*Anal.* Calcd. for $C_{13}H_{15}O_4N$: C, 62.65; H, 6.02; N, 5.62. Found: C, 62.84; H, 6.15, 5.95; N, 5.57.

**The Amide of (3-Hydroxy-1-ethyloxindolyl-3)-acetic Acid (IV).**—Compound II (1.0 g.) in 20 cc. of concentrated ammonoum hydroxide was allowed to stand at room temperature for sixteen days. During this time II dissolved slowly. The product was isolated by slow evaporation of the solution at room temperature. Compound IV is readily soluble in most common solvents, including benzene, ethyl alcohol, acetone, and water. It was purified by crystallization through slow evaporation of the aqueous solution; no attempt was made to isolate more than a small percentage of the theoretical yield; hexagonal colorless prisms, m. p. 186.5–188.5°.

*Anal.* Calcd. for $C_{12}H_{14}O_3N_2$: N, 11.97. Found: N, 11.53, 11.71.

**The Amide of (3-Hydroxy-1-methyloxindolyl-3)-acetic Acid (VII).**—Compound VII was prepared by the same method as that used for the preparation of IV: crystallized from water, by slow evaporation of the solution, as colorless stubby prisms; m. p. 191.5–193.5°.

*Anal.* Calcd. for $C_{11}H_{12}O_3N_2$: N, 12.73. Found: N, 12.41, 12.58.

**1-Ethyl-2-quinolone-4-acid (III). A. From Malonic Acid and N-Ethylisatin.**—N-Ethylisatin (3.4 g.) and malonic acid (2.1 g.) in 10 cc. of glacial acetic acid were refluxed for twenty hours. The product, which separated when the solution was cooled, was recrystallized from dilute ethyl alcohol and was obtained as long white needles, m. p. 205–206°.

**B. By Hydrolytic Treatment of II.**—A mixture of Compound II (0.5 g.) and 10 cc. of 50% potassium hydroxide solution was refluxed for two hours. At the end of this time the solution was diluted with an equal volume of water, decolorized with charcoal, and filtered. Acidification of the filtrate with dilute sulfuric acid caused the precipitation of III.

**C. By Hydrolytic Treatment of IV.**—Compound IV was substituted for II in the procedure outlined above in B. Compound III again resulted.

The crude samples of III from B and C were purified by crystallization from dilute ethyl alcohol. Each melted at 205–206°, and no depression of the melting point was observed when either was mixed with a sample of III from A.

**Ethyl Ester of III.**—Individual samples of III from procedures A, B and C above were esterified with ethyl alcohol. The products of these esterifications were found, by melting point methods, to be identical. The ester crystallizes from dilute ethyl alcohol as long white needles; m. p. 88.5–89°.

*Anal.* Calcd. for $C_{14}H_{15}O_3N$: N, 5.71. Found: N, 5.58.

**1-Methyl-2-quinolone-4-acid (VI). (A) From Malonic Acid and N-Methylisatin.**—These compounds were heated together in glacial acetic acid according to the method described by Aeschlimann,[3] and yielded VI.

**(B) By Hydrolytic Treatment of V or VII.**—Compound V (or VII) was heated for two hours in a 50% solution of potassium hydroxide. The product was precipitated by acidification with dilute sulfuric acid, and was obtained as short white needles by crystallization from ethyl alcohol; m. p. 248–250°. Melting point methods and comparison of the ethyl esters proved the samples of VI from A and B to be identical.

## Summary

N-Methyl- and N-ethylisatins have been shown to undergo the normal Reformatsky reaction with zinc and ethyl bromoacetate to yield the respective ethyl esters of (3-hydroxy-1-alkyloxindolyl-3)-acetic acid. These esters, and the amides derived from them, yield the corresponding 1-alkyl-2-quinolone-4-acids under hydrolytic treatment.

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# Alkylation of Benzene by Esters by the Friedel–Crafts Reaction

BY EVERETT BOWDEN

This paper describes the alkylation of benzene by certain esters using anhydrous aluminum chloride as the condensing agent.

Alkylation by the Friedel–Crafts reaction usually has employed alkyl halides. By analogy the same results might be expected using esters. For the most part this was found to be the case, although the structural analogy between esters and acid anhydrides led the author to anticipate the formation, in part at least, of ketones since benzene and acetic anhydride will consistently give more than one mole of acetophenone for each mole of the anhydride. Such formation of ketones from esters has in fact been observed by Kaschtanow,[1a] by Guyot,[2] and by Cryer.[3] Friedel and Crafts,[4] however, showed that ethyl chlorocarbonate alkylated benzene instead of acylating it, as might be expected. Every effort was made in our work to discover ketones in the by-products of the reactions we carried out, but at no time was sufficient material of proper boiling point obtained to permit such identification. The quantity of

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[1] (a) L. I. Kaschtanow, *Chem. Zentr.*, **104**, 600 (1933); (b) **104**, 2512 (1933).

[2] Guyot, *Compt. rend.*, **144**, 1120 (1908).

[3] J. Cryer, *Trans. Roy. Soc. Can.*, [3] **19**, 29 (1925); *C. A.*, **20**, 408 (1926).

