Cleavage of *o*-Halobenzophenones by Potassium Amide in Liquid Ammonia[1]

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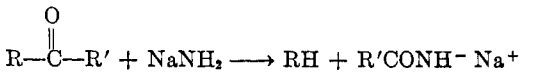
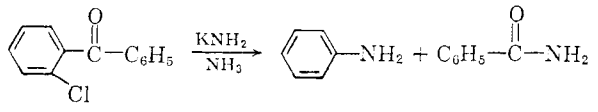
Although benzophenone is virtually unaffected, *o*-chlorobenzophenone is rapidly cleaved by potassium amide in liquid ammonia, yielding aniline, benzamide, and a little benzoic acid. 2-Chloro-2′,5′-dimethyl- and 2-chloro-2′,4′,6′-trimethylbenzophenones are smoothly cleaved according to the same pattern. *m*- and *p*-Chlorobenzophenones give mainly aminobenzophenones, evidently by an aryne mechanism. *o*-Fluorobenzophenone undergoes scission to fluorobenzene and benzamide. A rational mechanism involves addition of NH_2^- to the carbonyl group to form adduct I, proton loss to form II, separation into an *o*-halophenyl anion and benzamide anion III, and further transformations of the *o*-halophenyl anion. In the case of *o*-chlorobenzophenones, an alternative mechanism of concerted fragmentation of II into III, benzyne and chloride ion is rejected because 2-chloro-4-methylbenzophenone affords *o*-toluidine as well as its *meta* and *para* isomers.

The familiar Haller–Bauer cleavage of non-enolizable ketones[3] is generally slow even at ele-



vated temperatures. Thus sodium amide cleavage of benzophenone is effected by boiling for several hours in benzene or toluene.[4,5] Benzophenone is virtually unaffected by potassium amide in liquid ammonia.

In contrast, *o*-chlorobenzophenone is rapidly cleaved by potassium amide in ammonia. To judge from the boiling caused by the heat evolved, reaction commences on mixing and is complete within five or ten minutes. The products are aniline (77%), benzamide (79%)[6] and some tar.



Facile cleavage of several methyl derivatives of *o*-chlorobenzophenone has also been observed. These experiments are listed in Table I, which summarizes the principal results of this investigation. Every scission occurred between the carbonyl group and the halogenated benzene ring.

m- and *p*-Chlorobenzophenones do not give much cleavage; the main products are aminobenzophenones (Table I). *o*-Fluorobenzophenone is rapidly cleaved, giving benzamide and *fluorobenzene*. Aniline is not formed in this case.

Discussion

The Cleavage Reaction.—Our observations are most satisfactorily interpreted with respect to the mechanism of Chart I. Reasons for preferring this mechanism to certain alternatives which differ in detail will be presented.

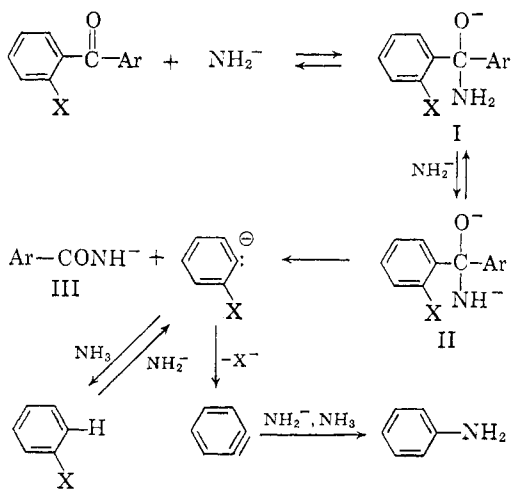
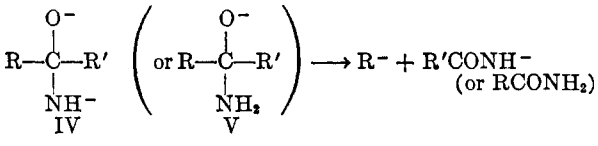


Chart I

The Haller–Bauer reaction is generally considered to involve fission of an adduct, perhaps IV or V, to form a carbanion and a carboxamide or the anion thereof.[3,7] Closely related are a number of



familiar ketone cleavages brought about by hydroxide or alkoxide ions, in which it is clear that the facility of cleavage depends on the stability of

(1) Based on the Ph.D. thesis of B. F. Hrutfiord, 1959. Presented at the 135th National Meeting of the American Chemical Society, Boston, Mass., April, 1959. Supported in part by the Army Research Office (Durham).

