Tetrahedron. Vol 24. pp. 485 to 489 Pergamon Press 1968 Printed in Great Britain

ELECTRONIC STRUCTURE AND CHEMICAL PROPERTIES OF 1,2,4-OXADIAZOLE, BIS-1,2,4-OXADIAZOLES AND OTHER DERIVATIVES

L. Paoloni and M. Cignitti

Laboratories of Chemistry, Instituto Superiore di Sanità, Roma, Italy

(*Received in UK* 18 *April* 1967; *accepted for publication* 4 *May* 1967)

Abstract—1,2,4-oxadiazole and various possible bis-1,2,4-oxadiazoles and di-(1,2,4-diazolyl)ethylenes have been studied by the Pariser–Parr–Pople approximation of the M.O. A.S.M.O. method. A discussion of the chemical properties and of the electronic absorption spectrum is given for the known compounds, and predictions are made about those derivatives which have not yet been described in the literature.

The chemistry of 1,2,4-oxidiazoles has been reviewed recently by Eloy,[1] but the calculations of the π-electron densities and energy levels of these compounds do not seem to have been reported in the literature.

We have carried out a study of the electronic structure of 1,2,4-oxadiazole and of various bis-1,2,4-oxadiazoles and di-(1,2,4-diazolyl) ethylenes, using several different approximations of the A.S.M.O., S.C.F. and C.I. procedures. In this paper, we wish to report some of our results and conclusions more directly related to the chemistry of these compounds.

The molecular diagrams of the molecules we have studied are given in the Figs 1, 2 and 3, and the calculated lowest transition energies are listed in Table 1.*

Electrophilic substitutions such as nitration, halogenation or Friedel–Craft reactions are known not to take place at the 3 or 5 carbon atoms of mono-substituted 1,2,4-oxadiazole. This is accounted for by our results which show C-3 and C-5 to be

TABLE 1. LOWEST TRANSITION ENERGIES (eV)*

Compound	S → S Calc.	S → S Obs.	S → T Calc.
Ia	6·21	—	3·85
Ib	6·58	—	4·07
II	6·20	>6·0	3·95
III	5·39	5·20	3·52
IV	5·86	—	3·84
V	4·95	5·10	2·97
VI	4·42	4·40	2·70
VII	4·42	—	2·72

* Molecules identified with reference to Figs 1, 2 and 3.
S = Singlet; T = Triplet. The values were calculated for the wave function expanded in terms of the lowest four mono-excited configurations. Observed data are from Ref. 1, p. 831 and Refs contained therein.

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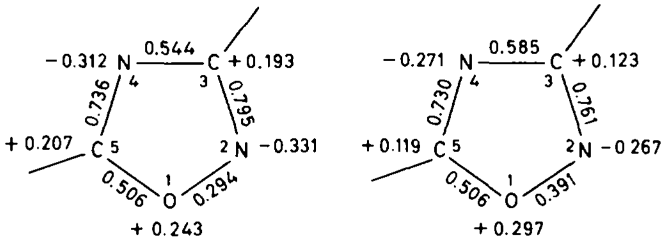
* The molecular diagrams were obtained by using the Pariser–Parr formulae for the 2-centre Coulomb repulsion integrals and without including penetration integrals in the core terms. The details of the different approximations are reported in *Theoret. Chim. Acta* 7, 383 (1967).

always π-electron-deficient and are, therefore, expected to favour nucleophilic substitutions. These are known to occur easily at the unsubstituted position of 1,2,4-oxadiazoles, and the attack is reported to be easier at C-5 than at C-3. However, this latter observation by Moussebois and Eloy[2] is apparently not related to the amount of the calculated π-electron deficiency. This value is somewhat similar for both positions and also seems to depend strongly on the assumed geometry of the molecule (Fig. 1).



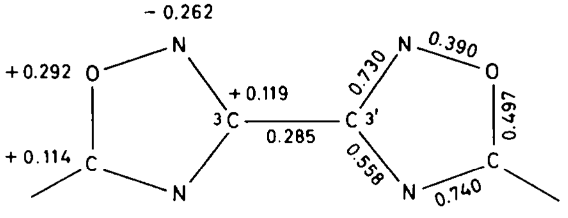
I-a I-b

Fig. 1. Molecular diagram of 1,2,4-oxadiazole (No X-ray data are reported in the literature for 1,2,4-oxadiazole. Diagram *a* is based on the molecular geometry of 1,2,5-oxadiazole,[14] with N–O distance 1·38 Å, and diagram *b* on benzo-1,2,5-oxadiazole[15] with N–O reported as 1·20 Å). These are qualitatively similar to the diagram, calculated by the simplest parametric M.O. procedure, reported by Zurawski.[16]

The very low π-bond order of the N—O bond, and the fact that it represents the largest localized N(−)–O(+) dipole of the molecule, makes it the preferred point of attack for any hydrolytic reagent. This bond is, in fact, broken during both acid and alkaline hydrolysis of 1,2,4-oxadiazole, and even during the spontaneous rearrangement of some monosubstituted derivatives.[1]

The high thermal stability of the 1,2,4-oxadiazoles has been considered as somewhat surprising[1] because their chemical behaviour and their electronic spectra suggest a poor aromatic character.[3] In our opinion, the loss of strength due to the reduced cyclic conjugation through the N—O bond is fairly well balanced by the energy gain from the ionic (electrostatic) interaction of the two opposite polarized N and O atoms. As a result, very little or no intrinsic weakness due to the valence state or to the bonding conditions of the ring atoms is to be found in the electronic structure of 1,2,4-oxadiazoles.

