1,3-Diphenylpentane.—1,3-Diphenyl-1-pentene, 9.5 g. (0.0426 mole), was added to 75 ml. of ethanol and 1 g. of Raney nickel W-2 catalyst.[12] The reaction mixture was placed in a Parr apparatus and subjected to a pressure of 3 atm. of hydrogen. The uptake of hydrogen was rapid and the theoretical volume of hydrogen was absorbed. The catalyst was removed by filtration, the ethanol removed under reduced pressure and the residue distilled to give 6.2 g. (65.5%) of product, b.p. 113° (0.8 mm.), $n^{25.5}D$ 1.5445.

Anal. Calcd. for $C_{17}H_{20}$: C, 91.01; H, 8.99. Found: C, 91.04; H, 8.88.

Product Analysis for the Thermal Decomposition of 1,1'-Azo-bis-(1,3-diphenylpentane).—1,1'-Azo-bis-(1,3-diphenylpentane) was decomposed in 300 ml. of bromobenzene at two different temperatures, (1) 89.7° and (2) 144.25°, and the amount of nitrogen evolved observed.[13] The procedure for product analysis was basically the same in each experiment.

After decomposition was complete (89.7°, 69 hr.; 144.25°, 1 hr.) the solvent was fractionally distilled at reduced pressure and residual bromobenzene was removed by maintaining the flask temperature at 30° and reducing the pressure to 0.5 mm. The residue was then passed through a chromatographic column packed with activated alumina. The residue was placed on the column with *n*-hexane and eluted with *n*-hexane. The column was then washed with 2 liters of hexane and 50-ml. samples were removed. The hexane was removed from each fraction and the wax residues present in 8 fractions were diluted with acetone. Two distinctly different solids were obtained in this manner, the first, solid 1, melted at 167.5–169°, gave negative tests with bromine and permanganate for unsaturation, and the infrared spectrum indicated a saturated hydrocarbon with the exception of aromatic frequencies.

Anal. Calcd. for $C_{34}H_{38}$: C, 91.42; H, 8.58; mol. wt., 447. Found: C, 91.33; H, 8.35; mol. wt., 422, 467 (Rast).

This compound is undoubtedly an isomer of 3,5,6,8-tetraphenyldecane obtained from the coupling reaction of two 1,3-diphenyl-1-pentyl radicals (II).

Solid 2, m.p. 141.5–142°, showed no unsaturation with bromine and permanganate, and the infrared spectrum was identical with solid 1.

Anal. Calcd. for $C_{34}H_{38}$: C, 91.42; H, 8.58; mol. wt., 447. Found: C, 91.57; H, 8.35; mol. wt., 458, 467 (Rast).

Solid 2 is, apparently, a stereoisomer of solid 1.

After removal of solids 1 and 2, the remaining wax was dissolved in isopropyl alcohol and on cooling to −5° overnight, a solid crystallized from solution, 3, m.p. 93.5–98°. The tests for unsaturation were negative and the infrared spectrum was identical with solids 1 and 2.

Anal. Calcd. for $C_{34}H_{38}$: C, 91.42; H, 8.58; mol. wt., 447. Found: C, 91.15; H, 8.88; mol. wt., 423, 431 (Rast).

Another isomer of 3,5,6,8-tetraphenyldecane is strongly indicated. Solid 3 was further recrystallized from isopropyl alcohol and gave a new solid 4, m.p. 99.5–100°, mol. wt. 428, 465 (Rast). Tests for unsaturation with permanganate and bromine were negative, and the infrared spectrum was identical with solids 1, 2 and 3.

Compound 3 was recovered from the solvent, isopropyl alcohol, m.p. 93.2–97.8°.

Table I outlines the amount of coupled product accounted for at both temperatures.

TABLE I

THERMAL DECOMPOSITION OF 1,1'-AZO-BIS-(1,3-DIPHENYLPENTANE)

	M.p., °C.	Decompn. temp., °C. 89.7 ± 0.1	Decompn. temp., °C. 144.25 ± 0.05
Amt. azo compd. decomp., g.		1.495	1.273
Percentage decomp.		72.70	101.0
Total solid 1, g.	167.5–169	0.073	0.068
Total solid 2, g.	141.5–142	.052	.048
Total solid 3, g.	93.5–98	.836	.938
Total solid 4, g.	99.5–100	.014	.016
Total solid, g.		.975	1.070
Percentage coupled products based on percentage decomp.		95.40	89.30
Total percentage unaccounted for based on percentage decomp.		4.60	10.70

In the decomposition run at 89.7° a yellow oil was isolated (0.275 g.) from the chromatographic column, on stirring the alumina in acetone. A sodium fusion indicated the presence of nitrogen. Attempts to make a solid derivative were unsuccessful. This oil would represent 67.2% of the 27.3% that was undecomposed. An infrared spectrum indicated the presence of a carbonyl group, 1680–1695/cm., an N–H stretching frequency, 3400–3600/cm., and an N=C group, 1630–1660/cm.

BROOKLYN, N. Y.

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(12) R. Mozingo, "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., p. 181.

(13) C. G. Overberger, M. T. O'Shaughnessy and H. Shalit, THIS JOURNAL, 71, 2661 (1949).

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

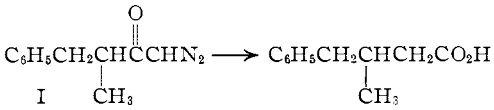
The Stereochemistry of the Wolff Rearrangement

BY KENNETH B. WIBERG AND THOMAS W. HUTTON[1]

RECEIVED AUGUST 2, 1955

The Wolff rearrangement of *sec*-butyl diazomethyl ketone using silver benzoate–triethylamine, silver oxide, silver thiosulfate or ultraviolet light as catalysts gave the expected products with 97 ± 3% retention of configuration. The rearrangement of benzylmethyldiazoacetone also gave mainly retention of configuration in contrast to a previous report. It is concluded that the rearrangement of *sec*-alkyl diazomethyl ketones proceeds largely with retention of configuration.

