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THE 1,4,2,3-DIOXADIAZINE RING SYSTEM

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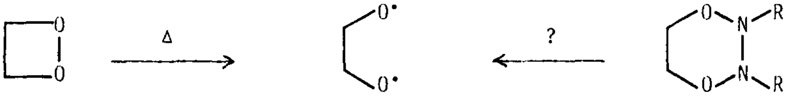
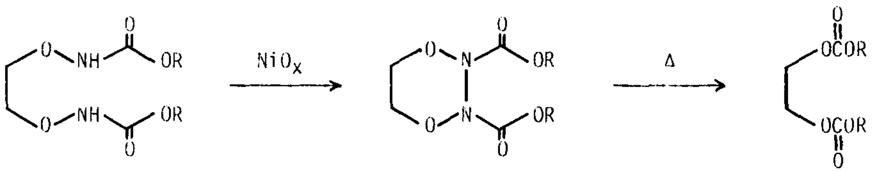
Abstract: The 1,4,2,3-dioxadiazine ring has been synthesized by oxidation of the corresponding 1,2-bishydroxylamine. When the nitrogen substituents are carbalkoxy groups, thermolysis gives the biscarbonate.

The chemiluminescence of dioxetanes **1** is an area of continuing interest.[1] Entry into the excited state is thought to involve homolysis of the peroxide bond to give a 1,4-dioxygen diradical **2** followed by cleavage to give excited products. The factors which control the activation energy, product triplet to singlet ratio, and distribution of energy between the two fragments are still not well understood. One approach to this area is to create the 1,4-dioxygen diradical from a precursor other than the dioxetane. To this end, we have synthesized the first 1,4,2,3-dioxadiazine **3**. This paper reports the synthesis and thermal decomposition of carbalkoxy derivatives of this class (R = CO_2Me, CO_2Et). These molecules are stable at room temperature but decompose when heated over 100°C in solution. The products are unexpected. Decomposition does not give two molecules of formaldehyde and the azodicarboxylate ester but the biscarbonate **4**.



1 **2** **3**

Compound **3a** was synthesized by condensation of 1,2-bis(aminooxy)ethane[2] with methyl chloroformate to give the bisurethane **5a**. This was treated with three oxidizing equivalents of nickel peroxide[3] in CH_2Cl_2 at room temperature. Standard workup followed by recrystalli-



5 **3** **4**

a = CH_3
b = CH_2CH_3

zation from $CHCl_3$/hexane gave fine, hard, white crystals which decomposed at 50° and melted at 85° (2°/min):[4] ^1H NMR (100 MHz, $CDCl_3$) 3.88 (s, 6 H) and 4.31 (s, 4 H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) 155.2, 73.3 and 54.8 ppm; IR ($CHCl_3$): 2960, 1758, 1438, 1275 and 907 cm^{-1}: mass spectrum m/e 176, 118, 103, 86 and 54.

The ethyl derivative **3b** was synthesized in a manner similar to **3a**: ^1H NMR ($CDCl_3$) 1.31 (t, J = 7 Hz, 6 H), 4.27 (q, J = 7 Hz, 4 H), 4.27 (s, 4 H) ppm; ^{13}C NMR ($CDCl_3$) 154.7, 73.1, 64.1, 14.2 ppm; IR ($CHCl_3$) 1760, 1373, 1270, 1060 cm^{-1}; mass spectrum m/e 132, 117, and 89.

Few dialkoxyhydrazines are known.[5] The N,N'-dicarbalkoxy derivatives are stable to distillation (~ 100° at ~ 1 torr), and can be refluxed in methanol-water without noticeable decomposition, but decompose rapidly in acid or base.[5a]

Thermolysis of **3a** in C_6D_5Br (137°C for 3 h) gave the corresponding biscarbonate in quantitative yield (NMR). Thermolysis of a mixture of the methyl, **3a**, and ethyl, **3b**, esters in Me_2SO-d_6 (157°C, 3 h) gave dimethyl, **4a**, and diethyl, **4b**, carbonates but no methyl ethyl carbonate (glc would have detected $\geq$ 1%).

