hydrochloric acid gives, in addition to the water-insoluble "ethanol lignin," a mixture of distillable oils in amount equal to about 8.2% of the weight of (Klason) lignin present in the original wood.

2. The mixture contains aldehydic, acidic, phenolic and neutral products. The principal constituent has been identified by analysis and synthesis as α-ethoxypropioveratrone.

3. Evidence is adduced to show that this product is probably derived from α-hydroxypropiovanillone either present, as such, in the wood, or formed as a fission product from a relatively simple molecular complex.

4. It is suggested that this derivative (α-hydroxypropiovanillone), or a dismutation isomer of it, forms the true building unit from which "extracted" lignins from soft woods are derived by condensation-polymerization reactions brought about by the extractant.

MONTREAL, CANADA RECEIVED DECEMBER 10, 1938

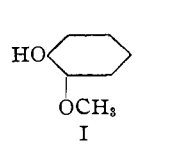
[CONTRIBUTION FROM THE DIVISION OF INDUSTRIAL AND CELLULOSE CHEMISTRY, MCGILL UNIVERSITY]

Studies on Lignin and Related Compounds. XXXVI. Ethanolysis of Maple Wood

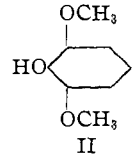
BY M. J. HUNTER,[1] A. B. CRAMER[2] AND HAROLD HIBBERT

Previous work in these laboratories has resulted in the isolation of a considerable number of aromatic fission products from "extracted" lignins, mostly lignin sulfonic acids. Thus, from spruce lignin sulfonic acid, vanillin,[3] acetovanillone[4] and guaiacol[5] have been obtained, while from maple lignin sulfonic acid, syringic aldehyde,[6] acetosyringone,[4b] pyrogallol 1,3-dimethyl ether,[7] in addition to vanillin[6] and guaiacol,[7] have been isolated.

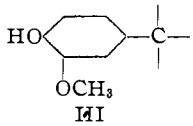
A sharp characteristic difference is thus to be found between soft and hard woods in that lignin constituents of the former are distinguished by containing only the guaiacyl (I), while the latter contain both the guaiacyl (I) and syringyl (II) radicals.



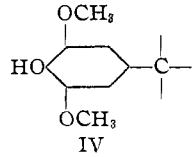
I



II



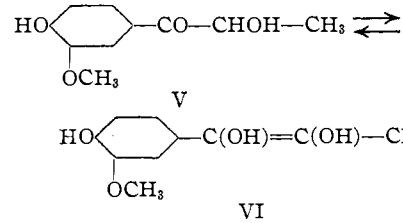
III



IV

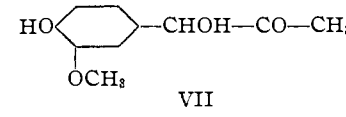
Moreover, the structure of these products indicates the presence of at least *one* carbon atom in the side chains of (III) and (IV).

In the preceding communication[8] experimental evidence is given indicating that the side chain of the building-unit in the case of spruce wood lignin is that shown in (V). The possibility, however, is not to be overlooked that the α-hydroxypropiovanillone (V) containing this side-chain may be in equilibrium, in the native lignin, with the isomeric dismutation forms portrayed in VI and VII.



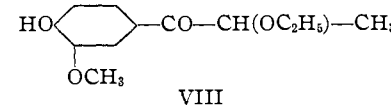
V

VI

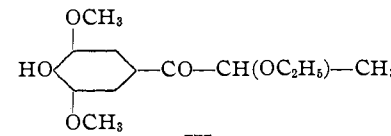


VII

It was therefore to be anticipated, in the light of the above, that in the case of hard woods the water-soluble ethanolysis fractions would be found to contain, in addition to α-ethoxypropiovanillone (VIII), the corresponding syringyl



VIII



IX

(1) Postgraduate student and holder of Dow Chemical Company Fellowship.

(2) Postgraduate student and holder of Hibbert-Cole Fellowship.

(3) Tomlinson and Hibbert, THIS JOURNAL, **58**, 345 (1936).

(4) (a) Buckland, Tomlinson and Hibbert, *Can. J. Research*, **B16**, 54 (1938); (b) Leger and Hibbert, THIS JOURNAL, **60**, 565 (1938).

(5) Leger and Hibbert, *Can. J. Research*, **B16**, 68 (1938).

