Anal. Calcd. for $C_6H_{14}N_2S_2$: C, 40.41; H, 7.91; N, 15.71; S, 35.96. Found: C, 40.58; H, 7.94; N, 15.79; S, 36.17.

1-[2-(N-Phenylthiolcarbamoyl)ethyl]-3-phenylurea.—To a suspension of 6.8 g. (0.05 mole) of 2-mercaptoethylamine hydrochloride in 50 ml. of acetonitrile was added 5.1 g. (0.05 mole) of triethylamine. A new solid came out of solution. To the resulting suspension was added 6.0 g. (0.05 mole) of phenyl isocyanate. The temperature rose rapidly from 25° to 53°, then dropped back to 25° over about 90 min. The reaction mixture was poured into 200 ml. of ice water and a solid separated. After recovery by suction filtration and drying, the 1-[2-(N-phenylthiolcarbamoyl)-ethyl]-3-phenylurea amounted to 7.6 g. (96%), m.p. 165–189°. A portion of this solid was recrystallized three times from 95% ethanol to give material melting at 196.5–200°.

Anal. Calcd. for $C_{16}H_{17}O_2N_3S$: C, 60.93; H, 5.43; N, 13.32; S, 10.17. Found: C, 60.76; H, 5.58; N, 13.31; S, 10.19.

1-(2-Mercaptoethyl)-3-phenylurea.—In a solution of 4.6 g. (0.0457 mole) of triethylamine in 75 ml. of acetonitrile was suspended 14.4 g. (0.0457 mole) of 1-[2-(N-phenylthiolcarbamoyl)-ethyl]-3-phenylurea. To the suspension was added a solution of 7.8 g. (0.0457 mole) of silver nitrate in 25 ml. of acetonitrile. The mixture was triturated for an hour, an intense odor of phenyl isocyanate becoming apparent. The pH at this point was about six. When 2 ml. of triethylamine was added, bringing the pH to 7.5, the isocyanate odor rapidly disappeared.

The solid silver mercaptide was recovered by suction filtration and washed with 25 ml. of acetonitrile. While still damp it was added to a solution of 18.0 g. (0.075 mole) of sodium sulfide nonahydrate in 75 ml. of water. Black silver sulfide appeared rapidly when the mixture was triturated. When conversion appeared to be complete, the silver sulfide was recovered by suction filtration, washed with 25 ml. of water, and air-dried. The aqueous filtrate was made strongly acid with 5 *N* hydrochloric acid, and a copious cream colored precipitate came down. This was recovered by suction filtration, washed with 25 ml. of water, and air-dried. The acetonitrile filtrate from the original reaction was poured into 300 ml. of water, and a white solid, presumably by-product 1,3-diphenylurea, came out. It was recovered by suction filtration and dried.

The silver sulfide recovered amounted to 6.2 g. (theory 5.7 g.). The by-product 1,3-diphenylurea amounted to 3.7 g. (77%), m.p. 221–228°. After recrystallization from ethanol it melted at 236–243°. The crude 1-(2-mercaptoethyl)-3-phenylurea amounted to 8.9 g. (99%). Recrystallization from 75 ml. of ethanol gave 7.2 g. of relatively pure material, m.p. 141–143°. Two more recrystallizations from ethanol gave an analytical sample, m.p. 141.5–143°.

Anal. Calcd. for $C_9H_{12}ON_2S$: C, 55.07; H, 6.16; N, 14.28; S, 16.33. Found: C, 55.18; H, 6.23; N, 14.22; S, 16.19.

1-(2-Mercaptoethyl)-3-carboxymethylurea.—To 16.8 g. (0.05 mole) of 1-[2-(N-ethoxycarbonylmethylthiolcarbamoyl)ethyl]-3-ethoxycarbonylmethylurea was added 80 ml. of 10% sodium hydroxide solution (0.20 mole). The solid went into solution rapidly, and the solution became warm. After an hour the solution was filtered and cooled in ice, and 40 ml. of 5 *N* hydrochloric acid was added slowly. Gas evolved vigorously, and a solid crystallized. It was recovered by suction filtration and dried in a vacuum oven. The crude 1-(2-mercaptoethyl)-3-carboxymethylurea amounted to 6.3 g. (71%), m.p. 143–147°. The crude product was dissolved in 60 ml. of hot ethanol, and the solution was filtered to remove a small amount of sodium chloride. Cooling brought down 3.7 g. of purified urea, m.p. 147–149°. A portion was recrystallized a second time from ethanol to give an analytical sample, m.p. 149.5–150.5°.

