1,3-Dipolar Addition of an Oxazolium 5-Oxide to Cyclopentadienequinone and to Anthracenequinone

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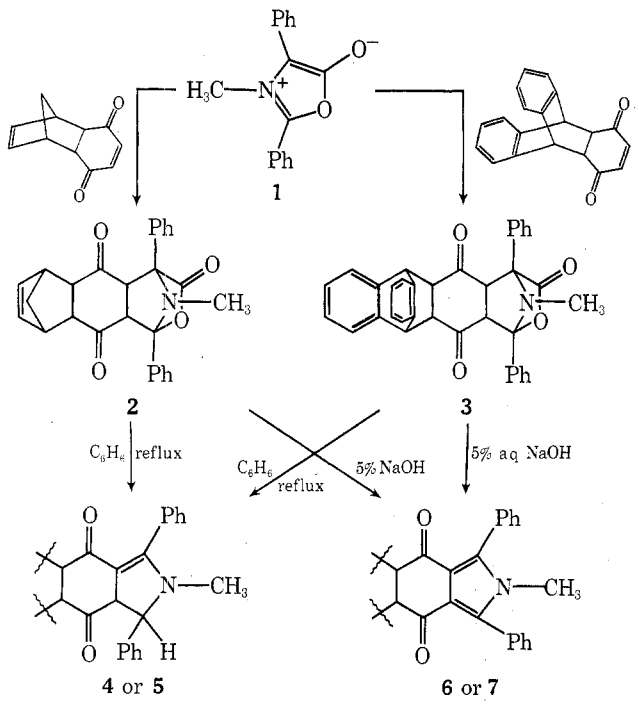
Reaction of 3-methyl-2,4-diphenyloxazolium 5-oxide (1) with cyclopentadienequinone and anthracenequinone, respectively, gave 1:1 adducts 2 and 3 in which the elements of carbon dioxide have been retained. The N-bridged lactone structures assigned to 2 and 3 are based on the spectral analyses and chemical decompositions. Conversions of 2 and 3 into the corresponding pyrrolines 4 and 5 and pyrroles 6 and 7 are described. Formation of a novel cage-type compound, 8-aza-7,9-diphenyl-8-methyltetracyclo[4.3.0.0^{3,9}.0^{4,7}]nona-2,5-dione (9), during thermal decomposition of 2 is also discussed.

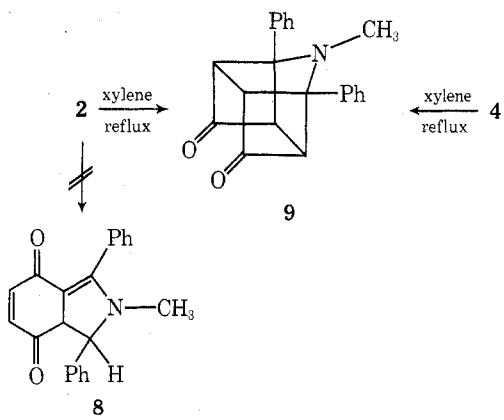
Oxazolium 5-oxides have recently been utilized in the synthesis of a variety of heterocyclic systems, for example pyrroles,[1] 2-pyrrolines,[2] 4-pyridones,[3] and polymers.[4] The accepted pathway[1-4] to each product involves a 1,3-dipolar cycloaddition of the oxazolium 5-oxide with a suitable dipolarophile to give an unstable, N-bridged intermediate which rapidly loses a molecule of carbon dioxide and forms the product. In this paper is described the isolation of two stable 1:1 adducts from analogous reactions in which the elements of carbon dioxide are retained. Each adduct decomposes thermally losing carbon dioxide and giving products which correspond to ones observed in previous work. Formation of an interesting cage-type compound during thermal decomposition of one of the adducts is also described.