(6) Hawkins, Wright and Hibbert, THIS JOURNAL, **59**, 2447 (1937).

(7) Leger and Hibbert, *Can. J. Research*, **B16**, 151 (1938).

(8) Cramer, Hunter and Hibbert, THIS JOURNAL, **61**, 509 (1939).

derivative, namely, α-ethoxypropiosyringone (IX) and experiments on maple wood have shown this to be the case.

When maple wood meal is subjected to the same ethanolysis treatment as previously outlined,[8] and the water-soluble products isolated, yields are obtained, as shown.

		% yield on wt. of dry wood	% yield on wt. of (Klason) lignin
Fraction 1	Aldehyde	1.20	5.4
Fraction 2	Acids	0.38	1.6
Fraction 3	Phenols		
	(a) low boiling	1.70	7.6
	(b) high boiling	1.10	4.8
Fraction 4	Neutral	0.49	2.1
Total		4.87	21.5

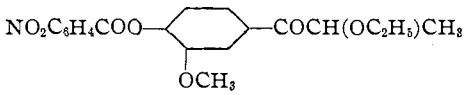
It can be seen that much higher yields are obtained from maple wood than from spruce, the total weight of identified products being approximately double that in the case of spruce. The phenolic fraction from maple wood contains, in appreciable amount, a higher boiling constituent, differing in this respect from spruce wood.

A concentration of 2% hydrogen chloride and refluxing for twenty hours is found sufficient for the extraction. In the case of maple wood only about 30% of the original (Klason) lignin remains in the wood residue.

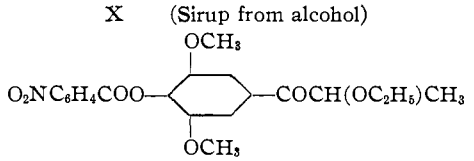
The above maple wood phenol fraction (3) is a thick brown oil which on distillation at 140–185° (bath temperature) and a pressure of 0.005–0.010 mm. gives a yield of about 50% of a thick yellowish-colored oil and leaves a viscous residue which could not be distilled.

If, however, the total crude phenol fraction (3) is subjected to a preliminary methylation with diazomethane, or dimethyl sulfate, then on distillation and removal of the lower boiling, methylated phenols, the thick tar which remains can be distilled at around 280–320° (bath temp.) at 0.020 mm. pressure, the distillate being a very viscous, deep orange-colored resin at room temperature.

Separation of the Guaiacyl and Syringyl Constituents.—Inoculation of the low-boiling, methylated fraction with crystalline α-ethoxypropioveratrone, obtained from spruce wood meal,[8] brought about a partial crystallization of the material during the course of several weeks. Filtration of the crystalline α-ethoxypropioveratrone left a clear yellow oil, which could not be induced to crystallize, either as such, or in the form of a hydrazone. Attention was then again directed to the unmethylated lower boiling phenol fraction. It was found that esterification of this phenol mixture with *p*-nitrobenzoyl chloride gave an ester product from which a well-characterized crystalline product (XI) (m. p. 141–142.5°) separated readily. Inasmuch as treatment of α-ethoxypropiovanillone with the same reagent, under identical conditions, yielded a *p*-nitrobenzoyl ester in the form of a *non*-crystallizable sirup (X), it was possible in this way to separate the syringyl from the guaiacyl fractions



X (Sirup from alcohol)



XI (Crystalline substance)

The crystalline ester XI, after purification and analysis, was shown to have the empirical formula $C_{20}H_{21}NO_8$, corresponding to the *p*-nitrobenzoate of a derivative $C_{13}H_{18}O_5$. Alkoxyl analysis, based on the latter, showed the presence of three alkoxyl groups. It reacted with 2,4-dinitrophenylhydrazine to give an amorphous, yellowish-colored hydrazone, analysis of which corresponded with the hydrazone of an ester of the syringyl analog of α-ethoxypropiovanillone (VIII), namely, α-ethoxypropiosyringone (IX).

This latter ethoxy derivative was therefore synthesized and converted into its *p*-nitrobenzoate, which was found to be identical with the crystalline benzoate prepared from the above low-boiling maple wood phenol fraction. A yield of about 40% of the crystalline ester (XI) was obtained from the esterification of the unmethylated phenols; on the other hand, methylation of the same phenols gave a product from which 25% could be recovered as the crystalline *α-ethoxypropioveratrone.*

Synthesis of α-Ethoxypropiosyringone *p*-Nitrobenzoate.—This synthesis was accomplished by the following series of reactions:

(1) 3,4,5-trimethoxypropiophenone[9] $\xrightarrow{Br}$

(2) α-bromo-3,4,5-trimethoxypropiophenone $\xrightarrow{H_2SO_4}$

(3) α-bromopropiosyringone $\xrightarrow{NaOAc}$

(9) M. T. Bogert and M. Isham, THIS JOURNAL, **36**, 514 (1914).

