

Carbonyl–carbonyl, carbonyl– π and carbonyl–halogen dipolar interactions as the directing motifs of the supramolecular structure of ethyl 6-chloro-2-oxo-2*H*-chromene-3-carboxylate and ethyl 6-bromo-2-oxo-2*H*-chromene-3-carboxylate

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Received 9 January 2007

Accepted 21 February 2007

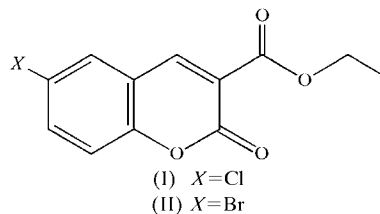
Online 17 March 2007

The title compounds, C₁₂H₉ClO₄, (I), and C₁₂H₉BrO₄, (II), are isomorphous and crystallize in the monoclinic space group *P*2₁/*c*. Both compounds present an *anti* conformation between the 3-carboxy and the lactone carbonyl groups. Both carbonyl groups are out of the plane defined by the remaining chromene atoms, by 8.37 (6) and 17.57 (6)° for (I), and by 9.07 (8) and 18.96 (18)° for (II), owing to their involvement in intermolecular interactions. In both compounds, layers of centrosymmetric hydrogen-bonded dimers are developed in the $[\bar{5} \bar{2} 22]$ plane through C–H...O interactions, involving both carbonyl groups as acceptors. Two families of dimers stack through C=O...C=O, C=O... π and C–X...C=O (*X* = Cl and Br) dipolar interactions, as well as a C–H... π interaction, developing the three-dimensional structure along the *c* axis.

Comment

Coumarins have demonstrated a great variety of biological properties as anti-inflammatories (Kontogiorgis & Hadjipavlou-Litina, 2005), antibacterials (Gursoy & Karali, 2003) and antihelmintics (de Marchi *et al.*, 2004). They have been proposed in HIV (Lee & Morris, 1999) and cancer (Lacy & O'Kennedy, 2004) treatment, as well as being inhibitors of monoaminoxidase (Chimenti *et al.*, 2004; Santana *et al.*, 2006). Non-covalent interactions are involved in most of the molecular recognition processes. Particularly, hydrogen

bonding and π -stacking interactions are responsible for the self-association of coumarin derivatives in the solid state (Magaña-Vergara *et al.*, 2004; García-Báez *et al.*, 2003). Following on from these studies, we report here the molecular and supramolecular structures of the isostructural ethyl 6-chloro- and 6-bromo-2-oxo-1*H*-benzopyran-3-carboxylates, *viz.* (I) and (II), respectively.



The title compounds are isomorphous; they crystallize in the monoclinic space group *P*2₁/*c* with four molecules in the unit cell. The molecular structures of (I) and (II) are shown in Figs. 1 and 2, and selected bond lengths and angles are listed in Tables 1 and 3, respectively. The geometric parameters of the coumarin ring are comparable to those reported for similar structures retrieved from the Cambridge Structural Database (Version of May 2005; Allen, 2002). Most of the bond distances and angles in (I) and (II) are very similar to the values reported for the isomorphous ethyl coumarin-3-carboxylate, (III) (García-Báez *et al.*, 2003), except for the O1–C9 bond length, which is slightly shorter; the mean value is 1.366 (2) Å for (I) and (II), compared with 1.377 (2) Å in (III). This is probably due to the inductive negative effect of the halogen atom on the lactone O atom (O1) lone pair of electrons. Compounds (I) and (II) present an *anti* conformation between the 3-carboxy and the lactone carbonyl groups, in contrast to the previously reported *syn* arrangement in (III). In both title molecules, the lactone and the carboxylate carbonyl groups are out of the plane defined by atoms O1/C3–C10 by 8.37 (6) and 17.57 (6)°, respectively, for (I), and by 9.07 (8) and 18.96 (18)°, respectively, for (II). The above-mentioned carbonyl deviations from planarity seem to be related to intermolecular interactions. It is interesting to note that the replacement of Cl by Br does not alter the molecular packing.

