

REACTIVITY OF THE DOUBLE BOND IN COUMARINS AND RELATED $\alpha : \beta$ -UNSATURATED CARBONYL COMPOUNDS.

Part VI. Action of Mercuric Acetate on the Methyl Ethers of Coumarinic and Coumaric Acids.

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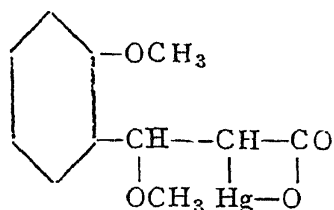
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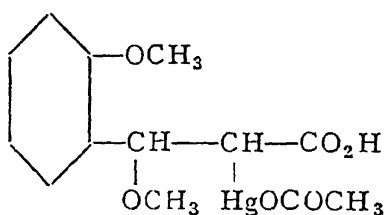
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Received April 23, 1938.

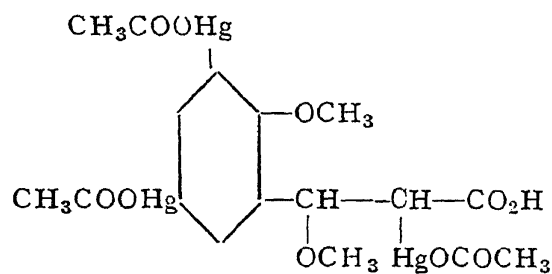
IN continuation of our work described in Part V¹ the action of mercuric acetate on the methyl ethers of coumarinic and coumaric acids and their 5-nitro derivatives has now been examined. Billmann² found that the first two compounds underwent addition only and that the anhydride form (I) was produced. In the case of coumaric acid it has already been shown by Rao and Seshadri³ that besides addition at the double bond, mercuration of the benzene ring also takes place and that the product has the carboxylic formula corresponding to (II).



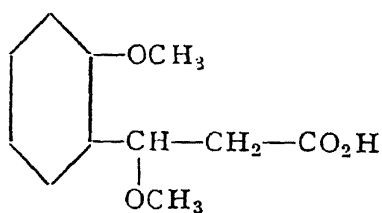
(I)



(II)



(III)



(IV)

At the temperature of the room (28°) the methyl ether of coumarinic acid has now been found to undergo simple addition at the double bond to form α -acetoxymercuri- β :2-dimethoxydihydrocinnamic acid (II). When the addition product is dissolved in aqueous sodium hydroxide and the

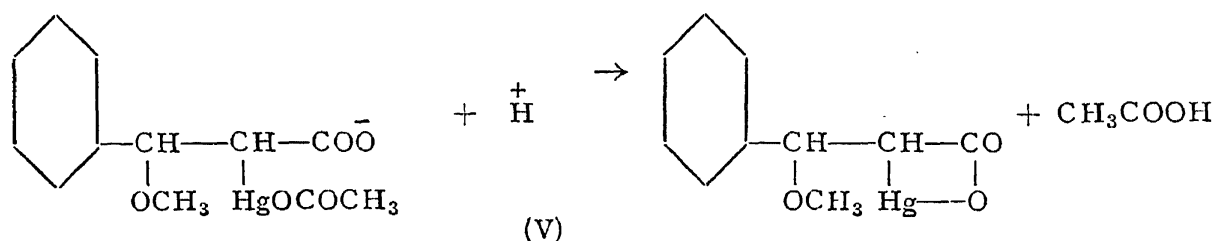
solution rendered acid with sulphuric acid the corresponding anhydro form (I) is produced. On heating, however, mercuration of the benzene ring also takes place so as to yield β :2-dimethoxy- α :3:5-triacetoxymercuridihydrocinnamic acid (III). The behaviour of this compound is very similar to that obtained from *para*-methoxycinnamic acid.¹ The methyl ether of coumaric acid is slower in reaction. In the cold it reacts slowly and no definite compound could be isolated, since besides addition there is some mercuration also. At the boiling point of methyl alcohol, however, mercuration is complete and compound (III) is produced. The nitro compounds undergo simple addition in the cold to give a carboxylic body corresponding to formula (II) and on heating they go over into the anhydride corresponding to formula (I). No mercuration of the nucleus has been found to be possible.

