aluminum chloride complex was usually 0.040 to 0.050 *M*. An excess (100%) of acetyl chloride was used. Data for individual experiments are summarized in Table V.

The acetyl chloride–aluminum chloride solution in ethylene dichloride was added with vigorous stirring over a period of 10 minutes to the solution of hydrocarbons in ethylene dichloride. This solution was 0.0200 *M* in 1,2,4-trichlorobenzene, used as an internal standard to determine the concentrations of the products. The reaction mixture was allowed to stand for 10 minutes, and then quenched with an ice–sodium hydroxide mixture. The organic layer was washed twice with water and the greater portion of the solvent removed by careful distillation. The acetylation products were analyzed using a 2-m. column with a polyadipate substrate (Rubber Corporation polymeric BGA on Celite) at 185° and 80 cc. of helium per min.

Identification of the Isomeric Hemimellitene Acetylation Products.—The two peaks were individually collected in cyclohexane solution and examined with a Perkin–Elmer Infracord spectrophotometer. The isomer having retention time 17.8 min. exhibited a band at 12.30 μ, characteristic of 1,2,3,4-tetrasubstituted benzenes,[17] and it was therefore assigned the structure 2,3,4-trimethylacetophenone. The isomer with a retention time of 24.0 min., exhibited a band at 11.30 μ, characteristic of 1,3,4,5-tetra-substituted benzenes.[17] It was assigned the structure 3,4,5-trimethylacetophenone. For additional confirmation, collection of this peak was repeated several times until a sample was collected sufficiently large for conversion to the semicarbazone. Recrystallized from 95% ethanol, it melted at 215.5–216.5°, in satisfactory agreement with the m.p. reported for this derivative.[11]

(17) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," 2nd ed., Methuen and Co., Ltd., London, 1958, pp. 78–79.

LAFAYETTE, INDIANA

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

Friedel–Crafts Isopropylation of Acetophenone, Methyl Benzoate and Benzoic Acid[1]

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The isopropylation of acetophenone, methyl benzoate and benzoic acid was studied to determine the composition of the resulting monoalkylated products. Although generally the yields were low, it was noted that with all the experimental conditions used the products were largely or entirely composed of the meta isomers. In most cases these isomers constituted 95% or more of the products. This is a far greater selectivity than has been observed in the nitration of these compounds, and can best be explained as resulting from complexing of the catalyst with the carbonyl oxygen to increase greatly the electron-withdrawing character of the substituent groups.

This paper describes the investigation of the isomeric composition of the products of Friedel–Crafts isopropylation of negatively substituted benzenes, in particular, acetophenone, methyl benzoate and benzoic acid. There are only three reports in the literature of the successful Friedel–Crafts alkylation of benzene compounds containing electron-withdrawing substituents. Baddeley[3] reports the alkylation of acetophenone and benzonitrile with methyl and ethyl ether. Benzaldehyde was alkylated with isopropyl and *t*-butyl chloride by Gilman and Burtner.[4] Aluminum chloride was the catalyst in both cases. Hydrogen fluoride and isopropyl ether was used by Calcott, Tinker and Weinmayr[5] to alkylate benzoic acid. In these three reports there was no clear evidence for the presence or absence of the *o*- or *p*-isomers. Further, the present authors desired to compare the results of the alkylation of acetophenone to those previously obtained in this Laboratory with 2-acetylthiophene[6] since the two compounds have in common the same electron-withdrawing substituent. In the latter case[6] it was found that neither the usual relative magnitudes of the directional influences of the acetyl group or the sulfur atom nor the influence of the incoming group could explain the preponderance of 4-isopropyl-2-acetylthiophene in the product.

