Crystal structure of 2,4,6-trimethylbenzoic anhydride

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The title compound, $C_{20}H_{22}O_3$, was formed in the reaction between 2,4,6-trimethylbenzoic acid and N,N-diisopropylethylamine in the presence of 1,3-dichloro-1,3-bis(dimethylamino)propenium hydrogen dichloride, and was recrystallized from diethyl ether solution. It is the first exclusively alkyl-substituted benzoic anhydride to have been structurally characterized. The asymmetric unit consists of a half molecule, the other half of which is generated by twofold rotation symmetry; the dihedral angle between the symmetry-related aromatic rings is 54.97 (3)°. The geometric parameters of the aromatic ring are typical of those for 2,4,6-trimethylphenyl substituted groups. The C=O and C—O bond lengths are 1.1934 (12) and 1.3958 (11) Å, respectively, and the angle between these three atoms (O=C—O) is 121.24 (9)°. In the crystal, molecules are linked by weak C—H⋯O hydrogen bonds and C—H⋯π interactions. The packing features wavy chains that extend parallel to [001].

1. Chemical context

Benzoic anhydrides have traditionally been used in synthetic organic chemistry for the preparation of aromatic esters, amides and carboxylic acids. Aromatic anhydrides have also been shown to be effective acylating agents (Shiina, 2004; Shiina & Nakata, 2007). The title compound has been used to trap deprotonated 3,4-epoxy-2,3,4,5-tetrahydrothiophene 1,1-dioxide, forming 3-(2,4,6-trimethylbenzoyloxy)-2,3-dihydro-thiophene 1,1-dioxide (Alonso et al., 2004, 2005). The synthesis of the compound we report here, 2,4,6-trimethylbenzoic anhydride (common name: mesitoic anhydride), was first published in 1941, where it was formed in the reaction between (2,4,6-trimethylphenyl)sodium and 2,4,6-trimethyl-benzoic acid in the presence of pyridine (Fuson et al., 1941). Recently, several new approaches for the syntheses of symmetric acid anhydrides, including the title compound, have been reported (Kazemi et al., 2004; Li et al., 2012; McCallum & Barriault, 2015). The most recent report involves the in situ generation of a Vilsmeier–Haack reagent for the coupling of symmetric carboxylic acids (McCallum & Barriault, 2015). Due to the structural similarities between this reagent and the 1,3-dichloro-1,3-bis(dimethylamino)propenium salt used here, it is possible that the title compound was formed via a similar method in our reaction. The crystal structure that we report is the first example of a benzoic anhydride where the aryl rings are substituted with only alkyl groups, although several other substituted benzoic anhydrides are known.
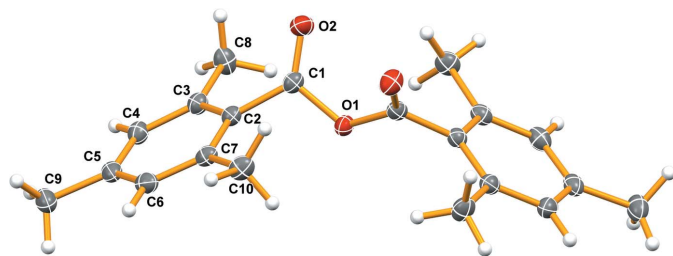
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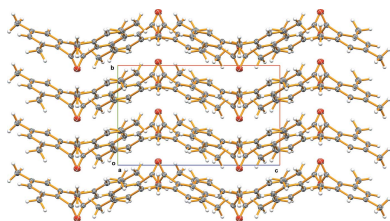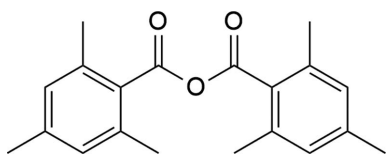
2. Structural commentary

