# Notes

## Stable Carbocations. CLXVII.[1] Protonation and Cleavage of Acetylsalicylic Acid and Isomeric Hydroxybenzoic Acids in $FSO_3H$–$SbF_5$ (Magic Acid) Solution

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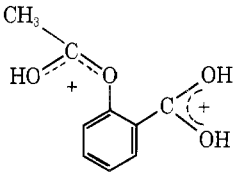
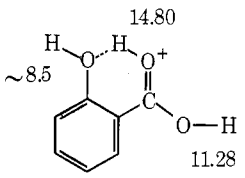
The protonation of monosubstituted benzene derivatives has been studied extensively by nuclear magnetic resonance spectroscopy.[3] The structure of protonated, disubstituted benzene derivatives, however, has received considerably less attention.[4] We wish to report now the pmr study of protonated acetylsalicylic acid and isomeric hydroxybenzoic acids in $FSO_3H$–$SbF_5$ (Magic Acid) solution. The relative biological activities of acetylsalicylic acid and salicylic acid, and the mechanism by which the former is hydrolyzed *in vivo*, have been extensively studied.[5] It was hoped that the *in vitro* observation and identification of the intermediates involved in the cleavage reaction would contribute to our better understanding of the mechanism of this biologically important hydrolysis.

### Results and Discussion

Treatment of an $SO_2ClF$ solution of acetylsalicylic acid (1) with excess $FSO_3H$–$SbF_5$ at −70° gave a solution whose pmr spectrum consisted of singlets at δ 3.44 (3 H), 12.64 (2 H), and 14.08 (1 H) and a multiplet between δ 7.92 and 8.97 (4 H). The two most deshielded singlets were differentiated on the basis of their relative intensities. The chemical-shift data indicate that acetylsalicylic acid in Magic Acid solution exists as the diprotonated species, **2**.



**2**

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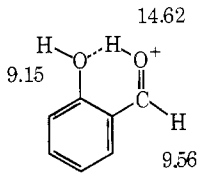
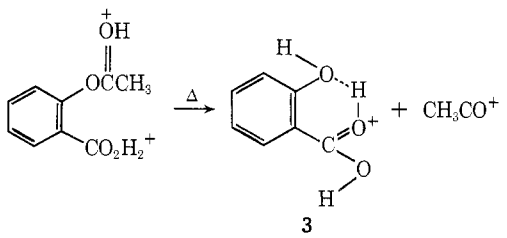


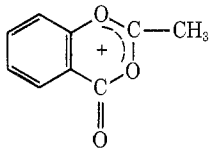

**4**

Warming the above solution to 0° resulted in a decrease in intensity of the singlet at δ 3.44 and the appearance of a singlet at δ 4.1, which is coincidental with the methyl proton resonance of an added sample of acetyl cation. It, therefore, seems that **2** on heating is cleaved, most likely by an $A_{AL}1$ mechanism,[3b] to the acetyl cation and protonated salicylic acid **3**.



**3**

No acetylsalicyloyl cation, which was recently shown by Ruchardt[6] to exist as the stable cyclic 2-methyl-4,5-benzo-1,3-diox-4-en-5-on-2-ylium ion (**5**), was observed in the system.



**5**

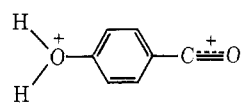
The above cleavage was confirmed in our studies by showing that the pmr spectrum of salicylic acid in excess $FSO_3H$–$SbF_5$ is identical with that of the ion resulting from cleavage of acetylsalicylic acid.