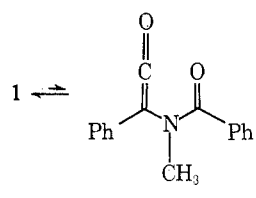
The reaction of 3-methyl-2,4-diphenyloxazolium 5-oxide (1)[5] with cyclopentadienequinone[6] and anthracenequinone[7] gave stable 1:1 adducts as evidenced by their elemental analyses. The adduct from 1 and cyclopentadienequinone revealed a very weak molecular ion in its electron-impact mass spectrum, while only the field-desorption[8] mass spectrum of the adduct from 1 and anthracenequinone showed the molecular ion. This is in agreement with an N-bridged lactone structure for each adduct which could readily lose carbon dioxide. The NMR spectrum of each adduct, when compared with that of its starting quinone, revealed a disappearance of two vinylic hydrogens and a corresponding increase in the relative integration area for the hydrogens α to a carbonyl of two. This supports 1,3 addition across the quinone carbon–carbon double bond. Therefore, the 1:1 adducts were assigned the N-bridged lactone structures **2**, 1-carboxy-1,3,3a,4,4a,5,8,8a,9,-9a-decahydro-4,9-dioxo-1,3-diphenyl-3-hydroxy-5,8-methano-2-methyl-2*H*-benz[*f*]isoindole-1,3-lactone, and **3**, 1-carboxy-1,3,3a,4,4a,5,8,8a,9,9a-decahydro-4,9-dioxo-1,3-diphenyl-3-hydroxy-5,8-benzethano-6,7-benzo-2-methyl-2*H*-benz[*f*]isoindole-1,3-lactone, respectively.



Thermal decomposition of lactones **2** and **3** in refluxing benzene released carbon dioxide and yielded the Δ^2-pyrrolines **4** and **5**, respectively. Huisgen and coworkers[2] had previously obtained Δ^2-pyrrolines from the reaction of **1** with olefinic dipolarophiles. Lactone **3** in refluxing xylene was converted to a mixture of pyrroline **5** and the corresponding pyrrole **7**. Huisgen had obtained similar mixtures from certain alkenes.[2] Treatment of lactones **2** and **3** with aqueous base afforded the pyrroles **6** and **7**, respectively.

Decomposition of lactone **2** in refluxing xylene did not produce pyrrole **6**. Instead, a dark red, crystalline compound, which revealed a molecular ion at *m/e* 315 in the mass spectrum, was obtained. Obviously, cyclopentadiene has been lost along with carbon dioxide. However, a concerted loss of the two fragments is apparently not required, since it was observed that pyrroline **4** also afforded the product under the same conditions. Simple cleavage of the cyclopentadiene fragment from **4** in a reverse Diels–Alder reaction[9] to give pyrroline **8** would not be in agreement

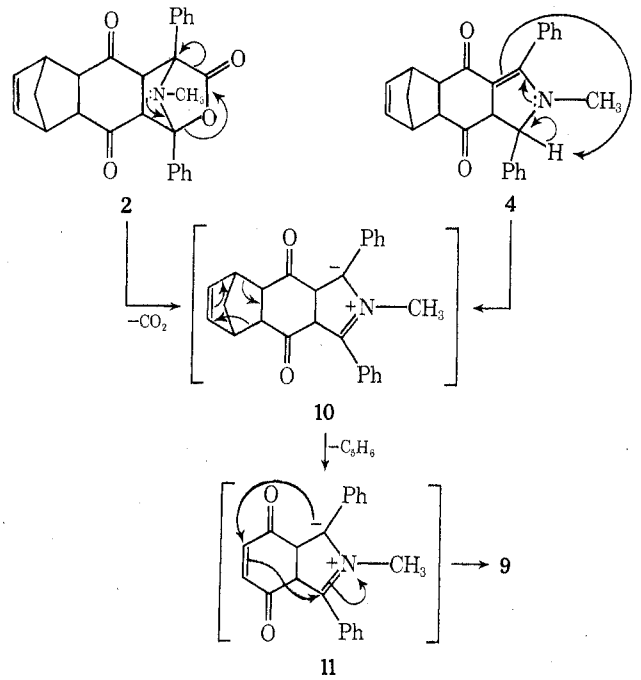




with the NMR spectrum. The proton NMR spectrum was very simple, having three singlets at δ 2.85, 3.30, and 7.47 in a ratio of 4:3:10. The structure assigned to the red solid is that of the novel tetracyclic diketone **9**, 8-aza-7,9-diphenyl-8-methyltetracyclo[4.3.0.0^{3,9}.0^{4,7}]nona-2,5-dione.