The isopropylations of acetophenone, methyl benzoate and benzoic acid could each produce three monoisopropylated isomers. The first step in the quantitative investigation of these reactions was the preparation of these nine compounds by unequivocal syntheses which do not use the Friedel–Crafts reaction or depend on isomer separation. The nine are: from acetophenone, *o*-isopropylacetophenone (I), *m*-isopropylacetophenone (II) and *p*-isopropylacetophenone (III); from methyl benzoate, methyl *o*-isopropylbenzoate (IV), methyl *m*-isopropylbenzoate (V) and methyl *p*-isopropylbenzoate (VI); and from benzoic acid, *o*-isopropylbenzoic acid (VII), *m*-isopropylbenzoic acid (VIII) and *p*-isopropylbenzoic acid (IX). The infrared spectra of acetophenone, I, II and III, and mixtures of them were recorded and used to establish a scheme for the analysis of these four compounds in the products of the isopropylation of acetophenone. Similarly, an infrared analysis scheme was set up for the esters. The solid product acids from the isopropylation of benzoic acid were converted with diazomethane to the methyl esters for analysis The three substrate compounds were then isopropylated under a variety of conditions, and the products were analyzed by fractional distillation and infrared spectrophotometry.

Experimental[7]

***o*-Isopropylacetophenone (I).**—The starting material from which all the standard compounds with *ortho* configuration were derived was methyl anthranilate, Eastman Kodak Co.,

(1) Based on part of the 1958 Ph.D. thesis of Bruce N. Campbell, Jr.

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(3) G. Baddeley, *J. Chem. Soc.*, S229 (1949).

(4) H. Gilman and R. R. Burtner, THIS JOURNAL, **57**, 909 (1935).

(5) W. S. Calcott, J. M. Tinker and V. Weinmayr, *ibid.*, **61**, 1010 (1939).

(6) E. C. Spaeth and C. B. Germain, *ibid.*, **77**, 4066 (1955).

(7) Melting points were taken with calibrated, completely immersed, short-stand thermometers. Careful fractionation was done with a Wheeler, all-glass, vacuum, semi-micro fractionating column with a modified Sargent hollow-tube design, model number GV-130-2 of the Precision Distillation Apparatus Co. Microanalyses were performed by The Laboratory of Microchemistry, Teaneck, N. J. Each analytical value for carbon or hydrogen is the average of the values from two analyses.

white label. *o*-Isopropylaniline, b.p. 88° (5 mm.), was prepared by the hydrogenation[8] of isopropenylaniline[9] and was transformed through *o*-bromoisopropylbenzene,[10] b.p. 87–89° (15 mm.), to *o*-isopropylacetophenone (I) by a modification of the method of Hauser and co-workers.[11] This compound (I) was collected at 72–73° (2 mm.), $n^{20}D$ 1.5225.

Anal. Calcd. for $C_{11}H_{14}O$: C, 81.44; H, 8.70. Found: C, 81.22; H, 8.54.

A semicarbazone of I was prepared, m.p. 147.5–148.2°.

Anal. Calcd. for $C_{12}H_{17}ON_3$: C, 65.72; H, 7.81. Found: C, 65.94; H, 7.82.

This compound (I) also was obtained from *o*-isopropylaniline using acetaldoxime by the method of Beech.[12]

***o*-Isopropylbenzoic Acid (VII).**—*o*-Bromoisopropylbenzene described above was transformed to this acid (VII) by an adaptation of the method of Barnes.[13] In the present work, carbonation was carried out by adding the solution of the Grignard reagent to dry ether containing a large excess of Dry Ice. The solid product which was collected after hydrolysis was extracted with hot water. The *o*-isopropylbenzoic acid (VII) crystallized from the water on cooling, m.p. 62.9-63.2°, reported[14] 63.0–63.5°.

