whereupon about 5 g. of crude aminosulfodehydroabietic acid precipitated in fine microscopic needles slightly brownish in color. These were recrystallized from water. The acid does not melt below 300°.

Anal. Calcd. for $C_{20}H_{29}O_5NS$: C, 60.73; H, 7.39. Found: C, 60.27, 60.49; H, 7.46, 7.46 (the sample contained 0.42% ash).

Summary

1. On nitration with fuming nitric acid the sulfonate of dehydroabietic acid gives a mononitrosulfodehydroabietic acid almost in quantitative yields. This mononitro product is characterized by the preparation of its diethyl and dimethyl esters.

2. The mononitrosulfodehydroabietic acid is readily reduced by ordinary means to the corresponding monoaminosulfodehydroabietic acid.

SAVANNAH, GEORGIA RECEIVED NOVEMBER 8, 1940

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE OHIO STATE UNIVERSITY]

Osage Orange Pigments. V. Isomerization[1]

BY M. L. WOLFROM, F. L. BENTON, A. S. GREGORY, W. W. HESS, J. E. MAHAN AND P. W. MORGAN

In a previous publication[2] from this Laboratory we have shown that the two closely related yellow pigments, osajin and pomiferin, of the fruit of the osage orange (*Maclura pomifera* Raf.) are isomerized by mineral acids to high melting isomers and that in each of these the single absorption maximum is shifted slightly toward the region of shorter wave lengths to produce colorless products. It is the purpose of the present communication to examine further the nature of this isomerization.

Pomiferin ($C_{25}H_{24}O_6$) differs from osajin ($C_{25}H_{24}O_5$) by one hydroxyl group and no other significant difference has yet been found. In a recent publication we have made a tentative assignment of a flavone structure for these substances, subject to confirmation by further degradative work. Mr. Mahan of this Laboratory now has found that an isoflavone structure is present, since alkaline treatment of methylated osajin has produced formic (one mole) and homoanisic (*p*-methoxyphenylacetic) acids and similar treatment of methylated pomiferin has yielded formic (one mole) and homoveratric (3,4-dimethoxyphenylacetic) acids. The details of this work will be communicated at a later date. Iso-osajin does not give a coloration with ferric chloride–alcohol but as there is every reason to believe that a phenolic group is still present in this substance, it would appear that we have in hand a not uncommon case of a phenolic group being undetectable by this color test. Otherwise, the isomerized substances exhibit the same reduction and other color tests as before isomerization, so that the isoflavone nucleus is still present.

Osajin has been shown to possess two hydroxyl groups and pomiferin three. Of these groups, one hydroxyl in both has been shown to be resistant toward acetylation with acetic anhydride and pyridine in the cold. The fully acetylated derivatives are obtainable on acetylation with hot acetic anhydride and sodium acetate. Under tosylation conditions, pomiferin has been shown to form a ditosyl (di-*p*-toluenesulfonate) derivative and osajin a monotosyl substitution product. Under stringent methylation conditions (hot methyl sulfate and alkali in the presence of acetone) the fully substituted methyl ethers are obtained. Under mild conditions of methylation (short treatment with sodium ethylate and methyl sulfate at 0° or, as now reported, on methylation with diazomethane) pomiferin forms a dimethyl ether which can be further methylated to the trimethyl ether under the more stringent conditions and which can be acetylated under the stringent conditions but not by the mild conditions of acetylation. An analogous behavior toward methylation is now reported for osajin.

The partially substituted derivatives of both substances give a strong ferric chloride–alcohol coloration so that the resistant hydroxyl group in each is phenolic (or enolic). Iso-osajin yields a mono-*p*-toluenesulfonate and isopomiferin produces a di-*p*-toluenesulfonate.[2] It is now shown that under either the mild or stringent conditions, iso-osajin produces a monoacetate and a monomethyl ether while pomiferin yields a diacetate and a dimethyl ether. These substitution prod-

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[1] Preceding publication in this series: M. L. Wolfrom, P. W. Morgan and F. L. Benton, THIS JOURNAL, **62**, 1484 (1940).

