

Anal. Calcd. for C₁₀H₁₅BrO: C, 51.96; H, 6.54; Br, 34.55. Found: C, 52.03; H, 6.84; Br, 33.80.

Bromo ketones Xa, VII and VIII were eluted in fractions 5-35, while from fractions 35-43 there was isolated 80 mg. of a new bromo ketone, which exhibited m.p. 85.5-86.5° after recrystallization from iso-octane and sublimation at 60° (0.001 mm.). The optically active form,¹⁸ (-)-2β-bromo-*cis*-1-decalone (XIIa), possessed m.p. 74-75° (softening at 65°) and an infrared spectrum (Table II) which was indistinguishable from that of the racemic ketone; R.D. (Fig. 2) in iso-octane (c 0.155): [α]₁₀₀ -18°, [α]₅₈₉ -26°, [α]₃₈₈ -50°, [α]₃₅₅ -20°, [α]₃₂₀ -304°, [α]₃₁₆ -285°, [α]₃₁₁ -337°.

[α]₃₀₅ -25°, [α]_{302.5} -273°, [α]_{292.5} -260° (inflect.), [α]₂₇₅ -150°, [α]₂₆₀ -197°; R.D. (Fig. 2) in methanol (c 0.175): [α]₇₀₀ -48°, [α]₅₈₉ -55°, [α]₃₁₉ -234°, [α]₂₉₄ -94°, [α]₂₆₅ -155°.

Anal. Calcd. for C₁₀H₁₅BrO: C, 51.96; H, 6.54. Found: C, 51.84; H, 6.28.

Debromination of either racemic XI or racemic XII (30 mg.) with 200 mg. of zinc and 3 cc. of acetic acid (4 hr., room temperature) and extraction with ether provided 12 mg. of *cis*-1-decalone, whose infrared spectrum (notably absence of 11.03 μ band—see Table II) showed the absence of significant amounts of *trans*-1-decalone.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY AND CHEMICAL ENGINEERING, CASE INSTITUTE OF TECHNOLOGY, CLEVELAND 6, OHIO]

Aromatic Amination with Alkylhydroxylamines^{1,2}

BY PETER KOVACIC AND J. LINDSLEY FOOTE³

RECEIVED SEPTEMBER 6, 1960

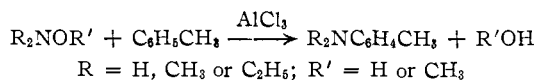
Various alkylhydroxylamines were investigated as aminating agents in the toluene-aluminum chloride system. The yields of aromatic amine decrease with increasing alkyl substitution on nitrogen. The orientation of substitution is predominantly *ortho-para* with a relatively high percentage *meta*. The mechanism of the reaction is discussed in terms of aromatic substitution by an electrophilic species of considerable activity.

Introduction

A brief survey of direct aromatic amination has been presented in a previous paper.⁴ The most pertinent examples in connection with the present work are the aminations with hydroxylammonium salts^{5,6} and hydroxylamine-O-sulfonic acid.^{4,7,8} The objectives of the present study were to effect aromatic amination with alkylhydroxylamines and determine the mechanism of this reaction.

Results and Discussion

O-Methyl-, O,N-dimethyl-, O,N,N-trimethyl-, N,N-diethylhydroxylamine and hydroxylamine were investigated as aminating agents in the toluene-aluminum chloride system. The amination reaction is illustrated by the equation

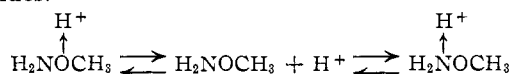


The reaction mixtures were heated at 100-111° for 10-60 minutes. In order to reduce the possibility of diamination, a tenfold molar excess of the aromatic compound was used. It was found that a twentyfold excess of toluene gave essentially the same results. Since amination with hydroxylamine-O-sulfonic acid is known⁹ to proceed best with two molar equivalents of aluminum chloride per mole of aminating agent, the same ratio was used in this

study. Isomer distributions were determined by infrared analysis of the purified amines.

The amination reactions displayed the following characteristics: predominant *ortho-para* orientation, relatively low *ortho-para* ratio, relatively high *meta* orientation, catalysis by aluminum chloride, and yield of aminated product related to the structure of the alkylhydroxylamine as: O-methyl- > O,N-dimethyl- > O,N,N-trimethyl-, N,N-diethyl (Table I).