(4) α-acetoxypropiosyringone $\xrightarrow{\text{alcoholic HCl}}$

(5) α-ethoxypropiosyringone $\xrightarrow{p\text{-nitrobenzoyl chloride}}$

(6) α-ethoxypropiosyringone *p*-nitrobenzoate

It can be seen that step (2) involves a demethylation process and in order to leave no doubt regarding the removal of the 4-methyl group additional confirmatory evidence was obtained as follows. Trimethylgallic acid is readily converted to syringic acid[9,10] by the action of strong sulfuric acid. When this method was applied to 3,4,5-trimethoxypropiophenone, a compound with the empirical formula and properties of propiosyringone was obtained. Obviously, the position of the free hydroxyl group remained uncertain; however, the identical compound was obtained by application of the Fries rearrangement[11] technique to the propionate of pyrogallol 1,3-dimethyl ether. This indicated more conclusively that the action of concentrated sulfuric acid on the α-bromo-3,4,5-trimethoxypropiophenone had removed the 4-methyl group to give α-bromopropiosyringone. An attempted bromination of the propiosyringone was unsuccessful, presumably due to the presence of the *p*-phenolic group. After thus establishing the nature of the reaction in step (2), the conversion to the α-acetoxy compound was effected by boiling the α-bromo derivative with sodium acetate in glacial acetic acid solution, this reagent proving much more suitable than the solution of potassium acetate in ethanol used previously with α-bromopropioveratrone.[8] The acetate was then transformed into the corresponding α-ethoxy derivative, which in turn gave, in satisfactory yield, the *p*-nitrobenzoate of α-ethoxypropiosyringone identical with the crystalline product obtained on benzoylation of the low-boiling maple wood phenol fraction isolated from the ethanolysis product.

The data thus obtained provide a further important contribution to the subject of characterization of soft and hard woods. Investigations are in progress on Douglas fir, hemlock, California red wood, Southern pine, straw, corn cobs, jute and flax and preliminary results indicate that the ethanolysis products formed are similar in character to those described in this and the preceding communication.[8]

(10) Hahn and Wassmuth, *Ber.*, **67**, 701 (1934).

(11) Coulthard, Marshall and Pyman, *J. Chem. Soc.*, 280 (1930).

Experimental

Maple wood (50 mesh) was submitted to the usual prior extraction treatment with (a) alcohol and benzene (equal parts), (b) alcohol and (c) water. It had a (Klason) lignin content of 23%. 450 g. of this vacuum-dried (56° at 30 mm.) wood meal was mixed with 3 liters of absolute ethanol containing 2% hydrogen chloride, and refluxed for twenty hours. The reaction mixture was filtered, and the residual wood washed with 2 liters of ethanol. The ethanol filtrate was then treated as described in the previous paper:[8] weight of residual wood meal, 268 g. (lignin (Klason) content, 13.1%); precipitated ethanol lignin, 44.6 g.; crude ether-soluble oils, 36.7 g. The ether-soluble oils apparently contained some carbohydrate material carried over during the continuous ether-extraction process. Fractionation of the crude oils according to the previous method[8] gave (1) aldehyde material, 5.6 g.; (2) acidic substances, 1.7 g.; (3) phenols, 17.5 g.; (4) neutral fraction, 2.2 g. The phenol fraction was methylated with dimethyl sulfate (60 cc.) and 31% sodium hydroxide solution (60 cc.) which were added simultaneously over a period of two hours with stirring, under nitrogen, at room temperature. The methylated material separated from the alkaline solution as an orange-colored oil which was then dissolved in ether and dried with anhydrous sodium sulfate. Concentration of the ether solution gave an oil (16.8 g.), from which, on distillation, the following fractions were obtained: (a) low boiling methylated phenols (7.9 g.), bath temperature 135–175° at 0.005 mm.; (b) high boiling phenols (5.0 g.), bath temperature 270–320° at 0.020–0.050 mm.; (c) charred residue (2.6 g.); (d) volatile decomposition products collected in "dry ice" trap (1.1 g.).

