

Synthesis of Di and Tetraoximes from the Reaction of Phenylendiamines with Dichloroglyoxime

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ABSTRACT: 2,5,10,13-Tetraazatricyclo [12,2,2,2^{6,9}] icoso-1(16),6,8,14,17,19-hexene-3,4,11,12-tetraone tetraoxime (**1a**) and 2,5,11,14-tetraazatricyclo [13,3,1,1^{6,10}] icoso-1(19),6,8,10(20),15,17-hexaene-3,4,12,13-tetraonetetraoxime (**1b**) were obtained from condensation of 1,4- and 1,3-phenylendiamine with dichloroglyoxime, respectively. The reaction of 1,2-phenylendiamine with dichloroglyoxime resulted in the production of (2Z,3Z)-1,4-dihydroquinoxaline-2,3-dione dioxime (**2**). The x-ray structure determination of compound **2** shows the piperazine ring is rather planar relative to the fused aromatic ring. The results show that a resonance occurs between the aromatic ring and the C=N bond, through N₄ and N₃ atoms of the molecule. The results from x-ray data, indicated that the molecules **2** could exist as a dimer by intermolecular hydrogen bonding between NH and OH groups.

KEY WORDS: Phenylendiamine, Dichloroglyoxime, vic-Dioximes, Crystal Structure, Intermolecular hydrogen bonds.

INTRODUCTION

vic-Dioximes have been used as general industrial chemicals [1]. Oxime ligands are used as analytical reagents [2,3] and serve as models for biological systems [4-7] as well as catalysts in chemical processes [8,10]. Dioxime ligands are also successful sequestering agents for transition metals and other ions [11]. vic-Dioximes and their complexes constitute an important class of compounds having versatile reactivity [8-9]. Since the discovery of cobaloximes as the model compound for coenzyme B₁₂ many advances have been made in structural and spectroscopic methodologies [6-10]. Tetraoxime molecules have been reported before as rare

[12,13]. In this report we describe a facile condensation of phenylendiamines with dichloroglyoxime to produce a new di and tetraoximes rings.

EXPERIMENTAL

All chemical reagents were obtained from Merck and were used without further purification. Melting points were measured on an Electrothermal 9200 apparatus and are uncorrected. Elemental analyses for C, H and N were performed using a Heraeus CHN-O Rapid analyzer. Mass spectra were recorded on a Finnigan-Matt 8430 GC-Mass and Shimatzu 5050 QD spectrometers. ¹H and ¹³C NMR

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spectra were recorded with a Bruker DRX-500 AVANCE, DMSO-d₆ was used as solvent. IR spectra were recorded on a Shimadzu IR-460 spectrometer.

Synthesis of 5,8,13,16-tetrahydrodibenzo[b,h] [1,4,7,10] tetraazacyclododecine [6,7,14,15] tetraonetetraoxime (1a)

To a stirring solution of 1,4-phenylenediamine (1.08 g, 10 mmole), 0.2 g, Na₂CO₃ in 40 ml MeCN a solution of dichloroglyoxime (1.57 g, 10 mmole) in 20 ml MeCN was added at 0-5 °C. After 2 h stirring at room temperature, the mixture was filtered and precipitate was washed with cold MeCN. Recrystallization from MeCN. Yield: 1.91 g (94%), mp 230-231 °C. IR (KBr) cm⁻¹: 3400(NH), 2500-3500(OH), 1620(C=N), 960(N-O). ¹H-NMR, ppm: 10.22(4H,OH), 8.83, 7.79(4H, NH), 6.56, 6.58(dd, 8H). ¹³C-NMR, ppm: 143.65, 134.59, 122.17, and 120.29. The EI-MS, m/z: 385(m+1)⁺. Elemental analysis calculated for C₁₆H₁₆N₈O₄: C, 50; H, 4.16; N, 29.16. Found: C, 50.03; H, 4.16; N, 29.15.

