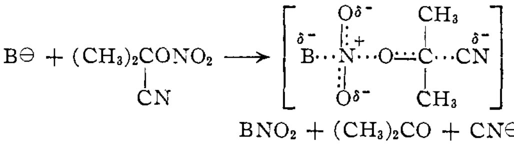
from other nitrate esters and, correspondingly, probably modify the key step of the nitration reaction. It is suggested that when acetone cyanohydrin nitrate is employed, an intermediate of type II in equation 4 is not actually formed. Instead the reaction amounts to a displacement on nitrogen, *i.e.*, the negative charge is transferred in the transition state from the reacting anion to the nitrile group instead of to the oxygen atoms of the nitro group (equation 6). The driving force for this charge transfer is the concerted formation of the carbon–oxygen double bond. Such a picture explains the reactivity of acetone cyanohydrin nitrate


$$B^{\ominus} + (CH_3)_2C(CN)ONO_2 \longrightarrow \left[\overset{\delta-}{B}\cdots \overset{+}{N}(O^{\delta-})_2 \cdots O \text{---} C(CH_3)_2 \cdots \overset{\delta-}{CN} \right] \longrightarrow BNO_2 + (CH_3)_2CO + CN^{\ominus} \quad (6)$$

toward anions that do not attack ordinary nitrate esters. This mechanism has also been used to explain the nitration of amines with this reagent.[7]

Experimental[15]

Diethyl Nitromalonate.—A solution of 48.0 g. (0.3 mole) of diethyl malonate in 150 ml. of dry tetrahydrofuran was added slowly to a slurry of 7.2 g. (0.3 mole) of sodium hydride in 200 ml. of tetrahydrofuran. This mixture was stirred under reflux for 30 minutes following the addition and then cooled to room temperature. A solution of 13.0 g. (0.1 mole) of acetone cyanohydrin nitrate[7] in 100 ml. of tetrahydrofuran was added and the mixture was stirred under reflux for two hours. Any unreacted hydride was decomposed by the addition of ethanol and the mixture was poured into 500 g. of ice containing 25 ml. of concentrated hydrochloric acid. This mixture was extracted with ether. The resulting organic extracts were extracted several times with 10% sodium hydroxide solution. These basic extracts were washed with ether and acidified with ice-cold 10% hydrochloric acid. The oil that separated was extracted with ether, dried and, after removal of the solvent, distilled to yield 9.2 g. (45%) of diethyl nitromalonate, b.p. 78–80° (0.2 mm.), n^{20}D 1.4275 (lit. values[16] b.p. 81–83° (0.3 mm.), n^{21}D 1.4274).

Preparation of α-Nitro Esters. General Method.—To a suspension of 5.0 g. (0.21 mole) of sodium hydride in 100 ml. of tetrahydrofuran was added 0.1 mole of the appropriate malonic or acetoacetic ester in 75 ml. of tetrahydrofuran. The mixture was heated under reflux for 30 minutes to ensure complete formation of the sodio derivative, and then cooled to room temperature. A solution of 19.5 g. (0.15 mole) of acetone cyanohydrin nitrate in 75 ml. of tetrahydrofuran was added slowly. After addition was complete, the mixture was heated under reflux for two hours and worked up as described for diethyl nitromalonate. All the α-nitro esters prepared had bands in their infrared spectra at 1748 and 1560 cm.$^{-1}$ attributable to carboxylic ester and nitro groups, respectively.

Phenylnitromethane.—The sodio derivative of phenylacetonitrile was prepared from 11.7 g. (0.1 mole) of the nitrile and 5.0 g. (0.21 mole) of sodium hydride in 200 ml. of tetrahydrofuran. This mixture was cooled to 15° and a solution of 19.5 g. (0.15 mole) of acetone cyanohydrin nitrate in 75 ml. of tetrahydrofuran was added at such a rate that the temperature of the reaction mixture did not rise above 30°. It was stirred at 30–35° for an hour and then stored in the refrigerator overnight. Dry ether was added and the precipitated solid was collected on a filter. This material, presumably a mixture of sodium phenylnitrocyanomethide and sodium cyanide, amounted to 22 g. (94%). The hydrolysis and acidification steps were carried out exactly as described by Black and Babers.[13] Phenylnitromethane was obtained as a pale yellow oil; yield 9.6 g. (70%).