When the reaction was followed by ^1H NMR (360 MHz, C_6D_5Br, 114°) asymmetric and complex spectra were seen (Figure). In this solvent, these spectra appear to reflect only one major intermediate, I. Conversion of **3a** to I is 5-10 times faster than conversion of I to **4a**. A similar result was found in Me_2SO-d_6. The half-life for the **3a** to I conversion at 114°C is ~ 1 hr in C_6D_5Br and ~ 3 hr in Me_2SO-d_6. The similarity of these rates argues against an ionic reaction. The lack of any cross product indicates either a concerted reaction or a radical rearrangement.

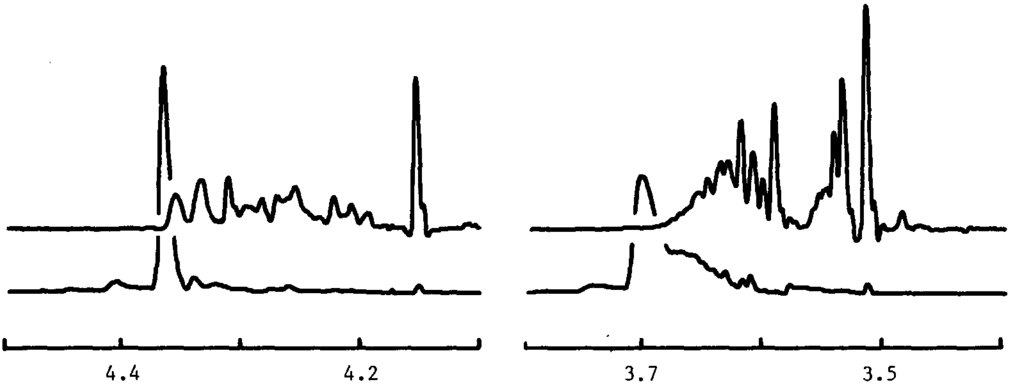
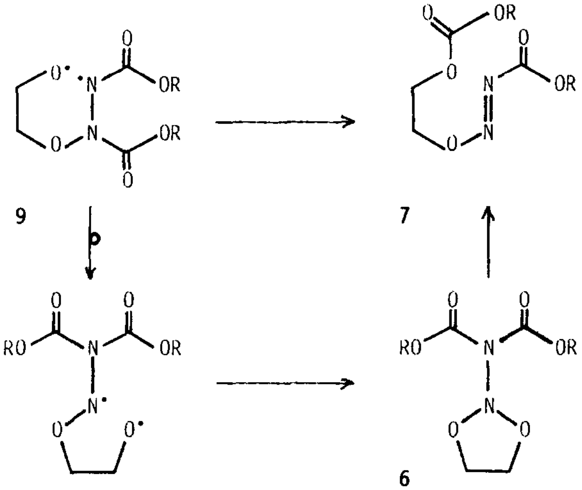
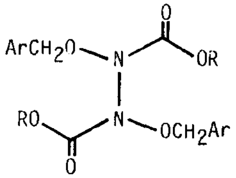


Figure. Methylene and methyl regions observed in the thermal decomposition of **3a**. Lower trace: after equilibrating at 114°C (~ 15 min). Upper trace: 4.5 h later. Peaks at 4.15 and 3.51 ppm are the CH_2 and CH_3 groups, respectively, of **4a**. Peaks are referenced to the downfield resonance of C_6D_5Br at 7.30. The spectra have been resolution enhanced.

We propose that the reaction proceeds through intermediates **6** and **7**, and that **6** is the major intermediate seen by ^1H NMR. Cooley et al. have postulated that **8** decomposes through an alkoxydiazene.[5f] The complexity of the ^1H NMR spectra in the thermal decomposition of **3a** argues against **7** as the only intermediate. If thermolyis begins by homolytic cleavage of the N,O bond to give **9**, rearrangement could give **6** as shown below. Formation of **6** demands either a 1,2-acyl shift or a cleavage-recombination reaction. Alkoxycarbonyl radicals add to aromatic solvents,[6] and usually escape the cage to a significant extent.[7] The high yield and lack of crossover product in this system argue against the free alkoxycarbonyl radical.