(2) Department of Chemistry, Brown University, Providence, R. I.

(3) K. E. Hamlin and A. W. Weston, "Organic Reaction," Vol. 9, J. Wiley & Sons, Inc., New York, N. Y., 1957, p. 1.

(4) A. Schönberg, *Ann.*, **436**, 205 (1924).

(5) P. J. Hamrick, Jr., and C. R. Hauser, *J. Am. Chem. Soc.*, **81**, 2096 (1959).

(6) On the assumption that all the benzoic acid isolated was from hydrolysis of benzamide.

(7) Walborsky and Impastato[8] postulated, because an optically active cyclopropane was obtained from sodium amide cleavage of an active cyclopropyl phenyl ketone and cyclopropyl anions were considered to be optically labile, that the Haller–Bauer reaction occurs *via* C—C rupture concerted with intraionic proton transfer so that formation of a carbanion intermediate is avoided. This postulate is weakened by Walborsky's subsequent demonstration,[9] and by that of Applequist and Peterson,[10] that cyclopropyl carbanions can maintain configurational stability.

(8) H. M. Walborsky and F. J. Impastato, *Chem. Ind.* (London), 1690 (1958).

(9) H. M. Walborsky and F. J. Impastato, *J. Am. Chem. Soc.*, **81**, 5835 (1959); H. M. Walborsky, A. A. Youssef, and J. M. Motes, *ibid.*, **84**, 2465 (1962).

(10) D. E. Applequist and A. H. Peterson, *ibid.*, **83**, 862 (1961).

TABLE I

PRODUCTS FROM ACTION OF KNH_2 ON HALOBENZOPHENONES[a]

Benzophenone derivative	Time, min.	Products
Unsubstituted	180	Benzophenone, 98%
2-Chloro	30	Benzamide, 59% Benzoic acid, 11% Aniline,[b] 39%
2-Chloro	20	Benzamide } 79%[c] Benzoic acid } Aniline,[d] 77% Impure residue,[e] *ca.* 14%
2-Chloro-2′,5′-dimethyl	390	2,5-Dimethylbenzamide, 61% 2,5-Dimethylbenzoic acid, 13% Aniline,[d] 55% 2-Amino-2′,5′-dimethylbenzophenone, 2% Impure residue,[e] *ca.* 12%
2-Chloro-2′,4′,6′-trimethyl	390	2,4,6-Trimethylbenzamide, 83% Aniline,[d] 51%
2-Chloro-4-methyl	30	Benzamide, 32% Benzoic acid, 37% Mixed toluidines,[f] 37% 2-Amino-4-methylbenzophenone, 1.4% Solid, m.p. 221°, *ca.* 2% Impure residue,[e] *ca.* 15%
2-Fluoro	15	Benzamide } 96%[e,g] Benzoic acid } Fluorobenzene, 29%
3-Chloro	300	*o*-Aminobenzophenone, 42% *m*-Aminobenzophenone, 25% Impure residue,[e,h] *ca.* 8%
4-Chloro	360	Benzoic acid,[i] 1.6% *m*-Aminobenzophenone, 42.5% *p*-Aminobenzophenone, 6.5% Impure residue,[e] *ca.* 20%

