Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

Structure and Synthesis of a New Library of N,N-Bis-[1,2,4]triazol-1-ylmethyl-amino Compounds

Hanane Al Bay [a], Rachid Touzani [a b], Mustafa Taleb [c], Nour-Eddine Benchat [a], Brahim El Bali [d], Michal Dusek [e], Karla Fejfarova [e] & Sghir El Kadiri [a]

[a] Laboratoire de Chimie Appliquée et Environnement, Département de Chimie, Faculté des Sciences, Université Mohamed 1 er, Oujda, Morocco

[b] Faculté Pluridisciplinaire de Nador, Université Mohamed 1 er, Nador, Morocco

[c] Département de Chimie, Faculté des Sciences, DEM, Fès, Morocco

[d] LCSMA, Département de Chimie, Faculté des Sciences, Université Mohamed 1 er, Oujda, Morocco

[e] Institute of Physics, Prague, Czech Republic

Published online: 09 Aug 2010.

To cite this article: Hanane Al Bay, Rachid Touzani, Mustafa Taleb, Nour-Eddine Benchat, Brahim El Bali, Michal Dusek, Karla Fejfarova & Sghir El Kadiri (2010) Structure and Synthesis of a New Library of N,N-Bis-[1,2,4]triazol-1-ylmethyl-amino Compounds, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 40:18, 2767-2779, DOI: 10.1080/00397910903318740

To link to this article: http://dx.doi.org/10.1080/00397910903318740

Synthetic Communications®, 40: 2767–2779, 2010

ISSN: 0039-7911 print/1532-2432 online
DOI: 10.1080/00397910903318740

Taylor & Francis
Taylor & Francis Group

STRUCTURE AND SYNTHESIS OF A NEW LIBRARY OF *N,N*-BIS-[1,2,4]TRIAZOL-1-YLMETHYL-AMINO COMPOUNDS

Hanane Al Bay,[1] Rachid Touzani,[1,2] Mustafa Taleb,[3] Nour-Eddine Benchat,[1] Brahim El Bali,[4] Michal Dusek,[5] Karla Fejfarova,[5] and Sghir El Kadiri[1]

[1]*Laboratoire de Chimie Appliquée et Environnement, Département de Chimie, Faculté des Sciences, Université Mohamed 1 er, Oujda, Morocco*
[2]*Faculté Pluridisciplinaire de Nador, Université Mohamed 1 er, Nador, Morocco*
[3]*Département de Chimie, Faculté des Sciences, DEM, Fès, Morocco*
[4]*LCSMA, Département de Chimie, Faculté des Sciences, Université Mohamed 1 er, Oujda, Morocco*
[5]*Institute of Physics, Prague, Czech Republic*

New* N,N-*bis(triazol-1-ylmethyl)amines have been prepared in one step by condensation of 1-(hydroxymethyl)triazole with a series of primary substituted aromatic amines. These reactions were carried out in refluxed CH_3CN for 4 h. The products were recuperated with excellent and good yields (75–90.5%). The x-ray crystallography structure of one of them has been studied.

Keywords: Heterocyclic compounds; nitrogen-rich; synthesis and crystallography; triazole; tridentate ligand

INTRODUCTION

Nitrogen-containing multipodal molecules are attracting current interest for the building of polynuclear metal complexes, as models for bioinorganic chemistry, for use in materials science and the transport and activation of small molecules, as well as for the discovery of new catalyst precursors.[1–7] For example, polypyrazolyl compounds have been used as mimics of active sites in copper oxidase.[8] The triazolyl ring seems to play a key role in antifungal drugs; for example, fluconazole is effective against oropharyngeal and esophageal candidiasis,[9,10] although fosfluconazole is some less active than fluconazole in vitro but has similar efficacy in animal models and patients[11,12] (Fig. 1).

Received August 8, 2009.
Address correspondence to Sghir El Kadiri or Rachid Touzani, Laboratoire de Chimie Appliquée et Environnement, Département de Chimie, Faculté des Sciences, Université Mohamed 1er, BP 717, 60 000 Oujda, Morocco. E-mail: elkadiri_sghir@yahoo.fr; touzanir@yahoo.fr

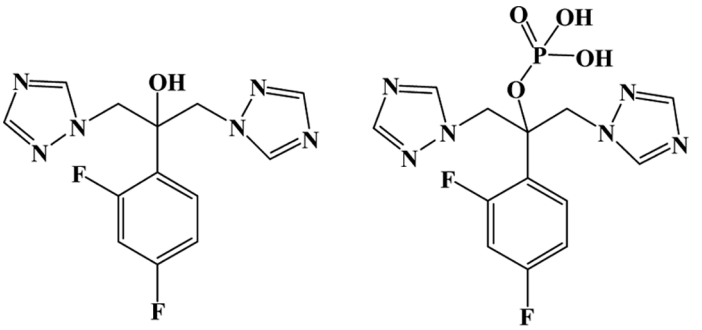

Figure 1. Structure of fluconazole and fosfluconazole.