Methyl *o*-isopropylbenzoate (IV), b.p. 72–73° (2 mm.), $n^{20}D$ 1.5086, was obtained by treating the corresponding acid VII dissolved in ether with excess diazomethane prepared as described by DeBoer.[15]

***m*-Isopropylacetophenone (II).**—Methyl *m*-bromobenzoate was prepared from *m*-bromobenzoic acid, Eastman Kodak Co., white label, by the method of Fieser.[16] *m*-Bromoisopropylbenzene, b.p. 70° (4.3 mm.), $n^{20}D$ 1.5380,[17] was prepared by the hydrogenation[8] of *m*-bromoisopropenylbenzene, b.p. 71–73° (7 mm.), $n^{20}D$ 1.5798,[18] which was obtained from methyl *m*-bromobenzoate by an adaptation of the procedure used to prepare *o*-isopropenylaniline. *m*-Bromoisopropylbenzene was converted to *m*-isopropylacetophenone (II), b.p. 84–85° (2 mm.), $n^{20}D$ 1.5195, by the same method used for I. The boiling point has been reported[19] as 84–90° (0.2 mm.).

A semicarbazone of II was prepared, m.p. 165.4–166.2°, reported[19] 170°.

Anal. Calcd. for $C_{12}H_{17}ON_3$: C, 65.72; H, 7.81. Found: C, 65.84; H, 7.83.

***m*-Isopropylbenzoic Acid (VIII).**—*m*-Bromoisopropylbenzene was transformed as described above in the preparation of VII to *m*-isopropylbenzoic acid (VIII), m.p. 51.2-51.8°, reported[14] 51–52°.

Methyl *m*-isopropylbenzoate (V) was obtained from VIII by the method used to produce IV. The fraction collected distilled at 82–83° (2.0–2.1 mm.), $n^{20}D$ 1.5084.

***p*-Isopropylacetophenone (III).**—*p*-Bromoisopropenylbenzene, b.p. 97–99° (13 mm.),[20] was obtained from *p*-dibromobenzene,[21,22] Eastman Kodak Co., white label, and was transformed by hydrogenation[8] to *p*-bromoisopropylbenzene, b.p. 68° (4 mm.), $n^{20}D$ 1.5398; reported[21] 97–98° (5 mm.), $n^{20}D$ 1.5569. The *p*-bromoisopropylbenzene was converted to *p*-isopropylacetophenone (III) by the method used for I. The fraction distilling at 86–87° (2 mm.), $n^{20}D$ 1.5221, was collected; reported 84–88° (0.2 mm.),[19] $n^{20}D$ 1.5204.[23]

The oxime of III was prepared, m.p. 70.4–70.9°, reported[24] 70–71°.

The semicarbazone of III was prepared, m.p. 165.0–165.8°, reported[19] 157–162°. The melting point of a mixture of the semicarbazones of II and III was 156–158°.

Anal. Calcd. for $C_{12}H_{17}ON_3$: C, 65.72; H, 7.81. Found: C, 65.50; H, 7.83.

***p*-Isopropylbenzoic acid (IX)** was produced in the same manner as (VII). This acid (IX) melted at 116.4–117.4°, reported[25] 116.5°.

Methyl *p*-isopropylbenzoate (VI) was obtained with diazomethane as were IV and V. The fraction collected distilled at 83° (1.9 mm.), $n^{20}D$ 1.5130; reported[26] 126° (14 mm.), $n^{19}D$ 1.5150.

Alkylation Procedures. Method A.—The appropriate amount of catalyst (usually 0.4 mole) and 500 ml. of dry carbon disulfide were placed in the reaction vessel. The alkylating agent, isopropyl chloride or isopropyl ether (usually 0.225 mole), and the compound to be isopropylated (usually 0.2 mole) were added together dropwise with stirring during 0.5 hour. The mixture was refluxed for 48 hours. On cooling, the mixture was poured onto 300 g. of ice, and the resulting layers were separated. The aqueous layer was extracted twice with ether and the organic layers combined. The combined organic layers were washed with four successive, 250-ml. portions: one of water, two of 10% sodium carbonate and one of saturated salt solution. The organic solution then was dried over anhydrous magnesium sulfate. The ether and carbon disulfide were removed by distillation. The product then was distilled at reduced pressure through a 10-cm. Vigreux column, and this was usually followed by a more careful fractional distillation.

