Generation and Dienophilic Properties of 1-Benzyl-1*H*-1,2,3-triazolo[4,5-*d*]pyridazine-4,7-dione

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1-Benzyl-5,6-dihydro-1*H*-1,2,3-triazolo[4,5-*d*]pyridazine-4,7-dione (**1**) by oxidation with lead tetraacetate afforded the corresponding triazolopyridazine-4,7-dione **2** as the intermediate, which was trapped with several dienes giving the hetero-Diels-Alder adducts **3** in good yields. The structure of the cycloadduct **3a** was determined by X-ray analysis.

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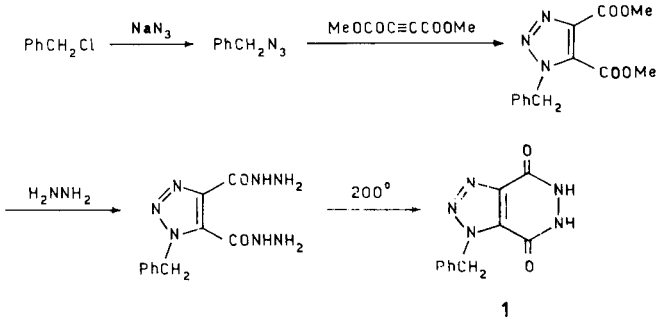
The oxidation of 1,2-dihydropyridazine-3,6-diones with several oxidizing agents [1-3] leads to the formation of the corresponding pyridazine-3,6-diones, which are unstable but also, like other cyclic diacyldiimides, some of the most reactive dienophiles [4].

As a further study on the 1,2,3-triazole chemistry [5] we synthesized the condensed dihydro-1,2,3-triazolopyridazine derivative **1** in order to examine the dienophilic properties of the expected diazaquinone **2** formed *in situ* upon oxidation of **1**, as well as its probable chemiluminescent properties.

The parent compound 1-benzyl-5,6-dihydro-1*H*-1,2,3-triazolo[4,5-*d*]pyridazine-4,7-dione (**1**) was prepared in very good yield by a modification of the method reported for the analogous 1-phenyl derivative [6], with the sequence of the reactions shown in Scheme 1.

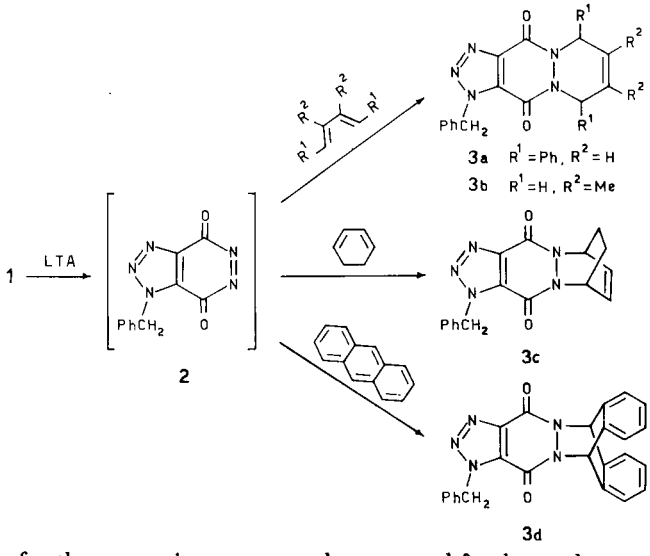
Scheme 1



The oxidation of **1** to the corresponding diazaquinone **2** was carried out with lead tetraacetate (LTA) in dichloromethane and in the presence of several dienes. These reactions (Scheme 2) afforded the expected [7] hetero-Diels-Alder adducts **3a-d** in moderate yields, which provide evidence for the generation of **2**.

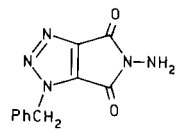
The cycloadducts **3** exhibit in ir spectra two carbonyl absorptions a weak at 1690-1705 cm^{-1} and a strong one at 1650-1675 cm^{-1}. In the ^1H-nmr they give resonance signals

Scheme 2



for the aromatic protons at the expected δ values, whereas the methinic protons adjacent to the pyridazinedione ring in **3a** and **3c** resonate at 6.40 and 6.64 δ respectively. In **3d** the same protons resonate into the aromatic region in agreement with other similar literature data [1,2,8]. The methylenic protons in **3b** resonate at 4.45 δ [9]. In the mass spectra the cycloadducts **3** show ion peaks for the molecular ion $M^{+\cdot}$ and also peaks corresponding to $[M-CO]^+$ and $[M-CO-N_2]^+$ as well as to the retro-Diels-Alder ion fragments [10].

