

Organic Reactions

Organic Reactions

VOLUME III

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PREFACE TO THE SERIES

In the course of nearly every program of research in organic chemistry the investigator finds it necessary to use several of the better-known synthetic reactions. To discover the optimum conditions for the application of even the most familiar one to a compound not previously subjected to the reaction often requires an extensive search of the literature; even then a series of experiments may be necessary. When the results of the investigation are published, the synthesis, which may have required months of work, is usually described without comment. The background of knowledge and experience gained in the literature search and experimentation is thus lost to those who subsequently have occasion to apply the general method. The student of preparative organic chemistry faces similar difficulties. The textbooks and laboratory manuals furnish numerous examples of the application of various syntheses, but only rarely do they convey an accurate conception of the scope and usefulness of the processes.

For many years American organic chemists have discussed these problems. The plan of compiling critical discussions of the more important reactions thus was evolved. The volumes of *Organic Reactions* are collections of about twelve chapters, each devoted to a single reaction, or a definite phase of a reaction, of wide applicability. The authors have had experience with the processes surveyed. The subjects are presented from the preparative viewpoint, and particular attention is given to limitations, interfering influences, effects of structure, and the selection of experimental techniques. Each chapter includes several detailed procedures illustrating the significant modifications of the method. Most of these procedures have been found satisfactory by the author or one of the editors, but unlike those in *Organic Syntheses* they have not been subjected to careful testing in two or more laboratories. When all known examples of the reaction are not mentioned in the text, tables are given to list compounds which have been prepared by or subjected to the reaction. Every effort has been made to include in the tables all such compounds and references; however, because of the very nature of the reactions discussed and their frequent use as one of the several steps of syntheses in which not all of the intermediates have been isolated, some instances may well have been missed.

Nevertheless, the investigator will be able to use the tables and their accompanying bibliographies in place of most or all of the literature search so often required.

Because of the systematic arrangement of the material in the chapters and the entries in the tables, users of the books will be able to find information desired by reference to the table of contents of the appropriate chapter. In the interest of economy the entries in the indices have been kept to a minimum, and, in particular, the compounds listed in the tables are not repeated in the indices.

The success of this publication, which will appear periodically in volumes of about twelve chapters, depends upon the cooperation of organic chemists and their willingness to devote time and effort to the preparation of the chapters. They have manifested their interest already by the almost unanimous acceptance of invitations to contribute to the work. The editors will welcome their continued interest and their suggestions for improvements in *Organic Reactions*.

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CHAPTER 1

THE ALKYLATION OF AROMATIC COMPOUNDS BY THE FRIEDEL-CRAFTS METHOD

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University of Illinois

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INTRODUCTION

Since the discovery by Friedel and Crafts¹ that aluminum chloride catalyzes the condensation of alkyl and acyl halides with various aromatic compounds to effect substitution of an alkyl or acyl group for one or more hydrogen atoms of the aromatic compound, this reaction has been greatly extended in scope with respect to alkylating or acylating agents and catalysts. The use of aluminum chloride as a catalyst for such condensations has been considered in detail by Thomas,² and certain aspects of the reaction have been treated in an earlier volume of this series.³ The present discussion is limited to the direct introduction of alkyl, cycloalkyl, or aralkyl residues containing no functional groups into various aromatic compounds under the influence of such catalysts as AlCl_3 , FeCl_3 , SbCl_5 , BF_3 , ZnCl_2 , TiCl_4 , HF , H_2SO_4 , H_3PO_4 , and P_2O_5 . The alkylating agents include olefins, highly strained cycloparaffins, polyalkylbenzenes, alkyl halides, alcohols, ethers, and esters of organic and inorganic acids. The aromatic compound may be a hydrocarbon, an aryl chloride or bromide, a mono- or poly-hydric phenol or its ether, an aromatic amine, an aldehyde, an acid, a quinone, or certain derivatives of heterocyclic aromatic compounds such as furfural or thiophene.