In 1940, Wallis and co-workers[2] reported that the rearrangement of optically active benzylmethyldiazoacetone (I) using silver thiosulfate gave the expected acid, which was however optically inactive. When ammoniacal silver nitrate in methanol was used as the catalyst, the amide obtained was found to be partially racemized. Since compound I was optically stable for long periods of time, even on distillation, and could be converted to an optically active ketol on treatment with aqueous formic acid, it was felt that enolization of the diazoketone was not responsible for the observed racemization.



$$C_6H_5CH_2\underset{CH_3}{\underset{|}{C}}H\overset{O}{\overset{\|}{C}}CHN_2 \longrightarrow C_6H_5CH_2\underset{CH_3}{\underset{|}{C}}HCH_2CO_2H$$

I

Later, Lane and Wallis[3] described the rearrange-

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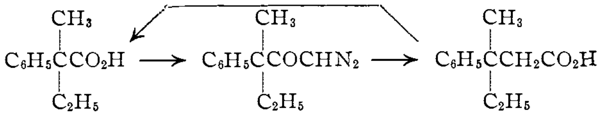
(1) Taken from part of a thesis submitted by T. W. Hutton to the University of Washington in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1954. Allied Chemical and Dye Corp. Fellow, 1952–1953.

(2) J. F. Lane, J. Willenz, A. Weissberger and E. S. Wallis, *J. Org. Chem.*, **5**, 276 (1940).

(3) J. F. Lane and E. S. Wallis, *ibid.*, **6**, 443 (1941).

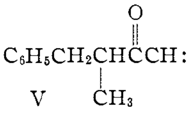
ment of methylethylphenyldiazoacetone (II), a tertiary diazoketone in which enolization was not possible. The diazoketone was rearranged to the homologous acid III, which was then converted back to the original acid *via* the Barbier–Wieland degradation sequence. The acid produced *via* rearrangement was found to be optically active, and starting with IV having a rotation of 24°, the entire sequence gave IV having a rotation of 20°. Recrystallization of a derivative of the acid IV obtained by degradation gave material with the same rotation as that of the derivative of pure IV.



$$C_6H_5\underset{C_2H_5}{\overset{CH_3}{C}}CO_2H \longrightarrow C_6H_5\underset{C_2H_5}{\overset{CH_3}{C}}COCHN_2 \longrightarrow C_6H_5\underset{C_2H_5}{\overset{CH_3}{C}}CH_2CO_2H$$

IV II III

Unfortunately, the recrystallization of the derivative could lead to the separation of racemic material from the optically active compound. Thus, although the results demonstrate retention of configuration, it is possible that some racemization occurred during the rearrangement. Since the tertiary diazoketone gave optically active rearranged acid, Lane and Wallis[3] concluded that the carbene intermediate (V) was the species which racemized in the benzylmethyldiazoacetone case, and that the racemization of V was probably catalyzed by silver.



$$C_6H_5CH_2\underset{CH_3}{CH}\overset{\overset{O}{\|}}{C}CH:$$

Gutsche[4] has shown that the Wolff rearrangement of *cis*- and *trans*-2-phenylcyclohexanecarboxylic acid gave retention of configuration, but here a small amount of isomerization would probably not be noted. After the present work was completed, Sax and Bergmann[5] reported that the Arndt–Eistert sequence from 2-methylbutyric acid to 3-methylvaleric acid gave 78% retention of configuration, but they did not show at which stage the racemization occurred.

The development of the ultraviolet light-catalyzed Wolff rearrangement[6] is of interest in this connection since it allows one to carry out the reaction in neutral solution in the absence of a metallic catalyst, and thus possibly avoid racemization during the reaction. We have therefore investigated the stereochemistry of the rearrangement of two diazoketones under several conditions.

The acid first examined was 2-methylbutyric acid (VI) since the configurations and maximum rotation of compounds derived from 2-butanol are fairly well known, and since none of the intermediates would be solids. The conversion of VI to the diazoketone VII was effected in the usual fashion, and the rearrangement of VII was effected in four ways, using ultraviolet light and a methanol solution, silver thiosulfate in aqueous dioxane, silver oxide in methanol and silver benzoate–triethylamine in methanol. The results obtained are shown in Chart I. It is interesting to note that all of the products were optically active, and within experimental error, had the same rotation.

In order to obtain definite information concerning the maximum rotations of VI and 3-methylvaleric acid (VIII), the reduction of VI to 2-butylcarbinol (IX) was effected by lithium aluminum hydride.[7] The conversion of IX to VIII proceeded *via* the chloride and carbonation of the Grignard reagent.[8] The rotations given below are the calculated maximum specific rotations based on $[\alpha]_D$ 6.04° for 2-butylcarbinol.[9]

Using the rotations of methyl 2-methylbutyrate obtained from 2-methylbutyric acid *via* treatment with diazomethane and by conversion to the acid chloride followed by treatment with methanol and pyridine, one may correct the rotation of the 2-methylbutyric acid used in the Arndt–Eistert sequence (Chart I) for the racemization of the acid chloride during its formation. Assuming an experimental error in measuring the rotations of 0.01°, the corrected rotation of the acid is then 3.16 ± 0.02°.[10] The rotation of methyl 3-methylvalerate derived from 2-methylbutyric acid having the above rotation would then be calculated to be 1.17 ± 0.02°. The product from the Arndt–Eistert sequence had a rotation of 1.14 ± 0.01°, and thus the sequence gave 97 ± 3% retention of configuration.

These observations make enolization unlikely as the explanation of the racemization observed in the rearrangement of benzylmethyldiazoacetone. For this reason, the rearrangement of I was investigated using the same four conditions previously employed for VII. The results are summarized in Chart I. It was considerably more difficult to completely purify the products than in the 2-methylbutyric acid case, and therefore a somewhat larger uncertainty is attached to the rotations of the products. However, the differences in rotation which were observed appear to be well outside of the probable error in the values.

In order to obtain definite information concerning the maximum rotation of 3-benzylbutyric acid (XVI), it was prepared from benzylmethylacetic acid (XIII) by the same sequence as used for the conversion of 2-methylbutyric acid to 3-methylvaleric acid. Using the maximum rotation for benzylmethylacetic acid reported by Pickard and Yates,[11] $[\alpha]_D$ 22.65°, the values for the maximum rotations of the compounds in the sequence are given above.

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(4) C. D. Gutsche, THIS JOURNAL, **70**, 4150 (1948).

(5) K. J. Sax and W. Bergmann, *ibid.*, **77**, 1910 (1955).

(6) L. Horner, E. Spietschka and A. Gross, *Ann.*, **573**, 17 (1951); L. Horner and E. Spietschka, *Ber.*, **85**, 225 (1952); A. Roedig and H. Lunk, *ibid.*, **87**, 971 (1954).