[2] M. L. Wolfrom, F. L. Benton, A. S. Gregory, W. W. Hess, J. E. Mahan and P. W. Morgan, *ibid.*, **61**, 2832 (1939).

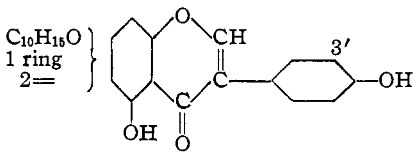
ucts of the iso-compounds no longer exhibit the strong ferric chloride-alcohol coloration. Furthermore, the partially methylated derivatives of osajin and pomiferin can be isomerized to the above ethers and the tosyl derivatives of each can be isomerized to products which are identical with those obtained by the direct tosylation of the iso-compounds (previously reported[2] for pomiferin). Pomiferin trimethyl ether was recovered unchanged under the usual isomerizing conditions but under more vigorous conditions demethylation occurred and a low yield of isopomiferin dimethyl ether was obtained.

Thus, it can be concluded that one hydroxyl group in osajin and pomiferin disappears in this isomerization and that this group is the one that is resistant toward acetylation, tosylation and methylation and exhibits a strong ferric chloride–alcohol phenol (or enol) test.

Both osajin and pomiferin possess two double bonds that are saturated easily and in a stepwise manner by catalytic hydrogenation.[1] Under prolonged conditions of hydrogenation a hexahydro-osajin, which is an isoflavanone, was obtained. It is now found that hexahydro-osajin and the tetrahydro derivatives of osajin and pomiferin are recovered unchanged under isomerizing conditions with mineral acids. On the other hand, dihydro-osajin and dihydro-pomiferin are isomerized under these conditions to substances which are identical with those obtained by the catalytic hydrogenation of iso-osajin (as the acetate) and isopomiferin. Dihydro-iso-osajin forms a monoacetate and dihydro-isopomiferin forms a diacetate under either the mild or stringent acetylation conditions.

Therefore, it can be concluded that a double bond as well as one hydroxyl group in osajin and pomiferin disappears in this isomerization and that this double bond is the one that is the least active toward catalytic hydrogenation of the two active points of unsaturation present in these substances. This type of acid isomerization is well established in organic compounds and is the type of isomerization exhibited by lapachol,[3] rotenonic acid[4] and cannabidiol.[5] In all of these cases a ring structure results. It is to be noted that the isomerizing conditions are such that the double bond may be shifted from its original position during the rearrangement.

A preliminary interpretation of the facts of this isomerization may be made in the light of the partial formula of osajin now known (pomiferin differs from osajin by the presence of an additional *ortho* phenolic group in the 3′-position). It would appear probable that the hydroxyl group in the *peri* (presumably) position to the carbonyl adds to one of the double bonds, probably in a side chain, in the $C_{10}H_{15}O$ group.



Osajin
(Pomiferin, 3′-OH)

Experimental

Osajin Monomethyl Ether.—A solution of osajin (6 g.) in 120 cc. of acetone was placed in a three-necked, round-bottom flask fitted with a reflux condenser and water trap, a nitrogen inlet tube, and an addition funnel. To this solution, cooled in an ice-bath and maintained under an atmosphere of nitrogen, was added 25 cc. of sodium ethylate solution (4 g. of sodium per 100 cc. of absolute ethanol) followed by 15 cc. of dimethyl sulfate. Then 15 cc. more of the sodium ethylate solution and 35 cc. more of dimethyl sulfate were added with shaking. The solution was allowed to stand for ten minutes and then was poured into an excess of ice and water. Twelve hours later the precipitate thus formed was removed by filtration and recrystallized from 95% ethanol; yield 4.4 g., m. p. 134–135°.[6]

The substance crystallized in long, individual, yellow needles that gave a green coloration with ferric chloride–alcohol, an orange color with sulfuric acid–acetic acid, and showed a negative Fehling and Tollens (pyridine solution) reduction.

