2,3,6-Trimethoxy-4-benzyloxyacetophenone (XVIII). A mixture of 4.0 g. (0.013 mole) of 2-hydroxy-3,6-dimethoxy-4-benzyloxyacetophenone (XVII), 10 g. (0.08 mole) of dimethyl sulfate, and 10 ml. of ethanol was stirred while a solution of 3.2 g. (0.08 mole) of sodium hydroxide in 8 ml. of water was added during the period of about 1 hr. After stirring the mixture for an additional 2 hr., it was poured onto ice, and stirring and scratching caused the oily product to solidify. It was collected by filtration, washed free of alkali with water, and dried in the air. The yield of white, crystalline powder was 4.2 g. (100%); m.p. 74–75° (F-J). After 1 recrystallization from petroleum ether (b.p. 65–70°), it melted at 74.5–75.5° (F-J).

Anal. Calcd. for $C_{18}H_{20}O_5$: C, 68.34; H, 6.37. Found: C, 68.39; H, 6.23.

2,3,5-Trimethoxy-4-ethylphenol (XIX). A mixture of 4.0 g. (0.013 mole) of 2,3,6-trimethoxy-4-benzyloxyacetophenone (XVIII), 0.5 g. of copper chromium oxide catalyst, and 100 ml. of methanol, under hydrogen at a pressure of 2500 p.s.i. at 22°, was shaken and heated to 150–155° for 1.5 hr. The mixture was cooled, filtered, and the solvent was evaporated to obtain an oil which crystallized. The tan crystals, 2.61 g. (97.5%), melted at 50–58° (F-J). After 3 recrystallizations from petroleum ether and one from methanol-water, the product melted at 62–63° (F-J).

Anal. Calcd. for $C_{11}H_{16}O_4$: C, 62.25; H, 7.60. Found: C, 62.13; H, 7.62.

2,3,5-Trimethoxy-4-ethylphenyl acetate (XX). Six ml. of acetic anhydride and 1 drop of concentrated sulfuric acid were added to 1.1 g. (0.0052 mole) of 2,3,5-trimethoxy-4-ethylphenol (XIX). The mixture, which warmed slightly, was allowed to stand for 1 hr. at room temperature, then was warmed on the steam bath for 10 min., and finally was poured onto crushed ice. After several hours, the oil was taken up in carbon tetrachloride, the organic solution was washed with water, dried over anhydrous sodium sulfate, and the solvent was evaporated *in vacuo*. A pale yellow, viscous oil remained; yield, 1.33 g. (100%); n_D^{25} 1.5007. A center cut (b.p. 115–116°/1 mm.) from the fractionation of the product of a larger run was submitted for analysis; n_D^{25} 1.5022.

Anal. Calcd. for $C_{13}H_{18}O_5$: C, 61.40; H, 7.14. Found: C, 60.99; H, 7.46.

Fries rearrangement of 2,3,5-trimethoxy-4-ethylphenyl acetate (XX). A solution of 0.65 g. (0.0049 mole) of anhydrous aluminum chloride in 25 ml. of anhydrous nitrobenzene was stirred at 0° while a solution of 1.2 g. (0.0047 mole) of 2,3,5-trimethoxy-4-ethylphenyl acetate (XX) in 25 ml. of nitrobenzene was added dropwise during about 20 min. The mixture was stirred while it warmed slowly to room temperature, and it was allowed to stand for about 60 hr. It was treated at 0° with a solution of 1 ml. of concentrated hydrochloric acid in 9 ml. of water, and hydrolysis was completed at room temperature. The mixture was extracted with benzene, the benzene solution was washed with water and then extracted several times with 10% aqueous sodium hydroxide. The alkaline extracts were combined, cooled, and acidified with dilute hydrochloric acid. The precipitated oil was taken up in methylene chloride, the solution was washed with water, dried over anhydrous magnesium sulfate, and the solvent was evaporated. There was obtained 0.47 g. (about 39%) of a brown, viscous oil which smelled faintly of nitrobenzene; n_D^{25} 1.5328. A drop of this crude product, treated with 10% sodium hydroxide solution and piperonal in ethanol, gave a few orange crystals; m.p. 106–107° (F-J). Further alkali extraction of the original organic solution provided an additional 0.15 g. (12%) of brown oil; n_D^{25} 1.540.