(7) The procedure of D. S. Noyce and D. B. Denney, THIS JOURNAL, **72**, 5743 (1950), was used. One may calculate a maximum rotation for VI of 20.5° from their data, which is in good agreement with the present result.

(8) K. B. Wiberg and B. I. Rowland, THIS JOURNAL, **77**, 1159 (1955).

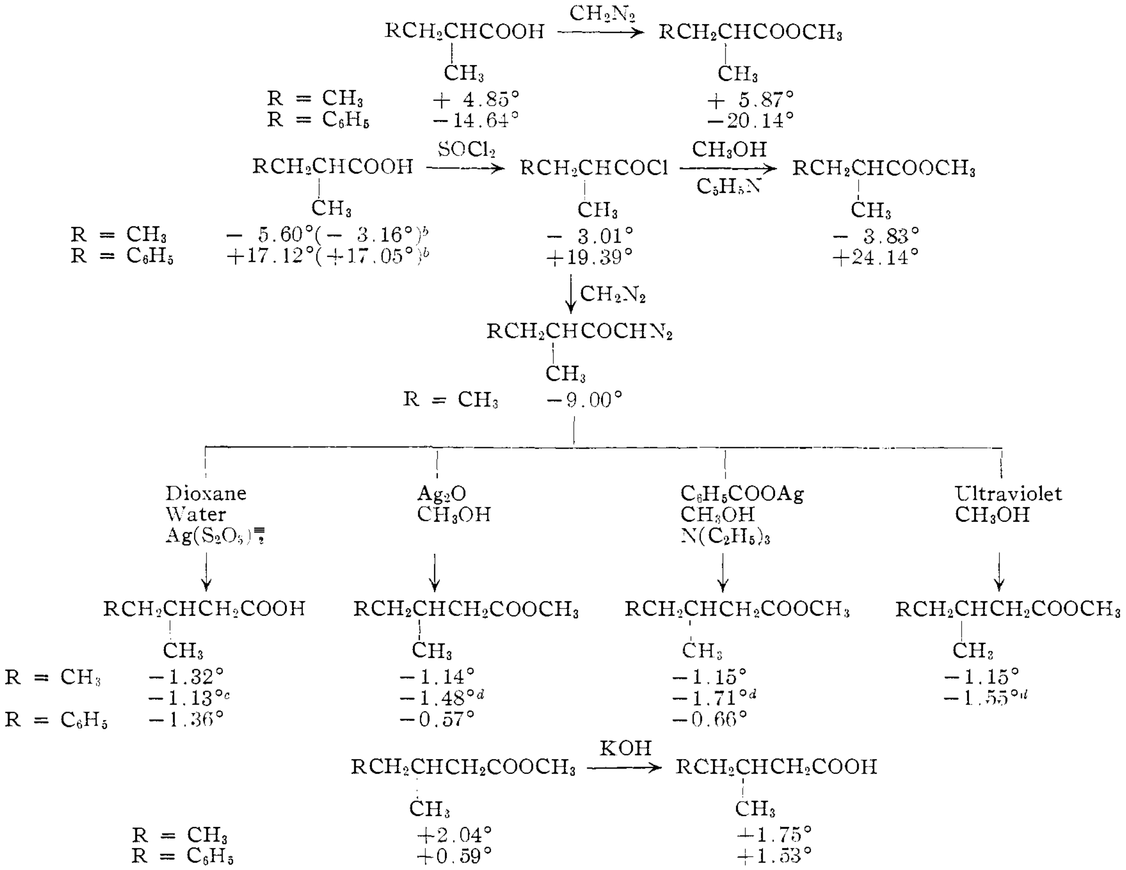
(9) F. C. Whitmore and J. H. Olewine, *ibid.*, **60**, 2569 (1938).

(10) In making these calculations, it is assumed that the reaction of an acid with diazomethane will not lead to any racemization. This is reasonable since neither the acid nor the ester are easily racemized and since the reaction is carried out under neutral conditions. If racemization occurred in any other step, this would appear in the net extent of racemization for the whole Arndt–Eistert sequence.

(11) R. H. Pickard and J. Yates, *J. Chem. Soc.*, **95**, 1011 (1909).

CHART I

RESULTS OF THE ARNDT–EISTERT SYNTHESIS WITH (−)-2-METHYLBUTYRIC ACID AND (+)-METHYLBENZYLACETIC ACID[a]

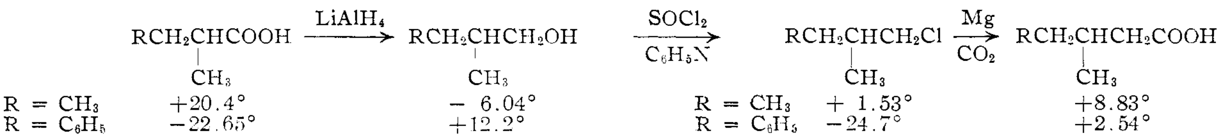


[a] All rotations are specific rotations, $l = 1$, neat. [b] Rotation corrected for racemization of the acid chloride. [c] Rotation is expressed in terms of the rotation of methyl 3-methylvalerate. [d] Rotations are expressed in terms of the rotation of 3-benzylbutyric acid.

The degree of retention of configuration may now be calculated as before. In the order in which the experiments were carried out, the photolysis gave 81% retention, the silver benzoate–triethylamine method gave 90% retention, the silver thiosulfate catalyst gave 72% retention and the silver oxide catalyst gave 78% retention. In a previous experiment using another batch of diazoketone, 95% retention of configuration was obtained using the silver benzoate–triethylamine catalyst.

Methylbenzyldiazoacetone is known to have fairly high optical stability. It has been reported that the rotation of the diazoketone changes only slowly with time, and that reaction with formic acid gives a ketol without racemization.[2] We have observed that a sample of this diazoketone, without purification, had 73% of its original activity after standing at room temperature for 18 months. The diazoketone has a much higher rotation than any other compound of the series, and thus it would seem reasonable to assume that the extent of racemization did not exceed 27%. Since all of the reactions were carried out in a two-day period, using the same batch of diazoketone, it would appear that the difference in the rotation of the products of the Wolff rearrangement cannot be ascribed to racemization of the diazoketone prior to its use in the reaction. This view is confirmed by the lack of correlation of the extent of racemization in the reaction with the order in which the reactions were carried out.