***o*-Chlorophenylnitromethane.**—By the same method as described for the preparation of phenylnitromethane, *o*-chlorophenylacetonitrile[17] (15.1 g., 0.1 mole) was converted to *o*-chlorophenylnitromethane, b.p. 74–76° (0.2 mm.), n^{20}D 1.5532; yield 8.2 g. (42%).

Anal. Calcd. for $C_7H_6NO_2Cl$: C, 49.00; H, 3.53; N, 8.16; Cl, 20.69. Found: C, 49.09; H, 3.26; N, 9.15; Cl, 20.79.

HUNTSVILLE, ALABAMA

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[15] We are indebted to Miss Annie Smelley for the microcombustion data and to Dr. Keith S. McCallum for infrared interpretations.

[16] D. I. Weisblat and D. A. Lyttle, THIS JOURNAL, **71**, 3079 (1949).

[17] H. Mehner, *J. prakt. Chem.*, [2] **62**, 554 (1900).

[CONTRIBUTION FROM THE BAKER CHEMISTRY LABORATORY OF CORNELL UNIVERSITY AND FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF SOUTH CAROLINA]

Some Reactions of an Optically Active Diazonium Salt and of an Optically Active Diacyl Peroxide

BY DELOS F. DETAR[1] AND JOHN CHARLES HOWARD[2]

RECEIVED MARCH 23, 1955

The thermal decomposition of the optically active peroxide of 2-methyl-6-nitro-2′-biphenylcarboxylic acid (I) in benzene, in carbon tetrachloride, and in bromotrichloromethane leads to replacement of the carboxyl function by phenyl, by chlorine or by bromine. The products are optically active, but have undergone some racemization. Since the starting materials and products are thermally stable toward racemization under the reaction conditions, the partial racemization occurred during the reaction. This result is not possible if the products were formed only by the reaction RCOO· + SY → RY + S· + CO_2, and shows that the radical RCOO· must undergo decarboxylation prior to reaction with the solvent. A parallel study has been carried out on the diazonium salt derived from 2-methyl-6-nitro-2′-aminobiphenyl (II).

Optically active biphenyls have been used effectively in the study of reaction mechanisms, notably in studies of the Hofmann rearrangement,[3] of the Curtius rearrangement,[4] of the Wolff rearrangement,[5] and indirectly in determining the direction of migration in the Beckmann rearrangement.[6] A typical example is the conversion of the optically active azide derived from 2-methyl-6-nitro-2′-biphenylcarboxylic acid (I) to the optically active amine, 2-methyl-6-nitro-2′-aminobiphenyl

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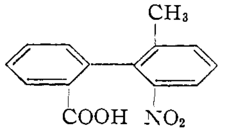
[3] E. S. Wallis and W. W. Moyer, THIS JOURNAL, **55**, 2598 (1933).

[4] F. Bell, *J. Chem. Soc.*, 835 (1934).

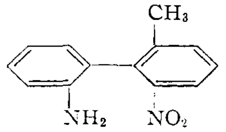
[5] J. F. Lane and E. S. Wallis, *J. Org. Chem.*, **6**, 443 (1941).

[6] J. Meisenheimer, W. Theilacker and O. Beisswenger, *Ann.*, **495**, 249 (1932).

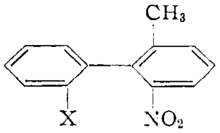
(II) by the Curtius reaction.[4] The fact that in this and in similar reactions the product is optically active has been used as an argument that the migrating group is never "free," for loss of the 2'-blocking group would lead to racemization.



I



II



III

The extensive work that has been carried out on replacement reactions permits a somewhat more sophisticated evaluation of this method as a tool in reaction mechanism studies. An all or nothing result is not necessary or even desirable for a successful application; if removal of the blocking group gives an intermediate ion or radical which undergoes a subsequent addition process at a rate comparable to the racemization rate, then one is dealing with a series of competitive reactions, *viz.*, the racemization process *versus* a series of possible ionic or radical reactions. Such a system can lead to an evaluation of relative reactivities.

