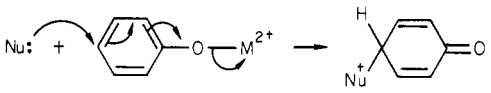
Intramolecular Cyclization of Aryloxenium Ions. C–O–C and C–C Bond Formation. A Novel Ortho Effect

Summary: *o*-Aryloxenium ions undergo intramolecular C–O–C bond formation readily as shown by the cyclizations yielding dibenzofurans. *m*-Aryloxenium ions cyclize via C–C bond formation provided the molecule can adopt the appropriate conformation for ring closure to occur. When an oxygen atom is ortho to the π-aryl cation center, cyclization to form five- or six-membered rings does not occur and this is attributed to an interaction between oxygen and the positive charge that imposes an unfavorable conformation for cyclization on the aryloxy or arylalkyloxy side chain.

Sir: There has been considerable interest recently in phenoxenium ionons, particularly in connection with phenol oxidation, and biosynthetic-type oxidative coupling reactions in particular.[1] Thus, while oxidative coupling of phenols generally proceeds via aryloxy radicals, other mechanisms have been considered, including sequences i–iii.[1a] It has been argued[2] that in acid ArO· would be

$$ArOH + ArO^+ \rightarrow \text{dimer} + H^+ \quad \text{(i)}$$

$$ArO^- + ArO^+ \rightarrow \text{dimer} \quad \text{(ii)}$$

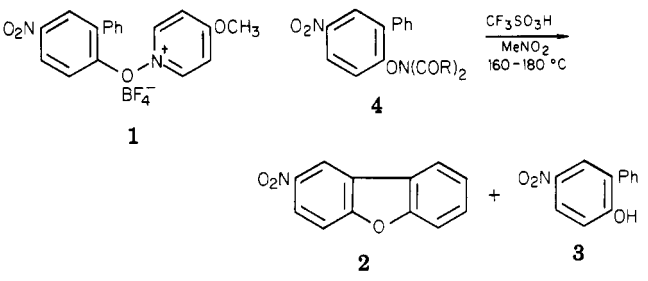


(iii)

metastable with respect to ArO^+ and ArO^- and would disproportionate rather than dimerize. At low pH values and other products would then arise by electrophilic aromatic substitution of ArO^+ upon ArOH (eq i) and give mainly C–C coupling products.

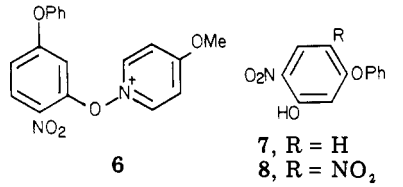
We have shown that aryloxenium ions can be generated conveniently in solution in organic solvents[3,4] and that, if the aryl nucleus bears an electron-withdrawing substituent, C–O–C products are the main ones formed, as expected, together with some C–C intermolecular substitution products from reactions with aromatic substrates. Intramolecular cyclizations leading to either C–O–C or to C–C bond formation would be of great interest, both from the biosynthetic and synthetic points of view, and we now report examples of these, together with the observation of a remarkable steric effect by an ortho oxygenated function.

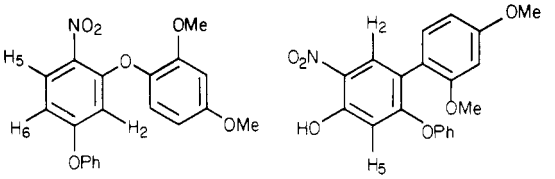
When 4-methoxy-1-(4-nitro-2-phenylphenoxy)-pyridinium tetrafluoroborate (**1**)[3,5] was heated in degassed dry benzene at 180 °C it gave 2-nitrodibenzofuran (**2**;[6] 22.5%) and 2-hydroxy-5-nitrobiphenyl (**3**;[7] 24.8%). Photolysis of **1** (2537 Å, CH_3CN solution, N_2) also gave **2** (18.4%) and **3** (31.2%). Similar results were obtained when the *N,N*-diacyl derivatives (**4**) of 5-nitro-2-biphenyloxyamine (**5**) were heated with 1 equiv of CF_3SO_3H[4,8] or **5** was treated with $NO^+BF_4^-$ in nitromethane at −10 °C and the solution then heated[4] at 180 °C (**2**, 60.5%; **3**, 12.5%). The best yield of **2** (82%) was obtained from the succinimide (**4c**). 2-Biphenyloxyamine hydrochloride[5] itself gave dibenzofuran (47%) on treatment with nitrosyl tetrafluoroborate and then heating.