The low-boiling phenol fraction (a) (5.3 g.) was now inoculated with crystals of α-ethoxypropioveratrone (obtained in the ethanolysis of spruce[8]) and after standing for four weeks, at room temperature, yielded 1.3 g. of a crystalline methylated product. This was recrystallized by solution in hot ethanol and dilution with water to turbidity. It melted at 81–82°; mixed melting point determination with α-ethoxypropioveratrone, obtained from spruce wood, showed no depression.

From a similar ethanolysis of maple wood there was obtained 16.1 g. of crude phenols, which on distillation (without prior methylation) gave a low-boiling phenol fraction (8.1 g.) at a bath temperature of 170–200° at 0.025 mm. This latter was then converted into a mixture of the *p*-nitrobenzoates.

Preparation of the Nitrobenzoates of the Mixed Phenols.—The above unmethylated "maple" wood phenol fraction (8.1 g.) was dissolved in dry pyridine (65 cc.) and *p*-nitrobenzoyl chloride (12.5 g.) added. After standing for two hours at room temperature the product was poured into a mixture of finely crushed ice (400 g.) and concentrated hydrochloric acid (100 cc.). The sticky precipitate was separated from the solution and washed well with cold sodium hydroxide (2%). After a series of partial crystallizations from ethanol and ethanol–water mixtures, 3.8 g. of crystalline product, m. p. 140–142°, was obtained. Concentration of the mother liquors gave a viscous mass which partially crystallized on standing.

Analysis of the crystalline syringyl p-nitrobenzoate.—Calcd. for $C_{16}H_{10}O_5(OCH_3)_2(OC_2H_5)$: C, 59.5; H, 5.26;

N, 3.47; alkoxyl (as methoxyl), 23.1. Found: C, 59.5; H, 5.28; N, 3.55; methoxyl, 23.1.

Nitrobenzoate of the Unmethylated "Spruce" Phenol.—Distilled unmethylated spruce phenol (1.0 g.)[8] was treated with *p*-nitrobenzoyl chloride (1.6 g.) in dry pyridine and the reaction product isolated in similar manner to that of the "maple" phenol esters. All attempts to obtain a *crystalline* product from ethanol and ethanol–water mixtures were unsuccessful.

Synthesis of α-Ethoxypropiosyringone *p*-Nitrobenzoate

(1) **Preparation of 3,4,5-Trimethoxypropiophenone.**—This was carried out according to the method of Bogert and Isham[9] by treating the methyl ester of trimethylgallic acid with an excess of ethylmagnesium bromide to give 3,4,5-trimethoxyphenyl-diethylcarbinol. This was converted to the corresponding pentene, which on ozonolysis gave an over-all yield of 30–40% of the ketone. (Bogert obtained 30% crystalline carbinol in this reaction. It is of interest that this can be increased to 85% by omitting the use of a drying agent with the ether extract from the Grignard products, and concentrating under reduced pressure.)

(2) **Formation of α-Bromo-3,4,5-trimethoxypropiophenone.**—3,4,5-Trimethoxypropiophenone (5.5 g.) was dissolved in chloroform (25 cc.) and a solution of bromine (3.9 g.) in chloroform (15 cc.) slowly added, with stirring, at room temperature. The solution was allowed to stand for one hour, then washed, first with water, then with bicarbonate solution and dried with anhydrous calcium chloride. It was now concentrated under reduced pressure to a thick yellow sirup, which quickly solidified. Recrystallization from ethanol (15 cc.) gave 5.6 g. (75%) of pure product (m. p. 83–84°). *Anal.* Calcd. for $C_{12}H_{15}O_4Br$: C, 47.5; H, 4.95; Br, 26.3; OCH_3, 30.7. Found: C, 47.7; H, 5.13; Br, 26.7; OCH_3, 30.7.

(3) **Conversion of the Trimethoxybromo Derivative to α-Bromopropiosyringone.**—3,4,5-Trimethoxy-α-bromopropiophenone (5.2 g.) was dissolved in concentrated sulfuric acid (27 cc.) and kept for twelve hours at 45–47°. The orange-colored solution turned deep brown and smelled of sulfur dioxide. It was poured onto cracked ice (150 g.) and the bluish-gray micro-crystalline precipitate then filtered and dissolved while wet in hot ethanol (25 cc.). The hot solution was diluted with hot water (10 cc.) and on standing at 0° crystallized to a solid mass. Use of this alcohol–water ratio resulted in most of the dark-colored impurities remaining in solution. The crystalline product was again dissolved in alcohol, the solution decolorized with animal charcoal and the above recrystallization procedure repeated: yield, 3.8 g. (77%); m. p. 89–90°.

