aceto nitrile, a procedure which could not be confirmed in the present work.

2. Among other new compounds described in this work are β-triphenylpropionamide, β-triphenylpropionhydroxamic acid and its benzoyl derivative, and *sym.*-di-β-triphenylethyl-urea.

3. Detailed directions for the preparation of β-triphenylpropionic acid by the method of Fosse are submitted.

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[CONTRIBUTION FROM THE KENT CHEMICAL LABORATORY OF THE UNIVERSITY OF CHICAGO]

THE OXIDATION OF COMPOUNDS POSSESSING THE PRIMARY AMINO GROUP. I. DIPHENYLMETHYLAMINE

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The mechanism of oxidation of compounds possessing an amino group linked to a primary or secondary carbon atom (RCH_2NH_2; $RR'CHNH_2$) is a problem of considerable interest to organic chemists, and is also of importance in biological chemistry, particularly in connection with the important question of the oxidation of amino acids. Because of the electronic relationship of amino derivatives to hydroxylated compounds,[2] it has seemed interesting to inquire to what extent oxidation of amino compounds may, in general, produce substances of the types (that is, aldehydes and ketones as the ultimate products) which are obtained when the corresponding hydroxy derivatives are oxidized. From a theoretical point of view, the question of intermediate compounds formed during the course of an oxidation reaction is of additional importance.

Considerable work is recorded[3] in which amino derivatives of types (1) RCH_2NH_2, (2) $RR'CHNH_2$ and (3) $RR'R''CNH_2$ have been subjected to oxidation with agents related to hydrogen peroxide. Bases of the

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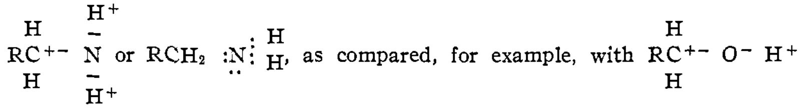
[1] This preliminary paper is an abstract of part of a dissertation submitted to the University of Chicago by Agnes Graham Sanders, in partial fulfilment of the requirements for the degree of Master of Science, August, 1925. Presented before the Virginia Section of the American Chemical Society, April, 1926.



[2] $\mathrm{R}\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}{}^{+-}\ \overset{\overset{\mathrm{H}^+}{-}}{\underset{\underset{\mathrm{H}^+}{-}}{\mathrm{N}}}$ or $\mathrm{RCH_2}\ :\underset{..}{\mathrm{N}}\vdots\ \substack{\mathrm{H}\\ \mathrm{H}}$, as compared, for example, with $\mathrm{R}\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}{}^{+-}\ \mathrm{O}^-\ \mathrm{H}^+$ or $\mathrm{RCH_2}\ :\overset{..}{\underset{..}{\mathrm{O}}}:\ \mathrm{H}$. The valence sign $^-$ as used here indicates the relative polarity of an atom resulting from the approach of a valence electron pair : , and the sign $^+$ the corresponding polarity of the other atom held by the doublet bond.

[3] (a) Bamberger and Seligman, *Ber.*, **36**, 701 (1903). (b) Bamberger and Tschirner, *Ber.*, **32**, 1675 (1899). For other references consult Houben-Weyl, "Methoden," Georg Thieme, Leipzig, **1922**, vol. 2, p. 144.

tertiary type (Type 3 and the anilines) yield hydroxylamino derivatives in the first stage of oxidation. Hydroxylamines are undoubtedly also first formed when bases of Types 1 and 2 are oxidized, but in either of these cases the adjacent carbon atom is so readily attacked that the product of the second oxidation stage, an oxime, is the first which may be isolated. For example, $RR'CHNH_2 \longrightarrow RR'CHNHOH \longrightarrow RR'C{=}NOH$. The formation of the hydroxylamino derivative may be considered, in a sense, an oxidation of the nitrogen atom. The second step, which leads to the oxidation of the carbon atom linked to nitrogen, involves from the point of view of this paper the more fundamental change. The more active amines of Types 1 and 2 may yield a variety of products; an aldoxime, $RCH{:}NOH$, for example, which appears from oxidation of RCH_2NH_2 may evidently be further oxidized to the hydroxamic acid stage, since the aldehydo carbon atom still possesses a readily oxidizable position.[4]

Controlled oxidations of amines where the oxidizing agents were other than of the peroxide type have also been reported. Thus, uramil is oxidized to alloxan with great ease by the action of chlorine.[5a,6] Benzylamine is largely converted to benzaldehyde by the action of potassium permanganate.[5b] The same amine, when oxidized with bromine in the presence of sodium ethylate in anhydrous alcoholic solution, yields a gummy product which may be completely hydrolyzed to benzaldehyde and benzonitrile.[7] Aldehydes have been obtained by the action of oxygen in the presence of copper upon amino compounds.[5c] Limitations of space prevent detailed discussion of these and other interesting examples.