It must then be concluded that either the diazoketone was racemized under the reaction conditions prior to rearrangement, or during the rearrangement. We cannot distinguish between these possibilities using the available data. The reason for racemization in this case but not with 2-butyl diazomethyl ketone is also not apparent. It is however clear that the use of the silver benzoate–triethylamine catalyst is the most satisfactory method for effecting the Wolff rearrangement of optically active diazoketones, since only a relatively small amount of racemization was observed using this catalyst.



Experimental[11a]

2-Methylbutyryl Chloride (X).—2-Methylbutyric acid was prepared and resolved by the procedure of Schutz and Marckwald.[12] To 95 g. (0.80 mole) of thionyl chloride purified by the method of Fieser[13] was added 57.5 g. (0.56 mole) of (−)-2-methylbutyric acid having b.p. 176–177.5°, n^{25}_{D} 1.4042, d^{25} 0.931 and $[\alpha]^{25}_{\mathrm{D}}$ −5.60°. The solution was allowed to stand for one hour at room temperature followed by warming on a steam-cone for one hour. The acid chloride was distilled through a 6″ column packed with glass helices giving 54 g. (81%) of 2-methylbutyryl chloride (X), b.p. 117–118.5°, n^{25}_{D} 1.4150, d^{25} 0.986, $[\alpha]^{26}_{\mathrm{D}}$ −3.01°.[14]

In an attempt to prepare active X from active 2-methylbutyric acid and benzoyl chloride by distilling the acid chloride from the reaction mixture[15] through a 6″ packed column, the resultant acid chloride was nearly completely racemic. When X was prepared from (+)-2-methylbutyric acid and oxalyl chloride,[16] only slight racemization occurred.

To determine the effect of heat on the racemization of X, a portion of the acid chloride having α^{26}_{D} 2.25° was heated to reflux. After four hours, a sample was withdrawn and on distillation had α^{26}_{D} 1.86°. After 16 hours, another sample was withdrawn and on distillation had α^{26}_{D} 0.91°.

Methyl(−)-2-Methylbutyrate (XI) from (−)-2-Methylbutyryl Chloride (X).—To a cold solution of 5 ml. of absolute methanol in 5.0 g. of dry pyridine was added slowly with stirring 6.5 g. (54 mmoles) of X having $[\alpha]^{26}_{\mathrm{D}}$ −3.01°. After the addition was completed, the solution was allowed to warm to room temperature. The solution was acidified with dilute hydrochloric acid and continuously extracted with pentane. Distillation gave 5.3 g. (84%) of methyl 2-methylbutyrate having b.p. 112–119°, which on redistillation through a 12″ spiral wire gauze column gave pure XI, b.p. 115–116°, n^{25}_{D} 1.3923, d^{25} 0.880, $[\alpha]^{26}_{\mathrm{D}}$ −3.83°.[17]

Methyl) (+)-2-Methylbutyrate (XI) from (+)-2-Methylbutyric Acid (VI).—To an excess of diazomethane in ether was added 7.5 g. (74 mmoles) of VI having b.p. 176°, n^{25}_{D} 1.4041, d^{25} 0.932, $[\alpha]^{25}_{\mathrm{D}}$ 4.85°. Distillation gave 6.8 g. (80%) of methyl 2-methylbutyrate (XI), b.p. 113–117°, which was redistilled through a spiral wire gauze column to give pure XI, b.p. 115.5–116°, n^{25}_{D} 1.3924, d^{25} 0.881 and $[\alpha]^{26}_{\mathrm{D}}$ 5.87°; *M*D calcd., 31.57; found 31.44.

(−)-2-Butyl Diazomethyl Ketone (VII).—To about two moles of an ice-cold ether solution of diazomethane, prepared from three moles of N-nitrosomethylurea, was added 46 g. (0.38 mole) of 2-methylbutyryl chloride, $[\alpha]^{25}_{\mathrm{D}}$ −3.01°. After standing overnight, the solution was distilled giving 33 g. (69%) of 2-butyl diazomethyl ketone, b.p. 70–71° at 11 mm. Redistillation gave the pure diazoketone, b.p. 75° at 13 mm., n^{25}_{D} 1.4770, d^{25} 0.969, $[\alpha]^{25}_{\mathrm{D}}$ −9.00°. The ultraviolet spectrum had $\lambda_{\max}$ 250 mμ, $\epsilon_{\max}$ 8,800; $\lambda_{\max}$ 267 mμ (inflection), $\epsilon_{\max}$ 7,600. The infrared spectrum had bands at 4.83 μ (N_2) and 6.14 μ (C=O).

Anal. Calcd. for $C_6H_{10}N_2O$: C, 57.1; H, 8.0; N, 22.2. Found: C, 56.9; H, 7.8; N, 22.4.

Silver Thiosulfate-catalyzed Rearrangement of (−)-2-Butyl Diazomethyl Ketone (VII) in Aqueous Dioxane.—To 75 ml. of purified dioxane[18] was added 7.0 g. (56 mmoles) of VII, $[\alpha]^{25}_{\mathrm{D}}$ −9.00°, and the mixture was placed in a 500-ml. flask attached to an azotometer, and heated to 50°. Silver oxide prepared from 6.5 g. (38 mmoles) of silver nitrate and 1.5 g. (38 mmoles) of sodium hydroxide was dissolved in a solution of 20 g. (81 mmoles) of sodium thiosulfate in 175 ml. of water. The catalyst solution was added to the reaction mixture in one portion. After 45 min., 66% of the theoretical amount of nitrogen had been evolved. Additional catalyst solution was prepared from 2 g. of silver nitrate, and portions of this catalyst were added whenever the evolution of nitrogen ceased. After seven hours, 90% of the nitrogen had been evolved and the reaction ceased.

After the reaction mixture had been made basic with 10% sodium hydroxide solution, it was extracted with ether and pentane to remove non-acidic materials. The aqueous solution was then acidified with 10% sulfuric acid and extracted continuously with pentane overnight. Distillation gave 5.1 g. (79%) of 3-methylvaleric acid (VIII), b.p. 187–200°. On redistillation, a good recovery of VIII was obtained, b.p. 198°, n^{25}_{D} 1.4145, d^{25} 0.923, $[\alpha]^{26}_{\mathrm{D}}$ −1.32°[19]; *M*D calcd., 31.45; found, 31.47.

