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Disubstituted 1,2,5-Selenadiazole *N*-Oxides. Preparation and Reactions*

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Treatment of 1,2-diketone dioximes with diselenium dichloride in dimethylformamide results in the formation of 1,2,5-selenadiazole *N*-oxides in moderate to good yields. Formation of the analogous di-*N*-oxides was not observed in any case. Thermolysis of some of the *N*-oxides gives the parent selenadiazoles as the major product. Photolysis of 2,1,3-benzoselenadiazole *N*-oxide gave a nearly quantitative yield of benzofurazan.

The 1,2,5-oxadiazole *N*-oxides (furoxans) have been known for almost a century and have since been intensely investigated,[2] but the corresponding 1,2,5-thiadiazole *N*-oxides were not recognized until recently [3] and have not yet been investigated in detail. The thiadiazole *N*-oxides were prepared in low yields from 1,2-diketone dioximes with excess of either sulfur dichloride in benzene or disulfur dichloride in dimethylformamide. The parent thiadiazoles were formed as well.

On the basis of these results, the parallel reaction with diselenium dichloride was examined to ascertain its usefulness for the preparation of the analogous selenium compounds.

RESULTS AND DISCUSSION

Preparation. A series of experiments were performed using the disubstituted glyoximes (*1a–c*) and the quinone dioximes (*1d,e*) (Chart 1) as substrates. The dioximes were allowed to react with a one molar excess of diselenium dichloride in dry dimethylformamide at ambient temperature. After hydrolysis and extraction with chloroform compounds *2a–e* crystallized on concentration. Preparative layer chromatography (PLC) of the mother liquors gave minor amounts of *2a–e* and the parent selenadiazoles *3a–c*. However, from *o*-benzoquinone dioxime (*1d*) benzofuroxan (*4*) was isolated as a by-product.

Methylphenylglyoxime (*1b*) could form two isomeric *N*-oxides, but only the isomer *2b* appears to be present (NMR, MS) in the crude product and in the product isolated from the reaction mixture by PLC. When *1b* is oxidized

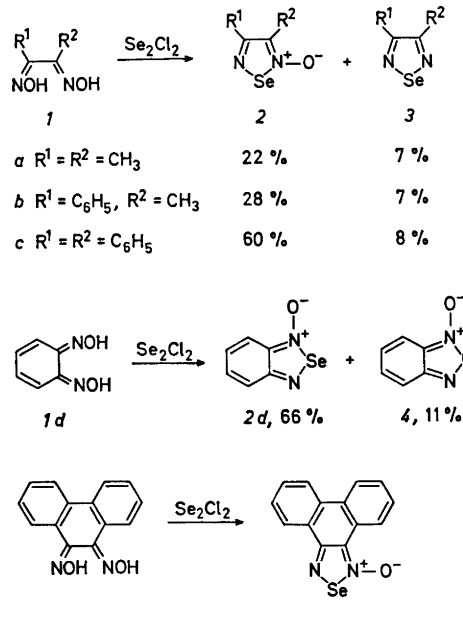
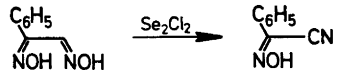


Chart 1.

* For a preliminary account of part of this work, see Ref. 1.

to methylphenylfuroxan, a mixture of the two isomers is formed.[4] Under equilibrium conditions, the more stable isomer is the analogue of *2b* with the exocyclic oxygen and the methyl substituent adjacent to each other.[4]

To obtain some insight into the limitations of this reaction, some experiments were carried out with phenylglyoxime (*1f*) (Chart 2) and the parent glyoxime. No products could be isolated from glyoxime. ^{1}H NMR analysis of the crude reaction mixture established the absence of NMR detectable amounts of 1,2,5-selenadiazole and its unknown *N*-oxide. Probably, degradation to cyanogen and water had taken place. Under the reaction conditions phenylglyoxime underwent only dehydration to give α-oximinobenzyl cyanide (*5*).



1f *5*, 90%

Chart 2.

No rationalization of the reactions leading to compounds *2* will be attempted. Mechanistic suggestions for formation of the analogous sulfur compounds are given by Pilgram.[3] Pilgram also suggests that the inability to detect any di-*N*-oxide might be due to their tendency to act as oxidizing agents, making them easily reduced by any S(I) or S(II) species present (in fact, pyridine and quinoline *N*-oxides are easily reduced using various sulfur compounds *e.g.* phenylsulfenyl chloride or disulfur dichloride[5]). Similar selenium species might also explain the formation of the deoxygenated compounds *3a–c*.