$(RCO)_2$: **a** = $(CH_3CO)_2$, **b** = *o*-$C_6H_4(CO)_2$, **c** = $-OC(CH_2)_2CO-$

The possibility of forming C–C bonds intramolecularly was next examined. *N*-(2-Nitro-5-phenoxyphenoxy)-4-methoxypyridinium tetrafluoroborate (**6**)[5,9] was thermolyzed in nitromethane at 200 °C to give 2-nitro-5-phenoxyphenol (**7**; 56%),[10] as the only isolable product. No *intramolecular* cyclization product was detected. *N*-(2,4-Dinitro-5-phenoxyphenoxy)pyridinium tetrafluoroborate behaved similarly, giving only uncyclized phenol





(H-abstraction product) **8** (75%). That aryloxenium ions were indeed formed was demonstrated by trapping them *intermolecularly*. Thus, heating **6** with *m*-dimethoxybenzene gave **9** (C–O–C bond formation; 68.5%) and **10** (C–C bond formation; 13.1%).[5] Similarly, **11** did not undergo intramolecular cyclization (only open phenol obtained) but reacted with *m*-dimethoxybenzene to give **12** (61%) and **13** (18%).[5] Absence of intramolecular cyclization was initially attributed to strain in the required five-membered transition state since the positive charge would be in a (delocalized) p orbital and approach of the two rings would have to be in approximately parallel planes, in addition to requiring a *5-endo-trig* ring closure.[11]

(1) (a) Barton, D. H. R. *Chem. Br.* **1967**, *3*, 330. (b) MacDonald, P. D.; Hamilton, G. A. In "Oxidation in Organic Chemistry", Part B.; Trahanovsky, W. S. Ed.; Academic Press: New York, **1973**; Chapter II, pp 97–133. (c) Hewgill, F. R. In "Free Radical Reactions"; Waters, W. A., Ed.; Butterworths: London, **1973**; Vol. 10, Chapter 6, pp 167–204. (d) Taylor, W. I.; Battersby, A. R. "Oxidative Coupling of Phenols"; Marcel Dekker: New York, **1967**.

(2) Waters, W. A. *J. Chem. Soc. B* **1971**, 2026.

(3) (a) Abramovitch, R. A.; Inbasekaran, M.; Kato, S. *J. Am. Chem. Soc.* **1973**, *95*, 5428. (b) Abramovitch, R. A.; Alvernhe, G.; Bartnik, R.; Dassanayake, N. L.; Inbasekaran, M. N., Kato, S. *Ibid.* **1981**, *103*, 4558.

(4) Abramovitch, R. A.; Alvernhe, G.; Inbasekaran, M. N. *Tetrahedron Lett.* **1977**, 1113. See also Shudo, K.; Orihara, Y.; Ohta, T.; Okamoto, T. *J. Am. Chem. Soc.* **1981**, *103*, 943.

(5) All new compounds gave satisfactory microanalytical and spectral data.

(6) Cullinane, N. K. *J. Chem. Soc.* **1930**, 2267. Dewar, M. J. S.; Urch, D. S. *Ibid.* **1957**, 345.

(7) Borsche, W.; Scholten, B. G. B. *Ber. Dtsch. Chem. Ges.* **1917**, *50*, 600.

