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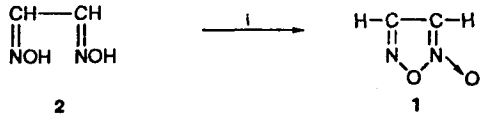
Synthesis and Properties of Unsubstituted Furoxan†

Tamara I. Godovikova, Svetlana P. Golova, Yurii A. Strelenko, Mikhail Yu. Antipin, Yurii T. Struchkov and Lenor I. Khmel'nitskii*

N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, 117913 Moscow, Russian Federation. Fax: +7 095 135 5328

For the first time a synthesis of unsubstituted furoxan,† the first member of the furoxan series, has been accomplished.

At the beginning of this century a synthesis of unsubstituted furoxan† **1** was attempted by oxidation of glyoxime **2** using various oxidizing agents. Concentrated HNO_3 (d 1.47 g cm^{-3}) or alkaline solution of NaOCl caused total decomposition of **2**, even at low temperature.[1] Oxidation with $KMnO_4$ in H_2SO_4,[1] with dilute HNO_3[2] or with N_2O_4 in ether[1–3] also failed to give **1**.

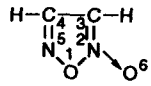


2 **1**

Scheme 1 *Reagents and conditions*: i, N_2O_4 (1 mol), CH_2Cl_2, 35–38 °C, 1 h; 45% yield of **1**. Purification of **1** by column chromatography (silica gel, 100/160μ, eluent CH_2Cl_2) with subsequent distillation.

† IUPAC recommended name furazan *N*-oxide.

Table 1 NMR spectral data of furoxan compared to the literature data.



Atoms in compounds		Furoxan		Dimethyl-,3-phenyl- and 4-phenylfuroxans	
	Chemical shifts, δ(ppm)	Coupling constants, *J*/Hz	Chemical shifts, δ (ppm)		Ref.
^{1}H H3	7.44	^{3}J(H3–H4) = 1.0	H3[a]	7.22	5
^{1}H H4	8.50	^{1}J(C3–H3) = 211.4	H4[b]	8.50	5
^{13}C C3	105.2	^{2}J(C3–H4) = 12.4	C3[a]	103.9	5
^{13}C C4	146.8	^{1}J(C4–H4) = 202.3	C4[b]	145.5	5
^{14}N N2	−16.3[d]	^{2}J(C4–H3) = 11.6	N2[c]	−25[d]	6
^{14}N N5	1.9[d]	^{1}J(C3–C4) = 62.2	N5[c]		6
^{15}N N2	−15.4	^{2}J(^{15}N2–H3) = 5.3	N2[c]	−19.1	7
^{15}N N5	3.9	^{3}J(^{15}N2–H4) = 4.3	N5[c]	7.0	7
^{17}O O1	507.5[e]	^{2}J(^{15}N5–H4) = 12.6	O1[c]	475[e]	8
^{17}O O6	364.0[e]	^{3}J(^{15}N5–H3) = 1.8	O6[c]	350[e]	8

[a] 4-Phenylfuroxan. [b] 3-Phenylfuroxan. [c] Dimethylfuroxan. [d] Very broad signals (~200Hz). [e] Very broad signals (~700 Hz).

We have pioneered the synthesis of **1**, the first member of the furoxan series, from **2** (Scheme 1).‡

Compound **1** is a colourless, stable liquid, decomposing by action of aqueous solutions of NH_3 and alkali, readily soluble in Et_2O, MeCN, Me_2CO, $MeCO_2H$, CH_2Cl_2 and $CHCl_3$; not soluble in H_2O or CCl_4. Compound **1** has b.p. 40 °C/2 mmHg, m.p. 13 °C, temperature at the onset of intense decomposition 145 °C, n_D^{20} 1.5040, d_4^{20} 1.4044, M_r(exp.) 18.14, M_r(calc.) 18.81, $EMR_D = -0.67$. Satisfactory elemental analyses and characterisation by IR, UV, mass, ^{1}H, ^{13}C, ^{14}N, ^{15}N and ^{17}O NMR spectroscopy were obtained.