Synthesis 2,5,11,14-tetraazatricyclo [13,3,1,1^{6,10}] icosa-1(19),6,8,10(20),15,17-hexaene-3,4,12,13-tetraonetetraoxime (1b)

It was prepared according to the same procedure as described for the preparation of **1a** at room temperature. Yield: 69%, mp 178 °C. IR (KBr) cm⁻¹: 3240(NH), 2500-3500(OH), 1610(C=N), 940(N-O). ¹H-NMR, ppm: 10.72(s, 4H, OH), 8.49(bs, 4H, NH), 6.23-7.18(m, 8H). ¹³C-NMR, ppm: 138.16, 134.49, 122.06, 119.30 and 116.90. The EI-MS, m/z: 385(m+1)⁺. Elemental analysis calculated for C₁₆H₁₆N₈O₄: C, 50; H, 4.16; N, 29.16. Found: C, 49.98; H, 4.17; N, 29.13.

Synthesis of (2Z,3Z)-1,4-dihydroquinoxaline-2,3-dione dioxime (2)

The reaction of 1,2-phenylenediamine with dichloroglyoxime under similar condition of **1a**, leads to **2**. Recrystallization from EtOH (70%). Yield: 1.78 g (93%), mp 239-240 °C. IR (KBr) cm⁻¹: 3400 (NH), 2500-3500(OH), 1640(C=N), 980(N-O). ¹H-NMR, ppm: 10.13(bs, 2H, OH), 9.46(bs, 2H, NH), 6.71, 7.18(dd, 4H). ¹³C-NMR, ppm: 138.45, 125.90, 121.03, and 114.57. The EI-MS, m/z: 384 (2m⁺), 192(m⁺), 193(m+1). Elemental analysis calculated for C₈H₈N₄O₂: C, 50; H, 4.16; N, 29.16. Found: C, 50.01; H, 4.17; N, 29.14. It should be

noted, that compound **2** has been synthesized via another procedure but resulting in low yield [12].

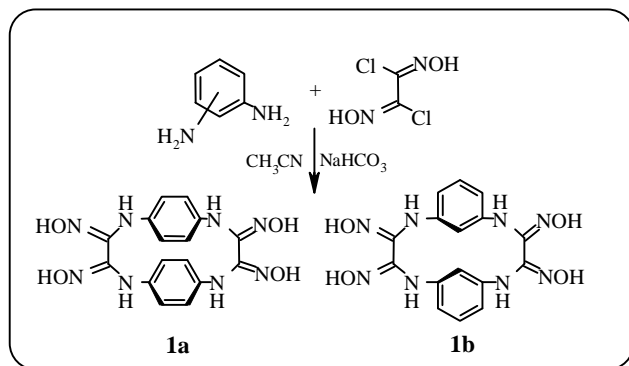
X-ray structure analysis of 2

The clear colorless crystal with dimensions 0.4×0.2×0.2 mm crystallized from MeCN/H₂O was used for data collection on a Bruker SMART 1000 CCD diffractometer with graphite monochromated MoKα (λ=0.71073 Å). C₈H₈N₄O₂, FW= 192.18. Triclinic crystals in a P1 Space group, a=8.3998 (16) Å, b=8.3888(13) Å, c=13.129(4) Å, α= 102.68(6)°, β=102.666(4)°, γ= 108.316(3)°, V=814.2(2) Å³. Z=4, D_{calc} = 1.568 g/cm³. μ=0.118 mm⁻¹, F(000)=400, T=120 (2) K. Of the 9581 total reflections 4648 were unique (R_{int} =0.0539). The structure was solved by direct methods (SHELXTL)[15] and refined by full-matrix least-squares on F² (isotropic refinement of the molecule and location of remaining non-hydrogen atoms from a difference Fourier map and subsequent anisotropy refinement on all atoms; H atoms were found after high-angle refinement in a difference Fourier map and their positions included in the final stages of refinement), factors of R1=0.0671, wR2=0.1347 for 2491 reflections with I<2σ (I). No significant features, only ripples from -0.290 to 0.341 e Å⁻³, were observed in the final difference map. The nonhydrogen atoms were refined anisotropically. Atomic coordinate, temperature factors, bond distances, bond and torsion angles have been deposited at the Cambridge Crystallographic Data Center (CCDC No; 271443). These data can be obtained free of charge via WWW.ccdc.cam.ac.uk/conts/retrieving; html (or from Cambridge Crystallographic Data Center; deposit@ccdc.cam.ac.uk).