A possible mechanism for the formation of **9** from **2** or **4** is presented in Scheme I. The 1,3 dipole **10** suggested in

Scheme I



this mechanism is the same intermediate anticipated[2] in the conversion of **2** to **4**. Hydrogen migration in **4** could result in the reversible formation of **10**. Reverse Diels–Alder cleavage of the cyclopentadiene fragment from **10** would produce a quinone-type double bond in **11**. Intramolecular cycloaddition of the 1,3 dipole to the activated double bond in **11** would afford **9**. The reverse Diels–Alder cleavage of cyclopentadiene could actually precede formation of the 1,3 dipole from **4**.

The 1:1 adducts **2** and **3** appear to be the first N-bridged lactone intermediates isolated from the 1,3-dipolar addition of an oxazolium 5-oxide (munchnone) to a dipolarophile. However, similar 1:1 adducts have been isolated from the reaction of a Reissert salt (munchnone imine) with acetylenic dipolarophiles,[10] from the reaction of an oxazolium 4-oxide (isomunchnone) with dimethyl fumarate,[11] and from the reaction of 4-hydroxythiazolium hydroxides (thiocarbonyl ylides) with olefinic dipolarophiles.[12] Formation of 1:1 adducts from the reaction of a tautomeric form of **1**, the ketene imine **12**, with the dipolarophile acting as a ketenophile as reported by Huisgen[13] is not observed.

Experimental Section

General. The uv, NMR, and mass spectral analyses and microanalyses were performed at the Burroughs-Wellcome Research Laboratories, Research Triangle Park, N.C. Certain mass spectra were also furnished by the Center for Mass Spectrometry at the Research Triangle Institute. Melting points are uncorrected. NMR absorptions are relative to Me_4Si as internal standard. The following spectrometers were used: NMR, Varian T-60; ir, Beckman IR-10; uv, Bausch and Lomb Spectronic 505; mass spectra, Varian CH-5[8b] (electron impact and field desorption) and AEI MS-902. Cycloadditions were carried out under nitrogen, and a barium hydroxide trap was attached to measure any carbon dioxide gas evolution.

Addition of 3-Methyl-2,4-diphenyloxazolium 5-Oxide (1) to Cyclopentadienequinone. Five grams (0.020 mol) of 1[5] was added to a solution of 3.48 g (0.026 mol) of cyclopentadienequinone[6] in 50 ml of benzene. After stirring for 2 hr at 55–60°, only a small amount of precipitate was observed in the trap. A yellow precipitate was filtered from the reaction mixture and washed with 50 ml of benzene. The yield was 7.4 g (88%) of **2**: mp 158–160°; ir (Nujol) 1755, 1590, 1525, 1160, 1150, 1110, 1045, 790, 690, and 675 cm^{-1}; uv (EtOH) 248 nm (ϵ 9090) and 363 (11,420); NMR (Me_2SO-d_6) δ 1.32 (2 H, broad s), 2.40 (3 H, s), 2.6–3.0 (2 H, m), 3.0–3.3 (4 H, m), 6.0–6.35 (2 H, m), 7.20–7.65 (10 H, m); mass spectrum (70 eV) *m/e* (rel intensity) 425 (2), 381 (29), 379 (19), 353 (21), 325 (39), 315 (100), 233 (75).

Anal. Calcd for $C_{27}H_{23}NO_4$: C, 76.22; H, 5.45; N, 3.29. Found: C, 76.48; H, 5.62; N, 3.13.