(8) Endo, Y.; Shudo, K.; Okamoto, T. *J. Am. Chem. Soc.* **1977**, *99*, 7721, reported the possible generation of PhO^+ from PhONHTos and CF_3SO_3H and obtained a 60% of C–C coupling product with anisole. The overall yield (60%) was about the same as that (65%) obtained by the thermolysis of the appropriate *N*-phenoxypyridinium salts in anisole,[3b] but the isomer ratios were somewhat different: 2,2′/4,2′ = 1.25, 4.4′/4,4′ = 0.45, as compared with 2,2′/4,2′ = 1.02, 2.4′/4,4′ = 1.18.[3b]

(9) Prepared from 5-bromo-2-nitroaniline by heating with PhOK–PhOH, Cu, at 120–130 °C for 12 h to give 2-nitro-5-phenoxyaniline (72%), which, in diazotization, gave the diazonium tetrafluoroborte (96%), and then heating the latter with 4-methoxypyridine 1-oxide in CH_3CN (85% yield).

(10) CIBA Ltd., French Patent 1 581 400; *Chem. Abstr.* **1970**, *73*, 35048f.

(11) Baldwin, J. E. *J. Chem. Soc., Chem. Commun.* **1976**, 734.

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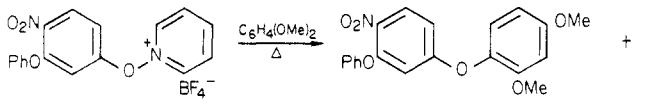
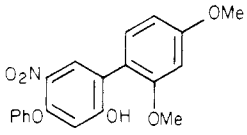


11 12



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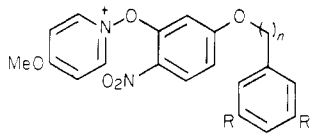
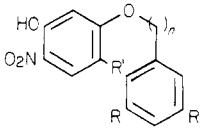
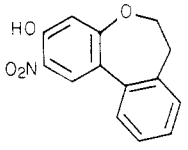
On the other hand, cyclization of the oxenium ion from **1**, which also leads to a five-membered transition state, is reasonable since the empty orbitals on oxygen are not constrained in a ring and closer proximity with the ring undergoing attack can be achieved. We therefore turned to the possible formation of a six-membered ring via C–C bond formation and decomposed **14**[12] in nitromethane at 180 °C. Again, no intramolecular cyclization product was formed, only hydrogen-abstraction product **15** being obtained (84%).[13] Thermolysis of **14** in benzene at 200 °C gave **15** (15%) and the *intermolecular* arylation product **16** (20%)[5] and in cyclohexane gave **15** (31%) and **17** (indicated by GC/MS). Again, thermolysis of **18** in degassed Freon 113 at 200 °C gave **19** (34%). No *intramolecular* C–C bond formation occurred in spite of the presence of a much more nucleophilic substrate nucleus.



14, R = H; n = 1
18, R = OMe; n = 1
20, R = H; n = 2



15, R′ = H; R = H; n = 1
16, R′ = Ph; R = H; n = 1
17, R′ = F; R = H; n = 1
19, R′ = H; R = OMe; n = 1
21, R′ = R = H; n = 2
22, R′ = F; R = H; n = 2



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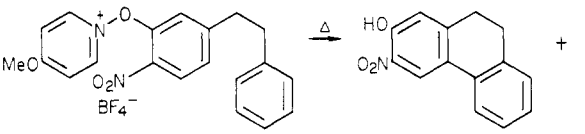
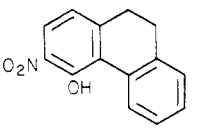
Finally, 1-[5-(phenethyloxy)-2-nitrophenoxy)-4-methoxypyridinium tetrafluoroborate (**20**)[14] in Freon 113 at 200 °C gave three products: phenol (**21**; 11%) and two products that were resolved by GC/MS (OV-101 on Gas Chrom Q column) which indicated that Schiemann product (**22**; trace; m/e 277 ($M^{+\cdot}$, 21%)), and the desired cyclization product (**23**; trace; m/e 259 ($M^{+\cdot}$, 14%)) were formed but in quantities too small to permit isolation and characterization.

