Tetrahedron Letters,Vol.23,No.12,pp 1305-1308,1982 0040-4039/82/121305-04$03.00/0
Printed in Great Britain

ENHANCEMENT OF THE CONJUGATIVE ELECTRON-RELEASING POWER OF THE HYDROXY-GROUP SHOWN BY THE KINETICS OF SOLVOLYSIS OF 2-BROMO-4-DIBROMOMETHYLPHENOL AND OF 2-BROMO-4-DIBROMOMETHYLANISOLE

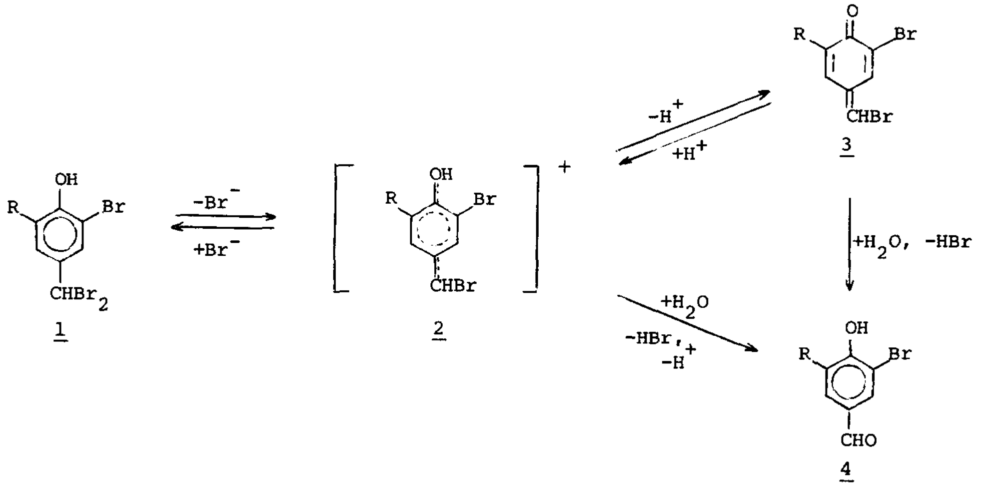
Peter B.D. de la Mare* and Paul A. Newman
Department of Chemistry, University of Auckland, Private Bag, Auckland, New Zealand.

ABSTRACT: The relative rates and kinetic forms for the solvolyses of 2-bromo-4-dibromomethylphenol and its methyl ether lead to a new estimate ($\sigma^+ = -1.6$) of the electron-releasing power of the hydroxy-group.

The conjugative electron-releasing properties of the hydroxy-group are well known, but rather few quantitative comparisons with other substituents are available. Phenol is brominated more rapidly than anisole,[1] and analysis of the relative rates of bromination of phenol, anisole, and their alkyl derivatives established that steric inhibition of resonance of the methoxy-group is responsible for only a part of this difference.[2] Eaborn[3] showed that the hydroxy-group is also more electron-releasing than the methoxy-group in activating the aromatic nucleus for protodesilylation; and Deno and Evans[4] drew similar conclusions from study of equilibria of the type $Ar_3C.OH + H^+ \rightleftharpoons Ar_3C^+ + H_2O$. As the result of these and other measurements,[5] the values for the substituent parameters are often quoted as $\sigma^+ = -0.92$ (OH) and $\sigma^+ = -0.78$ (OMe). Resonance constants dissected from inductive constants by measurements based on fluorine nuclear magnetic resonance,[6] on infra-red spectra[7] and on other processes[8] show even smaller (sometimes negative) estimates of the enhancement of the conjugative power of the hydroxy- as compared with the methoxy-substituent).