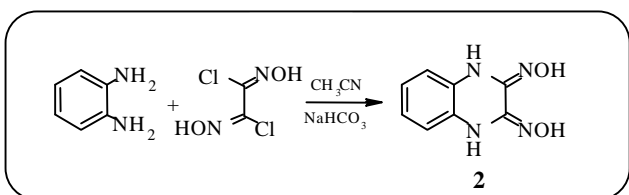
RESULTS AND DISCUSSION

The compounds 2,5,10,13-tetraazatricyclo [12,2,2,2^{6,9}] icosa-1(16),6,8,14,17,19-hexene-3,4,11,12-tetraonetetraoxime (**1a**) and 2,5,11,14-tetraazatricyclo [13,3, 1,1^{6,10}] icosa-1(19),6,8,10(20),15,17-hexaene-3,4,12,13-tetraonetetraoxime (**1b**) were obtained from condensation of dichloroglyoxime with 1,4-phenylenediamine and 1,3-phenylenediamine in alkaline solution of MeCN at 0-5 °C and room temperature, respectively (scheme 1).

But, in the similar conditions, the reaction of 1,2-phenylenediamine with dichloroglyoxime leads to product (2Z,3Z)-1,4-dihydroquinoxaline-2,3-dione dioxime (**2**).



Scheme 1.



Scheme 2.

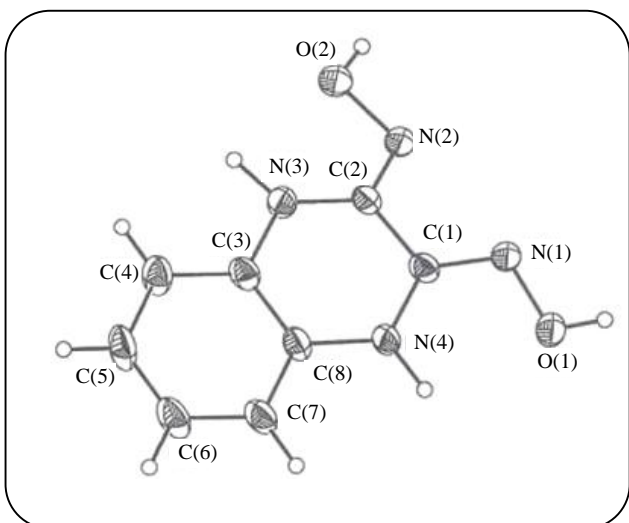


Fig. 1: ORTEP diagram of (2Z,3Z)-1,4-dihydroquinoxaline-2,3-dione dioxime (2).

The structures of **1** and **2** were deduced from their elemental analyses and their IR, ^1H and ^{13}C NMR spectra. The mass spectra of these compounds are fairly similar, and confirm their molecular weights, as expected. In alkaline solutions the products are stable. But, compounds **1** are decomposed in acidic media ($\text{pH} < 4$). The structure of the compound **2** was established by X-ray crystallography (Fig. 1).

There are unusual structural features in the molecule. The C-N bonds are smaller than usual values and bond