The data obtained confirm the structure of **1**. The negative exaltation of the molecular refraction, $EMR_D = -0.67$, falls into the interval characteristic of furoxan monocyclic compounds (−0.2 – 1.2[4]). UV absorption data λ_{max} 263 nm, ε 7200 (in CH_2Cl_2) also fits the interval traditional for these substances (λ_{max} 255–295 nm, ε 3000–9800 dm^3 mol^{-1} cm^{-1},[4]). The IR spectrum, ν/cm^{-1} 3170s, 2770w, 1620s, 1490s, 1400s, 1280w, 1240m, 1170s, 1060m, 990s, 910s and 780s, in addition to a C–H stretching vibration band at 3170 cm^{-1}, contains characteristic furoxan ring stretching bands at 1620, 1490 and 1400 cm^{-1}, an *N*-oxide group stretch at 1280 cm^{-1} and somewhat less characteristic ring deformation bands at 1170, 1060, 990, 910 and 780 cm^{-1}.[4]

The mass spectrum contains peaks representing molecular ion $M^{+\cdot}$ *m/z* 86 (100%) and the most characteristic furoxan fragment, $[M-NO]^+$ *m/z* 56 (52.8%).§

The NMR spectral data are collected in Table 1, which shows that the chemical shifts of the furoxan atomic nuclei agree rather well with the corresponding chemical shifts of dimethylfuroxan and of phenylfuroxan isomers.

‡ *General experimental details.* The IR spectrum was recorded on a UR-20 spectrophotometer using KBr pellets. The UV spectrum was recorded on a Specord Uv-vis apparatus. The mass-spectrum was obtained on a Kratos MS-30 apparatus with direct specimen input into the ion source at ionizing electron energy 70 eV, ionizing camera temperature 200 °C.

NMR spectra were recorded on a Bruker AM 300 spectrometer operating at frequencies 300.13 MHz (^{1}H), 75.47 MHz (^{13}C), 21.69 MHz (^{14}N), 30.42 MHz (^{15}N) and 40.67 MHz (^{17}O). Chemical shifts are measured relative to the signal of [$^{2}H_6$]acetone (δ = 2.05 ppm, ^{1}H; 30.0 ppm, ^{13}C; 573 ppm, ^{17}O), or relative to external standard CH_3NO_2 (δ = 0.0 ppm, ^{14}N, ^{15}N) uncorrected for diamagnetic susceptibility.

§ The mass spectrum of the furoxan will be detailed in a special article.

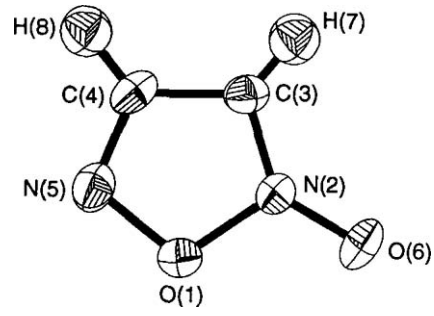


Fig. 1 The structure of the furoxan molecule in the crystal. Atoms are shown as 50% probability thermal ellipsoids. Bond lengths and angles: O(1)–N(5) 1.379(1), O(1)–N(2) 1.441(2), O(6)–N(2) 1.240(1), N(5)–C(4) 1.292(2), N(2)–C(3) 1.302(2), C(3)–C(4), 1.401(2), C(4)–H(8) 0.97(2), C(3)–H(7) 0.92(2), Å; N(5)O(1)N(2) 107.1(1), O(1)N(5)C(4) 106.6(1), O(1)N(2)O(6) 116.4(1), O(1)N(2)C(3) 107.2(1), O(6)N(2)C(3) 136.4(2), N(5)C(4)C(3) 111.9(1), N(2)C(3)C(4) 107.2(1), H(8)C(4)N(5) 120(1), H(8)C(4)C(3) 128(1), H(7)C(3)N(2) 123(1), H(7)C(3)C(4) 130(1)°.

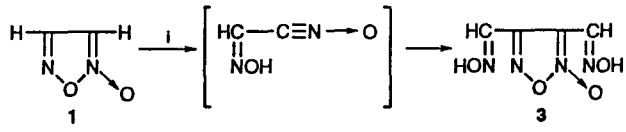
An X-ray method was used to determine the structure of the furoxan molecule **1** in the crystal.¶ A single crystal suitable for X-ray investigation was grown directly on a Syntex $P2_1$ diffractometer from the liquid **1** (m.p. ~12 °C) in a sealed, thin-walled capillary (diameter 0.4 mm) by slow cooling near its m.p. The grown crystal was slowly cooled down to −90 °C, at which temperature the X-ray experiment was performed.

The structure of the molecule **1** in the crystal and its main geometric parameters are indicated in Fig. 1. The molecule is in the plane, and the mean-square deviation of all atoms from the averaged plane, including H atoms, is 0.004 Å. The geometric parameters of **1** have the expected values[9] and are close to those found in the substituted furoxan derivatives studied earlier.[4] In common with numerous substituted derivatives the unsubstituted furoxan **1** is distinguished by a considerable difference between bond lengths O(1)–N(5) and O(1)–N(2), amounting to 0.062(2), as well as by an increase of the exocyclic bond angle C(3)N(2)O(6) between dative bond N(2)→O(6) and double bond C(3)=N(2) of the ring to the value of 136.4(1)°. The difference between bond lengths N(5)=C(4) and N(2)=C(3) is insignificant [0.010(2) Å], that adjacent to the *N*-oxide moiety being longer, as peculiar to furoxans. The bond angles H(8)C(4)C(3) and H(7)C(3)C(4) are strongly distorted in comparison with the ideal value of 120° for trigonal C atoms and amount to 128(1) and 130(1)°, respectively. Short intermolecular contacts in the crystal of **1** were not found.