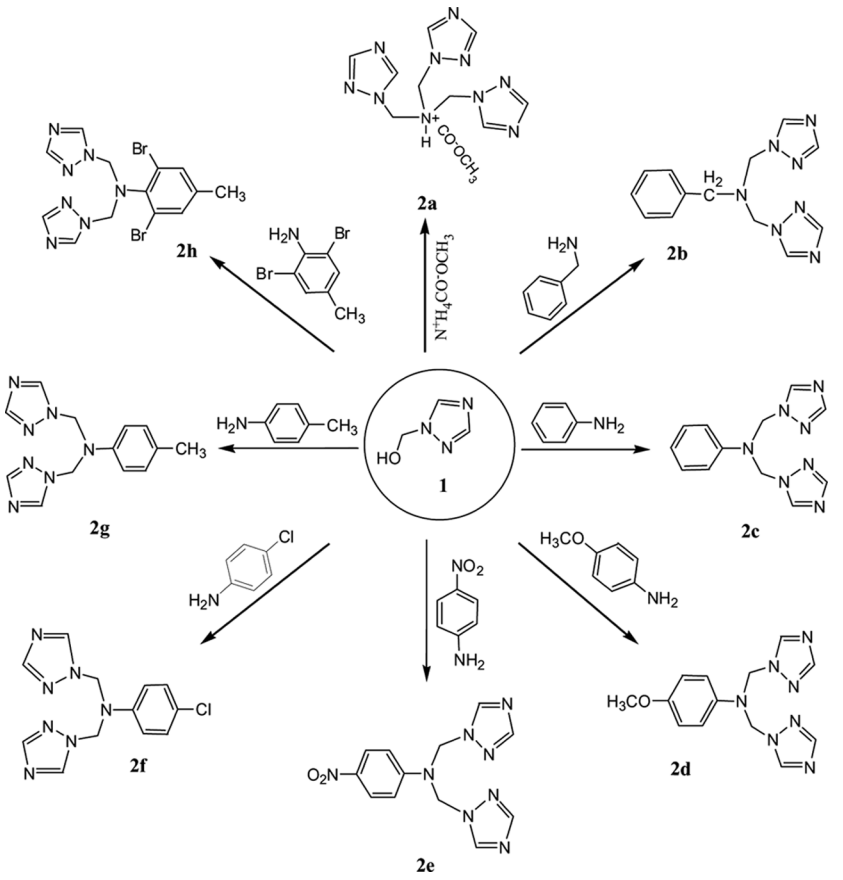

Figure 2. Diverse and library compounds.

Meanwhile, these compound derivatives have been involved in several types of chelating ligands. In particular, the bridging coordination mode of *N*-chelating substituted 1,2,4-triazoles has been actively explored in recent years; this may be able to lead to materials with interesting magnetic properties.[13] For instance, tris-triazolyl borates were studied as tripodal ligands in metal complexes and had been adapted for the discovery of new activation process and new catalytic reactions.[14–16] The *N,N*-bis(triazolyl)amines are classified as six- and eight–electron-donating tridentate ligands with a two *N*-donor sites of triazolyl rings and one *N*-donor site of amine. The coordination behavior of the *N,N*-bis(triazolyl)amines and the reactivity of the corresponding metal complexes are strongly dependent on the electron richness of the nitrogen atoms and the steric hindrance of the substituants. Thus, it seems crucial to synthesize a diversity of this type of tridentate ligands (Fig. 2). The synthesis of new tridentate nitrogen donor compounds that have biological activities such as antifungal[17] and anticancer[18] activities is one of our research interests. In addition, we are very interested in the study of their catalytic activities such as isomerization[19,20] and oxidation reactions.[21–23] To our knowledge, the 1,2,4-triazole unit has never been incorporated into a tridentate symmetrical structure (-N-CH_2-N- junction) or screened for biological activities. We report here an easy and facile synthesis of seven new *N,N*-bis(1,2,4-triazolyl)amines containing new bulky aromatic groups at the central nitrogen atom with diverse substituants.

EXPERIMENTAL

Melting points are uncorrected, and P NMR spectra are of the compounds dissolved in $CDCl_3$ and dimethylsulfoxide (DMSO), obtained with a Bruker 300 spectrometer. Infrared (IR) spectra were recorded on a Perkin-Elmer 1310 spectrophotometer. Mass spectra (MS) were determined on a Micromass LCT; tz refers to triazol and ar refers to aromatic compounds.

General Procedure

A mixture of *N*-hydroxymethyl-1,2,4-triazole (10 mmol) and arylamines (5 mmol) in acetonitrile (25 mL) was stirred and refluxed in a closed vessel for 4 h. The acetonitrile layer was dried from the water formed by treatment with anhydrous $MgSO_4$. After filtration, the solvent was removed under vacuum, and the crude products were washed with water, ether, or dichloromethane (DCM) and then dried. The products were analyzed as such. The compounds **2a** and **2c** are known and have spectral data in accordance with the literature data.[24,25]

Spectral Data

***N,N*-Bis((1H-1,2,4-triazol-1-yl)methyl)benzylamine 2b.** White solid (82.5%); mp 81–83 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ ppm: 8.14 (s, 2H, -CH_{tz}); 7.99 (s, 2H, -CH_{tz}); 7.40–7.28 (m, 5H, -CH_{ar}); 5.14 (s, 4H, -NCH_2N-); 3.83 (s, 2H, CH_2). ^{13}C NMR (75 MHz, $CDCl_3$) δ ppm: 152.35 (-CH_{tz}); 143.93 (-CH_{tz}); 135.99 (-CH_{ar}); 128.65 (-CH_{ar}); 64.86 (-NCH_2N-); 54.18 (-CH_2-C_{ar}). IR (KBr, ν cm^{-1}): 3432; 3115 (-CH_{ar}); 1673 (-C=C-); 1506 (-C=N); 1272 (-C-N); 1136; 1017; 744; 678. MS (ES) (m/z) (%) = 269.31 (10); 263.47 (24.5); 244.03 (83); 197.72 (100).

***N,N*-((1H-1,2,4-Triazol-1-yl)methyl)-4-methoxybenzenamine 2d.** Brown oil (90.5%). ^{1}H NMR (300 MHz, $CDCl_3$) δ ppm: 8.08 (s, 2H, -CH_{tz}); 7.97 (s, 2H,-CH_{tz}); 6.84 (d, 2H, -CH_{ar}, $J = 2.71$ Hz); 6.82 (d, 2H, -CH_{ar}, $J = 2.1$ Hz); 5.60 (s, 4H, -NCH_2N-); 3.73 (s, 3H, -OCH_3). ^{13}C NMR (75 MHz, $CDCl_3$) δ ppm: 156.68 (-C=C_{ar}); 152.34 (-C=N-$_{tz}$); 143.46 (-C=N-$_{tz}$); 137.7 (-C=C_{ar}); 115.08 (-CH_{ar}); 65.83 (-NCH_2N-); 55.48 (-OCH_3). IR (KBr, ν cm^{-1}): 3116 (C-H_{ar}); 1614 (C=C); 1510 (C=N); 1246 (C-N); 1189; 1136; 1030; 825; 678. MS (ES) (m/z) (%) = 269.13 (100); 253.51 (72.5); 175.85 (40.3).