Anal. Calcd. for $C_5H_{10}O_3N_2S$: C, 33.70; H, 5.66; N, 15.72; S, 17.99. Found: C, 33.76; H, 5.70; N, 15.83; S, 17.99.

The Dealkylation of Aromatic Amines

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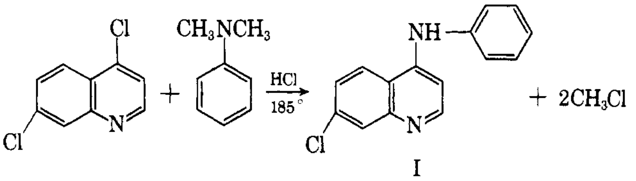
Tertiary aromatic amines were dealkylated smoothly to secondary aromatic amines at about 150° by passing hydrogen bromide through the molten salt. Secondary aromatic amines were converted to anilines at about 200°. All the rates followed pseudo first-order kinetics which made possible a comparative study among a number of tertiary amines under varying conditions.

We observed the rather unusual results of an attempted Friedel-Crafts reaction. *para* Substitution in dimethylaniline was anticipated but instead the product I was isolated in good yield. Obviously a dealkylation had occurred prior to the coupling process, and this paper reports our study of the dealkylation process.



I

Many methods of dealkylation are available.[3–11] Only a few methods deal with the direct action of a mineral acid on an alkylamine,[12] stemming mainly from the work of Hickinbottom,[13,14] who found that N-methylaniline, heated in a slow stream of hydrogen chloride, yields aniline. Monoalkylaniline hydrobromides decompose between 250–300° with the elimination of the alkyl group as olefin and alkyl bromide. Tertiary alkyl groups are removed readily by acids at 110–140°.[15] Treatment of N-methylaniline under Zeisel conditions results in a yield of only 3% methyl iodide. N-Butylaniline is unaffected by 19 *N* sulfuric acid at 140° for 30 hours. An interesting application

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(1) Abstracted from the Ph.D. thesis of R. A. C., National Defense Education Act Fellow, 1959–1962.

(2) To whom correspondence should be addressed.

(3) Cyanogen bromide: H. A. Hagemann, "Organic Reactions," Vol. 7, John Wiley and Sons, New York, N. Y., 1953, pp. 198–262.

(4) Acetyl bromide: W. Staedel, *Ber.*, **19**, 1947 (1886).

(5) Lead tetraacetate: H. von Foerst, "Neuere Methoden der Preparativen Organischen Chemie," Band 2, Verlag Chemie Weinheim, Germany, 1949, p. 267.

(6) Manganese dioxide: H. B. Henbest and J. W. Stratford, *Chem. Ind.* (London), 1170 (1960).

(7) Potassium ferricyanide: T. D. Perrine, *J. Org. Chem.*, **16**, 1303 (1951).

(8) Silicon tetrabromide: H. Breederveld, *Rec. trav. chim.*, **78**, 589 (1959).

(9) Tetranitromethane: E. Schmidt and H. Fischer, *Ber.*, **53**, 1537, (1920).

(10) Occasional nitration or halogenation: E. E. Ayling, J. H. Gorvin, and L. E. Hinkel, *J. Chem. Soc.*, 755 (1942).

(11) Zinc or cobalt halides: C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, pp. 615–618.

(12) The Hofmann–Martius rearrangement[11] concerns the direct action of a mineral acid, but, since it is carried out in a sealed tube at a high temperature and involves rearrangement, it is not included in the discussion.

(13) W. J. Hickinbottom, "Reactions of Organic Compounds," Longmans Green and Co., New York, N. Y., 1948, p. 306.