Some chemical properties of **1** have been studied. Numerous experiments on the nitration of **1** with N_2O_4, HNO_3, $NO_2^+BF_4^-$, mixtures of $HNO_3 + H_2SO_4$, $HNO_3 + CF_3CO_2H$, $HNO_3 + FSO_3H$, $HNO_3 + (MeCO)_2O$, as well as $HNO_3 + MeCO_2H$ in the presence of $(MeCO_2)_2Hg$ or with $Cu(NO_3)_2$ in $(MeCO)_2O + MeCO_2H$ gave no positive results. Nor was success achieved in attempts to mercurate **1** with HgO in the presence of 60% $HClO_4$ or with $(MeCO_2)_2Hg$ in $MeCO_2H + HClO_4$.

¶ *Crystallographic data for* **1**: $C_2H_2N_2O_2$, $M = 86.06$, monoclinic crystals, space group $P2_1/n$, at −90 °C, $a = 8.249$ (2), $b = 5.004$ (2), $c = 8.675$ (2) Å, $\beta = 104.72$ (2)°, $V = 346.3$ (3) Å^3, $Z = 4$, $d_{calc} = 1.650$ g cm^{-3}, μ(MoKα) = 1.39 cm^{-1}, $F(000) = 44$. Intensities of 2050 reflections were measured on a Syntex–$P2_1$, diffractometer at −90 °C (MoKα radiation, $\lambda = 0.7107$ Å, $\theta/2\theta$ scanning, $2\theta \leqslant 60$ °) and 598 independent observed ones with $I \geqslant 2\sigma(I)$ were used in calculation and refinement. The structure was solved by a direct method and refined by a least-squares method in an anisotropic-isotropic (H atoms) approximation to $R = 0.035$, $R_w = 0.040$, GOF = 1.58 using weight scheme $W^{-1} = \sigma^2(F) + 0.0005F^2$. All calculations were made with programs SHELXTL PLUS using an IBM PC/AT computer. Atomic coordinates, thermal parameters, bond lengths and bond angles have been deposited at the Cambridge Crystallographic Data Centre. For details, see Notice to Authors, *Mendeleev Commun.*, 1994, issue 1.

Reaction of **1** with concentrated H_2SO_4 followed by water treatment gave rise to 3,4-bis(oximinomethyl)furoxan **3**, described in ref. 10 (Scheme 2).



Scheme 2 *Reagents and conditions*: i, H_2SO_4 (*d* 1.84), 18–20 °C, 4 days, 100%, yield of **3**, m.p. 170–171 °C.

In conclusion, we have achieved for the first time a synthesis of unsubstituted furoxan and investigated some of the physical and chemical properties of this interesting compound.

References

1 C. Ulpiani and A. de Dominicis, *Gazz. Chim. Ital.*, 1912, **42**, 243.
2 E. Bamberger and U. Suzuki, *Ber.* 1912, **45**, 2740.
3 G. Ponzio, *Gazz. Chim. Ital.*, 1932, **62**, 637.
4 L. I. Khmel'nitskii, S. S. Novikov and T. I. Godovikova, *Khimiya furoksanov: Stroenie i sintez* (*Chemistry of Furoxanes: Structure and Synthesis*), Nauka, Moscow, 1981, 328 (in Russian).
5 L. I. Khmel'nitskii, T. I. Godovikova, N. A. Ruleva, B. N. Khasapov and S. S. Novikov, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1979, 2295 (*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1979, **28**, 2118).
6 M. Witanowski, L. Stefaniak, A. Grabowska and G. A. Webb, *Spectrochim. Acta, Sect. A*, 1978, **34**, 877.
7 I. Yavari, R. E. Botto and J. D. Roberts, *J. Org. Chem.*, 1978, **43**, 2542.
8 H. A. Christ, P. Diehl, H. R. Schneider and H. Dahn, *Helv. Chim. Acta*, 1961, **44**, 865.
9 F. H. Allen, O. Kennard, D. G. Watson, L. Brammer, A. G. Orpen and R. Taylor, *J. Chem. Soc., Perkin Trans. 2*, 1987, S1–S19.
10 H. Wieland, W. Frank and Z. Kitasato, *Liebigs Ann. Chem.*, 1929, **475**, 42.

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