The simplest 1,2,4-oxadiazoles are volatile (but relatively high-boiling) liquids or low-melting solids, very soluble in a variety of organic solvents. These properties are in line with the foregoing considerations on their electronic structure and our results suggest that dipole–dipole intermolecular forces play a major role in determining the molecular interactions in condensed phase. The bis-1,2,4-oxadiazoles and the di-(1,2,4-diazolyl) ethylenes can also exist in various configurations which are obtained from those shown in Figs 2 and 3 by rotating one ring around the axis of the joining C—C bond. The planar configuration alternative to the one described here has, for each compound, a smaller total π-energy, but the rotation barrier is expected to be low because the conjugation across the C—C bond adjacent to each ring is rather small. This could result in a mixture of different (planar and/or nonplanar) configurations of the same molecule being present in solution, and even in



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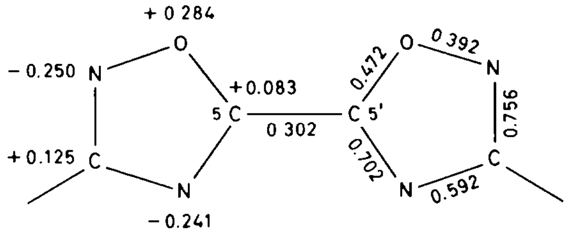

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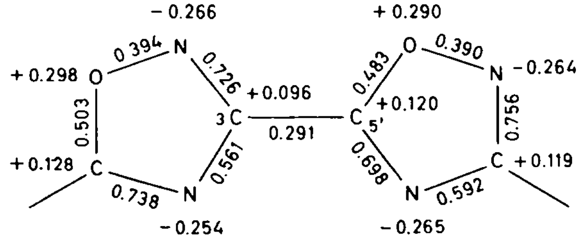


IV

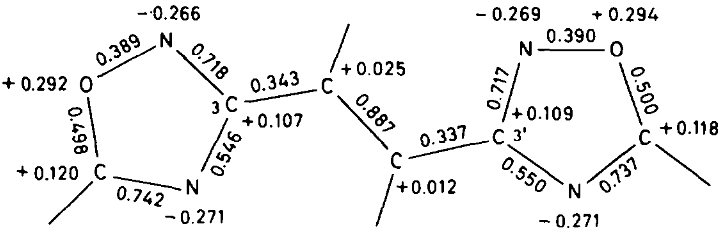
FIG. 2 Molecular diagrams of (3–3′)-, (5–5′)- and (3–5′)-bis-1,2,4-oxadiazole. The configurations considered here are those with the largest total π-energy and which are therefore predicted as the most likely to occur in the ground state of the molecule.

the crystals, with various consequences on such physical properties as UV spectra, m.ps, etc.

In this connection an interesting remark can be made about the m.ps of the bis-1,2,4-oxadiazoles of the 3–3′ and 5–5′ series which have the same substituent on 5 and 5′, and on 3 and 3′, respectively. From the charge distributions we have calculated, one would expect the compounds of the two series to have rather similar packing and hence similar m.ps. As shown in Table 2, this prediction is verified with the Ph- but not the Me-substituted compounds, where effects of this kind suggested above might possibly be present.

The molecular diagrams and the electronic transitions we have calculated are also referred to the so far unknown non-symmetric 3–5′ bis-1,2,4-oxadiazoles and 1,2,4-diazolylethylenes. Our predictions indicate for them an intermediate chemical behaviour, each ring remaining similar to that present in compounds with the corresponding type of symmetric substitution. The first absorption maximum is calculated at a position intermediate to that found for the symmetric derivatives.

Finally, the 3–5′ compounds could also offer a real test for a comparison of the relative rates of nucleophilic attack at the C-3 and C-5 positions. The reaction conditions would be strictly the same, with compounds in which well-separated and almost non-interacting 3 and 5 ring positions are available on the same molecule.



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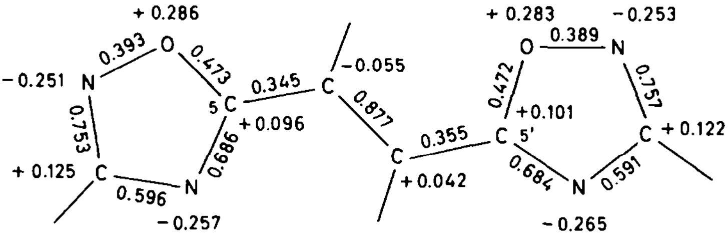

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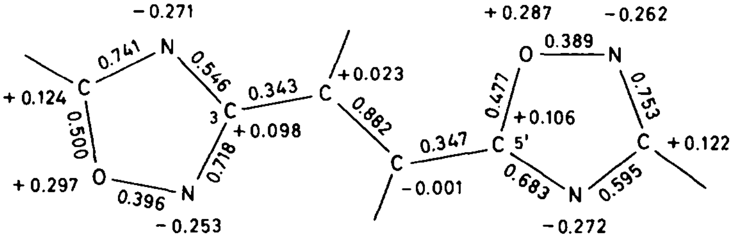

VII

FIG. 3 Molecular diagrams of di-(1,2,4-diazolyl) (3–3')-, -(5–5') and -(3–5') ethylene. The configurations considered here are those with the largest total π-energy and which are therefore predicted as the most likely to occur in the ground state of the molecule.

TABLE 2. M.PS OF (3–3')- AND (5–5')-BIS-1,2,4-OXADIAZOLES WITH EQUAL SUBSTITUENTS ON THE C-5 OR C-3, RESPECTIVELY, OF BOTH RINGS

Substituent	Bis-(3–3')	Bis-(5–5')
Me	167	100°
Ph	242	254

Acknowledgement—This work was carried out with the financial support of the Italian National Research Council (C.N.R.).

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