The molecular structure of the title compound is shown in Fig. 1. It crystallizes in the monoclinic space group $C2/c$ with one half of the molecule uniquely present in the asymmetric unit. The two C—O bond lengths are significantly different, as would be expected for anhydrides, with lengths of 1.1934 (12) (C1—O2) and 1.3958 (11) Å (C1—O1). The C1—C2 distance is normal for an sp^2–sp^2 bond, with a length of 1.4873 (13) Å. The second half of the molecule, which is generated by rotation about the twofold axis passing through O1 (0, y, 0.25), forms a dihedral angle of 54.97 (3)° between the equivalent aromatic rings. If the planes of the two overlapping CO_2 groups are chosen instead, the dihedral angle becomes 59.30 (11)°. The C—C bonds in the aromatic ring are not all statistically equivalent. Unsurprisingly, the longest C—C bonds in the ring are adjacent to the electron-withdrawing anhydride group, C2—C3 [1.4032 (13) Å] and C2—C7 [1.4059 (13) Å]. The remaining C—C bonds are statistically equivalent, averaging 1.3942 (8) Å. All of the C—CH$_3$ bond lengths are statistically equivalent with an average length of 1.5102 (8) Å.

3. Supramolecular features

The packing of the molecules, when viewed in projection down the a axis, forms wavy chains that run parallel to the c-axis direction (Fig. 2). Within the chains, the molecules are oriented in a alternating up and down fashion, shifting by $\frac{1}{2}$ along [001] each time, such that they overlap slightly. There are no close stacking interactions between the phenyl rings in various planes. However, if the packing is viewed down the b axis, the C5—C6—C7—C10 fragment of one trimethylphenyl group lies directly above/below the same fragment running in the opposite direction, C10—C7—C6—C5, in the plane above/below it.

There are short intramolecular contacts between the aromatic H atoms H4 (2.37 Å to H8A and 2.37 to H9C) and H6 (2.39 Å to H10A), and the designated methyl H atoms, which close five-membered rings in the molecule.

In the crystal, molecules are linked by weak intermolecular C—H···O hydrogen bonds and C—H···π contacts (Table 1, Fig. 3). It is notable that these contacts involve one H atom from each of the three methyl substituents on the phenyl ring. All of these contacts occur between the chains that run parallel to the c axis and not within the individual chains, thus consolidating the overall structure.

4. Database survey

A survey of the Cambridge Structural Database (CSD, Version 5.38; Groom *et al.*, 2016), performed on 24 July, 2017, located 25 substituted benzoic anhydrides, all of which were symmetric. Interestingly, there were no other benzoic anhydrides identified that were substituted exclusively with alkyl groups. The only other structurally characterized alkyl-substituted benzoic anhydrides are 2-acetoxy-5-methylbenzoic anhydride (CSD refcode IBOCOT; Solanko & Bond, 2011) and 2-methyl-3-nitrobenzoic anhydride (QUFTIW; Moreno-Fuquen *et al.*, 2015). Most of the examples found in the CSD contain various substitution patterns involving halogens (Cl, Br or I). There are also several structures that contain aromatic activating groups, such as ethers or amines. The parent compound, benzoic anhydride (ZZZQRI; van Alen & Krauze, 1964), is known, as is the precursor to the title compound, 2,4,6-trimethylbenzoic acid (TMBZAC; Florencio