In the crystal structures of compounds (I) and (II), hydrogen-bonded dimers are formed by self-complementary interactions involving the carboxylate carbonyl O atom as a

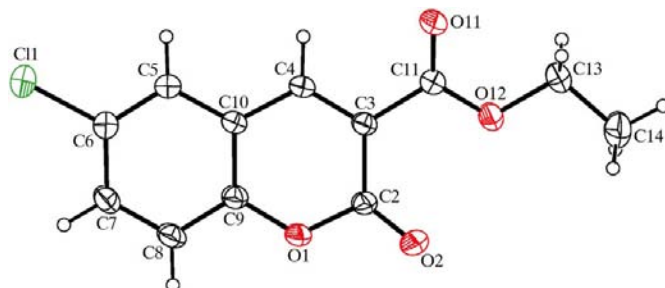


Figure 1
The molecular structure of (I), showing the atomic numbering scheme and displacement ellipsoids drawn at the 30% probability level.

hydrogen-bond acceptor, and the C4—H4 and C5—H5 groups as hydrogen-bond donors (Tables 2 and 4), so defining an $R_2^2(14)[R_2^1(6)]$ motif (Bernstein *et al.*, 1995). This dimer, which lies in the family of planes $[\bar{3} \ 3 \ 14]$, is hydrogen bonded to another dimer lying in the family of planes $[\bar{3} \ \bar{3} \ 14]$, through two C—H...O interactions (C7...O2ⁱⁱ and C8...O2ⁱⁱ; the symmetry code is as in Tables 2 and 4), to form an $R_2^1(5)$ motif. The hydrogen-bonding motifs are shown in Fig. 3 for compound (I). Thus, layers of centrosymmetric hydrogen-bonded dimers are developed in the $[\bar{5} \ \bar{2} \ 22]$ plane.

In both compounds, the two families of dimers stack through C=O...C=O, C=O... π and C—Cl...C=O dipolar interactions to develop the third dimension (Fig. 4). In the absence of strong hydrogen-bonding donors, carbonyl dipolar interactions are strong enough to direct the crystal packing of both isomorphs. Two self-complementary sheared parallel C=O...C=O interactions (Allen *et al.*, 1998) form a stacked

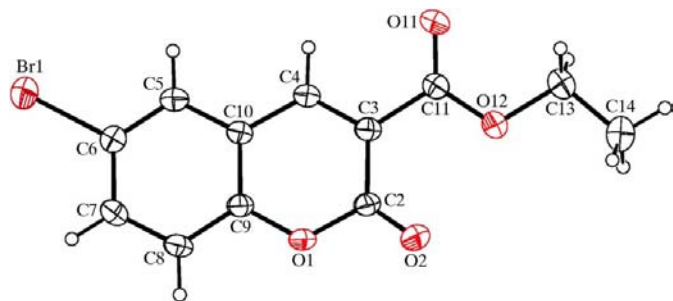


Figure 2
The molecular structure of (II), showing the atomic numbering scheme and displacement ellipsoids drawn at the 30% probability level.

centrosymmetric dimer [$O11...C2^{iii} = 3.130(2) \text{ \AA}$, $C11=O11...C2^{iii} = 108.9(1)^\circ$ and $C11...O2=C2 = 55.1(1)^\circ$ for (I); $O11...C2^{iii} = 3.130(3) \text{ \AA}$, $C11=O11...C2^{iii} = 109.0(2)^\circ$ and $C11...O2=C2 = 55.5(2)^\circ$ for (II); symmetry code: (iii) $-x + 1, -y, -z + 1$]. In this interaction, the 3-carboxy carbonyl group acts as the donor and the lactone carbonyl group as the acceptor of electronic density. The former carbonyl group and the lactone ring (centroid Cg1) are almost parallel [$C11=O11...Cg1^{iii} = 96.5(1)$ and $96.8(2)^\circ$ for (I) and (II), respectively], and are separated by $3.034(3) \text{ \AA}$ in (I) and $3.035(2) \text{ \AA}$ in (II). This gives rise to the interaction of the lone pair of atom O11 with the electron-deficient lactone ring (García-Báez *et al.*, 2003). This type of interaction has also been observed for 4-chloro-3-nitrocoumarin (Fujii *et al.*, 2005).