[4] Friedel and Crafts, *Compt. rend.*, **84**, 1450 (1877).

such material, if present, was negligible. However, it is possible that conditions might be altered to favor ketone formation.

Kaschtanow[1] also obtained alkylated benzenes. Boedtker[5] and Tronov[6] have used ethyl nitrate to nitrate benzene and its homologs in the presence of aluminum chloride.

## Experimental Part

The reaction between benzene and ester in the presence of aluminum chloride proceeded smoothly with alkylbenzenes as the final product, once the optimum conditions for *each* reaction had been approximately established. However, very great variation was found in the behavior of the esters. For ethyl formate, isobutyl formate, isoamyl acetate and *n*-amyl nitrite no satisfactory technique as yet has been developed. It was found that esters of acids that were resistant to decomposition, *e. g.*, *n*-butyl propionate, gave slower reactions and better yields than those derived from alcohols relatively resistant to dehydration and containing unstable acid radicals, such as *n*-propyl formate.

Procedures were therefore of three types: (A) esters found by experience to require no special technique; (B) esters of easily decomposed acids; (C) esters of stable acids. These methods are described below, and were designed to keep the concentration of the hypothetical intermediate alkene as low as possible, in (B) by slow addition of ester and in (C) by slow heating, and the inherent resistance of the ester. It is felt that any advantageous variation in procedure will be in the direction of a *slower* reaction, since such conditions were found to be favorable to a high yield.

Very slight changes in procedure frequently produced marked changes in results. When 30 g. of aluminum chloride was used with 0.25 mole of butyl propionate, followed by procedure (C), all of the ester was recovered unchanged. On the other hand the use of 40 g. of the chloride gave a 92% yield of product.

Insufficiency of aluminum chloride almost always caused a second layer to form, which disappeared on addition of more of the aluminum chloride, but if the mixture had been allowed to stand more than a short time with excess of ester over chloride, very little alkylation occurred. Such a mixture would stand boiling without change; a slight excess of aluminum chloride always produced polymerization on boiling. On this account in procedure (B) the ester was always added *to* the optimum quantity of aluminum chloride in benzene. Much of an excess of aluminum chloride caused the precipitation of a dark oil layer which would not redissolve and which contained all of the polymerized material.

The products of the reaction, in addition to the alkylated benzene, were high boiling light colored oils too small in quantity for fractionation. When more than a gram of dark tar-like material resulted it was due to an overcharge of aluminum chloride as previously noted. Much of the reactant may have been converted to volatile alkene, since the total amount of recovery was much less than the theoretical (in the case of *n*-butyl formate, 73% yield of hydrocarbon, no other product).

While the products of the reaction were usually rearranged hydrocarbons, extreme branching was not observed as has been noted with alkyl halides.[7] Ethyl benzoate did not alkylate its own nucleus, as the esters of hydroxybenzoic acids have been observed to do in the presence of boron fluoride.[8]

### Experimental Procedures

**Procedure (A).**—Forty grams of anhydrous aluminum chloride was added to 250 ml. of dry benzene followed by 0.25 mole of ester (0.125 mole of dibasic ester), added in several portions. The mixture was then boiled under reflux for one-half to one hour, and, after cooling, worked up by (C) below: ethyl acetate, 60% hydrocarbon (Table I); isopropyl acetate, 68%; *n*-butyl oxalate, 55%; ethyl sulfate, 80%; *n*-butyl sulfite, 41%.

TABLE I

CONSTANTS OF PRODUCTS

| Alkyl | Product | B. p., uncorr., °C. | M. p. diacetamino deriv. uncorr., °C. |
|---|---|---|---|
| Ethyl | Ethylbenzene | 134–137 | |
| *i*-Propyl | *i*-Propylbenzene | 145–148 | 215 |
| *n*-Propyl | *n*-Propylbenzene | 150–151 | 203[a] |
| *n*-Butyl | *s*-Butylbenzene | 170–172 | 192 |
| *i*-Butyl | *t*-Butylbenzene | 168.5 | 210 |

[a] This indicates admixture of iso compound, but microscopic examination showed only *very* small amounts of it.

**Procedure (B).**—Thirty grams of anhydrous aluminum chloride was added to 250 ml. of dry benzene and 0.25 mole of the ester (0.125 mole of dibasic ester) added very slowly over a period of four to nine hours with constant stirring at room temperature. If an insoluble oil separated, it was promptly redissolved by adding small portions of aluminum chloride. After standing overnight the mixture was heated gradually to 60°, four hours being required to reach this temperature. The rest of the procedure was the same as in (C): *n*-propyl sulfite, 66% yield; *n*-propyl formate, 66%; isobutyl acetate, 33%.

