The crystalline material was filtered off, washed well with water and then with methanol or ethyl acetate. Recrystallization of the crude product from ethyl acetate gave reddish needles melting at the temperatures summarized in Table I. In order to recover one mole of the unchanged aldehydes, the following procedure was employed. After evaporating the combined mother liquors and removing the solvent, the residue was carefully extracted many times with warm benzene and the combined extracts dried over anhydrous sodium sulfate and filtered. Removal of the benzene left a dark brown oily residue, which crystallized on standing in the ice-box. The crude unchanged aldehydes, except for 5-nitrofurfural, were recrystallized from ethyl acetate. The 5-nitrofurfural was recovered in 86% yield by vacuum distillation.

Preparation of 5-Nitrofuryl Polyene Aldehydes from Dialkyl Acetals (Method C).—Into a stirred solution of 0.1 mole of the nitrofuryl aldehyde dimethyl or diethyl acetal in 60 cc. of dry chloroform containing a catalytic quantity of $BF_3 \cdot O(C_2H_5)_2$ was bubbled 0.1 mole of methyl vinyl ether at 35°. The temperature was controlled by the rate of addition of methyl vinyl ether. As the temperature rose to 45° the reaction mixture turned brownish-black. The mixture was then shaken with 5% sodium acetate and washed well with cold water. The organic layer was separated, dried over anhydrous sodium sulfate, filtered, and concentrated under reduced pressure to a viscous oily residue. This was hydrolyzed with a mixture of 125 cc. of acetic acid, 5 cc. of 3% hydrochloric acid and 60 cc. of water on a water-bath at 90–95° for four hours. On cooling, crude crystals deposited which were filtered off and washed with a small amount of cold methanol. In order to remove adhering resinous matter, the crude crystals were dissolved in hot benzene, filtered, and the solvent removed by distillation. Recrystallization of the crude crystals from ethyl acetate gave a pure product, except for 5-nitrofurfural dimethyl and diethyl acetal, in about 75–87% yield. The products obtained by this method were identical with these obtained by method B.

Condensation of *p*-Nitrobenzaldehyde with Methyl Vinyl Ether in the Presence of BF_3.—Into a stirred solution of 10 g. (0.066 mole) of *p*-nitrobenzaldehyde in 70 cc. of dry benzene containing a catalytic quantity of $BF_3 \cdot O(C_2H_5)_2$ was gradually bubbled 2.0 g. (0.035 mole) of methyl vinyl ether at 25°. After addition of the vinyl ether, stirring was continued for an additional hour, when colorless needles gradually deposited from the reaction mixture. These were filtered off and washed with a small amount of warm ethyl acetate to remove unchanged *p*-nitrobenzaldehyde. Recrystallization of the crude product from benzene gave 8.5 g. of colorless needles melting at 209–211°.

Anal. Calcd. for $C_{17}H_{16}O_7N_2$: C, 56.66; H, 4.44; N, 7.78; mol. wt., 360.3. Found: C, 56.64; H, 4.35; N, 7.83; mol. wt. (Rast's method), 355.2.

An analogous crystalline intermediate was not obtained in the case of 5-nitrofurfural using the same procedure. A mixture of 5.0 g. of the crystalline intermediate (presumed to be the *m*-dioxane type), 2.5 cc. of concentrated hydrochloric acid, 30 cc. of acetic acid (or 20 cc. of dioxane) and 2.5 cc. of water was heated on a water-bath for three hours. Concentrating the reaction mixture under reduced pressure and cooling to room temperature gave a pale yellow crystalline mass. This was filtered off, and two crystallizations from absolute ethanol gave 1.8 g. of colorless needles, melting at 140–142°. The mixed melting point with authentic *p*-nitrocinnamic aldehyde[9] was 140–142°. Additionally, concentrating the filtrate from the earlier reaction mixture under reduced pressure and cooling in an ice–salt-bath gave a darkish orange crystalline mass. This was filtered off, and two recrystallizations from water gave 3.6 g. of colorless needles, melting at 106°. This mixed melting point with authentic *p*-nitrobenzaldehyde was 105–106°.

Preparation of Acetals.—The following procedure was used in all cases: A solution of 0.1 mole of the aldehyde in 0.1 mole of methyl orthoformate (or ethyl orthoformate) was heated on a water-bath for one hour in the presence of *p*-toluenesulfonic acid as catalyst. On cooling, the reaction mixture was diluted with 200 cc. of ether, washed well with 5% sodium acetate, dried over anhydrous sodium sulfate and filtered. After removal of the solvent, the residue solidified on cooling. Recrystallization from methanol (or ethanol) gave pale yellow prisms in good yield. The properties of six dialkyl acetals prepared by the above procedure are recorded in Table II.