The simple addition products readily dissolve in alkali and when the solutions are acidified with dilute sulphuric acid the anhydride forms are precipitated. When dilute hydrochloric acid is employed instead, the addenda are removed and the original acids are regenerated if they are *trans* bodies and if they are *cis* they undergo inversion during this process and yield the corresponding *trans* compounds. In those cases where acetoxymercuri groups have entered the nucleus the mineral acids yield sulphato-mercuri- and chloromercuri-compounds. By the action of alkali and hydrogen sulphide the entire mercury can be removed and β -methoxydihydro compounds (IV) are obtained as usual. These are found to be stable in the presence of dilute acid and alkali solutions.

At this stage it will be useful to sum up the results in regard to the action of mercuric acetate on cinnamic and substituted cinnamic acids in methyl alcoholic solutions. Some of them form mercuric salts which separate in a crystalline form immediately. In general these subsequently undergo change into addition and mercuration products. All the acids undergo addition at the double bond without any exception. Mercuration of the benzene ring with mercuric acetate does not seem to be a powerful reaction and hence the possibility of mercuration is dependent upon the nature of the substituent groups. Cinnamic acid itself does not undergo mercuration whereas the presence of a methoxyl or hydroxyl substituent renders mercuration possible owing to their activating influence on the benzene ring. On the other hand, the nitro group is known to have a powerful deactivating influence and consequently, the nitrocinnamic acids are not capable of mercuration. In the case of the methyl ethers of nitrocoumarinic and coumaric acids the nitro group counteracts effectively the activating influence of the methoxyl so that the compounds do not undergo mercuration. The hydroxyl

group however is evidently more powerfully activating and the hydroxycinnamic acids even in the presence of a nitro-group get mercurated.³

The hydroxy- and methoxy-cinnamic acids do not yield the anhydro form on treatment in the cold or on heating with mercuric acetate in methyl alcoholic solution. The same behaviour is exhibited by nitrocoumaric acid also. If, however, a nitro group is present along with a methoxyl the carboxyl form is produced in the cold and the anhydride on heating. On the other hand, cinnamic and nitrocinnamic acids yield the anhydride forms only. Hence the elimination of a molecule of acetic acid so as to form the anhydrides from the initial addition products seems to be definitely influenced by the nature of the substituents. Groups like the hydroxyl and methoxyl prevent this elimination whereas the nitro group facilitates the process. They probably play their part through their capacity to regulate the ionisation of the hydrogen of the carboxyl group present in these acids.



The β -methoxydihydrocinnamic acids that are produced by the action of hydrogen sulphide on the solutions of the mercuric compounds in alkali are quite stable in the presence of dilute alkali and acid when no hydroxyl group is present in the nucleus. Ordinary coumaric acid yields β -methoxymelilotic acid which is rather unstable whereas its nitro and methyl derivatives do not produce the corresponding methoxy-dihydro-compounds.³

Experimental.

The methods for the preparation of the methyl ethers of coumarinic and coumaric acids were given in detail by Rangaswami and Seshadri.⁴ The use of sodium ethoxide and methyl iodide has not proved quite consistent in yielding pure samples of the methyl ether of coumarinic acid. Frequently the isomeric ether of coumaric acid has contaminated it. The following method using aqueous alcoholic sodium hydroxide and dimethyl sulphate has been found to be the best. Coumarin (4 g.) was dissolved in a boiling mixture of methanol (50 c.c.) and 20% aqueous sodium hydroxide (50 c.c.) After cooling to about 50° C., it was treated with dimethyl sulphate (30 c.c.) which was added in small amounts with vigorous shaking. The mixture was then shaken for half-an-hour and 20% aqueous sodium hydroxide (100 c.c.) and more dimethyl sulphate (15 c.c.) again added. The reaction

was completed by heating the mixture for one hour. On acidifying the cooled solution the required methyl ether separated as a mass of crystals. It was purified by dissolving in sodium carbonate and reprecipitating with acid and finally recrystallising from alcohol. It melted at $91-2^{\circ}$, and the yield was 3.8 g.