Figure 1
The molecular structure of the title compound. Only half of the molecule is crystallographically unique (labelled atoms). Displacement ellipsoids are drawn at the 50% probability level.
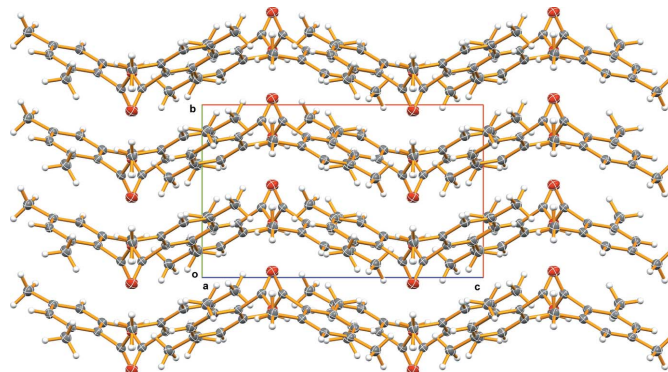
Figure 2
Packing diagram of the title compound, viewed in projection down [100], showing wavy [001] chains.
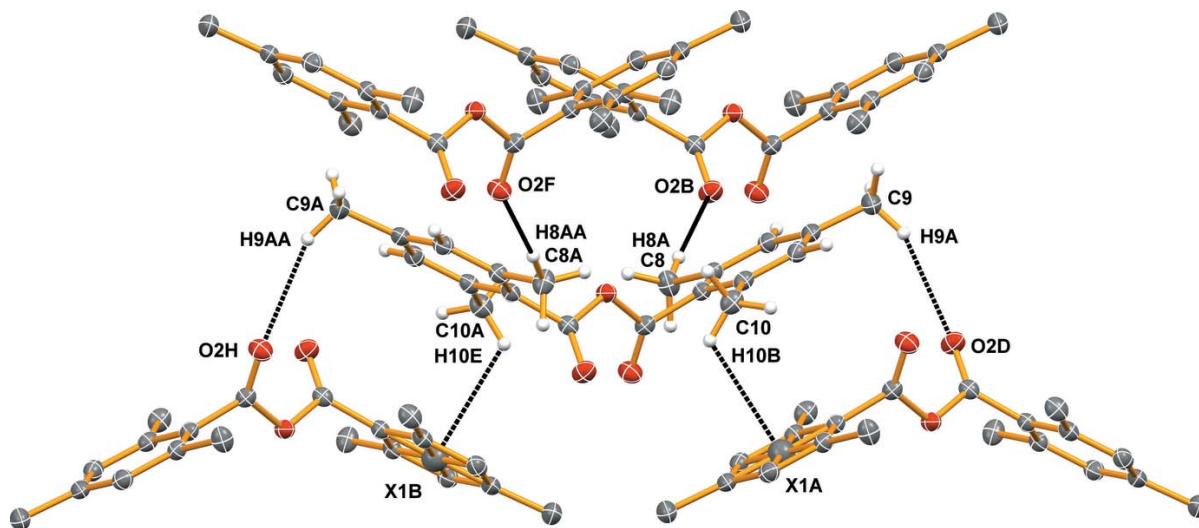
Figure 3
Short intermolecular contacts (defined in the text and close to the sum of the van der Waals radii; shown as heavy dotted lines), with only donors from the central molecule included (Table 1).

& Smith, 1970), which can be overlaid with the asymmetric unit of the title compound reasonably well.

5. Synthesis and crystallization

The title compound was isolated from the following reaction mixture, although more convenient synthetic methods are known (Fuson *et al.*, 1941; Kazemi *et al.*, 2004). 2,4,6-Tri-methylbenzoic acid (1.11 g, 6.78 mmol) and *N,N*-diisopropyl-ethylamine (1.21 ml, 6.94 mmol) were added to a chloroform solution (25 ml) of 1,3-dichloro-1,3-bis(dimethylamino)-propenium hydrogen dichloride (0.92 g, 3.42 mmol), which had been prepared following the known literature method (Janousek & Viehe, 1971), in chloroform (25 ml). The mixture was stirred at reflux for 18 h under nitrogen. After cooling to room temperature, a saturated KOH (aqueous) solution (~2 ml) and water (70 ml) were added to the mixture. The organic layer was extracted and the aqueous phase was washed with chloroform (two 25 ml portions). The combined organic extracts were washed with brine and dried with $MgSO_4$, and the solvent was removed *in vacuo*. The resulting material was washed with ice-cold water (25 ml) and then isolated *via* vacuum filtration. The off-white solid was further purified by recrystallization through slow evaporation of a saturated diethyl ether solution. After 3 h, clear and colourless thin plate-like crystals were obtained [yield: 0.98 g, 3.15 mmol, 93%; m.p. 374–375 K (literature = 375–377 K)]. Elemental analysis, calculated for $C_{20}H_{22}O_3$ (%): C 77.39, H 7.14, N 0.00; found (%): C 77.26, H 7.13, N 0.01. The ^1H and $^{13}C\{^1H\}$ NMR and IR spectroscopic data for the title compound are identical to those previously reported (Kazemi *et al.*, 2004).

