

in Table II. It is observed that the dinitrobenzoates have signs of rotation opposite to the alcohols from which they are derived.

### Experimental

**Resolution of 2-Phenyl-3-benzoylpropanoic Acid.**—A solution of the acid, 50.8 g. (0.2 mole) in 1 l. of ethyl acetate was mixed with 64.8 g. (0.2 mole) of (–) quinine in 1 l. of ethyl acetate and the mixture was allowed to crystallize at 8° overnight.<sup>4</sup> The first crop of crystals was alternately crystallized from methanol and ethyl acetate and decomposed by sodium hydroxide to produce the acid which was crystallized from ether,  $[\alpha]^{27D} +136^\circ$  (*c*, 1.03 in ethyl acetate). This acid was 86% optically pure as judged by Hann and Lapworth's values.<sup>4</sup>

The ethyl acetate-soluble salt gave 13 g. (51%) of acid,  $[\alpha]^{27D} -111^\circ$  (*c*, 1.40 in ethyl acetate).

**(+) and (–)2,4-Diphenylbutanoic Acids.**—The keto acid, I, was reduced over palladium-charcoal in glacial acetic acid containing perchloric acid as previously described for the racemic acid.<sup>3</sup> The acids were crystallized once from 60–70° petroleum ether to give the results shown in Table I.

**(+) and (–)2,4-Diphenylbutanols.**—The active diphenylbutanoic acids were reduced in ethyl ether by lithium aluminum hydride following the directions of Nyström and Brown.<sup>5</sup> After the addition of the acid the mixture was refluxed for one-half hour and then hydrolyzed with 10% hydrochloric acid. The alcohols were distilled,

(4) These are more specific directions than those of Hann and Lapworth, *J. Chem. Soc.*, **85**, 1355 (1904).

(5) Nyström and Brown, *THIS JOURNAL*, **69**, 2548 (1947).

b. p. 178–180° (1 mm.).<sup>6</sup> Rotations and yields are summarized in Table I.

**The  $\alpha$ -Naphthylcarbamates and 3,5-dinitrobenzoates** of the active alcohols were crystallized from petroleum ether and ethanol, respectively. Their constants are presented in Table II.

**Attempted Racemizations of 2,4-Diphenylbutanols.**—The procedure and essentially the apparatus which Doering and Aschner<sup>2</sup> had shown to be capable of excluding the effects of oxidants were used. The freshly prepared alcohols, 2 millimoles, were added to equivalent amounts of powdered sodium under toluene and allowed to react until hydrogen evolution had ceased. The suspension was then heated at 100° for a time and the alcohol recovered by washing the toluene with acid, then water, and distilling finally *in vacuo*. The specific rotations of the alcohols at comparable temperatures and concentrations before and after heating for specified times were

–15.1°	5 hr.	–14.6°
–14.6	8 hr.	–13.3
+24.3	8 hr.	+24.1

### Summary

Optically active forms of 2,4-diphenylbutanoic acid and 2,4-diphenylbutanol have been prepared by convenient methods. The latter compound is not racemized by heating of its sodium derivative at 100° for eight hours.

(6) Marion, *Canadian J. Res.*, **16B**, 213 (1938), gives 174–180° at 1 mm. for the racemic alcohol.

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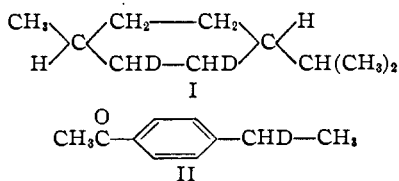
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[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE UNIVERSITY OF NOTRE DAME]

## The Reduction of Optically Active Phenylmethylcarbinyl Chloride with Lithium Aluminum Deuteride<sup>1</sup>

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Recently Alexander and Pinkus<sup>1a</sup> showed that the reduction of optically active *trans*-2-menthene gives rise to *active* 2,3-dideutero-*trans*-menthane (I) thus demonstrating that a compound of type  $R_1R_2CHD$  is capable of rotating the plane of polarized light.



Compound I has four asymmetric centers (not all of which, however, necessarily contribute towards its rotation<sup>1a</sup>) and it seemed desirable to investigate again the possibility of optical activity in the case of a compound having only one carbon atom of the  $R_1R_2CHD$ -type. Such a

(1) Presented before the Organic Division of the American Chemical Society at Atlantic City, N. J., September 20, 1949.