The pmr spectrum of salicylic acid in excess $FSO_3H$–$SbF_5$ at 0°, with $SO_2ClF$ as the diluent, consists of a multiplet for the aromatic protons between δ 7.5 and 8.8 and a broad singlet at δ 11.7, resulting from rapid proton exchange of the OH protons with the acid solvent. On cooling to −108°, the exchange rate is sufficiently slowed to observe sharp singlets at δ 14.80 (1 H) and 11.28 (1 H) (besides the $HSO_3F$ and $H_3O^+$ signals) and broad multiplets at δ 8.3–9.0 (3 H) and 7.5–8.2 (2 H). We propose that the spectrum at this temperature is that of monoprotonated salicylic acid **3**. For comparison we also obtained the pmr spectrum of protonated salicylaldehyde (**4**) in excess $FSO_3H$–$SbF_5$ at −120°. It shows doublets at δ 14.62 (1 H, $J$ = 15 Hz) and 9.56 (1 H, $J$ = 15 Hz), a singlet at δ 9.15 (1 H), and a multiplet arising from the aromatic protons at δ 7.5–8.9 (4 H). The resonances at δ 14.62 and 9.56 were assigned in analogy with previously observed $=OH^+$ and –CHO resonances in related systems.[7] The proton on the carbonyl oxygen and aldehydic protons, respectively, are coupled to each other, as shown by decoupling experiments. On the basis of coupling constant data from protonated aldehydes[8] the large coupling observed between these protons ($J$ = 15 Hz) indicates that they are trans to each other, as shown in structure **4**. Comparison of the pmr data for protonated salicaldehyde **4** and salicylic acid **3** confirms the assignments in the latter compound of the peaks at δ 14.80 and ~8.5. The remaining signal (δ 11.28) must be the carboxylic proton which is not hydrogen bonded to the phenolic oxygen atom. This resonance is shielded compared with the corresponding resonances in protonated benzoic acid[3g] (δ 12.10) and suggests that little of the positive charge is located on this oxygen atom (as shown in structure **3**). The nmr data, therefore, indicate that salicylic acid and salicylaldehyde are only monoprotonated in Magic Acid solution, and that protonation occurs on the carboxyl and aldehyde groups, respectively. The nonbonded electron pairs of the phenol oxygen atom undergo hydrogen bonding with the protonated acid and aldehyde group, preventing their own protonation, and this results, in the case of salicylic acid, in the nonequivalence of the two acidic OH protons. This contrasts with the situation in diprotonated acetylsalicylic acid and monoprotonated benzoic acid, where the two acidic OH protons are equivalent. Owing to the deactivating effect of the

carboxyl (and protonated carboxyl group) no ring protonation occurs, as is the case with phenol itself.[3f]

We have also obtained the pmr spectra of *m*- and *p*-hydroxybenzoic acids in excess $FSO_3H$–$SbF_5$ solution at low temperature. Unlike the ortho isomer (salicylic acid) the meta and para isomers are diprotonated. At −70° the spectrum of protonated *m*-hydroxybenzoic acid consists of singlets at δ 13.36 (2 H, $CO_2H_2^+$) and 12.50 (2 H, $OH_2^+$) and a complex pattern between δ 8.3 and 9.1 (4 H). The pmr spectrum of the para isomer at −110° consists of broad singlets at δ 13.97 (2 H, $CO_2H_2^+$) and 12.34 (2 H, $OH_2^+$) and a multiplet between δ 7.8 and 9.1. (Assignments were made based on comparison with data on protonated substituted benzoic acids and phenols.) At comparable acid concentrations, it therefore requires a lower temperature to freeze out the proton-exchange processes of the para isomer. The reason for this is not yet clearly understood. The proton resonances of the phenolic hydroxyls in the *m*- and *p*-hydroxybenzoic acids are considerably deshielded from that of the ortho isomer. This is probably the result of greater positive charge on the phenolic oxygen atom in these isomers, compared with the ortho isomer.

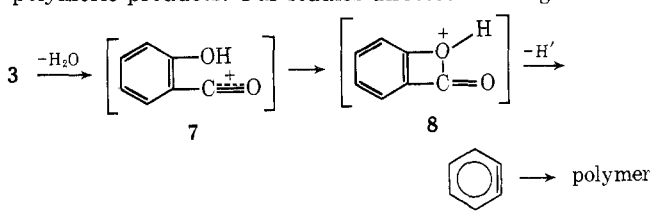
Protonated *m*- and *p*-hydroxybenzoic acids also react differently from the ortho isomer on heating. On warming a solution of *p*-hydroxybenzoic acid in $HSO_3F$–$SbF_5$ at 20°, the appearance of a multiplet with the characteristic pattern of an AA′BB′ spin system is observed in the nmr spectrum between δ 8.1 and 9.3. This spectral data and quenching experiments ($H_2O$), which yield *p*-hydroxybenzoic acid quantitatively, indicate the formation of dication **6**.



**6**

Similar results are observed for protonated *m*-hydroxybenzoic acid, which cleaves to the meta isomer of ion **6** on warming in $FSO_3H$–$SbF_5$ at room temperature. In the nmr spectrum of this dication a multiplet between δ 8.6 and 9.4 is found.