***N,N*-Bis((1H-1,2,4-triazol-1-yl)methyl)-4-nitrobenzenamine 2e.** Yellow solid (82%); mp 133–135 °C. ^{1}H NMR (300 MHz, DMSO) δ ppm: 8.66 (s, 2H, -CH_{tz}) 8.05 (s, 2H, -CH_{tz}); 8.01 (d, 2H, -CH_{ar}, $J = 9.3$ Hz); 6.96 (d, 2H, -CH_{ar}, $J = 9$ Hz); 5.47 (s, 4H, -NCH_2N-). ^{13}C NMR (75 MHz, DMSO) δ ppm: 152.81 (-C=C_{ar}); 152.00 (-C=N_{tz}); 151.88 (-C=N_{tz}); 138.58 (-C=C_{ar}); 125.7 (-CH_{ar}); 114.49 (-CH_{ar}); 63.45 (-NCH_2N-). IR (KBr, ν cm^{-1}): 3112 (-CH_{ar}); 1610 (-C=C-); 1508 (-C=N-); 1479; 1268 (-C=N-) 1336; 1195; 1137; 1117; 1025; 834; 750; 675. MS (ES) (m/z) (%) = 253.51 (100); 172.63 (10.9).

***N,N*-Bis((1H-1,2,4-triazol-1-yl)methyl)-4-chlorobenzenamine 2f.** White solid (83%); mp 90–92 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ ppm: 8.22 (s, 2H, -CH_{tr}); 7.97 (s, 2H, -CH_{tz}); 7.24 (d, 2H, -CH_{ar}, $J = 8.7$ Hz); 6.99 (d, 2H, -CH_{ar}, $J = 6.9$ Hz); 5.73 (s, 4H, -NCH_2N-). ^{13}C NMR (75 MHz, $CDCl_3$) δ ppm: 152.39 (-C=N_{tz}); 143.32 (-C=N_{tz}); 143.21 (-C=C_{ar}); 129.46 (-C=C-$_{ar}$); 128.32 (-CH_{ar}); 114.84 (-CH_{ar}); 65.00 (-NCH_2N-). IR (KBr, ν cm^{-1}): 3115 (C-H_{ar}); 1601 (-C=C-); 1502 (-C=N-); 1272 (-C-N-); 1192; 1136; 957; 819; 676. MS (ES) (m/z) (%) = 253.51 (100).

***N,N*-Bis((1H-1,2,4-triazol-1-yl)methyl)-4-methylbenzenamine 2g.** White solid (82%); mp 88–90 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ ppm: 8.15 (s, 2H, -CH_{tz}); 7.98 (s, 2H, -CH_{tz}); 7.10 (d, 2H, -CH_{ar}, $J = 8.4$ Hz); 6.89 (d, 2H, -CH_{ar}, $J = 6.6$ Hz); 5.72 (s, 4H, -NCH_2N-); 2.28 (s, 3H, -CH_3). ^{13}C NMR (75 MHz, $CDCl_3$) δ ppm: 152.31 (-C=N_{tz}); 143.27 (-C=N_{tz}); 142.04 (-C=C-$_{ar}$); 133.24 (-C=C_{ar}); 130.50 (-CH-$_{ar}$); 118.40 (-CH_{ar}); 65.05 (-NCH_2N-); 20.53 (-CH_3). IR (KBr, ν cm^{-1}): 3114 (-CH_{ar}); 2922; 2864 (-CH_3); 1617 (-C=C-), 1578; 1519 (-C=N-); 1271 (-C-N=); 1190; 1136; 1013; 958; 810; 753; 677; 642. MS (ES) (m/z) (%) = 269.67 (25.7); 255.97 (70.6); 253.71 (100); 237.13 (70.6).

***N,N*-Bis((1H-1,2,4-triazol-1-yl)methyl)-2,6-dibromo-4-methylbenzenamine 2h.** White solid (86.6%); mp 86–88 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ ppm: 8.13 (s, 2H, -CH_{tz}); 8.00 (s, 2H, -CH_{tz}); 7.40 (s, 2H, -CH_{ar}); 5.63 (s, 4H, -NCH_2N-); 2.31 (s, 3H, -CH_3). ^{13}C NMR (75 MHz, $CDCl_3$) δ ppm: 152.21 (-C=N_{tz}); 143.27 (-C=N_{tz}); 141.13 (-C=C_{ar}); 133.86 (-C=C_{ar}); 125.48 (-CH_{ar}); 108.70 (-CH_{ar}); 65.39 (-NCH_2N-); 20.46 (-CH_3). IR (KBr, ν cm^{-1}): 3460; 3346; 3200; 3115 (-C-H); 2922; 1620 (-C=C-); 1585; 1505 (-C=N-); 1477; 1270 (-C-N-); 1135; 1012; 854; 740; 676 (C-Br). MS (ES) (m/z) (%) = 427.42 (50); 358.84 (23); 269.11 (100).

Crystal Synthesis

A mixture of *N*-hydroxymethyl-1,2,4-triazole (10 mmol) and aniline (5 mmol) in acetonitrile (25 mL) was stirred and refluxed in a closed vessel for 4 h. The acetonitrile layer was dried from the water formed by treatment with anhydrous $MgSO_4$. After filtration, the solvent was removed under vacuum, and the crude product was solubilized in hot DCM. After solvent evaporation under ambient conditions, colorless crystals were obtained.