The problem of tautomerism in several pyridazinedione systems has been extensively studied [4,11] and concerning the parent compound **1** it is also possible to adopt the *N*-aminophthalimide form **4** [12,13]. For these reasons the structure of the cycloadduct **3a** was examined by X-ray crystallographic analysis which completely confirms the



proposed form. The molecular structure of 1-benzyl-6,9-diphenyl-4,6,9,11-tetrahydropyridazino[1,2-*a*][1,2,3]triazolo[4,5-*d*]pyridazine-4,11-dione (**3a**) is shown in Figure 1. The triazole and pyridazinedione rings in **3a** are almost coplanar, whereas the dihedral angle formed by the planes C1C4N1N2C5C8 (plane *1*) and C1C2C3C4 is equal to 18.8°. However it has been found [14] that in other pyridazinedione systems the two rings are not coplanar. The plane of the benzene ring attached to C1 forms with plane *1* a dihedral angle of 100.8°, whereas the corresponding dihedral angle between plane *1* and benzene ring attached to C4 is equal to 70.0° and the two benzene rings form an angle equal to 45.9°. The dihedral angle formed by the planes of the triazole ring and the attached benzyl ring is equal to 105.6°. The positional parameters and selected bond lengths and angles are given in Tables 1 and 2 respectively.

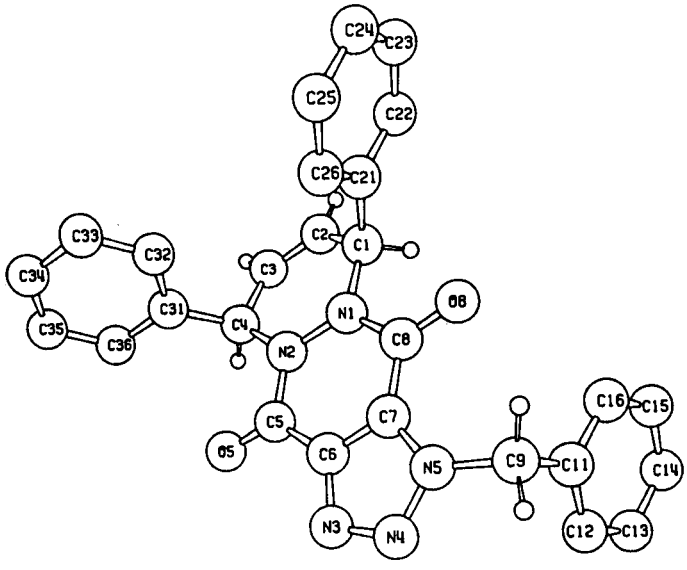


Figure 1. Crystal structure of the 1-benzyl-6,9-diphenyl-4,6,9,11-tetrahydropyridazino[1,2-*a*][1,2,3]triazolo[4,5-*d*]pyridazine-4,11-dione (**3a**), showing the atomic numbering used in this X-ray study.

The compound **1** also examined for its chemiluminescent properties by carrying out the oxidation in absence of dienes. Preliminary experiments showed that by oxidation of **1** with hydrogen peroxide and sodium hypochloride an emission of light is observed with a quantum yield about the 25% of that recorded for luminol under the same experimental conditions [15]. These experiments are, however, under further consideration.

X-Ray Analysis of Compound **3a**.

The compound **3a**, $C_{27}H_{21}N_5O_2$, M = 447.48, crystallizes (from chloroform-carbon tetrachloride) as monoclinic crystals, mp 155-158°; space group $P2_1/n$ ($P2_1/c$), a = 14.053(2), b = 8.464(1), c = 18.937(3) Å, β = 98.38(2)°, z