6. Refinement

Crystal data, data collection, and structure refinement details are summarized in Table 2. H atoms were included in calcu-lated positions (C—H = 0.95–0.98 Å) and refined as riding with $U_{iso}(H) = 1.2$ or $1.5U_{eq}(C)$.

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{20}H_{22}O_3$
M_r	310.37
Crystal system, space group	Monoclinic, $C2/c$
Temperature (K)	125
a, b, c (Å)	16.080 (2), 7.9997 (12), 14.308 (2)
β (°)	114.094 (2)
V (Å^3)	1680.1 (4)
Z	4
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.08
Crystal size (mm)	$0.55 \times 0.26 \times 0.25$
Data collection	
Diffractometer	Bruker APEXII CCD area-detector
Absorption correction	Multi-scan (*SADABS*; Bruker, 2008)
T_{min}, T_{max}	0.683, 0.746
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	9832, 2095, 1857
R_{int}	0.019
$(\sin\theta/\lambda)_{max}$ (Å^{-1})	0.679
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.037, 0.107, 1.05
No. of reflections	2095
No. of parameters	108
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{max}, \Delta\rho_{min}$ (e Å^{-3})	0.34, −0.19

Computer programs: *APEX2* and *SAINT* (Bruker, 2008), *SHELXT2014* (Sheldrick, 2015*a*), *SHELXL2014* (Sheldrick, 2015*b*) and *Mercury CSD 3.9* (Macrae *et al.*, 2008).

research communications

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Computing details

Data collection: *APEX2* (Bruker, 2008); cell refinement: *SAINT* (Bruker, 2008); data reduction: *SAINT* (Bruker, 2008); program(s) used to solve structure: SHELXT2014 (Sheldrick, 2015a); program(s) used to refine structure: *SHELXL2014* (Sheldrick, 2015b); molecular graphics: *Mercury* (Macrae *et al.*, 2008) [OK?]; software used to prepare material for publication: *SHELXL2014* (Sheldrick, 2015b).

2,4,6-Trimethylbenzoic anhydride

Crystal data

$C_{20}H_{22}O_3$	$D_x = 1.227$ Mg m^{-3}
$M_r = 310.37$	Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
Monoclinic, $C2/c$	Cell parameters from 6207 reflections
$a = 16.080$ (2) Å	$\theta = 2.8$–28.7°
$b = 7.9997$ (12) Å	$\mu = 0.08$ mm^{-1}
$c = 14.308$ (2) Å	$T = 125$ K
$\beta = 114.094$ (2)°	Wedge shaped (cut from a large block),
$V = 1680.1$ (4) Å^3	colourless
$Z = 4$	$0.55 \times 0.26 \times 0.25$ mm
$F(000) = 664$	

Data collection

Bruker APEXII CCD area-detector diffractometer	9832 measured reflections
	2095 independent reflections
Radiation source: sealed tube	1857 reflections with $I > 2\sigma(I)$
Graphite monochromator	$R_{int} = 0.019$
φ and ω scans	$\theta_{max} = 28.9°$, $\theta_{min} = 2.8°$
Absorption correction: multi-scan	$h = -21 \rightarrow 21$
(SADABS; Bruker, 2008)	$k = -10 \rightarrow 10$
$T_{min} = 0.683$, $T_{max} = 0.746$	$l = -19 \rightarrow 19$

Refinement

Refinement on F^2	Primary atom site location: structure-invariant direct methods
Least-squares matrix: full	
$R[F^2 > 2\sigma(F^2)] = 0.037$	Hydrogen site location: inferred from neighbouring sites
$wR(F^2) = 0.107$	
$S = 1.05$	H-atom parameters constrained
2095 reflections	$w = 1/[\sigma^2(F_o^2) + (0.0543P)^2 + 0.9964P]$
108 parameters	where $P = (F_o^2 + 2F_c^2)/3$
0 restraints	$(\Delta/\sigma)_{max} < 0.001$
	$\Delta\rho_{max} = 0.34$ e Å^{-3}
	$\Delta\rho_{min} = -0.19$ e Å^{-3}