Addition of 1 to Anthracenequinone. To a suspension of 8.00 g (0.028 mol) of anthracenequinone[7] in 100 ml of benzene was added 7.10 g (0.028 mol) of 1. The thick, yellow suspension was maintained at 55–60° with stirring for 30 min. No precipitate was observed in the $Ba(OH)_2$ trap. A bright yellow precipitate was filtered from the reaction mixture and washed with 50 ml each of benzene and ether. The yield was 13.5 g (89%) of **3**: mp 205–208°; ir (Nujol) 1700, 1525, 1220, 1180, 1165, 750, 700, and 695 cm^{-1}; NMR (Me_2SO-d_6) δ 2.35 (3 H, s), 2.8–3.5 (4 H, m), 4.60 (2 H, broad s), 6.9–7.7 (18 H, m); uv (EtOH) 245 nm (ϵ 8510) and 372 (14,040); electron-impact mass spectrum (70 eV) *m/e* (rel intensity) 493 (80), 315 (95), 287 (58), 233 (90), 178 (100); field-desorption mass spectrum[8] (3 kV, field anode voltage, and −5.9 kV cathode voltage, 25 and 26 mA through emitter) *m/e* (rel intensity) 537 (29), 493 (100), 491 (27).

Anal. Calcd for $C_{36}H_{27}NO_4$: C, 80.43; H, 5.06; N, 2.61. Found: C, 80.41; H, 5.34; N, 2.38.

Lactones **2** and **3** were prepared in similar yields at room temperature in xylene or tetrahydrofuran. Reaction times much longer than those specified or attempted recrystallization decreased the yield.

Decomposition of Lactone 2 in Refluxing Benzene. A suspension of 5.00 g (0.012 mol) of **2** in 50 ml of benzene was refluxed for 24 hr. Carbon dioxide was liberated. The resulting orange solution was evaporated to an orange solid residue. Recrystallization from warm petroleum ether–ether gave 3.95 g (86%) of the yellow-orange pyrroline **4**: mp 156–159°; ir (Nujol) 1695, 1660, 1620, 1600, 1530, 1345, 1335, 1225, 1165, 1020, 785, 750, 735, 715, and 690 cm^{-1}; NMR ($CDCl_3$) δ 1.43 (2 H, m), 2.47 (3 H, s), 2.8–3.5 (4 H, m), 3.72 (1 H, d, J = 11 Hz), 5.02 (1 H, d, J = 11 Hz), 5.85–6.15 (1 H, m), 6.25–6.55 (1 H, m), 7.3–7.6 (10 H, m); uv (EtOH) 245 nm (ϵ 13,770) and 361 (10,990); mass spectrum (70 eV) *m/e* (rel intensity) 381 (6), 379 (13), 315 (100), 313 (51), 258 (33), 118 (71), 77 (31), 66 (72).

Anal. Calcd for $C_{26}H_{23}NO_2$: C, 81.86; H, 6.08; N, 3.67. Found: C, 81.87; H, 6.12; N, 3.53.

Decomposition of Lactone 3 in Refluxing Benzene. A suspension of 5.38 g (0.010 mol) of **3** in 50 ml of benzene was refluxed for 24 hr. Carbon dioxide was liberated. The yellow solution was filtered from 0.2 g of a white solid which was not further characterized. Evaporation of the filtrate gave a yellow solid which turned orange on further drying. Recrystallization of the orange solid from methanol yielded 4.31 g (88%) of yellow-green crystals of **5**: mp 202–204°; ir (Nujol) 1710, 1660, 1615, 1530, 1165, 765, 745, and 695 cm^{-1}; NMR ($CDCl_3$) δ 1.92 (1 H, d, J = 10.5 Hz), 2.41 (3 H, s), 2.7–3.5 (2 H, m), 4.48 (1 H, d, J = 2.5 Hz), 4.90 (1 H, d, J = 2.0 Hz), 4.95 (1 H, d, J = 10.5 Hz), 6.7–7.6 (18 H, m); uv ($CHCl_3$) 318 nm (ϵ 5530) and 368 (15,260); mass spectrum (70 eV) *m/e* (rel intensity) 493 (3), 315 (100), 258 (30), 178 (95), 118 (35).