The corresponding *trans* ether is best obtained by starting with coumaric acid which is easily produced from coumarin by the action of mercuric oxide in the presence of alkali. Coumaric acid is then methylated by the above procedure.

The ethers derived from nitrocoumarin were obtained by methods already described.⁴

Action of Mercuric Acetate.

1. *On the Methyl Ether of Coumarinic Acid:*

α -Acetoxymercuri- β : 2-dimethoxydihydrocinnamic acid (II).—When equimolecular proportions of the methyl ether of coumarinic acid (1.8 g. in 10 c.c. of methyl alcohol) and mercuric acetate (3.2 g. in 20 c.c. of methyl alcohol) were mixed in methyl alcoholic solution there was no immediate precipitation of the mercuric salt. But after some minutes a colourless crystalline solid began to separate out and the reaction was complete in about 4 hours. The additive compound was filtered and washed thoroughly with methyl alcohol. It was found to decompose at 204° and was completely soluble in dilute sodium hydroxide. (Found: Hg, 42.7; $C_{13}H_{16}O_6Hg$ required Hg, 42.8%.) The anhydride (I) was obtained by dissolving the above compound in dilute sodium hydroxide and acidifying the solution with aqueous sulphuric acid. It decomposed at 189° and was found to be quite different from the above acid form. (Found: Hg, 48.3; $C_{11}H_{12}O_4Hg$ required Hg, 49.1%.) If, on the other hand, the alkaline solution was treated with aqueous hydrochloric acid the addenda were removed accompanied by geometrical inversion and the resulting product was identical with the methyl ether of coumaric acid melting at 183° .

α : 3: 5-Triacetoxymercuri- β : 2-dimethoxydihydrocinnamic acid.—When more than three molecular proportions of mercuric acetate (12.5 g.) were employed and heated with the methyl ether of coumarinic acid (1.8 g.) in methyl alcoholic solution for about 20 hours, addition and mercuration were effected and a good yield of the product (III) was obtained. It was advisable to discard the first precipitate formed during the first half hour. After repeatedly washing with methyl alcohol, the substance appeared as a white powder and decomposed at $220-21^{\circ}$. (Found: Hg, 60.6; C, 20.1; $C_{17}H_{20}O_{10}Hg_3$ required Hg, 61.0; C, 20.7%.) When a solution of the substance in

aqueous sodium hydroxide was acidified with hydrochloric acid a colourless precipitate of 3:5-dichloro-mercuri-2-methoxy-cinnamic acid was obtained. It decomposed at 216°. (Found: Hg, 62.5; $C_{10}H_8O_3Hg_2Cl_2$ required Hg, 61.9%.) With dilute sulphuric acid, however, the addenda were not removed and a sulphatomercuri compound, decomposing at 226° was produced. (Found: Hg, 66.0; $C_{11}H_{10}O_4Hg_3SO_4$ required Hg, 66.6%.)

β : 2-Dimethoxydihydrocinnamic acid.—This was obtained from any of the above mercuri-compounds by the action of hydrogen sulphide on their solutions in aqueous alkali. After filtering off mercuric sulphide the solution was cooled in ice and acidified with dilute sulphuric acid. The acid was thus obtained as a crystalline solid which was easily soluble in the common organic solvents and was best crystallised from hot water. It appeared as hexagonal plates melting at 84–5° and was found to be identical with the compound obtained by Biilmann.² It was found to be stable in the presence of dilute alkali and acid.

2. On the Methyl Ether of Coumaric Acid :

No mercury salt was formed in this case also. With one molecular equivalent of mercuric acetate in cold methyl alcoholic solution the addition was comparatively slow and a precipitate began to appear after about 20 minutes. When the product was collected after 4 hours it was mostly the addition product which had undergone some mercuration also. No definite compound could be obtained. When more than three molecular proportions of mercuric acetate were employed and the mixture boiled for about 20 hours a triacetoxymercuri-compound identical with the one obtained from the *cis* ether was produced. It decomposed at 220°. (Found: Hg, 61.6; $C_{17}H_{20}O_{10}Hg_3$ required Hg, 61.0%.) The chloro- and sulphatomercuri-compounds were also identical. By the action of hydrogen sulphide the same β : 2-dimethoxydihydrocinnamic acid was produced.