**Procedure (C).**—Forty grams of the anhydrous aluminum chloride was added to 250 ml. of dry benzene, followed all at once by 0.25 mole of the chosen ester. This was shaken, most of the chloride dissolved and the temperature rose to 35–40°. The solution was clear and light colored. In the case of esters of short chain acids the mixture was allowed to stand overnight. With increasing molecular weight of acid, the mixture was proceeded with directly. The reaction flask was fitted with a mercury bubbler, immersed in a water-bath and heated very slowly, no increase in heat being allowed till evolution of hydrogen chloride had practically ceased. Four to six hours were required to reach 75°. The longer the acid chain the slower the reaction began and a higher temperature and a longer period of heating were required to complete the reaction. After cooling, the solution was poured on ice and hydrochloric acid, the benzene layer washed with concentrated hydrochloric acid, with dilute acid, with water, with 10% sodium hydroxide, with water and then frac-

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(5) Boedtker, *Bull. soc. chim.*, [4] **3**, 726 (1908).

(6) Tronov, *C. A.*, **25**, 2973 (1931).

(7) *Cf. Chem. Rev.*, **17**, 332, 342 (1935).

(8) Croxall, Sowa and Nieuwland, THIS JOURNAL, **57**, 1549 (1935).

tionated directly through a Widmer column after distillation of the benzene; yields: *n*-butyl formate, 73%; *n*-butyl propionate, 92%; *n*-butyl isobutyrate, 73%; *n*-butyl *n*-valerate, 85%; *n*-butyl 2-ethylvalerate, 78%; *n*-butyl benzoate, 80%; *n*-butyl stearate 40%.

The hydrocarbons were refractionated, finally over metallic sodium. They were characterized by boiling point, by their diacetamino derivatives, and by microscopic appearance of derivative according to Ipatieff and Schmerling.[9] The hydrocarbon obtained was always the same for the same alkyl group irrespective of the acid radical. The difference in boiling point between the isopropyl and the normal propyl benzenes was very marked when distilled under identical conditions, and the microscopic identification of their derivatives was definite.

## Discussion of the Reaction

Much of the work described above was predicated on the assumption that alkene formation took place during the reaction followed either by condensation of the olefin with benzene (alkylation), or with another molecule of alkene. This assumption is well within much of the experimental facts; it does not explain all of them. Ipatieff and co-workers have shown that alkenes will combine either with paraffins, with themselves, or with benzene.[10] Ipatieff, however,[10d] believes that the real alkylating agent is the ester. This is open to the objection that while diethyl sulfate, for example, does not alkylate benzene alone, as repeatedly observed by the author, in the presence of aluminum chloride it might be converted to alkene and free acid. The free acids either decompose (formic, for example) or form salts with the aluminum chloride, liberating hydrogen chloride. Thus the aluminum chloride is used up, *i. e.*, it is no longer a catalyst. The alkene then condenses with the benzene, or with itself, forming polymerized material. However, if one assumes with Brochet[11] that the ester alkylates directly, the net result in this instance would be the same but it does not explain why *n*-propyl sulfate[12] yields isopropylbenzene, and *n*-butyl esters give secondary butyl benzene. However the alkene theory does not satisfy the fact that methyl sulfate[13] gives toluene, benzyl alcohol[14] yields diphenylmethane, and benzyl benzoate[1a] gives diphenylmethane. Nor does the alkene theory serve to explain why normal propyl esters yield normal propyl benzenes as the chief end-product, as shown in this paper. Thus neither of the two theories is entirely adequate, and neither explains how aluminum chloride functions. Both serve as useful working hypotheses.

It is of interest to compare the results of alkylating benzene with esters, using boron fluoride as catalyst as reported by McKenna and Sowa[12] with our own using aluminum chloride. In general, those esters which reacted so rapidly that the side reaction, polymerization, became the major reaction in the presence of aluminum chloride, reacted best in the presence of boron fluoride, for example, isobutyl formate, ethyl formate, and *n*-propyl formate. Those esters which reacted slowly enough with aluminum chloride to produce a good yield of hydrocarbon either reacted with difficulty or not at all in the presence of boron fluoride; for example, ethyl acetate and the normal butyl esters. Aluminum chloride appears to be much more active as a catalyst in this reaction.

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## Summary

The use of certain organic and inorganic esters in the Friedel–Crafts reaction has been described. Good yields of alkyl benzenes are obtained by the procedures given. Ketones are not found.

No entirely satisfactory mechanism for the reaction has been suggested.

The formation of *n*-propylbenzene from *n*-propyl esters is noteworthy, since alkyl halides and most esters give rearranged hydrocarbons.

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(9) Ipatieff and Schmerling, THIS JOURNAL, **59**, 1056 (1937).

(10) (a) Ipatieff, Komarewsky and Pines, *ibid.*, **58**, 918 (1936); (b) Ipatieff and Grosse, *ibid.*, **57**, 1616 (1935); *ibid.*, **58**, 915 (1936); (c) Ipatieff, Grosse, Pines and Komarewsky, *ibid.*, **58**, 913 (1936); (d) Ipatieff, Corson and Pines, *ibid.*, **58**, 919 (1936).

(11) Brochet, *Compt. rend.*, **117**, 115 (1893).

(12) McKenna and Sowa, THIS JOURNAL, **59**, 470, 1204 (1937).

(13) Kane and Lowy, *ibid.*, **58**, 2606 (1936).

(14) Meyer and Bernhauer, *Monatsh.*, **53**, 721 (1929); Kirrmann and Graves, *Bull. soc. chim.*, [5] **1**, 1494 (1934).