Table 1

Positional Parameters (x10^4) for the Non-Hydrogen Atoms of **3a**

Atom	X	Y	Z
C(1)	1441(2)	3236(3)	2070(1)
C(2)	999(2)	4703(3)	2302(1)
C(3)	192(2)	5295(3)	1979(1)
C(4)	-392(2)	4591(3)	1341(1)
C(5)	-200(2)	3095(3)	286(1)
C(6)	370(2)	1997(3)	-56(1)
C(7)	1189(2)	1365(3)	285(1)
C(8)	1570(2)	1679(3)	1025(1)
C(9)	2443(2)	-452(3)	-158(2)
C(11)	3282(2)	606(3)	-235(1)
C(12)	3404(3)	1201(5)	-889(2)
C(13)	4194(3)	2146(6)	-955(3)
C(14)	4846(3)	2505(5)	-371(3)
C(15)	4726(3)	1920(5)	279(3)
C(16)	3949(2)	977(4)	350(2)
C(21)	1444(2)	1930(3)	2625(1)
C(22)	2079(2)	2099(3)	3253(1)
C(23)	2110(2)	995(4)	3794(1)
C(24)	1508(2)	-287(4)	3718(2)
C(25)	887(2)	-481(4)	3093(2)
C(26)	860(2)	618(3)	2546(1)
C(31)	-1355(2)	3960(3)	1503(1)
C(32)	-1393(2)	2793(4)	2000(2)
C(33)	-2262(2)	2243(5)	2162(2)
C(34)	-3099(2)	2879(5)	1830(2)
C(35)	-3080(2)	4040(5)	1334(2)
C(36)	-2206(2)	4591(4)	1165(2)
N(1)	1016(1)	2722(2)	1343.1(9)
N(2)	145(1)	3382(2)	992.6(9)
N(3)	215(2)	1468(3)	-746(1)
N(4)	936(2)	532(3)	-830(1)
N(5)	1536(1)	451(3)	-202(1)
O(5)	-937(1)	3752(3)	-1.3(9)
O(8)	2311(1)	1116(2)	1348.8(8)

Table 2

Selected [a] Bond Lenghts (Å) and Angles (°) of **3a**

Bond	(Å)	Angle	(°)
C1-C2	1.483(4)	N1C1C2	133.0(2)
C1-N1	1.483(3)	C1C2C3	123.6(2)
C2-C3	1.307(4)	C2C3C4	124.5(3)
C3-C4	1.482(3)	N2C4C3	112.5(2)
C4-N2	1.482(3)	N1N2C4	121.5(2)
N1-N2	1.418(2)	N2N1C1	121.5(2)
C1-C21	1.525(3)	N1N2C5	122.9(2)
C4-C31	1.527(4)	N2N1C8	123.6(2)
N1-C8	1.374(3)	N2C5C6	114.2(2)
C8-O8	1.226(3)	C5C6C7	122.2(2)
N2-C5	1.377(3)	C6C7C8	124.1(2)
C5-O5	1.230(3)	N1C8C7	112.9(2)
C5-C6	1.441(4)	N5C7C6	105.6(2)
C6-C7	1.346(3)	N3C6C7	109.5(2)
C7-C8	1.449(3)	N4N3C6	107.1(2)
N3-C6	1.368(3)	N3N4N5	108.5(2)
N3-N4	1.314(3)	N4N5C7	109.3(2)
N4-N5	1.355(3)	N4N5C9	119.8(2)
N5-C7	1.349(3)	N5C9C11	111.6(2)
N5-C9	1.477(4)	O5C5N2	120.3(2)
C9-C11	1.504(4)	O8C8N1	121.6(2)
		C1N1C8	114.7(2)
		C4N2C5	115.1(2)

[a] The observed values for bond lengths and angles for phenyl groups are very close to those reported in the literature.

= 4, V = 2228.5(5) Å^3, D_m = 1.18 g cm^{-3}, Mo-K$\bar{\alpha}$, Zr-filtered radiation, λ = 0.71069 Å, μ = 0.5 cm^{-1}.

Data were collected using a crystal of *ca* 0.28 x 0.31 x 0.45 mm dimensions mounted on a Nicolet PZ_1 diffractometer, w/2θ mode ($2\theta_{max}$ = 48°). Reflections measured/unique 3535/3121, observed with I ≥ 1.50σ(I) 2439. The data were corrected for the Lorentz and polarization factors (Lp) but not for absorption.

The structure was solved by the direct methods using SHELX program [16] and full-matrix least squares refinements of the same program, with all non-hydrogen atoms anisotropic and hydrogen isotropic. Final R/Rw 0.040/-0.036 and unit weights gave satisfactory agreement analysis. All H-atoms were located from Fourier maps and then were refined.

EXPERIMENTAL

Melting points were determined on a Köfler hot stage apparatus and are uncorrected. The ir spectra were measured with a Perkin-Elmer 297 spectrometer and the ^{1}H-nmr spectra, reported in δ units, were recorded on a AW-80 Brucker spectrometer using TMS as internal standard. The mass spectra were measured with a Hitachi-Perkin-Elmer model RMU-6L spectrometer, with an ionization energy of 70 eV, at a temperatures in the ion source between 180-350°. Elemental microanalyses were performed with a Perkin-Elmer 240B CHN analyser.

1-Benzyl-5,6-dihydro-1*H*-1,2,3-triazolo[4,5-*d*]pyridazine-4,7-dione (**1**).