Condensation of 5-Nitrofuryl Polyene Aldehydes with Hydroxylamine, Semicarbazide, Thiosemicarbazide and Aminoguanidine.—These condensation products and their antibacterial properties are listed in Table III. One-tenth mole of aldehydes was dissolved in about one liter of warm ethanol. To each was added with stirring a small excess of semicarbazide hydrochloride, thiosemicarbazide or hydroxylamine and an additional quantity of 0.2 mole of sodium acetate. Each solution was heated on a water-bath at 50° for about one hour. The reaction mixture was then cooled to +5° and the crystalline mass which formed was filtered off. Recrystallization of the crude products from a large amount of ethanol gave the compounds presented in Table III. One-tenth mole of aminoguanidine carbonate was condensed, respectively, with an equivalent amount of three polyene aldehydes (n = 2, 3 and 4) under the experimental conditions described above.

The yellowish reaction mixture in each case was made acid to congo red with concentrated hydrochloric acid (or ethanol saturated with hydrogen chloride) and the solution then cooled in an ice-box. Reddish-yellow crystals of the hydrochloride gradually deposited. After standing at room temperature for six hours, the product was filtered off and purified by three recrystallizations from ethanol to give the three polyene aldehyde aminoguanidine hydrochlorides (n = 2, 3 and 4) summarized in Table III.

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(9) G. Garrara, *et al.*, THIS JOURNAL, **76**, 4391 (1954).

CITY OF FUKUOKA, JAPAN

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF MISSOURI]

Substituted Styrenes. III. The Syntheses and Some Chemical Properties of the Vinylphenols[1,2]

BY WESLEY J. DALE AND HENRY E. HENNIS

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The syntheses and some reactions of *o*-, *m*- and *p*-vinylphenol are described and discussed.

The effect that a strong electronegative nuclear substituent exerts on the double bond of a substituted styrene was clearly demonstrated when it was shown that enolates[3] and amines,[4] typical nucleophilic reagents, add readily to the vinyl group of *o*- and *p*-nitrostyrene.

As one phase of a series of studies in this Laboratory concerning the chemistry of a large variety of

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(1) Abstracted from a portion of a thesis submitted by H. E. H. to the Graduate School of the University of Missouri in partial fulfillment of the requirements for the Ph.D. degree.

(2) Presented in part at the 130th Meeting of The American Chemical Society, Atlantic City, N. J., September 17, 1956.

(3) W. J. Dale and C. W. Strobel, THIS JOURNAL, **76**, 6172 (1954).

(4) W. J. Dale and G. Buell, *J. Org. Chem.*, **21**, 45 (1956).

monomeric ring-substituted styrenes, an investigation of the isomeric vinylphenols, which bear an electron-releasing nuclear substituent, was therefore undertaken. Attention was given first to devising practical and convenient methods for the syntheses of these compounds.

It has been reported that *o*-vinylphenol can be obtained by the decarboxylation of *o*-hydroxycinnamic acid,[5–7] the reaction of methyl-2-methoxymethoxyphenylcarbinol with sulfuric acid,[8] the reaction of phenol with ethylene oxide and sulfuric acid,[9] the rearrangement and dehydration of β-phenoxyethanol,[9] the thermal depolymerization of the amorphous solid obtained from the reaction of phenol with vinyl acetate and sulfuric acid,[10] and by the thermal decomposition of various benzodioxins.[11]

The method employed to obtain *o*-vinylphenol for this study was the decarboxylation of *o*-hydroxycinnamic acid. The acid was prepared from coumarin by the method of Updegraff and Cassidy[12]; the over-all yield of *o*-vinylphenol from coumarin was 31%.

An attempt by us to obtain *o*-vinylphenol from the reaction of phenol with ethylene oxide and sulfuric acid failed to give a trace of the desired product and further work on this approach was discontinued when Bader[7] reported that he was unable to prepare *o*-vinylphenol by this method.

m-Vinylphenol has been prepared by the hydrolysis of diazonium salts of *m*-vinylaniline,[13–15] by the saponification of *m*-vinylphenyl benzoate,[16] and from cardanol, a phenolic constituent of cashew nut-shell oil.[17]

Since the preparation of *m*-vinylaniline requires several steps, this approach to *m*-vinylphenol was not investigated. The benzoylation of *m*-hydroxybenzaldehyde, the reaction of *m*-benzoyloxybenzaldehyde with methylmagnesium iodide and the saponification of the product according to the method of Hudson and Robinson[16] appeared more attractive. However, repetition of this method by us gave an over-all yield of only 2.6% of very crude *m*-vinylphenol. Hudson and Robinson did not report their yield of *m*-vinylphenol by this procedure. The attempt to obtain the *meta* isomer by the decarboxylation of *m*-benzoyloxycinnamic acid to *m*-vinylphenyl benzoate, followed by the saponification of the crude ester, was also unsuccessful. By this method impure *m*-vinylphenol was obtained in only 1.1% over-all yield.