Silver Oxide-catalyzed Rearrangement of (−)-2-Butyl Diazomethyl Ketone (VII) in Methanol.—A solution of 6.0 g. (48 mmoles) of VII, $[\alpha]^{26}_{\mathrm{D}}$ −9.00°, in 100 ml. of absolute methanol was placed in a 250-ml. flask attached to an azotometer, and the solution was heated to 50°. Silver oxide prepared from 1.5 g. (8.8 mmoles) of silver nitrate was washed with methanol. A slurry of the silver oxide in methanol was added to the reaction solution in small portions at a rate sufficient to maintain the evolution of nitrogen. After 26 hr., the evolution of nitrogen had ceased at 96% of the theoretical amount. To the alcoholic solution was added 100 ml. of water, and the solution was extracted continuously with pentane. Distillation gave 4.4 g. (71%) of methyl 3-methylvalerate (XII), b.p. 138–149°. After distillation through a 12″ spiral wire gauze packed column, XII had b.p. 142–142.5°, n^{25}_{D} 1.4029, d^{25} 0.880, and $[\alpha]^{26}_{\mathrm{D}}$ −1.14°[20]; *M*D calcd., 36.19; found, 36.07.

Silver Benzoate–Triethylamine-catalyzed Rearrangement of (−)-2-Butyl Diazomethyl Ketone (VII).—A solution of 5.5 g. (44 mmoles) of VII, $[\alpha]^{26}_{\mathrm{D}}$ −9.00°, in 50 ml. of absolute methanol was placed in a 250-ml. flask attached to an azotometer, and the solution was cooled in an ice-bath. Fifty drops of catalyst prepared from 1.0 g. (4.4 mmoles) of silver benzoate and 10 ml. of triethylamine (distilled from barium oxide) was added to the diazoketone solution. The addition of the catalyst promoted a rapid reaction and after one hour, 96% of the theoretical amount of nitrogen had been obtained. After the solution had been filtered, it was made acidic with dilute sulfuric acid and extracted continuously with pentane. Distillation gave 4.8 g. (84%) of methyl 3-methylvalerate (XII), b.p. 141–149°. On distillation through a 12″ packed column, a good recovery of XII was obtained, b.p. 143°, n^{25}_{D} 1.4030, d^{25} 0.880, $[\alpha]^{26}_{\mathrm{D}}$ −1.15°.

Photolysis of a Methanolic Solution of (−)-2-Butyl Diazomethyl Ketone (VII).—A solution of 6.0 g. (48 mmoles) of VII, $[\alpha]^{26}_{\mathrm{D}}$ −9.00°, in 60 ml. of absolute methanol was placed in a quartz flask and irradiated with ultraviolet light from a Hanovia 100-watt mercury arc. After two days, the reaction was complete as indicated by the disappearance of the characteristic 250 mμ band of the diazoketone. The solution was diluted with 20 ml. of water and extracted continuously with pentane. Distillation gave 5.3 g. (86%) of methyl 3-methylvalerate (XII), b.p. 141–147°. On redistillation through a 12″ packed column, XII, b.p. 142–142.5°, n^{25}_{D} 1.4032, $[\alpha]^{26}_{\mathrm{D}}$ −1.15°, was obtained.

Methyl (+)-3-Methylvalerate (XII) from (+)-3-Methylvaleric Acid (VIII).—To a solution of diazomethane in ether prepared from 10 g. (0.1 mole) of N-nitrosomethylurea was added 6.5 g. (56 mmoles) of VIII having $[\alpha]^{27}_{\mathrm{D}}$ 2.04°.[21] The solution was distilled giving 5.8 g. (80%) of methyl 3-methylvalerate (XII), b.p. 140–143°, which on redistillation gave pure XII, b.p. 142.5–143°, n^{25}_{D} 1.4028, d^{25} 0.880 and $[\alpha]^{27}_{\mathrm{D}}$ 1.75°.

[11a] All rotations were determined neat in 1-dm. tubes unless otherwise noted. In each case, the samples were distilled to a constant rotation and refractive index, and the infrared spectra corresponded to that of a highly purified sample.

[12] O. Schutz and W. Marckwald, *Ber.*, **29**, 52 (1896).

[13] L. F. Fieser, "Experiments in Organic Chemistry," 3rd Ed., D. C. Heath and Co., Boston, Mass., 1955, p. 345.

[14] R. Leimu, *Ber.*, **70**, 1040 (1937), reported b.p. 118–118.3°, n^{20}_{D} 1.4170 and d^{20} 0.992. M. Heintzler, *Ann.*, **569**, 97 (1950), has prepared X having α_{D} 1.07° from 2-methylbutyric acid having α_{D} 1.23°.

[15] H. C. Brown, THIS JOURNAL, **60**, 1325 (1938).

[16] R. Adams, *ibid.*, **42**, 599 (1920).

[17] P. A. Guye and L. Chavanne, *Bull. soc. chim.*, [3] **15**, 275 (1896), reported b.p. 113–115°, n^{25}_{D} 1.3936, d^{22} 0.882 and $[\alpha]^{22}_{\mathrm{D}}$ 16.83° when prepared from VI having $[\alpha]^{25}_{\mathrm{D}}$ 13.65°.

[18] Reference 13, p. 284.

[19] P. A. Levene and R. E. Marker, *J. Biol. Chem.*, **91**, 761 (1931), reported VIII to have b.p. 110° at 30 mm. and d^{25} 0.925. P. von Romburgh, *Rec. trav. chim.*, **5**, 219 (1886), reported the maximum rotation of VIII to be $[\alpha]^{19}_{\mathrm{D}}$ −8.92°.

[20] D. Hardin and S. Sikorsky, *J. chim. phys.*, **6**, 179 (1908), reported b.p. 141–142°, d^{7} 0.8886.

[21] Obtained by diluting (+)-VIII prepared from active amyl alcohol (K. B. Wiberg and B. I. Rowland, THIS JOURNAL, **77**, 1159 (1955)), with inactive VIII, followed by two distillations through a 6″ packed column to give an optically homogeneous sample, b.p. 196–197°, n^{25}_{D} 1.4142, d^{25} 0.922.

