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N-(4-Azobenzenyl)-5-norbornene-2,3-dicarboximide

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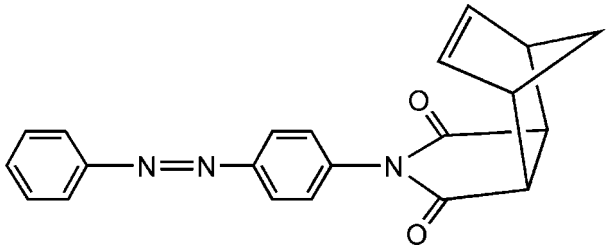
Key indicators: single-crystal X-ray study; T = 292 K; mean σ(C–C) = 0.004 Å; disorder in main residue; R factor = 0.059; wR factor = 0.139; data-to-parameter ratio = 14.9.

The title compound, $C_{21}H_{17}N_3O_2$, is a norbornene derivative containing an azo group which is disordered over two sites in an approximate 2:1 ratio. The two aromatic rings are almost coplanar [dihedral angle 9.25 (10)°]. The crystal packing is stabilized by an intermolecular C—H···O hydrogen bond.

Related literature

For related literature, see: Tian *et al.* (2007); Zhao *et al.* (1999).



Experimental

Crystal data

$C_{21}H_{17}N_3O_2$
M_r = 343.38
Monoclinic, $C2/c$
a = 25.190 (2) Å
b = 6.5076 (5) Å
c = 24.2792 (19) Å
β = 119.567 (1)°
V = 3461.7 (5) Å^3
Z = 8
Mo $K\alpha$ radiation
μ = 0.09 mm^{-1}
T = 292 (2) K
0.20 × 0.20 × 0.10 mm

Data collection

Bruker SMART CCD area-detector diffractometer
Absorption correction: none
13859 measured reflections
3778 independent reflections
2363 reflections with $I > 2\sigma(I)$
R_{int} = 0.041

Refinement

$R[F^2 > 2\sigma(F^2)]$ = 0.059
$wR(F^2)$ = 0.139
S = 1.06
3778 reflections
254 parameters
2 restraints
H-atom parameters constrained
$\Delta\rho_{max}$ = 0.16 e Å^{-3}
$\Delta\rho_{min}$ = −0.18 e Å^{-3}

Table 1
Hydrogen-bond geometry (Å, °).

D—H···A	D—H	H···A	D···A	D—H···A
C9—H9···O2^{i}	0.93	2.53	3.155 (3)	125

Symmetry code: (i) $x, y-1, z$.

Data collection: *SMART* (Bruker 2001); cell refinement: *SAINT* (Bruker 2001); data reduction: *SAINT*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1990); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *SHELXTL* (Bruker 2001); software used to prepare material for publication: *SHELXTL*.

The authors thank Dr Meng Xianggao (College of Chemistry, Central China Normal University) for the data collection.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: BT2500).

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supplementary materials

Acta Cryst. (2007). E**63**, o4040 [**doi:10.1107/S1600536807043863**]

N-(4-Azobenzenyl)-5-norbornene-2,3-dicarboximide

D. Tian, B. Hu and Y. Niu

Comment

The family of azobenzenes has been investigated intensively due to the their remarkable photochemically induced *trans* to *cis* isomerism. Azo polymers are of interest in various fields (Zhao *et al.*, 1999). As a part of our investigation of preparing azo polymers, we report the crystal structure of the title compound (Fig. 1).

Bond lengths and angles of the norbornene moiety are similar to those in other norbornene derivatives (Tian *et al.*, 2007). By means of C–H···O hydrogen bonds, the molecules are linked into a ribbon. (Tab. 1, Fig. 2). The two aromatic rings are almost coplanar [dihedral angle 9.25 (10)°]. The dihedral angle between the rings C13—C14—C15—C16—N13 and C7—C8—C9—C10—C11—C12 is 64.32 (7)° (Fig. 1).

Experimental

The title compound was prepared from norbornene dianhydride and 4-azobenzene according to the literature method (Tian *et al.*, 2007). Single crystals were obtained by slow evaporation of a ethanol solution.