It is likely that an alkylhydroxylamine-catalyst complex is involved in the transition state. The actual catalyst might be either aluminum chloride or a proton¹⁰ (for the sake of simplicity, the proton will be used to designate the catalyst). Since there are two basic sites (nitrogen and oxygen) in the hydroxylamine compounds capable of coordination with the catalyst, the situation is more complex than in aromatic substitution with alcohols or alkyl halides.



By analogy with the Friedel-Crafts reaction and since it is improbable that amination would be

affected by the ammonium species, the H₂NOCH₃ complex is presumed to be the attacking reagent. With a Lewis acid catalyst coordinated on oxygen, the oxygen-nitrogen bond would be polarized so as to increase the cationic character of the nitrogen.

Those alkylhydroxylamines possessing an O-methyl group would also be expected to alkylate toluene, perhaps as the initial preferred reaction. Indeed, xylene was isolated as a reaction product, although it is not known to what extent disproportionation of toluene was involved. Formation of benzene, xylene and mesitylene in the hydroxylamine reaction definitely shows that disproportiona-

(10) G. F. Hennion and R. A. Kurtz, *J. Am. Chem. Soc.*, **65**, 1001 (1943).

(1) Part II of a series on "Direct Aromatic Amination."

(2) Taken in part from the Ph.D. thesis of J. L. Foote, Case Institute of Technology, 1960. This paper was presented at the 137th Meeting of the American Chemical Society in Cleveland, Ohio, April, 1960, Abstracts of Papers, p. 56-O.

(3) National Science Foundation Predoctoral Fellow, 1958-1960.

(4) P. Kovacic and R. P. Bennett, *J. Am. Chem. Soc.*, **83**, 221 (1961).

(5) C. Graebe, *Ber.*, **34**, 1778 (1901).

(6) G. F. Jaubert, *Compt. rend.*, **132**, 841 (1901).

(7) R. N. Keller and P. A. S. Smith, *J. Am. Chem. Soc.*, **68**, 899 (1946).

(8) R. N. Keller and P. A. S. Smith, *ibid.*, **66**, 1122 (1944).

(9) P. A. S. Smith, Doctoral Dissertation, University of Michigan, 1944.

TABLE I
 TOLUIDINES FROM HYDROXYLAMINES AND TOLUENE^a

Expt.	Aminating agent	Mole	—CH ₃ C ₆ H ₄ NR ₂ (R = H, CH ₃ , or C ₂ H ₅)—								
			C ₆ H ₅ CH ₃ moles	Yield, ^b %	°C.	B.p.	Mm.	n _D ²⁰	Isomer distribution, %		S _t
								<i>o</i>	<i>m</i>	<i>p</i>	
1	H ₂ NOCH ₃	0.25	2.5	42	98-106	28 ^c	1.5645	34	16	50	0.80
2	CH ₃ NHOCH ₃ ¹¹	.2	2	24	138-145	90 ^d	1.5534	22	18	60	.82
3	CH ₃ NHOCH ₃	.2	4	24	104-110	25 ^{d,e}	1.5549	24	17	59	.84
4	(CH ₃) ₂ NOCH ₃	.08	0.8	0							
5 ^{f,g}	(C ₂ H ₅) ₂ NOH	1.1	11	2 ^h	108-125	28 ⁱ	1.5298				
6 ^j	H ₂ NOH	0.3 ^k	5.1	37	83-92	11	1.5639	31	14	55	.89

^a At 111° for 10 min. with aluminum chloride according to the General Procedure (work-up A), unless otherwise indicated. ^b Based on aminating agent. ^c *Anal.* Calcd. for C₇H₉N: C, 78.46; H, 8.46; N, 13.07. Found: C, 78.45; H, 8.51; N, 13.20. ^d There was a fore-run, 0.7 g., b.p. 59-64° (95 mm.). ^e *Anal.* Calcd. for C₈H₁₁N: C, 79.30; H, 9.15; N, 11.56. Found: C, 79.40; H, 9.14; N, 11.80. ^f See Experimental. ^g At 100-107° for 1 hr. with work-up B. ^h Based on total aromatic amine isolated. ⁱ *Anal.* Calcd. for C₁₁H₁₇N: C, 80.90; H, 10.50; N, 8.58. Found: C, 80.50; H, 10.43; N, 9.07. ^j At 100-106° for 20 min. with work-up B. ^k Hydroxylamine was added in small portions to a cold mixture of toluene and aluminum chloride (1 mole).