Conversion of (+)-2-Methylbutyric Acid (VI) to (+)-3-Methylvaleric Acid (VIII).—The reduction of 2-methylbutyric acid, b.p. 176–177°, $[\alpha]^{25}_{\mathrm{D}}$ 5.34°, was effected using lithium aluminum hydride[5] giving 2-methyl-1-butanol, b.p. 128.5–129.5°, $[\alpha]^{25}_{\mathrm{D}}$ −1.58° (l = 2, neat), d^{25} 0.812. The alcohol was converted to 2-methyl-1-butyl chloride, b.p. 99–100°, $[\alpha]^{25}_{\mathrm{D}}$ 0.70° (l = 2, neat), d^{25} 0.875 by treatment with thionyl chloride and pyridine.[6] The chloride was converted to the Grignard reagent which was carbonated with Dry Ice[6] giving 3-methylvaleric acid (VIII), b.p. 199°, $[\alpha]^{25}_{\mathrm{D}}$ 2.31°, d^{25} 0.922.

(+)-Methylbenzylacetyl Chloride (XV).—To 85 g. (0.71 mole) of thionyl chloride was added 68 g. (0.42 mole) of methylbenzylacetic acid[22] having b.p. 156.5–157° at 11 mm., n^{25}_{D} 1.5130, d^{25} 1.061 and $[\alpha]^{26}_{\mathrm{D}}$ +17.12°. The reaction was allowed to proceed overnight at room temperature after which the reaction mixture was warmed to 65° for one hour. The excess thionyl chloride was removed under reduced pressure, and on distillation there was obtained 72.5 g. (95%) of methylbenzylacetyl chloride (XV), b.p. 74.5–75.5° at 1.1 mm., n^{25}_{D} 1.5166, d^{25} 1.096 and $[\alpha]^{26}_{\mathrm{D}}$ +19.39°.[23]

(+)-Benzylmethyldiazoacetone (I).—In the conventional manner, Compound I was prepared from about 1.5 moles of diazomethane and 55 g. (0.30 mole) of methylbenzylacetyl chloride having $[\alpha]^{26}_{\mathrm{D}}$ +19.39°. The crude diazoketone (55 g., 97%) had α^{25}_{D} +58.1° (l = 0.5). It was not possible to purify the diazoketone by distillation because of its thermal decomposition on heating. The ultraviolet spectrum had $\lambda_{\max}$ 250 mμ, $\epsilon_{\max}$ 9,500; $\lambda_{\max}$ 270 mμ (inflection), $\epsilon_{\max}$ 7700. The infrared spectrum had bands at 4.78 μ (N_2) and 6.09 μ (C=O).

Silver Thiosulfate-catalyzed Rearrangement of (+)-Benzylmethyldiazoacetone (I) in Aqueous Dioxane.—The procedure described above was used. A solution of 12 g. (64 mmoles) of I, α^{26}_{D} +58.1°, in 100 ml. of purified dioxane was treated with a catalyst solution prepared from 8.5 g. (50 mmoles) of silver nitrate. A maximum of 77% of the theoretical amount of nitrogen was obtained. The pentane solution from the continuous extraction was distilled giving 7.4 g. (66%) of 3-benzylbutyric acid (XVI), b.p. 166–168° at 11 mm. On redistillation from Raney nickel, XVI had b.p. 152.5–153° at 5 mm., n^{25}_{D} 1.5106, d^{25} 1.042 and $[\alpha]^{26}_{\mathrm{D}}$ −1.37°[24]; M_{D} calcd., 51.09; found, 51.20.

Silver Oxide-catalyzed Rearrangement of (+)-Benzylmethyldiazoacetone (I) in Methanol.—The procedure described above was used. A solution of 9.0 g. (48 mmoles) of I, α^{26}_{D} +58.1°, in 100 ml. of methanol was treated with silver oxide prepared from 1.5 g. (8.8 mmoles) of silver nitrate. The reaction was complete after two hours at 45°, and 83% of the theoretical amount of nitrogen had been obtained. Distillation gave 4.9 g. (52%) of methyl 3-benzylbutyrate (XVII), b.p. 255–257°.

Two more distillations, one from Raney nickel, afforded pure XVII, b.p. 256°, n^{25}_{D} 1.4935, d^{25} 0.998, $[\alpha]^{26}_{\mathrm{D}}$ −0.57°; M_{D} calcd., 55.83; found, 56.00.

Anal. Calcd. for $C_{12}H_{26}O_2$: C, 75.0; H, 8.4. Found: C, 74.7; H, 8.2.

Silver Benzoate–Triethylamine-catalyzed Rearrangement of (+)-Benzylmethyldiazoacetone (I) in Methanol.—The procedure described above was used. A solution of 10.1 g. (54 mmoles) of I, α^{26}_{D} +58.1°, in 70 ml. of methanol was treated with one ml. of the catalyst solution at 15°. After 15 minutes, 99% of the theoretical amount of nitrogen had been collected. Distillation gave 7.5 g. (72%) of methyl 3-benzylbutyrate (XVII), b.p. 133–135° at 19 mm. After four more distillations, two from Raney nickel, optically homogeneous XVII was obtained, b.p. 128° at 15 mm., n^{25}_{D} 1.4936, d^{25} 0.999 and $[\alpha]^{26}_{\mathrm{D}}$ −0.66°.

In another experiment, methylbenzylacetic acid, $[\alpha]^{26}_{\mathrm{D}}$ −14.28°, was converted to the acid chloride, $[\alpha]^{26}_{\mathrm{D}}$ −16.55, which was in turn converted to the diazoketone, α^{26}_{D} −49.1°. When the diazoketone was rearranged using the silver benzoate–triethylamine catalyst, the resulting ester XVII had b.p. 127° at 13 mm., n^{25}_{D} 1.4939, d^{25} 0.999 and $[\alpha]^{26}_{\mathrm{D}}$ 0.59°.

Photolysis of a Methanolic Solution of (+)-Benzyldiazoacetone (I).—The procedure described above was used. A solution of 10.1 g. (54 mmoles) of I, α^{26}_{D} 58.1°, in 100 ml. of methanol was treated with ultraviolet light for 44 hours, which was sufficient for complete reaction. Distillation gave 8.1 g. (79%) of methyl 3-benzylbutyrate, b.p. 130–133° at 16 mm. Repeated distillation failed to give a homogeneous product. The ester was then hydrolyzed with methanolic potassium hydroxide (a twofold excess). The solution was diluted with water and extracted with pentane to remove base-insoluble impurities. Acidification with 20% sulfuric acid was followed by pentane extraction and distillation giving 68% of 3-benzylbutyric acid (XVI), b.p. 158–159° at 8 mm. Redistillation gave pure XVI, b.p. 163° at 10 mm., n^{25}_{D} 1.5103, d^{25} 1.038 and $[\alpha]^{26}_{\mathrm{D}}$ −1.55° (l = 0.5).