The Friedel-Crafts process is frequently the most useful method for the introduction of an alkyl group. The reaction is capable of many practical applications, and a large number of patents have appeared on the preparation of alkyl derivatives of various aromatic compounds such as xylene,⁴ naphthalene, and phenols. Patents have covered the utilization of such alkylating agents as the olefins derived from cracking, the mixtures prepared by chlorination of petroleum fractions,⁵ and various naturally occurring waxy esters.⁶ The most important application is the synthesis of ethylbenzene from ethylene and benzene.

SCOPE AND LIMITATIONS

Activity of Catalysts. Very little work has been done on the direct comparison of the relative efficacy of the catalysts used in the Friedel-

¹ Friedel and Crafts, *Compt. rend.*, **84**, 1392, 1450 (1877).

² Thomas, "Anhydrous Aluminum Chloride in Organic Chemistry," American Chemical Society Monograph 87, Reinhold Publishing Corp., New York, N. Y., 1941.

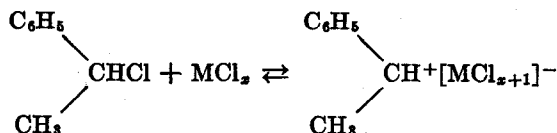
³ (a) Blatt, *Organic Reactions*, I, "The Fries Rearrangement"; (b) Fuson, *ibid.*, "Chloromethylation of Aromatic Compounds."

⁴ Akt.-Ges. f. Anilinf., Ger. pat., 184,230 [*Chem. Zentr.*, II, 366 (1907)].

⁵ Thomas (to Sharples Solvents Corp.), U. S. pat., 2,072,061 [*C. A.*, **31**, 2613 (1937)]. Wiggins, Hunter, and Nash, *J. Inst. Petroleum*, **26**, 129 (1940).

⁶ Robinson (to National Aniline and Chemical Co.), U. S. pat., 2,061,593 [*C. A.*, **31**, 785 (1937)].

Crafts reaction. The catalytic activity for various metal chlorides in the condensation of toluene with acetyl chloride⁷ is in the order $\text{AlCl}_3 > \text{SbCl}_5 > \text{FeCl}_3 > \text{TeCl}_2 > \text{SnCl}_4 > \text{TiCl}_4 > \text{TeCl}_4 > \text{BiCl}_3 > \text{ZnCl}_2$. The effect of catalysts for the Friedel-Crafts reaction in promoting the racemization of α -phenylethyl chloride,⁸ which should parallel their effect in catalyzing alkylation,⁹ is in the order $\text{SbCl}_5 > \text{SnCl}_4 > \text{TiCl}_4 > \text{BCl}_3 > \text{ZnCl}_2 > \text{HgCl}_2$.



Hydrogen chloride, lithium chloride, and tetramethylammonium chloride are ineffective as catalysts for both racemization and alkylation.

No direct comparison of the acidic catalysts has been made, although the order appears to be $\text{HF} > \text{H}_2\text{SO}_4 > \text{P}_2\text{O}_5 > \text{H}_3\text{PO}_4$. In general, a direct comparison of the metal halides with the acids is limited by the fact that the activity varies to some extent with the alkylating agent selected. Sulfuric and phosphoric acids are usually more effective for olefins or alcohols than for alkyl halides. For example, allyl chloride and allyl alcohol condense principally at the double bond in the presence of sulfuric acid,¹⁰ whereas in the presence of boron fluoride,¹¹ ferric chloride,¹² or zinc chloride¹² these substances react chiefly to form the allyl derivative. Aluminum chloride causes condensation at both functional groups.¹²

It is of interest to note that in several instances the effect of a catalyst such as aluminum chloride or boron fluoride is enhanced by the presence of an acidic "assistant." Alkylation by olefins with aluminum chloride as a catalyst is favored by the presence of anhydrous hydrogen chloride,¹³ and the condensation of primary alcohols with benzene using boron fluoride is possible only with the aid of an assistant such as phosphoric anhydride, benzenesulfonic acid, or sulfuric acid.¹⁴ It has been found also that chlorides of tin, silicon, or titanium increase the catalytic activity of aluminum chloride, whereas ferric chloride decreases the

⁷ Dermer, Wilson, Johnson, and Dermer, *J. Am. Chem. Soc.*, **63**, 2881 (1941).