Data collection and refinements. A colorless crystal of dimensions $0.3669 \times 0.2087 \times 0.1759$ mm was selected for x-ray diffraction analysis. The data were recorded at room temperature with an Oxford diffraction CCD diffractometer Gemini equipped with an Atlas area detector using graphite monochromatized MoK_α radiation ($\lambda = 0.7173$ Å). Data were processed with the program Crysalis RED.[26,27] The phase problem was solved by direct methods using the program SIR2002,[28] and the structure was refined with Jana 2006.[29] Crystal structure figures were drawn using the Diamond program.[30] All hydrogen atoms were discernible in difference Fourier maps and could be refined to reasonable geometry. According to common practice, hydrogen atoms in organic molecules were kept in ideal positions during the refinement. The O-H distances in water molecule were restrained to 0.82 Å. The isotropic atomic displacement parameters of hydrogen

Table 1. Crystal and refinement data for **2c**

Parameter	Value
Chemical name	*N,N*-Bis((*1H*-1,2,4-triazol-1-yl)methyl) benzenamine monohydrate
Chemical formula	$C_{12}H_{13}N_7$, H_2O
M	273.3 g/mol
F000	288
Symmetry	Triclinic (P/–1)
Cell parameters	
a (Å)	7.9361(6)
b (Å)	8.5605(6)
c (Å)	10.6075(8)
α (°)	110.383(6)
β (°)	92.057(6)
γ (°)	99.486(6)
V (Å^3)	662.88(9)
Z	2
μ	0.789
T min	0.680
T max	0.870
θ_{min}	10.2
θ_{max}	59.89
Reciprocal space	$-8 < h < 8$, $-9 < k < 9$, $-11 < l < 11$
Number of parameters	188
Reflections number	1665 [with $I > 3 \setminus \sigma(I)$: 1412]
R / Wr	0.0447 /0.1379

atoms were evaluated as $1.2 * U_{eq}$ of the parent atom. The structure was a twin with twinning matrix applied to indices as column vectors:

$$\begin{matrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0.259 & 0.9 & 1 \end{matrix}$$

This led to partial overlaps of diffraction spots. See also Table 1.

RESULTS AND DISCUSSION

Synthesis

The syntheses of *N,N*-bis(1,2,4-triazol-1-ylmethyl)amines **2a–h** are based on the condensation of 1 equivalent of an aromatic amine with 2 equivalents of 1-(hydroxymethyl)-1,2,4-triazole **1** (Fig. 2). The electronic effect of the substituents R as an electron-donating or electron-accepting group represents only one way to modify the coordination properties of donor sites from the triazolyl rings. The nature of the substituents R, particularly the electronic effect of alkyl versus aryl group R, and the steric hindrance of R are also important factors. Thus, eight bulky amines, differently substituted in *ortho, meta,* and *para* positions, were condensed with the precursors **1**.[31] These nine reactions were performed in a refluxed CH_3CN solvent during 4 h. The electronic impact of the different groups' R is visible on the chemical shift in proton and carbon NMR of the methylene bridge between the central nitrogen atom and the triazolyl rings as well as on the two –CH triazolic. As expected, the hydrogen atoms of the triazolyl rings are more strongly influenced by the nature of R according to the observed values for **2c** [8.01, 8.21 ppm (phenyl)], **2e** [8.05, 8.66 ppm (phenyl and attracting group on *para*) and 7.97, 8.22 ppm (phenyl and donating group on *para*)] (Table 2).

The variation of the proton and carbon shifts of the methylene groups (5.14 to 5.73 and 63.45 to 71.94) could be correlated to the tuning of the electron richness of these ligands. One can envisage that with the new electron-attracting and/or bulky substituants, these nine ligands have more potential for different coordination

Table 2. Chemical shift in ^{1}H NMR and ^{13}C NMR of the methylene bridge between the central nitrogen atom and the triazolyl rings and the -CH triazolic

Compounds	Yield (%)	^{1}H NMRδ ppm (N-CH_2-N)	^{13}C NMRδ ppm (N-CH_2-N)	^{1}H NMRδ ppm (H triazol)	^{13}C NMRδ ppm (C triazol)
2a	75	5.38; 5.63	64.43; 71.94	7.93; 7.99; 8.21; 8.34	143.25; 146.62; 151.78; 152.17
2b	82.5	5.14	64.86	7.99; 8.14	143.93; 152.35
2c	87.2	5.79	64.63	8.01; 8.21	143.23; 152.41
2d	90.5	5.60	65.83	7.97; 8.08	143.46; 152.34
2e	82	5.47	63.45	8.05; 8.66	151.88; 152.00
2f	83	5.73	65.00	7.97; 8.22	143.32; 152.39
2g	82	5.72	65.05	7.98; 8.15	143.27; 152.31
2h	86.6	5.63	65.39	8.00; 8.13	143.27; 152.21

behavior than other reported similar ligands[32,33] and more potential for biological activities.

X-Ray Diffraction Analysis

The R value, based on data of the first domain and taking twinning into the account for fully overlapped reflections, was 6%, goodness of fit (g.o.f.) 3.73. In another attempt, we used an hklf5 file generated by the Crysalis program.[26,27] It should take into the account overlaps, but in fact it did not improve the results and yielded an R value of about 10% regardless of various options (deconvolution limits, merging or not merging reflections, using data from the first domain or both domains). Finally, we used a classical approach implemented in the program