In the present work, it seemed interesting to inquire what would be the ultimate product of oxidation when a substituted methylamine of high molecular weight is oxidized by bromine in the presence of sodium ethylate in anhydrous alcoholic solution. The amine selected for study was diphenylmethylamine, $(C_6H_5)_2CHNH_2$.[8] Bromine was chosen as the

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[4] According to the theory of Stieglitz, aldehydes and their addition products possess "exposed" electrons (readily lost to oxidizing agents) on the aldehydo carbon atom due chiefly to the labile character of the hydrogen atom. Compare Stieglitz, THIS JOURNAL, **44,** 1308 (1922); "Qualitative Chemical Analysis," The Century Co., New York, **1911**, vol. 1, p. 291.

[5] (a) Baeyer, *Ann.*, **131,** 298 (1864). (b) Goldschmidt and Voeth, *Ann.*, **435,** 265 (1924). (c) Traube and Schönewald, *Ber.*, **39,** 178 (1906).

[6] See the discussion on p. 1745.

[7] Hellerman, unpublished work.

[8] Since the completion of this work and the writing of the paper Goldschmidt and Beuschel have reported [*Ann.*, **447,** 197 (1926)] the results of work on the oxidation of the same compound with permanganate in absolute acetone solution, the product of oxidation being iminobenzophenone. (Compare results reported in the present work.) These workers assume that the amine is "dehydrogenated" by the oxidizing agent, the resulting intermediate product, $(C_6H_5)_2CH.N{<}$, transforming itself to the imino compound.

oxidizing agent because it was considered that if the formation of a bromo-amine, $R_2CHNHBr$, should constitute the first step in the oxidation series, we should have initially a situation comparable[9] to that which obtains when amines are oxidized to oximes by means of Caro's acid. This distinction must, however, be noted: the hydroxylamines are *much more stable substances* than the bromo-amine derivatives. Anhydrous alcohol was selected as the reaction medium in order that hydrolysis of the bromo-amine derivative, if formed intermediately, might be practically entirely prevented.

As recorded in the experimental section, benzophenone in excellent yield was the ultimate product of the oxidation.[3a] In order to attempt an elucidation of the nature of the change, it was postulated that the assumed initial product of reaction—the monobromo derivative of the amine, $(C_6H_5)_2CH.NHBr$—rearranges or undergoes intramolecular oxidation-reduction, yielding iminobenzophenone according to the equation $(C_6H_5)_2CH.NHBr + NaOC_2H_5 \longrightarrow (C_6H_5)_2C{=}NH + NaBr + C_2H_5OH$. This imine has been well described;[10] water hydrolyzes it promptly to benzophenone and ammonia. This hydrolysis would constitute the final step in the assumed series of reactions leading from diphenylmethylamine to benzophenone.

In order to ascertain if such an hypothesis of reaction mechanism could be justified experimentally, the behavior of N-chlorodiphenylmethylamine, $(C_6H_5)_2CHNHCl$, in the presence of sodium ethylate in anhydrous alcoholic solution was observed. The N-chloro compound was used because N-chloro-amines stand close to N-bromo-amines chemically and are more easily synthesized than the latter. Its preparation was accomplished by treatment of a solution of the amine hydrochloride with a *neutral* solution of an equimolecular quantity of sodium hypochlorite. This chloro-amine was, in fact, found to resolve itself with great ease, under the conditions of experiment, into iminobenzophenone.

While it would appear undesirable to become committed at the present time to any complete interpretation of such a reaction, the change undoubtedly is related essentially to this fundamental fact: the carbon atom has become oxidized at the expense, ultimately, of the "positive" halogen atom, which has become reduced to halide ion. Such an intramolecular change might, for example, take place very much in the manner of the Hofmann rearrangement.[11] In terms of the more recent practices

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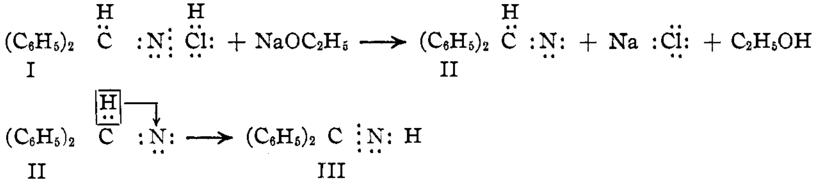
[9] Compare the many well-known chemical characteristics manifested in common by hydroxylamino derivatives, RNHOH, and halogeno-amines, RNHX.

[10] Hantzsch and Kraft, *Ber.*, **24**, 3516 (1891). Moureu and Mignonac, *Compt. rend.*, **156**, 1801 (1913).