We have been especially interested in obtaining an optically active biphenyl in which an amino group or a carboxyl group is the blocking group. Of the various requirements in the compound selected for study two warrant mention: the compound should be available in reasonable quantities, and the blocking groups should be large enough so that the starting materials and products do not undergo serious thermal racemization under the reaction conditions and small enough so that the hydrogen atom does not serve as a blocking group.[7a] 2-Methyl-6-nitro-2'-biphenylcarboxylic acid (I) and 2-methyl-6-nitro-2'-aminobiphenyl (II) were selected for the purpose and proved satisfactory in most respects.

The acid I is reported[7b] to have a half time for racemization of about 34 hours in refluxing acetic acid. The chloro compound, 2-methyl-6-nitro-2'-chlorobiphenyl (III, X = Cl) was shown in this work to have a similar half life at 100° in the molten state. The racemization of the corresponding methoxyl compound, 2-methyl-6-nitro-2'-methoxybiphenyl, has not been studied, but the similar 2-methyl-6-methoxy-2'-nitrobiphenyl (which should have the same oppositions in the racemization stage, nitro-methoxyl, methyl-hydrogen) has a half time of about four hours at 25°. Since the diazonium salt reacts at a comparable rate, this ionic replacement reaction of the diazonium group cannot readily be studied with this amine II. The nitro group also interferes with some reactions, the conversion of the diazotized amine II to the phenol by heating the aqueous solution led to black reaction mixtures which furnished very little of the phenol. On the other hand there is probably no such thing as an inert blocking group; halogens are subject to attack, and so are methyl groups (giving fluorene derivatives).[8]

The reactions studied are summarized in Table I. An attempt was made in all cases to determine the maximum rotation of the starting materials and of the products. The peroxide of acid I was probably obtained with maximum rotation, and the values for the amine II, for 2-methyl-6-nitro-2'-iodobiphenyl, and for 2-methyl-6-nitro-2'-bromobiphenyl are fairly good. The value for the chloro compound, 2-methyl-6-nitro-2'-chlorobiphenyl, may be in error by ten per cent. or so, and that for the phenyl compound, 2-methyl-6-nitro-2'-phenylbiphenyl, is only an approximation; it is perhaps low.

The Sandmeyer replacement of the diazonium group with chlorine and with bromine led to little racemization, a perhaps expected result since complex formation seems to be an important feature, and reaction within the complex might well not involve free ions or radicals. The mechanism of the reaction of diazonium salts with iodide ion is complex. The high activity of the products suggests either a direct replacement of nitrogen (aromatic S_N2 type reaction) or formation and intramolecular reaction of a covalent diazoiodide of some sort. The S_N1 type of replacement[9] is probably not involved since this particular diazonium salt gives little phenol and a very dark reaction mixture when heated in aqueous solution under conditions that should favor an S_N1 process.

The Gomberg–Bachmann replacement of the diazonium group with phenyl is of considerable interest. According to the radical substitution hypotheses usually proposed, the reaction involves the key step

$$\mathrm{Ar}\cdot + \mathrm{Ar'H} \longrightarrow \text{complex} \longrightarrow \mathrm{ArAr'} + (\mathrm{H}\cdot) \quad (1)$$

The parentheses around the hydrogen atom indicate that this atom may be picked up by some radical which reacts with the complex and that a free atom is probably not produced. The radical substitution step thus involves a free radical Ar· which is expected to racemize rapidly. If the hypothesis is correct, then it is necessary to conclude that the radical substitution step, eq. 1, is faster than the racemization of the radical. The reaction of the peroxide derived from 2-methyl-6-nitro-2'-biphenylcarboxylic acid with benzene poses a similar problem. The greater amount of racemization with the peroxide is probably a real effect. Since the peroxide reaction was carried out at 80° while the Gomberg–Bachman reaction was carried out below room temperature, it is necessary to conclude (on the radical substitution hypothesis) that the racemization process has a slightly higher temperature coefficient than the substitution step; and this is a reasonable hypothesis. These data do not exclude the possibility that some of the reaction may go via a step such as

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[7] (a) *Cf.* Review by R. L. Shriner and R. Adams in "Organic Chemistry," Ed. by H. Gilman, John Wiley and Sons, Inc., New York, N. Y., 2nd Ed., Vol. I, 1943, p. 347. (b) R. W. Stoughton and R. Adams, This Journal, **52**, 5263 (1930).

