

## 3,5-Diphenyl-1,2,4-triazin-6(1*H*)-one: synthesis, and X-ray and DFT-calculated structures

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Received 20 January 2012

Accepted 24 February 2012

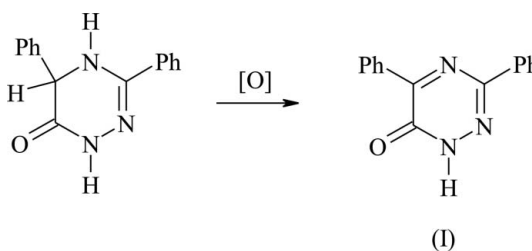
Online 3 March 2012

The title compound, C<sub>15</sub>H<sub>11</sub>N<sub>3</sub>O, (I), was obtained by the air oxidation of 3,5-diphenyl-4,5-dihydro-1,2,4-triazin-6(1*H*)-one. In the crystal structure, (I) forms centrosymmetric hydrogen-bonded dimers through pairs of N—H···N hydrogen bonds. The molecular structure of (I) deviates somewhat from planarity in the crystalline state, whereas a density functional theory (DFT) study predicts a completely planar conformation (C<sub>s</sub> point-group symmetry) for the isolated molecule. The solid-state conformation of (I) is stabilized by intramolecular hydrogen bonds, *viz.* one C—H···O interaction, which forms a six-membered ring, and three C—H···N interactions that each form five-membered rings. To estimate the influence of the intramolecular hydrogen-bonded rings on the aromaticity of the phenyl rings, the HOMA (harmonic oscillator model of aromaticity) descriptor of  $\pi$ -electron delocalization has been calculated for conformations of (I) with and without intramolecular hydrogen bonds. In the planar conformation of (I), the HOMA values for both benzene rings are lower than in hypothetical conformations without intramolecular hydrogen bonds.

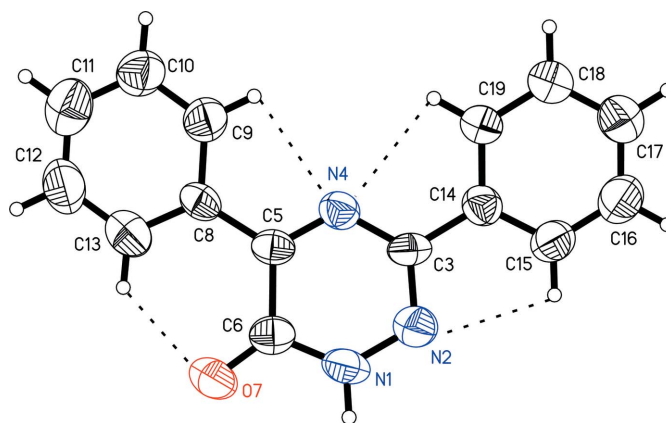
### Comment

1,2,4-Triazine derivatives display a broad spectrum of biological activity and have numerous applications in many fields. They are thus compounds of general interest (Neunhoeffer, 1996). They are applied in medicine as potential antibacterial and antifungal agents, in the agrochemical industry as plant-protection materials, and as components of commercial dyes (Abdel Hamide, 1997; Freidinger *et al.*, 1993; Ackerman, 2007; Bettati *et al.*, 2002). A wide range of synthetic procedures have been reported for the related 1,2,4-triazin-6-ones. They are commonly prepared from acid hydrazides (Zhao *et al.*, 2003), amides (Blass *et al.*, 2002) or iminoesters (Martinez-Teipel *et al.*, 2001; Kammoun *et al.*, 2000), or from small heterocyclic