Special details

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

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

	x	*y*	*z*	U_{iso}*/U_{eq}
O1	0.0000	0.31743 (12)	0.2500	0.0206 (2)
O2	0.08932 (5)	0.53524 (10)	0.24991 (6)	0.0272 (2)
C1	0.05461 (6)	0.40599 (12)	0.21238 (7)	0.0193 (2)
C2	0.06727 (6)	0.31349 (12)	0.12897 (7)	0.0190 (2)
C3	0.15548 (7)	0.26116 (12)	0.14551 (7)	0.0206 (2)
C4	0.16788 (7)	0.18095 (13)	0.06542 (8)	0.0229 (2)
H4	0.2269	0.1425	0.0759	0.028*
C5	0.09582 (8)	0.15592 (13)	−0.02937 (8)	0.0237 (2)
C6	0.00895 (7)	0.20904 (13)	−0.04303 (8)	0.0245 (2)
H6	−0.0406	0.1912	−0.1073	0.029*
C7	−0.00725 (7)	0.28740 (12)	0.03480 (8)	0.0213 (2)
C8	0.23514 (7)	0.28879 (15)	0.24696 (8)	0.0275 (2)
H8A	0.2859	0.2167	0.2514	0.041*
H8B	0.2170	0.2615	0.3028	0.041*
H8C	0.2542	0.4061	0.2526	0.041*
C9	0.11059 (9)	0.07659 (15)	−0.11716 (9)	0.0310 (3)
H9A	0.1003	0.1600	−0.1709	0.047*
H9B	0.0679	−0.0164	−0.1449	0.047*
H9C	0.1732	0.0347	−0.0926	0.047*
C10	−0.10199 (7)	0.34744 (15)	0.01547 (8)	0.0268 (2)
H10A	−0.1368	0.3649	−0.0581	0.040*
H10B	−0.0980	0.4530	0.0519	0.040*
H10C	−0.1326	0.2634	0.0401	0.040*

Atomic displacement parameters (Å^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O1	0.0218 (5)	0.0187 (5)	0.0253 (5)	0.000	0.0138 (4)	0.000
O2	0.0251 (4)	0.0256 (4)	0.0340 (4)	−0.0059 (3)	0.0153 (3)	−0.0060 (3)
C1	0.0149 (4)	0.0210 (5)	0.0220 (5)	0.0018 (3)	0.0074 (4)	0.0031 (4)
C2	0.0187 (5)	0.0190 (4)	0.0200 (5)	−0.0001 (3)	0.0086 (4)	0.0023 (3)
C3	0.0200 (5)	0.0211 (5)	0.0212 (5)	0.0013 (4)	0.0089 (4)	0.0026 (4)
C4	0.0242 (5)	0.0219 (5)	0.0257 (5)	0.0023 (4)	0.0133 (4)	0.0025 (4)
C5	0.0328 (6)	0.0182 (5)	0.0232 (5)	−0.0022 (4)	0.0146 (4)	0.0011 (4)
C6	0.0271 (5)	0.0238 (5)	0.0199 (5)	−0.0043 (4)	0.0067 (4)	0.0013 (4)
C7	0.0200 (5)	0.0208 (5)	0.0222 (5)	−0.0014 (4)	0.0076 (4)	0.0037 (4)
C8	0.0194 (5)	0.0369 (6)	0.0243 (5)	0.0060 (4)	0.0068 (4)	−0.0018 (4)
C9	0.0439 (7)	0.0273 (5)	0.0270 (5)	−0.0031 (5)	0.0197 (5)	−0.0032 (4)
C10	0.0188 (5)	0.0311 (6)	0.0267 (5)	−0.0002 (4)	0.0053 (4)	0.0039 (4)

Geometric parameters (Å, º)