Anal. Calcd. for $C_{25}H_{23}O_4(OCH_3)$: C, 74.64; H, 6.26; OCH_3, 7.41. Found: C, 74.32; H, 6.39; OCH_3, 7.06.

The same substance was obtained on methylating osajin in dioxane solution with an excess of diazomethane as described below for pomiferin dimethyl ether. Treatment of osajin monomethyl ether according to the procedure used for the preparation of osajin dimethyl ether[7] resulted in the formation of the dimethyl ether in good yield.

Osajin Monomethyl Ether Monoacetate (I).—Osajin monomethyl ether (1.37 g.) was acetylated by refluxing for two hours with acetic anhydride (50 parts) and twice-fused sodium acetate (10 parts) and the material obtained on pouring the cooled reaction mixture into an excess of

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(3) E. Paterno, *Gazz. chim. ital.*, **12**, 372 (1882); S. C. Hooker, *J. Chem. Soc.*, **61**, 611 (1892); **69**, 1355 (1896).

(4) H. L. Haller, THIS JOURNAL, **53**, 733 (1931); **54**, 2126 (1932).

(5) R. Adams, D. C. Pease, C. K. Cain and J. H. Clark, *ibid.*, **62**, 2402 (1940).

(6) All melting points recorded are uncorrected and those below 210° were taken on a 360° thermometer with immersion to the −20° mark. Those above 210° were taken on a modified Berl-Kullmann block as described by F. W. Bergstrom, *Ind. Eng. Chem., Anal. Ed.*, **9**, 340 (1937).

(7) M. L. Wolfrom and A. S. Gregory, THIS JOURNAL, **62**, 651 (1940).

water was recrystallized from 95% ethanol; yield 1.35 g., m. p. 139–140°. Pure material was obtained on further crystallization from the same solvent; m. p. 140–140.5°. The substance crystallized in colorless prisms.

Anal. Calcd. for $C_{25}H_{22}O_4(OCH_3)(CH_3CO)$: C, 73.0; H, 6.13; OCH_3, 6.74; CH_3CO, 2.17 cc. 0.1 *N* NaOH per 100 mg. Found: C, 72.9; H, 6.18; OCH_3, 6.58; CH_3CO,[8] 2.29 cc.

Osajin monomethyl ether was recovered unchanged when acetylated overnight at ice-box temperature with acetic anhydride (70 parts) and pyridine (35 parts). The acetylation mixture was poured into an excess of water and the separated solid removed by filtration and recrystallized from 95% ethanol.

Dihydro-iso-osajin (II).—Dihydro-osajin[1] (0.88 g.) was dissolved in 50 cc. of boiling glacial acetic acid and 2 cc. of concentrated sulfuric acid was added slowly to the hot solution. The solution turned orange immediately. This solution was kept overnight at room temperature and was then poured into ice and water and the precipitate removed by filtration; yield 0.87 g., m. p. 210–215°. Pure material was obtained on recrystallization from acetone–water and the melting point was unchanged on further crystallization from ethanol–water or absolute ethanol; yield 0.58 g., m. p. 287° (dec.).

The substance crystallized in the form of elongated, colorless plates that were moderately soluble in acetone and more soluble in alcohol. The ferric chloride–alcohol test was negative. An immediate yellow color was developed in glacial acetic acid solution on the addition of a few drops of concentrated sulfuric acid.

Anal. Calcd. for $C_{25}H_{26}O_5$: C, 73.87; H, 6.45; mol. wt., 406.4. Found: C, 73.82; H, 6.30; mol. wt. (Rast), 417, 438.

Dihydro-iso-osajin also was formed on heating the monoacetate and the diacetate of dihydro-osajin[1] in ethanol solution with *p*-toluenesulfonic acid, *i. e.*, it was recovered from the acetyl analyses made on these substances according to the procedure of Freudenberg and Harder.[8] The alcoholic solution from the analysis was poured into a large excess of water, the separated solid removed by filtration and recrystallized from acetone–water.