[a] Solvent was *ca.* 25% diethyl ether : 75% ammonia except that 2-chloro-4-methylbenzophenone was run in ammonia alone. In each reaction 0.05 mole of ketone and 0.25 mole of potassium amide were used except for those of benzophenone itself (0.05 and 0.15) and of 2-chloro-4-methylbenzophenone (0.10 and 0.50). [b] As aniline hydrochloride. [c] Yield of benzoic acid; benzamide intentionally hydrolyzed to benzoic acid during product work-up. [d] As benzanilide. [e] The "yield" of impure residue is 100 (wt. of residue)/(wt. of starting ketone). [f] See Experimental concerning composition. [g] In a similar experiment, 41% of benzamide and 58% of benzoic acid (much of which may represent benzamide hydrolysis during work-up) were isolated. [h] A 0.35-g. sample of a solid, m.p. 130°, possibly benzamide (if so, 6%), was also isolated. [i] The conditions of isolation would have hydrolyzed any benzamide present.

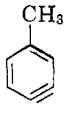
the carbanion which may be formed. Thus trihalomethyl ketones and β-diketones, which give relatively stable CX_3^- or $RCOCH_2^-$ anions, are easily cleaved. That ease of ketone cleavage by metal amides is also related to carbanion stability is indicated, among others, by Leake and Levine's report that phenyl triphenylmethyl ketone is partially split by sodium amide in ammonia, with formation of benzamide and triphenylmethane.[11]

The facility of cleavage in the present instance is ascribed to the comparative stability of *o*-halophenyl anions. Research on the elimination–addition (benzyne) mechanism of aromatic nucleophilic substitution[12,13] has shown that *o*-halophenyl anions are more rapidly formed, and therefore presumably more stable, than most phenyl anions. The rate of formation of *m*- and *p*-halophenyl anions is notably lower.

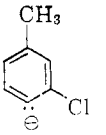
The facts that *o*-halogenated benzophenones, acetophenones, and benzaldehydes[14,15] are prone to cleavage by alkali between the halogenated ring and the carbonyl group are further manifestations of the same principle. A kinetic study of the cleavage of 2,6-dihalobenzaldehydes by aqueous alkali indicated the intermediacy of 2,6-dihalophenyl anions.[15]

The *o*-halophenyl anion initially formed might, in liquid ammonia, either lose halide ion to form benzyne and thence aniline[16] or capture a proton to form halobenzene. There is evidence that *o*-fluorophenyl anion follows only the latter course in refluxing liquid ammonia.[12] Any chlorobenzene resulting from proton capture would proceed to aniline *via* benzyne under the conditions of our cleavage experiments.[16]

It was conceivable, however, that intermediates such as I or II from *o*-chlorobenzophenones might experience concerted rupture of C—C and C—Cl bonds, forming benzyne, III and chloride ion in a single step without the intermediacy of *o*-chlorophenyl anion. The experiment with 2-chloro-4-methylbenzophenone was designed to test this possibility. Concerted scission would form 4-methylbenzyne (VI), which would progress to *m*- and *p*-toluidines.[17] But no *o*-toluidine would be formed. Stepwise scission would give initially