Table 3. Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2) for **2c**

	x	*Y*	*z*	U^*_{iso}/U_{eq}
O1	0.2511 (3)	0.2433 (3)	−0.0016 (2)	0.0338 (9)
N1	0.2158 (3)	0.1485 (3)	0.3192 (2)	0.0219 (9)
N2	0.1299 (3)	0.0868 (3)	0.4060 (2)	0.0256 (9)
N3	0.0607 (3)	−0.0953 (3)	0.1895 (2)	0.0283 (10)
N4	0.2612 (3)	0.4573 (3)	0.4232 (2)	0.0205 (8)
N5	0.3203 (3)	0.6450 (3)	0.2957 (2)	0.0220 (9)
N6	0.3954 (3)	0.7973 (3)	0.3909 (2)	0.0249 (9)
N7	0.4873 (3)	0.7724 (3)	0.1870 (2)	0.0280 (10)
C1	0.0396 (4)	−0.0592 (4)	0.3224 (3)	0.0264 (11)
C2	0.1733 (4)	0.0398 (3)	0.1927 (3)	0.0252 (11)
C3	0.3385 (3)	0.3103 (3)	0.3688 (3)	0.0223 (11)
C4	0.1930 (3)	0.5215 (3)	0.3268 (3)	0.0243 (11)
C5	0.4939 (3)	0.8675 (4)	0.3198 (3)	0.0252 (11)
C6	0.3766 (4)	0.6331 (4)	0.1764 (3)	0.0262 (11)
C7	0.2432 (3)	0.5299 (3)	0.5622 (3)	0.0208 (10)
C8	0.2679 (3)	0.4434 (3)	0.6499 (3)	0.0214 (11)
C9	0.2591 (3)	0.5191 (4)	0.7873 (3)	0.0269 (11)
C10	0.2240 (4)	0.6811 (4)	0.8422 (3)	0.0284 (11)
C11	0.1971 (4)	0.7660 (4)	0.7550 (3)	0.0284 (12)
C12	0.2060 (3)	0.6935 (3)	0.6183 (3)	0.0237 (11)
H1	−0.035858	−0.134588	0.353729	0.0317*
H2	0.217809	0.056771	0.114569	0.0303*
H3a	0.421741	0.308479	0.435917	0.0267*
H3b	0.404782	0.320887	0.297267	0.0267*
H4a	0.147114	0.428487	0.2449	0.0291*
H4b	0.096768	0.572498	0.360503	0.0291*
H5	0.564988	0.978148	0.359532	0.0302*
H6	0.341893	0.536992	0.094166	0.0315*
H8	0.291169	0.330456	0.614246	0.0257*
H9	0.277637	0.458185	0.845681	0.0323*
H10	0.218522	0.733305	0.937626	0.034*
H11	0.171553	0.877999	0.791278	0.0341*
H12	0.186741	0.755244	0.560722	0.0284*
H1a	0.161 (3)	0.215 (4)	−0.052 (3)	0.0405*
H1b	0.329 (3)	0.230 (4)	−0.052 (3)	0.0405*

Jana2006 whereby pairs of reflections from different twin domains are discarded or used based in their difference in degrees of theta. Reflections falling into an interval where partial overlaps are suspected are discarded. The carefully chosen interval between 0.25 and 0.50 degrees theta led to discarding 210 reflections (i.e., 11% of the data set), and the resulting R value was 4.47%, g.o.f. 2.62 (see Table 1). Table 1 reports crystallographic data and experimental details for **2c**. Atomic coordinates and isotropic displacement parameters are reported in Table 3.

Interatomic distances are summarized in Table 4. Supplementary tables of crystal structure and refinements, as well as the anisotropic thermal parameters, have been deposited at the CCDC data base, code CCDC 734067 (www.ccdc.cam.ac.uk).

Crystal Structure Description of 2c

The framework of the compound **2c** is built up from isolated *N,N*-bis((*1H*-1,2,4-triazol-1-yl)methyl)benzenamine molecules and water molecules. The organic molecules are associated only by dipole–dipole interactions and weak C—H . . . N hydrogen bonds. In Fig. 3, we can distinguish slabs parallel with the *ab* plane. Water molecules are located between them and bound via weak O-H . . . C hydrogen

Table 4. Bonds and angles in the structure of **2c** (Å, °)

Bond	Value	Angle	Value
O1—H1a	0.83 (2)	H1a—O1—H1b	106 (3)
N5—C4	1.471 (4)	N2—C1—N3	115.6 (3)
O1—H1b	0.83 (3)	N2—N1—C2	109.9 (2)
N5—C6	1.333 (4)	N1—C2—N3	110.8 (3)
N1—N2	1.363 (4)	N2—N1—C3	121.2 (2)
N6—C5	1.320 (4)	N1—C3—N4	114.4 (2)
N1—C2	1.332 (3)	C2—N1—C3	128.8 (3)
N7—C5	1.354 (3)	N4—C4—N5	113.4 (2)
N1—C3	1.468 (3)	N1—N2—C1	101.8 (2)
N7—C6	1.327 (4)	N6—C5—N7	115.2 (2)
N2—C1	1.322 (3)	C1—N3—C2	102.0 (2)
C7—C8	1.403 (5)	N5—C6—N7	110.6 (2)
N3—C1	1.357 (4)	C3—N4—C4	116.5 (2)
C7—C12	1.403 (4)	N4—C7—C8	121.0 (3)
N3—C2	1.330 (4)	C3—N4—C7	122.1 (3)
C8—C9	1.383 (4)	N4—C7—C12	121.2 (3)
N4—C3	1.438 (4)	C4—N4—C7	121.3 (2)
C9—C10	1.384 (4)	C8—C7—C12	117.8 (2)
N4—C4	1.445 (4)	N6—N5—C4	122.4 (2)
C10—C11	1.390 (5)	C7—C8—C9	120.7 (3)
N4—C7	1.410 (3)	N6—N5—C6	109.6 (2)
C11—C12	1.374 (4)	C8—C9—C10	121.3 (3)
N5—N6	1.363 (3)	C4—N5—C6	128.0 (2)
		C9—C10—C11	118.1 (3)
		N5—N6—C5	102.2 (2)
		C10—C11—C12	121.6 (3)
		C5—N7—C6	102.4 (2)
		C7—C12—C11	120.6 (3)