(1a) Alexander and Pinkus, *THIS JOURNAL*, **71**, 1786 (1949). This publication reviews earlier unsuccessful attempts to synthesize optically active compounds of the  $R_1R_2CHD$  type. The present author is indebted to Dr. Elliot R. Alexander for information regarding the results of his investigation several months in advance of publication.

compound is  $\alpha$ -deuteroethylbenzene,  $C_6H_5CHDCH_3$ . This hydrocarbon was expected to be accessible by the reduction of phenylmethylcarbinyl chloride,  $C_6H_5CHClCH_3$ , with lithium aluminum deuteride–lithium deuteride according to a method recently described<sup>2</sup> for reductions of alkyl halides to alkanes. The fact that primary halides are reduced more easily by lithium aluminum hydride than secondary, while tertiary ones are not reduced at all,<sup>2,3</sup> might lead one to believe that the reaction is of the nucleophilic displacement ( $S_N2$ ) type and that the reduction of optically active  $\alpha$ -phenethyl chloride with lithium aluminum deuteride might proceed with Walden inversion and give rise to an active product. Walden inversion has been demonstrated for the reduction of epoxides with lithium aluminum hydride.<sup>3</sup>

The reduction of (–)- $\alpha$ -chloroethylbenzene with lithium aluminum deuteride–lithium deuteride in tetrahydrofuran yielded about 80% of the theoretical amount of  $\alpha$ -deuteroethylbenzene which was free of chlorine-containing impurities

(2) Johnson, Blizzard and Carhart, *ibid.*, **70**, 3644 (1948).

(3) Trevoay and Brown, *ibid.*, **71**, 1675 (1949). At the time this paper appeared, the present investigation was almost complete.

and showed optical rotation far in excess of possible observational errors. Its deuterium content, calculated on the basis of density by the formula of McLean and Adams<sup>4</sup> appeared to be very close to the theoretical. Acetylation of the active hydrocarbon by the Friedel-Crafts procedure yielded active *p*-acetyl- $\alpha$ -deuteroethylbenzene (II) which, in turn, gave rise to an optically active crystalline oxime. The activity of the once-recrystallized oxime was not affected by further recrystallizations and the active ketone was regenerated by acid hydrolysis of its crystalline derivative.

It is thus established beyond doubt that  $\alpha$ -deuteroethylbenzene is capable of rotating the plane of polarized light. The degree of optical purity and the configuration of the deuterated hydrocarbon are not known, but on the basis of the work of Trevoy and Brown<sup>3</sup> it seems likely that the reduction involves Walden inversion.

2,3-Diphenylbutane was obtained as a by-product in the reduction of  $\alpha$ -chloroethylbenzene by either lithium aluminum deuteride-lithium deuteride or lithium aluminum hydride-lithium hydride. The origin of this by-product is under investigation.

### Experimental

*dl*-Phenylmethylcarbinol.<sup>5</sup>—Acetophenone was distilled *in vacuo* from Raney nickel. One mole (120 g.) of the distillate was reduced in the presence of about 5 g. of copper chromite<sup>6</sup> at a temperature of 110–120° and an initial hydrogen pressure of 2500 lb. Reduction was complete in three hours. The catalyst was separated by filtration and the liner of the bomb and catalyst were rinsed with ether. The filtrate was fractionated, *dl*-phenylmethylcarbinol being collected at 92.5–93.5° (16 mm.). The purity of the product, as established by titration of the hydroxyl group,<sup>7</sup> was 99%, yield 118 g. (97%).

(+) and (–)-Phenylmethylcarbinol.—*dl*-Phenylmethylcarbinol was converted to its acid phthalate by the method of Houssa and Kenyon.<sup>8</sup> The product precipitated as an oil when its pyridine solution was poured into dilute hydrochloric acid. It was extracted with ether and the extract was washed with water, dried over sodium sulfate and freed of solvent by distillation. The residue was crystallized from benzene and melted at 107–108° (lit.<sup>8</sup> 108°). The acid phthalate (300 g.) was resolved *via* its brucine salt as described in the literature.<sup>9</sup> Crystallization of the diastereoisomeric salts proved quite tedious until seed crystals were obtained, but once the laboratory was nucleated, crystallization proceeded with great ease and in one case part of the more soluble salt precipitated along with the less soluble. Decomposition of the salts was effected by dissolving them in methanol, pouring the solution into an excess of dilute hydrochloric acid and extracting the precipitated oily phthalate with ether.