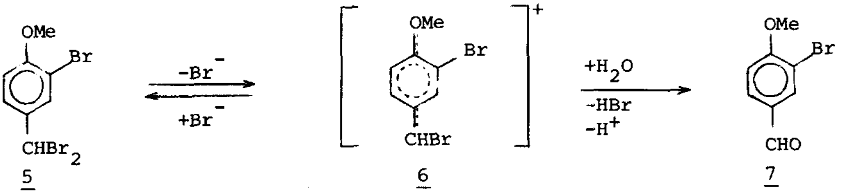
Up till now, as far as we are aware, no quantitative estimation has been made of the effect of a hydroxy-group on the rate of a unimolecular (S_N1) solvolysis. The observation[9] that 2-bromo-4-dibromomethylphenol is very unstable in moist air led us to investigate its rate of solvolysis, which required dioxan containing only 5% of water for convenient measurement at 34°C. The reaction requires discussion in terms of the Scheme; first-order rate-coefficients for the disappearance of 1, for the appearance of 3, and for the appearance of 4 can be estimated by conventional analysis of the successive ultraviolet absorption spectra of reacting mixtures. The intermediacy of the carbocation 2 follows from the observation of mass-law retardation[10] of the disappearance of 1 as bromide ion develops in the reaction medium, or when bromide ion is added initially. Both the initial rate and the very high mass-law constant were found to be

:HEME: Reaction paths in the solvolysis of 2-bromo-4-dibromomethylphenol ($\underline{1}$, R = H) and of 2,6-dibromo-4-dibromomethylphenol ($\underline{1}$, R = Br)



:arly independent of acidity over the range 0.001-0.01 $\underline{\underline{M}}$, so the proton of the hydroxy-group is ·esent not only in the transition-state for loss of bromide ion but also in the intermediate ·om which the quinone methide $\underline{3}$ is formed. The hypothetical sequence $\underline{1} \underset{+HBr}{\overset{-HBr}{\rightleftarrows}} \underline{3} \xrightarrow[-HBr]{+H_2O} \underline{4}$, with ·ncerted dehydrobromination of $\underline{1}$, is not consistent with the combined dependence of rate on conntration of bromide ion and on acidity.

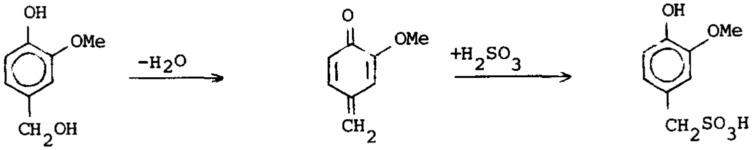
The rate of the first stage of the forward reaction for $\underline{1}$ (R = H), viz. k_1 = 0.459 min^{-1} at °C, has been compared with that of the corresponding stage of reaction (1), namely = 1.39 x 10^{-4} min^{-1} at 34°C in the same solvent.



...(1)

σ^+ for the OMe group is taken as -0.78, and the ρ-value for this reaction is about -4.5, as ems likely from available analogies,[11] then σ^+ for the hydroxy-group as determined by using e present reaction is about -1.6, much larger than has been found by using aromatic substitutn as a basis for comparison, despite the larger ρ-values for the latter reactions.

Solvent effects on the reactivities of alkyl-substituted substrates reveal a complex balance tween hyperconjugative and inductive influences,[12] with both ground-state and transition-state ergies probably affected differentially. Intuitively, it seems likely that, as long as fluences on the transition state dominate, H-O hyperconjugation would be enhanced by a dipolar solvent capable of hydrogen-bonding. The present case appears to provide a spectacular example, in which 1 (R = H), expected from known analogies to be only some 5 times more reactive than 5, is in fact 3300 times more reactive. Despite the general rapidity of proton-transfers to and from oxygen, this particular very large rate-enhancement promoted by the hydroxy-group does not result in concerted proton-loss to the medium (which of course follows rapidly), just as proton-loss is not a necessary consequence of H-C hyperconjugation.[13] Ivnäs and Lindberg[14] noted an analogous rate-enhancement by the hydroxy-group in the sulphitodehydroxylation of 4-hydroxy-3-methoxybenzyl alcohol [equation (2)]. In their treatment, the corresponding reaction of 3,4-dimethoxybenzyl alcohol, which was 1000 times slower than that of its 4-hydroxy-analogue, was considered to proceed by a different mechanism, but they seem to have had no compelling evidence to bear on this matter.