A weak $Csp^3-H...C=O$ interaction (Umezawa *et al.*, 1998) complements the packing [$C13...Cg2^{iii} = 3.787(2) \text{ \AA}$ for (I) and $3.833(3) \text{ \AA}$ for (II), and $C13-H13A...Cg2^{iii} = 150.8(2)^\circ$ for (I) and $150.3(3)^\circ$ for (II); Cg2 is the centroid of the benzene ring]. This set of stacked dimers lying in the family of planes $[\bar{3} \ 3 \ 14]$ is linked to the set of stacked dimers lying in the family of planes $[\bar{3} \ \bar{3} \ 14]$ through dipolar C—Cl(δ^-)...C(δ^+)=O interactions [$C11...C2^{iv} = 3.456(2) \text{ \AA}$ and $C11-C11...C2^{iv} = 95.8(1)^\circ$ for (I); $Br1...C2^{iv} = 3.516(3) \text{ \AA}$ and $C11-Br1...C2^{iv} = 95.5(2)^\circ$ for (II); symmetry code: (iv) $-x + 1, y + \frac{1}{2}, -z + \frac{1}{2}$]. This interaction shows distances below the sum of the van der Waals radii of the halogen and C atoms (C = 1.70 \AA , Cl = 1.80 \AA and Br = 1.90 \AA ; Bondi, 1964), with an almost perpendicular arrangement between the donor and the acceptor groups, in agreement with the side-on geometry

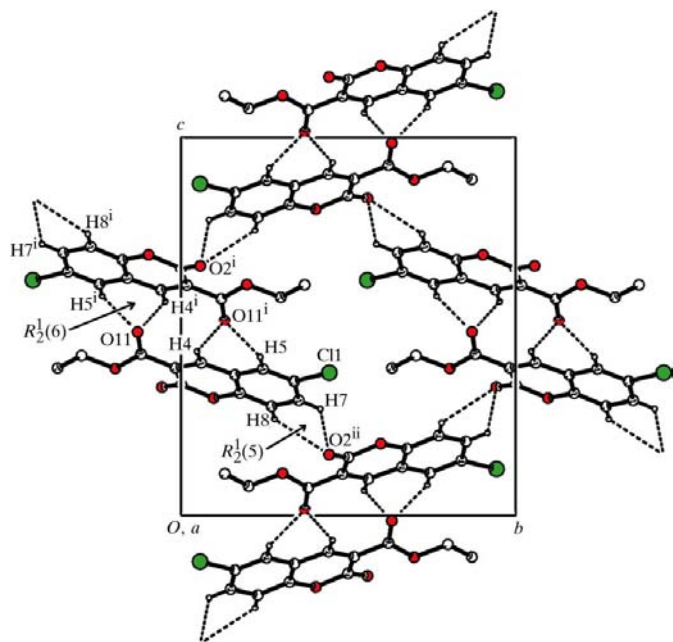


Figure 3
Layers of centrosymmetric hydrogen-bonded dimers of (I), viewed in the ab plane. $R_2^1(14)[R_2^1(6)]$ and $R_2^1(5)$ motifs are shown. Some H atoms have been omitted for clarity. [Symmetry codes: (i) $-x + 2, -y, -z + 1$; (ii) $-x, y + \frac{1}{2}, -z + \frac{1}{2}$].