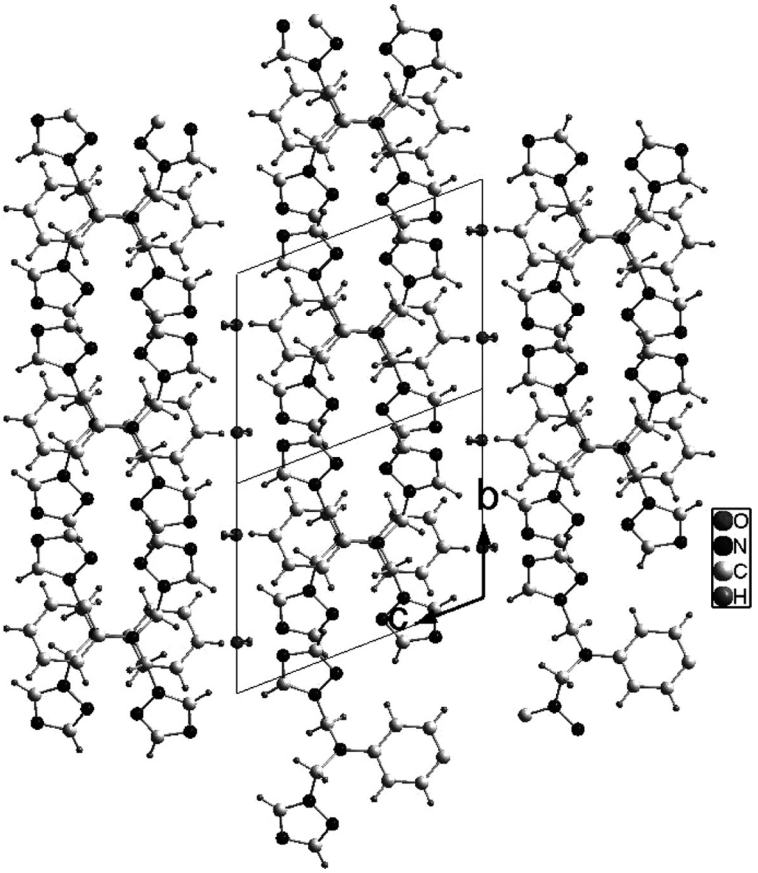

Figure 3. Projection along [100] from the structure of **2c**; the color is polyedra as atoms. Molecules of *N,N*-bis((*1H*-1,2,4-triazol-1-yl)methyl)benzenamine stack in slabs interconnected by H bonds via water molecules.

bonds. The C—H . . . N hydrogen bonds exist between the slabs as well as inside the slabs.

Inside the organic slabs, the title molecules form zigzag chains as shown in Fig. 4. C—H . . . N interactions link the two triazol fragments of two neighboring *N,N*-bis((*1H*-1,2,4-triazol-1-yl)methyl)benzenamine molecules, both inside the hypothetical chain as between two neighboring chains.

We report in Table 5 the short $\pi-\pi$ interactions between five-ring triazol and six-ring groups inside and between the chains. Notice that the strongest such interactions are between two triazol groups at 3.5736 Å.

Because of steric effects in *N,N*-bis((*1H*-1,2,4-triazol-1-yl)methyl)benzenamine, the molecule is not planar. This is expressed in terms of torsion angles as depicted in Table 6.

Globally, *N,N*-bis((*1H*-1,2,4-triazol-1-yl)methyl)benzenamine shows usual bonds, angles, and torsion angle features. Figure 5 depicts a perspective view of *N,N*-bis((*1H*-1,2,4-triazol-1-yl)methyl)benzenamine.

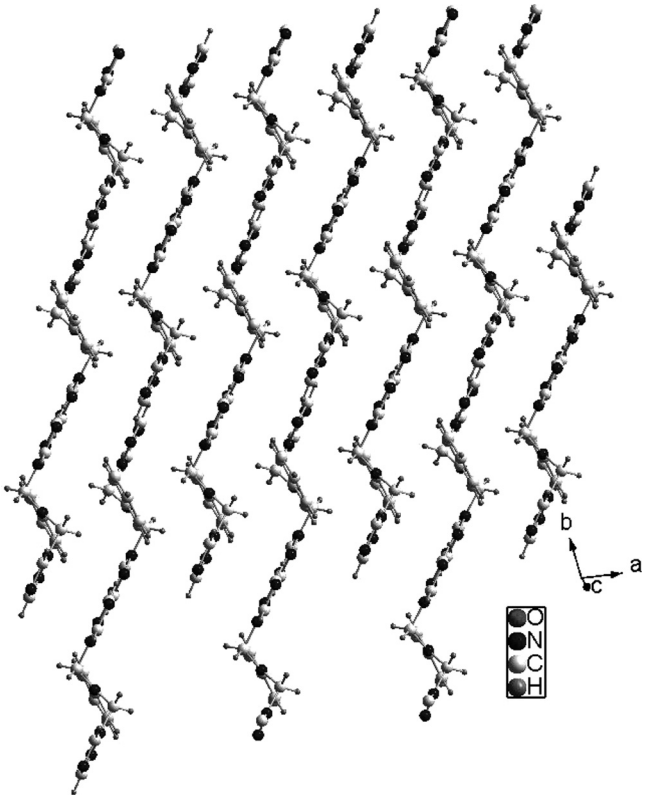

Figure 4. Morphology of the organic slab; π–π interactions between triazol groups lead in chains of the molecules connected by H bonds.

Table 5. Short ring interactions in the molecule of **2c** (distances <6 Å)

Cg(I)	Cg(J)	Cg-Cg	α
Cg(1)	Cg(2)	5.7229 (18)	6.36
Cg(1)	**Cg(2)**	**3.5736 (18)**	**6.36**
Cg(1)	Cg(2)	5.3907 (16)	6.36
Cg(1)	Cg(3)	4.5603 (18)	1.1459
Cg(2)	Cg(1)	3.5736 (18)	−4.2070
Cg(2)	Cg(1)	5.7228 (18)	2.4946
Cg(2)	Cg(1)	5.3907 (16)	−2.2219
Cg(2)	Cg(3)	4.4730 (18)	−6.1768
Cg(3)	Cg(1)	5.7041 (19)	−1.1662
Cg(3)	Cg(1)	5.5206 (18)	−2.2219
Cg(3)	Cg(2)	5.5620 (17)	1.5064
Cg(3)	Cg(2)	5.7290 (19)	0.4454
Cg(3)	Cg(3)	5.1607 (17)	1.1459

Notes. Cg(X) = Plane #(X). Ring (1): five-membered N(1), N(2), C(1), N(3), C(2). Ring (2): five-membered N(15), N(6), C(5), N(7), C(6)]. Six-membered C(7), C(8), C(9), C(10), C(11), C(12).α = dihedral angle between planes I and J (°).

