

dilute ethanol in the presence of decolorizing carbon to give colorless crystals of *N*-butylvanillamide melting at 98–99°. The analyses of this and other *N*-substituted amides are given in Table II.

**Method IV. Preparation of *N*-Heptyl-3-ethoxy-4-hydroxybenzamide.**—A solution of 50 g. of *N*-heptyl-*O*-carbethoxy-3-ethoxy-4-hydroxybenzamide in 250 cc. of methanol was treated with 250 cc. of *N* sodium hydroxide and allowed to stand 2 hours at 20°. The solution was filtered and acidified with 1:1 hydrochloric acid. The methanol was removed under reduced pressure, and the viscous oil which separated from the aqueous solution was distilled under reduced pressure to give 80% of *N*-heptyl-3-ethoxy-4-

hydroxybenzamide as a very viscous slightly yellow oil boiling at 233° (2.4 mm.). Upon standing the product solidified to crystals melting at 79–80°.

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[CONTRIBUTION FROM THE INSTITUTE OF PAPER CHEMISTRY]

## Reactions of Vanillin and its Derived Compounds. XXII.<sup>1</sup> Ethers of Protocatechuic Acid and their Ethyl Esters<sup>2</sup>

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Vanillin was demethylated to protocatechualdehyde by means of anhydrous aluminum bromide, and the aldehyde was alkylated to several of its mono- and dialkyl ethers by reaction with alkyl halide in the presence of alkali or alkali carbonate. The alkyl ethers of protocatechualdehyde were oxidized to their respective acids with one mole of silver oxide in the presence of excess aqueous alkali. Ethyl esters of these acids were prepared by reaction with anhydrous ethanol in the presence of concentrated sulfuric acid. The sulfuric acid was removed by means of anion-exchange resin. Inhibiting concentrations of these esters toward *Bacillus mycoides* indicated a slight increase in activity with increasing chain length in the ether group, but no effect caused by change in position of the ether group.

During the course of our studies on the use of vanillin as a raw material for the production of organic chemicals it was desired to demethylate vanillin to the parent protocatechualdehyde and realkylate the latter to several of its mono- and dialkyl ethers. These ethers of protocatechualdehyde were desired as intermediates for preparing their derived acids and esters for inclusion in our testing program on the inhibiting concentrations of esters of vanillic and related acids for representative microorganisms.<sup>3–7</sup> Indications were that increasing the molecular weight of the alkyl radical in the ether group of protocatechuic acid esters resulted in increased activity.<sup>7</sup>

Vanillin was demethylated easily with anhydrous aluminum bromide in nitrobenzene solution to give a good yield of protocatechualdehyde, which was alkylated with one mole of ethyl bromide and two moles of potassium hydroxide in ethanolic solution by the procedure of Bertram<sup>8</sup> for preparing vanillin from protocatechualdehyde. In addition to the desired 3-ethoxy-4-hydroxybenzaldehyde, some 3,4-diethoxybenzaldehyde and unchanged protocatechualdehyde were obtained. However, no 4-ethoxy-3-hydroxybenzaldehyde was formed. Similar alkylation with butyl bromide yielded a

mixture of unchanged protocatechualdehyde, 3-butoxy-4-hydroxybenzaldehyde and 3,4-dibutoxybenzaldehyde. Ethyl protocatechuate was also alkylated with one mole of alkyl halide in the presence of two moles of potassium carbonate in anhydrous acetone to yield only the meta-ether. Ethyl protocatechuate was also alkylated with ethyl bromide and two moles of potassium carbonate in ethanol in accordance with the procedure reported by Sommer<sup>9</sup> for the preparation of vanillin from protocatechualdehyde. In this case all possible alkylation products were obtained and isolated by chromatographing from petroleum ether on acid-washed Magnesol and developing with 50:1 petroleum ether-ethanol. Thus, all ethers of protocatechuic acid become available.

