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SPIRODIENONES VIA A THERMAL UNCATALYZED [1,3]-OXYGEN-TO-CARBON MIGRATION

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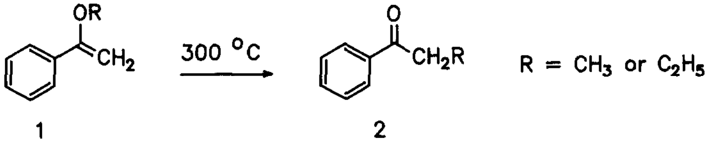
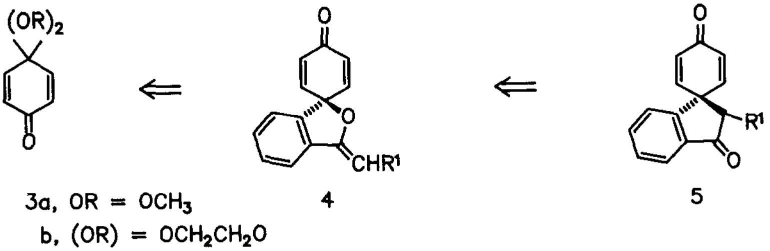
Exocyclic vinyl ethers derived from p-quinols, readily available from aryllithium addition to quinone monoketals, undergo high-yield thermal [1,3]-oxygen-to-carbon migration, yielding spirodienones.[1]

The thermal rearrangement of α-ethoxystyrene to butyrophenone was first reported in 1896,[2a] and the scope of the reaction was further studied in 1930-1940.[3] Mechanistic studies[4,5] supported earlier proposals[3] that a radical or radical chain mechanism was involved in these thermal reactions. The high temperature (250-300 °C) required for this rearrangement, the modest isolated yields, and the absence of generality of the process[3a,6] apparently discouraged any major synthetic use of the reaction.[7]



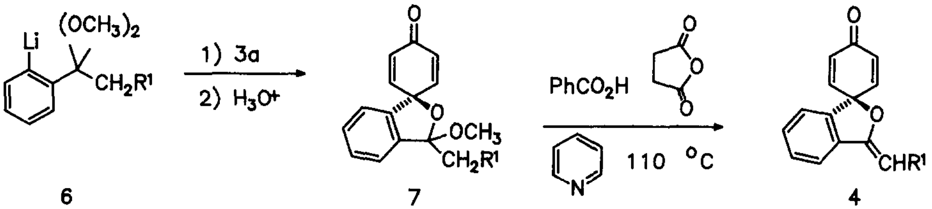
The [1,3]-shift in vinyl ethers involves the conversion of a carbon-oxygen to a carbon-carbon bond; such a process could be of synthetic value in forming carbon-carbon bonds at quaternary centers. The direct availability of p-quinols by aryllithium addition to



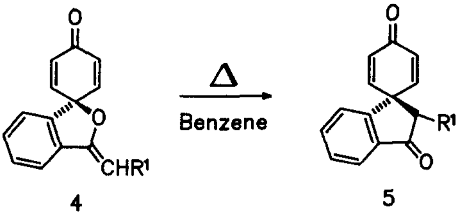
Scheme. Strategy for Conversion of Quinone Monoketals to Spirodienones

quinone monoketals and the expected facile conversion of these compounds to vinyl ethers, **4**, prompted a study of the thermal chemistry of these spirovinyl ethers (Scheme). The intermediates formed from cleavage of the C-O bond in **4** would be resonance stabilized, and it was hoped that the formal [1,3]-shift would occur at moderate temperatures in high yield. Spirodienones formed from such a reaction would be especially attractive intermediates for further synthetic transformations.

To investigate the feasibility of this idea, **6a** (R = H)--obtained from the dimethylketal of o-bromoacetophenone via metal-halogen exchange--was reacted with **3a** (R = CH_3) to give **7a** (78%) and thence the vinyl ether,[8] **4a** (50%), as outlined below. Thermolysis of a degassed solution of **4a** at 170 °C gave a quantitative yield of the diketone **5a**. Although a clean reaction occurs in toluene and o-dichlorobenzene, highly colored reaction mixtures containing the product resulted when tetrahydrofuran or methanol were solvents for the reaction. Alkyl substitution lowers the temperature for the rearrangement; thus, under reaction conditions for conversion of **7b** to the vinyl ether **4b**, the ketone **5b** (50%) was formed. Since the yield for the **7** → **4** conversion is ca. 50% in other systems, the yield for the thermal rearrangement **4b** → **5b** probably is quantitative, as in **4a** → **5a**.