Reactions. Some thermolysis experiments were carried out on the *N*-oxides in high boiling solvents (decalin, xylene, see Experimental). In all cases the parent selenadiazoles were formed as major products (Chart 3). From the fused *N*-oxide *2d*, which decomposed more slowly than the disubstituted compounds, two products were isolated, benzoselenadiazole (*6*) and benzofurazan (*7*). No furazan formation was detected (TLC) from compounds *2b, c*.

When compound *2d* was photolyzed (wavelength >390 nm) in methylene chloride, a nearly quantitative yield of benzofurazan (*7*) was obtained.

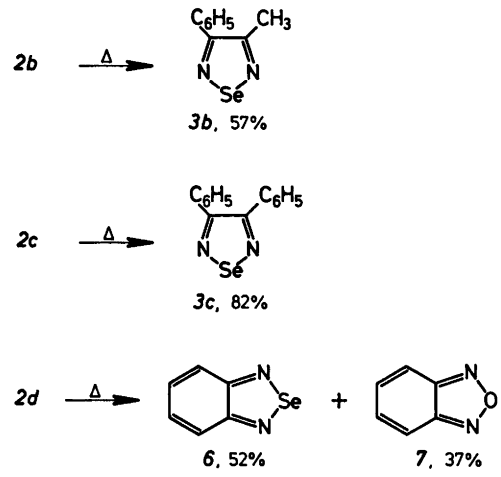


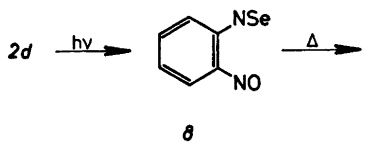
Chart 3.

The thermal results can be explained by assuming the operation of two pathways, *viz.* the reduction of *N*-oxide by solvent and a ring-opening-reclosure sequence involving the intermediacy of a nitroso-selenonitroso species which might either eliminate selenium to give a 1,2,5-oxadiazole or return to starting material. The analogous 1,2-dinitroso compounds are believed to be intermediates in the thermal interconversion of furoxans. The evidence is based mainly on spectroscopy.[6] However, 1,2-dinitrosobenzene has recently been claimed to be trapped by *p*-anisylazide.[7]

Provisional results suggest that an analogue of the latter pathway dominates in the photolysis of compound *2d*. When *2d* was photolyzed in a methanol-ethanol glass at 100 K a red-coloured intermediate (λ_{max} = 525 nm) was formed. It disappeared slowly upon heating the glass to 130 K and simultaneously formation of benzofurazan (*7*) occurred as observed in the low-temperature UV spectra. The intermediate can tentatively be identified as *8* (Chart 4).* The latter species can also be observed by flash photolysis at room temperature.[8]

The simplest synthesis of aromatic amine *N*-oxides often involves oxidation of the parent amine with a peracid.[5] However, when diphenylselenadiazole (*3c*) was oxidized with

* Benzothiadiazole *N*-oxide has been shown by low-temperature spectroscopy and flash photolysis to undergo reversible conversion to a compound believed to be *o*-nitroso-thionitrosobenzene.[8]



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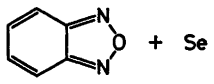

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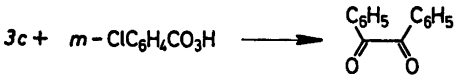
Chart 4.

m-chloroperbenzoic acid in chloroform only benzil (*9*) was isolated in low yield (Chart 5). No detectable amounts (TLC) of the *N*-oxide *2c* were present. The remaining starting material had probably been oxidized to benzoic acid. No material was extracted from the aqueous phase when benzoselenadiazole (*6*) was similarly oxidized (see Experimental).



9, 35%

Chart 5.

IDENTIFICATION OF PRODUCTS

The structural assignment of compounds *2* is based on spectroscopic evidence, on elemental analysis * and on the thermal reactions.

A characteristic feature of aromatic *N*-oxides is the presence of a strong absorption often found in the 1200 – 1300 cm^{-1} region due to the N – O stretching vibration.[5a] Compounds *2* all showed this absorption near 1350 cm^{-1} (Table 1). The values found are very close to those published for the analogous sulfur compounds [3] (*e.g.* benzothiadiazole *N*-oxide at 1365 cm^{-1} and diphenylthiadiazole *N*-oxide at 1360 cm^{-1}).