Refinement

All hydrogen atoms were located in a difference Fourier map, but they were constrained to ride on their parent atoms with *C*—H_{aryl}, *C*—$H_{methylene}$ and C—$H_{methine-H}$ distances of 0.93, 0.97 and 0.98 Å, respectively. U_{iso}(H) was set to 1.2U_{eq}(C). The two N atoms of the azo moiety are disordered over two sites with occupancies of 0.681 (12) and 0.319 (12). The C—N bond distances of the disordered N atoms were restrained to be equal within 0.01 Å.

Figures

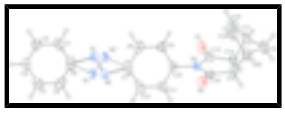


Fig. 1. The molecular structure of the title compound with displacement ellipsoids drawn at the 50% probability level.

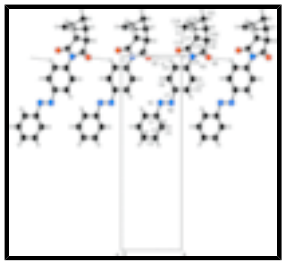


Fig. 2. Crystal packing of the title compound.

N-(4-Azobenzenyl)-5-norbornene-2,3-dicarboximide

Crystal data

$C_{21}H_{17}N_3O_2$	F_{000} = 1440
M_r = 343.38	D_x = 1.318 Mg m^{-3}
Monoclinic, *C*2/*c*	Mo *K*α radiation λ = 0.71073 Å
Hall symbol: -C 2yc	Cell parameters from 1899 reflections
a = 25.190 (2) Å	θ = 3.2–20.8º
b = 6.5076 (5) Å	μ = 0.09 mm^{-1}
c = 24.2792 (19) Å	*T* = 292 (2) K
β = 119.567 (1)º	Block, red
V = 3461.7 (5) Å^3	0.20 × 0.20 × 0.10 mm
Z = 8	

Data collection

CCD area detector diffractometer	2363 reflections with $I > 2\sigma(I)$
Radiation source: fine-focus sealed tube	R_{int} = 0.041
Monochromator: graphite	θ_{max} = 27.0º
T = 292(2) K	θ_{min} = 1.9º
φ and ω scans	*h* = −32→32
Absorption correction: none	*k* = −8→7
13859 measured reflections	*l* = −31→29
3778 independent reflections	

Refinement

Refinement on F^2	Secondary atom site location: difference Fourier map
Least-squares matrix: full	Hydrogen site location: inferred from neighbouring sites
$R[F^2 > 2\sigma(F^2)]$ = 0.059	H-atom parameters constrained
$wR(F^2)$ = 0.139	$w = 1/[\sigma^2(F_o^2) + (0.0477P)^2 + 1.3571P]$ where $P = (F_o^2 + 2F_c^2)/3$
S = 1.06	$(\Delta/\sigma)_{max}$ = 0.001
3778 reflections	$\Delta\rho_{max}$ = 0.16 e Å^{-3}
254 parameters	$\Delta\rho_{min}$ = −0.18 e Å^{-3}
2 restraints	Extinction correction: none
Primary atom site location: structure-invariant direct methods	

Special details

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

Refinement. Refinement of F^2 against ALL reflections. The weighted *R*-factor *wR* and goodness of fit S are based on F^2, conventional *R*-factors *R* are based on F, with F set to zero for negative F^2. The threshold expression of $F^2 > 2\text{sigma}(F^2)$ is used only for calculating *R*-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. *R*-factors based on F^2 are statistically about twice as large as those based on F, and R– factors based on ALL data will be even larger.