The latter material was converted to its piperonal chalcone. The purified product melted at 108–109°, and when mixed with the previously prepared 2′-hydroxy-3′,4′,6′-trimethoxy-5′-ethyl-3,4-methylenedioxychalcone (VII), it melted at 107–108.5° (F-J). The infrared spectra of the two compounds were found to be identical.

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[CONTRIBUTION FROM THE RESEARCH DEPARTMENT OF UNION CARBIDE CHEMICALS COMPANY]

Reaction of *o*-Alkenylphenols with Peracetic Acid

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The reaction of *o*-allylphenol and *o*-propenylphenol with peracetic acid has been reported to give *o*-2,3-epoxypropylphenol and *o*-1,2-epoxypropylphenol, respectively. Investigation of these reactions has shown that the product from *o*-allylphenol is 2-hydroxymethylcoumaran. *o*-Crotylphenol forms a similar heterocyclic derivative. The epoxides appear to be intermediates in this reaction. The product from *o*-propenylphenol is 1-(*o*-hydroxyphenyl)-2-propanone. This compound is formed by the loss of acetic acid from an intermediate product, 1-(*o*-hydroxyphenyl)-2-hydroxypropyl acetate, rather than by rearrangement of an epoxide intermediate.

The study of the synthesis and reactions of peracetic acid was initiated in this laboratory several years ago. In connection with this work the reaction of peracetic acid with *o*-alkenylphenols was briefly investigated. This reaction has been reported[1] to give the expected epoxides in reasonable yield; thus, *o*-allylphenol and *o*-propenylphenol reportedly gave *o*-2,3-epoxypropylphenol and *o*-1,2-epoxypropylphenol, respectively, by treatment with concentrated (73–93%) peracetic acid. It was further reported that the *o*-2,3-epoxypropylphenol, upon boiling with acetic anhydride, yielded *o*-2,3-epoxypropylphenyl acetate and that *o*-1,2-epoxypropylphenol, upon standing in a desiccator over sulfuric acid, gave 2-methylcoumarone.

In our study *o*-allylphenol was allowed to react with a 28% solution of peracetic acid in ethyl acetate at 20–30° and a product was obtained which had the same physical properties as that reported by the previous workers,[1] but which contained no epoxide group as determined by HBr analysis. The product was converted to a monoacetate by boiling with acetic anhydride; however, this acetate was markedly different from an authentic sample

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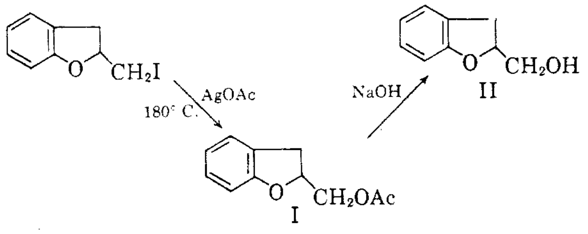
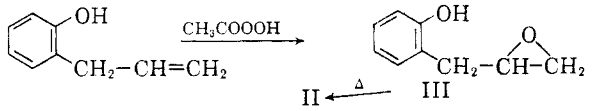
(1) V. I. Pansevich-Kolyada and Z. B. Idel'chik, *J. Gen. Chem. U.S.S.R.*, **24**, 809 (1954) (Eng. Trans.)

of *o*-2,3-epoxypropylphenyl acetate prepared by the epoxidation of *o*-allylphenyl acetate with peracetic acid.

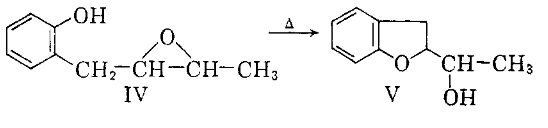
The compound obtained from *o*-allylphenol and peracetic acid proved to be 2-hydroxymethylcoumaran as shown by conversion to its known benzoate ester and bromide and by independent synthesis from 2-iodomethylcoumaran, derived from *o*-allylphenol and mercuric chloride,[2] as shown below. The infrared absorption spectra of I and II were identical with those of the compounds obtained from the allylphenol and peracetic acid.



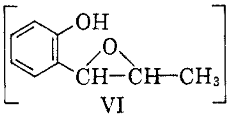
The epoxide (III) is apparently an intermediate in this reaction since azeotropic removal of the volatile material from the reaction mixture under reduced pressure gave a residue whose infrared absorption was quite different from II and which contained 65% of *o*-2,3-epoxypropylphenol as indicated by epoxide analysis (HBr method). Efforts to isolate a pure sample of this intermediate failed since distillation or heating to 100° caused ring closure to the coumaran.