VI



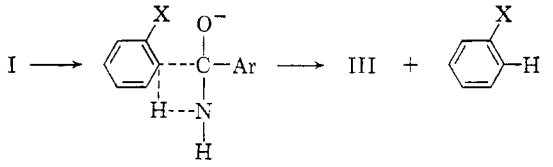
VII

(11) W. W. Leake and R. Levine, *J. Am Chem. Soc.*, **81**, 1169 (1959).
(12) G. E. Hall, R. Piccolini, and J. D. Roberts, *ibid.*, **77**, 4540 (1955).
(13) R. Huisgen, W. Mack, K. Herbig, N. Ott, and E. Anneser, *Chem. Ber.*, **93**, 412 (1960).
(14) P. J. Montagne, *Rec. trav. chim.*, **27**, 327 (1908); G. Lock, *Ber.*, **66**, 1527, 1759 (1933); **68**, 1505 (1935); G. Lock, E. Stoits, and H. Glassner, *ibid.*, **69**, 2253 (1936); G. Lock and E. Bock, *ibid.*, **70**, 916 (1937); G. Lock and R. Schreckeneder, *ibid.*, **72**, 511 (1939); G. Lock and E. Rodiger, *ibid.*, **72**, 861 (1939).
(15) J. F. Bunnett, J. H. Miles, and K. V. Nahabedian, *J. Am. Chem. Soc.*, **83**, 2512 (1961).
(16) J. D. Roberts, D. A. Semenow, H. E. Simmons, Jr., and L. A. Carlsmith, *ibid.*, **78**, 601 (1956).
(17) J. D. Roberts, C. W. Vaughan, L. A. Carlsmith, and D. A. Semenow, *ibid.*, **78**, 611 (1956).

anion VII which might then either expel chloride ion generating VI or capture a proton to form *m*-chlorotoluene. From the action of potassium amide on *m*-chlorotoluene all three toluidines would result.[17] Whether or not *o*-toluidine were produced would thus be decisive.

In the event, a considerable amount of *o*-toluidine was formed, together with its *meta* and *para* isomers. This was demonstrated by the infrared spectrum of the toluidine mixture and by isolation of pure acet-*o*-toluidide from chromatography of the acetylated mixture on alumina.[18] The concerted mechanism is therefore dismissed.

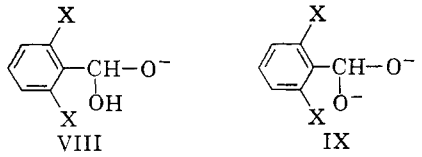
Another conceivable alternative is that intermediate I transfers a proton from nitrogen to carbon in concert with scission of the C—C bond.[7] The immediate products would be a halobenzene and carboxamide ion III. Except when the halogen



transition state

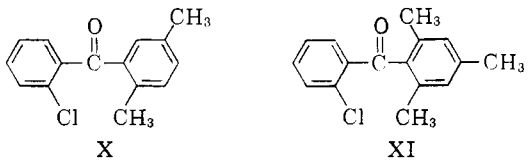
were fluorine, the halobenzene would then be converted to one or more aromatic amines through the action of potassium amide via the familiar aryne mechanism. This mechanism accounts for the formation of *o*-toluidine from 2-chloro-4-methylbenzophenone but does not give a satisfying interpretation of why only *o*-halobenzophenones are readily cleaved. However, a less-than-fully synchronous version of this mechanism, wherein C—C bond rupture were far advanced over C—H bond formation at the transition state, with consequent development of considerable anionic character at aromatic carbon, warrants consideration.

We do not know whether it is complex I or II which undergoes the vital fission. However, the kinetics of hydroxide cleavage of 2,6-dihalobenzaldehydes[15] indicate that no significant fraction of fission occurs in intermediate VIII and point to



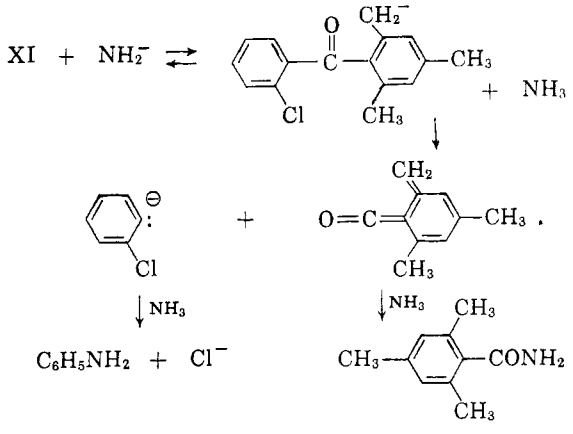
unimolecular heterolysis in IX as the rate-determining step. If IX can be formed to a kinetically adequate extent in aqueous hydroxide solutions, it is reasonable that II should be an effective intermediate in ammonia solutions of potassium amide.

