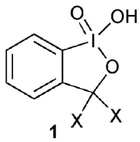
Preparation and X-ray crystal structure of 2-iodyl-*N*,*N*-dialkylaniline oxides: first entry into the heterocyclic system of benziodoxazole†‡

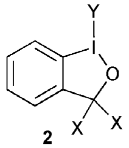
Viktor V. Zhdankin,* Victor N. Nemykin,* Rashad R. Karimov and Zeinul-Gabiden Kazhkenov

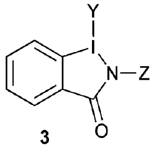
Received (in Cambridge, UK) 30th July 2008, Accepted 25th September 2008
First published as an Advance Article on the web 20th October 2008
DOI: 10.1039/b813163e

The oxidation of 2-iodo-*N*,*N*-dialkylanilines with an excess of dimethyldioxirane in acetone affords 2-iodyl-*N*,*N*-dialkylaniline oxides, structural features of which are in agreement with the new heterocyclic system of benziodoxazole.

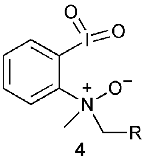
Hypervalent iodine compounds are employed extensively in organic synthesis as highly selective and environmentally friendly oxidizing reagents.[1] Especially important are the heterocyclic iodine(III) and iodine(V) derivatives, known under the common name of benziodoxoles (structures **1** and **2**), which have higher thermal stabilities and more useful reactivity patterns compared to the analogous non-cyclic derivatives.[2] 2-Iodylbenzoic acid (IBX) and 2-iodosylbenzoic acid (IBA) in their cyclic tautomeric forms **1** (2X = O) and **2** (2X = O, Y = OH) are the best known and practically important representatives of benziodoxoles. Structural aspects of IBX, IBA and other benziodoxoles have been investigated by several research groups,[3,4] most notably by Katritzky and co-workers in a series of papers published in 1989–1990.[4] Besides benziodoxoles, the only other known five-membered heterocyclic system incorporating hypervalent iodine is represented by benziodazoles **3**.[5] In this *communication* we report the preparation of 2-iodyl-*N*,*N*-dialkylaniline oxides **4**, structural features of which are in agreement with the new heterocyclic system of benziodoxazole **5**.

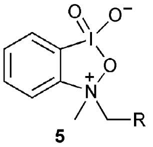

1

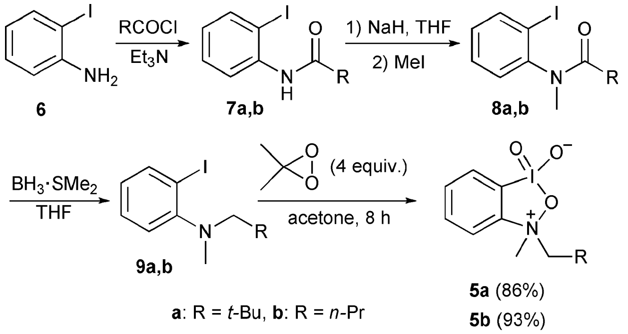

2


3

X = Me, CF_3 or 2X = O; Y = OH, OAc, N_3, CN, etc.; Z = H, Ac, etc.


4


5


Scheme 1 Preparation of 2-iodyl-*N*,*N*-dialkylaniline oxides **5**.

Compounds **5a,b** were prepared in the form of stable, white microcrystalline products by the oxidation of 2-iodo-*N*,*N*-dialkylanilines **9a,b** with excess dimethyldioxirane in acetone. The starting anilines **9a,b** can be conveniently prepared from commercially available 2-iodoaniline **6** by acylation to give amides **7**,[6] subsequent methylation, and reduction of *N*-methylamides **8** to give dialkylanilines **9** as outlined in Scheme 1.