 TABLE II
 SELECTIVITY FACTORS AND *ortho-para* RATIOS

Reaction	Reagent	Conditions	S _t	<i>o/p</i>	Ref.
Amination	H ₂ NOCH ₃	AlCl ₃ , 111°	0.80	0.68	
Methylation	CH ₃ NHOCH ₃	AlCl ₃ , 111°	.83	0.39	
Methylation	CH ₃ Br	GaBr ₃ , C ₆ H ₆ , 25°	.84	1.86	17, 18
Isopropylation	<i>i</i> -PrBr	GaBr ₃ , C ₆ H ₆ , 25°	.55	1.15	17, 18
Nitration	HNO ₃	CH ₃ CO ₂ H (90%), 45°	1.37	1.41	17, 18

tion can occur under the standard conditions. The fact that hydroxylamine effected amination of toluene and produced an isomer distribution similar to that of *O*-methylhydroxylamine (Table I) is also consistent with the concept of initial C-O bond cleavage. If this is the case, then the *O*-methylhydroxylamines, as well as hydroxylamine, may form intermediates of the structure, R₂NOAlCl₂ (R = H or CH₃), and catalyst complexes of the type,

$\begin{matrix} \text{H}^+ \\ \uparrow \\ \text{R}_2\text{NOAlCl}_2 \end{matrix}$. Analogous compounds (ROAlCl₂) are reported for the reaction of alcohols with aluminum chloride.^{12,13a}

The predominant *ortho-para* orientation (82-86%) observed in the amination of toluene by hydroxylamines provides additional support for the proposed electrophilic substitution mechanism. The relatively high *meta* orientation (14-18%) points to an attacking species of considerable activity. To test the possibility of isomerization during the course of reaction, each of the toluidine and *N*-methyltoluidine isomers was subjected to simulated reaction conditions. No isomerization was detected.

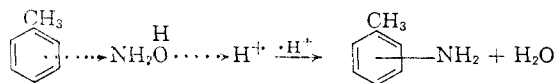
Brown proposed^{14,15} that the extent of *meta* substitution in toluene is a measure of the activity of the attacking electrophile, *i.e.*, a species of high activity will approach a statistical distribution in its reaction and therefore yield relatively large amounts of the *meta* isomer. More recently, Brown and Smoot have calculated¹⁶ for various electro-

philic substitutions in toluene the selectivity factor, S_t, defined as S_t = log(*p_t*/*m_t*), with *p_t* and *m_t* representing the partial rate factors. In the absence of data for the partial rate factors, the selectivity factor may be obtained¹⁶ from the isomer distribu-

tion according to the formula, S_t = log($\frac{2 \times \%o\text{p}}{\%om}$).

Selectivity factors have been calculated by means of this expression and are listed in Table I. Accordingly, the relatively low S_t values (0.80-0.89) indicate that the attacking species in the amination reactions are of high activity. A clearer picture of the high activity of these reagents is obtained by comparison of the selectivity factors for various electrophilic substitution reactions involving toluene (Table II).

For alkylations by the Friedel-Crafts method, there is a change in mechanism in going from methylation to *t*-butylation.^{16,19} In the latter instance reaction proceeds *via* carbonium ion formation, whereas methylation apparently takes place by a concerted process. It should be noted that the selectivity factors for the amination of toluene are very near that for methylation. These considerations lead to the conclusion that amination of toluene proceeds by a concerted mechanism similar to the methylation reaction.



In regard to the *ortho-para* ratios, the lower ratio for methylation (by CH₃NHOCH₃) would indicate a larger steric factor than for amination (by

(11) Preliminary work was done by the senior author at E. I. du Pont de Nemours and Co.

(12) C. C. Price in "Organic Reactions," Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1946, pp. 4-5.

(13) C. A. Thomas, "Anhydrous Aluminum Chloride in Organic Chemistry," Reinhold Publishing Corp., New York, N. Y., 1941; (a) p. 617, (b) p. 713.

(14) H. C. Brown and K. L. Nelson, *J. Am. Chem. Soc.*, **75**, 6292 (1953).

(15) H. C. Brown and C. W. McGary, Jr., *ibid.*, **77**, 2300 (1955).

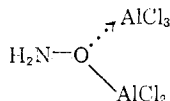
(16) H. C. Brown and C. R. Smoot, *ibid.*, **78**, 6255 (1956).

(17) L. M. Stock and H. C. Brown, *ibid.*, **81**, 3323 (1959).

(18) K. L. Nelson and H. C. Brown in "The Chemistry of Petroleum Hydrocarbons," Vol. 3, Reinhold Publishing Corp., New York, N. Y., 1955, p. 501.