Iso-osajin Monoacetate.—Iso-osajin[2] (0.60 g.) was acetylated in the cold with pyridine and acetic anhydride (*cf.* I) and the crude product (0.62 g., m. p. 196–197°) obtained by pouring the reaction mixture into cold water was purified from 95% ethanol; yield 0.52 g., m. p. 198.5°. The substance formed long, radiating, colorless needles; gave no coloration with ferric chloride–alcohol but gave a yellow color with sulfuric acid–acetic acid.

Anal. Calcd. for $C_{25}H_{23}O_5(CH_3CO)$: C, 72.6; H, 5.87; CH_3CO, 2.24 cc. 0.1 *N* NaOH per 100 mg.; mol. wt., 446.5. Found: C, 72.60; H, 6.00; CH_3CO, 2.34 cc.; mol. wt. (Rast), 390, 409.

Iso-osajin was recovered from the acetyl analyses. Iso-osajin monoacetate was obtained also on refluxing iso-osajin with sodium acetate and acetic anhydride (*cf.* I).

Dihydro-iso-osajin Monoacetate.—Dihydro-iso-osajin (0.40 g.) was acetylated in the cold with acetic anhydride and pyridine (*cf.* I), yield 0.43 g., m. p. 232°. Pure material was obtained on crystallization from 90% ethanol and was unchanged in melting point on further crystallization from methanol; yield 0.37 g., m. p. 234°. The substance crystallized as fine, colorless, radiating needles that were water-insoluble and were moderately soluble in acetone and alcohol. It gave a negative ferric chloride–alcohol test and a positive yellow color with acetic acid–sulfuric acid.

Anal. Calcd. for $C_{25}H_{25}O_5(CH_3CO)$: C, 72.30; H, 6.29; CH_3CO, 2.23 cc. 0.1 *N* NaOH per 100 mg.; mol. wt., 448.5. Found: C, 72.30; H, 6.20; CH_3CO, 2.23 cc.; mol. wt. (Rast), 413, 485.

Dihydro-iso-osajin was recovered from the acetyl analysis. Dihydro-iso-osajin monoacetate was recovered unchanged on acetylation with hot acetic anhydride and sodium acetate (*cf.* I). It was obtained also by the hydrogenation of iso-osajin monoacetate. Iso-osajin monoacetate (0.42 g.) in 40 cc. of absolute ethanol was reduced at atmospheric pressure with platinic oxide (0.05 g.), the reduction being stopped when one mol of hydrogen had been absorbed. With the catalyst preparation used this required a time of about three minutes. The catalyst was removed by filtration and the product was crystallized from the concentrated filtrate by the addition of water; yield 0.37 g., m. p. 220°. Pure material was obtained on repeated crystallization from 95% ethanol and was identified by melting point and mixed melting point.

Iso-osajin Mono-*p*-toluenesulfonate.—Iso-osajin[2] (0.3 g.) was dissolved in dry pyridine (5 cc.) and treated with a solution of *p*-toluenesulfonyl chloride (2 g.) in dry pyridine (10 cc.). The solution was kept at room temperature for three days and the water-insoluble material obtained on pouring the solution into cold water (300 cc.) was removed by filtration and crystallized from 95% ethanol by the addition of water; yield 0.4 g., m. p. 180°. Pure material was obtained on further recrystallization from alcohol and was unchanged in melting point on further crystallization from benzene–petroleum ether; m. p. 189.5°. The substance was colorless, gave no coloration with ferric chloride–alcohol, and exhibited no reduction with Fehling or Tollens (pyridine) reagents.

Anal. Calcd. for $C_{25}H_{23}O_5(SO_2C_6H_4CH_3)$: C, 68.79; H, 5.41; S, 5.73; mol. wt., 558.5. Found: C, 68.50; H, 5.39; S, 5.60; mol. wt. (Rast), 500.

Iso-osajin mono-*p*-toluenesulfonate also was obtained (identification by m. p. and mixed m. p.) by the isomerization of osajin mono-*p*-toluenesulfonate[2] with sulfuric acid–acetic acid as described above (*cf.* II).