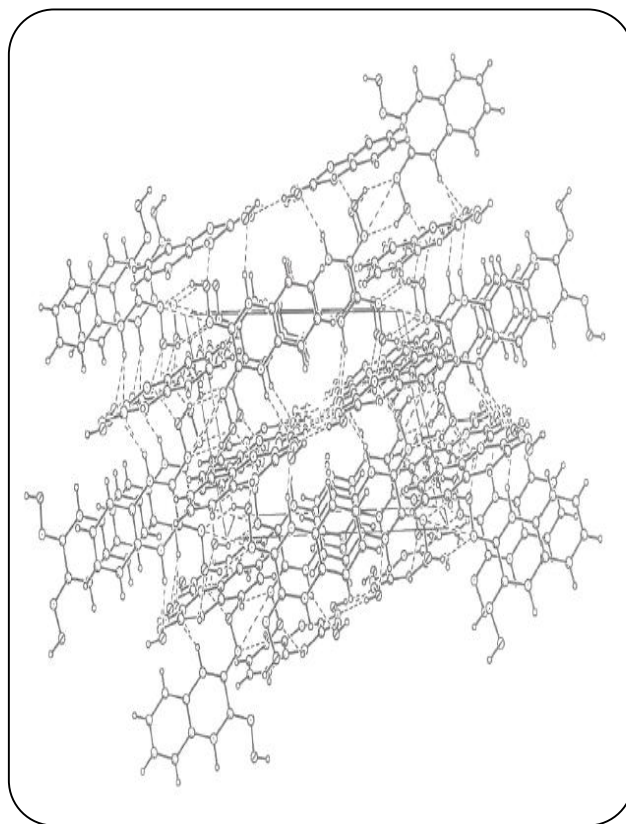


Fig. 2: Unit cell showing π - π stacking interaction between aromatic rings and hydrogen bonding in compound **2**.

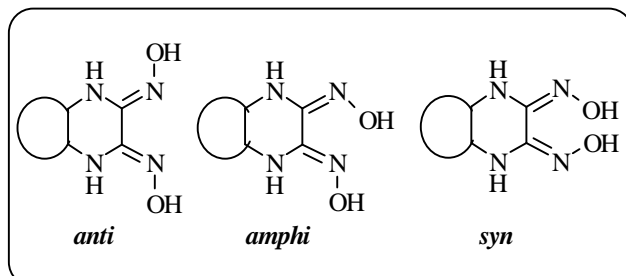


Fig. 3: Possible isomer of cyclic vic-Dioximes.

angles around the N_3 or N_4 have sp^2 characteristics (table 1). Torsion angles for $\text{N}_4\text{-C}_8\text{-C}_3\text{-N}_3$, $\text{C}_8\text{-C}_3\text{-N}_3\text{-C}_2$, $\text{C}_3\text{-C}_8\text{-N}_4\text{-C}_1$ are 2.2° , 3.0° and 3.0° respectively. The piprazine ring is rather planar relative to fused aromatic ring. These results show that a resonance occurs between aromatic ring and $\text{C}=\text{N}$ bond, through N_4 and N_3 atoms of the molecule. This could be the result of influence on bond lengths, angles, pyramidal and planarity of piprazine ring.

The torsion angles of $\text{N}_1\text{-C}_1\text{-C}_2\text{-N}_2$, $\text{N}_4\text{-C}_1\text{-C}_2\text{-N}_3$, and $\text{C}_1\text{-C}_2\text{-N}_3\text{-C}_3$ are 14.1° , 16.6° , and -12.3° respectively.

Table 1: Selected bond lengths (Å), bond angles (°) and torsion angles (°).

| Bond lengths | (Å) | Bond lengths | (Å) |
|--|------------|--|------------|
| C ₁ -N ₁ | 1.290(3) | C ₃ -C ₈ | 1.392 |
| C ₁ -N ₄ | 1.360(3) | N ₄ -C ₈ | 1.420(3) |
| C ₁ -C ₂ | 1.481(3) | N ₂ -O ₂ | 1.420(2) |
| C ₂ -N ₂ | 1.287(3) | O ₁ -H ₁₀ | 0.8661 |
| C ₂ -C ₃ | 1.361 | O ₂ -H ₂₀ | 0.8364 |
| N ₃ -C ₃ | 1.403(3) | N ₃ -H _{3N} | 1.0465 |
| Bond angles | (°) | Bond angles | (°) |
| N ₁ -C ₁ -N ₄ | 124.8(2) | C ₁ -N ₄ -C ₈ | 122.97(19) |
| N ₁ -C ₁ -C ₂ | 117.94(18) | C ₁ -N ₄ -H _{4N} | 119.6 |
| N ₄ -C ₁ -C ₂ | 117.20(19) | C ₈ -N ₄ -H _{4N} | 116.3 |
| N ₂ -C ₂ -N ₃ | 125.02 | N ₃ -C ₃ -C ₈ | 118.88(19) |
| N ₂ -C ₂ -C ₁ | 117.86(19) | C ₃ -C ₈ -N ₄ | 118.82(19) |
| N ₃ -C ₂ -C ₁ | 117.16(18) | C ₁ -N ₁ -O ₁ | 110.04(17) |
| C ₂ -N ₃ -C ₃ | 123.06 | N ₁ -O ₁ -H ₁₀ | 105.5 |
| C ₂ -N ₃ -H ₃ | 121.0 | C ₂ -N ₂ -O ₂ | 109.92(17) |
| C ₃ -N ₃ -H | 113.1 | N ₂ -O ₂ -H ₂₀ | 103.6 |
| Torsion angles | (°) | Torsion angles | (°) |
| N ₁ -C ₁ -C ₂ -N ₂ | 14.1(3) | C ₁ -C ₂ -N ₂ -O ₂ | -178.4(18) |
| N ₄ -C ₁ -C ₂ -N ₃ | 16.6(3) | N ₂ -C ₂ -N ₃ -C ₃ | 168.9(2) |
| N ₃ -C ₃ -C ₈ -N ₄ | 2.2(3) | C ₁ -C ₂ -N ₃ -C ₃ | -12.3(3) |
| N ₄ -C ₁ -N ₁ -O ₁ | 0.1(3) | C ₈ -C ₃ -N ₃ -C ₂ | 3.0(3) |
| C ₂ -C ₁ -N ₁ -O ₁ | 178.44(18) | N ₁ -C ₁ -N ₄ -C ₈ | 169.1(2) |
| N ₃ -C ₂ -N ₂ -O ₂ | 0.4(3) | C ₂ -C ₁ -N ₄ -C ₈ | -12.3(3) |