Anal. Calcd for $C_{35}H_{27}NO_2$: C, 85.17; H, 5.51; N, 2.84. Found: C, 84.96; H, 5.55; N, 2.80.

Decomposition of Lactone 2 in Aqueous Sodium Hydroxide. Three grams (0.007 mol) of **2** was stirred with 50 ml of 5% aqueous sodium hydroxide for 4 hr. The dark red, turbid solution was allowed to stand for 18 hr, then filtered, leaving no measureable amount of residue. The red solution was concentrated to dryness, and the residue was resuspended in methylene chloride. The undissolved solid was collected and washed with additional CH_2Cl_2. The solid was sodium carbonate. Evaporation of the filtrate left an orange solid, which was taken up in hot methanol and left standing for 1 week. Orange-red crystals, 1.46 g (54%), of pyrrole **6** were collected: mp 184–185°; ir (Nujol) 1660, 1155, 755, 690 cm^{-1}; NMR ($CDCl_3$) δ 1.45 (2 H, broad s), 3.29 (3 H, s), 3.20–3.65 (4 H, m), 6.10 (2 H, m), 7.48 (10 H, s); uv (EtOH) 244 nm (ϵ 30,760) and 314 (11,540); mass spectrum (70 eV) *m/e* (rel intensity) 379 (29), 313 (100), 118 (36), 77 (20), 66 (94).

Anal. Calcd for $C_{26}H_{21}NO_2$: C, 82.30; H, 5.58; N, 3.69. Found: C, 82.01; H, 5.68; N, 3.65.

Decomposition of Lactone 3 in Aqueous Sodium Hydroxide. Three grams (0.006 mol) of **3** was stirred with 50 ml of 5% aqueous sodium hydroxide for 4 hr. Normal work-up gave 1.8 g of a mixture of pale yellow plates and small orange crystals. They proved to be identical except in melting point with the plates melting at 234–238° and the crystals melting at 238–241°. This represents a 65% yield of two crystalline forms of pyrrole **7**: ir (Nujol) 1655, 1525, 1260, 1145, 1095, 750, 690 cm^{-1}; NMR ($CDCl_3$) δ 3.13 (5 H, apparent s), 4.95 (2 H, broad s), 6.9–7.6 (18 H, m); uv ($CHCl_3$) 316 nm (ϵ 12,600); mass spectrum (70 eV) *m/e* (rel intensity) 491 (13), 313 (22), 178 (100).

Anal. Calcd for $C_{35}H_{25}NO_2$: C, 85.52; H, 5.13; N, 2.85. Found: C, 85.39; H, 5.20; N, 2.83 (orange crystals). Found: C, 85.61; H, 5.19; N, 2.76 (pale yellow plates).

Decomposition of Lactone 2 in Refluxing Xylene. Two grams (0.005 mol) of **2** was decomposed in 50 ml of refluxing xylene over a 2-hr period. Carbon dioxide was liberated. Evaporation of the resulting solution under reduced pressure gave a dark oil, which was taken up in hot methanol and left standing for 1 week. Dark red crystals separated, and 1.13 g (76%) of the tetracyclic diketone **9** was collected: sublimation at 185°, mp 224–227°; ir (Nujol) 1665, 1530, 1110, 1000, 975, 755, 705, 690 cm^{-1}; NMR ($CDCl_3$) δ 2.85 (4 H, s), 3.30 (3 H, s), and 7.47 (10 H, s); uv (EtOH) 238 nm (ϵ 29,000), 249 (28,700), and 308 (10,400); mass spectrum (70 eV) *m/e* (rel intensity) 315 (100), 287 (7), 259 (18), 258 (22), 157.5 (7), 118 (53).

Anal. Calcd for $C_{21}H_{17}NO_2$: C, 79.98; H, 5.43; N, 4.44. Found: C, 79.62; H, 5.47; N, 4.44.