Table 6. H bond interactions in the crystal structure of **2c**

	D-H	H...A	D...A	D-H...A
O(1)–H(1A)...N(3)	0.83 (3)	2.11 (3)	2.925 (3)	169 (3)
O(1)–H(1B)...N(7)	0.83 (3)	2.08 (3)	2.898 (3)	171 (3)
C(1) –H(1)...N(2)	0.96	2.59	3.288 (4)	129
C(2)–H(2)...O(1)	0.96	2.32	3.147 (4)	144
C(6)–H(6)...O(1)	0.96	2.33	3.174 (4)	146
C(8)–H(8)...N(2)	0.96	2.56	3.226 (4)	126
C(12)–H(12)...N(6)	0.96	2.57	3.191 (4)	123

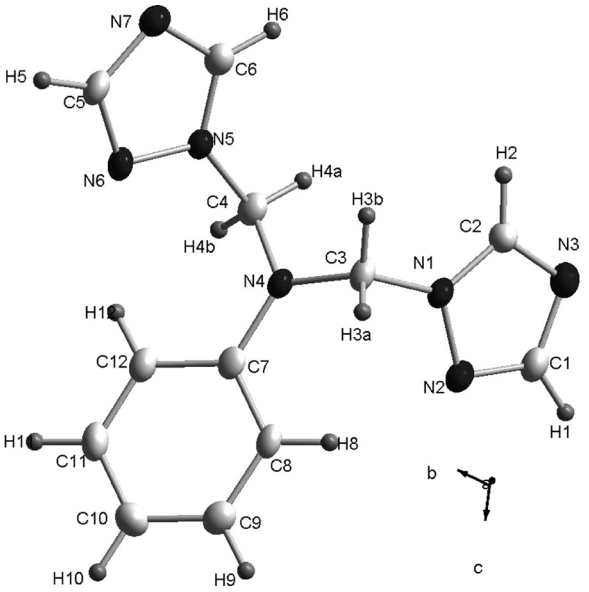

Figure 5. Spatial representation of **2c** crystal. Displacement ellipsoids are drawn at the 50% probability level.

CONCLUSION

In conclusion, we have synthesized new tripodal triazolic compounds with the opportunity to change the substituents easily and generate good to excellent yields. The x-ray structure of one of these compounds has been investigated. Such structural and electronic diversity may have potential applications in medicinal or coordination chemistry. Further developments on this subject are currently in progress.

ACKNOWLEDGMENTS

We thank the Centre National de la Recherche Scientifique et Technique, CNRST (Morocco), and the Commission Universitaire pour le Développement, CUD (Belgium), for financial support. We also acknowledge Institutional research

plan No. AVOZ10100521 of the Institute of Physics and the project Praemium Academiae of the Academy of Sciences of the Czech Republic.

REFERENCES

1. Hanot, V.; Robert, T. Synthesis and preliminary study of Cu(II) and Pd(II) complexes with a new chelating bis(triazolyl)triazenido ligand. *J. Coord. Chem.* **1994**, *32*, 349–352.
2. Sorrell, T. N.; Vankai, V. A.; Garrity, M. L. Synthesis and reactivity of dinuclear copper complexes having a m-xylyl spacer between coordination units. *Inorg. Chem.* **1991**, *30*, 207–210.
3. Pate, J. E.; Cruse, R. W.; Karlin, K. D.; Solomon, E. I. Vibrational, electronic, and resonance raman spectral studies of $[Cu_2(YXL\text{-}O\text{-})O_2]^+$, a copper(II) peroxide model complex of oxyhemocyanin. *J. Am. Chem. Soc.* **1987**, *109*, 2624–2630.
4. El Zemity, S. R.; Radwan, M. Synthesis and structure–activity relationships for anticipated molluscicidal activity of some 2-amino-5-substituted pyridine derivatives. *Pestic. Sci.* **1999**, *55*, 1203–1209.
5. Xu, X.-Y.; Chen, J.-L.; Luo, Q.-H.; Shen, M.-C.; Huang, X.-Y.; Wu, Q.-J. Synthesis and crystal structure of a new phenoxy oxygen bridged binuclear cadmium(II) polyaza cryptate. *Polyhedron* **1997**, *16*, 223–227.
6. Kumar, M.; Aran, V. J.; Navarro, P. New proton ionizable 3,5-disubstituted pyrazole cryptands able to form tripyrazolate-derived di- and tetra-nuclear complexes of Cu^{2+} or Zn^{2+}. *Tetrahedron Lett.* **1995**, *36*, 2161–2164.
7. Togni, A.; Venanzi, L. M. Nitrogen donors in organometallic chemistry and homogeneous catalysis. *Angew. Chem., Int. Ed. Eng.* **1994**, *33*, 497–526.
8. Gamez, P.; Aubel, P. G.; Driessen, W. L.; Reedijk, J. Homogeneous bio-inspired copper-catalyzed oxidation reactions. *Chem. Soc. Rev.* **2001**, *30*, 376–385.
9. Johnson, D. S.; Li, J. J. *The Art of Drug Synthesis*; Wiley: New York, 2007.
10. Bartroli, J.; Turmo, E.; Algueró, M.; Boncompte, E.; Vericat, M. L.; Conte, L.; Ramis, J.; Merlos, M.; García-Rafanell, J.; Forn, J. New azole antifungals, 3: Synthesis and antifungal activity of 3-substituted-4(3*H*)-quinazolinones. *J. Med. Chem.* **1998**, *41*, 1869–1882.
11. Bentley, A.; Butters, M.; Green, S. P.; Learmonth, W. J.; MacRae, J. A.; Morland, M. C.; O'Connor, G.; Skuse, J. The discovery and process development of a commercial route to the water-soluble prodrug fosfluconazole. *Org. Process Res. Dev.* **2002**, *6*, 109–112.
12. Vennerstrom, J. L. Book review of *The Art of Drug Synthesis*. *J. Med. Chem.* **2008**, *51*, 1502–1503.
13. Slangen, P. M.; Van Koningsbruggen, J.; Goubitz, K.; Haasnoot, J. G.; Reedijk, J. Isotropic magnetic exchange interaction through double μ-1,2,4-triazolato-N1,N2 bridges: X-ray crystal structure, magnetic properties, and EPR study of bis(μ – 3-pyridin-2-yl-1,2,4-triazolato-N′,N1,N2)(sulfato-O)aquacopper(II)diaquacopper(II). trihydrate. *Inorg. Chem.* **1994**, *33*, 1121–1126.
14. Trofimenko, S. Recent advances in poly(pyrazolyl)borate (scorpionate) chemistry. *Chem. Rev.* **1993**, *93*, 943–980.
15. Kitajima, N.; Moro-Oka, Y. Copper-dioxygen complexes: Inorganic and bioinorganic perspectives. *Chem. Rev.* **1994**, *94*, 737–757.
16. Janiak, C.; Scharmann, T. G.; Albrecht, P.; Marlow, F.; Macdonald, R. [Hydrotris(1,2,4-triazolyl)borato]silver(I): Structure and optical properties of a coordination polymer constructed from a modified poly(pyrazolyl)borate ligand. *J. Am. Chem. Soc.* **1996**, *118*, 6307–6308.