Several 3-substituted and 4-substituted monoethers of protocatechualdehyde, namely, 3-isopropoxy-4-hydroxybenzaldehyde, 3-butoxy-4-hydroxybenzaldehyde, 3-*s*-butoxy-4-hydroxybenzaldehyde, 3-benzyloxy-4-hydroxybenzaldehyde, 3-hydroxy-4-methoxybenzaldehyde (isovanillin), and 4-ethoxy-3-hydroxybenzaldehyde were obtained from Monsanto Chemical Company. These aldehydes were oxidized to their respective acids by treatment with one mole of freshly prepared silver oxide in the presence of an excess of aqueous alkali.<sup>7</sup> Data for these acids are given in Table I. The acids were esterified with ethanol in the presence of sulfuric acid. The sulfuric acid was removed with the anion-exchange resin, Duolite A-2, in ethanolic solution, and the solution thus obtained was concentrated to dryness to yield the substantially pure ester. Data for these esters are given in Table II.

The inhibiting concentrations of these esters

(1) For paper XXI of this series, see THIS JOURNAL, **75**, 2627 (1953).

(2) This paper represents a portion of the results obtained in the research program sponsored by the Sulphite Pulp Manufacturers' Research League and conducted for the League by The Institute of Paper Chemistry. Acknowledgment is made by the Institute for permission on the part of the League to publish these results.

(3) I. A. Pearl and J. F. McCoy, THIS JOURNAL, **69**, 3071 (1947).

(4) I. A. Pearl and D. L. Beyer, *ibid.*, **71**, 1066 (1949).

(5) I. A. Pearl and D. L. Beyer, *ibid.*, **72**, 1743 (1950).

(6) I. A. Pearl and D. L. Beyer, *ibid.*, **73**, 4091 (1951).

(7) I. A. Pearl and D. L. Beyer, *ibid.*, **74**, 3188 (1952).

(8) J. Bertram, German Patent 63,007 (Aug. 19, 1890); *Ber.* **25**, 8823 (1892).

(9) R. Sommer, German Patent 122,851 (May 27, 1900).

TABLE I  
 ETHERS OF PROTOCATECHUIC ACID<sup>a</sup>

Ether	Yield, %	Solvent <sup>b</sup>	M.p., °C.	Formula	Analyses, %			
					Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found
3-Isopropyl	84.1	A	144-145	C <sub>10</sub> H <sub>12</sub> O <sub>4</sub>	61.22	61.25	6.16	6.21
3-Butyl	94.4	A	137-138	C <sub>11</sub> H <sub>14</sub> O <sub>4</sub>	62.84	62.95	6.71	6.78
3- <i>s</i> -Butyl	90.4	A	143-144	C <sub>11</sub> H <sub>14</sub> O <sub>4</sub>	62.84	62.84	6.71	6.77
3-Benzyl	98.8	B	172-173	C <sub>14</sub> H <sub>18</sub> O <sub>4</sub>	68.84	68.80	4.95	4.99
4-Methyl	97.4	C	252-253 <sup>c</sup>					
4-Ethyl	93.2	A	49-50 <sup>d</sup>					

<sup>a</sup> Prepared from their respective aldehydes by oxidation with one mole of freshly prepared silver oxide and excess aqueous alkali.<sup>7</sup> <sup>b</sup> For recrystallization: A = petroleum ether (b.p. 65-110°); B = water; C = methanol. <sup>c</sup> Agrees with published values for melting point of isovanillic acid. <sup>d</sup> E. Larsson [*Trans. Chalmers Univ. Technol. Gothenberg* No. 59, 21 (1947)] recorded 219-220° as the melting point for 3-hydroxy-4-ethoxybenzoic acid.

 TABLE II  
 ETHYL ESTERS OF ETHERS OF PROTOCATECHUIC ACID

Ether	Yield, %	Solvent <sup>a</sup>	M.p., °C.	Formula	Analyses, %				Inhibiting concn., % <i>Bacillus mycooides</i>
					Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	
3-Isopropyl	100	A	70-71	C <sub>12</sub> H <sub>16</sub> O <sub>4</sub>	64.27	64.28	7.19	7.21	0.015
3-Butyl	93.8	A	48-50	C <sub>13</sub> H <sub>18</sub> O <sub>4</sub>	65.53	65.50	7.61	7.63	.009
3- <i>s</i> -Butyl	94.4		<sup>b</sup>	C <sub>13</sub> H <sub>18</sub> O <sub>4</sub>	65.53	65.52	7.61	7.63	.015
3-Benzyl	91.4	A	69-70	C <sub>16</sub> H <sub>18</sub> O <sub>4</sub>	70.57	70.60	5.92	5.99	.009
4-Methyl	93.2	B	49-50 <sup>c</sup>						.015
4-Ethyl	100	B	79-80	C <sub>11</sub> H <sub>14</sub> O <sub>4</sub>	62.84	62.89	6.71	6.79	.015
4-Butyl									.009
3,4-Diethyl									.012