Methyl (+)-Methylbenzylacetate (XIV) from (+)-Methylbenzylacetyl Chloride (XV).—To a cold mixture of 5.5 g. (70 mmoles) of dry pyridine and 15 ml. of absolute methanol was slowly added with stirring 10.5 g. (58 mmoles) of XV having $[\alpha]^{26}_{\mathrm{D}}$ 19.39°. The mixture was allowed to warm to room temperature and then treated with dilute hydrochloric acid followed by pentane extraction. Distillation of the pentane solution gave 8.2 g. (80%) of methyl methylbenzylacetate (XIV), b.p. 121–122° at 19 mm., which when redistilled at atm. pressure had b.p. 237–237.5°, n^{25}_{D} 1.4943, d^{25} 1.013 and $[\alpha]^{26}_{\mathrm{D}}$ 24.14°.

Methyl (−)-Methylbenzylacetate (XIV) from (−)-Methylbenzylacetic Acid (XIII).—To an ether solution of diazomethane prepared from 15 g. (0.14 mole) of N-nitrosomethylurea was added 8.6 g. (52 mmoles) of XIII, b.p. 152–152.5° at 10 mm., n^{25}_{D} 1.5135, d^{25} 1.016 and $[\alpha]^{26}_{\mathrm{D}}$ −14.64°. After the reaction was completed, the solution was distilled giving 9.1 g. (98%) of XIV, b.p. 233–237.5°. Redistillation gave pure methyl methylbenzylacetate (XIV), b.p. 236.5–237°, n^{25}_{D} 1.4942, d^{25} 1.013 and $[\alpha]^{26}_{\mathrm{D}}$ −20.71°[25]; M_{D} calcd. 51.21; found, 51.20.

(+)-3-Benzylbutyric Acid (XVI) from Methyl (+)-3-Benzylbutyrate (XVII).—To 5.0 g. (90 mmoles) of potassium hydroxide in 30 ml. of methanol was added 10.5 g. (55 mmoles) of XVII, $[\alpha]^{26}_{\mathrm{D}}$ 0.59°. After heating for two hours, 20 ml. of water was added followed by 10% sulfuric acid. Pentane extraction was followed by distillation giving 7.7 g. (79%) of 3-benzylbutyric acid (XVI), b.p. 166–168.5° at 11 mm., which when redistilled gave optically homogeneous XVI, b.p. 168.5–169° at 12 mm., n^{25}_{D} 1.5110, d^{25} 1.043 and $[\alpha]^{26}_{\mathrm{D}}$ 1.53°.

Conversion of (−)-Methylbenzylacetic Acid (XIII) to (+)-3-Benzylbutyric Acid (XVI).—To a solution of 9 g. of lithium aluminum hydride in 250 ml. of anhydrous ether was added slowly with stirring 32 g. (0.20 mole) of methylbenzylacetic acid, $[\alpha]^{26}_{\mathrm{D}}$ −21.94°, n^{25}_{D} 1.5131, in 30 ml. of ether. The solution was allowed to stand overnight. The reaction solution was then treated with 30% Rochelle salt solution and the ether layer was separated and distilled giving 24 g. (80%) of 2-benzylpropanol, b.p. 128° at 16 mm., n^{25}_{D} 1.5189, d^{25} 0.980, $[\alpha]^{26}_{\mathrm{D}}$ +11.83°.[26]

A solution of 24 g. (0.16 mole) of 2-benzylpropanol in 12.6 g. (0.16 mole) of pyridine was treated with 24 g. (0.20 mole) of thionyl chloride over the period of one hour using ice-salt-bath cooling. The solution was allowed to stand overnight and was then added to ice and dilute hydrochloric acid. The chloride was extracted with pentane and the pentane solution was distilled giving 14.0 g. (52%) of 2-benzylpropyl chloride, b.p. 109–110° at 17 mm., n^{25}_{D} 1.5150, d^{25} 1.01, $[\alpha]^{27}_{\mathrm{D}}$ − 23.79°.[27] The yield was low because approximately one-third of the material was lost when a flask cracked during the distillation.

2-Benzylpropyl chloride (14.0 g., 0.083 mole) was converted to the Grignard reagent using 3 ml. of ethyl bromide, 3.0 g. of magnesium and 200 ml. of anhydrous ether. The solution was added to an excess of Dry Ice with stirring. After the Dry Ice had evaporated, the residue was treated with ice and dilute hydrochloric acid followed by ether extraction. The ether solution was extracted with 10%

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[22] Prepared and resolved by the procedure of L. Jones and E. S. Wallis, THIS JOURNAL, **48**, 169 (1926).

[23] L. Jones and E. S. Wallis, ref. 22, reported b.p. 89–90° at 1.7 mm. and $[\alpha]^{20}_{\mathrm{D}}$ +12.4°, when prepared from XIII having $[\alpha]^{20}_{\mathrm{D}}$ +11.35°.

[24] J. v. Braun and A. Stuckenschmidt, *Ber.*, **56**, 1728 (1923), reported b.p. 161° at 13 mm.; P. A. Levene and R. E. Marker, *J. Biol. Chem.*, **110**, 299 (1935), reported b.p. 160° at 1 mm. and d^{25} 1.040.

[25] L. Edeleanu, *J. Chem. Soc.*, **53**, 588 (1888), reported b.p. 232°.

[26] J. v. Braun, A. Grabowski and G. Kirschenbaum, *Ber.*, **46**, 1278 (1913,) reported b.p. 128–129° at 16 mm., d^{20} 0.9826.

[27] Reference 26 reported b.p. 112–114° at 17 mm.

sodium hydroxide solution. The basic solution was boiled to remove ether and then acidified and extracted with benzene. Distillation of the benzene solution gave 10.5 g. (71%) of 3-benzylbutyric acid, b.p. 166° at 11 mm., $n^{25}\mathrm{D}$ 1.5109, d^{25} 1.042, $[\alpha]^{26}\mathrm{D}$ +2.46°.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, STATE UNIVERSITY OF IOWA]

The Synthesis of Alkylhydrazines. I. The Reaction of Lithium Aluminum Hydride with Mono- and Diacylhydrazines[1]

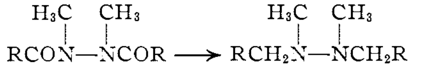
BY RICHARD L. HINMAN

RECEIVED AUGUST 22, 1955

Lithium aluminum hydride in refluxing ether or tetrahydrofuran reduces 1,2-diacyl-1,2-dimethylhydrazines $(\mathrm{RCO\overset{|}{N}CH_3})_2$ rapidly and in fair yields to the corresponding tetraalkylhydrazines $(\mathrm{RCH_2\overset{|}{N}CH_3})_2$. Acylhydrazines, such as RCONH-NHCOR and $\mathrm{RCONHN(CH_3)_2}$, which have hydrogens on the acyl-substituted nitrogens, are reduced much more slowly under similar conditions.