[8] L. Mascarelli and B. Longo, *Gazz. chim. ital.*, **67**, 812 (1937).

[9] For a discussion of the mechanism of phenol formation see D. F. DeTar and D. I. Relyea, This Journal, **76**, 1680 (1954).

TABLE I

SUMMARY OF REACTIONS OF OPTICALLY ACTIVE DIAZOTIZED 2-METHYL-6-NITRO-2'-AMINOBIPHENYL AND OF THE DIACYL PEROXIDE

Reaction	Optical purity of starting material	Optical purity of product	% Retention[a] of opt. purity	Yield of product, %
Diazonium chloride from 2-methyl-6-nitro-2'-aminobiphenyl with benzene and sodium hydroxide to give 2-methyl-6-nitro-2'-phenylbiphenyl	73	(60)	(80 max.)[b]	13
Diazonium fluoborate, from 2-methyl-6-nitro-2'-aminobiphenyl with benzene and sodium hydroxide to give 2-methyl-6-nitro-2'-phenylbiphenyl	73	(43)	(60 max.)[b]	16
Diazonium chloride with hydroiodic acid to give 2-methyl-6-nitro-2'-iodobiphenyl	67	52	80	45
Diazonium chloride with hydroiodic acid to give 2-methyl-6-nitro-2'-iodobiphenyl	100	89	90	40
Diazonium bromide with cuprous bromide and hydrobromic acid to give 2-methyl-6-nitro-2'-bromobiphenyl	67	60	90	40
Diacyl peroxide of 2-methyl-6-nitro-2'-biphenylcarboxylic acid with benzene to give 2-methyl-6-nitro-2'-phenylbiphenyl	100	(50)	(50 max.)[b]	5
Diacyl peroxide of 2-methyl-6-nitro-2'-biphenylcarboxylic acid with benzene to give 2-methyl-6-nitro-2'-phenylbiphenyl	100	(25)	(25)[b]	5
Diacyl peroxide in CCl_4 to give 2-methyl-6-nitro-2'-chlorobiphenyl	100		45	7
Diacyl peroxide in CCl_4 to give 2-methyl-6-nitro-2'-chlorobiphenyl	100	50	40	4
Diacyl peroxide in CCl_3Br to give 2-methyl-6-nitro-2'-bromobiphenyl	100	90	90	18
Diacyl peroxide in CCl_3Br to give 2-methyl-6-nitro-2'-bromobiphenyl	100		(90)	20

[a] Given by 100 (optical purity of product)/(optical purity of starting material). [b] The $[\alpha]_D$ of completely resolved 2-methyl-6-nitro-2'-phenylbiphenyl is uncertain.

eq. 2 or eq. 3, but they do seem to require part of

$$ArN_2OR + Ar'\cdot \longrightarrow ArAr' + N_2 + RO \quad (2)$$

$$ArN_2 + Ar'\cdot \longrightarrow \text{complex} \xrightarrow{R\cdot} ArAr' + N_2 + R^{\oplus} \quad (3)$$

the reaction to involve a racemizable intermediate such as the radical Ar· (III, X = ·) of eq. 1.

The reactions of the peroxide of acid I with carbon tetrachloride and with bromotrichloromethane are consistent with the above stated hypothesis that a radical R· (III, X = ·) is formed which can abstract a halogen atom, eq. 4, at a rate which is fast compared with the racemization.

$$R\cdot\,(\text{III}, X = \cdot) + CCl_3Br \longrightarrow RBr + \cdot CCl_3 \quad (4)$$

The higher yield of bromo compound (III, X = Br) than of chloro compound (III, X = Cl) can be attributed to a more extensive decarboxylation process occurring at the higher reflux temperature of bromotrichloromethane or possibly to a varying oxygen content of the reaction media. The near absence of racemization of the bromo compound (III, X = Br) compared with the chloro compound (III, X = Cl) can be explained on the known greater reactivity of the bromotrichloromethane with free radical intermediates.[10]