Similar experiments for protonated *o*-hydroxybenzoic acid gave only polymeric material, most likely *via* intermediates **7** and **8**, leading subsequently to benzyne and its polymeric products. Our studies directed to the generation



**7** **8**

of benzyne from salicylic acid derivatives will be reported separately.

## Experimental Section

**Materials.** All compounds were reagent-grade commercial chemicals and were used without further purification.

**Nmr Spectra.** A Varian A56/60A nmr spectrometer with variable-temperature probe was used for all spectra. Solutions were prepared at −80° using a 1:1 *M* solution of $HSO_3F$–$SbF_5$ and $SO_2ClF$ as a diluent according to procedures described previously.[3,4,6] Chemical shifts were referred to external TMS.

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**Registry No.**—**1**, 50-78-2; **2**, 50977-96-3; **3**, 51016-05-8; **4**, 50977-97-4; **6**, 50977-98-5; *m*-**6**, 50977-99-6; Magic Acid, 37204-12-9; salicylic acid, 69-72-7; *m*-hydroxybenzoic acid, 99-06-9; *p*-hydroxybenzoic acid, 99-96-7; protonated *m*-hydroxybenzoic acid, 51016-03-6; protonated *p*-hydroxybenzoic acid, 51016-04-7.

## References and Notes

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(2) Postdoctoral Research Fellow, 1971–1973.
(3) (a) G. A. Olah and A. M. White, *J. Amer. Chem. Soc.*, **89**, 7072 (1967); (b) G. A. Olah, D H. O'Brien, and A. M. White, *ibid.*, **89**, 5694 (1967); (c) G. A. Olah and T. E. Kiovsky, *ibid.*, **90**, 6461 (1968); (d) G. A. Olah, A. T. Ku, and J. A. Olah, *J. Org. Chem.*, **35**, 3908, 3925 (1970); (e) N. C. Deno, R. W. Gaugler, and M. J. Wisotsky, *ibid.*, **31**, 1967 (1966); (f) T. Birchall, A. N. Bourns, R. J. Gillespie, and P. J. Smith, *Can. J. Chem.*, **42**, 1433 (1964); (g) T. Birchall and R. J. Gillespie, *ibid.*, **43**, 1045 (1965); (h) M. Brookhart, G. C. Levy, and S. Winstein, *J. Amer. Chem. Soc.*, **89**, 1735 (1967).
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(5) H. O. J. Collier, *Sci. Amer.*, 97 (Nov 1963).
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(8) G. A. Olah, D. H. O'Brien, and M. Calin, *J. Amer. Chem. Soc.*, **89**, 3582 (1967).

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# Photoelectron Spectra of Mesitylene Derivatives. Electronic Interactions Between Arene Ion Groups

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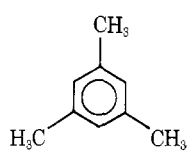
We wish to report the results of our investigation of the He(I) photoelectron spectra of mesitylene (**1**), bimesityl (**2**), 2,7-dimethyl-4,5,9,10-tetrahydropyrene (**3**), *anti*-6,13-dimethyl[2.2]metacyclophane (**4**), and [2.2.2](1,3,5)cyclophane (**5**). These compounds were chosen for study because of their relationship with mesitylene. The symmetry of this parent system dictates a degeneracy among the II ionic states. All of the derivatives (**2**–**5**) are substituted in such a way that this degeneracy should be approximately preserved in the absence of interring interaction. With this approximation the observed splittings, which remove these degeneracies, can be simply interpreted in terms of interring interactions.



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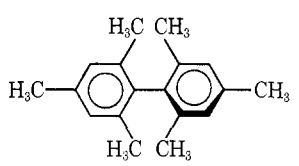

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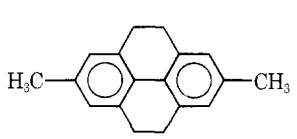

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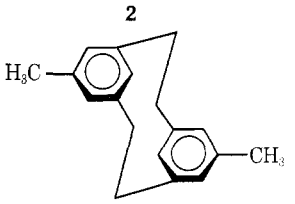
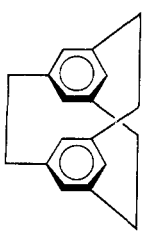


**4**



**5**

The spectra are shown as Figures 1 and 2. The first band in the spectrum of mesitylene ($IP_{vert}$ = 8.42 eV)[1]