(19) C. R. Smoot and H. C. Brown, *J. Am. Chem. Soc.*, **78**, 6249 (1956).

H₂NOCH₃). Comparison of the *ortho-para* ratios obtained in the amination of toluene with those for alkylation reactions shows, interestingly enough, that amination gives a significantly lower ratio (Table II). A possible interpretation of the data is that an increased steric effect is operating to hinder *ortho* substitution in the amination reactions. However, this approach does not seem reasonable on the basis of the relative size of the -NH₂ and -CH₃ groups. Nevertheless, the steric interpretation may well be valid in terms of the steric factors associated with the catalyst complexes which appear to be the actual reactants. It is apparent from a consideration of the CH₃Cl-AlCl₃ complex that the carbon is relatively unhindered. With reference to the indicated catalyst complex for the amination reaction some crowding of the -NH₂ site



is evident from an inspection of the model. An "ortho-effect" (coördination between the attacking species and the methyl group) may possibly be involved in certain cases.²⁰

Since hydroxylamine is a nitrogen analog of methanol, a comparison of amination with alkylation by alcohols is in order. Our findings concerning the effect of structure of the aminating agent on yield of aromatic amine (Table I) are in sharp contrast with the results from alkylation effected by alcohols. With the butyl alcohols and benzene in the Friedel-Crafts reaction, yields of butylbenzene decreased in the order, *tert* > *sec* > *pri*.²¹ This trend, the opposite of that for amination, is generally interpreted on the basis of ease of formation of the corresponding carbonium ion. Various possibilities should be considered as a rationalization of the amination results, with attention focused on the dialkylhydroxylamines: (a) selective coördination of the catalyst on nitrogen, (b) side reactions, (c) steric effects and (d) inability to form a "nitrogenium" ion. The formation of diethylamine in high yield from N,N-diethylhydroxylamine-toluene, and evidence for the presence of cresols, indicate preference for another reaction pathway in this case. The observed reaction may well be intimately associated with the nature of the alkylhydroxylamine-catalyst complex in the transition state.

The reaction of N,N-diethylhydroxylamine with toluene gave N,N-diethyltoluidine, N-ethyltoluidine, diethylamine, a phenolic product (presumably cresol) and a hydrocarbon fraction, apparently ethyltoluene. Two alternative routes may account for the formation of N-ethyltoluidine and ethyltoluene: Lewis acid-catalyzed dealkylation of N,N-diethyltoluidine, or dealkylation of N,N-diethylhydroxylamine followed by amination with N-ethylhydroxylamine. Although the C-N bond of amines appears to be relatively resistant^{22a} to

heterolytic cleavage by Lewis acid catalysts, dealkylation can be accomplished under the appropriate conditions.^{22b,c} The wide divergence in the yields of diethylamine (50-60%) and phenolic product (2%) is not surprising in view of the large amount of tar and poor recovery of starting material from the phenol-hydroxylammonium chloride-aluminum chloride reaction.²⁰ On assumption that the cresol is formed by electrophilic substitution, with simultaneous generation of diethylamine, the attacking entity would then consist of HO⁺. Similarly, the aluminum chloride catalyzed reaction of benzoyl peroxide with benzene leading to phenyl benzoate²³ may also be interpreted as proceeding by a cationic oxygen intermediate. Various examples of oxygen analogs of carbonium ions are discussed by Leffler.²⁴ On the other hand, one must recognize that the phenolic fraction might originate from a reaction involving oxygen of the air.^{13b}

Experimental

Materials.—Toluene was redistilled and subsequently dried over sodium. Aluminum chloride was in the form of anhydrous powder from Matheson, Coleman and Bell, or Mallinckrodt. O,N-Dimethylhydroxylamine was synthesized by the method previously reported²⁵; b.p. 42-43° and 41.7-42.5°, reported²⁶ b.p. 42.3°. O,N,N-Tri-methylhydroxylamine was prepared according to the procedure of Jones and Major²⁷; b.p. 27-32°, reported²⁶ b.p. 30°. O-Methylhydroxylamine, b.p. 47-48°, reported²⁶ b.p. 48.1°, was obtained by acid hydrolysis of the methoxyurethan by-product from the preparation of O,N-dimethylhydroxylamine. N,N-Diethylhydroxylamine, kindly supplied by Pennsalt Chemicals Corp., was redistilled, b.p. 61-64° (40 mm.) and 125-129°, reported^{28a} b.p. 133°. Free hydroxylamine²⁹ was crystallized from 1-butanol at -10°. The white, crystalline hydroxylamine was collected by vacuum filtration, washed with cold ether and used at once.