Decomposition of Lactone 3 in Refluxing Xylene. Two grams (0.004 mol) of **3** was decomposed in 50 ml of refluxing xylene over a 2-hr period. Carbon dioxide was liberated. The resulting dark solution was concentrated under reduced pressure to a dark oil. The oil was dissolved in hot methanol and left standing for 1 week. An orange solid, 1.2 g, which appeared to be composed of two types of crystals—finely powdered, bright yellow crystals and larger, dark orange crystals—was deposited. All spectra indicated that the product was a mixture of pyrroline **5** and pyrrole **7**. Extraction of the product with hot cyclohexane–benzene yielded a yellow solid, mp 231–235°, with spectral characteristics matching those of pyrrole **7**.

Decomposition of Pyrroline 4 in Refluxing Xylene. Two grams (0.005 mol) of pyrroline **4** was added to 50 ml of xylene, and the mixture was refluxed for 2 hr. The resulting dark green solution was concentrated to one-third of the original volume under reduced pressure. On standing 0.35 g (21%) of dark red-green crystals, mp 221–224°, separated. The ir spectrum was identical with that of the tetracyclic diketone **9**. Further concentration of the filtrate gave 0.70 g (35%) of pyrrole **6**.

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References and Notes

(1) (a) R. Huisgen, H. Gotthardt, H. O. Bayer, and F. C. Schaefer, *Chem. Ber.*, **103**, 2611 (1970); (b) R. Huisgen, H. Gotthardt, H. O. Bayer, and F. C. Schaefer, *Angew. Chem., Int. Ed. Engl.*, **3**, 136 (1964); (c) K. T. Potts and U. P. Singh, *Chem. Commun.*, 66 (1969).
(2) (a) H. Gotthardt and R. Huisgen, *Chem. Ber.*, **103**, 2625 (1970); (b) H. Gotthardt, R. Huisgen, and F. C. Schaefer, *Tetrahedron Lett.*, 487 (1964).
(3) (a) K. T. Potts and J. Baum, *J. Chem. Soc., Chem. Commun.*, 833 (1973); (b) H. Matsukubo and H. Kato, *ibid.*, 412 (1974).
(4) G. Manecke and J. Klawitter, *Makromol. Chem.*, **175**, 3383 (1974).
(5) H. O. Bayer, R. Huisgen, R. Knorr, and F. C. Schaefer, *Chem. Ber.*, **103**, 2581 (1970).
(6) W. Albrecht, *Justus Liebigs Ann. Chem.*, **34**, 348 (1906).
(7) E. Clar, *Chem. Ber.*, **64**, 1676 (1931).
(8) (a) For a description of field-desorption mass spectroscopy see H. D. Beckey, G. Hoffman, K. H. Maurer, and H. U. Winkler, *Adv. Mass Spectrom.*, **5**, 626 (1971). (b) For a description of the instrumentation and method used for this field-desorption mass spectral study see D. A. Brent, P. de Miranda, and H.-R. Schulten, *J. Pharm. Sci.*, **63**, 1370 (1974).
(9) H. Kwart and K. King, *Chem. Rev.*, **68**, 415 (1968).
(10) (a) W. E. McEwen, I. C. Mineo, and Y. H. Shen, *J. Am. Chem. Soc.*, **93**, 4479 (1971); (b) W. E. McEwen, K. B. Kanitkar and W. M. Hung, *ibid.*, **93**, 4484 (1971).
(11) M. Hamaguchi and T. Ibata, *Tetrahedron Lett.*, 4475 (1974).
(12) K. T. Potts, J. Baum, and E. Houghton, *J. Org. Chem.*, **39**, 3631 (1974).
(13) (a) R. Huisgen, E. Funke, F. C. Schaefer, and R. Knorr, *Angew. Chem., Int. Ed. Engl.*, **6**, 367 (1967); (b) E. Funke and R. Huisgen, *Chem. Ber.*, **104**, 3222 (1971).