(4) McLean and Adams, *ibid.*, **58**, 804 (1936).

(5) (a) Adkins, "Reactions of Hydrogen with Organic Compounds over Copper-Chromium Oxide and Nickel Catalysts," The University of Wisconsin Press, Madison, Wis., 1937, p. 50; (b) Yamamoto and Kawata, *J. Soc. Chem. Ind. Japan*, **43**, Suppl. Binding 279–280 (1940); *C. A.*, **35**, 1893 (1941).

(6) Ref. 5a, p. 13.

(7) Siggia, "Quantitative Organic Analysis via Functional Groups," John Wiley and Sons, Inc., New York, N. Y., 1949, p. 4.

(8) Houssa and Kenyon, *J. Chem. Soc.*, 2260 (1930).

(9) Downer and Kenyon, *ibid.*, 1156 (1939).

The ether was washed with water, dried over sodium sulfate and distilled and the residue was crystallized as described.<sup>9</sup> Basic hydrolysis<sup>9</sup> of the resolved phthalates yielded 33 g. of the (+)-carbinol,  $[\alpha]_D +39.7^\circ$ , and 35 g. of the (–)-carbinol b. p. 93° (14 mm.),  $[\alpha]_D -43.6^\circ$ . Since Downer and Kenyon report<sup>9</sup> a specific rotation of  $-43.5^\circ$ , the (–)-carbinol obtained in this work was presumably optically pure and the (+)-carbinol about 93% pure.

(+) and (–)-Phenylmethylcarbinyl Chlorides.—The chlorides were obtained from the corresponding alcohols by treatment with purified thionyl chloride in the cold followed by fractional distillation.<sup>10</sup> The (–)-alcohol yielded a chloride of  $[\alpha]^{25}_D -49.2^\circ$ , boiling at 74–75° (14 mm.), while the (+)-carbinol yielded a chloride of  $[\alpha]^{25}_D +45.2^\circ$ . Since McKenzie and Clough<sup>10</sup> consistently obtained material whose specific rotation was  $+50.6^\circ$ , and Ott<sup>11</sup> reports a specific rotation for  $\alpha$ -chloroethylbenzene of  $-50.3^\circ$ , it is estimated that the (–)-chloride obtained here was 97–98% pure while the purity of the (+)-chloride was between 89 and 90%.

(–)- $\alpha$ -Deuteroethylbenzene.—The general method of Johnson, *et al.*,<sup>9</sup> was followed. To a well-stirred mixture of 75 ml. of tetrahydrofuran<sup>12</sup> (distilled first over potassium hydroxide, then over lithium aluminum hydride), 1 g. of lithium aluminum deuteride<sup>13</sup> and 3 g. of finely-ground (100 mesh) lithium deuteride,<sup>13</sup> 33.5 g. of phenylmethylcarbinyl chloride,  $[\alpha]^{25}_D -49.2^\circ$ , was added rapidly. The reaction was not markedly exothermic. The mixture was refluxed with efficient stirring for four hours, without stirring for nine and one-half hours, and with stirring for ten more hours. It was then cooled, excess deuteride was destroyed by the addition of a solution of 20 ml. of water in 30 ml. of tetrahydrofuran, and the mixture was poured onto ice-water containing 20 ml. of sulfuric acid. The product was extracted with two portions of *ca.* 100 ml. of pentane<sup>12</sup> and the pentane solution was washed twice with water, four times with 85% phosphoric acid, twice with water, once with 10% sodium carbonate solution and once with water. It was dried over calcium chloride and fractionated through a Vigreux column.  $\alpha$ -Deuteroethylbenzene was collected at 133–135° (747 mm.) and weighed 20.7 g. (79%). Its rotation was  $\alpha^{25}_D -0.51 \pm 0.01^\circ$  ( $l = 2$  dm., no solvent).