General Procedure.—This procedure was used unless otherwise indicated. Aluminum chloride (twice the molar quantity as the aminating agent used) was added all at once to the cold (about 0°) mixture of aromatic compound and aminating agent in a flask equipped with an efficient stirrer, reflux condenser and thermometer. The mixture was heated during 1-1.5 hr. to the reaction temperature. During the heating time, the mixture darkened gradually and appeared to become one phase. The rapid evolution of acidic fumes, presumably hydrogen chloride, necessitated control of the heating rate and to some extent determined the ultimate temperature in experiments 5 and 6. The processing followed either of two procedures, A and B.

(A).—The cooled, two-phase mixture was poured onto ice containing hydrochloric acid. The resulting organic layer was separated and extracted with 2 N hydrochloric acid. The combined acid solution was extracted with ether (the ether layer combined with the organic solution) and made basic with concentrated sodium hydroxide. The caustic mixture was extracted with ether, the ether solution dried over sodium sulfate and distilled. The residue from distillation did not exceed 6% by weight of the aromatic amine obtained, except for experiments 2 and 5 (8 and 28%, respectively). The infrared spectrum of the major

(23) A. F. A. Reynhart, *Rec. trav. chim.*, **46**, 54 (1927).

(24) J. E. Leffler, "The Reactive Intermediates of Organic Chemistry," Interscience Publishers, Inc., New York, N. Y., 1956, p. 166.

(25) R. T. Major and E. E. Fleck, *J. Am. Chem. Soc.*, **50**, 1479 (1928).

(26) T. C. Bissot, R. W. Parry and D. H. Campbell, *ibid.*, **79**, 796 (1957).

(27) L. W. Jones and R. T. Major, *ibid.*, **50**, 2742 (1928).

(28) I. Heilbron and H. M. Bunbury, "Dictionary of Organic Compounds," Vol. II, Oxford University Press, New York, N. Y., 1953; (a) p. 185, (b) p. 524.

(29) C. D. Hurd in "Inorganic Syntheses," Vol. I, McGraw-Hill Book Co., Inc., New York, N. Y., 1939, p. 87.

(20) P. Kovacic, R. P. Bennett and J. L. Foote, to be published.

(21) W. M. Potts and R. J. Dodson, *J. Am. Chem. Soc.*, **61**, 2553 (1939).

(22) (a) J. F. Norris and H. S. Turner, *ibid.*, **61**, 2128 (1939); (b) W. J. Hickinbottom, *J. Chem. Soc.*, 404 (1937); (c) A. G. Hill and A. J. Hill, *Ind. Eng. Chem.*, **43**, 1583 (1951).

fraction from distillation agreed favorably with spectra of the expected amines.

(B).—The cooled, two-phase mixture was poured onto ice and sufficient sodium hydroxide was added to dissolve aluminum salts. The separated aqueous layer was extracted with ether which was then combined with the organic layer. The organic layer was extracted with hydrochloric acid and the procedure continued as in A.

In general, procedure A is preferred. The data are summarized in Table I.

Neutral Aromatic Product.—The neutral organic layer from the work-up was washed successively with water, bicarbonate solution, and water, then dried over magnesium sulfate and distilled. The results of these distillations are summarized: Experiment 1-3: xylene, b.p. 132-145°, characterized by infrared analysis, was obtained in yields comparable to the yields of aromatic amines, and small amounts of higher boiling material, about 2 g.; expt. 4.: 0.4 g. of oil, b.p. 53-60° (136 mm.); 1.3 g. of oil, b.p. 182-200° (77 mm.) and 0.3 g. of residue. *Anal.* (2nd fraction): C, 91.44; H, 8.03. Molecular formula $C_{14}H_{14}$, estimated from the boiling point. Experiment 5: about 10 g. of benzene; about 3 g. of xylene; 0.5 g. of oil, b.p. 60-80° (40-38 mm.), n_D^{25} 1.4986; 1.4 g. of oil, b.p. 60-115° (18 mm.); and 61 g. of black oil as residue; expt. 6: about 20 g. of benzene, about 15 g. of xylene, 20.6 g. of oil which was collected in various fractions between 30 and 180° (11 mm.), and 11.1 g. of semi-solid residue. Mesitylene was identified from a redistilled fraction, b.p. 159-161°, n_D^{25} 1.4949.