Anal. Calcd. for $C_{11}H_{13}O_4Br$: C, 45.7; H, 4.45; Br, 27.5; OCH_3, 21.5. Found: C, 45.7; H, 4.64; Br, 27.7; OCH_3, 21.7.

Preparation of Propiosyringone.—This was carried out by two methods (a) and (b) as below.

(a) 3,4,5-Trimethoxypropiophenone (2.5 g.) was dissolved in concentrated sulfuric acid (12 cc.) and the solution maintained at 45–47° for twelve hours. The acid solution was then poured onto finely cracked ice (100 g.) and the grayish micro-crystalline reaction product recrystallized from ethanol: yield 1.6 g. (67%); m. p. 109–110°.

(b) A mixture of pyrogallol 1,3-dimethyl ether (Eastman Kodak Co.) (15.4 g.) and propionic acid (7.5 cc.) was treated with thionyl chloride (13 g.) according to the method of Miller, Hartung, Rock and Crossley.[12] The pale yellow oil (propionate of pyrogallol 1,3-dimethyl ether) thus obtained (13.6 g.) boiled at 125–127° at 0.5 mm.; yield 64%.

Anal. Calcd.: OCH_3, 29.6. Found: OCH_3, 30.2.

This propionate was now mixed with nitrobenzene (40 cc.) containing aluminum chloride (18 g.) and the same procedure followed as with guaiacol propionate.[11] The nitrobenzene solution was poured, with stirring, into a mixture of chipped ice (200 g.) and concentrated hydrochloric acid (50 cc.). The mixture was extracted with three 100-cc. portions of ether and the resulting ether solution then extracted five times with 50-cc. portions of potassium carbonate solution (5%). Neutralization of the carbonate solution gave a finely divided crystalline mass (2.0 g.), which after decoloration was recrystallized from aqueous alcohol: yield, 1.5 g. (11%); m. p. 109–110°. A mixed melting point determination with the product obtained from the demethylation of trimethoxypropiophenone with concentrated sulfuric acid showed no depression.

(4) **Synthesis of α-Acetoxypropiosyringone.**—α-Bromopropiosyringone (1.5 g.) was dissolved in a mixture of glacial acetic acid (10 cc.) and anhydrous sodium acetate (4.0 g.). The solution was heated to 100° for six hours and then poured into 100 cc. of cold water. After standing for some time at 0° crystallization was induced by scratching the side of the beaker. The acetoxy derivative was crystallized from a small amount of absolute ethanol in the form of diamond-shaped crystals: yield, 0.85 g. (61%); m. p. 172–173°.

Anal. Calcd. for $C_{13}H_{16}O_6$: C, 58.2; H, 5.98; OCH_3, 23.1. Found: C, 57.8; H, 6.17; OCH_3, 22.9.

(5) **Preparation of α-Ethoxypropiosyringone.**—α-Acetoxypropiosyringone (1.3 g.) was dissolved in absolute ethanol (40 cc.) containing 2% hydrochloric acid by volume. This solution was refluxed for twelve hours. The color turned from red to dark purple. The solvent was removed under reduced pressure, leaving a purplish-colored oil. On the addition of dry ether, the oil dissolved, leaving behind most of the insoluble coloring matter. Removal of the ether and distillation of the sirupy residue at a bath temperature of 160–180° (0.007 mm.) gave 0.66 g. (53%) of a sirupy yellow oil.

(6) **Conversion of the Sirupy α-Ethoxypropiosyringone to the Crystalline *p*-Nitrobenzoate.**—α-Ethoxypropiosyringone (0.66 g.) was dissolved in dry pyridine (15 cc.) and *p*-nitrobenzoyl chloride (1.2 g.—one mol excess) added. The product was allowed to stand at room temperature for two hours and then poured into a mixture of finely cracked ice (50 g.) and concentrated hydrochloric acid (20 cc.). The light-yellow, amorphous precipitate was filtered, washed well with 50 cc. of cold sodium hydroxide solution (2%) and the benzoate then crystallized

(12) Miller, Hartung, Rock and Crossley, THIS JOURNAL, **60**, 7 (1938).

twice from hot absolute ethanol (25 cc.): yield, 0.56 g. (62%); m. p. 141–142.5°. Mixed melting point with the benzoate obtained from the low-boiling (ethanolysis) phenol fraction, 141–142.5°.