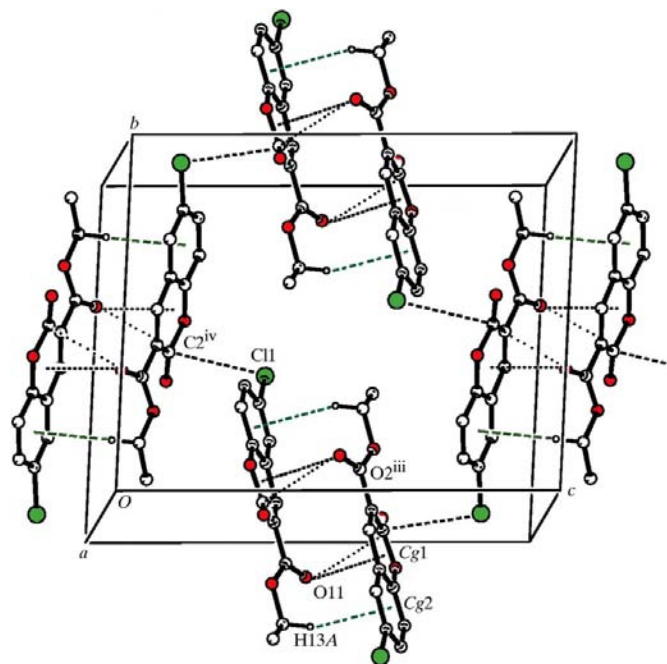


Figure 4
The stacking arrangement of (I), in centrosymmetric pairs, viewed along the c axis. $C11=O11...C2=O2$, $C11=O11...Cg1$ and $C6-X...C2=O2$ ($X = Cl$ and Br) dipolar interactions, as well as $C13-H13A...Cg2$ interactions, combine to develop the third dimension along the c axis. [Symmetry codes: (iii) $-x + 1, -y, -z + 1$; (iv) $-x + 1, y + \frac{1}{2}, -z + \frac{1}{2}$].

proposed for C—X···E interactions (X = halogen and E = electrophile; Lommerse *et al.*, 1996; Bosch & Barnes, 2002) and in contrast to the head-on geometry proposed for C—X···Nu (X = halogen and Nu = nucleophile) interactions (Ouvrard *et al.*, 2003; Auffinger *et al.*, 2004).

As a consequence of the above-mentioned group of interactions, a block of zigzag centrosymmetric pairs of dimers stacking along the c -axis direction is formed. The C3···C4ⁱⁱⁱ distances of 3.602 (3) and 3.592 (4) Å for (I) and (II), respectively, are in the expected range for photochemical dimerization (Gnanaguru *et al.*, 1985). Thus, further studies on the photoreactivity of compounds (I) and (II) are currently being carried out.

Experimental

Compounds (I) and (II) were synthesized as reported by Bonsignore *et al.* (1995), starting from 5-chloro- or 5-bromosalicylaldehyde with diethyl malonate in equimolar amounts. All reagents were purchased from Aldrich. Crystals suitable for X-ray analysis were obtained by recrystallization from ethanol. For compound (I) (m.p. 440 K), FT-IR (ν , cm⁻¹): 1743, 1700 (C=O); ¹H NMR (DMSO-*d*₆): δ 8.72 (*s*, 1H, H-4), 8.06 (*d*, 1H, H-5), 7.78 (*dd*, 1H, H-7), 7.48 (*d*, 1H, H-8), 4.3 (*q*, 2H, OCH₂), 1.31 (*t*, 3H, CH₃); ¹³C NMR (DMSO-*d*₆): δ 155.4 (C2), 118.6 (C3), 147.3 (C4), 129.0 (C5), 128.3 (C6), 133.7 (C7), 118.2 (C8), 153.3 (C9), 119.1 (C10), 162.2 (C11), 61.3 (C13), 13.9 (C14). For compound (II) (m.p. 445 K), FT-IR (ν , cm⁻¹): 1743, 1718 (C=O); ¹H NMR (CDCl₃): δ 8.42 (*s*, 1H, H-4), 7.69 (*d*, 1H, H-5), 7.73 (*dd*, 1H, H-7), 7.23 (*d*, 1H, H-8), 4.4 (*q*, 2H, OCH₂), 1.39 (*t*, 3H, CH₃); ¹³C NMR (CDCl₃): δ 155.9 (C2), 117.3 (C3), 147.0 (C4), 131.4 (C5), 119.3 (C6), 136.8 (C7), 118.4 (C8), 153.8 (C9), 119.2 (C10), 162.5 (C11), 62.1 (C13), 14.0 (C14).

Compound (I)

Crystal data

C ₁₂ H ₉ ClO ₄	$V = 1119.83$ (17) Å ³
$M_r = 252.64$	$Z = 4$
Monoclinic, $P2_1/c$	Mo $K\alpha$ radiation
$a = 5.7982$ (5) Å	$\mu = 0.34$ mm ⁻¹
$b = 13.0702$ (12) Å	$T = 293$ (2) K
$c = 15.5540$ (12) Å	$0.20 \times 0.18 \times 0.14$ mm
$\beta = 108.191$ (3)°	

Data collection

Bruker SMART CCD area-detector diffractometer	8206 measured reflections
Absorption correction: multi-scan (SADABS; Sheldrick, 1996)	2615 independent reflections
$T_{\min} = 0.935$, $T_{\max} = 0.954$	2310 reflections with $I > 2\sigma(I)$
	$R_{\text{int}} = 0.024$