Anal. Calcd. for C_9H_{12} : C, 89.94; H, 10.06. Found: C, 89.83; H, 10.05.

N,N-Diethylhydroxylamine-Toluene-Aluminum Chloride.—This supplements material already given for this reaction. The first mole of aluminum chloride which was added in portions to the mixture of the two reactants appeared to dissolve with a temperature rise to 33°.

Basic Products.—Distillation of the ether solution containing basic products gave 5 g. of liquid, b.p. 35-53°; 18 g. of liquid possessing an ammoniacal odor, b.p. 53-55°; a trace of liquid with sharp odor, b.p. 50-100°; 3 g. of N,N-diethylhydroxylamine, b.p. 52-55° (28 mm.); 3.5 g. of oil, b.p. 108-125° (28 mm.); and 1 g. of tar residue. Partial distillation of the aqueous layer after extraction gave 25 g. of liquid with a strong ammoniacal odor, b.p. 33-57°.

The diethylamine, b.p. 53-55°, n_D^{15} 1.3870 (reported³⁰ b.p. 55°, n_D^{15} 1.3873) yielded an oxalate melting at 209-210° from ethanol-acetone. The oxalate of an authentic sample of diethylamine and a mixture of the two oxalates melted at 209-210°. A portion of the fraction, b.p. 33-57°, which was distilled from the aqueous mixture, yielded a white crystalline solid on treatment with *p*-toluenesulfonyl chloride. Recrystallization from 95% ethanol gave crystals, m.p. 59-60°; reported³¹ for N,N-diethyl-*p*-toluenesulfonamide, m.p. 60°. Based on N,N-diethylhydroxylamine, the yield of diethylamine was 50-60%.

The aromatic amine fraction, b.p. 108-125° (28 mm.), was redistilled from sodium in order to remove any N,N-diethylhydroxylamine present, and the distillate appeared to be a mixture of N,N-diethyl-*p*-toluidine and N-ethyl-*p*-toluidine. The infrared spectrum had a strong band near 2.8 μ characteristic of the NH structure in *sec*-amines.

Anal. Calcd. for $C_{11}H_{17}N$ (50%) + $C_9H_{13}N$ (50%); C, 80.48; H, 10.13; N, 9.39. Found: C, 80.41; H, 10.13; N, 9.50.

The amines were separated by treatment of the distillate with *p*-toluenesulfonyl chloride. A second run was made to obtain additional product. The work-up was by procedure A. Two additional procedures were used to separate the *sec*- and *t*-aromatic amines, one involving benzenesulfonyl chloride and the other acetyl chloride. N,N-Diethyltoluidine was separated from each of these derivatives of N-ethyltoluidine by extraction with acid in the presence of ether. Excess *p*-toluenesulfonyl chloride and benzenesulfonyl chloride were removed by treatment with aniline in the presence of sodium hydroxide. Infrared spectra of the *p*-toluenesulfonamide, benzenesulfonamide

and acetamide derivatives were in good agreement, except for relative peak intensities, with the spectra of corresponding derivatives made from a mixture consisting of 50% *p*-, 15% *m*- and 35% *o*-N-ethyltoluidine. All of the derivatives were oils.

Anal. Calcd. for $C_{16}H_{19}NSO_2$ (N-ethyltoluene-*p*-toluenesulfonamide): C, 66.44; H, 6.62; N, 4.84. Found: C, 66.14; H, 6.61; N, 4.99.

A portion of the *t*-amine, separated by the acetyl chloride procedure, on heating with picric acid gave yellow crystals, m.p. 112° (soft at 102°) from alcohol. Authentic N,N-diethyl-*p*-toluidine give a picrate which melted at 114.5-115° from ethanol. Mixed with picric acid this material melted below 90°. A mixture of the picrates from the two sources melted at 112-113°.

Anal. Calcd. for $C_{17}H_{20}N_4O_7$: C, 52.04; H, 5.15; N, 14.28. Found: C, 51.77; H, 4.81; N, 14.11.

Acidic Product.—The toluene layer from the second preparation was extracted with 2 *N* sodium hydroxide after the acid extractions. Acidification of the caustic solution yielded 0.8 g. (2%) of brown oil, b.p. 186° (test-tube), n_D^{20} 1.5236, which possessed the characteristic cresol odor; lit.³⁰ for cresols, b.p. 191-203°, n_D^{20} 1.5395-1.5453. A dilute caustic solution of this product gave a dark orange oil upon addition of anilinediazonium chloride. The infrared spectrum was essentially identical with that of a mixture of the three cresol isomers.