Iso-osajin Monomethyl Ether.—Iso-osajin[2] (2.6 g.) was dissolved in boiling acetone (300 cc.). To the refluxing solution was added simultaneously in a dropwise manner dimethyl sulfate (100 cc.) and an aqueous solution of potassium hydroxide (100 cc., 42.5%). This addition required one and one-half hours and the refluxing was continued for an additional hour whereupon the solution was poured into an excess of ice and water and allowed to stand overnight. The precipitate was removed by filtration and recrystallized from ethanol–water; yield 2.2 g., m. p. 190–190.5° unchanged on further crystallization from ethanol–water or benzene–petroleum ether.

The substance formed colorless crystals that gave no

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[8] All acetyl analyses were made by the method of K. Freudenberg and M. Harder, *Ann.*, **433**, 230 (1923).

coloration with ferric chloride–alcohol and did not reduce Fehling or Tollens (pyridine) reagents.

Anal. Calcd. for $C_{25}H_{23}O_4(OCH_3)$: C, 74.62; H, 6.26; OCH_3, 7.42. Found: C, 74.60; H, 6.30; OCH_3, 7.31.

Osajin monomethyl ether (3 g.) was isomerized in glacial acetic acid with sulfuric acid (*cf.* II) and the crude water-insoluble product was purified from 95% ethanol and identified as iso-osajin monomethyl ether by melting point and mixed melting point.

Iso-osajin monomethyl ether also was produced in good yield by the mild methylation of iso-osajin according to the procedure described above for the preparation of osajin monomethyl ether.

Pomiferin Dimethyl Ether by Diazomethane Methylation.—Methylation of pomiferin at room temperature in dioxane solution with an excess of diazomethane, allowing to stand overnight, remethylating, and again allowing to stand overnight, removing any diazomethane by heating at 98°, cooling, pouring into an excess of cold water, and recrystallizing the filtered precipitate from 95% ethanol, resulted in the formation of pomiferin dimethyl ether[2] (identification by m. p. and mixed m. p.).

Pomiferin dimethyl ether was recovered unchanged when acetylated in the cold with pyridine and acetic anhydride (*cf.* I). As previously reported,[2] the monoacetate is obtained on hot acetylation with acetic anhydride and sodium acetate.

Dihydro-isopomiferin.—Dihydropomiferin[1] (0.95 g.) was isomerized in glacial acetic acid solution with sulfuric acid as described for the isomerization of dihydro-osajin (*cf.* II) and the crude product was isolated in the same manner; yield 0.90 g., m. p. 215–220°. Pure material was obtained on recrystallization from acetone–water and was unchanged in melting point on further crystallization from 80% ethanol; yield 0.46 g., m. p. 258–259° (dec.).

The substance formed long, glistening, colorless needles that were water-insoluble but were moderately soluble in acetone and alcohol. In alcoholic solution, the substance gave a dull green color with ferric chloride, changing to a deep violet on the addition of ammonia. It gave an immediate yellow color with sulfuric acid–acetic acid.

Anal. Calcd. for $C_{25}H_{26}O_6$: C, 71.08; H, 6.20; mol. wt., 422.5. Found: C, 70.76; H, 6.38; mol. wt. (Rast), 444, 480.

Dihydro-isopomiferin was recovered from the acetyl analyses of the diacetate and the triacetate of dihydropomiferin.[1] It was obtained also by the hydrogenation of isopomiferin according to the procedure described above for the production of dihydro-iso-osajin monoacetate from iso-osajin monoacetate.

Isopomiferin Diacetate.—Acetylation of isopomiferin[2] by either the cold pyridine or the hot sodium acetate method (*cf.* I) and recrystallization of the crude water-insoluble product from 95% ethanol gave the same product in good yield; m. p. 193°. The substance crystallized in fine, cottony, colorless needles which gave no coloration with ferric chloride–alcohol.

