *et al.*, 2004, 2005).

Using computational methods (GAUSSIAN03; Frisch *et al.*, 2003), we explored the conformational preferences of the carbonyl substituent with respect to the pyran ring in compounds (II) and (III). For the molecule of (II), a restricted Hartree–Fock calculation on the conformer in the crystal [basis set 6-311++G(d,p)] gave a conformation that was not significantly different from that found in the crystal itself. Next, an AM1 calculation was carried out to minimize the

conformer in the crystal. Continuing at the AM1 level, the $\text{O2}-\text{C8}-\text{C5}-\text{C4}$ angle was rotated in 10° increments and the conformations encountered were minimized until the starting conformer was encountered again. A map of the total energy *versus* scan step number showed only one distinct minimum conformer, similar to that found in the crystal. Two maxima were encountered, with the carbonyl group either *ca* 90° out of the plane of the pyran ring (about $2.2 \text{ kcal mol}^{-1}$ above the energy of the minimum; $1 \text{ kcal mol}^{-1} = 4.184 \text{ kJ mol}^{-1}$) or nearly *anti* with respect to the double bond of the pyran ring (about $4.1 \text{ kcal mol}^{-1}$ above the energy of the minimum). The maxima show severe methyl–phenyl and methyl–methyl steric interactions, respectively.

In contrast with compound (II), the calculations on (III) indicated somewhat different intrinsic preferred conformations than those displayed in the crystal. For the molecule of (III), a restricted Hartree–Fock calculation on the conformer in the crystal [basis set 6-311++G(d,p)] gave a conformation with the carbonyl group and the double bond still *anti*, but with a somewhat different dihedral angle (-141° *versus* -119°). Continuing at the AM1 level, the $\text{O2}-\text{C8}-\text{C5}-\text{C4}$ angle was rotated in 10° increments and the conformations encountered were minimized until the starting conformer was encountered again. A map of the total energy *versus* scan step number showed two distinct minima and two distinct maxima. In the found global minimum, the carbonyl group and double bond are approaching a *syn* relationship, with an associated dihedral angle of 54° . The second minimum had this dihedral angle at about -119° (this was the starting conformer from the crystal), with an associated energy $0.08 \text{ kcal mol}^{-1}$ above the global minimum. The first maximum is $3.26 \text{ kcal mol}^{-1}$ higher in energy than the global minimum and it displays a severe

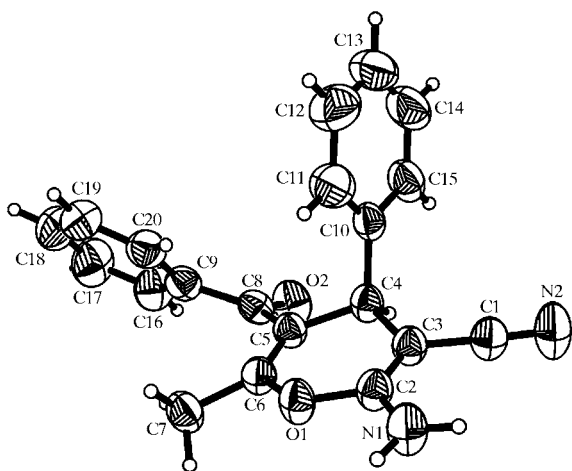


Figure 2
A view of compound (III), showing the atom numbering used. Displacement ellipsoids are drawn at the 50% probability level and H atoms are shown as small spheres of arbitrary radii.

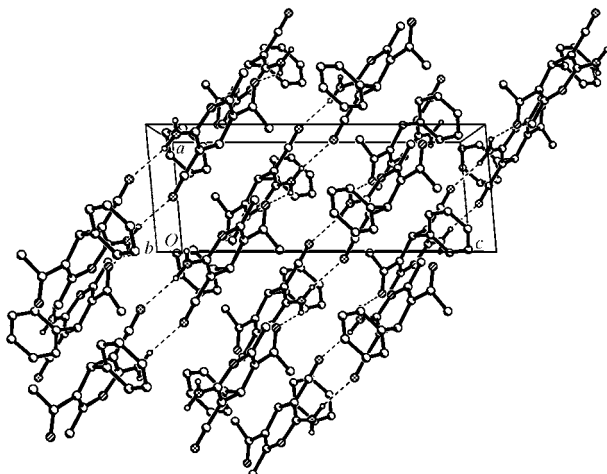


Figure 3
A projection of the crystal packing of (II) along the b axis. Dashed lines denote intermolecular $\text{N}-\text{H}\cdots\text{N}$ and $\text{N}-\text{H}\cdots\text{O}$ hydrogen bonds.