Anal. Calcd. for C_7H_8O : C, 77.73; H, 7.47. Found: C, 75.11; H, 7.26.

Neutral Product.—The repeat reaction gave 0.5 g. of oil, b.p. 155-170°, n_D^{25} 1.4968; reported for ethyltoluenes,^{28b} b.p. 157-165°, n_D^{20} 1.4959-1.5042, whose infrared spectrum could be accounted for by the reported³² spectra of ethyltoluenes, except for an extraneous band at about 7.9 μ .

O-Methylhydroxylamine and Toluene.—A solution consisting of toluene (61.3 g.) and O-methylhydroxylamine (3.1 g.) was prepared. The infrared spectrum was taken, as well as the refractive index, n_D^{27} 1.4870. The solution was placed in a closed bottle and submerged in an oil-bath for 30 min. at 100-105°. Samples of the cooled solution gave n_D^{27} 1.4872 and an infrared spectrum identical with that taken before heating. Distillation of the remaining solution yielded 2.7 g. of O-methylhydroxylamine and 57 g. of toluene, including the distillation residue (infrared spectrum identical with that of toluene).

Isomerization Studies.—Each of the aromatic amines listed in Table III was separately subjected to conditions simulating those of amination. Water and methanol were added, and hydrogen chloride was continuously introduced below the surface of the mixture. The mixtures were refluxed for 1 hr. Procedure A was used for the work-up, except that the recovered amines were not distilled after removal of ether. Infrared analyses showed no isomerization.

TABLE III
ISOMERIZATION STUDIES

Aromatic amine	Mole	$C_6H_5CH_3$, moles	$AlCl_3$, mole	H_2O , mole	CH_3OH , mole	Recovery, %
Toluidine						
<i>ortho</i>	0.1	3	0.6	0.1	0.1	97
<i>meta</i>	.1	3	.6	.1	.1	98
<i>para</i>	.1	3	.6	.1	.1	95
N-Methyltoluidine						
<i>ortho</i>	0.1	4	0.8	0.1	0.1	96
<i>meta</i>	.04	1.6	.33	.04	.04	97
<i>para</i>	.1	4	.8	.1	.1	87

Analytical Method.³³—Analysis of the mixtures of toluidine and N-methyltoluidine isomers was effected by use of a plot of the known concentration in cyclohexane solution *versus* the absorbance according to the base line method. The

(30) "Handbook of Chemistry and Physics," C. D. Hodgman, Ed., Chemical Rubber Publishing Co., Cleveland, Ohio, 1949.

(31) R. L. Shriner, R. C. Fuson and D. Y. Curtin, "The Systematic Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1956, p. 288.

(32) Infrared Spectral Data, American Petroleum Institute Research Project 44, No. 164-166.

(33) Elemental analyses were performed by Drs. Weiler and Strauss, Oxford, England, and Geller Laboratories, Bardonia, N. Y.

absorbance was measured at the indicated wave length (μ): toluidine (*o*-, 13.43; *m*-, 13.02; *p*-, 12.37); *N*-methyltoluidine (*o*-, 13.44; *m*-, 13.05; *p*-, 12.43). Comparison

with known mixtures showed a deviation of no more than $\pm 1\%$ for any isomer. Infrared spectra were obtained with a Perkin-Elmer model 21 infrared spectrophotometer.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, WESTERN MICHIGAN UNIVERSITY, KALAMAZOO, MICH.]

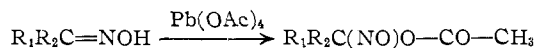
The Preparation and Structure of Azoacetates, a New Class of Compounds¹

BY DON C. IFFLAND, LYNN SALISBURY AND WM. R. SCHAFER

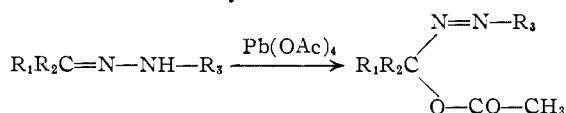
RECEIVED SEPTEMBER 13, 1960

Lead tetraacetate is shown to react with ketohydrazone to form azoacetates. The structure for these compounds, $R_1R_2C(OAc)N=NR_3$, is established from analysis of the ultraviolet spectra; a mechanism is proposed for the reaction.

In an earlier report² it was shown that lead tetraacetate reacts with ketoximes to form nitrosoacetates



An apparently similar reaction of lead tetraacetate with cyclohexanone phenylhydrazone that formed an unidentified high boiling oil was also described. This reaction of lead tetraacetate has now been examined in detail and found to be general for the preparation of a new class of compounds, the azoacetates,³ from ketohydrazone.