3. On the Methyl Ether of 5-Nitro Coumarinic Acid :

β : 2-Dimethoxy- α -acetoxymercuri-5-nitro-cinnamic acid (II).—When a clear solution of this acid (2 g.) in methyl alcohol (40 c.c.) was mixed with a similar solution of mercuric acetate (3 g. in 20 c.c.) in the cold, there was an immediate precipitation of the mercuric salt of the acid as colourless needles decomposing at 141–42°. With aqueous sodium hydroxide it yielded mercuric oxide and from the filtered solution the original acid could be precipitated pure by acidification. The salt gradually underwent conversion into β : 2-dimethoxy- α -acetoxymercuri-5-nitro-cinnamic acid and the change was complete in 24 hours. The pale yellow solid had no definite crystal structure and it decomposed at 199°. (Found: Hg, 38.4; $C_{13}H_{15}O_8Hg N$ required Hg, 39.0%.)

The anhydride form (I).—After mixing the two solutions the mixture was heated on a water-bath for about 5 hours. The mercuric salt that was first precipitated rapidly dissolved and a deep yellow solid began to separate after about an hour. After the completion of the heating the solid was filtered and washed with methyl alcohol. It had no definite crystal structure and decomposed at 210°. It was different from the solid obtained in the cold, but could be obtained from it by dissolution in aqueous caustic soda and subsequent acidification with dilute sulphuric acid. (Found: Hg, 44.4; C, 29.0; $C_{11}H_{11}O_6HgN$ required Hg, 44.2; C, 29.1%.)

On acidifying an aqueous alkaline solution of the simple addition product or the anhydride with dilute hydrochloric acid geometrical inversion was produced and the methyl ether of 5-nitro-coumaric acid melting at 233° was obtained.

β : 2-Dimethoxy-5-nitrodihydrocinnamic acid was obtained from the alkaline solutions of the above addition compounds by the action of hydrogen sulphide. It crystallised from hot water in the form of spear heads and melted at 158°. (Found: N, 5.8; $C_{11}H_{13}O_6N$ required N, 5.5%.) It was easily soluble in all common solvents and was quite stable in the presence of alkali and acid.

4. On the Methyl Ether of 5-Nitro-Coumaric Acid:

The acid (2 g.) was dissolved in methyl alcohol (50 c.c.) and mixed with a solution of mercuric acetate (3 g. in 20 c.c.) to which a few drops of acetic acid had been added. A bulky precipitate separated out immediately and it gave all the reactions of the mercuric salt. (Found: Hg, 32.0; $C_{20}H_{16}O_{10}HgN_2$ required Hg, 31.1%.) It decomposed at 205°.

The mercuric salt underwent change slowly when it was not separated and after two days it was completely converted into the addition compound, α -acetoxymercuri- β : 2-dimethoxy-5-nitro-dihydrocinnamic acid. It was a pale yellow solid decomposing at 196° and identical with the one obtained from the methyl ether of nitro-coumarinic acid. On heating the mixture, however, on the water-bath for 5 hours the corresponding anhydride decomposing at 210° was easily produced. This was found to be identical with the compound obtained from the *cis* ether. Both the acid and anhydride gave rise to β : 2-dimethoxy-5-nitro-dihydrocinnamic acid when decomposed with hydrogen sulphide.

Summary.

The action of mercuric acetate on the methyl ethers of coumarinic and coumaric acids and their 5-nitro derivatives has been described. The first two undergo addition at the double bond as well as mercuriation and the

compounds have the carboxylic formula. The nitrocoumarinic and coumaric acids undergo addition only and yield the carboxylic form in the cold and the anhydro form on heating. When the addenda are eliminated by the action of dilute hydrochloric acid the change is accompanied by geometrical inversion from *cis* to *trans*. The results so far obtained with cinnamic acid and its derivatives are reviewed.

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