(14) P. Sabatier and G. Gaudion, *Compt. rend.*, **165**, 309 (1917).

(15) W. J. Hickinbottom, *J. Chem. Soc.*, 1070 (1933).

$$C_6H_5NH(CH_2)_4NHC_6H_5 \xrightarrow[230^\circ]{HBr} C_6H_5NH_2.HBr + \text{tetrahydroquinoline hydrobromide}$$

of dealkylation in preparative work has been reported recently.[16]

The purpose of this paper is to determine the mildest conditions under which dealkylation occurs with mineral acid and to run several comparative studies to understand the scope of the reaction. Without going into the details of the development of the procedure, the following conditions were found most useful: hydrogen bromide as a gas was introduced into the molten salt maintained at *ca.* 150°; the rate of dealkylation of tertiary alkyl amines at this temperature was quite rapid and independent of the flow rate of hydrogen bromide above 200 ml./min. Remarkably, the rates in this medium of molten aromatic amine–hydrobromide salt through which hydrogen bromide was passing to maintain the hydrogen bromide concentration and to sweep out alkyl bromide, followed pseudo first-order kinetic laws as shown in Experimental and in Table I. The rates of dealkylation of secondary aromatic amines were sufficiently slow at this temperature so that pure secondary amines could be isolated. Nevertheless, secondary aromatic amines could be dealkylated smoothly at a higher temperature, *ca.* 195°. All the facts established in this study are listed below:

TABLE I

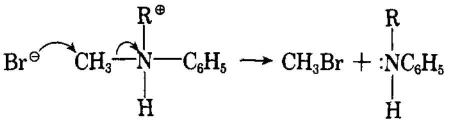
RATES OF DEALKYLATION OF TERTIARY TO SECONDARY AMINES BY HYDROGEN BROMIDE AT 156°[a]

N,N-Amines	k, min.$^{-1}$	$t_{1/2}$, min.
Dimethylaniline	0.012	58
Di-*n*-propylaniline[b]	0.0031	223
Dimethyl-*m*-chloroaniline	0.016	43
Dimethyl-*p*-toluidine	0.0058	119
Dimethyl-*o*-toluidine	0.021	34
Diethylaniline[c]	Very slow, 20% dealkylation in 2 hr.	

[a] Pseudo first-order rates at flow rate of hydrogen bromide 425 ml./min. ± 25 ml. [b] 20% silicone gum rubber used for stationary phase in g.l.c. [c] 10% Carbowax used for stationary phase.

1. Tertiary aromatic amines are dealkylated more readily than secondary aromatic amines.
2. Hydrogen bromide is more effective than hydrogen chloride.
3. The sequence of ease of elimination of alkyl groups is in the order: methyl > *n*-propyl > ethyl in tertiary aromatic amines.
4. A small but appreciable amount of isopropyl bromide was isolated in addition to *n*-propyl bromide in the dealkylation of di-*n*-propylaniline.
5. Electron-attracting groups in the aromatic ring increase the rate of dealkylation and *vice versa*.
6. *ortho* Substituents increase the rate of dealkylation to a greater extent than any other factor.
7. Aliphatic amines are more resistant to dealkylation and are not dealkylated in any useful manner by this procedure.[17] Cyclic amines such as N-methylpiperidine and nicotine gave polymeric products, and tri-*n*-butylamine was largely unaffected.

The preceding facts were accumulated under conditions to stress the synthetic rather than the mechanistic aspects of dealkylation. Nevertheless, the facts are suggestive of a simple mechanism which has been useful in carrying out the preceding work and in predicting these and other results. We believe that the reaction is remarkably akin to a solvolytic reaction of the S_N2 type reverting to the S_N1 type as the alkyl group is changed.