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

	x	*y*	*z*	U_{iso}*/U_{eq}	Occ. (<1)
C1	0.08004 (11)	0.3958 (5)	0.69015 (11)	0.0732 (7)	
H1	0.1091	0.3373	0.7281	0.088*	
C2	0.06036 (11)	0.2911 (4)	0.63479 (12)	0.0678 (7)	
H2	0.0767	0.1626	0.6351	0.081*	
C3	0.01680 (10)	0.3736 (4)	0.57875 (10)	0.0602 (6)	
H3	0.0032	0.3005	0.5412	0.072*	
C4	−0.00677 (10)	0.5639 (4)	0.57788 (11)	0.0618 (6)	
H4	−0.0363	0.6205	0.5398	0.074*	
C5	0.01360 (11)	0.6716 (4)	0.63394 (13)	0.0679 (7)	
H5	−0.0022	0.8010	0.6337	0.081*	
C6	0.05724 (11)	0.5864 (4)	0.68998 (11)	0.0688 (7)	
C7	0.09946 (11)	0.8942 (5)	0.82488 (11)	0.0725 (8)	
C8	0.13603 (12)	0.7963 (4)	0.88181 (12)	0.0699 (7)	
H8	0.1504	0.6646	0.8821	0.084*	
C9	0.15139 (10)	0.8937 (3)	0.93864 (10)	0.0558 (6)	
H9	0.1767	0.8295	0.9771	0.067*	
C10	0.12857 (8)	1.0860 (3)	0.93703 (9)	0.0430 (5)	
C11	0.09270 (9)	1.1846 (4)	0.88030 (9)	0.0554 (6)	
H11	0.0779	1.3159	0.8798	0.067*	
C12	0.07893 (10)	1.0891 (5)	0.82462 (10)	0.0707 (7)	
H12	0.0555	1.1570	0.7864	0.085*	
C13	0.12212 (9)	1.1082 (3)	1.03599 (9)	0.0504 (5)	
C14	0.14222 (9)	1.2552 (3)	1.09033 (9)	0.0522 (6)	
H14	0.1070	1.3146	1.0914	0.063*	
C15	0.17851 (9)	1.4214 (3)	1.07873 (9)	0.0522 (5)	
H15	0.1604	1.5573	1.0756	0.063*	
C16	0.17573 (9)	1.3640 (3)	1.01730 (9)	0.0470 (5)	
C17	0.18936 (10)	1.1676 (4)	1.15637 (9)	0.0629 (6)	
H17	0.1725	1.0893	1.1787	0.075*	
C18	0.23697 (11)	1.0607 (4)	1.14686 (10)	0.0648 (7)	
H18	0.2435	0.9197	1.1484	0.078*	
C19	0.26790 (10)	1.2020 (4)	1.13589 (10)	0.0639 (6)	
H19	0.2998	1.1786	1.1278	0.077*	

C20	0.24259 (10)	1.4069 (4)	1.13884 (10)	0.0607 (6)	
H20	0.2696	1.5250	1.1471	0.073*	
C21	0.22356 (11)	1.3637 (4)	1.18850 (11)	0.0750 (7)	
H21A	0.2580	1.3396	1.2304	0.090*	
H21B	0.1972	1.4693	1.1902	0.090*	
N1	0.08481 (19)	0.6515 (8)	0.7579 (2)	0.0587 (14)	0.681 (12)
N2	0.07375 (17)	0.8321 (8)	0.75791 (19)	0.0555 (14)	0.681 (12)
N1'	0.0608 (4)	0.7694 (12)	0.7278 (5)	0.053 (3)	0.319 (12)
N2'	0.0990 (4)	0.7111 (15)	0.7852 (4)	0.054 (3)	0.319 (12)
N3	0.14098 (7)	1.1850 (2)	0.99484 (7)	0.0426 (4)	
O1	0.09449 (8)	0.9498 (3)	1.02764 (7)	0.0773 (5)	
O2	0.19937 (8)	1.4485 (2)	0.99100 (8)	0.0686 (5)	