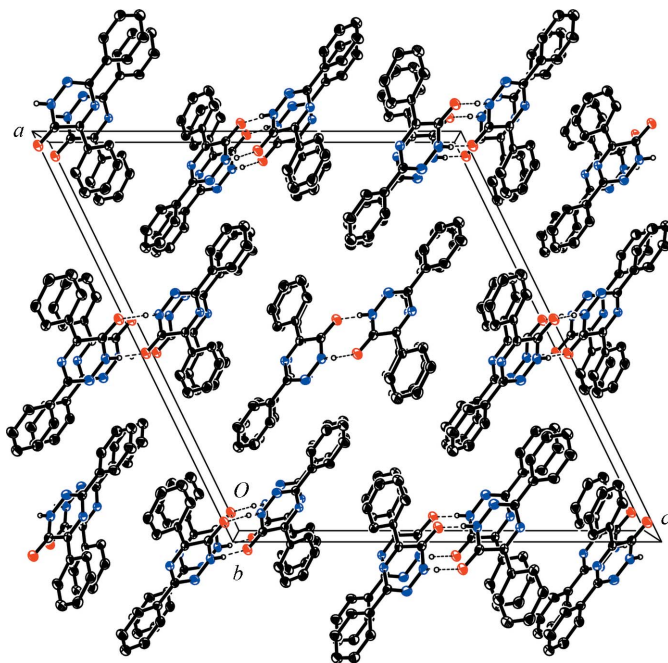
azirine structures (Nishiwaki & Saito, 1970). Recently, whilst investigating the reactions of optically active  $\alpha$ -aminocarboxylic acid hydrazides with triethyl orthoesters, we obtained two groups of products: five-membered 2-(1-amino-1-phenylmethyl)-1,3,4-oxadiazoles and six-membered 5-substituted 3-phenyl-1,2,4-triazin-6-ones (Kudelko *et al.*, 2011). One of the by-products, separated from the post-reaction mixture in low yields, was the title compound, (I). A literature survey revealed that similar compounds are usually constructed *via* oxidation of the appropriate 4,5-dihydro-1,2,4-triazin-6(1*H*)-ones with the use of mild oxidizing agents such as 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ; Miesel, 1982). We believe that (I) was formed by the air oxidation of 3,5-diphenyl-4,5-dihydro-1,2,4-triazin-6(1*H*)-one, as it was exposed to the atmosphere whilst standing in ethanol solution for 10 d. A search of the Cambridge Structural Database (CSD; *ConQuest* Version 1.13; Allen, 2002) afforded only a few examples of 3,5-disubstituted 1,2,4-triazin-6(1*H*)-one derivatives (Buscemi *et al.*, 2006; Garg & Stoltz, 2005; Sanudo *et al.*, 2006; Trávníček *et al.*, 1995). Therefore, the synthesis and structural characterization of (I) are reported herein.



The molecular structure of (I) and the atomic numbering scheme are presented in Fig. 1, and the packing arrangement in the crystal state is presented in Fig. 2. The main intermolecular interaction consists of centrosymmetric dimers formed by pairs of N—H···O hydrogen bonds (Table 2). The molecular structure of (I) consists of three rings: *A* (the phenyl ring containing atoms C8–C13), *B* (the triazine ring containing



**Figure 1**  
The molecular structure of (I), showing the atom-numbering scheme. Displacement ellipsoids are drawn at the 50% probability level. Dashed lines indicate intramolecular hydrogen bonds.



**Figure 2**  
A packing diagram for (I), showing the  $N1-H1 \cdots O7^i$  hydrogen bonds as dashed lines. [Symmetry code: (i)  $-x + 1, -y + 2, -z + 1$ .]

atoms  $N1/N2/C3/N4/C5/C6$ ) and  $C$  (the phenyl ring containing atoms from  $C14-C19$ ). These are nearly coplanar in the crystalline state, with the angles between the ring planes for  $A/B$  and  $B/C$  being similar [ $8.6(2)$  and  $8.4(2)^\circ$ , respectively]. The  $A$  and  $C$  planes are arranged in a mutually *cis* position. The twists (described by torsion angles) around the  $C3-C14$  and  $C5-C8$  bonds are less than  $10^\circ$  (Table 1). These small deformations from planarity probably result from the intermolecular interactions present in the crystal lattice. A density functional theory (DFT) study predicts a completely planar conformation ( $C_s$  point-group symmetry) as the preferred one for the isolated molecule of (I). See *Supplementary materials* for further details of the DFT calculations.