In this example also there are alternative routes to the chloro and the bromo products involving a direct replacement reaction such as eq. 5.

$$RCOO\cdot + CCl_3Br \longrightarrow RBr + CO_2 + \cdot CCl_3 \quad (5)$$

Reactions of this type have been postulated a number of times for diacyl peroxide reactions,[11] but without any evidence to favor the reactions of either eq. 4 or of eq. 5. Edwards and Mayo[12] have tended to favor eq. 5 for diacetyl peroxide reactions in their study of the methane–methyl chloride ratio obtained in solvent mixtures in which carbon tetrachloride was a constant component, since otherwise the calculated chain transfer reactivity of the methyl radical appeared abnormal.

While the evidence regarding these two steps is still somewhat inconclusive, we favor the process given in eq. 4 over that in eq. 5 for the reason that the occurrence of the former reaction (eq. 4) can be convincingly demonstrated, and no such evidence is available regarding the latter reaction.

Examples of reactions which do demonstrate the operation of eq. 4, in part at least, are the partial racemizations reported for the production of 2-methyl-6-nitro-2'-chlorobiphenyl (III, X = Cl) and of 2-methyl-6-nitro-2'-bromobiphenyl (III, X = Br) in the present work. The decomposition of the peroxide of 1-apocamphanecarboxylic acid in carbon tetrachloride[13a] gave a 35% yield of 1-chloroapocamphane, and ditriptoyl peroxide when refluxed in benzene gave a 45% yield of triptyrene.[13b] There can be no serious consideration given to the hypothesis that these highly hindered peroxides are undergoing chlorine or hydrogen replacement reactions according to the decarboxylative substitution mechanism represented by eq. 5.

One complicated feature of the decarboxylative substitution step is the necessity of assuming either that the reaction involves the simultaneous transfer of three bonds (formation of one bond and homolytic cleavage of two more bonds), or else that some type of complex is formed. The simultaneous reaction of three bonds would seem to be unlikely, for there is no obvious energetic advantage; the cleavage of a peroxide into four fragments is a related problem that has been discussed by Bartlett.[13b] Complex formation also has little precedent for the type of compounds involved.

Westheimer[14] has shown how to calculate the

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(10) M. S. Kharasch, O. Reinmuth and W. H. Urry, THIS JOURNAL, **69**, 1105 (1947).

(11) W. E. Cass, *ibid.*, **69**, 500 (1947); M. S. Kharasch, E. V. Jensen and W. H. Urry, *J. Org. Chem.*, **10**, 386 (1945).

(12) F. G. Edwards and F. R. Mayo, THIS JOURNAL, **72**, 1265 (1950).

(13) (a) M. S. Kharasch, F. Englemann and W. H. Urry, *ibid.*, **65**, 2428 (1943); (b) P. D. Bartlett and F. D. Greene, *ibid.*, **76**, 1088 (1954).

(14) F. H. Westheimer, *J. Chem. Phys.*, **15**, 252 (1947).

activation energy for the racemization of optically active biphenyls. It is possible to make a rough estimate for the energy of racemization of the 2-(2′-methyl-6′-nitrophenyl)phenyl radical (III, X = ·) by assuming that the only blocking effect to be considered is that between the 6-hydrogen atom and the nitrogen atom of the 6′-nitro group. In the model in which the two benzene rings are coplanar, and all bond distances and angles are normal, the H–N distance is 1.7 Å., using the bond distances given in Table IV of ref. 14, and assuming that the C–N bond distance is 1.45 Å. Using the potential function $V = 1.6 \times 10^{-8} e^{-d/0.165 \times 10^{-8}}$ ergs/molecule (which gives the same U value for a H–N separation of 2.7 Å., the assumed sum of Van der Waals radii, that eq. 11 of ref. 14 gives for a H–Br separation of 3.15 Å.), the energy of repulsion is about 6 kcal. Although such a figure is quite crude, any interaction of the odd electron with the CH_3 group being neglected, it is clear that the free energy of activation for the racemization process may well be low enough so that the racemization reaction and the halogen abstraction reaction can be competitive.