Atomic displacement parameters (Å^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
C1	0.0621 (14)	0.108 (2)	0.0493 (14)	0.0060 (14)	0.0272 (11)	−0.0015 (14)
C2	0.0740 (16)	0.0677 (16)	0.0706 (17)	0.0052 (13)	0.0426 (14)	−0.0057 (13)
C3	0.0613 (13)	0.0777 (17)	0.0491 (13)	−0.0168 (12)	0.0331 (11)	−0.0194 (12)
C4	0.0522 (13)	0.0806 (17)	0.0563 (14)	−0.0011 (12)	0.0296 (11)	0.0076 (13)
C5	0.0664 (15)	0.0599 (15)	0.101 (2)	−0.0058 (12)	0.0591 (15)	−0.0159 (14)
C6	0.0588 (14)	0.099 (2)	0.0625 (15)	−0.0196 (14)	0.0404 (13)	−0.0319 (15)
C7	0.0657 (15)	0.113 (2)	0.0516 (15)	−0.0391 (15)	0.0388 (13)	−0.0333 (15)
C8	0.0912 (18)	0.0579 (15)	0.0824 (18)	−0.0183 (13)	0.0594 (16)	−0.0232 (14)
C9	0.0693 (14)	0.0482 (13)	0.0553 (13)	−0.0041 (11)	0.0349 (11)	−0.0018 (11)
C10	0.0445 (10)	0.0465 (12)	0.0406 (11)	−0.0080 (9)	0.0229 (9)	−0.0039 (9)
C11	0.0469 (11)	0.0739 (15)	0.0454 (12)	0.0032 (10)	0.0227 (10)	0.0055 (11)
C12	0.0510 (13)	0.119 (2)	0.0402 (12)	−0.0088 (14)	0.0210 (10)	−0.0045 (14)
C13	0.0465 (11)	0.0610 (14)	0.0441 (11)	−0.0087 (10)	0.0226 (9)	−0.0034 (10)
C14	0.0428 (11)	0.0709 (15)	0.0468 (12)	0.0027 (10)	0.0251 (9)	−0.0102 (10)
C15	0.0613 (13)	0.0399 (12)	0.0546 (12)	0.0064 (10)	0.0279 (10)	−0.0065 (10)
C16	0.0519 (12)	0.0352 (11)	0.0517 (12)	0.0022 (9)	0.0238 (10)	0.0038 (9)
C17	0.0655 (14)	0.0846 (17)	0.0416 (12)	−0.0100 (13)	0.0286 (11)	−0.0020 (12)
C18	0.0693 (15)	0.0596 (15)	0.0498 (13)	0.0124 (12)	0.0174 (11)	0.0061 (11)
C19	0.0440 (12)	0.0839 (18)	0.0554 (13)	0.0080 (12)	0.0181 (10)	−0.0037 (13)
C20	0.0565 (13)	0.0640 (15)	0.0551 (13)	−0.0147 (11)	0.0226 (11)	−0.0184 (11)
C21	0.0697 (15)	0.099 (2)	0.0496 (13)	−0.0036 (14)	0.0244 (12)	−0.0237 (14)
N1	0.061 (3)	0.067 (3)	0.047 (3)	0.010 (2)	0.025 (2)	0.000 (2)
N2	0.057 (2)	0.062 (3)	0.046 (3)	−0.0013 (17)	0.025 (2)	0.0017 (19)
N1'	0.052 (4)	0.067 (6)	0.030 (5)	0.005 (4)	0.014 (4)	−0.007 (4)
N2'	0.056 (5)	0.068 (7)	0.024 (5)	0.003 (4)	0.010 (4)	−0.009 (4)
N3	0.0480 (9)	0.0428 (10)	0.0373 (8)	−0.0031 (7)	0.0213 (7)	−0.0001 (7)
O1	0.0894 (12)	0.0902 (13)	0.0616 (10)	−0.0448 (10)	0.0443 (9)	−0.0165 (9)
O2	0.0898 (11)	0.0520 (9)	0.0711 (10)	−0.0171 (8)	0.0450 (9)	0.0034 (8)

Geometric parameters (Å, °)

C1—C2	1.363 (3)	C12—H12	0.9300
C1—C6	1.366 (4)	C13—O1	1.204 (2)