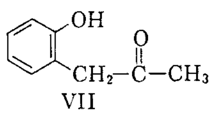
o-Crotylphenol was found to behave in a similar manner. The residue product, gently isolated from the reaction with peracetic acid, contained about 63% of *o*-2,3-epoxybutylphenol (IV); however, upon heating or distillation, the epoxyphenol cyclized to form 2-(1-hydroxyethyl)coumaran (V). This structure was inferred by comparison of known physical properties and by conversion to the phenylurethane.



The oxidation of *o*-propenylphenol was reported by the previous workers[1] to give *o*-1,2-epoxypropylphenol (VI), m.p. 58–59°. When this reaction was carried out and the volatile material was removed from the product at low temperature, a viscous residue product was obtained. Flash distillation of the material gave a product which solidified and, on crystallization from toluene-hexane, melted at 62°. This compound contained no epoxide group and its infrared absorption was characterized by bands at 2.9μ (intramolecularly hydrogen-bonded phenol), 5.83μ (aliphatic ketone), and 13.35μ (*o*-disubstituted benzene). This evidence, together with its elemental analysis, its dinitrophenylhydrazone formation, and a positive iodoform test, suggests that the compound reported as VI is 1-(*o*-hydroxyphenyl)-2-propanone (VII).

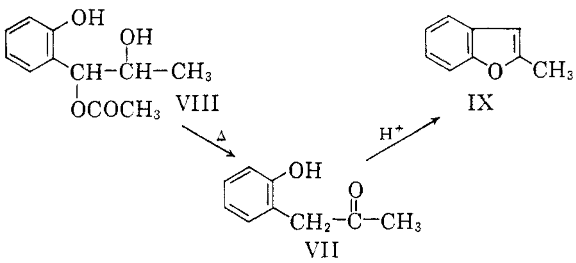


VI



VII

During a repeat run on *o*-propenylphenol the residue product, obtained after removal of the volatile material under reduced pressure, was stored overnight in a brine bath at −5° and crystallization occurred. Separation and recrystallization gave a product, m.p. 128–129°, which was identified as 1-(*o*-hydroxyphenyl)-2-hydroxypropyl acetate (VIII) by molecular weight determination, elemental analysis, saponification equivalent, and by its conversion, on heating, with loss of acetic acid to 1-(*o*-hydroxyphenyl)-2-propanone (VII). This latter transformation could be brought about by distillation or by refluxing in toluene or ethylbenzene. Since the hydroxyacetate (VIII) was found to react with the HBr reagent, epoxide determinations on the residue product from the epoxidation of *o*-propenylphenol were meaningless; however, the infrared absorption spectra of the residue product showed mainly hydroxyacetate, rather than epoxide, present.



On standing for 48 hr. in a desiccator over sulfuric acid 1-(*o*-hydroxyphenyl)-2-propanone was converted to a liquid whose infrared spectrum was identical with that of 2-methylcoumarone (IX) (Sadtler Standard Spectra #3740).

EXPERIMENTAL[3]

Reaction of o-allylphenol with peracetic acid. A solution of 1117 g. of 28.5% peracetic acid in ethyl acetate was added dropwise, with stirring, to 449 g. of *o*-allylphenol while maintaining a reaction temperature of 20–30° by cooling with a Dry Ice-acetone mixture. After 12 hr., analysis for peracetic acid indicated a conversion of 89%. The mixture was added slowly to refluxing ethylbenzene, keeping the kettle temperature below 50° by operating under reduced pressure. After all the acetic acid had been azeotropically removed, the residue product was stripped free of ethyl-

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[2] R. Adams, F. L. Roman, and W. N. Sperry, *J. Am. Chem. Soc.*, **44**, 1781 (1922).

[3] Melting points were taken on a Fisher-Johns block.

benzene by warming to 80° at a pressure of 5 mm. The stripped residue product weighed 439 g. and contained 65.5% *o*-2,3-epoxypropylphenol by hydrogen bromide analysis; however, the pure epoxyphenol could not be isolated. Flash distillation gave 250 g. of overhead product containing no epoxy groups. The distillate was washed with 5% caustic, dried, and fractionated to give 200 grams of 2-hydroxymethylcoumaran (IV), b.p. 83°/0.1 mm., n_D^{30} 1.5548, benzoate m.p. 61–62°, bromide (from IV with phosphorous tribromide and pyridine) m.p. 28–29°. Normant[4] reports 2-hydroxymethyl coumaran as b.p. 138°/9.5 mm., n_D^{8} 1.5648, benzoate m.p. 63°, bromide m.p. 29–30°. The properties given by Pansevich-Kolyada and Idel'chik for "*o*-2,3-epoxypropylphenol" are b.p. 154°/15 mm., n_D^{20} 1.5558.