⁸ Bodendorf and Bohme, *Ann.*, **516**, 1 (1935).

⁹ Price, *Chem. Revs.*, **29**, 37 (1941).

¹⁰ Truffault, *Compt. rend.*, **202**, 1286 (1936); see also Niederl, Smith, and McGreal, *J. Am. Chem. Soc.*, **53**, 3390 (1931); Smith and Niederl, *ibid.*, **55**, 4151 (1933).

¹¹ McKenna and Sowa, *J. Am. Chem. Soc.*, **59**, 470 (1937).

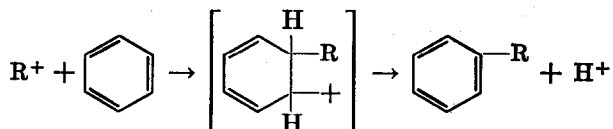
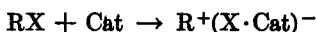
¹² Ninetescu and Isacescu, *Ber.*, **66**, 1100 (1933).

¹³ Berry and Reid, *J. Am. Chem. Soc.*, **49**, 3142 (1927).

¹⁴ Toussaint and Hennion, *J. Am. Chem. Soc.*, **62**, 1145 (1940).

activity.¹⁵ Limited amounts of water frequently increase the effectiveness of boron fluoride or hydrogen fluoride.

Alkylating Agents. The ease of alkylation by means of a reagent RX is dependent not only on the nature of X but also on the structure of the group R . Structural factors in the alkyl group promoting the polarization of RX in the sense R^+X^- facilitate alkylation.¹⁶



Thus, with halides, alcohols, ethers, and esters, alkylation proceeds most readily for tertiary or benzyl types, less readily for secondary types, still less readily for primary types, and least readily for methyl.¹⁷ It is therefore generally necessary to use increasingly vigorous catalysts or conditions to introduce the alkyl groups in the above sequence. For example, reactive halides like benzyl chloride will react with benzene in the presence of traces of such a weak catalyst as zinc chloride, whereas an inert halide like methyl chloride requires a considerable quantity of a powerful catalyst such as aluminum chloride.

The relative reactivity of the alkyl halides is also conditioned by the halogen atom. For aluminum chloride-catalyzed alkylations with either *n*-butyl or *t*-butyl halides,¹⁸ the order of activity is $F > Cl > Br > I$.¹⁹ This same order of reactivity has been found for hydrogen fluoride-catalyzed alkylation of benzene with cyclohexyl and *s*-octyl halides.²⁰ The order of reactivity of the halides is thus the reverse of the normal order.

Of the wide variety of alkylating agents which have been reported, the alkyl halides, olefins, and alcohols are by far the most useful. Aluminum chloride is an effective catalyst for all three classes. With halides and olefins, it is required in only catalytic amounts; but with alcohols con-

¹⁵ Ott and Brugger, *Z. Elektrochem.*, **46**, 105 (1940).

¹⁶ For reviews summarizing the evidence on the mechanism of the Friedel-Crafts reaction see Calloway, *Chem. Revs.*, **17**, 327 (1935); Nightingale, *ibid.*, **25**, 329 (1939); Price, *ibid.*, **29**, 37 (1941).

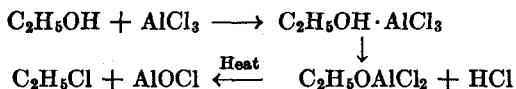
¹⁷ This same order of activity holds for the ease of migration and displacement of alkyl groups already attached to the aromatic nucleus.

¹⁸ Calloway, *J. Am. Chem. Soc.*, **59**, 1474 (1937).

¹⁹ Calloway (see reference 18) made the interesting observation that the ease of acylation with acyl halides is in the reverse order.