C1—H1	0.9300	C13—N3	1.393 (2)
C2—C3	1.368 (3)	C13—C14	1.501 (3)
C2—H2	0.9300	C14—C15	1.529 (3)
C3—C4	1.369 (3)	C14—C17	1.558 (3)
C3—H3	0.9300	C14—H14	0.9800
C4—C5	1.385 (3)	C15—C16	1.505 (3)
C4—H4	0.9300	C15—C20	1.555 (3)
C5—C6	1.375 (3)	C15—H15	0.9800
C5—H5	0.9300	C16—O2	1.200 (2)
C6—N1'	1.480 (7)	C16—N3	1.397 (2)
C6—N1	1.500 (5)	C17—C18	1.499 (3)
C7—C12	1.369 (4)	C17—C21	1.522 (3)
C7—C8	1.381 (4)	C17—H17	0.9800
C7—N2	1.479 (5)	C18—C19	1.314 (3)
C7—N2'	1.529 (9)	C18—H18	0.9300
C8—C9	1.389 (3)	C19—C20	1.495 (3)
C8—H8	0.9300	C19—H19	0.9300
C9—C10	1.370 (3)	C20—C21	1.528 (3)
C9—H9	0.9300	C20—H20	0.9800
C10—C11	1.377 (3)	C21—H21A	0.9700
C10—N3	1.432 (2)	C21—H21B	0.9700
C11—C12	1.368 (3)	N1—N2	1.207 (9)
C11—H11	0.9300	N1'—N2'	1.298 (18)
C2—C1—C6	120.2 (2)	C15—C14—C17	103.14 (16)
C2—C1—H1	119.9	C13—C14—H14	110.9
C6—C1—H1	119.9	C15—C14—H14	110.9
C1—C2—C3	120.5 (2)	C17—C14—H14	110.9
C1—C2—H2	119.7	C16—C15—C14	105.49 (16)
C3—C2—H2	119.7	C16—C15—C20	115.72 (17)
C2—C3—C4	120.0 (2)	C14—C15—C20	102.83 (17)
C2—C3—H3	120.0	C16—C15—H15	110.8
C4—C3—H3	120.0	C14—C15—H15	110.8
C3—C4—C5	119.7 (2)	C20—C15—H15	110.8
C3—C4—H4	120.2	O2—C16—N3	123.68 (19)
C5—C4—H4	120.2	O2—C16—C15	128.39 (19)
C6—C5—C4	119.7 (2)	N3—C16—C15	107.92 (17)
C6—C5—H5	120.1	C18—C17—C21	100.03 (19)
C4—C5—H5	120.1	C18—C17—C14	105.81 (17)
C1—C6—C5	119.9 (2)	C21—C17—C14	99.88 (18)
C1—C6—N1'	146.4 (5)	C18—C17—H17	116.2
C5—C6—N1'	93.7 (5)	C21—C17—H17	116.2
C1—C6—N1	106.7 (3)	C14—C17—H17	116.2
C5—C6—N1	133.2 (3)	C19—C18—C17	107.8 (2)
C12—C7—C8	119.7 (2)	C19—C18—H18	126.1
C12—C7—N2	106.8 (3)	C17—C18—H18	126.1
C8—C7—N2	133.5 (3)	C18—C19—C20	107.7 (2)
C12—C7—N2'	146.5 (5)	C18—C19—H19	126.1
C8—C7—N2'	93.8 (5)	C20—C19—H19	126.1
C7—C8—C9	120.4 (2)	C19—C20—C21	100.4 (2)