When the distillation residue was taken up in acetone, the solution was found to be weakly dextrorotatory. Removal of the acetone left 0.77 g. of a semisolid material, presumably a mixture of *meso* and active 2,3-diphenylbutane. In a model experiment in which *dl*- $\alpha$ -chloroethylbenzene was reduced with lithium aluminum hydride-lithium hydride, the solid *meso*-form was recrystallized from 95% ethanol; it then melted at 124.5–125° and did not depress the melting point of an authentic sample of *meso*-2,3-diphenylbutane.<sup>11</sup>

The active  $\alpha$ -deuteroethylbenzene was fractionated through an eight-inch helix-packed column the following fractions being obtained<sup>14</sup>

Fraction	Weight, g.	$n^{25}_D$	$\alpha^{25}_D$ deg.
1	5.5	1.4921	$-0.47 \pm 0.02$
2	3.9	1.4925	$- .48 \pm .02$
3	4.4	1.4923	$- .53 \pm .02$
4	4.6	1.4922	$- .52 \pm .02$
5	0.9	1.4922	Not observed

Fractions 1 through 4 were recombined and their rotation was found to be  $\alpha^{25}_D -0.52 \pm 0.01^\circ$  ( $l = 2$  dm., no sol-

(10) McKenzie and Clough, *ibid.*, **103**, 694 (1913).

(11) Ott, *Ber.*, **61**, 2124 (1928).

(12) All solvents used in this work were checked for optical rotation which in no case was found to exceed 0.01° in a 2-dm. tube.

(13) Metal Hydrides, Inc., Beverly, Mass., isotopic purity 99+%.

(14) Rotations observed in a 2-dm. capillary tube of 2-ml. capacity. All other rotations were observed in a wide-bore 2-dm. tube of 13-ml. capacity.

vent) whence, taking  $d = 0.87$ ,<sup>15</sup>  $[\alpha]^{25D} - 0.30^\circ$ . The compound gave negative halogen tests both by the Beilstein method and with alcoholic silver nitrate.<sup>16</sup>

The reduction of 9 g. of (+)- $\alpha$ -phenethyl chloride by means of 0.35 g. of lithium aluminum hydride and 1.0 g. of lithium hydride in 30 ml. of tetrahydrofuran gave rise to 3.9 g. of ethylbenzene boiling at 132.5–134.5° (742 mm.) whose rotation was  $\alpha_D - 0.03 \pm 0.02^\circ$  ( $l = 2$  dm., no solvent).<sup>14</sup>

(-)- $\alpha$ -Deuteroethyl-*p*-acetylbenzene (II).—The method of Klages<sup>17</sup> was followed. To a solution of 14.5 g. of (-)- $\alpha$ -deuteroethylbenzene and 18 g. of acetyl chloride in 60 ml. of petroleum ether<sup>12</sup> (b. p. 30–60°), 19 g. of aluminum chloride was added gradually with efficient stirring. The mixture was refluxed for one-half hour and poured onto ice and hydrochloric acid. The layers were separated and the aqueous layer was extracted once with ether.<sup>12</sup> The petroleum ether and ether layers were successively washed with dilute hydrochloric acid, water, 10% sodium carbonate solution and water and then dried over sodium sulfate. Fractionation of the solvents followed by distillation *in vacuo* yielded 1.3 g. of unchanged  $\alpha$ -deuteroethylbenzene,<sup>18</sup> b. p. 37–38° (17 mm.), and 14.5 g. (72%) of the desired ketone collected at 123–126.5° (18 mm.). The ketone had  $n^{25D} 1.5260$ <sup>19</sup> and  $\alpha^{25D} - 0.54 \pm 0.01^\circ$  ( $l = 2$  dm., no solvent), whence, assuming a density of 0.99 (see below),  $[\alpha]^{25D} - 0.27^\circ$ .

Oxime of II.—Sodium acetate trihydrate (29 g.) and hydroxylamine hydrochloride (14.5 g.) were ground together in a mortar and the resultant slurry was extracted three times with 50-ml. portions of ethanol.<sup>12</sup> The filtered ethanol solution was added to a solution of 14 g. of II in 15 ml. of ethanol and refluxed for twelve hours. Part of the ethanol was then distilled and crystallization induced by the addition of water to the cloud point and cooling. The crystalline oxime was collected, washed with dilute ethanol and dried; it weighed 13.2 g. (85% and melted in 82.5–84°. The optical rotation of a solution of 5 g. of oxime in benzene<sup>12</sup> (total volume 15 ml.) was

(15) The values for  $d^{25}$ , found were 0.8628 for ethylbenzene and 0.8712 for deuteroethylbenzene. Application of the formula of McLean and Adams (ref. 4) to the ethylbenzene value gives an expected density of 0.8710 for the deuterium compound.