<sup>a</sup> For recrystallization: A = petroleum ether (b.p. 30-60°); B = petroleum ether (b.p. 65-110°). <sup>b</sup> Colorless oil boiling at 146° (1.7 mm.),  $n_{20}^D$  1.5253. <sup>c</sup> E. Späth [*Monatsh.*, 41, 300 (1920)] reported 51-52° as the melting point for this ester.

were determined for *Bacillus mycooides*. Esters were dissolved in 60% ethanol for testing. Results are collected in Table II. All the esters studied in this work demonstrated higher activity against *Bacillus mycooides* than the ethyl esters of vanillic,<sup>3</sup> protocatechuic<sup>5</sup> and 3-ethoxy-4-hydroxybenzoic acids.<sup>7</sup> Increasing chain length in the ether group caused slight increase in activity, but change in position of the ether group had little influence on the inhibiting concentrations.

Ultraviolet absorption spectra in ethanol were determined for the above aldehydes and acids. The spectra of the 3-alkoxy-4-hydroxybenzaldehydes were found to be almost identical with that of vanillin<sup>10</sup> except for actual extinction values. Maxima were exhibited at 310, 280 and 232  $m\mu$ , and minima were exhibited at 295, 250 and 218  $m\mu$ . The spectra of the 4-alkoxy-3-hydroxybenzaldehydes were almost the same as their isomers except for slight shifts in maxima and minima. These curves possessed maxima at 313, 276 and 233  $m\mu$  and minima at 295, 248 and 217  $m\mu$ . The chief distinguishing characteristic of the latter curves is the high absorption of the 276  $m\mu$  band relative to the 313  $m\mu$  band, whereas in the curves of the 3-alkoxy-4-hydroxybenzaldehydes the absorptions of the 280 and 310  $m\mu$  bands are nearly equal. Thus, the curve for 4-ethoxy-3-hydroxybenzaldehyde has specific extinctions for the 276 and 313  $m\mu$  bands of 66.25 and 52.50, respectively, whereas the curve for 3-ethoxy-4-hydroxybenzaldehyde has specific extinctions for the 280 and 310  $m\mu$  bands of 63.1 and 60.9, respectively.

The ultraviolet absorption spectra of the 3- and 4-alkyl ethers of protocatechuic acid and its ethyl

ester are almost identical with those for vanillic<sup>10</sup> and 3-ethoxy-4-hydroxybenzoic acids<sup>7</sup> and their ethyl esters. The spectra for 3-alkoxy-4-hydroxybenzoic acids and their esters are characterized by maxima at 293, 263 and 222  $m\mu$ , and the curves for the isomeric 4-alkoxy-3-hydroxybenzoic acids and their esters are characterized by maxima at 296, 260 and 220  $m\mu$ .

### Experimental

All melting points are uncorrected.

**Starting Materials Obtained from Monsanto.** 3-Isopropoxy-4-hydroxybenzaldehyde.—Colorless crystals melting at 47-48°. Chemische Fabrik auf Aktien<sup>11</sup> debenzylated 3-isopropoxy-4-benzoyloxybenzaldehyde with hydrochloric acid to yield a thick oil which they reported as 3-isopropoxy-4-hydroxybenzaldehyde, but the description of which does not correspond with the product obtained from Monsanto.

3-Butoxy-4-hydroxybenzaldehyde.—Colorless crystals melting at 45-46°.

3-*s*-Butoxy-4-hydroxybenzaldehyde.—Colorless crystals melting at 48-49°. Boedecker and Volk<sup>12</sup> prepared this compound by condensing glyoxylic acid with the mono-*s*-butyl ether of catechol in the presence of alkali and oxidizing the resultant product. These authors reported a melting point of 45-46°.

3-Benzoyloxy-4-hydroxybenzaldehyde.—Colorless crystals melting at 113-114°, apparently identical with that obtained by Chemische Fabrik auf Aktien<sup>13</sup> as a by-product in the preparation of its isomer, 4-benzoyloxy-3-hydroxybenzaldehyde by benzoylation of protocatechualdehyde.