II III

The nitrogen atom in II is tetrahedral and in III is tending toward the trigonal planar structure, *i.e.*, R and H in the same plane as the benzene ring. Thus, a driving force exists in II to be transformed to the resonance-stabilized III. The driving force possibly could explain the more facile dealkylation of aromatic amines compared to aliphatic amines. If the R group in II is an alkyl group rather than a hydrogen atom, some steric crowding may exist, and this would explain the more facile dealkylation of tertiary amines compared to secondary amines.[18] Obviously, the reactivity sequences: HBr > HCl > H_2SO_4 for acids and *m*-chloro > hydrogen > *p*-methyl for aromatic substituents, should hold as long as the mechanism is S_N2. A methyl group should dealkylate in preference to an ethyl or other primary alkyl groups, and this prediction has been found to be true in the demethylation of kairoline (see Experimental). In our interpretation, the S_N2 mechanism reverts in part to the S_N1 mechanism with the introduction of a propyl group, judging from the faster rate of dealkylation and the isolation of a small amount of isopropyl bromide in the reaction of di-*n*-propylaniline with hydrogen bromide. Unquestionably, the tertiary alkyl group must dealkylate by the S_N1 mechanism.[15,19]

Whether the working hypothesis can be accepted as a mechanism remains to be seen. But disregarding this point, we were impressed in this work by the ease of cleavage of the carbon–nitrogen bond and the resemblance of the cleavage to that of the carbon–oxygen bond.

The experimental work was facilitated greatly by the gas chromatographic techniques described in the next section.

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(16) G. B. Russell, G. J. Sutherland, R. D. Topsom, and J. Vaughan, *J. Org. Chem.*, **27**, 4375 (1962).

(17) Other comments on dealkylation of aliphatic amines are to be found in C. D. Hurd, "The Pyrolysis of Carbon Compounds," A.C.S. Monograph 50, Chemical Catalog Co., New York, N. Y., 1929, pp. 310-329, and in reference by C. Ainsworth and N. R. Easton, *J. Org. Chem.*, **27**, 4118 (1962).

(18) If steric crowding exists in II when R is an alkyl group, a greater steric crowding effect should be present in a quaternary ammonium salt which should therefore dealkylate more easily with hydrogen bromide than II. We propose to test this prediction, although an example has been noted: A. T. Babayan, M. G. Indzhikyan, Z. G. Gegelyan, and A. A. Grigoryan, *Dokl. Akad. Nauk Arm., SSR*, **35**, 67 (1962); *Chem. Abstr.*, **58**, 5543 (1963). $C_6H_5NHCH_3 + CH_2{=}CH{-}CH_2\overset{+}{N}R_3 \longrightarrow C_6H_5N(CH_3)CH_2CH{=}CH_2 + R_3\overset{+}{N}H$

(19) Anchimerically assisted groups also should be cleaved easily from the nitrogen atom by the S_N1 mechanism. Such a cleavage has been observed with a norbornane lactam using 5% hydrochloric acid: L. H. Zalkow and C. D. Kennedy, *J. Org. Chem.*, **28**, 852 (1963).

TABLE II

RETENTION TIMES OF AROMATIC AMINES[a]

Aromatic amine	B.p., °C.	Retention time, sec.	Aromatic amine	B.p., °C.	Retention time, sec.
Aniline	184	122	*m*-Toluidine	203	184
N-Methylaniline	196	138	N,N-Dimethyl-*m*-toluidine	212	132
N,N-Dimethylaniline	193	98	*o*-Chloraniline	209	242
o-Toluidine	201	142	N,N-Dimethyl-*o*-chloroaniline	206	120
N-Methyl-*o*-toluidine	208	178	*m*-Chloroaniline	230	484
N,N-Dimethyl-*o*-toluidine	185	56	N-Methyl-*m*-chloroaniline	235	492
p-Toluidine	200	172	N,N-Dimethyl-*m*-chloroaniline	232	300
N-Methyl-*p*-toluidine	211	196	2,6-Xylidene	214	242
N,N-Dimethyl-*p*-toluidine	211	132	N,N-Dimethyl-2,6-xylidene	196	52
N-Ethylaniline	205	160	N-*n*-Propylaniline	222	210
N,N-Diethylaniline	215	124	N,N-Di-*n*-propylaniline	245	210
			N-Methylpiperidine	107	26

[a] The conditions are given in g.l.c. analysis section. Most curves are Gaussian in shape with about 1-cm. width at base of curve.