[11] Hofmann, *Ber.*, **14**, 2725 (1881). The formulation which follows is intimately related to the general theories of molecular rearrangements which have been advanced by Stieglitz and his collaborators. See THIS JOURNAL, **36**, 272 (1914); **38**, 2046 (1916) for references to the literature. Compare also Jones, *Am. Chem. J.*, **50**, 440 (1913).

of polarity expression we should have



$$\underset{\text{I}}{(C_6H_5)_2}\ \overset{H}{\ddot{C}}\ :\underset{..}{N}\vdots\,\overset{H}{\underset{..}{\ddot{Cl}}}: + NaOC_2H_5 \longrightarrow \underset{\text{II}}{(C_6H_5)_2}\ \overset{H}{\ddot{C}}\ :\underset{..}{N}: + Na\ :\underset{..}{\ddot{Cl}}: + C_2H_5OH$$

$$\underset{\text{II}}{(C_6H_5)_2}\ \overset{\boxed{\underset{..}{H}}}{C}\ :\underset{..}{N}: \longrightarrow \underset{\text{III}}{(C_6H_5)_2\ C}\ \vdots\underset{..}{N}:\ H$$

Briefly stated, in the presence of the base sodium ethylate, H + Cl− is removed from the nitrogen atom in compound I, the nitrogen atom being at the same time oxidized by virtue of the removal of an electron pair by $\underset{..}{\overset{..}{Cl}}$:. The unstable univalent nitrogen derivative II results (intermediately). The nitrogen atom in II now completes its octet by attracting :H from the carbon atom. The loss of :H by the carbon atom involves the oxidation of the latter and the whole process results in the formation of iminobenzophenone (III).

In spite of the significant result here obtained for the intramolecular oxidation-reduction of the chloro-amine derivative, it is not to be concluded that *direct* oxidation of amines of Types $RR'CHNH_2$ and RCH_2NH_2 with halogens or other oxidizing agents necessarily follows exclusively such a course as has been suggested. *Direct attack* at the carbon atom vicinal to the amino group is by no means excluded. Such a path must, indeed, be especially considered when such activating groups as phenyl (as in benzylamine and in the case under present study) or carbonyl (as in the case of uramil) are carried by the vicinal carbon atom; under such circumstances we should have characteristic labilization of hydrogen atoms carried by the carbon atom and the susceptibility of the latter to oxidation would be markedly enhanced.[4] The subject will be discussed in greater detail in a later paper which will describe further work on the oxidation of amines of the type $RR'CHNH_2$, and of the secondary amines. Work is being continued also on substances of the type RCH_2NH_2, particularly β-diphenylethylamine and β-triphenylethylamine, $(C_6H_5)_3CCH_2$-NH_2,[12] and on the oxidative mechanism of the α-amino acids, $RCHNH_2$.-COOH.

Experimental Part

1. **Oxidation of Diphenylmethylamine.**—Diphenylmethylamine hydrochloride[13] (5 g.), dissolved in 50 cc. of anhydrous alcohol,[14] was treated with an alcoholic solution of 3

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[12] Hellerman, THIS JOURNAL, **49**, 1735 (1927).

[13] The melting point assigned to this compound in the literature [Leuckart and Bach, *Ber.*, **19**, 2130 (1886)] is 270°. It was found in the present work that the hydrochloride had not melted at 293°.

[14] Prepared from commercial absolute alcohol by prolonged treatment with lime and careful distillation, care to prevent the introduction of moisture being exercised both in the preparation and storing of the alcohol.

equivalents of sodium ethylate, prepared by treatment of 1.57 g. of sodium with 50 cc. of anhydrous alcohol. With constant shaking, one equivalent of bromine (3.64 g.) was then quickly added; sodium halides precipitated at once. After the reaction mixture had been gently refluxed for half an hour, a test with hydriodic acid for active halogen failed, and the reaction was then considered complete. The solution was slightly acidified with dil. sulfuric acid, and the alcohol was removed by distillation with steam. The reaction product separated from the residual aqueous solution as a light yellow oil. This was extracted with ether and the ethereal extract dried. After evaporation of the ether an oil remained which, when cooled, promptly solidified to a mass of slightly colored, radiating prismatic crystals. The melting point was found to be 47° and was not depressed when the material was mixed with some known benzophenone. The identity of the product as benzophenone was thus established. Of the product, 2.72 g. was obtained (yield, 66%).[15]

2. **Preparation of N-Monochlorodiphenylmethylamine,** $(C_6H_5)_2CHNHCl$.—This compound was prepared by the action of the calculated amount of sodium hypochlorite upon a solution of diphenylmethylamine hydrochloride. An alkaline solution of sodium hypochlorite was prepared in the usual way by means of passing chlorine gas into an excess of sodium hydroxide solution at 0°. The active chlorine content of this solution was determined in the usual manner. The solution was analyzed for excess alkalinity by the procedure of Berg.[16] Before use it was titrated for active chlorine, and the required quantity was then treated at 0°, as described by Berg, with the exact amount of standard acid necessary to neutralize the excess of alkali.