The NMR spectra (Table 1) of compounds *2a* and *2d* establish the non-equivalence of the 3,4-substituents (*2d*: the unsymmetrical pattern of the aromatic multiplet). This rules out a symmetrical structure, *e.g.* the isomeric and yet unknown Se-oxides. (The 1,2,5-thiadiazole *S*-oxide structure is known [9]).

Compound *2b*, for which two positional isomers *a priori* are possible, was identified by its mass spectrum * (Fig. 1, IP 70 eV, direct inlet at 90 °C). Provided that no essential thermal rearrangements occur prior to ionization (see below) the spectrum excludes one of the two possible isomers. The metastable defocussing technique showed that *m/e* 183 ($[C_6H_5CNSe]^+$) was formed from the molecular ion by loss of a fragment with mass 57 (CH_3CNO). The further fragmentation of *m/e* 183 is identical to that encountered in the spectrum of the parent selenadiazole (*3b*) and diphenyl-1,2,5-selenadiazole (*3c*).[10] The other positional isomer of *2b* would be expected to undergo

* All compounds gave elemental analyses within ±0.3 % units relative to the calculated values.

* Naturally abundant selenium is a mixture of 6 isotopes.

Table 1. Melting points and spectroscopic properties of *N*-oxides *2a-e* and methylphenylselenadiazole (*3b*).

Compound	M.p. °C [a]	IR (KBr) cm^{-1}	UV [b] (96 % ethanol) λ_{max} nm	log ε	λ_{max} nm	log ε	λ_{max} nm	log ε	^{1}H NMR [c] Aromatic, δ	Methyl, δ
2a	125(d) (A)	1350 (N – O)	245	3.39	285	3.87				2.58, 2.70
2b	175 – 180 (A)	1340 (N – O)	233	4.11	299	3.99			7.68 (5H)	2.69 (3H)
2c	131 – 132 (B)	1330 or 1345 (N – O)	243	4.30	316	4.00			7.0 – 7.5	
2d	180 – 182 (C)	1360 (N – O)	234	3.83	346	3.65	413	3.45	7.0 – 7.7	
2e	237 – 239 (D)	1380 (N – O)	238	4.50	302	4.15	377	4.05	–	
3b	70 – 72 (E)	–	223	3.85	305	4.00			7.0 – 7.5 (5H)	2.56 (3H)

[a] Recrystallization solvent given in parentheses; A, acetonitrile; B, ether; C, methanol; D, ethanol/benzene; E, light petroleum. [b] Vibrational fine structure is observed in the spectra of compounds *2d*, *e*. Only the major bands are given. [c] Spectra recorded at 60 MHz. Compounds *2a – c* were recorded in CF_3COOH, *2d* in DMSO-d_6 and *3b* in $CDCl_3$. *2e* was too insoluble to be recorded.

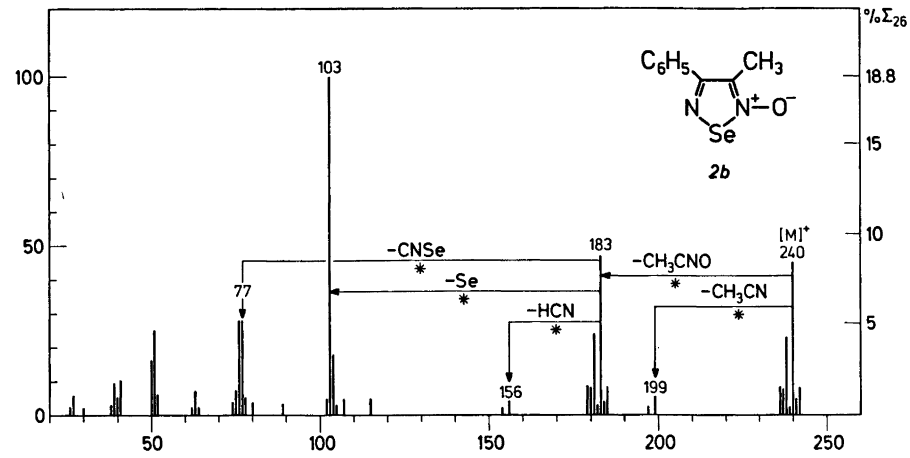


Fig. 1. Mass spectrum of compound *2b*.

cleavage to C_6H_5CNO and CH_3CNSe, either of which may be ionized. However, the absence of *m/e* 119 ($[C_6H_5CNO]^+$) and of *m/e* 121 ($[CH_3CNSe]^+$) in the spectrum of *2b* is important evidence for the assigned structure. The loss of CH_3CN from the molecular ion might be due to some thermal rearrangement prior to ionization, but *m/e* 199 is only of minor abundance (5.2 %).