As one phase of a search for new and flexible methods for the preparation of alkylhydrazines the reactions of mono- and diacylhydrazines with lithium aluminum hydride are being investigated. Since acylhydrazines have a formal and in many respects an actual resemblance to amides, many of which have been reduced to amines by lithium aluminum hydride,[2] this approach appeared attractive. However, the results of the only two previously reported experiments of this type stand in marked contrast to each other. 1,2-Diacetylhydrazine is not reduced by lithium aluminum hydride, presumably because of the low solubility of the acylhydrazine in the solvents used.[3] However, 1,2-diformyl-1,2-dimethylhydrazine, which is but slightly soluble in ether, is rapidly reduced in that solvent to tetramethylhydrazine.[4,5]

In the present study it has been found that several mono- and diacylhydrazines can be converted to the corresponding alkylhydrazines by an excess of lithium aluminum hydride in refluxing ether or tetrahydrofuran. The reactions are summarized in equations 1–3.



$$\mathrm{RCO\overset{H_3C}{\overset{|}{N}}{-}\overset{CH_3}{\overset{|}{N}}COR \longrightarrow RCH_2\overset{H_3C}{\overset{|}{N}}{-}\overset{CH_3}{\overset{|}{N}}CH_2R} \qquad (1)$$

I

$$\mathrm{RCONHNHCOR \longrightarrow RCH_2NHNHCH_2R} \qquad (2)$$

II

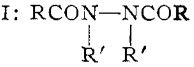
$$\mathrm{RCONHN(CH_3)_2 \longrightarrow RCH_2NHN(CH_3)_2} \qquad (3)$$

III

That the ease of reduction varies greatly with the type of structure of the acylhydrazine is evident from the data in Table I. 1,2-Diacyl-1,2-dimethylhydrazines (I) are reduced to the corresponding tetraalkylhydrazines in two to four hours. (The experiment described in ref. 4 is included for comparison.)

TABLE I

REACTIONS OF LITHIUM ALUMINUM HYDRIDE WITH DIACYLHYDRAZINES OF TYPES I AND II:

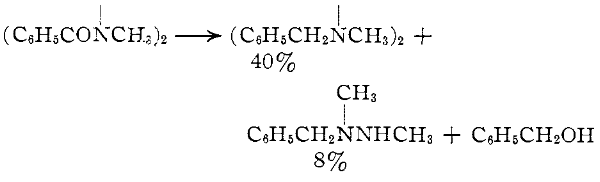


$$\mathrm{RCO\underset{R'}{\underset{|}{N}}{-}\underset{R'}{\underset{|}{N}}COR}$$

R	R'	Reaction time, hr.	Yield of alkylhydrazine, %	Excess of $\mathrm{LiAlH_4}$, %	Solvent[a]	Solubility of acylhydrazine[b]	Homogeneity[c]
C_6H_5	CH_3	4	48[d]	80	T	S	H
CH_3	CH_3	2	57	30	T	S	H
H[e]	CH_3	1	15[f]	20	E	PS	P[g]
C_6H_5	H	24	0[h]	70	T	PS	P
CH_3	H	68	26	80	T	PS	P
H	H	30	0[i]	100	T	I	P
C_2H_5O	H	24 70	49 72	60	T	S	H

[a] T = tetrahydrofuran; E = ether. [b] S = completely soluble; PS = partly soluble; I = effectively insoluble. [c] H = homogeneous reaction mixture throughout reaction period (aside from a small amount of gray insoluble matter from the lithium aluminum hydride); P = precipitate because of the low solubility of the acylhydrazine. [d] This is the over-all yield of reduction products, composed of 40% of tetraalkylhydrazine and 8% of 1-benzyl-1,2-dimethylhydrazine, the latter from reductive cleavage. [e] This experiment is reported in ref. 4. [f] Considerable product was lost during isolation. [g] Although not stated explicitly in the paper, it is assumed from the concentrations of reactants and the low solubility of 1,2-diformyl-1,2-dimethylhydrazine in ether that the reaction mixture was heterogeneous. [h] 88% of starting material recovered. [i] 75% of starting material recovered.

In addition to its reduction to 1,2-dibenzyl-1,2-dimethylhydrazine, 1,2-dibenzoyl-1,2-dimethylhydrazine also underwent a small amount of cleavage to 1-benzyl-1,2-dimethylhydrazine, identified as the methiodide, and to benzyl alcohol, identified as the α-naphthylurethan.



$$\mathrm{(C_6H_5CO\overset{|}{N}CH_3)_2 \longrightarrow \underset{40\%}{(C_6H_5CH_2\overset{|}{N}CH_3)_2} + \underset{8\%}{C_6H_5CH_2\overset{CH_3}{\overset{|}{N}}NHCH_3} + C_6H_5CH_2OH}$$

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(1) Presented in part at the Minneapolis Meeting of the American Chemical Society, September 16, 1955.

(2) V. M. Mičović and M. L. Mihailović, *J. Org. Chem.*, **18**, 1190 (1953).

(3) R. Renaud and L. C. Leitch, *Can. J. Chem.*, **32**, 545 (1954).

(4) J. B. Class, J. G. Aston and T. S. Oakwood, THIS JOURNAL, **75**, 2937 (1953).

(5) The reduction of other functional groups by lithium aluminum hydride has been used in syntheses of alkylhydrazines. Thus N-nitrosamines are reduced to *unsym*-dialkylhydrazines (F. W. Schueler and C. Hanna, THIS JOURNAL, **73**, 4996 (1951); **74**, 3693 (1952); H. Zimmer, L. F. Audrieth, M. Zimmer and R. A. Rowe, *ibid.*, **77**, 790 (1955)). The reduction of a hydrazone to a hydrazine is described in ref. 4; see also S. G. Cohen and C. H. Wang, *ibid.*, **77**, 2457, 3628 (1955). Reductions of azines to *sym*-dialkylhydrazines are described in ref. 3.