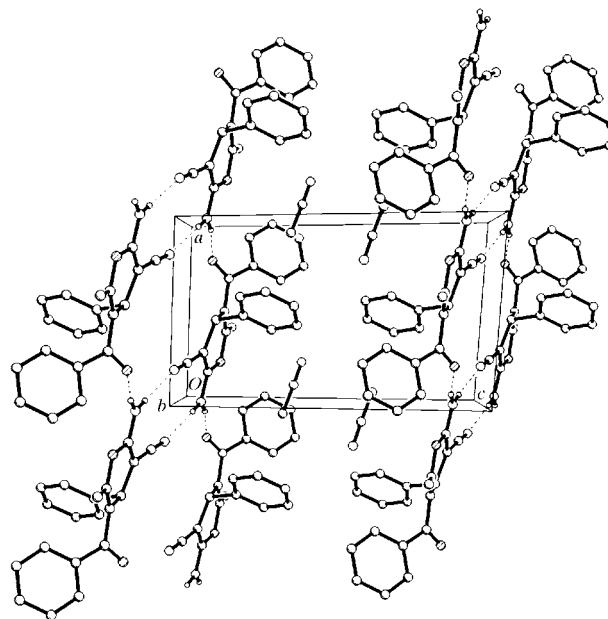


Figure 4
A projection of the crystal packing of (III) along the b axis. Dashed lines denote intermolecular $\text{N}-\text{H}\cdots\text{N}$ and $\text{N}-\text{H}\cdots\text{O}$ hydrogen bonds.

steric interaction between the two phenyl rings; the dihedral angle between the carbonyl group and double bond is -38° . The second maximum is $4.04 \text{ kcal mol}^{-1}$ higher in energy than the global minimum and it displays a severe steric interaction between the phenyl ring of the benzoyl group and the methyl group; the dihedral angle between the double bond and carbonyl group is about 176° . The calculations indicate that the preferred conformations of (II) and (III) result from an interplay of the steric interactions between the bulky groups in these molecules with the normal intrinsic preferences of enone-type moieties.

Experimental

Compounds (II) and (III) were obtained by the reaction of benzylidenemalononitrile, (I), with acetylacetone and benzoylacetone, respectively, according to the literature (Nesterov & Viltchinskaia, 2001; Nesterov *et al.*, 2004). The precipitates were isolated and recrystallized from ethanol for (II) (m.p. 421 K, yield 78%) and from acetonitrile for (III) (m.p. 458 K, yield 87%). Crystals of both compounds were grown by slow evaporation of ethanol and acetonitrile solutions, respectively. Both compounds were characterized by ^1H and ^{13}C NMR spectroscopy; details are available in the archived CIF.

Compound (II)

Crystal data

$\text{C}_{15}\text{H}_{14}\text{N}_2\text{O}_2$ $Z = 4$
 $M_r = 254.28$ $D_x = 1.281 \text{ Mg m}^{-3}$
 Monoclinic, $P2_1/n$ Mo $K\alpha$ radiation
 $a = 6.001 (2) \text{ \AA}$ $\mu = 0.09 \text{ mm}^{-1}$
 $b = 13.910 (3) \text{ \AA}$ $T = 295 (2) \text{ K}$
 $c = 15.862 (3) \text{ \AA}$ Prism, colourless
 $\beta = 94.989 (5)^\circ$ $0.30 \times 0.25 \times 0.20 \text{ mm}$
 $V = 1319.1 (6) \text{ \AA}^3$

Data collection

Bruker SMART APEX-II CCD 13889 measured reflections
 area-detector diffractometer 3465 independent reflections
 φ and ω scans 2448 reflections with $I > 2\sigma(I)$
 Absorption correction: multi-scan $R_{\text{int}} = 0.031$
 (SADABS; Sheldrick, 2003) $\theta_{\text{max}} = 28.9^\circ$
 $T_{\text{min}} = 0.975$, $T_{\text{max}} = 0.983$

Refinement

Refinement on F^2 $w = 1/[\sigma^2(F_o^2) + (0.061P)^2 + 0.26P]$
 $R[F^2 > 2\sigma(F^2)] = 0.045$ where $P = (F_o^2 + 2F_c^2)/3$
 $wR(F^2) = 0.128$ $(\Delta/\sigma)_{\text{max}} < 0.001$
 $S = 1.01$ $\Delta\rho_{\text{max}} = 0.25 \text{ e \AA}^{-3}$
 3465 reflections $\Delta\rho_{\text{min}} = -0.17 \text{ e \AA}^{-3}$
 174 parameters
 H-atom parameters constrained

Table 1

Selected geometric parameters (\AA , $^\circ$) for (II).