3-Hydroxy-4-methoxybenzaldehyde (Isovanillin).—Colorless crystals melting at 109-110°.

4-Ethoxy-3-hydroxybenzaldehyde.—Colorless crystals melting at 126-127°.

(11) Chemische Fabrik auf Aktien, German Patent 85,196 (Jan. 22, 1896).

(12) F. Boedecker and H. Volk, U. S. Patent 2,062,205 (Nov. 24, 1936).

(13) Chemische Fabrik auf Aktien, German Patent 82,816 (Aug. 27, 1895).

(10) I. A. Pearl, *THIS JOURNAL*, 71, 2331 (1949).

**Protocatechualdehyde.**—A solution of 15.2 g. (0.1 mole) of vanillin in 45 cc. of nitrobenzene at 15° was treated with a solution of 53.4 g. (0.2 mole) of anhydrous aluminum bromide<sup>14</sup> in 60 cc. of nitrobenzene at 10°. The gel which formed was stirred with 125 cc. of nitrobenzene, warmed on the steam-bath to 95°, and allowed to stand at room temperature for 30 minutes. The dark mixture was cooled and poured into one liter of water containing a little hydrochloric acid. This mixture was extracted with ether, and the ether was extracted with 5% sodium hydroxide solution. The alkaline solution was washed with ether, acidified with dilute sulfuric acid, and extracted with ether. The ether was dried and distilled, leaving 12.8 g. (93%) of oily protocatechualdehyde which crystallized on cooling. Recrystallization from toluene gave colorless needles melting at 151–152° and not depressing a mixed melting point with authentic protocatechualdehyde.<sup>15</sup>

**Ethylation of Protocatechualdehyde.**—A solution of 4.1 g. (0.03 mole) of protocatechualdehyde in 100 cc. of anhydrous ethanol was treated with a solution of 4.0 g. (0.06 mole) of 85% potassium hydroxide in 95% ethanol, and the resulting mixture was heated to boiling under reflux 1.5 hours. The mixture was concentrated under reduced pressure, diluted with water, and distilled until all ethanol was removed. The aqueous mixture was extracted with ether and the ether was dried and distilled to yield 0.5 g. of 3,4-diethoxybenzaldehyde as an oil which gave an oxime melting at 98° and not depressing the melting point of a mixture with authentic 3,4-diethoxybenzaldehyde.<sup>16</sup>

The aqueous solution was acidified with dilute sulfuric acid and extracted with ether. The ether was dried and distilled, leaving 5.0 g. of solid residue. This residue was extracted with boiling petroleum ether (b.p. 65–110°) to give 3.8 g. of crystals melting at 77–79° which did not depress a mixed melting point with authentic 3-ethoxy-4-hydroxybenzaldehyde.

The residue from the petroleum ether extraction was recrystallized from benzene to yield 1.0 g. of protocatechualdehyde melting at 148–149°.

**Butylation of Protocatechualdehyde.**—Similar reaction of 5 g. (0.036 mole) of protocatechualdehyde, 5 g. (0.036 mole) of butyl bromide and 4.7 g. (0.072 mole) of potassium hydroxide in 100 cc. of 95% ethanol for 7.5 hours and removal of the ethanol yielded an aqueous solution which was extracted with ether. The ether was dried and distilled to yield 2.15 g. of colorless oil which was boiled with petroleum ether (b.p. 30–60°) and filtered. Cooling of the filtrate yielded clusters of crystals of 3,4-dibutoxybenzaldehyde melting at 32–33°.

*Anal.* Calcd. for C<sub>15</sub>H<sub>22</sub>O<sub>4</sub>: C, 71.96; H, 8.86. Found: C, 71.86; H, 8.87.

The aqueous alkaline solution was acidified with dilute sulfuric acid and again extracted with ether. The ether was dried and distilled to yield 3.0 g. of oil which was boiled with petroleum ether (b.p. 30–60°) and filtered. Cooling of the filtrate gave crystals melting at 39–45° which, upon recrystallization from petroleum ether, melted at 45–46° and did not depress a mixed melting point with authentic 3-butoxy-4-hydroxybenzaldehyde. Protocatechualdehyde melting at 151–152° was recovered from the petroleum ether-insoluble portion by recrystallization from toluene.