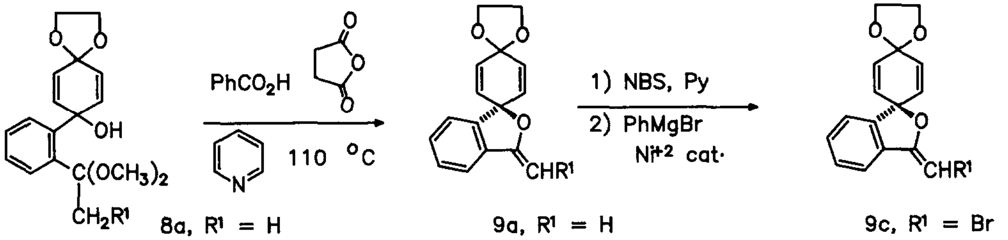


[a, R¹ = H; b, R¹ = CH₃]



[a, R¹ = H; b, R¹ = CH₃; c, R¹ = Ph]

The chemistry described above establishes that the thermal [1,3]-oxygen to carbon rearrangement is a high-yield route to spirodienones of type **5**. Two other systems were studied to further define the scope of the chemistry. Reaction of **3b** [$(OR)_2$ = OCH_2CH_2O] with **6a** followed by workup gave the quinol **8a** (78%) which was then transformed into the vinyl ether **9a** (83%). Bromination of **9a** gave the vinyl bromide **9c** (50%). Replacement of this halide with an alkyl or aryl group would lead to a convergent preparation of substituted systems. Thus, reaction of **9c** with phenylmagnesium bromide in the presence of a dichloro-[1,3-bis-(diphenylphosphino)propane]nickel(II) catalyst gave **9d**[9] (49%) which was hydrolyzed to **4c** (96%).[10] Heating to reflux a degassed toluene solution of **4c** for four hours gave **5c** (83%).

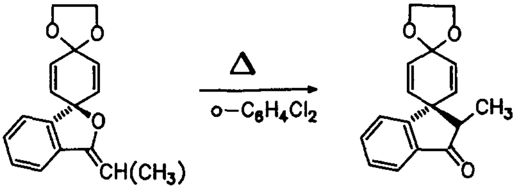


8a, R^1 = H
b, R^1 = CH_3

9a, R^1 = H
b, R^1 = CH_3

9c, R^1 = Br
d, R^1 = Ph

This thermal rearrangement would be especially valuable if the two carbonyl groups in the product could be differentiated chemically. One method for accomplishing this would be thermal rearrangement of a quinol ether ketal such as **9b**. Indeed, heating **9b** in _o_-dichlorobenzene at reflux under nitrogen gave **10** (50%). Although the scope and catalyzed version of this reaction remain to be studied, systems such as **9b** allow preparation of compounds wherein the dienone carbonyl group is protected.



9b

10

To examine the effect of substituents on the rate of the rearrangement, the kinetics of the thermolysis of **4a** and **4c** were determined in degassed benzene as solvent using standard sealed-tube kinetic methods. For **4a**, product formation was determined by ^1H NMR spectroscopy; for **4c**, the rate of product formation was followed by UV analysis at 346.5 nm. The kinetic data (Table) gave $\Delta H \sim 30$ kcal/mol and $\Delta S \sim 0$–5 eu for both reactions. Interestingly, the activation enthalpy is somewhat less than the calculated bond energy of the carbon-oxygen bond which is broken (BDE $\simeq$ 35.4 kcal/mol).[11] This indicates that there could be some

Table. Kinetic Data For Thermal [1,3]-Oxygen-to-Carbon Migration for 4a and 4c

4a[a]		**4c**[a]	
Temperature (°C)	Rate[b] (x 10^5 sec^{-1})	Temperature (°C)	Rate[b] (x 10^5 sec^{-1})
153	1.12	99	1.14
169	4.62	113	5.33
182	13.1	128	22.3
$k = kT/h\ e^{-31,800/RT}e^{5.5/R}$		$k = kT/h\ e^{-29.7/RT}e^{0.1/R}$	

[a] Concentration of **4a** was 6.3 x 10^{-2} M and **4c** was 5.81 x 10^{-4} M.
[b] Rates are averages of two determinations and are thought to be accurate to ± 5%.

stabilization of the developing radical centers by the initially orthogonal aryl ring in the transition state or there could be some concerted character in this [1,3]-shift. Interestingly, replacement of the hydrogen on the vinyl carbon by a phenyl group leads to a decrease of only about 2 kcal/mol in the activation enthalpy.[14]

Further studies dealing with the scope, mechanism, synthetic utility, and catalyzed version of this chemistry will be reported.