For the preparation of N-monochlorodiphenylmethylamine, diphenylmethylamine hydrochloride (5 g.) was dissolved in about 30 cc. of water, and to this was added at 5° a neutral solution of sodium hypochlorite containing exactly one molecule of the hypochlorite for each molecule of the amine salt. The mixture almost immediately became cloudy and very soon a pale yellow solid precipitated. This product was collected on a filter at once, washed with three small portions of cold chlorine water, and dried in a vacuum over phosphorus pentoxide. The substance was found to possess the properties characteristic of chloro-amine derivatives. The yield was almost quantitative.

Anal. Calcd. for $C_{13}H_{11}NCl_2$: Cl, 28.15. Calcd. for $C_{13}H_{12}NCl$: Cl, 16.3. Found: 15.7, 15.9.

3. **Intramolecular Oxidation-Reduction of N-Monochlorodiphenylmethylamine.**—The chloro-amine (5 g.) was dissolved in 30 cc. of anhydrous alcohol and treated with an equimolecular quantity of sodium ethylate prepared by treatment of 0.52 g. of sodium with 50 cc. of anhydrous alcohol. The mixture was vigorously shaken. Precipitation of a solid (sodium chloride) began at once with the evolution of heat. The mixture was gently refluxed for five minutes. A test at this point for active halogen failed, and the reaction was considered complete. Care to prevent the introduction of moisture was exercised throughout the entire experiment. The alcohol was removed by distillation under reduced pressure (20 mm.). The residue consisted of a mixture of sodium chloride with a quantity of a yellow oil. The oil was found to be identical with iminobenzophenone, as proved in the succeeding section.

4. **Isolation of Iminobenzophenone Hydrochloride,** $(C_6H_5)_2C{=}NH_2Cl$.—The

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[15] When diaryl methylamines are oxidized under the conditions described in this section by either bromine or iodine, iminoketones have been found to be present in the reaction mixtures, easily isolated as hydrochlorides. Experimental details will be submitted later

[16] Berg, *Ann. chim. phys.*, [7] 3, 289 (1894).

residual oil was extracted with anhydrous ether. The imino compound was next isolated in the form of its hydrochloride in the following manner. The ethereal solution was saturated with dry hydrogen chloride. A white precipitate resulted, which was brought upon a filter, washed with absolute ether, and dried in a vacuum in order to remove ether and traces of free hydrogen chloride. That the product was the hydrochloride of iminobenzophenone was indicated by analysis for chlorine by the Volhard method. The yield was 90% of that expected.

Anal. Calcd. for $C_{13}H_{12}NCl$: Cl, 16.30. Found: 16.43.

This analysis would not, of course, differentiate between the hydrochloride of iminobenzophenone and that of diphenylmethylamine, if present. The former compound may, however, be completely differentiated from the latter by its characteristic behavior when hydrolyzed with water.[17] That the product was *completely hydrolyzed to benzophenone* when dissolved in water is demonstrated by the following. Of the hydrochloride, 1.5 g. was dissolved in 25 cc. of water. A clear solution resulted which almost immediately became milky. After several minutes' standing, it was found that droplets of an oil had collected. The reaction product was carefully extracted with ether. The extract was dried, and the ether was evaporated. A light yellow oil remained which crystallized when it was cooled. The melting point of the product was found to be 47.9° and that of a mixture with some benzophenone was also 47.9°. The recorded melting point of benzophenone is 48°. The yield, 1.2 g., was practically quantitative. A test of the aqueous solution after the ether extraction proved that chloride ion and ammonium ion were present.

Merely as an accessory test, some of the iminobenzophenone hydrochloride obtained in this work was added to a solution of hydroxylamine and sodium carbonate, and the mixture was treated in the manner customarily employed for the preparation of benzophenone oxime. An excellent yield of the pure oxime was obtained.

Summary

1. Some aspects of the problem of the mechanism of oxidation of amino derivatives of the types RCH_2NH_2 and $RR'CHNH_2$ are briefly discussed from the point of view of modern concepts of oxidation-reduction.

2. The oxidation of diphenylmethylamine in anhydrous alcoholic solution in the presence of sodium ethylate is shown to yield benzophenone as the chief product.

3. A mechanism of reaction to account for the product obtained and to elucidate the nature of the reaction is postulated; experimental work is presented which is considered, in a measure, to justify the proposed theory.

4. The conversion of N-monochlorodiphenylmethylamine into iminobenzophenone by means of an anhydrous alcoholic solution of sodium ethylate was accomplished.

5. The preparation of N-monochlorodiphenylmethylamine is described.

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[17] See the theoretical part and the references cited there.