The method of preparation of *m*-vinylphenol used in this study began with the direct reaction of *m*-hydroxybenzaldehyde with excess methyl-magnesium iodide to give methyl-*m*-hydroxyphenylcarbinol, according to the method of von Auwers,[18] which was then followed by the dehydration of the carbinol over aluminum oxide to give *m*-vinylphenol in an over-all yield of 29%. This procedure offers a new and practical laboratory synthesis for this compound.

The literature records no convenient laboratory method for the preparation of monomeric *p*-vinylphenol. The hydrolysis of diazotized *p*-vinylaniline has been reported to give only tars[18,19,20] and the decarboxylation of *p*-hydroxycinnamic acid yields only traces of monomer and considerable polymer.[18,21] Bernthsen and Bender[19] first claimed the preparation of monomeric *p*-vinylphenol when they obtained small amounts of an almost colorless oil of phenolic odor by the thermal decomposition of barium *p*-hydroxycinnamate. Their product gave no color with ferric chloride and added hydrogen bromide to give a liquid of phenolic properties which contained bromine. Whitney and Evans[17] reported that they obtained crude *p*-vinylphenol by passing *n*-hexylphenol through a hot tube packed with 5.3% vanadium on granular magnesite and purified the product by distillation *in vacuo*.

The first monomeric *p*-vinylphenol apparently isolated in any quantity was obtained as a natural product from poppy seed straw by Schmid and Karrer.[21] They fully characterized the compound and reported it to be a white crystalline solid which gives a blue-green color with ferric salts and polymerizes when heated above its melting point. These chemical and physical properties are quite different from those reported by Bernthsen and Bender[19] and Whitney and Evans[17] and it may be concluded that these investigators did not obtain monomeric *p*-vinylphenol.

The methods by which *p*-vinylphenol was synthesized in this Laboratory are illustrated below (I-VI). The preparation of *p*-vinylphenyl benzoate (IV) by the decarboxylation of *p*-benzoyloxycinnamic acid (III) is the better of the alternate methods (34% over-all yield).

Although synthesis of IV from the reaction of *p*-benzoyloxybenzaldehyde (II) with methylmagnesium iodide involves only one step, it suffers two disadvantages. Compound IV prepared from II contains considerable amounts of unreacted II and it was necessary to resort to the use of Girard reagent T to remove the aldehyde. Also, the over-all yield of IV from II is 5% less than *via* III. *p*-Vinylphenyl tosylate (VI), prepared as reported recently by the authors[22] also was converted to V, but is a less satisfactory intermediate because of

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(5) K. Fries and G. Fickewirth, *Ber.*, **41**, 367 (1908).

(6) H. Kunz-Krause and P. Manicke, *Arch. Pharm.*, **267**, 555 (1929); *Chem. Zentr.*, **100**, II, 3004 (1929).

(7) A. R. Bader, THIS JOURNAL, **77**, 4155 (1955).

(8) P. Hoering and F. Baum, German Patent 208,886; *Chem. Zentr.*, **80**, I, 1521 (1909).

(9) R. A. Smith and J. B. Niederl, THIS JOURNAL, **53**, 806 (1931).

(10) J. B. Niederl, R. A. Smith and M. E. McGreal. *ibid.*, **53**, 3390 (1931).

(11) E. Adler, H. von Euler and G. Gie, *Arkiv. Kemi, Mineral. Geol.*, **16A**, No. 12, 1 (1943); *C. A.*, **38**, 5839 (1944).

(12) I. H. Updegraff and H. G. Cassidy, THIS JOURNAL, **71**, 407 (1947).

(13) G. Komppa, *Ber.*, **26** ref., 677 (1893).

(14) E. Matsui, *J. Soc. Chem. Ind., Japan*, **46**, Suppl. binding, 125 (1943); *C. A.*, **44**, 9188 (1950).

(15) W. Dahlig, *Prace Placowek I auk-Badawcz Minesterstwa Przemyslu Chem.*, No. 1, 29 (1952); *C. A.*, **48**, 619 (1954).

(16) B. J. F. Hudson and R. Robinson, *J. Chem. Soc.*, 715 (1941).

(17) J. E. S. Whitney and E. M. Evans, British Patent 669,074 (Mar. 26, 1952); *C. A.*, **47**, 1738 (1953).