A solution of benzyl chloride (4.8 ml, 42 mmoles), sodium azide (2.9 g, 45 mmoles) and water (5 ml) in ethanol (40 ml) was heated at reflux for 10 hours. The reaction mixture was cooled at room temperature, poured in 200 ml of water and was extracted with diethyl ether. The ethereal layer was washed with water, dried over anhydrous sodium sulfate and the solvent was removed under reduced pressure to give the benzyl azide as chromatographically pure colourless liquid; ir: ν 2090 (N_3) cm^{-1}. The benzyl azide was diluted with aceton (5 ml), dimethyl acetylenedicarboxylate (7 g, 49 mmoles) was added gradually and the mixture was stirred overnight. When all the azide has been reacted (tlc inspection), the reaction mixture was cooled at 0° and a solution of hydrazine hydrate (5 ml, 0.5 moles) in ethanol (40 ml) was added with stirring. The white crystals precipitated were filtered, washed with cold ethanol and recrystallized from the same solvent to give 8.9 g (78%) of 1-benzyl-4,5-bis-hydrazinocarbonyl-1,2,3-triazole, mp 174-176°, (lit [17] 174-176°), ir: ν 1640 (C=O) cm^{-1}. The bis-hydrazide (3.75 g, 13.6 mmoles) was heated at 200° for 3 hours. The light brown residue was well-pulverized and washed with cold ethanol and diethyl ether to give 2.3 g (87%) of **1**, which subjected to Diels-Alder reactions without further purification. Repeated recrystallizations from ethanol-ethyl acetate afforded **1** in white amorphous crystals, mp 278-281°, ir: ν 3190 (NH), 1667 (C=O) cm^{-1}.

Oxidation of **1** with Lead Tetraacetate in the Presence of Dienes. General Procedure.

To a suspension containing 500 mg (2 mmoles) of **1** and excess (4-6 mmoles) of the corresponding diene in 15 ml of dry dichloromethane a solution of LTA (1.2 g, 3 mmoles) in 20 ml of the same solvent was gradually added. The mixture was stirred for 2 hours, filtered from the precipitated lead oxides and washed with 10% aqueous sodium thiosulfate, with 5% sodium bicarbonate and finally with water. It was dried over anhydrous sodium sulfate and the solvent was removed *in vacuo*, leaving a light brown oil. Compound **3a** was separated from the mixture by column chromatography using silica gel and light petroleum ether-ethyl acetate as eluent, whereas compounds **3b**, **3c** and **3d** crystallized upon the addition of ethyl acetate to the oily residue. Recrystallizations from ethyl acetate-light petroleum ether (chloroform-

Table 3

Physical, Spectral and Analytical Data of Compounds **3**

Compound	Yield (%)	Mp (°C)	IR ν, cm^{-1} C=O	^{1}H-NMR deuteriochloroform (δ ppm)	MS m/z (% Relatve Intensity)	Formula MW	Elemental Analysis (%) Calcd./(Found) C	H	N
3a	45	155-158	1705 w 1655 s	5.94 (2H, s), 6.45 (4H, m), 6.90-7.56 (15H, m)	447 (M$^+$, 1), 206 (7), 198 (9) 119 (93), 117 (100)	$C_{27}H_{21}N_5O_2$ 447.1	72.45 (72.33)	4.73 (4.45)	15.66 (15.67)
3b	40	164-166	1690 w 1658 s	1.80 (6H, s) 4.45 (4H, s), 5.96 (2H, s), 7.20-7.60 (5H, m)	323 (M$^+$, 32), 295(4), 266 (4), 214 (22), 157 (20), 129 (36), 91 (100)	$C_{17}H_{17}N_5O_2$ 323.2	63.12 (62.99)	5.30 (5.11)	21.67 (21.48)
3c	37	186-187	1690 w 1655 s	1.50-2.20 (4H, m) 5.94 (2H, s), 6.64 (2H, m), 7.20-7.60 (7H, m)	321 (M$^+$, 18), 293 (3), 265 (1), 237 (3), 214 (15), 157 (7), 122 (22), 84 (100)	$C_{17}H_{15}N_5O_2$ 321.15	63.52 (63.63)	4.71 (4.96)	21.81 (21.84)
3d	36	317-320	1690 w 1660 s	5.90 (2H, s) 7.10-7.70 (15H, m)	419 (M$^+$, 3) 219 (2), 178 (100), 157 (9), 129 (20), 91 (57)	$C_{25}H_{17}N_5O_2$ 419.2	71.57 (71.67)	4.09 (3.92)	16.71 (16.68)

carbon tetrachloride for compound **3d**) afforded pure samples of these compounds. Melting points and other spectral data are given in Table 3.

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