Experimental

The Reaction of Dimethylaniline and 4,7-Dichloroquinoline.[20]—This experiment led to the subsequent results reported here. N N-Dimethylaniline (0.3 mole) and 4,7-dichloroquinoline (0.1 mole) were heated to 100° whereupon a slow stream of hydrogen chloride was passed beneath the surface. The temperature climbed rapidly to 160° and after heat of neutralization had spent itself external heating was applied to maintain a temperature of 185°. After 2 hr. the mixture was cooled, poured into water, filtered, and washed with more water. The brown precipitate (26.2 g.) was recrystallized from ethanol containing an equal volume of hydrochloric acid. The crystalline hydrochloride (m.p. 295–300°; neut. equiv., 293) was converted to the free base by dissolving in ethanol and adding 0.1 *N* sodium hydroxide solution until the solution was basic. The white platelets were collected by filtration, washed thoroughly with water, air-dried and sublimed under reduced pressure, m.p. 207–207.5°, mixture melting point with 4-phenylamino-7-chloroquinoline, synthesized from aniline and 4,7-dichloroquinoline, the same.

Apparatus and General Procedure for Dealkylation.—The constant temperature bath was a three-necked two-piece 2-l. resin kettle equipped with thermometer, condenser, and a 200 × 25 mm. test tube. The test tube, inserted in one of the necks of the resin flask, was long enough to be bathed in the vapors of the refluxing liquid. A gas inlet tube for hydrogen halide entered the side of the test tube and terminated at the bottom in a sintered glass disk to give a well distributed flow of hydrogen halide. Temperatures in the apparatus could be maintained within 0.5° over long periods of time.

The pure amine (0.25 mole) was placed in the test tube to which a drying tube was attached. Dry hydrogen halide was passed through the amine until the hydrohalide had precipitated. The heat was dissipated with a water bath. To prevent pressure building up when the hydrohalide solidified, the hydrogen halide was by passed by opening the closed end of a Y tube in the piping system. The test tube was now placed in the constant temtemperature bath, the drying tube being replaced by a condenser. The temperature of the bath fell about 15° but was regained in about 3–5 min. When the hydrohalide melted, the safety valve was closed again to pass hydrogen halide through the molten salt. The exit hydrogen halide was led to a water trap.

To obtain rates an aliquot was removed from the test tube at appropriate intervals with a 1-ml. glass dipper and dissolved in water. The aliquot was made strongly basic and thoroughly extracted with ether. The ether layer was dried with solid potassium hydroxide and evaporated by means of a Rinco evaporator. The amine residue, about 0.5 g., was analyzed by gas–liquid chromatography when all aliquots had been accumulated. It was unnecessary to withdraw exact amounts of aliquot as analysis was based on the ratio of tertiary to secondary or primary amines.

G.l.c. **Analysis.**—Temperatures: column 230°; Gowmac detector, 217°. Column: 6 ft., $^1/_4$ in. copper tubing packed with 60–80-mesh Chromosorb W, containing 5% polyethylene-benzonitrile as a stationary phase.[21] Flow rate: 90 ml. of He/min. Detector current: 100 ma. Sample volume: 5 μl. The retention times are given in Table II.

Where separation was not brought about by the polyethylene benzonitrile resin, such a mixture of dipropylaniline and propylaniline, other resins that are specified were utilized.

Considerable study was done on calibration curves using known percentages of tertiary amine dissolved in secondary amine.[1] In all cases, the approximate area (peak height × 0.5 peak width at base of peak) was linear with respect to the concentration of tertiary amine. Therefore, rates were obtained by plotting log area of the tertiary amine peak *vs.* time.[22]

Results of Kinetic Studies Using Optimum Conditions for Dealkylation.—Hydrogen bromide was found to be more reactive than hydrogen chloride. A temperature of 156° (b.p. of 3-heptanol) and a flow rate of hydrogen bromide of 400 ml./min. were selected for comparison conditions. (The rate of dealkylation was independent of flow rate as low as 200 ml./min.; below this flow rate, however, the rate of dealkylation was dependent on flow rate.) All rates followed pseudo first-order rate kinetics. A typical rate is shown with N,N-dimethylaniline (k = 0.012 min.$^{-1}$; $t_{1/2}$ = 58 min.).