Experimental Part[15]

3-Nitro-2-aminotoluene.—Conditions for the successful nitration of *o*-acetotoluidide are critical. One mole (107 g.) of *o*-toluidine was added to 650 ml. of acetic anhydride in a 1-l. 3-necked flask equipped with a tantalum Hershberg stirrer,[16] the solution cooled and the resulting slurry maintained at 10–12° (critical) while 126 ml. (2 moles) of 70% nitric acid was added (about two hours). The deeply colored resultant solution was poured into 3 l. of ice-water, the precipitated mixture of nitroacetotoludides filtered, washed thoroughly, and the moist cake transferred to a large flask arranged for steam distillation. The amides were hydrolyzed by adding 300 ml. of concd. hydrochloric acid and heating to boiling, then the 3-nitro-2-aminotoluene was isolated by steam distillation; 36 l. of distillate contained 75–84 g. (48–54%) of bright orange needles, m.p. 92–94°; redistillation of a 10-g. sample gave 8.7 g. of orange needles, m.p. 95–96°. The once-distilled material was used in subsequent reactions.

3-Nitro-2-bromotoluene.—(This material is a bad skin and eye irritant.) A slurry of 152 g. (1 mole) of the amine in 1.8 l. of glacial acetic acid was diazotized at 20–25° with a cooled nitrosyl sulfuric acid solution prepared by adding 80 g. (1.2 moles) of sodium nitrite to 560 ml. of 96% sulfuric acid in the cold followed by a 15-min. heating period at 50°. The diazonium solution was added to a solution of cuprous bromide[17] (from 1.1 formula wt. of copper sulfate) in 445 ml. of 48% hydrobromic acid, the mixture allowed to stand for about ten hours and then steam distilled until 9–10 l. of distillate had been collected. About 750 g. of sodium hydroxide was added to the cool distillate, and the solid crude 3-nitro-2-bromotoluene filtered. Purification was effected by dissolving in 1 l. of benzene and passing through a column of 450 g. of F-20 alumina[18]; the column was eluted with an additional liter of benzene. Evaporation of the solvent left 189 g. (88%) of a pale yellow oil which solidified to yellow crystals, m.p. 36–38°.

Ethyl *o*-Iodobenzoate.—This was obtained as a liquid, b.p. 120–125° at 2.5 mm., in 88% yield by esterification of *o*-iodobenzoic acid with ethanol and dry hydrogen chloride.

2-Methyl-6-nitrobiphenyl-2′-carboxylic Acid.—A mixture of 72 g. (0.33 mole) of 2-bromo-3-nitrotoluene, 92 g. (0.33 mole) of ethyl *o*-iodobenzoate, 170 g. of activated copper bronze[19] and 240 g. of nitrobenzene (solvent) was heated at 210° with stirring (Hershberg type) for 45 minutes. The copper and copper salts were separated by centrifuging, using methylene chloride as solvent. The solvents were removed by distillation, and the mixture of coupling products distilled, 83 g., b.p. 90–180° at 0.5 mm. The esters were hydrolyzed by refluxing with 325 ml. of 10% sodium hydroxide and about 5 ml. of ethanol for eight hours, with efficient stirring by a centrifugal stirrer.[20] The dark mixture was cooled and immediately extracted with ether; during the extraction 40 g. of the sodium salt of 2-methyl-6-nitrobiphenyl-2′-carboxylic acid precipitated. The crude salt was dissolved in 500 ml. of water, filtered, and the acid precipitated with hydrochloric acid; the precipitated acid had a m.p. of 169–171° and weighed 26 g. (30%).

A number of preliminary experiments revealed the advantage of using a diluent in the Ullmann reaction, otherwise reaction was incomplete at the temperature and time specified. It is possible to effect separation of the coupling products by use of a still designed for high temperature, low pressure, operation. The fact that the sodium salt does precipitate furnished a more convenient procedure. The use of alcoholic sodium hydroxide solutions for hydrolysis leads to extensive decomposition and is not recommended.