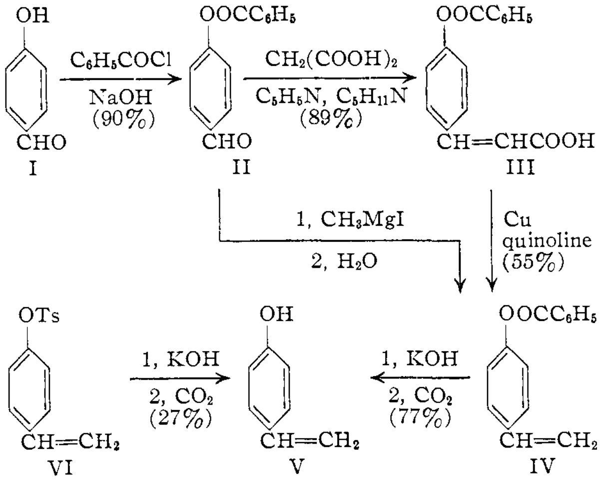
(18) K. von Auwers, *Ann.*, **413**, 253 (1917).

(19) A. Bernthsen and F. Bender, *Ber.*, **15**, 1982 (1882).

(20) M. Pestemer, L. Langer and F. Manchen, *Monatsh.*, **68**, 326 (1936); *C. A.*, **30**, 8023 (1936).

(21) H. Schmid and P. Karrer, *Helv. Chim. Acta*, **28**, 722 (1945).

(22) W. J. Dale and H. E. Hennis, THIS JOURNAL, **78**, 2543 (1956).



the low yields in the decarboxylation of *p*-tosyloxycinnamic acid and the saponification of VI.

It was noted that a normal Grignard product was obtained from the reaction of *p*-benzoyloxybenzaldehyde with methylmagnesium iodide *via* the inverse technique in contrast to the anomalous product, *p*-isopropenylphenyl tosylate, which was obtained from the reaction of the tosylate of *p*-hydroxybenzaldehyde with methylmagnesium iodide under similar conditions.[22]

The physical properties and the various color reactions of the *p*-vinylphenol prepared by the above methods agree with those reported for *p*-vinylphenol from natural sources.[21] The compound is very unstable and rapidly softens to a viscous yellow oil in a few hours at room temperature. In fact, this softening is visible within a few minutes. It may be stored at Dry Ice temperature for a few days before marked depression of its melting point is evident.

Bromination of *p*-vinylphenol in a variety of solvents gave non-crystallizable oils and solids. However, it was possible to prepare the benzoate and tosylate esters under Schotten–Baumann conditions; the mixed melting points of these derivatives with the authentic esters were undepressed. The allyl ether of *p*-vinylphenol was also successfully prepared in 32% over-all yield beginning with *p*-vinylphenyl benzoate.

The chemical evidence for the enhanced nucleophilic character of the vinyl group in *o*- and *p*-vinylphenol is very inconclusive at this point. Almost all of the electrophilic substitution reactions attempted on the isomers thus far have given polymeric products. In those cases where crystalline products were isolated, the yields were low because of competing polymerization reactions. No definite structures of any reaction products obtained to date can be offered.

The reaction of *o*-vinylphenol with *p*-nitrobenzenediazonium chloride in sodium hydroxide solution gave crude mono-coupled and di-coupled products in 35 and 10% yields, respectively. However, *p*-bromo-, *p*-methoxy- and unsubstituted benzenediazonium chloride yielded tarry products from which no crystalline compounds could be isolated. The reaction of *m*-vinylphenol with *p*-nitrobenzenediazonium chloride gave a very small amount of crude mono-coupled product. *p*-Vinylphenol gave a solid product with the same reagent; however, the product could not be induced to crystallize from various solvents. The addition of benzoyl chloride to the alkaline reaction mixture in an attempt to obtain a more stable product caused a yellow amorphous solid to separate which could not be obtained in a crystalline form. Methylation with methyl sulfate in the alkaline solution of the coupled products of *p*-vinylphenol with benzene- and *p*-phenylbenzenediazonium chloride gave dark oils which could not be further purified.

The reaction of *p*-vinylphenol with chloroform in sodium hydroxide solution (Reimer–Tiemann conditions), with nitrous acid, and with mercuric acetate failed to give monomeric products. Non-crystallizable oils and solids were obtained from each reaction. The reaction of *p*-vinylphenyl benzoate with aluminum chloride in nitrobenzene (Fries rearrangement), which are the conditions favoring the *para* rearrangement of phenolic esters, gave a tacky white solid which could not be induced to crystallize. Further studies on the reactions of the isomeric vinylphenols are being carried out, using other reagents and other experimental conditions and solvents.