The properties of fourteen compounds prepared in this way from hydrazones are collected in Table I. The reactions producing these compounds are marked by simplicity, generally high yields and freedom from reaction by-products which might interfere with easy isolation of the azoacetates. As indicated by the yields in Table I, the course of the reaction is not affected by variation of alkyl, cycloalkyl or phenyl substituents at the carbonyl carbon in the hydrazone or by variation of the aryl or alkyl substituent at the hydrazone nitrogen. In addition to the reactions of lead tetraacetate, lead tetrabenzoate with benzophenone phenylhydrazone gave an azobenzoate in 86% yield.

Generally, these reactions have been carried out in methylene chloride solution at 0 to 10°. Benzene and acetic acid solvents have also been used with no change in the nature of the reaction. However, the latter solvents are much less convenient because of lower solvent capacity for both reactants and result in greater difficulty in isolation of the reaction product.

The structure of the azoacetates obtained from hydrazones in the lead tetraacetate reaction is similar to the autoxidation product described by Pausaker. It has been concluded that the autoxidation of hydrazones, such as benzaldehyde phenyl-

hydrazone, with oxygen form azohydroperoxides,^{4a} $C_6H_5CH(O-OH)N=NC_6H_5$, while peracids (perphthalic acid) gave azoxy compounds.^{4b,5} The structure for the azoacetates is established conclusively by the ultraviolet spectra. As shown in Table II, the azoacetates derived from ketoalkylhydrazones show only a weak absorption band at 350–357 $m\mu$. This absorption is clearly the R-band characteristic of azoalkanes as shown by azomethane.⁶ In contrast, those azoacetates prepared from arylhydrazones are characterized by an intense absorption at 266–277 $m\mu$ with a weak absorption at 395–404 $m\mu$. These values are independent of the alkyl or aryl structure of R_1 and R_2 as well as a change from acetate to benzoate. This absorption resembles the spectra of alkylazobenzenes.^{6a} The intensive band is undoubtedly due to the azo conjugation with the benzene ring (K-band) while the weak absorption shows the characteristic bathochromic shift of the R-band. These values are also similar to the spectra of the recently described azonitriles.⁷ α -(Phenylazo)-isobutyronitrile for example has maxima at 270 and 390 $m\mu$ ($\log \epsilon$ 3.81 and 2.30, respectively). Thus, the observed spectra indicate that the azoacetate structure rather than the unrearranged structure, $R_1R_2C=NN(OAc)R_3$, is correct for these compounds.

The rate of the reaction of lead tetraacetate with hydrazones was followed in a few instances by measuring the amount of unchanged lead tetraacetate. The reaction in an aliquot sample was halted immediately by adding water and converting the unreacted lead tetraacetate to lead dioxide. This brown precipitate was washed, dried and weighed. The determination was completed entirely in a centrifuge tube and a precision of 96 to 98% was realized with known amounts of pure lead tetraacetate.

With acetone phenylhydrazone and acetone *p*-nitrophenylhydrazone reactions were 90 to 95% complete at 30 sec. when the first aliquot was ob-

(4) (a) K. A. Pausaker, *J. Chem. Soc.*, 3478 (1950); (b) B. M. Lynch and K. A. Pausaker, *ibid.*, 2517 (1950), and following papers.

(5) Dr. Bernard Gillis, Duquesne University (private communication), has indicated that peracetic acid oxidation of phenylhydrazones also leads to azoacetates as described in this paper; he will publish details of his procedure.

(6) (a) A. Burawoy, *J. Chem. Soc.*, 1865 (1937); (b) for a review of correlation between structure and absorption, see E. A. Braude and F. C. Nachod, "Determination of Organic Structures by Physical Methods," Academic Press, Inc., New York, N. Y., 1955, Chap. 4.

(7) M. C. Ford and R. A. Rust, *ibid.*, 1297 (1958).

(1) Presented in part at the 137th Meeting of the American Chemical Society, Cleveland, Ohio, April, 1960. This work was supported in part by the National Science Foundation under Grant NSF-G 5789.

(2) D. C. Iffland and G. X. Criner, *Chemistry & Industry*, 176 (1956).

(3) For convenience the designation azoacetate is suggested for the general structure shown. In the experimental section the systematic acetoxyarylaalkane or acetoxyalkylazoalkane name is used.