Time (min.)	Log area
17	0.89
30	0.82
43	0.76
59	0.67
73	0.61
90	0.52

At this temperature, negligible amounts of primary amines were formed, perhaps amounting to a few per cent in the case of the fastest dealkylating amine. Thus the dealkylation rate is mainly that of tertiary aromatic amine degrading to secondary amine. The comparative results using optimum conditions are shown in Table I.

Direct Comparison of Hydrogen Chloride and Hydrogen Bromide as Dealkylating Agents.—A direct comparison was made on dimethylaniline at a temperature of 177° and a flow rate of 146 ml./min.

$$\text{HCl:}\quad k = 0.015\ \text{min.}^{-1};\quad t_{1/2} = 46\ \text{min.}$$
$$\text{HBr:}\quad k = 0.021\ \text{min.}^{-1};\quad t_{1/2} = 33\ \text{min.}$$

Dealkylation of N-methylaniline.—As stated earlier, the rates of dealkylation of secondary amines are much slower than tertiary amines. A comparison was made at 195° at an approximate flow-rate of 100 ml./min. of hydrogen chloride.

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(20) We are indebted to Mr. W. Carl Dyer for making the initial run on this reaction.

(21) The resin was made by the condensation of equimolecular quantities of benzonitrile and ethylene bromide following the conditions for bromination of acetophenone reported by D. E. Pearson, H. W. Pope, and W. W. Hargrove, *Org. Syn.*, **40,** 7 (1960).

(22) This method of analysis placed emphasis on accurate delivery of 5μg. samples for g.l.c. Therefore, two or three samples were injected, and the average area for the tertiary amine was used to obtain rates. Usually, all areas were identical.

N,N-Dimethylaniline[23]: $k = 0.014$ min.$^{-1}$; $t_{1/2} = 50$ min.

N-Methylaniline: Very slow; kinetics complicated by appearance of N,N-dimethylaniline, reaching 10% by weight of total amine fraction at end of 1 hr. This means that rate of alkylation of N-methylaniline is faster than its rate of dealkylation, the latter being extremely slow. To demonstrate this, methyl chloride was passed through molten N-methylaniline hydrochloride at 195° and at a flow rate af 154 ml./min. After 3 hr., an aliquot contained 20% tertiary amine. This experiment demonstrates that the reverse reaction, alkylation, is slow under the conditions of dealkylation. Besides being slow it does not become important until the concentration of secondary amine is high.

The Isolation of the Alkyl Bromide from Dealkylation of N,N-Di-*n*-propylaniline.—The effluent hydrogen bromide containing alkyl bromide was passed through an efficient trap cooled with ice–water–salt mixture. The condensate was washed with cold water, separated, and dried. Analysis by gas chromatography (oven temperature, 93°; 10% SE-30 stationary phase, 32 ml./min. He flow rate, retention time for *n*-propyl bromide = 154 sec., retention time for isopropyl bromide = 126 sec.) showed 96% *n*-propyl bromide, 4% isopropyl bromide, and no propylene bromide. Pure *n*-propyl bromide did not isomerize when subjected to conditions identical with isolation procedure.

Demethylation of N-Methyltetrahydroquinoline (Kairoline) to Tetrahydroquinoline.—To show that methyl groups are removed preferentially, kairoline (0.2 mole) was treated with hydrogen chloride at 195° for 13 hr. Recovery of the basic product gave tetrahydroquinoline (0.19 mole, free from tertiary amine as denoted by g.l.c., benzenesulfonamide m.p. 65.6–66.5°, lit. m.p. 67°).

Attempts to Dealkylate Aliphatic Amines.—Regardless of changes in conditions and irrespective of the addition of catalysts or trapping agents such as 4,7-dichloroquinoline or 2,4-dinitrochlorobenzene, the dealkylation of nicotine and of N-methylpiperidine led only to black, polymeric tars. The attempted dealkylation of tri-*n*-butylamine at 195° for 6 hr. gave approximately 1% *n*-butyl bromide.