Anal. Calcd. for $C_{25}H_{22}O_6(CH_3CO)_2$: C, 69.03; H, 5.59; CH_3CO, 3.96 cc. 0.1 *N* NaOH per 100 mg. Found: C, 68.83; H, 5.58; CH_3CO, 4.00 cc.

Dihydro-isopomiferin Diacetate.—Dihydro-isopomiferin (0.25 g.) was acetylated in the cold with pyridine and acetic anhydride (*cf.* I) and the product (0.29 g., m. p. 218°) obtained by pouring the reaction mixture into cold water was unchanged in melting point on recrystallization from methanol or 95% ethanol. The substance crystallized as fine, colorless needles and was easily soluble in acetone, chloroform and absolute ethanol; moderately so in methanol and 95% ethanol. It gave a negative ferric chloride–alcohol test and a yellow coloration with acetic acid–sulfuric acid.

Anal. Calcd. for $C_{25}H_{24}O_6(CH_3CO)_2$: C, 68.77; H, 5.97; CH_3CO, 3.96 cc. 0.1 *N* NaOH per 100 mg.; mol. wt., 506.5. Found: C, 68.76; H, 6.14; CH_3CO, 3.92 cc.; mol. wt. (Rast), 502, 463.

Dihydro-isopomiferin was recovered from the acetyl analysis. Dihydro-isopomiferin diacetate was recovered unchanged on refluxing for two hours with acetic anhydride and sodium acetate (*cf.* I). It was obtained also by the hydrogenation of isopomiferin diacetate as described above for the production of dihydro-iso-osajin monoacetate from iso-osajin monoacetate. All identifications were made by melting point and mixed melting point.

Isopomiferin Dimethyl Ether.—This substance was obtainable in good yield by either the mild (*cf.* osajin monomethyl ether) or the vigorous (*cf.* iso-osajin monomethyl ether) methylation procedure and was isolated in the same manner. Pure material was obtained on crystallization from 95% ethanol; m. p. 180°, unchanged on further crystallization from methanol or benzene–petroleum ether. The substance crystallized as colorless needles and gave no coloration with ferric chloride–alcohol.

Anal. Calcd. for $C_{25}H_{22}O_4(OCH_3)_2$: C, 72.30; H, 6.29; OCH_3, 13.84. Found: C, 72.39; H, 6.41; OCH_3, 13.91.

Pomiferin dimethyl ether[2] (2.4 g.) was isomerized in glacial acetic acid with sulfuric acid (*cf.* II) and the crude water-insoluble product was purified from 95% ethanol and identified as isopomiferin dimethyl ether by melting point and mixed melting point. Pomiferin trimethyl ether[2] was recovered unchanged under the above isomerizing conditions but under more vigorous conditions of temperature (one hour of reflux) a small yield of isopomiferin dimethyl ether was obtained (identification by m. p. and mixed m. p.).

Non-isomerization of Tetrahydro-osajin, Tetrahydropomiferin and Hexahydro-osajin.—The preceding three substances were recovered unchanged when subjected to the above-described (*cf.* II) isomerizing conditions (sulfuric acid in glacial acetic acid solution). They also were stable to isomerization in ethanol solution with *p*-toluenesulfonic acid as is evidenced by the recovery of the above three substances from the acetyl analyses (Freudenberg and Harder method[8]) of their acetates.[1]

Color Reactions.—Both iso-osajin and isopomiferin gave positive Wilson[9] boric acid color tests. Neither was reduced by magnesium and hydrochloric acid but both reacted with sodium amalgam[1] to produce purple solutions and purple precipitates. This behavior is that shown by the unisomerized substances.

We are indebted to Mr. John Walker (W. P. A. Project 18062) for assistance rendered in the analytical determinations and to N. Y. A. Project

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(9) C. W. Wilson, THIS JOURNAL, **61**, 2303 (1939).

O. S. U. 181 for assistance in preparing the plant material.

Summary

1. Osajin on methylation with diazomethane or with methyl sulfate under specified conditions yields osajin monomethyl ether which on further methylation is convertible into osajin dimethyl ether.