These data show that C₁ and C₂ atoms are not coplanar, therefore the C₁-C₂ bond shows a single bond characteristic and there is not a resonance between them. The results from x-ray data, as shown in Fig. 1, indicated that the molecule **2** could exist as a dimer by intermolecular hydrogen bonding between NH and OH groups. The corresponding distance and angle for hydrogen bonds are given in table 2. The unit cell of the resulting crystal, shown in Fig. 2, clearly revealed that a three dimensional network is formed owing to the presence of intermolecular hydrogen bonding interaction. There is a face to face π - π stacking [14]. The experimental data and structural models show the existence of three possible cyclic *vic*-dioximes configurations (anti, amphi

and syn) (Fig. 3). The isomer distribution depends on steric effects of substitutions and the possibility of hydrogen bonding between the oxime groups [16]. The torsion angles of molecule **2**, N₃-C₂-C₁-N₁, C₂-C₁-N₁-O₁, N₄-C₁-C₂-N₂, C₁-C₂-N₂-O₂, confirm an anti configuration and the oxime groups will not be coplanar unless they are linked by a hydrogen bond. Mass spectra of **2** show a molecular ion peak at 384 m/z.

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Table 2: Hydrogen bonds D-H...A in the crystal of (2Z,3Z)-1,4-dihydroquinoxaline-2,3-dione dioxime (2).

| D-H | D (D-H) Å | d (H...A) Å | <DHA° | d (D...A) Å | A |
|-----------------------------------|-----------|-------------|--------|-------------|-----------------|
| O ₁ -H ₁₀ | 0.866 | 1.981 | 149.41 | 2.762 | N ₁ |
| O ₂ -H ₂₀ | 0.836 | 2.003 | 151.13 | 2.765 | N ₂ |
| O _{1A} -H _{10A} | 0.866 | 1.973 | 151.42 | 2.765 | N _{1A} |
| O _{2A} -H _{20A} | 0.845 | 1.986 | 152.94 | 2.766 | N _{2A} |
| O _{2A} -H _{20A} | 0.845 | 2.649 | 128.25 | 3.241 | O _{2A} |
| N _{3A} -H _{3NA} | 1.069 | 2.430 | 131.26 | 3.237 | O ₁ |
| N _{3A} -H _{3NA} | 1.069 | 2.558 | 147.07 | 3.504 | O ₂ |
| N ₃ -H _{3N} | 1.081 | 2.428 | 130.89 | 3.240 | O _{1A} |
| N ₃ -H _{3N} | 1.081 | 2.546 | 146.71 | 3.500 | O _{2A} |
| N ₄ -H _{4N} | 1.047 | 2.546 | 123.19 | 3.241 | O _{2A} |
| N ₄ -H _{4NA} | 1.015 | 2.495 | 129.62 | 3.238 | O ₂ |
| N ₄ -H _{4NA} | 1.047 | 2.544 | 151.56 | 3.500 | O _{1A} |

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