Method A'.—This was method A adapted for benzoic acid. Benzoic acid was placed in the flask first, not added with the alkylating agent. The principal difference was in the isolation of the product. After the reaction mixture was poured on ice, 30 ml. of concentrated nitric acid was added, and the resulting layers were separated. The aqueous layer was extracted three times with ether and the ether extracts were combined with the carbon disulfide layer. The combined organic solution was extracted with four portions as in method A, but two portions of 10% sodium hydroxide were used in place of the two portions of sodium carbonate. The last three of these aqueous extracts were combined and acidified with nitric acid. After standing overnight, the acids were collected by suction filtration and dried in a vacuum desiccator. These solid acids were dissolved in ether and treated with excess diazomethane to convert them to the corresponding methyl esters. The excess diazomethane was destroyed with formic acid. The procedure from this point was the same as method A.

Method B.—In a one-neck flask (500 ml). was placed 120 g. (0.9 mole) of aluminum chloride. Then the alkylating agent (0.4 mole) and the compound to be isopropylated (0.2 mole) were added slowly during two hours with intermittent cooling. When isopropyl chloride was used the mole ratio of catalyst to alkylating agent was 0.4/0.225. The mixture was allowed to stand overnight under a drying tube. Then the mixture was heated to 190° in a period of 40–60 minutes. The mixture now was poured onto 600 g. of ice and the resulting aqueous layer was extracted three times with ether. The subsequent procedure was that described for method A.

Method C.—The apparatus for the start of this method consisted of the stainless steel base of a Parr medium pressure bomb (model 4511) and a temporary stainless steel cover equipped with a stirrer, a Weston thermometer, and a simple funnel. Into this vessel, cooled in an ice–salt-bath, was placed 145 ml. (about 7 moles) of hydrogen fluoride. Then 0.2 mole of the compound to be alkylated was added over a period of five minutes. When the temperature returned to zero, 28.2 ml. (0.2 mole) of isopropyl ether was added over a period of 0.75 hour. The temporary top then was removed and the Parr bomb reassembled. The sealed bomb was allowed to come to room temperature overnight and then

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(10) L. A. Bigelow, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1941, p. 135.

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(12) W. F. Beech, *J. Chem. Soc.*, 1297 (1954).

(13) R. P. Barnes, "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 555.

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(15) Th. J. DeBoer, *Rec. trav. chim.*, **73**, 229 (1954).

(16) L. F. Fieser, "Experiments in Organic Chemistry," D. C. Heath and Co., Boston, Mass., 1955, p. 78.

(17) Parham, *et al.*,[8] reported b.p. 89.5–91.0° (15 mm.), $n^{20}D$ 1.5351.

(18) Parham, *et al.*,[8] reported b.p. 85–86° (3 mm.), $n^{20}D$ 1.5787.

(19) G. Baddeley, G. Holt and W. Pickles, *J. Chem. Soc.*, 4162 (1952).

(20) D. Seymour and K. B. Wolfstirn, THIS JOURNAL, **70**, 1178 (1948), reported 114.5–117.5° (24 mm.).

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(22) M. R. Quelet, *Bull. soc. chim.*, **41**, 933 (1928).

(23) D. V. Nightingale, H. B. Hucher and O. L. Wright, *J. Org. Chem.*, **18**, 244 (1953).

(24) O. Widman, *Ber.*, **21**, 2224 (1888).

(25) A. A. Morton, J. T. Massengale and M. L. Brown, THIS JOURNAL, **67**, 1620 (1945).

(26) L. Bert, *Bull. soc. chim.*, **37**, 1397 (1925).

heated with stirring to 70° within 90 minutes. The pressure gauge at this point registered 70–75 p.s.i. Heating at this temperature and stirring were maintained for over 7 hours. The bomb then was cooled to 10–12° in an ice-bath, opened, and the hydrogen fluoride was allowed to evaporate over a period of 18 hours. Then 250 ml. of water and sufficient sodium carbonate to neutralize the remaining acid were added. The aqueous layer was extracted three times with ether and method A was followed from this point.