²⁰ Simons and Bassler, *J. Am. Chem. Soc.*, **63**, 880 (1941).

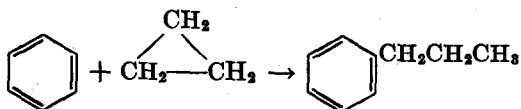
siderably larger quantities are necessary because of the reaction of the aluminum chloride with the alcohol. (See the article by Norris and Sturgis cited on p. 8, reference 30.)



Although boron fluoride or hydrogen fluoride will catalyze alkylation by means of alkyl halides, these catalysts are much more effective and useful with olefins or alcohols. Reactions carried out with either of these catalysts are distinguished by the lack of colored and resinous by-products which so generally accompany the use of aluminum chloride.

Ethers and esters have not been widely applied in syntheses by the Friedel-Crafts reaction, chiefly because they offer no particular advantage over the alcohols. In fact, with esters of organic acids and aluminum chloride as catalyst, a disadvantage is the simultaneous acylation which may occur. However, the synthesis of toluene in 60% yield from benzene, methyl sulfate, and aluminum chloride represents the most successful procedure for the monomethylation of benzene (see p. 22).

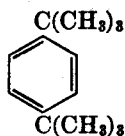
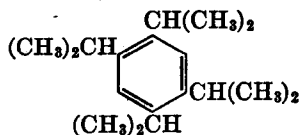
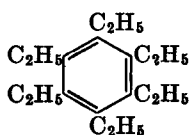
The use of cyclopropane as an alkylating agent has yielded *n*-propylbenzene in 65% yield (see references 26 and 36 on p. 8), but other syntheses, such as the preparation from *n*-propyl alcohol in 52% yield (see references 26 and 27, p. 8), are probably of more practical application.



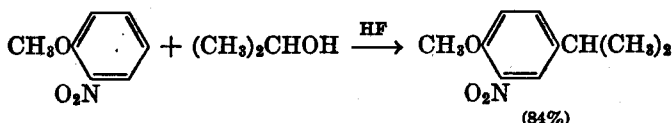
Aromatic Compounds. One characteristic feature of alkylation by the Friedel-Crafts procedure is that alkyl substituents in the aromatic ring markedly increase the ease of alkylation. Thus, there is a general tendency for the formation of considerable amounts of polyalkyl derivatives.

An interesting observation in this connection is that the structure of the alkyl group is an important factor regulating the maximum number of alkyl groups which can be introduced into the benzene ring by the Friedel-Crafts method. (See reference 36, p. 8.) Although all six of the hydrogen atoms of benzene can be replaced by methyl, ethyl, or *n*-propyl groups, only four can be replaced by isopropyl groups, and,

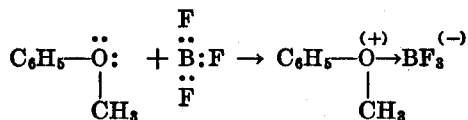
although three have been replaced by *t*-butyl groups, the usual and principal product in this instance is the *p*-di-*t*-butyl derivative.



The effect of a hydroxyl or an alkoxy group on the ease of alkylation is complex. In some instances, the effect appears to be an activation. For example, although nitrobenzene has not been alkylated, *o*-nitroanisole has been converted into the isopropyl derivative in good yield.



The normal activating influence of the hydroxyl or alkoxy group is counterbalanced by the tendency for the catalyst to coördinate with the oxygen atom.



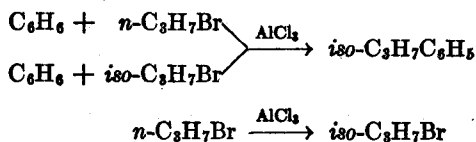
This process not only decreases the activity of the catalyst but also tends to nullify the activating effect of the oxygen atom. This general effect is still more pronounced for aromatic amines, so that alkylation of these substances has found only very limited application.