To judge from our preparative observations, ketones X and XI, which have respectively some and much steric hindrance about the carbonyl



group, were cleaved nearly as readily as *o*-chlorobenzophenone. We consider it likely that the thermodynamic affinity of amide ion for the carbonyl group of benzophenones is so great that nearly complete conversion to intermediates of type I is attained regardless of whether there are *ortho*-methyl substituents.[19] In such a case, the rate of amide ion attack on the carbonyl carbon is of little consequence as long as it is considerably greater than the rate of the fission step.

An alternative mechanism of cleavage of 2-chloro-2′-methylbenzophenones is the following:



We see no grounds for rejecting this mechanism. However, it obviously cannot operate when a 2′- or 4′-methyl group is lacking. The mechanism of Chart I, which accounts for all the cleavages observed, is therefore preferred.

***m*- and *p*-Chlorobenzophenones.**—On treatment with potassium amide in ammonia, these ketones give mainly aminobenzophenones and little cleavage (Table I). From each chlorobenzophenone two aminobenzophenones were obtained, the predominant one having a "rearranged" orientation. An elimination–addition mechanism is indicated.

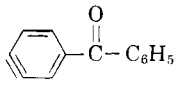
That the *meta* and *para* isomers give little cleavage suggests that cleavage is much slower when the halogen is *meta* to the carbonyl group. This deduction is correct providing that aryne formation is as fast or faster from *o*- as from *m*- and *p*-chlorobenzophenones. *A priori*, there is no reason to believe that the *ortho* isomer should lag behind both the *meta* and *para* isomers in this respect. One concludes that this cleavage, like

(18) We are grateful to Mr. Knowlton J. O'Reilly (Brown University), who prepared and separated the acetotoluidides.

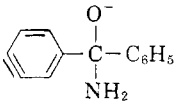
(19) Hamrick and Hauser[5] have isolated the adduct of potassium amide to benzophenone; the adduct was precipitated when the ammonia solvent was replaced by ether.

others related to it, is vitally dependent on the presence of an *ortho* halogen substituent.[20]

The aryne intermediate from *p*-chlorobenzophenone may be either XII or XIII, depending on whether the carbonyl group is free or has added

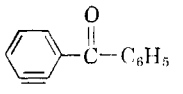


XII

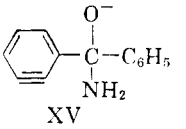


XIII

amide ion. From *m*-chlorobenzophenone, both XII (or XIII) and XIV (or XV) might have been expected. Were it not that about a third of the



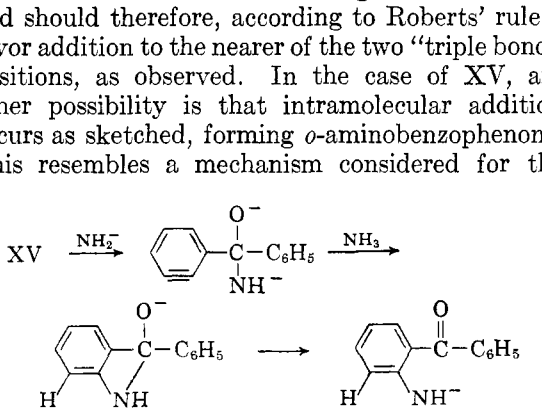
XIV



XV

starting ketone was unaccounted for, the fact that no *p*-aminobenzophenone was obtained from the *m*-chloro ketone would indicate that none of the reaction occurred *via* XII (or XIII). Nevertheless it is clear that a large fraction progressed through XIV (or XV). It is also evident that both aryne intermediates added amide ion preferentially at the position nearer the carbonyl carbon.