**Butylation of Ethyl Protocatechuate.**—A mixture of 9 g. (0.05 mole) of ethyl protocatechuate, 7 g. (0.05 mole) of butyl bromide, 13.8 g. (0.1 mole) of anhydrous potassium carbonate and 50 cc. of dried acetone was boiled under reflux for 2 hours. The acetone was removed by distillation on the steam-bath, and the residue was diluted with water. The alkaline aqueous solution was extracted with ether, and the ether was dried and distilled, giving 8.3 g. of non-phenolic material. Recrystallization from petroleum ether (b.p. 30–60°) yielded colorless crystals of ethyl 4-butoxy-3-hydroxybenzoate melting at 80–81°.

*Anal.* Calcd. for C<sub>13</sub>H<sub>18</sub>O<sub>4</sub>: C, 65.53; H, 7.61. Found: C, 65.48; H, 7.61.

Hydrolysis of this ester with 3% sodium hydroxide and acidification yielded a white fluffy compound which was re-

crystallized from water to give white crystals of 4-butoxy-3-hydroxybenzoic acid melting at 143–144°.

*Anal.* Calcd. for C<sub>11</sub>H<sub>14</sub>O<sub>4</sub>: C, 62.84; H, 6.71. Found: C, 62.86; H, 6.71.

The original aqueous alkaline solution was acidified with dilute hydrochloric acid and extracted with ether. The ether was dried and distilled to yield 2.1 g. of product which was recrystallized from carbon tetrachloride to give crystals of ethyl protocatechuate melting at 129–130° and not depressing a mixed melting point with the starting material.

**Ethylation of Ethyl Protocatechuate.**—A mixture of 18.2 g. (0.1 mole) of ethyl protocatechuate, 11 g. (0.1 mole) of ethyl bromide, 27.6 g. (0.2 mole) of powdered anhydrous potassium carbonate and 100 cc. of absolute ethanol was boiled under reflux for 7 hours. The ethanol was removed under reduced pressure and finally replaced with water. The alkaline aqueous solution was extracted and the ether was dried and distilled to yield 16.35 g. of viscous oil. The aqueous solution was acidified with dilute sulfuric acid and extracted with ether to yield 4.0 g. of ethyl protocatechuate as crystals (from petroleum ether) melting at 126–127°.

The viscous oil (2.0 g.) was chromatographed from petroleum ether (b.p. 65–110°) on a column (44 mm. in diameter and 240 mm. long) of acid-washed Magnesol<sup>17</sup> and developed with 375 cc. of 50:1 petroleum ether-ethanol. Three bands were indicated by streaking with alkaline permanganate. The leading band on elution with acetone yielded a product which, on crystallization from petroleum ether (b.p. 30–60°), gave colorless needles of ethyl 3,4-diethoxybenzoate melting at 52–53°.

*Anal.* Calcd. for C<sub>13</sub>H<sub>18</sub>O<sub>4</sub>: C, 65.53; H, 7.61. Found: C, 65.38; H, 7.59.

Hydrolysis with ethanolic sodium hydroxide yielded 3,4-diethoxybenzoic acid which, upon recrystallization from water, was obtained as fluffy white needles melting at 162–163°.

*Anal.* Calcd. for C<sub>11</sub>H<sub>14</sub>O<sub>4</sub>: C, 62.84; H, 6.71. Found: C, 62.74; H, 6.71.

Herzig<sup>18</sup> treated the tetraethyl ether of quercetin with alcoholic potassium hydroxide and obtained 3,4-diethoxybenzoic acid melting at 165–166°; ethyl ester, m.p. 56–57°.

The other two chromatographic bands were combined and eluted. The acetone eluate, upon removal of solvent, yielded crystals and oil. The crystals were removed and recrystallized from petroleum ether (b.p. 65–110°) to give ethyl 4-ethoxy-3-hydroxybenzoate as slightly yellow crystals melting at 77–78° and not depressing the melting point of a mixture with ethyl 4-ethoxy-3-hydroxybenzoate prepared from authentic 4-ethoxy-3-hydroxybenzoic acid.

The residual oil was boiled with dilute sodium hydroxide solution, cooled and acidified with dilute sulfuric acid. The solid obtained was filtered, washed with water, and recrystallized from dilute methanol; 3-ethoxy-4-hydroxybenzoic acid was obtained as white needles melting at 164–165° and not depressing a mixed melting point with authentic 3-ethoxy-4-hydroxybenzoic acid.