Anal. Calcd. for $C_{20}H_{21}NO_8$: C, 59.5; H, 5.26; N, 3.47; alkoxyl as methoxyl, 23.1. Found: C, 59.3; H, 5.30; N, 3.60; methoxyl, 22.9.

Repetition of this work starting with 6.3 g. of carefully purified α-bromo-3,4,5-trimethoxypropiophenone gave identical results and somewhat better yields.

Acknowledgment.—The authors wish to thank the Carnegie Corporation, New York, and the Canadian Pulp and Paper Association for kind financial assistance. They also wish to acknowledge their indebtedness to Dr. Joseph L. McCarthy and Dr. W. Lincoln Hawkins for the kind help rendered during this research.

Summary

1. Ethanolysis of maple wood with ethanol–hydrochloric acid gives, in addition to the water insoluble "ethanol lignin," a mixture of distillable oils in amount equal to around 20% of the weight of (Klason) lignin present in the original wood.

2. The mixture contains aldehydic, acidic, phenolic and neutral products. The principal constituents of the phenolic fraction have been identified by analysis and synthesis as α-ethoxypropioveratrone and α-ethoxypropiosyringone.

3. These products are in all probability derived from the corresponding hydroxy derivatives either present as such, or formed as fission products from a relatively simple molecular complex.

4. It is suggested that these derivatives (α-hydroxypropiovanillone and α-hydroxypropiosyringone), or their dismutation isomers, form the true building-units of which native lignins are composed, or from which "extracted" lignins from hard woods are derived by condensation–polymerization reactions brought about by the extractant.

MONTREAL, CANADA RECEIVED DECEMBER 13, 1938

[CONTRIBUTION FROM THE ORGANIC CHEMICAL LABORATORY OF PHARMACY, UNIVERSITY OF LA PLATA]

Secondary Amines by the Leuckart Synthesis

BY ARMANDO NOVELLI

The Leuckart synthesis[1] of primary amines by heating ketones with formamide or ammonium formate has been improved by Ingersoll and coworkers.[2] Needing several secondary β-phenylethylamines for pharmacological assays, we varied the Ingersoll adaptation by using the corresponding alkylformamides, and obtained the desired amines, as formyl derivatives, by the general equation

$$RCOR' + 2HCONHR'' \longrightarrow NH_2R'' + RCH(NR''COH)R' + CO_2$$

This method has been applied by Wallach[3] to certain alicyclic and terpenoid ketones, but, curiously enough, has been used very little by others. The advantages of simplicity and economy are evident, but possibly have been outweighed, as Ingersoll suggests, by the troublesome procedure, low yields, and formation of secondary and tertiary amines as by-products.

We have found that this method of obtaining secondary amines is general and satisfactory, giving 50–80% yields based on the ketone, taken in 0.01 to 1 mole lots. Excess of alkylformamide is used (4 moles to 1 of ketone) but the excess is recovered. The secondary amines are obtained directly as hydrochlorides, and are very pure, with no tertiary derivative.

In this paper we describe a number of newly prepared amines and some others previously made only by more complicated procedures. The methyl and ethyl derivatives of phenethylamine were obtained by Busch and Lefhelm[4] from benzalmethylamine and methyl- or ethylmagnesium iodide.

The formyl derivatives were not isolated but were hydrolyzed directly by refluxing with hydrochloric acid. In later papers we hope to discuss the little known mechanism of the Leuckart synthesis and describe a new series of secondary amines from β-phenylethylamines.

Experimental

General Method.—In a distilling flask fitted with a cork bearing a thermometer extending nearly to the bottom is placed 4 moles of alkylammonium formate prepared by adding the proper amine to

(1) Leuckart, *et al.*, *Ber.*, **18**, 2341 (1885); **19**, 2128 (1886); etc.
(2) Ingersoll, *et al.*, THIS JOURNAL, **58**, 1809 (1936).
(3) Wallach, *Ann.*, **343**, 54 (1905).
(4) Busch and Lefhelm, *J. prakt. Chem.*, [2] **77**, 21, 23 (1908).