Experimental[23]

o-**Vinylphenol.**—*o*-Hydroxycinnamic acid was prepared by the method of Updegraff and Cassidy.[12] From 212 g. (1.45 moles) of coumarin and 77 g. (3.3 moles) of sodium dissolved in 1 l. of absolute ethanol, there was obtained 176 g. (74%) of almost colorless product, m.p. 207–208° (lit.[12] m.p. 207–208°). The acid was decarboxylated according to the procedure of Fries and Fickewirth[5] at 215° under diminished pressure (18 mm.). From 50.0 g. (0.305 mole) of *o*-hydroxycinnamic acid, there was obtained 15.3 g. (42%) of colorless oil, b.p. 98–102° (14 mm.), n^{24}D (supercooled) 1.5787 (lit.[5] b.p. 108° (15 mm.)), which solidified to a white crystalline mass, m.p. 28–29° (lit.[5] m.p. 29°). A sample used for the absorption spectrum, obtained from a center cut of a careful fractionation of this product at a 10:1 reflux ratio through a 32 in. Todd precise fractionation assembly packed with glass helices, had these physical properties: b.p. 101° (14 mm.), n^{24}D (supercooled) 1.5808, m.p. 29–29.5°.

m-**Benzoyloxycinnamic Acid.**—A mixture of 58.2 g. (0.257 mole) of *m*-benzoyloxybenzaldehyde,[16] 40.0 g. (0.385 mole) of malonic acid and 10 ml. of pyridine was heated at 110° for 2 hours, during which time the mixture melted, vigorously evolved carbon dioxide, and solidified. The solid was recrystallized from aqueous ethanol to give 39.4 g. (57%) of white crystalline solid, m.p. 169–171°. Further recrystallization from ethanol afforded fine white needles, m.p. 177–177.5°.

Anal. Calcd. for $C_{16}H_{12}O_4$: C, 71.63; H, 4.51. Found: C, 71.50; H, 4.68.

The *p*-bromophenacyl ester was recrystallized from aqueous ethanol and benzene–petroleum ether (b.p. 60–68°) mixtures which resulted in fine white needles, m.p. 142–143°.

Anal. Calcd. for $C_{24}H_{17}O_5Br$: C, 61.95; H, 3.68. Found: C, 61.53; H, 3.74.

m-**Vinylphenol from** *m*-**Benzoyloxycinnamic Acid.**—A mixture of 38.1 g. (0.142 mole) of *m*-benzoyloxycinnamic acid, 100 ml. of freshly distilled quinoline and 5 g. of finely divided copper powder was heated at 220° for one hour and then distilled under diminished pressure. The fraction boiling at 120–190° (2 mm.), a dark yellow oil, was retained. The oil, 25 g. of potassium hydroxide dissolved in 100 ml. of water and 75 ml. of ethanol were mixed and allowed to

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(23) All melting points and boiling points are uncorrected. The carbon and hydrogen analyses were performed by R. Bolin, R. Hankins, R. Elliot and A. Mendel.

remain at room temperature for 2 days, during which time the oil saponified and solution was effected. The solution was extracted twice with ether and the aqueous solution was carbonated with Dry Ice. The weakly alkaline mixture was extracted twice with ether and the combined ethereal extracts were dried over anhydrous sodium sulfate. The ether was removed under diminished pressure and the small residue was distilled to give 0.4 g. (2%) of colorless oil, b.p. 75.5–77° (2 mm.).

Methyl-*m*-hydroxyphenylcarbinol.—The method described only briefly by von Auwers[18] was adopted. The details of a typical preparation are given here because this compound was a key intermediate in the preparation of *m*-vinylphenol.

Methylmagnesium iodide was prepared in the usual manner from 44.8 g. (1.95 gram atoms) of magnesium turnings and 262 g. (1.95 moles) of methyl iodide dissolved in 300 ml. of absolute ether. To the Grignard reagent was added dropwise, with stirring, 100 g. (0.818 mole) of *m*-hydroxybenzaldehyde dissolved in 1 l. of absolute ether. A green granular solid separated during the addition. When the addition was complete, the mixture was stirred and heated at the reflux temperature for 4 hours and then poured onto a mixture of 1 kg. of crushed ice and 100 ml. of concentrated hydrochloric acid. The ethereal and aqueous layers were separated and the aqueous solution was extracted twice with ether. The combined ethereal solutions were extracted twice with water and twice with 5% sodium bicarbonate solution. The ether was removed under slightly diminished pressure and the solid brown residue was dissolved in hot water, clarified with charcoal, and recrystallized from the same solvent to give 56.2 g. (50%) of white crystalline solid, m.p. 117–118° (lit.[18] m.p. 118°).