Rearrangements of Alkyl Groups. One factor involved in alkylation by the Friedel-Crafts method which has led to many conflicting and erroneous reports in the literature is the tendency for rearrangements of the alkyl group to occur during alkylation. The exact nature of the influence involved in these rearrangements is still not entirely clear. In general, the tendency of the rearrangements is in the direction: primary \rightarrow secondary \rightarrow tertiary. Usually the rearrangements involve only the migration of hydrogen atoms in the alkyl group rather than a rearrangement of the carbon skeleton.

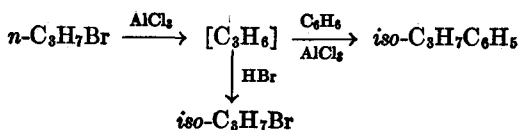
The first observation of such a rearrangement was made by Gustavson²¹ only a year after the announcement of the Friedel-Crafts reaction. He found that *n*-propyl and isopropyl bromides react with

²¹ Gustavson, *Ber.*, 11, 1251 (1878).

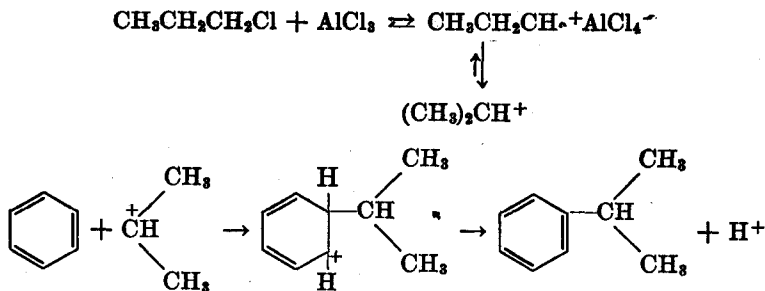
benzene in the presence of aluminum chloride to form the same substance, isopropylbenzene (cumene). The discovery that *n*-propyl bromide is isomerized to isopropyl bromide in the presence of aluminum chloride offers an explanation for this observation.²²



Since such rearrangements may be represented as occurring by intermediate formation of an olefin, it has been suggested that olefins are involved as intermediates in the alkylations.^{11, 23}



The general theory of molecular rearrangements as outlined by Whitmore²⁴ offers an alternative explanation of the isomerizations of alkyl groups during alkylation.⁹



It is by no means necessary to suppose that an olefin is formed as an intermediate in all alkylations. For example, benzyl alcohol and benzhydrol are particularly effective alkylating agents, but the intermediate formation of an olefin is impossible. Furthermore, under many conditions alkylation may proceed without rearrangement. It has been found that *n*-propyl chloride *in the cold* will react with benzene in the presence

²² Kekulé and Schrötter, *Bull. soc. chim.*, [2] **34**, 485 (1879).

²³ McKenna and Sowa, *J. Am. Chem. Soc.*, **59**, 1204 (1937).

²⁴ Whitmore, *J. Am. Chem. Soc.*, **54**, 3274 (1932).

of aluminum chloride to give chiefly *n*-propylbenzene whereas at higher temperatures the product is chiefly isopropylbenzene.^{24, 25, 26}

The catalyst may also influence the fate of the alkyl group. Normal alcohols, for example, usually alkylate without rearrangement in the presence of aluminum chloride,^{26, 27, 28} but rearrangement does occur when sulfuric acid^{26, 29} or boron fluoride^{11, 14} is used as a catalyst.

Under vigorous conditions changes even more extensive than isomerization of the alkyl group can occur. Although benzene is alkylated normally in good yield with *t*-butyl alcohol and aluminum chloride at 30°, the products at 80–95° are toluene, ethylbenzene, and isopropylbenzene.³⁰ Alkylation with 2,4,4- or 2,3,3-trimethyl-2-pentanol can proceed to yield both normal and degraded alkylation products, the extent of degradation increasing with temperature.³¹ The alkylation of methyl 2-furoate proceeds normally at the active 5-position, but the alkylation of methyl 5-bromo-2-furoate at the inactive 4-position proceeds with degradation of all alkyl groups with more than four carbon atoms to give the 4-*t*-butyl derivative in every case.^{32, 33} Treatment of paraffin hydrocarbons with benzene in the presence of aluminum chloride leads to the formation of various alkylbenzenes by degradation of the paraffin, a reaction which has been termed "destructive alkylation."³⁴