Compounds **5** were identified on the basis of spectroscopic data, ESI mass spectrometry and single crystal X-ray analysis in the case of **5b**.§ IR spectra of all compounds showed a strong I═O absorption at 750–770 cm^{-1}. ^1H NMR spectra of compounds **5** show signals in the aromatic region which look very similar to the spectrum of IBX **1** (2X = O), as well as the appropriate signals of the two alkyl groups. In the ^{13}C NMR spectra of products **5**, the signal of $C–IO_2$ is observed at 147–149 ppm, which is typical of iodylarenes.[6] The ESI-HRMS spectrum of compound **5b** demonstrated strong peaks $[2M + Na]^+$ and $[2M + H]^+$ corresponding to a dimer as well as weaker $[M + Na]^+$ and $[M + H]^+$ peaks. Interestingly the addition of trifluoroacetic acid to compound **5b** leads to the disappearance of the dimer peaks $[2M + Na]^+$ and $[2M + H]^+$ leaving only the monomer peak 338.2308 $[M + H]^+$ in the MS spectrum.

The solid state structure of compound **5b** was established by single crystal X-ray crystallography (Fig. 1).§ The X-ray data reveal that two crystallographically independent molecules are present in the crystal unit cell. Selected bond distances, bond angles and torsion angles for both molecules are listed in Table 1. The five-membered benziodoxazole ring is present in both independent molecules and in both cases it is nearly planar with the maximum observed C–I–O–N torsion angle of ~17°. However, the structural parameters, in particular, the endocyclic I–O bond distances ($I_2–O_3$ 2.366(10) Å and $I_1–O_8$

Department of Chemistry and Biochemistry, University of Minnesota Duluth, Duluth, Minnesota 55812, USA. E-mail: vzhdanki@d.umn.edu; Fax: +1-218-726-7394; Tel: +1-218-726-6902

† Dedicated to Professor Alan R. Katritzky on the occasion of his 80th birthday.

‡ Electronic supplementary information (ESI) available: Experimental details and characterization data, including crystallographic data for **5b**. CCDC 696745. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/b813163e

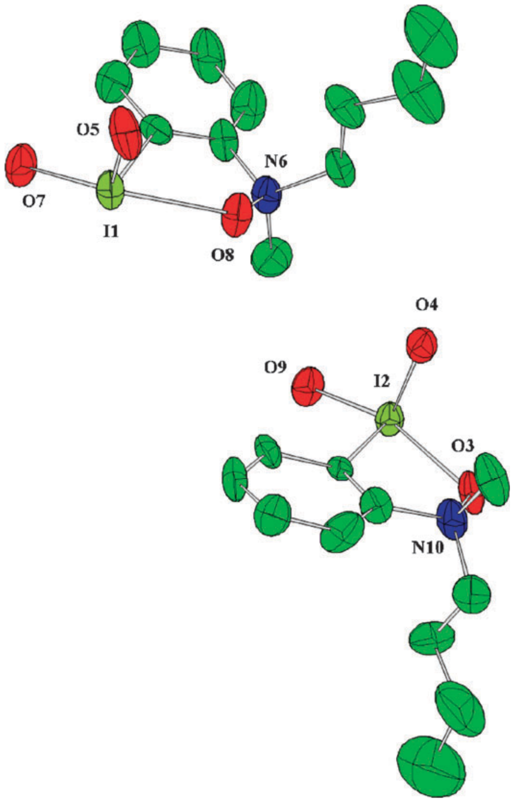


Fig. 1 X-Ray crystal structure of two independent molecules of **5b** (at the 50% probability level) in the unit cell. Selected bond distances, bond angles and torsion angles for both independent molecules are listed in Table 1.

2.466(9) Å), are significantly different. This difference reflects different intermolecular interactions between the molecules in the unit cell (Fig. 2). Indeed, two pairs of independent molecules observed in the unit cell of **5b** form a very unusual cluster in which two pairs of iodine centers (I_2(A) and I_2(C) as well as I_1(B) and I_1(D), Fig. 2) have significantly different hexacoordinated pseudo-octahedral geometries. As a result, the five-membered cycle with hexacoordinated iodine I_2(A) and I_2(C) centers is more planar as compared to that with iodine centers I_1(B) and I_1(D) (Table 1). It is interesting to note that *S* enantiomers (molecules A and C, Fig. 2) interact both with each other as well as with the corresponding *R* enantiomers B and D. On the other hand, *R* enantiomers B and D interact only with appropriate *S* enantiomers A and C but not with each other. Both the $I_2{=}O$ oxygen atoms are involved in formation of intermolecular bonds, while one of the $I_1{=}O$ oxygen atoms does not participate in the formation of the tetramolecular cluster and, as expected, the $I_1{=}O_5$ bond is significantly shorter.