***m*-Vinylphenol from Methyl-*m*-hydroxyphenylcarbinol.**—The dehydration apparatus consisted of a 50-ml. Claisen distilling flask with the side-arm attached to a Pyrex tube (5″ × 3/4″ internal diameter) packed with activated alumina. The dehydration tube was connected, in turn, to a water-cooled condenser. The distillation flask was charged with 35.0 g. (0.254 mole) of methyl-*m*-hydroxyphenylcarbinol, the dehydration tube was heated at 300°, and the entire system was evacuated (1 mm.). The alcohol was distilled slowly through the dehydration tube. The distillate, a pale yellow oil, was redistilled to give 17.9 g. (59%) of colorless oil, b.p. 104–110° (6 mm.), n^{20}D 1.5795 (lit.[16] b.p. 114–116° (16 mm.), lit.[11] n^{31}D 1.5804). A sample used for the absorption spectrum, obtained from a center cut of a careful fractionation of this product at a 10:1 reflux ratio through a 32 in. Todd precise fractionation assembly packed with glass helices, had the following physical properties; b.p. 105° (5 mm.), n^{20}D 1.5812.

***p*-Benzoyloxycinnamic Acid.**—A mixture consisting of 173 g. (0.759 mole) of *p*-benzoyloxybenzaldehyde,[24] 110 g. (1.06 moles) of malonic acid and 20 ml. of pyridine was heated at 110° for one hour, during which time the mixture melted, evolved carbon dioxide and solidified. The solid was recrystallized from ethanol to give 180 g. (89%) of white crystalline solid, m.p. 233–234.5°. An analytical sample recrystallized from the same solvent afforded white needles, m.p. 234–234.5°.

Anal. Calcd. for $C_{16}H_{12}O_4$: C, 71.63; H, 4.51. Found: C, 71.82; H, 4.82.

The amide, prepared in the usual manner by the conversion of the acid to the acid chloride with thionyl chloride and the subsequent reaction with aqueous ammonia, was recrystallized from aqueous ethanol to give white needles, m.p. 212.5–213°.

Anal. Calcd. for $C_{16}H_{13}O_3N$: C, 71.90; H, 4.90. Found: C, 71.82; H, 4.96.

***p*-Vinylphenyl Benzoate from *p*-Benzoyloxycinnamic Acid.** *p*-Benzoyloxycinnamic acid (44.4 g., 0.168 mole) was added in 5-g. portions to a stirred mixture of 80 ml. of freshly distilled quinoline and 5 g. of finely divided copper powder heated at 225°. The addition was complete in 30 minutes and heating and stirring were continued for an additional 30 minutes. The crude reaction mixture was then distilled under diminished pressure; the fraction boiling at 95–180° (1 mm.) was retained. This fraction solidified when cooled and it was recrystallized twice from petroleum ether (b.p. 60–68°) to give 20.6 g. (55%) of white crystalline product, m.p. 72–75°. An analytical sample further recrystallized from the same solvent afforded fine white needles, m.p. 75.5–76°.

Anal. Calcd. for $C_{15}H_{12}O_2$: C, 80.33; H, 5.39. Found: C, 80.36; H, 5.66.

The dibromide was prepared by dissolving a portion of the product in chloroform, adding bromine until the bromine color persisted, removing the solvent by evaporation, and recrystallizing the residue from aqueous ethanol to give white needles, m.p. 115.5–116°.

Anal. Calcd. for $C_{15}H_{12}O_2Br_2$: C, 46.90; H, 3.15. Found: C, 46.86; H, 3.45.

***p*-Vinylphenyl Benzoate from *p*-Benzoyloxybenzaldehyde and Methylmagnesium Iodide.**—Methylmagnesium iodide was prepared in the usual manner from 4.37 g. (0.180 gram atom) of magnesium turnings and 26.3 g. (0.185 mole) of methyl iodide dissolved in 125 ml. of absolute ether. The Grignard reagent was added dropwise to a stirred solution of 40.6 g. (0.180 mole) of *p*-benzoyloxybenzaldehyde and 150 ml. of absolute ether. After the addition was complete, the reaction mixture was poured onto a mixture of 60 g. of ice and 20 ml. of concentrated hydrochloric acid. The layers were separated and the aqueous layer was extracted twice with ether. The combined ethereal solutions were extracted twice with water, once with 5% sodium bicarbonate solution, once again with water, and dried over anhydrous sodium sulfate. The ether was removed by distillation under diminished pressure and the residue, a pale yellow semi-solid, was distilled; the fraction, b.p. 152–179° (1 mm.), was retained. The fraction solidified when cooled and attempts to obtain a pure product by recrystallization were unsuccessful.

A mixture containing 4.6 g. of this crude product, 2.8 g. of Girard reagent T, 3 ml. of glacial acetic acid and 50 ml. of absolute ethanol was heated at the reflux temperature for 4 hours, cooled and poured onto a mixture of 50 g. of crushed ice and 3 g. of sodium carbonate. The white solid which separated was recrystallized from aqueous ethanol to give 3.3 g. of fine white needles, m.p. 75.5–76°. This corresponds to a total yield of 43%. The melting point of an intimate mixture (1:1) of this product and authentic *p*-vinylphenyl benzoate, m.p. 75.5–76°, was undepressed. The mixed melting point of an intimate mixture (1:1) of the dibromide, m.p. 115–116°, and authentic *p*-vinylphenyl benzoate dibromide, m.p. 115.5–116°, was 115–116°.