There is precedent in the literature for both five- and six-membered ring formation by intramolecular aromatic substitution of π-aryl cations.[15,16] Indeed, Okamoto and his co-workers[8] obtained both possible intramolecular C–C products from the acid-catalyzed decomposition of *O*-[(3-β-phenethyl)phenyl]-*N*-tosylhydroxylamine. We believe that the fact that the aryloxenium derived from **6**, **11**, and **14** will undergo inter- but not intramolecular aromatic substitutions is related to the presence of an oxygen atom ortho to the π-aryl cation center, which imposes a rotational conformation on the aryloxy or aralkyloxy group in which intramolecular attack by the cation is geometrically unlikely. That the ortho oxygen plays an important role receives strong support from the thermal decomposition of **24**[17] in various solvents,[18] when the main products formed were the desired C–C intramolecular cyclization products **25** (30.8%) and **26** (12.7%).



24 **25**



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We conclude the aryloxenium ions will undergo both C–O–C and C–C intramolecular bond formation with aromatic nuclei provided the molecule can adopt the appropriate conformation for cyclization to occur.

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Registry No. 1, 83486-48-0; **2**, 20927-95-1; **3**, 4291-29-6; **4a**, 83486-49-1; **4b**, 83486-50-4; **4c**, 83486-51-5; **6**, 83486-53-7; **7**, 27684-87-3; **8**, 83486-54-8; **9**, 83486-55-9; **10**, 83486-56-0; **11**, 83486-58-2; **12**, 83486-59-3; **13**, 83486-60-6; **14**, 83486-62-8; **15**, 83486-63-9; **16**, 83486-64-0; **17**, 83486-65-1; **18**, 83510-91-2; **19**, 83486-66-2; **20**, 83486-68-4; **21**, 83486-69-5; **22**, 83486-70-8; **23**, 83486-71-9; **24**, 83486-73-1; **25**, 83486-74-2; **26**, 83486-75-3; 2-biphenyloxyamine hydrochloride, 83486-76-4; dibenzofuran, 132-64-9; *N*-(2,4-dinitro-5-phenoxyphenoxy)pyridinium tetrafluoroborate, 83486-78-6.

Supplementary Material Available: Some spectroscopic data for compounds **8–10**, **12**, **13**, **25**, and **26** (2 pages). Ordering information is given on any current masthead page.

(12) Prepared from 3-amino-4-nitrophenol by O-benzylation (56%),[5] diazotization, and treatment of the diazonium tetrafluoroborate with 4-methoxypyridine 1-oxide. **14**: mp 97–98.5 °C (67% yield).
(13) Identical with an authentic sample, mp 104.5–105 °C, prepared from the diazonium salt and Cu_2O in water containing $Cu(NO_3)_2$.
(14) **20**: mp 118–119 °C was prepared (56%) by the sequence 3-amino-4-nitrophenol → 6-nitro-3-(phenethyloxy)aniline (mp 160.5–161 °C) → diazonium tetrafluoroborate (mp 104–105 °C) → **20**.
(15) Lloyd, D.; Walton, D. J.; Odenco, J.; Germain, G.; Meerasche, J. M. *J. Chem. Res., S* **1979**, *7*, 249.
(16) Becker, H. D.; Sanchez, D. *J. Org. Chem.* **1979**, *44*, 1787.
(17) **24**: mp 126.5–127.5 °C (benzene–methanol) was prepared (51%) by the following sequence: nitration of 3-aminobibenzyl with $Cu(NO_3)_2$ in Ac_2O gave mainly 3-acetamido-4-nitrobibenzyl: mp 105.5–106 °C (MeOH); hydrolysis with hot HCl/EtOH gave the nitroamine: mp 87–88 °C (C_6H_6–petroleum ether), which, in turn, gave the diazonium tetrafluoroborate: mp 134–135 °C (acetone–petroleum ether); reaction with 4-methoxypyridine 1-oxide in sulfolane at 60 °C gave **24**.
(18) The best yields were obtained in nitrobenzene at 180–185 °C.

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