Orientation in Alkylation. An additional factor complicating the usefulness of Friedel-Crafts alkylations is the orientation involved in the introduction of more than one alkyl group.^{35, 36} It was discovered at an early date that alkylation with aluminum chloride and alkyl halides yields considerable proportions of *m*-dialkylbenzenes, as well as the expected *o*- and *p*-isomers. The relative extent of normal and abnormal orientation has been found to be a function of the conditions of alkylation. In general, the more vigorous the conditions with respect to the activity of the catalyst or the alkylating agent or the severity of the time and temperature factors, the greater is the tendency for the forma-

²⁴ Heise, *Ber.*, **24**, 768 (1891).

²⁵ Konowalow, *J. Russ. Phys.-Chem. Soc.*, **27**, 457 (1895).

²⁶ Ipatieff, Pines, and Schmerling, *J. Org. Chem.*, **5**, 253 (1940).

²⁷ Tsukervanik and Vikhrova, *J. Gen. Chem. U.S.S.R.*, **7**, 632 (1937) [*C. A.*, **31**, 5779 (1937)].

²⁸ Bowden, *J. Am. Chem. Soc.*, **60**, 645 (1938).

²⁹ Meyer and Bernhauer, *Monatsh.*, **53** and **54**, 721 (1929).

³⁰ Norris and Sturgis, *J. Am. Chem. Soc.*, **61**, 1413 (1939).

³¹ Huston, Guile, Sculati, and Wasson, *J. Org. Chem.*, **6**, 252 (1941).

³² Gilman and Burtner, *J. Am. Chem. Soc.*, **57**, 909 (1935).

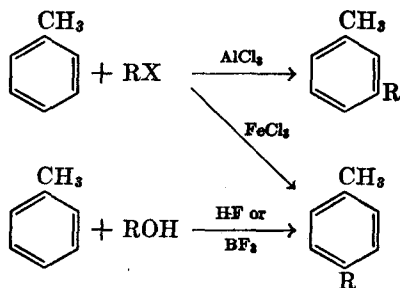
³³ Gilman and Turek, *J. Am. Chem. Soc.*, **61**, 473 (1939).

³⁴ Grosse, Mavity, and Ipatieff, *J. Org. Chem.*, **3**, 137 (1938).

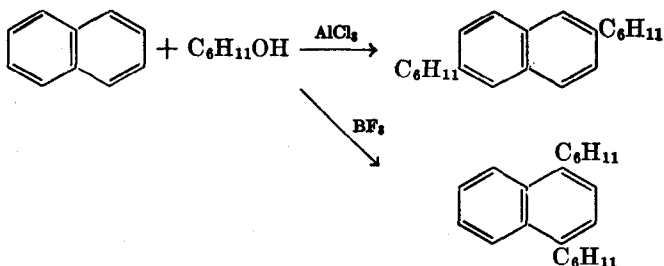
³⁵ See Ingold, Lapworth, Rothstein, and Ward, *J. Chem. Soc.*, **1931**, 1959; Bird and Ingold, *ibid.*, **1938**, 918.

³⁶ Grosse and Ipatieff, *J. Org. Chem.*, **2**, 447 (1937).

tion of the abnormal *m*-derivatives. Thus, alkylation catalyzed by aluminum chloride, the most active catalyst, leads to large proportions of *m*-dialkylbenzenes, particularly with large amounts of catalyst at high temperatures or for long reaction times. Alkylations catalyzed with boron fluoride, sulfuric acid, ferric chloride, and most other catalysts yield chiefly the normal *p*-dialkylbenzenes.