C7—C8—H8	119.8	C19—C20—C15	106.20 (17)
C9—C8—H8	119.8	C21—C20—C15	99.63 (18)
C10—C9—C8	118.8 (2)	C19—C20—H20	116.1
C10—C9—H9	120.6	C21—C20—H20	116.1
C8—C9—H9	120.6	C15—C20—H20	116.1
C9—C10—C11	120.9 (2)	C17—C21—C20	93.94 (17)
C9—C10—N3	119.84 (18)	C17—C21—H21A	112.9
C11—C10—N3	119.27 (18)	C20—C21—H21A	112.9
C12—C11—C10	119.8 (2)	C17—C21—H21B	112.9
C12—C11—H11	120.1	C20—C21—H21B	112.9
C10—C11—H11	120.1	H21A—C21—H21B	110.4
C11—C12—C7	120.4 (2)	N2—N1—C6	107.1 (4)
C11—C12—H12	119.8	N1—N2—C7	106.9 (4)
C7—C12—H12	119.8	N2'—N1'—C6	102.5 (7)
O1—C13—N3	124.03 (19)	N1'—N2'—C7	102.7 (8)
O1—C13—C14	127.59 (19)	C13—N3—C16	112.89 (16)
N3—C13—C14	108.38 (18)	C13—N3—C10	123.70 (16)
C13—C14—C15	105.19 (16)	C16—N3—C10	123.35 (16)
C13—C14—C17	115.26 (18)		
C6—C1—C2—C3	−1.3 (4)	C14—C17—C18—C19	69.5 (2)
C1—C2—C3—C4	0.9 (4)	C17—C18—C19—C20	0.9 (2)
C2—C3—C4—C5	−0.2 (3)	C18—C19—C20—C21	32.3 (2)
C3—C4—C5—C6	−0.1 (3)	C18—C19—C20—C15	−71.1 (2)
C2—C1—C6—C5	1.0 (4)	C16—C15—C20—C19	−48.1 (3)
C2—C1—C6—N1'	−174.7 (6)	C14—C15—C20—C19	66.3 (2)
C2—C1—C6—N1	176.3 (3)	C16—C15—C20—C21	−152.03 (19)
C4—C5—C6—C1	−0.3 (4)	C14—C15—C20—C21	−37.6 (2)
C4—C5—C6—N1'	177.3 (3)	C18—C17—C21—C20	49.8 (2)
C4—C5—C6—N1	−174.1 (3)	C14—C17—C21—C20	−58.39 (19)
C12—C7—C8—C9	0.8 (3)	C19—C20—C21—C17	−49.44 (19)
N2—C7—C8—C9	−177.6 (3)	C15—C20—C21—C17	59.2 (2)
N2'—C7—C8—C9	−178.1 (4)	C1—C6—N1—N2	168.1 (3)
C7—C8—C9—C10	1.4 (3)	C5—C6—N1—N2	−17.6 (5)
C8—C9—C10—C11	−2.2 (3)	N1'—C6—N1—N2	−4.2 (6)
C8—C9—C10—N3	176.58 (18)	C6—N1—N2—C7	178.4 (3)
C9—C10—C11—C12	0.8 (3)	C12—C7—N2—N1	−170.9 (3)
N3—C10—C11—C12	−177.98 (18)	C8—C7—N2—N1	7.7 (5)
C10—C11—C12—C7	1.5 (3)	N2'—C7—N2—N1	8.4 (6)
C8—C7—C12—C11	−2.2 (3)	C1—C6—N1'—N2'	−7.1 (10)
N2—C7—C12—C11	176.6 (2)	C5—C6—N1'—N2'	176.6 (6)
N2'—C7—C12—C11	175.8 (7)	N1—C6—N1'—N2'	6.4 (6)
O1—C13—C14—C15	176.6 (2)	C6—N1'—N2'—C7	−176.3 (5)
N3—C13—C14—C15	−3.3 (2)	C12—C7—N2'—N1'	−4.1 (11)
O1—C13—C14—C17	63.8 (3)	C8—C7—N2'—N1'	174.2 (6)
N3—C13—C14—C17	−116.16 (19)	N2—C7—N2'—N1'	−5.3 (5)
C13—C14—C15—C16	1.6 (2)	O1—C13—N3—C16	−175.9 (2)
C17—C14—C15—C16	122.73 (17)	C14—C13—N3—C16	4.0 (2)
C13—C14—C15—C20	−120.09 (17)	O1—C13—N3—C10	1.3 (3)
C17—C14—C15—C20	1.1 (2)	C14—C13—N3—C10	−178.78 (16)

C14—C15—C16—O2	−177.8 (2)	O2—C16—N3—C13	175.6 (2)
C20—C15—C16—O2	−64.9 (3)	C15—C16—N3—C13	−2.9 (2)
C14—C15—C16—N3	0.6 (2)	O2—C16—N3—C10	−1.7 (3)
C20—C15—C16—N3	113.55 (19)	C15—C16—N3—C10	179.84 (16)
C13—C14—C17—C18	46.5 (2)	C9—C10—N3—C13	−62.1 (3)
C15—C14—C17—C18	−67.5 (2)	C11—C10—N3—C13	116.6 (2)
C13—C14—C17—C21	150.03 (18)	C9—C10—N3—C16	114.8 (2)
C15—C14—C17—C21	36.0 (2)	C11—C10—N3—C16	−66.4 (2)
C21—C17—C18—C19	−33.9 (2)		

Hydrogen-bond geometry (Å, °)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
C9—H9···O2^{i}	0.93	2.53	3.155 (3)	125

Symmetry codes: (i) *x*, *y*−1, *z*.