2. Osajin monomethyl ether is convertible by vigorous (but not by mild) acetylation into osajin monomethyl ether monoacetate.

3. Diazomethane methylation of pomiferin results in the formation of pomiferin dimethyl ether which is not acetylatable by acetic anhydride and pyridine in the cold.

4. Dihydro-osajin (and its monoacetate and diacetate) was isomerized to dihydro-iso-osajin, which forms a monoacetate identical with that obtained by the hydrogenation of iso-osajin monoacetate.

5. Dihydropomiferin (and its diacetate and triacetate) was isomerized to dihydro-isopomiferin, identical with that obtained by the hydrogenation of isopomiferin. Dihydro-isopomiferin forms a diacetate identical with that obtained by the hydrogenation of isopomiferin diacetate.

6. Osajin mono-*p*-toluenesulfonate was isomerized to iso-osajin mono-*p*-toluenesulfonate, identical with the product obtained by the tosylation of iso-osajin.

7. Osajin monomethyl ether (and pomiferin dimethyl ether) was isomerized to a product identical with that obtained by the methylation of iso-osajin (and isopomiferin). Pomiferin trimethyl ether was not isomerized under the usual conditions but under more vigorous conditions produced isopomiferin dimethyl ether.

8. Iso-osajin forms a monoacetate and a monomethyl ether and offers no resistance to such substitution. Isopomiferin behaves similarly to produce a diacetate and a dimethyl ether.

9. Tetrahydro-osajin, tetrahydropomiferin and hexahydro-osajin could not be isomerized.

10. The above results together with others previously reported demonstrate that in the isomerization of osajin and pomiferin by mineral acids one hydroxyl group and a double bond disappear. The hydroxyl group involved gives a strong phenol (enol) test and is the hydroxyl that resists substitution. The double bond involved is the one that is the least active (toward hydrogenation) of the two active (toward hydrogenation) double bonds present in each of these substances.

COLUMBUS, OHIO RECEIVED OCTOBER 15, 1940

[CONTRIBUTION FROM THE GEORGE HERBERT JONES LABORATORY, THE UNIVERSITY OF CHICAGO]

The Cleavage of Diethyl Ether by Hydrogen Bromide[1]

BY FRANK R. MAYO, WILLIAM B. HARDY[2] AND CHARLES G. SCHULTZ

This paper deals with the kinetics of the cleavage of diethyl ether by hydrogen bromide in glacial acetic acid and in several non-hydroxylic solvents. Both the order of the reaction and the effect of the alcohol formed vary with the solvent. The present results are of interest in indicating the nature of the much-discussed reverse reaction, that is, the alcoholysis of alkyl halides, when the concentration of hydroxylic reagent becomes vanishingly small. This work is the first step in an attempt to explain the direction of cleavage of unsymmetrical ethers and oxides by halogen acids.

Previous Work

So far as we have been able to determine, no kinetic studies have been made of the cleavage of ethers by a halogen acid in the absence of a hydroxylic solvent, but several studies on the reaction in glacial or aqueous acetic acid have been carried out without obtaining conclusive results. In acetic acid, the reaction is of first order with respect to ether[3,4]; the products are an alkyl halide and an alcohol (or a phenol). In aqueous acetic acid, the reaction seems to be of second order with respect to halogen acid,[4] but in no case has the order been definitely established. Previous work on reactions in glacial acetic acid demonstrates only that the order of the reaction depends on the ether. Tronow and

(1) Presented before the Division of Organic Chemistry at the Cincinnati Meeting of the American Chemical Society, April 9, 1940.

(2) This paper is a condensation of a portion of a thesis submitted by William B. Hardy in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Chicago. His present address is, Calco Chemical Division, American Cyanamid Co., Bound Brook, N. J. A few experiments from a preliminary study by Charles G. Schultz are included in this paper.

(3) Birosel, THIS JOURNAL, **53**, 1408 (1931).

(4) Ghaswalla and Donnan, *J. Chem. Soc.*, 1341 (1936).