Method C′ was similar to method C but adapted for benzoic acid. The benzoic acid was placed in the vessel before rather than after the catalyst. When, in this method, the hydrogen fluoride had largely evaporated, 250 ml. of water was added with enough sodium carbonate to react with almost all of the remaining HF. Then 100 ml. of 10% sodium hydroxide was added. The basic solution was extracted twice with ether, and the ether was, in turn, washed with 10% sodium hydroxide. The combined basic portions were filtered and acidified with concentrated hydrochloric acid. The procedure from this point was the same as in method A′.

Infrared Absorption Analysis.—The Perkin–Elmer double beam infrared spectrophotometer (model 21) and a standard sealed-liquid cell with rock salt windows were used. The scans were made in the region 5000–650 cm.$^{-1}$ and took about 0.5 hour. The spectra[27] of acetophenone, I, II and III were recorded and examined for absorption peaks sufficiently unique to be used for analysis. The spectra[27] of methyl benzoate, IV, V and VI were also recorded and examined. For analysis of ketone mixtures the following peaks[28] were used: for acetophenone, (691) 760 and 1025 cm.$^{-1}$; I, (755), 829 and (1033) cm.$^{-1}$; II, (697), 798, 900 and 910 cm.$^{-1}$; and III, 830, (1100), (1111) and (1183) cm.$^{-1}$. For analysis of ester mixtures the following peaks were used: methyl benzoate, 688, 714 and 1030 cm.$^{-1}$; IV, 762 and 800 cm.$^{-1}$; V, 757, 841, 904 and 910 cm.$^{-1}$; and VI, 775, 852 and 1022 cm.$^{-1}$. Then for each of these systems two and three component mixtures, whose weight compositions were known, were made up, and their spectra recorded. Plots of absorbance[29] *versus* composition were made for each useful peak.

Analysis of Products.—As mentioned above, the last step in the isolation of reaction products was fractional distillation. Each fraction then was weighed, and its infrared spectrum recorded. The absorbance[29] at the appropriate wave numbers was measured and compared to the corresponding plots to determine the percentage composition of the fraction. This with the weight of the fraction gave the weight of each component in the fraction. The sums of these weights gave the weights of the compounds in the product. These weights were used to calculate the yield, based on the amount of unalkylated material used, and the composition of the isopropylated product. The conversions were calculated by using these yields and the amounts of the aromatic reactant recovered. In general the percentage composition in any fraction could be determined within 1% for the ketones and the esters.

Results

Tables I, II and III contain a summary of the results of selected experiments for the isopropylation of these three negatively substituted benzenes. Other experiments such as those with no solvent (method B) for methyl benzoate and benzoic acid, and with $FeCl_3$ for the acid, gave singularly poor results. Under all conditions studied here it would appear that there exists a very strong tendency for Friedel–Crafts isopropylation to take place at the *m*-position.

It might be noted that while the best yields from acetophenone are obtained with $AlCl_3$ (method A), the use of HF gives the best yields with methyl benzoate and benzoic acid. In the latter case, the conditions are quite similar to those of Calcott, Tinker and Weinmayr.[5]

In the experiment using $AlCl_3$, isopropyl ether and no solvent, reported in Table I, the reaction conditions were similar to those used by Baddeley.[3] The yields from such experiments were generally very low, and the spectra indicated a considerable decrease in the proportion of the *m*-isomer in the products. However, when isopropyl chloride was used in place of isopropyl ether with essentially the same conditions, the composition of the product was the same as that obtained with $AlCl_3$ and method A. Similarly, when isopropyl ether was used with solvent (method A), the product appeared to be pure II. An attempt then was made to duplicate roughly the work of Baddeley by using ethyl ether and method B. The distillation ranges observed were quite analogous to those reported by Baddeley.[3] No explanation is apparent at this time for the difference in the results when isopropyl ether and no solvent were used.