Fig. 1

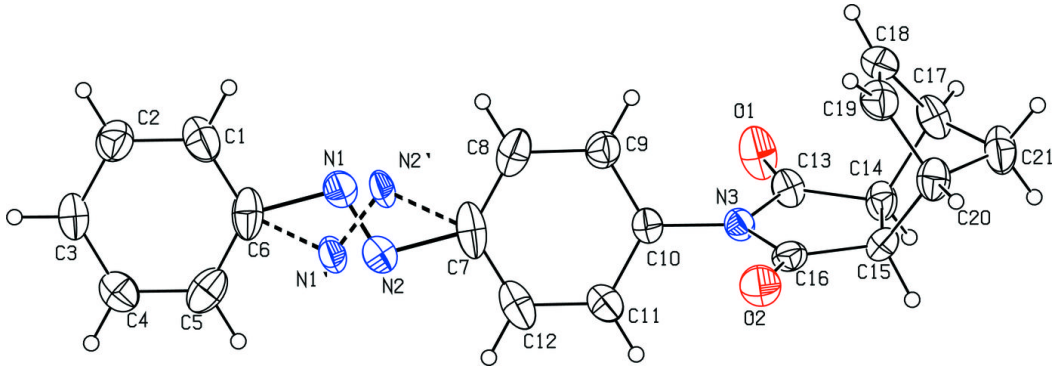
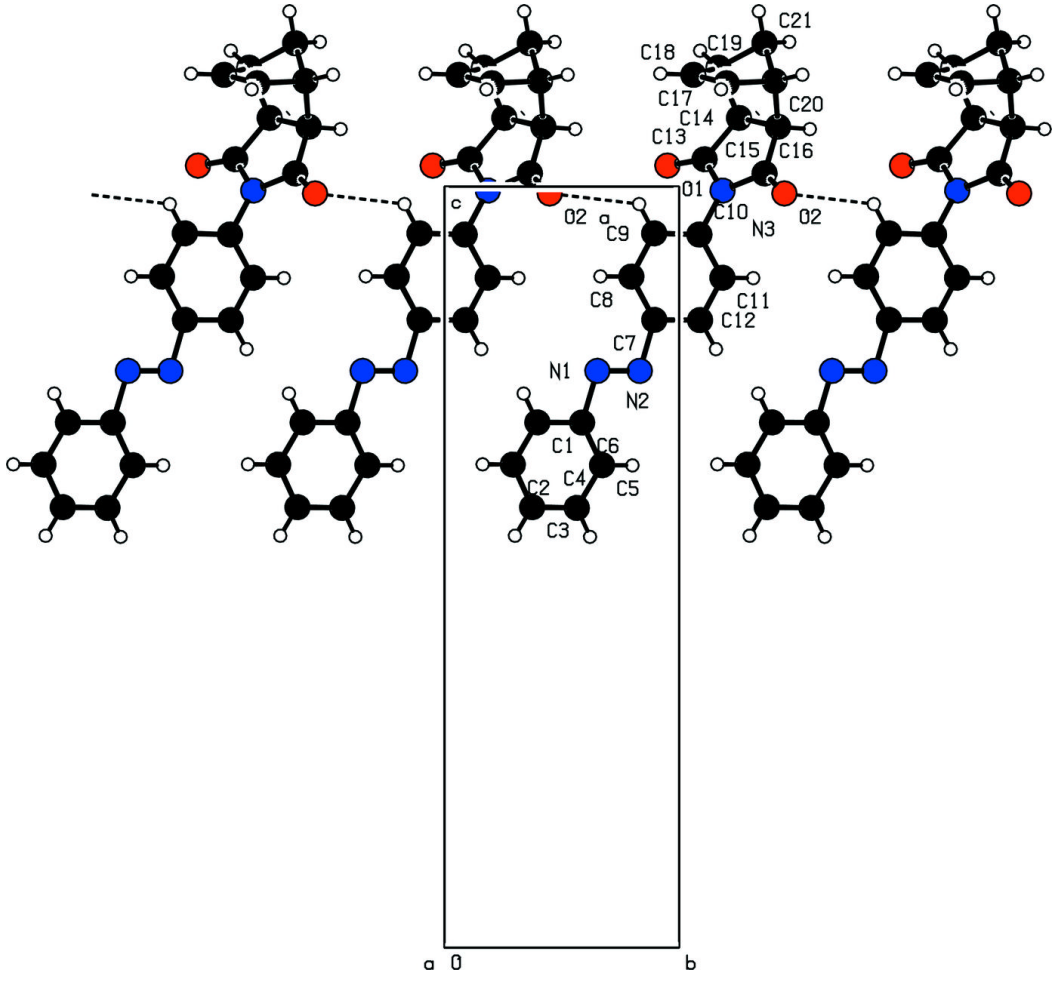

C18
C17
C19
O1
C21
C2
C1
N1
N2'
C8
C9
C13
C14
N3
C20
C3
C6
N1'
N2
C7
C10
C16
C15
C4
C5
C12
C11
O2

Fig. 2


C21
C18
C19
C17
C20
C14
C13
C15
C16
O1
C10
N3
O2
O2
C9
C8
C11
C12
C7
N1
N2
C1
C6
C4
C5
C2
C3
c
a
a
0
b