The near planarity of the system favours the formation of intramolecular hydrogen bonds and  $\pi$ -electron delocalization. The molecular structure of (I) contains four weak intramolecular hydrogen bonds (Fig. 1 and Table 2); one  $C-H \cdots O$  interaction, which forms a six-membered ring, and three  $C-H \cdots N$  interactions that form five-membered rings, denoted quasi-rings. The resulting rings can be investigated as molecular patterns of intramolecular resonance assisted by hydrogen bonds. The position of the extra ring formed by the substituent interacting through the hydrogen bond is found to influence both the strength of that hydrogen bond and the local aromaticity of the polycyclic aromatic hydrocarbon skeleton. Relatively speaking, a greater loss of aromaticity of the *ipso*-ring (phenyl ring) can be observed for these kinked-like structures because of the greater participation of  $\pi$ -electrons from the *ipso*-ring in the formation of the quasi-ring (Krygowski *et al.*, 2010; Palusiak *et al.*, 2009).

The harmonic oscillator model of aromaticity (HOMA) is a leading method for the quantitative determination of cyclic

$\pi$ -electron delocalization in chemical compounds. It is based on the geometric criterion of aromaticity, which stipulates that bond lengths in aromatic systems lie between values that are typical for single and double bonds (Kruszewski & Krygowski, 1973; Krygowski, 1993). Therefore,  $HOMA = 0$  for a model non-aromatic system (*e.g.* the Kekulé structure of benzene) and  $HOMA = 1$  for a system with all bonds equal to the optimal value, assumed to be realised for fully aromatic systems. The HOMA value (based on B3LYP/6-311++G\*\* optimized geometries) calculated for ring  $A$  (0.960) is lower than that of ring  $C$  (0.979). This loss of aromaticity of ring  $A$  is caused by both the electron-withdrawing properties of the neighbouring carbonyl group and the above-mentioned interactions with the quasi-rings formed by intramolecular hydrogen bonds, in particular by  $C13-H13 \cdots O7$ . Breaking the intramolecular hydrogen bonds by a twist of  $90^\circ$  around the  $C5-C8$  bond results in an increase in energy of  $5.65 \text{ kcal mol}^{-1}$  ( $1 \text{ kcal mol}^{-1} = 4.184 \text{ kJ mol}^{-1}$ ), based on the B3LYP/6-311++G\*\* calculations, as well as an increase in the aromaticity of ring  $A$  ( $HOMA = 0.989$ ). The aromaticity of ring  $C$  remains almost unchanged ( $HOMA = 0.978$ ).

Similar sequences of values were obtained for a twist about the  $C3-C14$  bond. In this case, the increase in energy is  $5.22 \text{ kcal mol}^{-1}$ , and the HOMA value rises to 0.988 for ring  $C$  and decreases to 0.958 for ring  $A$ . Finally, in a hypothetical conformation without intramolecular hydrogen bonds, *viz.* with both phenyl groups perpendicular to the triazine ring, the energy is higher by  $11.75 \text{ kcal mol}^{-1}$  and the HOMA index is the same for rings  $A$  and  $C$  (0.989).

Note that there are no significant differences between the values of the bond lengths and angles of (I) in the solid state and those found for the calculated planar structure; the differences do not exceed  $0.02 \text{ \AA}$  for bond distances and  $2^\circ$  for bond angles. All bond distances and angles are normal (Table 1) and are in good agreement with the geometry of other 3,5-disubstituted 1,2,4-triazin-6(1*H*)-one derivatives (Buscemi *et al.*, 2006; Garg & Stoltz, 2005; Sanudo *et al.*, 2006; Trávníček *et al.*, 1995).

## Experimental

$D(-)\alpha$ -Phenylglycine hydrazide (3.30 g, 20 mmol) was added to a mixture of triethyl orthobenzoate (4.57 g, 20 mmol) and *p*-toluenesulfonic acid (0.1 g) in xylene (20 ml) and the resulting solution kept under reflux for 3 h (monitored by thin-layer chromatography). After cooling, the mixture was washed with water (30 ml), dried over  $MgSO_4$  and then concentrated under reduced pressure. The oily residue was subjected to column chromatography (silica gel; eluent: hexane–AcOEt, 1:2 *v/v*), yielding 3,5-diphenyl-4,5-dihydro-1,2,4-triazin-6(1*H*)-one (2.60 g). This crude product was dissolved in ethanol (50 ml) and left in solution for 10 d at room temperature. Yellow needles of (I) were filtered off and dried in air [yield 0.35 g, 14%; m.p. 494–495 K, reference 491–493 K (Camparini *et al.*, 1978)]. Due to the fact that the oxidation of 3,5-diphenyl-4,5-dihydro-1,2,4-triazin-6(1*H*)-one occurred simultaneously with the crystallization of (I), the crystals of (I) obtained were of poor quality (cracked) and weakly diffracting.