Naphthalene likewise yields two dialkyl derivatives; the principal dialkylation product from the reaction of naphthalene and cyclohexanol or cyclohexene with aluminum chloride as the catalyst has been shown to be 2,6-dicyclohexylnaphthalene,^{36a} but from cyclohexanol and boron fluoride, 1,4-dicyclohexylnaphthalene is obtained.^{36b}



A similar situation obtains in the trialkylation of benzene, the 1,2,4-trialkyl derivative being formed only under mild conditions, the 1,3,5-isomer under more vigorous conditions.³⁷ It has been shown that the 1,2,4-trialkyl derivatives will, in many instances, rearrange to the 1,3,5-isomer under the influence of aluminum chloride.^{38, 39, 40, 41, 42}

^{36a} Price and Tomisek, *J. Am. Chem. Soc.*, **65**, 439 (1943).

^{36b} Price, Shafer, Huber, and Bernstein, *J. Org. Chem.*, **7**, 517 (1942).

³⁷ Norris and Rubinstein, *J. Am. Chem. Soc.*, **61**, 1163 (1939).

³⁸ Baddeley and Kenner, *J. Chem. Soc.*, **1935**, 303.

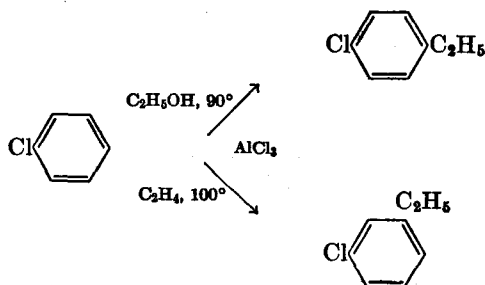
³⁹ Nightingale and Smith, *J. Am. Chem. Soc.*, **61**, 101 (1939).

⁴⁰ Smith and Perry, *J. Am. Chem. Soc.*, **61**, 1411 (1939).

⁴¹ Nightingale and Carton, *J. Am. Chem. Soc.*, **62**, 280 (1940).

⁴² Nightingale, Taylor, and Smelser, *J. Am. Chem. Soc.*, **63**, 258 (1941).

Even in the alkylation of phenols and aromatic halides similar effects on orientation have been observed. Thus, the ethylation of phenol with ethanol and aluminum chloride yields the *o*- and *p*-derivatives,⁴⁸ whereas with ethyl ether as the alkylating agent at a higher temperature 3,5-diethylphenol⁴⁴ is obtained. Alkylation of chlorobenzene with ethanol and aluminum chloride at 80–90° yields *p*-chloroethylbenzene,⁴⁵ but with ethylene at 100°, the principal product is the *m*-isomer.⁴⁶



Since alkylation by the Friedel-Crafts reaction has been demonstrated to be a reversible reaction,^{47, 48, 49} it has been suggested that the various anomalous orientations can be explained on this basis. Jacobsen⁵⁰ was the first of many^{38, 51, 52, 53} to point out that normal alkylation to form the 1,2,4-trialkyl derivative, followed by loss of the alkyl group in the 1-position, might account for the anomalous formation of *m*-dialkyl derivatives.

Identification. The many possibilities for the formation of isomeric or anomalous products due to rearrangement, unusual orientation, or degradation of alkyl groups during the Friedel-Crafts reaction, coupled with the fact that the products are usually liquids, difficult to separate and identify, frequently necessitate particular care in establishing the structure and the purity of the products.⁵⁴ The most effective method

⁴⁸ Tsukervanik and Nazarova, *J. Gen. Chem. U.S.S.R.*, **7**, 623 (1937) [*C. A.* **31**, 5778 (1937)].

⁴⁴ Jannasch and Rathjen, *Ber.*, **32**, 2391 (1899).

⁴⁵ Tsukervanik, *J. Gen. Chem. U.S.S.R.*, **8**, 1512 (1938) [*C. A.*, **33**, 4587 (1939)].

⁴⁶ Istrati, *Ann. chim.*, [6] **6**, 395 (1885).