O1—C2	1.3634 (16)	C2—C3	1.3533 (19)
O1—C6	1.3823 (16)	C4—C10	1.5246 (18)
O2—C8	1.2158 (18)	C5—C6	1.3398 (19)
N1—C2	1.3331 (18)	C5—C8	1.4927 (19)
N2—C1	1.1394 (19)		
C2—O1—C6	119.58 (10)		
C6—C5—C8—O2	38.0 (2)	C3—C4—C10—C11	-68.15 (16)

Table 2

Hydrogen-bond geometry (\AA , $^\circ$) for (II).

$D\cdots H\cdots A$	$D\cdots H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
N1—H1A \cdots N2 ⁱ	0.86	2.16	3.012 (2)	170
N1—H1B \cdots O2 ⁱⁱ	0.86	2.35	3.077 (2)	143

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

Compound (III)

Crystal data

$\text{C}_{20}\text{H}_{16}\text{N}_2\text{O}_2\cdot\text{C}_2\text{H}_3\text{N}$ $V = 977.8 (4) \text{ \AA}^3$
 $M_r = 357.40$ $Z = 2$
 Triclinic, $P\bar{1}$ $D_x = 1.214 \text{ Mg m}^{-3}$
 $a = 8.273 (2) \text{ \AA}$ Mo $K\alpha$ radiation
 $b = 9.313 (2) \text{ \AA}$ $\mu = 0.08 \text{ mm}^{-1}$
 $c = 13.881 (3) \text{ \AA}$ $T = 295 (2) \text{ K}$
 $\alpha = 73.376 (7)^\circ$ Prism, colourless
 $\beta = 82.308 (6)^\circ$ $0.35 \times 0.26 \times 0.18 \text{ mm}$
 $\gamma = 72.856 (7)^\circ$

Data collection

Bruker SMART APEX-II CCD 8803 measured reflections
 area-detector diffractometer 4059 independent reflections
 φ and ω scans 2935 reflections with $I > 2\sigma(I)$
 Absorption correction: multi-scan $R_{\text{int}} = 0.015$
 (SADABS; Sheldrick, 2003) $\theta_{\text{max}} = 26.5^\circ$
 $T_{\text{min}} = 0.973$, $T_{\text{max}} = 0.986$

Refinement

Refinement on F^2 $w = 1/[\sigma^2(F_o^2) + (0.069P)^2 + 0.13P]$
 $R[F^2 > 2\sigma(F^2)] = 0.044$ where $P = (F_o^2 + 2F_c^2)/3$
 $wR(F^2) = 0.133$ $(\Delta/\sigma)_{\text{max}} < 0.001$
 $S = 1.02$ $\Delta\rho_{\text{max}} = 0.16 \text{ e \AA}^{-3}$
 4059 reflections $\Delta\rho_{\text{min}} = -0.16 \text{ e \AA}^{-3}$
 246 parameters
 H-atom parameters constrained

Table 3

Selected geometric parameters (\AA , $^\circ$) for (III).

O1—C2	1.3604 (17)	C2—C3	1.3534 (19)
O1—C6	1.3883 (17)	C4—C10	1.519 (2)
O2—C8	1.2224 (17)	C5—C6	1.3353 (19)
N1—C2	1.3340 (18)	C5—C8	1.487 (2)
N2—C1	1.1437 (19)		
C2—O1—C6	120.09 (10)		
C6—C5—C8—O2	-141.37 (15)	C3—C4—C10—C11	-68.85 (17)

Table 4

Hydrogen-bond geometry (\AA , $^\circ$) for (III).

$D\cdots H\cdots A$	$D\cdots H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
N1—H1A \cdots N2 ⁱ	0.86	2.18	3.023 (2)	167
N1—H1B \cdots O2 ⁱⁱ	0.86	2.11	2.959 (2)	170

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

For both compounds, all H atoms were placed in geometrically calculated positions and refined using a riding model, with $\text{C—H} = 0.93 \text{ \AA}$ and $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ for aromatic, $\text{C—H} = 0.96 \text{ \AA}$ and $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{C})$ for methyl, $\text{C—H} = 0.98 \text{ \AA}$ and $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ for methine, and $\text{N—H} = 0.86 \text{ \AA}$ and $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{N})$ for NH_2 H atoms.

For both compounds, data collection: *APEX2* (Bruker, 2005); cell refinement: *SAINT-Plus* (Bruker, 2001); data reduction: *SAINT-Plus*; program(s) used to solve structure: *SHELXTL* (Sheldrick, 2001); program(s) used to refine structure: *SHELXTL*; molecular graphics: *SHELXTL*; software used to prepare material for publication: *SHELXTL*.

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: SQ3047). Services for accessing these data are described at the back of the journal.

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