O1—C1[i]	1.3958 (11)	C6—C7	1.3921 (15)
O1—C1	1.3958 (11)	C6—H6	0.9500
O2—C1	1.1934 (12)	C7—C10	1.5111 (14)
C1—C2	1.4873 (13)	C8—H8A	0.9800
C2—C3	1.4032 (13)	C8—H8B	0.9800
C2—C7	1.4059 (13)	C8—H8C	0.9800
C3—C4	1.3968 (14)	C9—H9A	0.9800
C3—C8	1.5095 (14)	C9—H9B	0.9800
C4—C5	1.3924 (15)	C9—H9C	0.9800
C4—H4	0.9500	C10—H10A	0.9800
C5—C6	1.3953 (16)	C10—H10B	0.9800
C5—C9	1.5101 (14)	C10—H10C	0.9800
C1[i]—O1—C1	119.00 (11)	C6—C7—C10	120.03 (9)
O2—C1—O1	121.24 (9)	C2—C7—C10	121.97 (9)
O2—C1—C2	126.87 (9)	C3—C8—H8A	109.5
O1—C1—C2	111.76 (8)	C3—C8—H8B	109.5
C3—C2—C7	121.65 (9)	H8A—C8—H8B	109.5
C3—C2—C1	118.24 (8)	C3—C8—H8C	109.5
C7—C2—C1	120.03 (9)	H8A—C8—H8C	109.5
C4—C3—C2	118.14 (9)	H8B—C8—H8C	109.5
C4—C3—C8	120.45 (9)	C5—C9—H9A	109.5
C2—C3—C8	121.40 (9)	C5—C9—H9B	109.5
C5—C4—C3	121.63 (9)	H9A—C9—H9B	109.5
C5—C4—H4	119.2	C5—C9—H9C	109.5
C3—C4—H4	119.2	H9A—C9—H9C	109.5
C4—C5—C6	118.69 (9)	H9B—C9—H9C	109.5
C4—C5—C9	121.31 (10)	C7—C10—H10A	109.5
C6—C5—C9	119.99 (10)	C7—C10—H10B	109.5
C7—C6—C5	121.91 (9)	H10A—C10—H10B	109.5
C7—C6—H6	119.0	C7—C10—H10C	109.5
C5—C6—H6	119.0	H10A—C10—H10C	109.5
C6—C7—C2	117.96 (9)	H10B—C10—H10C	109.5
C1[i]—O1—C1—O2	35.04 (7)	C8—C3—C4—C5	−179.10 (10)
C1[i]—O1—C1—C2	−148.96 (8)	C3—C4—C5—C6	−1.62 (15)
O2—C1—C2—C3	59.63 (14)	C3—C4—C5—C9	177.01 (9)
O1—C1—C2—C3	−116.09 (9)	C4—C5—C6—C7	0.66 (15)
O2—C1—C2—C7	−117.38 (11)	C9—C5—C6—C7	−177.99 (9)
O1—C1—C2—C7	66.89 (11)	C5—C6—C7—C2	0.47 (15)
C7—C2—C3—C4	−0.20 (14)	C5—C6—C7—C10	178.17 (9)
C1—C2—C3—C4	−177.17 (9)	C3—C2—C7—C6	−0.70 (14)
C7—C2—C3—C8	−179.70 (9)	C1—C2—C7—C6	176.21 (9)

C1—C2—C3—C8	3.33 (14)	C3—C2—C7—C10	−178.35 (9)
C2—C3—C4—C5	1.39 (15)	C1—C2—C7—C10	−1.44 (14)

Symmetry code: (i) −x, y, −z+1/2.

Hydrogen-bond geometry (Å, º)

Cg1 is the centroid of the C2–C7 ring.

D—H···A	D—H	H···A	D···A	D—H···A
C8—H8A···O2ii	0.98	2.48	3.4612 (13)	176
C9—H9A···O2iii	0.98	2.66	3.5842 (14)	157
C10—H10B···Cg1iv	0.98	2.96	3.5255 (14)	118

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