⁴⁷ Boedtker, *Bull. soc. chim.*, [3] **35**, 834 (1906).

⁴⁸ Boedtker and Halse, *Bull. soc. chim.*, [4] **19**, 447 (1916).

⁴⁹ Woodward, Borchardt, and Fuson, *J. Am. Chem. Soc.*, **56**, 2103 (1934).

⁵⁰ Jacobsen, *Ber.*, **18**, 342 (1885).

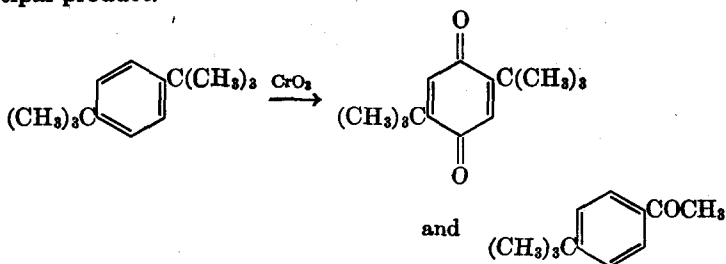
⁵¹ Anschütz, *Ann.*, **235**, 177 (1886); Moyle and Smith, *J. Org. Chem.*, **2**, 114 (1937).

⁵² Schorger, *J. Am. Chem. Soc.*, **39**, 2671 (1917).

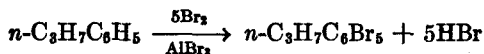
⁵³ Price and Ciskowski, *J. Am. Chem. Soc.*, **60**, 2499 (1938).

⁵⁴ See Marvel and Himel, *J. Am. Chem. Soc.*, **62**, 1550 (1940), who found that the aluminum chloride-catalyzed condensation of cyclohexyl chloride with bromobenzene yielded a mixture of all three bromocyclohexylbenzenes.

of establishing the orientation of the alkyl groups is oxidation to the corresponding aromatic acids. This is sometimes difficult for the tertiary groups, particularly *t*-butyl; for example, the oxidation of *p*-di-*t*-butylbenzene with chromic acid yields 2,5-di-*t*-butylbenzoquinone as the principal product.⁵⁵



The structure of the side chain may be established by a synthesis that leaves no doubt about the structure of the product. Alkylbenzenes containing primary alkyl groups may be prepared by Clemmensen reduction of an aryl alkyl ketone,^{59, 60} and those containing secondary groups by reaction of an aryl alkyl ketone with a Grignard reagent followed by dehydration and reduction.⁵⁷ A primary alkyl group attached to a benzene ring can be distinguished from a secondary or tertiary group by bromination in the presence of aluminum bromide; all hydrogen atoms and secondary or tertiary alkyl groups attached to a benzene ring are replaced by bromine under these conditions, whereas primary alkyl groups are not affected.⁵⁸



Identification of alkylated benzenes can be accomplished to some degree by the physical properties, more definitely by preparation of a solid derivative such as a sulfonamide,^{59, 60} a diacetamino derivative,^{60a} or a picrate.^{58, 59}

⁵⁵ Boedtker, *Bull. soc. chim.*, [3] **31**, 969 (1904).

⁵⁶ Gilman and Turck, *J. Am. Chem. Soc.*, **61**, 478 (1939); Martin, *Organic Reactions*, I, "The Clemmensen Reduction."

⁵⁷ Klages, *Ber.*, **35**, 3509 (1902).

⁵⁸ Bodroux, *Ann. chim.*, [10] **11**, 511 (1929); Hennion, *J. Am. Chem. Soc.*, **66**, 1801 (1944).

⁵⁹ Shriner and Fuson, "Identification of Organic Compounds," John Wiley & Sons, New York, 2nd ed., 1940.

⁶⁰ Huntress and Autenrieth, *J. Am. Chem. Soc.*, **63**, 3446 (1941).

^{60a} Ipatieff and Schmerling, *J. Am. Chem. Soc.*, **59**, 1056 (1937); **60**, 1476 (1938); see also reference 42.