Preparation of 2-acetoxymethylcoumaran (I). A solution of 49 g. of 2-hydroxymethylcoumaran in 250 ml. of acetic anhydride was refluxed 4 hr. and then distilled to give 56 g. of the acetate (I), b.p. 130–132°/6 mm., n_D^{30} 1.5199, no titration for epoxide, saponification equivalent 180—theory 192. Pansevich-Kolyada[1] reported "*o*-2,3-epoxypropylphenyl acetate" as b.p. 142–143°/8 mm. n_D^{20} 1.5220.

Anal. Calcd. for $C_{11}H_{12}O_3$: C, 68.73; H, 6.29. Found: C, 68.66; H, 6.30.

Preparation of o-2,3-epoxypropylphenyl acetate. The reaction of *o*-allylphenol with acetic anhydride gave *o*-allylphenyl acetate, b.p. 70°/1 mm., n_D^{30} 1.5053. The acetate, 245 g., was stirred at 50° and 428 g. of 27.2% peracetic acid in ethyl acetate was added dropwise over a period of 65 min. The temperature was then raised to 60° and held there for 6 hr. when a titration for peracetic acid indicated a conversion of 92.4%. The reaction mixture was added dropwise to refluxing ethylbenzene at 25–30 mm. and the ethyl acetate and acetic acid were azeotropically removed overhead. Distillation of the stripped residue gave 220 g. of authentic *o*-2,3-epoxypropylphenyl acetate, b.p. 120°/2 mm., n_D^{30} 1.5137.

Anal. Calcd. for $C_{11}H_{12}O_3$: C, 68.73; H, 6.29. Found: C, 68.61; H, 6.32.

Independent synthesis of 2-hydroxymethylcoumaran (IV). 2-Iodomethylcoumaran, m.p. 35–36°, was prepared from *o*-allylphenol and mercuric chloride according to the method of Adams *et al.*[2] The iodide, 10 g., was heated to 180° for 30 min. with 12 g. of silver acetate. Filtration and distillation gave 5 g. of 2-acetoxymethylcoumaran, b.p. 100°/0.8 mm., n_D^{30} 1.5260, infrared absorption identical with the acetate obtained above by acetylation of the product from *o*-allylphenol and peracetic acid. Saponification of this ester gave authentic 2-hydroxymethylcoumaran, infrared absorption identical with the product from *o*-allylphenol and peracetic acid, benzoate m.p. 61–62° and mixed m.p. of both benzoates 61–63°.

Reaction of o-crotylphenol with peracetic acid. To 263 g. of *o*-crotylphenol, b.p. 76°/1.2 mm., n_D^{30} 1.5368, was added 610 g. of 27.8% peracetic acid in ethyl acetate dropwise over a period of 3 hr. while maintaining a temperature of 25° by cooling the reaction mixture. After 4 hr. a 95% conversion was indicated by peracetic acid titration. The reaction mixture was fed dropwise to 600 g. of ethylbenzene, refluxing under sufficient vacuum to maintain a kettle temperature of 50° or less. After removal of the volatiles the residue was stripped of ethylbenzene by heating for 1 hr. at 50° at a pressure of 5 mm. The residue contained 63% *o*-2,3-epoxybutylphenol by HBr analysis.[5] Flash distillation followed by fractional distillation gave 200 g. of product, b.p. 107–108°/3 mm., n_D^{30} 1.5400–1.5407, phenylurethane m.p. 116–117°. 2-(1-Hydroxyethyl)coumaran is reported[6] to have the following properties: b.p. 145°/20 mm., n_D^{25} 1.5470, phenylurethane m.p. 115–116°.