Table 1 Selected interatomic distances, angles and torsion angles in two independent molecules of **5b**

Bond	Distance/Å or angle/°	Bond	Distance/Å or angle/°
I_1–O_8	2.466(9)	I_2–O_3	2.366(10)
I_1–O_5	1.745(12)	I_2–O_4	1.771(11)
I_1–O_7	1.836(10)	I_2–O_9	1.807(10)
O_8–N_6	1.374(14)	O_3–N_{10}	1.407(14)
C_{14}–I_1–O_8	69.8(5)	C_{19}–I_2–O_3	70.8(4)
O_5–I_1–O_8	90.5(5)	O_4–I_2–O_3	91.1(4)
O_5–I_1–O_7	101.7(5)	O_4–I_2–O_9	101.9(5)
O_7–I_1–O_8	159.9(4)	O_9–I_2–O_3	160.8(4)
C_{14}–I_1–O_8–N_6	17.39	C_{19}–I_2–O_3–N_{10}	11.50

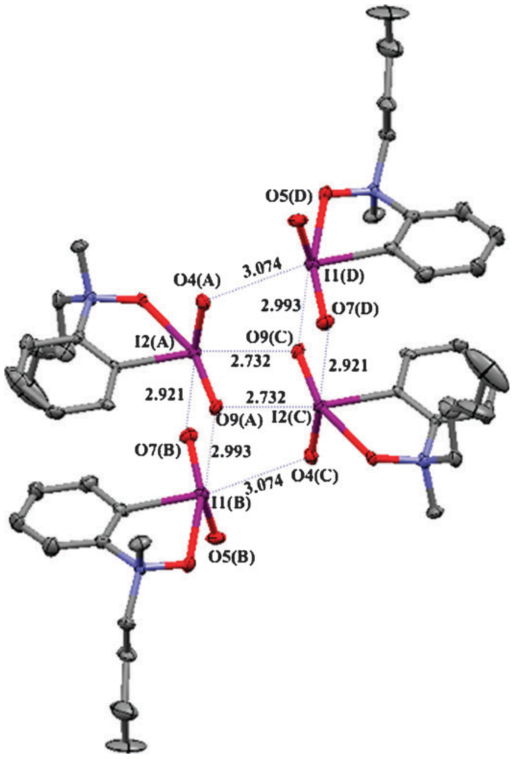


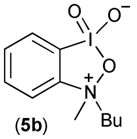
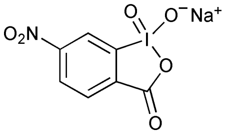
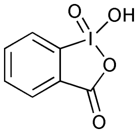
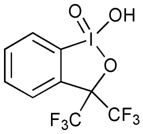
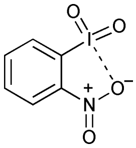
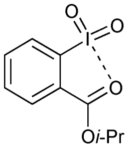
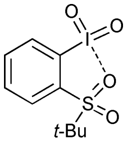
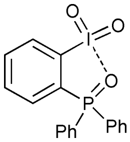
Fig. 2 Intermolecular interactions between molecules A–D formed by two pairs of independent molecules in the unit cell found in the crystal structure of **5b** (at the 50% probability level).

A comparison of the endocyclic I–O bond distances and C–I–O bond angles in **5b** (entry 1) with the known pentavalent iodine heterocycles (entries 2–4) and pseudo-heterocycles (entries 5–8) is given in Table 2. The I–O bond distances in the five-membered ring of benziodoxoles are generally found in the range of 2.26 Å (entry 3) to 2.48 Å (entry 2). The structural parameters in molecule **5b** are in the middle of this range, which allows us to classify this molecule as an iodine(V) heterocycle, in contrast to the previously reported *o*-iodylnitrobenzene (entry 5), which belongs to the group of pseudo-heterocycles (intramolecular I–O bond distances 2.6–2.8 Å).