***p*-Vinylphenol from *p*-Vinylphenyl Benzoate.**—A mixture of 20.0 g. (0.0894 mole) of *p*-vinylphenyl benzoate, 25 g. (0.0447 mole) of potassium hydroxide dissolved in 100 ml. of water and 100 ml. of ethanol was stirred at room temperature for three days, after which time saponification was complete and solution was attained. The alkaline solution was carbonated with Dry Ice and then extracted three times with a petroleum ether (b.p. 60–68°)–ethyl acetate mixture (4:1 by volume).[25] The combined extracts were dried over anhydrous sodium sulfate. The solvent was removed under a slightly diminished pressure and a nitrogen atmosphere.[26] The residue, a pale yellow solid, was recrystallized from petroleum ether (b.p. 60–68°) to give 8.2 g. (77%) of white crystalline product, m.p. 69–71° (lit.[21] m.p. 73.5°). Further recrystallization from the same solvent afforded fine white needles, m.p. 71–72°.

Anal. Calcd. for C_8H_8O: C, 79.97; H, 6.71. Found: C, 79.84; H, 6.84.

The sample used for ultraviolet absorption study was further recrystallized three times from petroleum ether (b.p. 60–68°) to a constant melting point, 71.5–72°.

The *p*-vinylphenol gave a blue-green color with dilute aqueous ferric chloride solution, red solutions in concentrated sulfuric and phosphoric acids, and a cornflower-blue resin in concentrated hydrochloric acid which was consistent with the color reactions obtained from the natural product isolated by Schmid and Karrer.[21]

The benzoate derivative, prepared under Schotten–Baumann conditions, was recrystallized from aqueous ethanol to give fine white needles, m.p. 74.5–75.5°. An inti-

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(24) L. C. Raiford and J. E. Milbery, This Journal, **56**, 2727 (1934).

(25) No monomeric product was obtained when ether was used as an extraction solvent.

(26) The lack of an inert atmosphere gave only polymeric product.

mate mixture (1:1) of this ester and authentic *p*-vinylphenyl benzoate, m.p. 75.5–76°, melted at 74.5–75.5°. The tosylate derivative, prepared under the same conditions, was recrystallized from aqueous ethanol to afford fine white needles, m.p. 66–67°. An intimate mixture (1:1) of this ester and authentic *p*-vinylphenyl tosylate,[22] m.p. 68–68.5°, melted at 67–68°.

The allyloxy ether of *p*-vinylphenol was prepared for another study. *p*-Vinylphenyl benzoate (20.0 g., 0.0894 mole) was saponified as described earlier and a mixture of the crude product, 12.1 g. (0.100 mole) of allyl bromide, 15 g. of anhydrous potassium carbonate and 25 ml. of absolute ethanol was heated at the reflux temperature for 4 hours. At the completion of the reaction, 100 ml. of water and 100 ml. of petroleum ether (b.p. 60–68°) were added. The layers were separated and the organic layer was extracted with 5% sodium hydroxide solution and dried over anhydrous sodium sulfate. The solvent was removed by distillation and the residue was distilled under diminished pressure to give 4.59 g. (32% over-all) of colorless oil, b.p. 77–84° (1 mm.), $n^{20}\text{D}$ 1.5588. A center cut, b.p. 82–83°, $n^{20}\text{D}$ 1.5588, was selected for the analytical sample.

Anal. Calcd. for $C_{11}H_{12}O$: C, 82.46; H, 7.55. Found: C, 82.21; H, 7,87.

The tetrabromide derivative was recrystallized from petroleum ether (b.p. 60–68°) to give thick white needles, m.p. 119.5–120°.

Anal. Calcd. for $C_{11}H_{12}OBr_4$: C, 27.53; H, 2.52. Found: C, 27.80; H, 2.73.

***p*-Vinylphenol from *p*-Vinylphenyl Tosylate.**—A mixture of 7.50 g. (0.0274 mole) of *p*-vinylphenyl tosylate,[22] 7.7 g. of potassium hydroxide dissolved in 40 ml. of water and 20 ml. of ethanol was stirred at room temperature for 4 days before complete solution was attained. The product was isolated in the same manner as described for the saponification of *p*-vinylphenyl benzoate to give 0.89 g. (27%) of product, m.p. 69–71°.