Compound **6** has a 1,1-dialkoxyhydrazine structure. 1,1-Dialkoxyamines are pyramidal at nitrogen, and invert slowly on the NMR time scale.[8] Hydrazines generally adopt a conformation with the lone pairs perpendicular to one another. Rotation and/or inversion of the nitrogens is often slow.[9] Compound **6** also has the 1,1-dicarbalkoxyamine group, in which the two carbalkoxy moieties can adopt syn,syn; syn,anti; and anti,anti conformations. If inversion at the dialkoxyamine and rotation around the N-N bond are slow, and the dicarbalkoxy nitrogen is planar (one conformation shown below), there should be eight methyl resonances. Other conformations or intermediates would increase this number. The resonances observed in the Figure reflect both solvent (C_6D_5Br) and field (360 MHz). In Me_2SO-d_6 at 100 MHz only two methyl singlets were seen throughout the reaction.


9 **7** **6**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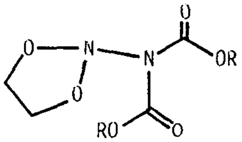

When the reaction was followed by ^{13}C NMR (25 MHz, 137°C, DMSO-d_6), two intermediate peaks that belonged to neither **3a** nor **4a** were seen. One was appropriate for a $CH_2CH_2ONRCO_2R$ group (~ 72.5 ppm) and the second for a $CH_2CH_2OCO_2R$ group (~ 64.5 ppm). The methyl peaks were not resolved, and it is possible that there are other accidentally equivalent peaks. This was found to be the case in a similar thermolysis experiment using C_6D_5Br as solvent.

When the reaction was followed by IR (C_6H_5Br, 114°) changes in the carbonyl (1765→1754 cm^{-1}) and N-O (1275→1272 cm^{-1}) regions were seen. No absorptions with intensity > 10% of that of the carbonyl were seen in the 1480-1700 cm^{-1} region. Asymmetric azo compounds have ν_s frequencies in the 1540-1600 cm^{-1} region.[10] If **7** is present in substantial amounts, the extinction coefficient of the N=N stretch is low.

We expect the RCO-N=N-OR (**7**) moiety to be more thermally labile than the $(RO)_2N$-$N(COR)_2$ (**6**). The former should be intermediate in stability between a hyponitrite [e.g. $(CH_3)_3CON{=}NOC(CH_3)_3$, $\Delta H^{\ddagger} = 27.9$ kcal mol^{-1} and $\Delta S^{\ddagger} = 8.2$ eu; $\tau_{1/2}$ (calc.) ≈ 10 sec at 114°C][11] and an azodicarboxylate diester [e.g. $CH_3O_2CN{=}NCO_2CH_3$, $k = 6.4 \times 10^{-6}$ s^{-1} at 162°, gas phase].[12] The $(RO)_2N$-$N(COR)_2$ moiety is likely to be reasonably stable. Dialkoxyamines (including some 1,3,2-dioxazolidines[8b]) and 1,1-diacylhydrazines are distillable compounds.

In summary, bisurethanes **5** can be oxidized to the dioxadiazines **3**. Upon thermolysis this new ring system gives, not formaldehyde and the dialkyl azodicarboxylate, but the biscarbonate **4**. Intermediates **6** and **7** are proposed.

Acknowledgements:

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References:

1. a) Bartlett, P.D.; Landis, M.E. in "Singlet Oxygen"; Academic Press: New York, 1979; pp. 243-286. b) Horn, K.A.; Koo, J.-Y.; Schmidt, S.P.; Schuster, G.B. Mol. Photochem. **1978-79**, 9, 1-37. c) Adam, W. Adv. Heterocycl. Chem. **1977**, 21, 437-481. d) Wilson, T. MTP Int. Rev. Sci.: Phys. Chem., Ser. Two **1976**, 9, 265.