Since the electronic characteristics of the benzoyl group resemble those of CF_3, one might expect amide ion to add exclusively to the *meta* position of XIV and about equally to the *meta* and *para* positions of XII.[17] Because the aminobenzophenones obtained (Table I) do not substantiate these expectations, the amide-complexed arynes XIII and XV are more likely the intermediates to which addition occurs. As a substituent group, $-C(NH_2)(C_6H_5)O^-$ should have an electron-releasing inductive effect and should therefore, according to Roberts' rule,[17] favor addition to the nearer of the two "triple bond" positions, as observed. In the case of XV, another possibility is that intramolecular addition occurs as sketched, forming *o*-aminobenzophenone. This resembles a mechanism considered for the



formation of 2-methylindole from potassium amide treatment of *o*-chlorophenylacetone.[21]

Carboxylic Acids as Cleavage Products.—As detailed in Table I, benzoic acid invariably accompanied benzamide among the cleavage products. We regret that our experiments do not allow a decison as to whether the benzoic acid was formed in the original reaction or secondarily from hydrolysis of benzamide during product isolation. Part of the benzoic acid is surely from the latter source. It is conceivable that benzoic acid could be formed in the reaction proper through complex I acting as a cleavage reagent towards other ketone molecules.[22] The fact that 2,4,6-trimethylbenzamide was not accompanied by its acid is compatible with either view. Benzoic acid does not stem from ketone cleavage by potassium hydroxide (from small amounts of water in the ammonia), because potassium hydroxide in ammonia was shown to be unable to cleave *o*-chlorobenzophenone.

Experimental

The following benzophenone derivatives were prepared by the Friedel–Crafts method of Berliner,[23] a halogenated benzoyl chloride being used in all cases: *o*-chlorobenzophenone, m.p. 46° (lit.,[23] m.p. 43–44°); *m*-chlorobenzophenone, m.p. 83–84° (lit.,[24] m.p. 81–82°); *p*-chlorobenzophenone, m.p. 75–77° (lit.,[25] m.p. 77–78°); and *o*-fluorobenzophenone,[26] b.p. 164–166° (14 mm.), oxime m.p. 123° (lit.,[27] m.p. 126°).

2-Chloro-4-methylbenzophenone.—2-Chloro-4-methylbenzoic acid, m.p. 152–154° (lit.,[28] m.p. 155–155.5°), was converted by treatment with thionyl chloride to its acid chloride, b.p. 87–89° (2 mm.). Reaction of the latter with benzene by Berliner's Friedel–Crafts procedure[23] furnished 2-chloro-4-methylbenzophenone, m.p. 58–60°, b.p. 184–186° (9 mm.), in 92% yield. The ketone was crystallized from ethanol.

Anal. Calcd. for $C_{14}H_{11}ClO$: C, 72.88; H, 4.81. Found:[29] C, 72.75; H, 5.02.

2-Chloro-2′,4′,6′-trimethylbenzophenone, m.p. 99–101° (lit.,[30] m.p. 100°) was prepared in 80% yield from *o*-chlorobenzoyl chloride and mesitylene by the Perrier modification of the Friedel–Crafts reaction,[31] and crystallized from ethanol.

2-Chloro-2′,5′-dimethylbenzophenone was prepared from *o*-chlorobenzoyl chloride and *p*-xylene by the same method in 77% yield. This ketone boiled at 187° (10 mm.) and was obtained as white crystals (from ethanol), m.p. 39–41°.

Anal. Calcd. for $C_{15}H_{13}ClO$: C, 73.72; H, 5.31. Found[29]: C, 73.62; H, 5.35.

o-Aminobenzophenone, yellow crystals of m.p. 102–104° (lit.,[32] m.p. 105°) was prepared by treatment of *o*-benzoylbenzamide with chlorine in aqueous potassium hydroxide. *m*-Aminobenzophenone, yellow crystals of m.p. 85–87° (lit.,[33] m.p. 87°), was prepared by reduction of *m*-nitro-

(20) More direct evidence to the same point is the recent demonstration by Mr. Daniel S. Connor (unpublished work at Brown University) that *m*- and *p*-fluorobenzophenones resist cleavage by potassium amide in ammonia, and may be recovered unchanged.