Acknowledgment.—The authors are indebted to the National Science Foundation for a grant in support of this work.

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(23) One notes that the rate of dealkylation at 195° is about the same as the rate at 177°. Part of this similarity is caused by different flow rates. But, another factor is that hydrogen chloride is not as soluble at higher temperatures in the melt. Thus, an increase in temperature does not necessarily increase the rate appreciably. An experiment to determine the amount of hydrogen chloride dissolved showed that 1 equivalent of hydrogen chloride dissolved per 1 equivalent of amine.

The Swamping Catalyst Effect. V. The Halogenation of Aromatic Acid Derivatives[1]

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A study of the halogenation of the aluminum chloride complexes of acid derivatives using excess aluminum chloride was undertaken. All the following acid derivatives were halogenated as aluminum chloride complexes. Methyl benzoate gave 86% methyl 3-bromobenzoate on monobromination and 89% methyl 2,5-dibromobenzoate on dibromination. *p*-Toluyl chloride gave 85% methyl 3,5-dibromo-4-toluate on dibromination. Methyl *p*-toluate gave 71% 3-chloro-4-toluic acid on chlorination and 65% methyl 3-iodo-4-toluate on iodination. Coumarin gave 74% 6-bromocoumarin. Benzonitrile gave 64% 3-bromobenzonitrile on monobromination and 79% 2,5-dibromobenzonitrile on dibromination. N-Methyl- and N,N-dimethylbenzamides gave poor yields in bromination. Methyl *o*-toluate gave a mixture of halogenated products which could not be separated easily. The preceding procedure is probably the best method of direct introduction of chlorine or bromine into aromatic acid derivatives.

One may ask the question: how is *m*-bromobenzoic acid obtained? The immediate answer would seem to be direct bromination of benzoic acid. This pathway is fraught with obstacles. The halogenation is very slow and incomplete, and the temperature of halogenation is high enough to bring about sublimation of unreacted benzoic acid.[4] To quote one source,[5] "direct halogenation is seldom successful and scarcely ever used" with aromatic acids.

We have now found that direct halogenation of the aromatic acid esters or chlorides can be carried out with eminent success using the swamping catalyst effect as shown.

$$C_6H_5COOCH_3 + 2AlCl_3 + Br_2 \xrightarrow{65^\circ} m\text{-}BrC_6H_4COOCH_3(86\%) + HBr$$

The swamping catalyst effect entails halogenation of the aluminum chloride complex with a highly reactive halogenation species, either X^+ itself, or the ion pair, $X^+\overset{-}{A}lCl_3X$. The halogenating species cannot be obtained unless more than one equivalent, and preferably two equivalents, of aluminum chloride are used.[6] No solvent is employed.

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(1) Part IV: B. R. Suthers, P. H. Riggins, and D. E. Pearson, *J. Org. Chem.*, **27**, 447 (1962).

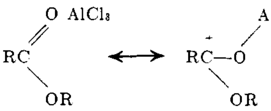
(2) Abstracted mainly from the Ph.D. thesis of W. E. S., 1962.

(3) Abstracted in part from the Ph.D. thesis of B. R. S., 1961.

(4) H. Hubner and G. Weiss, *Ber.*, **6**, 175 (1873): P. S. Varma and P. B. Panicker, *J. Indian Chem. Soc.*, **7**, 503 (1930).

(5) G. M. Dyson, "Manual of Organic Chemistry," Vol. I, Longmans, Green and Co., New York, N. Y., 1950, p. 590.

(6) In an earlier paper,[7] we stated that a unique part of the swamping catalyst effect with ketones was the formation of an eight-membered ring between two moles of acetophenone and two moles of aluminum chloride. From further study of the literature on complexes,[8] we believe that these structures are somewhat variable[9] and it is best to consider the complex simply as a Lewis salt: $R_2C{=}O\ AlCl_3 \longleftrightarrow R_2\overset{+}{C}{-}O\overset{-}{A}lCl_3$ or



, which may associate to give complexes of higher molecular weight or even dissociate.

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