2. Bauer, L.; Suresh, K.S. J. Org. Chem. **1963**, 28, 1604-1608.

3. Nakagawa, K.; Konaka, R.; Nakata, T. J. Org. Chem. **1962**, 27, 1597-1601.

4. Repeated attempts at elemental analyses gave percentages that were low in nitrogen. Examples are **3a**: Anal. Calcd. for $C_6H_{10}N_2O_6$: C, 34.96; H, 4.89; N, 13.59. Found: C, 35.07; H, 4.85; N, 12.01 and **3b**: Anal. Calcd. for $C_8H_{14}N_2O_6$: C, 41.03; H, 6.03; N, 11.96. Found: C, 41.54, H, 5.95; N, 11.24. This is consistent with the facile loss of N_2 from these compounds.

5. a) Crawford, R.J.; Raap, R. J. Org. Chem. **1963**, 28, 2419-2424. b) Koenig, T.; Hoobler, J.A.; Mabey, W.R. J. Am. Chem. Soc. **1972**, 94, 2514-2515. c) Norman, R.O.C.; Purchase, R.; Thomas, C.B. J. Chem. Soc., Perkin Trans. 1 **1972**, 1701-1704. d) Barton, D.H.R.; Harris, R.L.; Hesse, R.H.; Pechet, M.M.; Urban, F.J. J. Chem. Soc., Perkin Trans. 1 **1974**, 2344-2346. e) Kaba, R.A.; Ingold, K.U. J. Am. Chem. Soc. **1976**, 98, 7357-7380. f) Cooley, J.H.; Stone, D.M.; Oguri, H. J. Org. Chem. **1977**, 42, 3096-3097. g) Forrester, A.R.; Johansson, E.M.; Thomson, R.H. J. Chem. Soc., Perkin Trans. 1 **1979**, 1112-1119. h) Ozaki, S.; Masui, M. Chem. Pharm. Bull. **1979**, 27, 357-365.

6. Fiorentino, M.; Testaferri, L.; Tiecco, M.; Troisi, L. J. Org. Chem. **1976**, 41, 173-175. b) Zabel, D.E.; Trahanovsky, W.S. J. Org. Chem. **1972**, 37, 2413-2418.

7. a) Bartlett, P.D.; Pincock, R.E. J. Am. Chem. Soc. **1960**, 82, 1769-1773. b) McClelland, R.A.; Norman, R.O.C.; Thomas, C.B. J. Chem. Soc., Perkin Trans. 1 **1972**, 578-581.

8. a) Kostyanovsky, R.G.; Rudchenko, V.F.; Shtamburg, V.G.; Chervin, I.I.; Nasibov, S.S. Tetrahedron **1981**, 37, 4245-4254. b) Rudchenko, V.F.; Shtamburg, V.G.; Pleshkzova, A.P.; Nasibov, Sh.S.; Chervin, I.I.; Kostyanovskii, R.G. Bull. Acad. Sci. USSR **1981**, 2100-2109.

9. a) Sutherland, I.O. Annu. Rep. NMR Spectrosc. **1971**, 4, 71-235. b) Lambert, J.B. in "Topics in Stereochemistry", Vol. VI; Eliel, E.L.; Allinger, N.L. Eds.; Wiley: New York, 1971, pp. 19-105. c) Lehn, J.M. Fort. Chem. Forsch. **1970**, 15, 311-377.

10. a) Tsuji, T.; Kosower, E.M. J. Am. Chem. Soc. **1971**, 93, 1992-1999. b) Kübler, R.; Lüttke, W. Ber. Bunsenges. Physik. Chem. **1963**, 67, 2-16. c) Dinwoodie, A.H.; Hazeldine, R.N. J. Chem. Soc. **1965**, 2266-2268.

11. Kiefer, H.; Traylor, T.G. Tetrahedron Lett. **1966**, 6163-6168.

12. In dodecane the DMAD polymerized. Jones, A.; Morris, E.R.; Thynne, J.C.J. J. Phys. Chem. **1968**, 72, 2677-2678.

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