The analysis of the products of the isopropylation of benzoic acid requires further mention since the

TABLE I

THE ISOPROPYLATION OF ACETOPHENONE

Catalyst	Alkylating agent	Method	Yield,[a] %	Conversion,[a] %	Position substituted[a] % *meta*	% *para*
$AlCl_3$[b]	*i*-PrCl	A	15	33	>99[c]	Trace
$AlBr_3$[d]	*i*-PrCl	A	10.5	38	100	...
$FeCl_3$[d]	*i*-PrCl	A	9	23.5	97	3[e]
$AlCl_3$	*i*-Pr ether	B	3	6	83	17[e]
$AlCl_3$	*i*-PrCl	B	5	11	100	..
$AlCl_3$[f]	*i*-Pr ether	A	10	24	100	..
HF	*i*-Pr ether	C	5	15	95	5[g]

[a] These figures represent the averages for the experiments of each type cited. [b] The average of eight runs including variations in brand of catalyst used (3 brands) time of reflux and the mole ratio of catalyst to isopropyl chloride to acetophenone. [c] All values either >99 or 100%. [d] The average of two identical runs. [e] *Para* plus *ortho*, predominantly *para*. [f] Used 0.8 mole of catalyst. [g] Trace of *ortho*.

TABLE II

THE ISOPROPYLATION OF METHYL BENZOATE

Catalyst	Alkylating agent	Method	Yield, %	Conversion, %	Position substituted % *meta*	% *para*
$AlCl_3$[a]	*i*-PrCl	A	18	33	98	2[b]
$AlBr_3$	*i*-PrCl	A	16	34	97	3[b]
$FeCl_3$	*i*-PrCl	A	2	8	91	9[b]
HF	*i*-Pr ether	C	23	30	89	11

[a] The values are the average of three runs, two with the same brand of catalyst and no other variation. [b] Trace of *ortho*.

TABLE III

THE ISOPROPYLATION OF BENZOIC ACID

Catalyst	Alkylating agent	Method	Yield, %	Conversion, %	Position substituted % *meta*	% *para*
$AlCl_3$[a]	*i*-PrCl	A′	3	6	98	2[b]
$AlCl_3$[c]	*i*-PrCl	A′	6	15.5	98	2
$AlCl_3$[c,d]	*i*-PrCl	A′	7	20	97	3
$AlBr_3$	*i*-PrCl	A′	6.5	17	98	2[b]
HF	*i*-Pr ether	C′	13	17	94.5	5.5

[a] On 3/4 the usual scale with Baker catalyst. [b] Trace of *ortho*. [c] Matheson, Coleman and Bell catalyst. [d] On twice the usual scale.

(27) These spectra are contained in the Ph.D. thesis of B. N. C., University of Connecticut, 1958.

(28) Peaks in parentheses were not useful in most of the cases studied except for qualitative or rough quantitative estimation.

(29) The total, actual, absorbance was not used, but rather it was modified by the use of a constructed average background line in an attempt to eliminate errors from changes in absorption not due to the compounds being studied; explained in detail in the Ph.D. thesis of B. N. C., University of Connecticut, 1958.