Reaction of o-propenylphenol with peracetic acid. A solution, 248 g., of 28.5% peracetic acid in ethyl acetate was added dropwise to 102 g. of *o*-propenylphenol which was stirred at 25–30°. The addition required 90 min. After an additional 2 hr. a titration for peracetic acid indicated a conversion of 101%. The mixture was worked up by adding to ethylbenzene and stripping as above. Distillation of the viscous residue by dropwise addition to a kettle maintained at 220–230° at a pressure of 0.2–5.0 mm. gave 91 g. of overhead product and 23 g. of residue. The overhead product partially crystallized on standing and the solid was separated and crystallized from benzene-hexane to give 29 g. white plates, m.p. 63–64°. Pansevich-Kolyada and Idel'chik reported m.p. 58–59° for "*o*-1,2-epoxypropylphenol." The infrared absorption of this product was characterized by bands at 2.9μ, 5.83μ, and 13.35μ.

Anal. Calcd. for $C_9H_{10}O_2$: C, 71.97; H, 6.71. Found: C, 71.79; H, 6.61.

The compound gave a positive iodoform test and formed a 2,4-dinitrophenylhydrazone, m.p. 127–129°.

Anal. Calcd. for $C_{15}H_{14}O_{0}N_4$: N, 16.96. Found: N, 16.94.

Thus, the product appears to be 1-(*o*-hydroxyphenyl)-2-propanone (VII). Distillation of the mother liquor remaining from the crystallization of this product gave a small amount of unreacted phenol, 14 grams of 2-methylcoumarone, b.p. 61°/2 mm., and an additional 20 g. of 1-(*o*-hydroxyphenyl)-2-propanone, b.p. 110°/1 mm. The coumarone, which was also formed by allowing VII to stand 48 hr. in a desiccator over sulfuric acid, was identified by comparison of its infrared spectrum with that of a standard. Upon boiling 10 g. of VII with 40 g. of acetic anhydride for 4 hr., there was obtained, upon distillation, 8 g. of 1-(*o*-actoxyphenyl)-2-propanone, b.p. 122–125°/2 mm., n_D^{30} 1.5105, 2,4-dinitrophenylhydrazone, m.p. 119–120°.

Anal. Calcd. for $C_{17}H_{16}N_4O_6$: N, 15.08. Found: N, 15.11.

During a repeat run using 191 g. of *o*-propenylphenyl and 497 g. of a 27% solution of peracetic acid in ethyl acetate, the residue from the ethylbenzene stripping operation was stored overnight at 0°. The partially crystalline mass, thus obtained, was filtered and the filter cake was washed with benzene to give 143 g. of a colorless product, m.p. 116–118°. The compound had a saponification equivalent of 221, a molecular weight (Menzies-Wright) of 204 ± 5%, and, upon distillation or prolonged refluxing in toluene or ethylbenzene, lost acetic acid and formed 1-(*o*-hydroxyphenyl)-2-propanone (VII). This evidence suggests that the compound is 1-(*o*-hydroxyphenyl)-2-hydroxypropyl acetate (VIII).

Anal. Calcd. for $C_{11}H_{14}O_4$: C, 62.85; H, 6.71. Found: C, 63.23; H, 6.78.

Acknowledgment. The author is indebted to Dr. H. F. White and Mr. C. M. Lovell for the infrared determinations.

SOUTH CHARLESTON, W. VA.

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(4) H. Normant, *Compt. Rend.*, **218**, 683 (1944) and **235**, 1407 (1952).

(5) At the suggestion of a referee this residue was distilled on a molecular still below 51°/0.02 mm., n_D^{30} 1.5324. The product was a straw-colored liquid which analyzed 68% *o*-2,3-epoxybutylphenol by HBr analysis or 80% by pyridine hydrochloride analysis. The infrared spectrum, however, was characterized by a strong epoxide band at 11.85μ and by the absence of both the strong *trans*-RCH=CHR, of *o*-crotylphenol and the strong 11.15μ band which is characteristic of 2-(1-hydroxyethyl)coumaran. *Anal.* Calcd. for $C_{10}H_{12}O_2$: C, 73.14; H, 7.37. Found: C, 73.33, 73.22; H, 7.60, 7.52. On attempted fractionation through a 4″ Vigreaux column at 0.1 mm., several cuts were taken in the 71–76° boiling range (kettle temperature 80–84°). The refractive indices at 30° showed a gradual increase from 1.5338 to 1.5365 and infrared spectrum showed the appearance of a shoulder at 11.15μ, indicative of coumaran formation.

(6) R. L. Shriner and J. Anderson, *J. Am. Chem. Soc.*, **61**, 2705 (1939).