As typical for the known pentavalent iodine heterocycles,[1,2] compounds **5** are powerful oxidants toward organic substrates. We have found that compound **5b** reacts with various alcohols (primary and secondary alkyl, cycloalkyl, benzylic and allylic alcohols) under mild conditions to afford the respective aldehydes and ketones in excellent yields. The details of these oxidations are provided in the ESI.‡

In conclusion, we have reported the preparation of 2-iodyl-*N*,*N*-dialkylaniline oxides, structural features of which are in agreement with the new heterocyclic system of benziodoxazole. These new pentavalent iodine heterocycles can be used as efficient oxidizing reagents for the selective oxidation of alcohols to the respective carbonyl compounds.

Table 2 Endocyclic I–O bond distances and C–I–O bond angles in hypervalent iodine heterocycles (entries 1–4) and pseudo-heterocycles (entries 5–8)

Entry	Structure	I–O distance/Å	C–I–O angle/°	Ref.
1	 (**5b**)	2.366[a] 2.466[a]	70.8[a] 69.8[a]	This work
2		2.481	72.3	4a
3		2.324 2.263	75.6 77.15	3*c*,*d*
4		2.296	74.0	3*a*
5		2.77[a] 2.68[a]	66.65[b] 67.66[b]	7*a*
6		2.8185[a] 2.6979[a]	69.13[b] 70.25[b]	7*b*,*c*
7		2.693	73.11[b]	7*d*
8		2.603	76.06[b]	7*e*

[a] Data for two independent molecules in crystal unit cell. [b] Angles obtained from the CCDC database.

This work was supported by a research grant from the National Science Foundation (CHE-0702734).

Notes and references

§ Crystal data for **5b**. $C_{11}H_{16}INO_3$: $M = 337.15$, triclinic, space group $P\bar{1}$, $a = 8.1788(16)$, $b = 10.512(2)$, $c = 15.850(3)$ Å, $\alpha = 71.58(3)$, $\beta = 82.16(3)$, $\gamma = 78.02(3)$°, $V = 1261.1(5)$ Å^3, $Z = 4$, μ(Mo Kα) = 2.532 mm^{-1}, $T = 298$ K, 4478 reflections measured, 4429 unique; final $R_1 = 0.0698$ ($I \geq 2\sigma(I)$), $R_w = 0.0886$ ($I \geq 2\sigma(I)$); $R_{int} = 0.00$. CCDC 696745.

1 (*a*) R. M. Moriarty and O. Prakash, *Hypervalent Iodine in Organic Chemistry: Chemical Transformations*, Wiley-Interscience, Weinheim, 2008; (*b*) T. Wirth, *Hypervalent Iodine Chemistry: Modern Developments in Organic Synthesis*, *Top. Curr. Chem.*, Springer, Berlin-Tokyo, 2003, vol. 224; (*c*) A. Varvoglis, *Hypervalent Iodine in Organic Synthesis*, Academic Press, London, 1997; (*d*) G. F. Koser, *Adv. Heterocycl. Chem.*, 2004, **86**, 225; (*e*) V. V. Zhdankin, *Sci. Synth.*, 2007, **31a**, 161; (*f*) U. Ladziata and V. V. Zhdankin, *ARKIVOC*, 2006, **ix**, 26; (*g*) V. V. Zhdankin and P. J. Stang, *Chem. Rev.*, 2002, **102**, 2523; (*h*) M. Ochiai, *Coord. Chem. Rev.*, 2006, **250**, 2771; (*i*) M. Ochiai, *Chem. Rec.*, 2007, **7**, 12; (*j*) N. R. Deprez and M. S. Sanford, *Inorg. Chem.*, 2007, **46**, 1924; (*k*) H. Tohma and Y. Kita, *Adv. Synth. Catal.*, 2004, **346**, 111; (*l*) Y. Kita and H. Fujioka, *Pure Appl. Chem.*, 2007, **79**, 701; (*m*) S. Quideau, L. Pouysegu and D. Deffieux, *Synlett*, 2008, 467; (*n*) H. Togo and K. Sakuratani, *Synlett*, 2002, 1966.

2 (*a*) T. Wirth, *Angew. Chem., Int. Ed.*, 2001, **40**, 2812; (*b*) V. V. Zhdankin, *Curr. Org. Synth.*, 2005, **2**, 121; (*c*) V. V. Zhdankin, *Rev. Heteroat. Chem.*, 1997, **17**, 133; (*d*) H. Morales-Rojas and R. A. Moss, *Chem. Rev.*, 2002, **102**, 2497.