The mass spectra of the remaining compounds were not investigated in detail. However, the masses of the ions found at the highest *m/e* values were identical with the calculated molecular weights. Compounds *3a,c*,[11] *4*,[12] *5*,[13] *6*,[14] and *7*[15] were identical (mixed melting point and IR) to authentic samples. *3b* was identical to a sample prepared analogous to compounds *3a,c*.

EXPERIMENTAL

Elemental analyses were carried out in the Microanalysis Department of this university. Spectroscopic analyses and PLC were performed as previously reported.[16]

*Dioximes.** These were prepared according to previously described methods: *1b* [4] (*anti*), *1c* [17] (*anti*), *1d* [15] (*amfi*? [18]), *1e*,[19] *1f* [20] (*amfi*) and glyoxime [21] (*anti*).

Reaction of 1,2-dioximes with diselenium dichloride. The reactions were performed analogously to the following procedure: *anti*-Diphenylglyoxime (*1c*, 1.50 g, 6.3 mmol) was dissolved in dry dimethylformamide (15 ml) and diselenium dichloride (2.90 g, 12.7 mmol) was slowly added with external cooling to keep the temperature at *ca.* 20 °C. After 18 h at room temperature the mixture was poured into water and extracted with chloroform. Compound *2c* (1.00 g) crystallized on concentration of the solvent. PLC (eluent: benzene – light petroleum – acetone, 7:7:1) of the oily residue gave diphenylselenadiazole (*3c*, 0.14 g ~ 8 %) and diphenylselenadiazole *N*-oxide (*2c*, 0.13 g, total yield 1.13 g ~ 60 %).

Thermolysis of 2,1,3-benzoselenadiazole N-oxide (2d). Compound *2d* (0.50 g) was suspended in decalin (10 ml) and the mixture was refluxed for 16 h. PLC (eluent: benzene, all operations were carried out at 5 °C due to the high volatility of benzofurazan) gave benzofurazan (*7*, 0.11 g ~ 37 %) and 2,1,3-benzoselenadiazole (*6*, 0.24 g ~ 52 %).

Thermolysis of 3-methyl-4-phenyl-1,2,5-selenadiazole N-oxide (2b). Compound *2b* (1.00 g) was suspended in decalin (20 ml) and the mixture was refluxed for 4 h. PLC (eluent: benzene – light petroleum – acetone, 7:7:1) gave 3-methyl-4-phenyl-1,2,5-selenadiazole (*3b*, 0.45 g ~ 57 % from reacted starting material) and starting material (0.15 g).

Thermolysis of diphenyl-1,2,5-selenadiazole N-oxide (2c). Compound *2c* (0.40 g) was suspended in xylene (10 ml) and the mixture was refluxed for 2 h. PLC (eluent: benzene – light petroleum – acetone, 7:7:1) gave diphenyl-1,2,5-selenadiazole (*3c*) (0.31 g ~ 82 %).

Photolysis of 2,1,3-benzoselenadiazole N-oxide (2d). Compound *2d* (0.50 g) was dissolved in methylene chloride (400 ml) and the solution was irradiated for 26 h with Thorn "Blue" lamps. A saturated solution of anthracene in acetone (absorbance > 2 below 390 nm) was used as cut-off filter. During the photolysis

* *1a* (commercially available) has the *anti* configuration.[22]

argon was bubbled through the solution. After partial evaporation of the solvent 0.12 g (~ 65 %) of selenium was isolated. PLC (eluent: benzene; all operations were carried out at 5 °C due to the high volatility of benzofurazan) gave benzofurazan (0.26 g ~94 % of reacted starting material) and starting material (0.04 g).

Peroxidation of diphenyl-1,2,5-selenadiazole (3c). Compound *3c* (0.50 g, 1.8 mmol) was dissolved in chloroform (5 ml). To this solution was added *ca.* 85 % *m*-chloroperbenzoic acid (0.54 g, *ca.* 2.7 mmol) in chloroform (10 ml). After 2 days at room temperature the reaction mixture was poured into 2 mol l^{-1} aqueous sodium hydroxide and extracted with chloroform. The chloroform solution was worked up by PLC (eluent: benzene – light petroleum, 1:1) into benzil (*9*) (0.10 g ~35 % of reacted starting material) and starting material (0.11 g).

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