Reaction of *o*-Vinylphenol and *p*-Nitrobenzenediazonium Chloride.—*p*-Nitrobenzenediazonium chloride was prepared in the usual manner from 2.30 g. (0.0167 mole) of *p*-nitroaniline dissolved in a solution of 20 ml. of 5% hydrochloric acid and 50 ml. of water and 1.16 g. (0.0167 mole) of sodium nitrite dissolved in 20 ml. of water. The diazonium chloride solution was added dropwise, with stirring, to a cold (5°) solution of 2.00 g. (0.0167 mole) of *o*-vinylphenol, 2.8 g. of sodium hydroxide and 200 ml. of water. The reaction mixture was carbonated with Dry Ice after which a brick-red solid separated. The solid was extracted with three 100-ml. portions of hot ethanol. The extracts were diluted with water and cooled and the solids which separated were collected and air-dried. The first extract gave 1.57 g. (35%) of crude mono-coupled product, m.p. 107–111° (softening at 78°). A sample recrystallized further from aqueous ethanol gave bright orange plates, m.p. 127–129° (softening at 123°).

Anal. Calcd. for $C_{14}H_{11}O_3N_3$: C, 62.46; H, 4.12. Found: C, 62.76; H, 4.52.

The benzoate ester, prepared under Schotten–Baumann conditions, was recrystallized from ethyl acetate–ethanol mixtures to give red needles, m.p. 153–155°.

Anal. Calcd. for $C_{21}H_{15}O_4N_3$: C, 67.55; H, 4.05. Found: C, 67.26; H, 4.14.

The solids which separated from the second and third extracts were combined to give 0.72 g. (10%) of crude di-coupled product, m.p. 174–186° dec. A sample recrystallized 5 times from ethyl acetate–ethanol mixtures gave an orange powder, m.p. 180–181° dec. The recrystallizations were not successful in removing all of the mono-coupled product.

Anal. Calcd. for $C_{20}H_{24}O_5N_6$: C, 57.41; H, 3.37. Found: C, 58.58; H, 3.90.

Reaction of *m*-Vinylphenol and *p*-Nitrobenzenediazonium Chloride.—*p*-Nitrobenzenediazonium chloride (0.0417 mole) was prepared as described in the previous experiment and added dropwise, with stirring, to a cold (5°) solution containing 5.00 g. (0.0417 mole) of *m*-vinylphenol, 7 g. of sodium hydroxide and 500 ml. of water. The solution, which had turned deep red during the addition, was carbonated with Dry Ice, after which a black tar separated. The tar was dissolved in hot ethanol and after a process of cooling, decanting the solution from tars which had separated, reheating and diluting the solution with water and cooling again, was repeated several times, there was obtained about 50 mg. of red needles, m.p. 163–165°. The product was dissolved in benzene and chromatographed through acid-washed alumina. The major band was retained. The solvent was removed by evaporation and the residue was recrystallized from aqueous ethanol to give fine red needles, m.p. 166–167°.

Anal. Calcd. for $C_{14}H_{13}O_3N_3$: C, 62.45; H, 4.12. Found: C, 62.81; H, 4.21.

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[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

Restricted Rotation in Aryl Amines. XXII. N-Benzenesulfonyl-N-carboxymethyl-3-amino-2,4,6-trimethylpyridine and its N-Oxide

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The synthesis of N-benzenesulfonyl-N-carboxymethyl-3-amino-2,4,6-trimethylpyridine (II) and its 1-oxide (III) is described. Unlike the analogous 3-substituted mesidines, which were readily resolvable, resolution of these pyridine compounds failed.

Free rotation of the substituted nitrogen atom about the pivot bond in N-benzenesulfonyl-N-carboxymethylmesidine (I) is inhibited by the two *o*-methyl groups, and asymmetry is imparted to the molecule by the presence of the *m*-substituent. Such compounds have been resolved into their respective enantiomorphs, and their rates of racemization have been measured.[2,3] The present work was undertaken to determine if N-benzenesulfonyl-N-carboxymethyl-3-amino-2,4,6-trimethylpyridine (II) might also exist as a *dl*-pair, since models indicate that free rotation of the substituted nitrogen atom about the pivot bond as in the benzene analogs (I) is inhibited by the two *o*-methyl groups. Asymmetry is introduced by the presence of the heterocyclic nitrogen atom in the *m*-position.

Compound II is such a weak acid that the salts with alkaloids were unstable. Various alkaloids and solvents were employed unsuccessfully in an effort to obtain an alkaloid salt of II suitable for resolution. The strychnine and cinchonine salts

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[1] An abstract of a portion of a thesis submitted by Joseph E. Dunbar to the Graduate College of the University of Illinois in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1956; Standard Oil of California Fellow 1954–1955.

[2] R. Adams and K. R. Brower, THIS JOURNAL, **78**, 663 (1956).

[3] R. Adams and M. Gortatowski, *ibid.*, **79**, 5525 (1957).