3 (*a*) D. B. Dess and J. C. Martin, *J. Am. Chem. Soc.*, 1991, **113**, 7277; (*b*) D. B. Dess, S. R. Wilson and J. C. Martin, *J. Am. Chem. Soc.*, 1993, **115**, 2488; (*c*) J. Z. Gougoutas, *Cryst. Struct. Commun.*, 1981, **10**, 489; (*d*) P. J. Stevenson, A. B. Treacy and M. Nieuwenhuyzen, *J. Chem. Soc., Perkin Trans. 2*, 1997, 589; (*e*) V. V. Zhdankin, O. Maydanovych, J. Herschbach, R. McDonald and R. R. Tykwinski, *J. Am. Chem. Soc.*, 2002, **124**, 11614; (*f*) V. V. Zhdankin, A. P. Krasutsky, C. J. Kuehl, A. J. Simonsen, J. K. Woodward, B. Mismash and J. T. Bolz, *J. Am. Chem. Soc.*, 1996, **118**, 5192.

4 (*a*) A. R. Katritzky, G. P. Savage, G. J. Palenik, K. Qian, Z. Zhang and H. D. Durst, *J. Chem. Soc., Perkin Trans. 2*, 1990, 1657; (*b*) A. R. Katritzky, G. P. Savage, J. K. Gallos and H. D. Durst, *J. Chem. Soc., Perkin Trans. 2*, 1990, 1515; (*c*) A. R. Katritzky, B. L. Duell, J. K. Gallos and H. D. Durst, *Magn. Reson. Chem.*, 1989, **27**, 1007.

5 (*a*) W. Wolf and L. Steinberg, *Chem. Commun.*, 1965, 449; (*b*) H. J. Barber and M. A. Henderson, *J. Chem. Soc. C*, 1970, 862; (*c*) T. M. Balthazor, D. E. Godar and B. R. Stults, *J. Org. Chem.*, 1979, **44**, 1447; (*d*) S. Akai, T. Okuno, T. Takada, H. Tohma and Y. Kita, *Heterocycles*, 1996, **42**, 47; (*e*) V. V. Zhdankin, R. M. Arbit, M. McSherry, B. Mismash and V. G. Young, *J. Am. Chem. Soc.*, 1997, **119**, 7408; (*f*) V. V. Zhdankin, R. M. Arbit, B. J. Lynch, P. Kiprof and V. G. Young, *J. Org. Chem.*, 1998, **63**, 6590; (*g*) R. A. Moss, S. Chatterjee and B. Wilk, *J. Org. Chem.*, 1986, **51**, 4303; (*h*) V. V. Zhdankin, A. Y. Koposov, L. S. Su, V. V. Boyarskikh, B. C. Netzel and V. G. Young, *Org. Lett.*, 2003, **5**, 1583; (*i*) V. V. Zhdankin, A. E. Koposov, J. T. Smart, R. R. Tykwinski, R. McDonald and A. Morales-Izquierdo, *J. Am. Chem. Soc.*, 2001, **123**, 4095.

6 U. Ladziata, A. Y. Koposov, K. Y. Lo, J. Willging, V. N. Nemykin and V. V. Zhdankin, *Angew. Chem., Int. Ed.*, 2005, **44**, 7127.

7 (*a*) V. A. Nikiforov, V. S. Karavan, S. A. Miltsov, S. I. Selivanov, E. Kolehmainen, E. Wegelius and M. Nissine, *ARKIVOC*, 2003, **2vi**, 191; (*b*) V. V. Zhdankin, D. N. Litvinov, A. Y. Koposov, T. Luu, M. J. Ferguson, R. McDonald and R. R. Tykwinski, *Chem. Commun.*, 2004, 106; (*c*) V. V. Zhdankin, A. Y. Koposov, D. N. Litvinov, M. J. Ferguson, R. McDonald, T. Luu and R. R. Tykwinski, *J. Org. Chem.*, 2005, **70**, 6484; (*d*) D. Macikenas, E. Skrzypczak-Jankun and J. D. Protasiewicz, *Angew. Chem., Int. Ed.*, 2000, **39**, 2007; (*e*) B. V. Meprathu, M. W. Justik and J. D. Protasiewicz, *Tetrahedron Lett.*, 2005, **46**, 5187.