...(2)

The deuterium isotope effects on the initial rates of solvolysis have been found to be k^H/k^D = 1.7 (R = H) and 1.9 (R = Br). These isotope-effects are composite, including the solvent isotope-effect on ionization and the secondary isotope-effect on H-O hyperconjugation. They are similar in magnitude to that found in the bromination of phenol,[15] a result which suggests that the hydroxy-proton is still present in the rate-determining transition state in this reaction also.

The quinone methide 3 (R = H) has been observed only as a transient intermediate; but its analogue 3 (R = Br) is more stable, and can be isolated.[16] Its conversion back to 1 (R = Br) in the presence of added bromide ion has been established. Its hydration in the initial absence of bromide ion is subject only to a small inverse solvent deuterium isotope effect (k^{H_2O}/k^{D_2O} = ca. 0.8). A larger inverse effect might be expected if its conversion to 4 proceeded entirely through 3, with pre-equilibrium protonation on oxygen, so we think it likely that both the routes from 3 to 4 shown in the scheme are available. A normal solvent deuterium isotope effect, implicating a route other than that involving a proton pre-equilibrium, has been found for the acid-catalysed hydration of other quinone methides.[17]

The identities of 1 (R = H, Br), 3 (R = Br), 4 (R = H, Br), 5 and 7 were established or confirmed by ^1H n.m.r. spectroscopy. Rates were determined spectrophotometrically by using a Varian DMS-90 spectrophotometer, with jacketed cells held at 34°C. The solvent was normally dioxan containing 5% of water by volume. For determining the dependence of rate on acidity ($HClO_4$) and on concentration of Br^- (LiBr), the ionic strength was held constant by the addition of the appropriate amounts of $LiClO_4$.

Acknowledgements:

We thank the N.Z. University Grants Committee for grants for equipment.

References:

1. P.W. Robertson, P.B.D. de la Mare, and B.E. Swedlund, J. Chem. Soc., 1953, 782.
2. P.B.D. de la Mare, Tetrahedron, 1959, 5, 107.
3. C. Eaborn, J. Chem. Soc., 1956, 4858.
4. N.C. Deno and W.L. Evans, J. Amer. Chem. Soc., 1957, 79, 5804.
5. O. Exner, in 'Correlation Analysis of Chemistry: Recent Advances', Ed. N.B. Chapman and J. Shorter, Plenum, New York, 1978, pp 439-540.
6. R.W. Taft, E. Price, I.R. Fox, I.C. Lewis, K.K. Andersen, and G.T. Davis. J. Amer. Chem. Soc., 1963, 85, 709, 3146.
7. R.T.C. Brownlee, R.E.J. Hutchinson, A.R. Katritzky, T.T. Tidwell, and R.D. Topsom, J. Amer. Chem. Soc., 1968, 90, 1757.
8. M. Charton, Progr. Phys. Org. Chem., 1981, 13, 119.
9. J.M. Brittain, P.B.D. de la Mare, and P.A. Newman, J. Chem. Soc., Perkin Trans. 2, 1981, 32.
10. L.C. Bateman, M.G. Church, E.D. Hughes, C.K. Ingold, and N.A. Taher, J. Chem. Soc., 1940, 979.
11. H.C. Brown and Y. Okamoto, J. Amer. Chem. Soc., 1958, 80, 4979.
12. E. Berliner, M.C. Beckett, E.A. Blommers, and B. Newman, J. Amer. Chem. Soc., 1952, 74, 4940; E. Berliner, Tetrahedron, 1959, 5, 202.
13. E.D. Hughes, C.K. Ingold, and N.A. Taher, J. Chem. Soc., 1940, 949.
14. L. Ivnäs and B. Lindberg, Acta Chem. Scand., 1961, 15, 1081.
15. P.B.D. de la Mare and O.M.H. El Dusouqui, J. Chem. Soc., B, 1967, 251.
16. H. Lindemann, Liebig's Ann. Chem., 1923, 431, 270.
17. J. Velek, B. Koutek, and M. Soucek, Coll. Czech. Chem. Comm., 1979, 44, 110.

(Received in UK 20 January 1982)