**Table 1**  
Selected geometric parameters (Å, °).

N1—C6	1.365 (3)	C3—N4	1.357 (3)
N1—N2	1.364 (3)	N4—C5	1.276 (3)
N2—C3	1.321 (3)	C5—C6	1.497 (4)
C6—N1—N2	126.8 (3)	C5—N4—C3	122.2 (3)
C3—N2—N1	115.3 (3)	N4—C5—C6	119.8 (4)
N2—C3—N4	123.5 (3)	N1—C6—C5	112.3 (3)
N4—C5—C8—C13	170.8 (3)	N2—C3—C14—C19	−171.6 (3)
C6—C5—C8—C13	−7.3 (5)	N4—C3—C14—C19	8.8 (5)
N4—C5—C8—C9	−8.9 (4)	N2—C3—C14—C15	5.8 (5)
C6—C5—C8—C9	173.0 (3)	N4—C3—C14—C15	−173.8 (3)

**Table 2**  
Hydrogen-bond geometry (Å, °).

D—H...A	D—H	H...A	D...A	D—H...A
N1—H1...O7 <sup>i</sup>	0.86	1.93	2.787 (3)	171
C13—H13...O7	0.93	2.21	2.871 (5)	127
C15—H15...N2	0.93	2.45	2.757 (5)	99
C9—H9...N4	0.93	2.41	2.740 (5)	101
C19—H19...N4	0.93	2.46	2.801 (5)	102

Symmetry code: (i)  $-x + 1, -y + 2, -z + 1$ .**Crystal data**

$C_{15}H_{11}N_3O$	$V = 2483.5 (9) \text{ \AA}^3$
$M_r = 249.27$	$Z = 8$
Monoclinic, $C2/c$	Mo $K\alpha$ radiation
$a = 22.975 (5) \text{ \AA}$	$\mu = 0.09 \text{ mm}^{-1}$
$b = 5.5835 (10) \text{ \AA}$	$T = 293 \text{ K}$
$c = 21.550 (5) \text{ \AA}$	$0.22 \times 0.18 \times 0.15 \text{ mm}$
$\beta = 116.06 (3)^\circ$	

**Data collection**

Oxford Xcalibur diffractometer	703 reflections with $I > 2\sigma(I)$
7417 measured reflections	$R_{\text{int}} = 0.084$
2174 independent reflections	

**Refinement**

$R[F^2 > 2\sigma(F^2)] = 0.047$	172 parameters
$wR(F^2) = 0.050$	H-atom parameters constrained
$S = 0.96$	$\Delta\rho_{\text{max}} = 0.14 \text{ e \AA}^{-3}$
2174 reflections	$\Delta\rho_{\text{min}} = -0.15 \text{ e \AA}^{-3}$

Based on the solid-state geometry, the molecular structure of (I) was optimized using standard density functional theory (DFT) employing the B3LYP hybrid function (Becke, 1988; 1993; Lee *et al.*, 1988) at the 6-311++G\*\* level of theory. All species corresponded to minima at the B3LYP/6-311++G\*\* level with no imaginary frequencies. All calculations were performed using the GAUSSIAN09 program package (Frisch *et al.*, 2010). Further details are given in the *Supplementary materials*.

All H atoms were generated in idealized positions and then refined in riding mode. For aromatic C atoms, C—H = 0.93 Å and  $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ . For the amide NH group, N—H = 0.86 Å and  $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{N})$ .

Data collection: *CrysAlis CCD* (Oxford Diffraction, 2008); cell refinement: *CrysAlis RED* (Oxford Diffraction, 2008); data reduction: *CrysAlis RED*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXL97*.

The Interdisciplinary Centre for Mathematical and Computational Modelling (Warsaw) is acknowledged for providing computational facilities (grant ID G33-17).

Supplementary data for this paper are available from the IUCr electronic archives (Reference: KY3010). Services for accessing these data are described at the back of the journal.

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