The approximate yields obtained were ethyl 4-ethoxy-3-hydroxybenzoate, 15%; ethyl 3,4-diethoxybenzoate, 20%; and 3-ethoxy-4-hydroxybenzoic acid, 30%.

**Esterification Procedure. Preparation of Ethyl 3-Isopropoxy-4-hydroxybenzoate.**—A small anion-exchange column was prepared by packing 8 g. of Duolite A-2 resin<sup>19</sup> in a 50-ml. buret. The column was backwashed with water, regenerated with 50 cc. of 4% sodium hydroxide, washed with water until the effluent was in the pH range 7–8 (about 300 cc. of water was required), and drained. The column was then washed with absolute ethanol until the effluent contained more than 95% ethanol.

A mixture of 2 g. of 3-isopropoxy-4-hydroxybenzoic acid, 15 cc. of absolute ethanol and 0.4 cc. of concentrated sulfuric acid was boiled under reflux for 7 hours and allowed to cool. The reaction mixture was passed through the anion-exchange column and washed with 100 cc. of absolute ethanol. The effluent and washings were distilled to dryness under reduced pressure, leaving 2.3 g. (100%) of ethyl 3-isopropoxy-4-hydroxybenzoate as an almost colorless oil

(14) A commercial product received from the Westvaco Chemical Division of Food Machinery and Chemical Corporation.

(15) J. S. Buck and F. J. Zimmermann, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 549.

(16) J. S. Buck and W. S. Ide, *THIS JOURNAL*, **54**, 3302 (1932).

(17) I. A. Pearl and E. E. Dickey, *ibid.*, **73**, 863 (1951).

(18) J. Herzig, *Monatsh.*, **5**, 81 (1884).

(19) An anion-exchange resin manufactured by Chemical Process Company, Redwood City, California.

which solidified upon cooling to a crystalline solid melting at 70–71°. Recrystallization from petroleum ether (b.p. 30–60°) gave colorless needles melting at 70–71°. Analytical data are given in Table II.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE POLYTECHNIC INSTITUTE OF BROOKLYN]

## The Aromatization and Rearrangement of Cyclic Ketones. III. 2,3,5- and 3,4,5-Trimethylphenol from Isophorone<sup>1</sup>

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By modification of the bromination–dehydrobromination method of Knoevenagel isophorone and its enol acetate have been converted to a mixture of 2,3,5- and 3,4,5-trimethylphenol. Isophorone dibromide was investigated as a possible reaction intermediate. Related aromatizations in the literature are pointed out.

Previous studies have shown that isophorone<sup>2</sup> and 3-phenyl-5,5-dimethylcyclohexenone<sup>3</sup> could be converted to sulfonic acids, treatment of which with hot acetic anhydride yielded the acetates of 3,4,5-trimethylphenol and 3,4-dimethyl-5-phenylphenol.<sup>4</sup> It has since seemed of interest to see whether this oxidative rearrangement could be effected by the bromination–dehydrobromination method introduced by Knoevenagel<sup>5</sup> in 1893 and used in the preparation of phenol,<sup>6,7</sup> *m*-cresol,<sup>8</sup> dialkylphenols,<sup>8–10</sup> a trialkylphenol,<sup>9</sup> and phenolic esters.<sup>6,8,11</sup>

As in Knoevenagel's procedure,<sup>8</sup> bromine was added to isophorone in cold acetic acid, and the resulting solution was heated on the steam-bath and then at reflux to give a 1.2% yield of trimethylphenols. More successfully, when bromine was added to isophorone in trichlorobenzene and the solution was refluxed until the evolution of hydrogen bromide ceased, a 44–47% yield of mixed trimethylphenols<sup>12</sup> was obtained. Crystallization, sublimation and chromatography effected a separation of the mixture into 2,3,5-trimethylphenol<sup>13,14</sup>

and 3,4,5-trimethylphenol<sup>2,13,15</sup> in the ratio of about 1:3.

In attempts to accelerate or improve the yield of the reaction several possible catalysts were tried. With hydrogen bromide continuously added, the yield was slightly higher (49%), while with benzoyl peroxide added from time to time, the yield was slightly lower (34%), possibly due to a faulty work-up. Runs with catalytic amounts of aluminum chloride or stannic chloride gave tars with only traces of phenols. Other conditions investigated are summarized in the Experimental section.