(21) J. F. Bunnett and B. F. Hrutfiord, *J. Am. Chem. Soc.*, **83**, 1691 (1961).

(22) See the explanation of S. Selman and J. F. Eastham, *Quart. Rev.*, **14**, 221 (1960), for benzilic *acid* formation from the action of sodium amide on benzil.

(23) E. Berliner, *J. Am. Chem. Soc.*, **66**, 534 (1944).

(24) S. A. Koopal, *Rec. trav. chim.*, **34**, 153 (1915).

(25) P. Wegerhoff, *Ann.*, **252**, 6 (1889).

(26) We thank Mr. Guy Dority for a gift of *o*-fluorobenzoyl chloride.

(27) E. Bergmann and A. Bondi, *Ber.*, **64**, 1474 (1931).

(28) A. Claus and N. Davidson, *J. prakt. Chem.*, **39**, 491 (1889).

(29) Analysis by Micro-Tech Laboratories, Skokie, Ill.

(30) I. I. Lapkin, N. M. Puchkin, and P. A. Lykov, *Sb. Statei Obshch. Khim. Akad. Naut SSSR*, **2**, 823 (1953); *Chem. Abstr.*, **49**, 6876 (1955).

(31) L. F. Fieser, "Experiments in Organic Chemistry," 2nd ed., D. C. Heath & Co., Boston, Mass., 1941, p. 192.

(32) C. Graebe and F. Ullmann, *Ann.*, **291**, 12 (1896).

(33) R. Geigy and W. Koenigs, *Ber.*, **18**, 2400 (1885).

benzophenone with stannous chloride and hydrochloric acid. *p*-Aminobenzophenone, m.p. 121–122° (lit.,[34] m.p. 124°), was similarly prepared by reduction of the corresponding nitro compound. 2-Amino-2′,5′-dimethylbenzophenone, m.p. 98–100° (lit.,[35] m.p. 100°), was prepared by the method of Boëtius and Römisch.[35]

Cleavage Reactions.—We used the same apparatus and "general procedure" as described in another publication.[21] The "crude reaction product" (after neutralization of potassium amide and evaporation of the ammonia) was for the most part separated into its constituents by standard extraction procedures, steam distillation, etc. Noteworthy features received special comment below. The products obtained are stated in Table I. Except as otherwise noted, product identity was confirmed by the agreement of melting points with those of authentic samples, and the failure of mixture melting points to be depressed.

***o*-Chlorobenzophenone Cleavage.**—Benzoic acid was also identified by the m.p. (116°) of its *p*-bromophenacyl derivative (lit.,[36] m.p. 119°). In one run, the entire "crude reaction product" was refluxed with aqueous sodium hydroxide so as to convert benzamide to benzoic acid, simplifying isolation of the two principle cleavage fragments.

2-Chloro-2′,5′-dimethylbenzophenone Cleavage.—Identification of 2,5-dimethylbenzoic acid (m.p. 132°) and the corresponding amide (m.p. 186°) rest on the agreement of these melting points with literature values (132 and 186°, respectively),[37] on the fact that a sample of the acid was converted through action of thionyl chloride and then ammonia to the same amide, and on the m.p. (141–142°) of the anilide made from the acid (lit.,[38] m.p. 143°). 2-Amino-2′,5′-dimethylbenzophenone was isolated by chromatography of extraction residues on alumina.

2-Chloro-2′,4′,6′-trimethylbenzophenone Cleavage.—Identification of 2,4,6-trimethylbenzamide rests on the agreement of its melting point (188–189°) with the literature value (189°).[39] Small amounts of yellow oils, suggestive of aminobenzophenones, could not be resolved into pure components by chromatography on alumina.