Acknowledgment. We thank the National Science Foundation for partial support.

References

1) Some of this work has been presented at the Third Chemical Congress of North America June 5-10, paper #352. For an anodic oxidation approach to spirodienones, see: Morrow, G.; Swenton, J. Tetrahedron Lett. **1987**, 28, 5445.

2a) Claisen, L. Chem. Ber. **1896**, 29, 2931. (b) Claisen, L.; Hasse, E. ibid. **1900**, 33, 3778. (c) Claisen, L., ibid. **1912**, 45, 3157.

3a) Lauer, W.M.; Spielman, M.A. J. Am. Chem. Soc. **1933**, 55, 4923. (b) Mortenson, C.W.; Spielman, M.A. J. Am. Chem. Soc. **1940**, 62, 1609.

4a) Wiberg, K.B.; Rowland, B.I. J. Am. Chem. Soc. **1955**, 77, 1159. (b) Wiberg, K.B.; Shryne, T.M., Kinter, R.R. ibid. **1957**, 79, 3160. (c) Wiberg, K.B.; Kinter, R.R.; Motell, E.L. J. Am. Chem. Soc. **1963**, 85, 450.

5) For studies of the thermal reactions of alkyl aryl ethers, see: Elkobaisi, F.M.; Hickinbottom, W.J. J. Chem. Soc. **1959**, 1873. Hart, H.; Eleuterio, H.S. J. Am. Chem. Soc. **1954**, 76, 519 and references cited therein.

6) Wislicenus, W. Chem. Ber. **1900**, 33, 1469. Powell, S.G.; Adams R. J. Am. Chem. Soc. **1920**, 42, 646. Lauer, W.M. ; Spielman, M.A. ibid. **1933**, 55, 1572.

7) For a palladium-catalyzed version of a [1,3]-oxygen to carbon shift, see: Trost, B.M.; Runge, T.A.; Jungheim, L.N. J. Am. Chem. Soc. **1980**, 102, 2840.

8) Newman, M.S.; Zwander Zwan, M.C. J. Org. Chem. **1973**, 38, 2910.

9) Tamao, K.; Sumitani, K.; Kumada, M. J. Am. Chem. Soc. **1972**, 94, 4374. Kumada, N. Pure and Applied Chemistry **1980**, 52, 669. Kumada, M.; Tamao, K. Organic Synthesis **1978**, 58, 127.

10) The selective hydrolysis of the ethylene glycol ketal in the presence of the vinyl ether was conducted with 2:1 THF/0.1N HCl at 0 °C for 12 h.

11) This value was determined by subtracting: the resonance energy of the phenoxy radical (O-H bond energy of water - phenol = 34 kcal/mol), the resonance energy of the acetonyl radical[12] (~ 8.6 kcal/mol), and the strain energy of cyclopentene[13] (~ 6 kcal/mol) from the energy of a carbon-oxygen single bond (84 kcal/mol).

12) For leading references, see: Camaioni, D.M.; Walter, H.F.; Jordan, J.E.; Pratt, D.W. J. Am. Chem. Soc. **1973**, 95, 7978. Huyser, E.S.; Feller, D.; Borden, W.T.; Davidson, E.R. J. Am. Chem. Soc. **1982**, 104, 2956.

13) Lowry, T.H.; Richardson, K.S., Mechanism and Theory in Organic Chemistry, Harper and Row, New York, 1981, p. 150.

14) All yields reported are isolated yields of pure compounds which showed spectroscopic and analytical data (exact mass measurement or combustion analysis) in agreement with the assigned structure. The compounds obtained as solids showed the following mp's (°C): **7a**, 161-162; **7b**, 112-114; **4a**, 89-91; **5a**, 186-188 (dec); **5b**, 159-160; **5c**, 155-157; **8a**, 123-125; **8b**, 102-104; **9a**, 123-125; **9b**, 115-117; **9c**, 128-129; **9d**, 168-170; **10**, oil.

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