Isophorone dibromide<sup>16</sup> was prepared and studied as a possible intermediate in the reaction. While this material seemed stable in an evacuated desiccator, a sample in air lost in two days weight corresponding approximately to a molar equivalent of hydrogen bromide, with the residue on distillation giving 62% of isophorone. Attempts were made to convert isophorone dibromide to trimethylphenols by heating in carbon tetrachloride, 2,4-lutidine and trichlorobenzene. Only in the last case was there obtained even a trace of phenols. Two possible interpretations suggest themselves: either isophorone dibromide is not an intermediate in the reaction, or in trichlorobenzene there is formed along with isophorone dibromide a material which catalyzes the aromatization of the isophorone dibromide during the period of heating.

The enol acetate of isophorone was prepared by the method of Hagemeyer and Hull.<sup>17</sup> Bromination and rearrangement in the usual manner gave a 35% yield of phenols.

By aromatizations with rearrangements rather similar to that reported here, phenols were obtained by Crossley and co-workers<sup>18,19</sup> and by Hinkel and Williams<sup>20</sup> from halogenated cyclohexenones obtained by the action of phosphorus halides and

(1) This paper, taken from a thesis submitted by Emil J. Geering in partial fulfillment of the requirements of the degree of Master of Science in Chemistry in the Graduate School of the Polytechnic Institute of Brooklyn in June, 1950, was presented in part at the 122nd meeting of the American Chemical Society, September 14 to 19, 1952, Atlantic City, N. J.

(2) W. von E. Doering and F. M. Beringer, *THIS JOURNAL*, **71**, 2221 (1949).

(3) F. M. Beringer and I. Kuntz, *ibid.*, **73**, 364 (1951).

(4) E. C. Horning has surveyed alicyclic-aromatic conversions in *Chem. Revs.*, **33**, 89 (1943).

(5) E. Knoevenagel, *Ber.*, **26**, 1951 (1893).

(6) A. Kötz and C. Götz, *Ann.*, **358**, 183 (1908).

(7) O. Wallach, *ibid.*, **343**, 40 (1905).

(8) E. Knoevenagel, *ibid.*, **281**, 25 (1894).

(9) J. Decombe, *Bull. soc. chim.*, **12**, 651 (1945).

(10) E. Knoevenagel, *Ann.*, **288**, 321 (1895); E. Beckmann and H. Eickelberg, *Ber.*, **29**, 418 (1896); A. D. Petrow, *ibid.*, **68**, 898 (1930).

(11) P. Rabe and F. Rahm, *Ber.*, **38**, 969 (1905); W. A. Noyes, *Am. Chem. J.*, **20**, 789 (1898).

(12) Melting point ranges for mixtures of 2,3,5- and 3,4,5-trimethylphenol were found to be: for 20% 2,3,5-trimethylphenol, 74–86°, for 40% and for 60%, 67–68°, and for 80%, 68–73°. These data are in accord with the m.p. of 66–66.5° reported for a mixture of these trimethylphenols obtained by the aromatization of dihydroisophorone with fuming sulfuric acid (ref. 2, see footnote 10).

(13) K. von Auwers and K. Saurwein, *Ber.*, **55**, 2372 (1922); G. Baddeley, *J. Chem. Soc.*, 330 (1944).

(14) O. Kruber and A. Schmitt, *Ber.*, **64**, 2270 (1931).

(15) O. Kruber and A. Marx, *ibid.*, **73B**, 1175 (1940).

(16) J. C. Baker, *J. Chem. Soc.*, 663 (1926).

(17) H. J. Hagemeyer, Jr., and D. C. Hull, *Ind. Eng. Chem.*, **41**, 2920 (1949).

(18) A. W. Crossley and H. R. LeSueur, *J. Chem. Soc.*, **81**, 821 and 1533 (1902); *ibid.*, **83**, 110 (1903); A. W. Crossley, *ibid.*, **85**, 264 (1904).

(19) A. W. Crossley and N. Renouf, *ibid.*, **105**, 165 (1914).

(20) L. E. Hinkel and W. D. Williams, *ibid.*, **121**, 2498 (1922); L. E. Hinkel, *ibid.*, **125**, 1847 (1924).