product acids underwent a chemical transformation before analysis. This possibly could lead to distortion of the composition as determined by infrared analysis. Two experiments were performed which have direct bearing on this question. In the first of these experiments a mixture of benzoic acid, VII, VIII and IX of known composition was dissolved in ether and treated with excess diazomethane as in method A'. Analysis was by two successive fractional distillations and by studying the infrared absorption of the fractions from both distillations. The initial composition was: benzoic acid, 78.3%; VII, 8.96%; VIII, 9.51%; and IX, 3.23%. After simple Vigreux distillation, the indicated composition of the resulting esters was: methyl benzoate, 78%; IV, 8.6%; V, 9.5%; and VI, 3.2%. After further fractionation the composition, in the same order, was: 81, 7.9, 8.7, 2.8%. The composition of the alkylated acid in the original mixture was: 41.5% *ortho*, 44% *meta* and 15% *para*. After conversion to the esters and two distillations, the indicated composition was: 40.5% *ortho*, 44.5% *meta* and 15% *para*. Thus the overall analysis reflects the composition of the original alkylated acid mixture within 2% and does much better if only the simple distillation is used. The second experiment was an ordinary alkylation on twice the usual scale which is cited in Table III. The product acid was divided into two portions of equal weight, and each portion was treated as in method A' including a simple distillation. The results of one sample showed a yield of 7.3% monoalkylated ester of which 97.1% was V and 2.9% was VI. For the other, the yield of monoalkylated ester was 7.3% of which 97.1% was V and 2.9% was VI. This seems to indicate that the results of this method are reproducible, particularly with regard to the composition of the alkylated product.

Discussion

Two factors may be considered in the explanation of the orientation of the products of electrophilic aromatic substitution. The first is the influence of groups already substituted on the ring which are believed, by increasing or decreasing the electron density unequally at various positions, to encourage substitution at certain sites. The second is the influence of the incoming group or reaction conditions on the position substituted as has been discussed by Brown.[30] The nitration of these three negatively substituted benzenes has been reported and the results are summarized in Table IV.

From Table IV it can be seen that the directive influences of these *m*-directing substituents are not sufficient to account for the predominance of the *m*-isomer in the products of the isopropylations studied here. Brown has noted that, in the substitution of toluene, isopropylation is less selective or less influenced in the choice of the site for substitution by the substituent on the ring than is nitration. Thus this consideration would predict that less *m*-substitution would be found in the present case than with nitration which is contrary to the observations made in this investigation.

TABLE IV

THE MONONITRATION OF THREE NEGATIVELY SUBSTITUTED BENZENES

Substituent	Composition of products, %—meta	ortho	para	Ref.
–COOH	80	18	2	*a*
	80.2[c]	18.5	1.3	*b*
$-COOCH_3$	73	21	6	*a*
	73			*b*
$-COCH_3$	68	30		*b*

[a] L. N. Ferguson, *Chem. Revs.*, **50**, 48 (1952). [b] C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, Ch. VI. [c] Ingold (ref. *b*) also records 82%.

One possible explanation for the preponderance of the *m*-isomer is that the *o*- and *p*-isomers are formed also but can isomerize to the *meta* under these reaction conditions. To test this possibility, mixtures of the unalkylated compound, the *o*- and the *p*-isopropylated compounds for each system were subjected to conditions as similar as possible to the reaction conditions on method A without any alkylating agent. These simulated reaction mixtures were also saturated periodically with gaseous HCl since this would have been present if alkylation were taking place and since several investigators[30,31] have noted that the hydrogen halide plays a significant role in the isomerization of alkylated aromatics. In all three cases no trace of the *m*-isomer could be found in the infrared spectra of the products, and only negligible differences were found in the compositions.

It must be then, since isomerization is apparently ruled out, that with the reaction conditions of this investigation either the directive influence of these groups is greatly enhanced or isopropylation has become much more selective than nitration. The former would seem more logical. It would seem quite reasonable that a complex of the catalyst with the carbonyl oxygen, which is well known,[32] would form and would increase the polarization of the carbonyl carbon-to-oxygen bond. This polarization would greatly enhance the electron-withdrawing character of these substituent groups. Such strongly *m*-directing complexes would explain the observed results: the preponderance of the *m*-isomers in the products; the variation in directive influence with substituent group and catalyst; and the low yields. The secondary selection of the *p*-position over the *o*-position which was not the case with nitration probably is due to the increased steric hindrance of the complexed groups.

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