2-Chloro-4-methylbenzophenone Cleavage.—The ketone did not dissolve in liquid ammonia, but went into solution on addition of potassium amide (in ammonia). To the "crude reaction product," water was added and a solid (mostly benzamide) was collected. Both the solid and the water layer were extracted with ether, and the ether extracts were at first slowly distilled to remove ether and then rapidly distilled *in vacuo* without any separation of fractions. The distillate was redistilled through a micro column at atmospheric pressure, and the fraction boiling at 196–202° was collected and examined directly by infrared spectroscopy. The spectrum was compared with the spectra of pure samples of the three toluidines, and it was possible to discern peaks uniquely characteristic of each isomer. In particular, peaks at 6.67, 6.83, 6.96, 8.76, and 14.06 μ spoke for *o*-toluidine. From this spectrum, the proportions of the three isomers were estimated to be about 30% *ortho*, 60% *meta*, and 10% *para*. By chromatography of residues on alumina, a compound, m.p. 106°, presumed to be 3-amino-4-methylbenzophenone, (lit.,[40] m.p. 107.5°) was isolated. Identification rests on the agreement of melting points and on the characteristic yellow color.

A small portion of the toluidine mixture was dissolved in 5% aqueous hydrochloric acid. Dilute sodium hydroxide was added till a faint turbidity remained, and a few drops of hydrochloric acid were added to clarify the solution. Acetic anhydride was added, the mixture was shaken vigorously, a 20% solution of sodium acetate in water was added, and vigorous agitation was continued several minutes. A pasty brownish precipitate separated on cooling. It was allowed to settle, the water layer was decanted, and the impure solid was placed on an alumina chromatographic column. Elution was performed in succession with 75% ethyl ether–25% chloroform (v./v.), 50% ether–50% chloroform, and 25% ether–75% chloroform. These solvents eluted, respectively, the *meta*, *para*, and *ortho* isomers of acettoluidide. Separation was clean. Fractions taken as acet-*m*-toluidide melted at 66°, had infrared spectra identical to that of an authentic sample and caused no depression of the mixture melting point. Fractions taken as acet-*p*-toluidide melted at 146° and by the same criteria were identical with an authentic sample. Fractions taken as acet-*o*-toluidide melted from 100 to 109.4° and, in the cases of those melting over 108°, were identical with an authentic sample by the same criteria. The weights of the acettoluidides recovered from the column were in the ratio 65% *meta*, 7% *para*, and 28% *ortho*. About 80% of the weight of the crude acettoluidide mixture was isolated as these three pure amides.[18]

***o*-Fluorobenzophenone Cleavage.** The reaction occurred with little generation of heat; there was no obvious boiling of the liquid ammonia. A voluminous precipitate formed within 5 min. After ammonium nitrate had been added to destroy potassium amide, ether was added and the ammonia was slowly distilled through a water-cooled condenser. The mixture was notably free of tars or other colored substances (except ferric hydroxide). Water and sodium hydroxide were added, the ether was distilled and collected, and the remaining mixture was heated at 90° for 1 hr. and finally steam distilled. The distillate was extracted with ether. The ether extract was combined with the ether collected above, dried, and fractionally distilled. From this, 1.4 g. of a liquid of b.p. 83–84° was collected. The infrared spectrum was identical in all respects to that of authentic fluorobenzene. Authentic fluorobenzene distilled in the same apparatus registered the same boiling point.

***m*-Chlorobenzophenone Reaction.**—The "crude reaction product" was notably dark in color. Part of the *o*-aminobenzophenone was isolated by crystallization from the neutral fraction, and the rest by chromatographing the acid-soluble fraction plus crystallization residues on alumina. *m*-Aminobenzophenone was isolated by treatment of a benzene solution of chromatographic residues with dry hydrogen chloride. It separated as the hydrochloride, m.p. 180–185° (lit.,[33] m.p. 187°), and was then converted to the free base.

***p*-Chlorobenzophenone Reaction.**—The reaction did not cause much boiling of the liquid ammonia. Much *m*-aminobenzophenone was isolated by crystallization of the acid-soluble fraction from ethanol. Chromatography of the crystallization residues on alumina furnished more *m*- as well as the *p*-aminobenzophenone.

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