17. Waring, M. J.; Ben-Hadda, T.; Kotchevar, A. T.; Ramdani, A.; Touzani, R.; El Kadiri, S.; Hakkou, A.; Bouakka, M.; Ellis, T. 2,3-Bifunctionalized quinoxalines: Synthesis, DNA interactions, and evaluation of anticancer, antituberculosis, and antifungal activity. *Molecules* **2002**, *7*, 641–656.
18. El Kodadi, M.; Benamar, M.; Bouabdallah, I.; Zyad, A.; Malek, F.; Touzani, R.; Ramdani, A.; Melhaoui, A. New synthesis of two tridentate bipyrazolic compounds and their cytotoxic activity tumor cell lines. *Nat. Prod. Res.* **2007**, *21*, 947–952.
19. Lavastre, O.; Touzani, R.; Garbacia, S. Thin-layer chromatography for the detection of unexpected reactions in organometallic combinatorial catalysis. *Adv. Synth. Cat.* **2003**, *345*, 974–977.
20. Le Notre, J.; Touzani, R.; Lavastre, O.; Bruneau, C.; Dixneuf, P. H. Homologation of monoterpenoids into new sesquiterpenoids via tandem isomerization/Claisen rearrangement reactions with three-component ruthenium catalysts, and Ru(methallyl)2 (COD) revealed by high throughput screening techniques. *Adv. Synth. Catal.* **2005**, *347*, 783–791.
21. Boussalah, N.; Touzani, R.; Bouabdallah, I.; El Kadiri, S.; Ghalem, S. Synthesis, structure and catalytic properties of tripodal amino-acid derivatized pyrazole-based ligands. *J. Mol. Catal. A: Chem.* **2009**, *306*, 113–117.
22. El Kodadi, M.; Malek, F.; Touzani, R.; Ramdani, A. Synthesis of new tripodal ligand 5-(bis(3,5-dimethyl-1H-pyrazol-1-ylmethyl)amino)pentan-1-ol: Catecholase activities studies of three functional tripodal pyrazolyl N-donor ligands, with different copper(II) salts. *Catal. Commun.* **2008**, *9*, 966–969.
23. Bouabdallah, I.; Touzani, R.; Zidane, I.; Ramdani, A. Synthesis of new tripodal ligand: *N,N*-Bis[(1,5-dimethyl-3- yl)methyl] benzylamine: Catecholase activity of two series of tripodal ligands with some copper(II) salts. *Catal. Commun.* **2007**, *8*, 707–712.
24. Que Jr., L.; Kim, C.; Kim, J.; Zang, Y. Iron complexes for bleach activation and stereospecific oxidation catalysts. PCT Int. 6,107,528, Aug. 22, 2000.
25. Phillips, E.; Holt, B. Metal deactivators. *Eur. Pat. Appl.* 19851106, 1985.
26. Oxford Diffraction. *Crysalis CCD, CCD Data Collection, and GUI*. Oxford Diffraction Ltd.: Oxford, 2009.
27. Oxford Diffraction. *Crysalis RED, CCD Data Reduction GUI*. Oxford Diffraction Ltd.: Oxford, UK, 2009.
28. Burla, M. C.; Camalli, M.; Carrozzini, B.; Cascarano, G.; Giacovazzo, C.; Polidori, G.; Spagna, R. SIR2002: The program. *J. Appl. Cryst.* **2003**, *36*, 1103–1103.
29. Petricek, V.; Dusek, M.; Palatinus, L. *Jana2006, Structure Determination Software Programs*. Institute of Physics: Prague, Czech Republic, 2007.
30. Brandenburg, K.; Putz, H. *Diamond, Version 3*. Crystal Impact GbR: Bonn, Germany, 2005.
31. Pevzner, M. S.; Ivanov, P. A.; Gladkova, N. V.; Sushchenko, O. N.; Tverdokhlebov, V. P.; Myasnikova, Z. S. Heterocyclic nitro compounds, 25: 1-Hydroxymethyl-3-nitro-1,2,4-triazoles and their derivatives. *Chem. Heterocycl. Compd.* **1980**, *16*, 189–194.
32. Touzani, R.; Ramdani, A.; Ben-Hadda, T.; El Kadiri, S.; Maury, O.; Le Bozec, H.; Dixneuf, P. H. Efficient synthesis of new nitrogen donor containing tripods under microwave irradiation and without solvent. *Synth. Commun.* **2001**, *31*, 1315–1321.
33. Touzani, R.; Garbacia, S.; Lavastre, O.; Yadav, V. K.; Carboni, B. Efficient solution phase combinatorial access to a library of pyrazole- and triazole-containing compounds. *J. Comb. Chem.* **2003**, *5*, 375–378.