(16) The silver nitrate test was shown to be sensitive to a solution containing one part of  $\alpha$ -phenethyl chloride in 700 of ethylbenzene.

(17) Klages, *Ber.*, **32**, 1558 (1899).

(18) The rotation of the recovered hydrocarbon was determined by diluting 0.8 ml. with 2.4 ml. of ordinary ethylbenzene and taking readings in a 2-dm. capillary tube (*cf.* ref. 14). The observed rotation was  $-0.13 \pm 0.01^\circ$ , corresponding to a rotation of  $-0.52^\circ$  for the undiluted material.

(19) The data reported by Klages, ref. 16, for the hydrogen compound are: b. p. 130° (23 mm.),  $n^{25D} 1.5310$ ,  $d^{25}$ , 0.991. Here observed: b. p. 114–116° (13 mm.),  $n^{25D} 1.5260$ ,  $d^{25}$ , 0.9851.

$-0.16 \pm 0.01^\circ$  ( $l = 2$  dm.,  $t = 23^\circ$ ).<sup>20</sup> Recrystallization of the oxime from dilute ethanol raised the melting point to 83–84°<sup>21</sup> and changed  $\alpha^{25D}$  to  $-0.11 \pm 0.01^\circ$  ( $l = 2$  cm., in benzene). Further recrystallization from the same solvent did not change the melting point;  $\alpha^{25D} - 0.12 \pm 0.01^\circ$  ( $l = 2$  dm., in benzene). Recrystallization from benzene–petroleum ether left the melting point unchanged,  $\alpha^{25D} - 0.11 \pm 0.01^\circ$  ( $l = 2$  dm., in benzene), whence  $[\alpha]^{25D} - 0.17^\circ$  in benzene.

Recovery of the Ketone II from its Oxime.—A suspension of 7 g. of the oxime of II in 100 ml. of *ca.* 1 *N* hydrochloric acid was steam distilled. The distillate was extracted twice with ether and the ether layers were washed with 5% sodium carbonate solution and then three times with water. Drying over sodium sulfate followed by concentration and distillation *in vacuo* yielded 5.5 g. (86%) of the recovered ketone (II) collected at 127–129° (25 mm.). Its physical constants were as follows:  $n^{25D} 1.5261$ ,  $d^{25}$ , 0.9915<sup>22</sup>;  $\alpha^{30D} - 0.50 \pm 0.02^\circ$ <sup>14</sup> ( $l = 2$  dm., no solvent). The rotation of the ketone was unaffected by eleven hours of refluxing with 1 *N* aqueous hydrochloric acid.

**Acknowledgments.**—The author wishes to express his appreciation to Dr. Charles C. Price for helpful advice, to Mr. Erwin Kohn for carrying out the high-pressure hydrogenation of acetophenone and to the Electrochemicals Department of the du Pont Company for a generous supply of tetrahydrofuran.

### Summary

1. The reduction of (-)-phenylmethylcarbinyl chloride of  $[\alpha]^{25D} - 49.2^\circ$  with lithium deuteroethylbenzene yields active  $\alpha$ -deuteroethylbenzene of  $[\alpha]^{25D} - 0.30^\circ$ .

2. The active  $\alpha$ -deuteroethylbenzene has been converted into optically active *p*-acetyl- $\alpha$ -deuteroethylbenzene whose crystalline oxime retained its activity through several recrystallizations and regenerated the active ketone upon hydrolysis.

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(20) This reading may have been affected by a systematic error; the field was very much distorted.

(21) Klages, *Ber.*, **35**, 2245 (1902), reports a melting point of 82–83° for the hydrogen compound while the present author observed 83–84°.

(22) The expected density on the basis of the corresponding value for the hydrogen compound (ref. 19) and the formula of McLean and Adams (ref. 4) is 0.9917.