Table 1

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

C11—C6	1.736 (2)	O11—C11	1.200 (3)
O1—C2	1.382 (2)	C2—C3	1.470 (3)
O1—C9	1.366 (2)	C3—C4	1.342 (3)
O2—C2	1.188 (2)		
C2—O1—C9	122.98 (15)	O11—C11—O12	124.10 (18)
O1—C2—C3	115.78 (15)	O11—C11—C3	121.72 (17)
C3—C4—C10	121.38 (17)	O12—C11—C3	114.18 (16)
C11—C6—C5	119.20 (17)		
O2—C2—C3—C11	5.4 (3)	C2—C3—C11—O11	-156.44 (19)

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.055$	155 parameters
$wR(F^2) = 0.155$	H-atom parameters constrained
$S = 1.08$	$\Delta\rho_{\text{max}} = 0.34$ e Å ⁻³
2615 reflections	$\Delta\rho_{\text{min}} = -0.32$ e Å ⁻³

Table 2

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

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
C4—H4···O11 ⁱ	0.93	2.54	3.346 (3)	145
C5—H5···O11 ⁱ	0.93	2.43	3.263 (3)	149
C7—H7···O2 ⁱⁱ	0.93	2.59	3.182 (3)	122
C8—H8···O2 ⁱⁱ	0.93	2.59	3.182 (3)	122

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

Compound (II)

Crystal data

C ₁₂ H ₉ BrO ₄	$V = 1143.0$ (2) Å ³
$M_r = 297.10$	$Z = 4$
Monoclinic, $P2_1/c$	Mo $K\alpha$ radiation
$a = 5.8432$ (6) Å	$\mu = 3.60$ mm ⁻¹
$b = 13.2073$ (14) Å	$T = 293$ (2) K
$c = 15.6959$ (15) Å	$0.26 \times 0.15 \times 0.12$ mm
$\beta = 109.327$ (3)°	

Data collection

Bruker SMART CCD area-detector diffractometer	12998 measured reflections
Absorption correction: multi-scan (SADABS; Sheldrick, 1996)	2754 independent reflections
$T_{\min} = 0.455$, $T_{\max} = 0.672$	2091 reflections with $I > 2\sigma(I)$
	$R_{\text{int}} = 0.041$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.045$	155 parameters
$wR(F^2) = 0.123$	H-atom parameters constrained
$S = 1.05$	$\Delta\rho_{\text{max}} = 1.00$ e Å ⁻³
2754 reflections	$\Delta\rho_{\text{min}} = -0.26$ e Å ⁻³

Table 3

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

Br1—C6	1.888 (3)	O2—C2	1.189 (4)
O1—C2	1.379 (3)	O11—C11	1.198 (4)
O1—C9	1.366 (3)	C3—C4	1.341 (4)
C2—O1—C9	123.1 (2)	Br1—C6—C5	119.0 (2)
O1—C2—C3	115.6 (2)	O11—C11—O12	124.4 (3)
C3—C4—C10	121.3 (3)	O12—C11—C3	114.1 (2)
O2—C2—C3—C11	6.1 (5)	C2—C3—C11—O11	-155.0 (3)

Table 4

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

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
C4—H4···O11 ⁱ	0.93	2.60	3.394 (3)	143
C5—H5···O11 ⁱ	0.93	2.42	3.264 (4)	151
C7—H7···O2 ⁱⁱ	0.93	2.55	3.171 (4)	125
C8—H8···O2 ⁱⁱ	0.93	2.69	3.239 (3)	119

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

H atoms were included in calculated positions and refined as riding atoms. The C–H distances are in the range 0.93–0.97 Å and $U_{\text{iso}}(\text{H})$ values were set at 1.5 or 1.2 times $U_{\text{eq}}(\text{parent C atom})$.

For both compounds, data collection: *SMART* (Bruker, 2002); cell refinement: *SAINT* (Bruker, 2002); data reduction: *SAINT*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *MERCURY* (Version 1.4; Bruno *et al.*, 2002); software used to prepare material for publication: *SHELXL97* and *WinGX2003* (Farrugia, 1999).

This work was supported by the SIP–IPN (Secretaría de Investigación y Posgrado del Instituto Politécnico Nacional), the CGIC–UC (Coordinación General de Investigación Científica de la Universidad de Colima) and PROMEP–SEP.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: SU3001). Services for accessing these data are described at the back of the journal.

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