***d*- and *l*-2-Methyl-6-nitrobiphenyl-2′-carboxylic Acid.**—The *dl*-acid was resolved by crystallization of the quinidine salt from ethanol; the recrystallized salt had $[\alpha]^{20}\mathrm{D}$ +217° in 1.5% solution in acetic acid. Other salt samples had $[\alpha]\mathrm{D}$ +217°, +221°, +233° and +218°. The *d*-2-methyl-6-nitrobiphenyl-2′-carboxylic acid was obtained (4.5 g. from 15.3 g. *dl*-acid) by stirring the salt with 6 *N* hydrochloric acid; it had $[\alpha]^{23}\mathrm{D}$ +65° in 1.5% solution in methanol. Other preparations of the acid had $[\alpha]\mathrm{D}$ +69°, +71°, m.p. 170–173°.

The 8 g. of recovered crude *l*-acid was converted to the brucine salt, which was recrystallized from acetone. This salt had $[\alpha]^{20}\mathrm{D}$ −23° in 1% solution in acetic acid. Crude *l*-acid (5.78) obtained on treatment with hydrochloric acid had $[\alpha]^{20}\mathrm{D}$ −57° in 1.3% solution in methanol; recrystallization from methanol gave 3.20 g. of almost colorless crystals, m.p. 172–175°, $[\alpha]^{25}\mathrm{D}$ −69° in 2% solution in methanol.

***dl*-2-Methyl-6-nitro-2′-aminobiphenyl.**—A solution of 8.4 g. of *dl*-2-methyl-6-nitrobiphenyl-2′-carboxylic acid was refluxed with 10 ml. of thionyl chloride for 20 minutes; 7.5 g. (82%) of the acid chloride, m.p. 82–83°, precipitated upon addition of hexane. The acid chloride was dissolved in 20 ml. of acetone and a solution of 2.6 g. of sodium azide in 25 ml. of water added. The 2-phase mixture was allowed to stand with occasional swirling for 20 minutes, and water added to precipitate 7.0 g. of azide, m.p. 65–70° dec. The azide was dissolved in toluene, the solution refluxed for 30 minutes, and then stirred with 50% sulfuric acid for three hours. Neutralization with aqueous ammonia gave 4.3 g. of crude *dl*-2-methyl-6-nitro-2′-aminobiphenyl, m.p. 53–55°; recrystallization from ethanol gave 3.4 g. of yellow crystals, m.p. 63–64°; 45% yield based on the acid. An analytical sample had m.p. 64–65°.

Anal. Calcd. for $C_{13}H_{12}N_2O_2$: C, 68.41; H, 5.30; N, 12.27. Found: C, 68.47; H, 5.24; N, 12.47.

***d*-2-Methyl-6-nitro-2′-aminobiphenyl.**—The active amine was obtained by a procedure similar to that used for the *dl*-amine. The acid chloride of *d*-2-methyl-6-nitro-2′-biphenylcarboxylic acid had a m.p. of 113–114° and $[\alpha]^{25}\mathrm{D}$ +142° in 1.7% solution in chloroform. The crude *d*-amine, 7.1 g., m.p. 72–78°, gave 6.2 g. (52% based on the acid) of recrystallized amine (from ethanol), m.p. 80–80.5° and $[\alpha]^{25}\mathrm{D}$ +224° in 1.4% solution in methanol. An alternative procedure for hydrolysis of the isocyanate involved use of 96% sulfuric acid and gave a 62% yield. The Curtius reaction resulted in about 93% retention of optical purity in one run, but this is not significantly different from 100% on the basis of the present work. Other samples of the amine were less completely resolved; m.p. 73–79°, $[\alpha]\mathrm{D}$ +195°; m.p. 63–64°, $[\alpha]\mathrm{D}$ −162°; m.p. 69–72°, $[\alpha]\mathrm{D}$ +164°.

***dl*-2-Methyl-6-nitro-2′-phenylbiphenyl.**—This *o*-terphenyl derivative was prepared by the Gomberg–Bachmann

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[15] All melting points are corrected. Analyses by Mrs. M. Libowitz.

[16] L. F. Fieser, "Experiments in Organic Chemistry," D. C. Heath and Company, New York, N. Y., 2d Ed., 1941, p. 308.

[17] L. A. Bigelow, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 2d ed., 1941, p. 135.

[18] Alkaline chromatographic grade alumina from Aluminum Ore Company.

[19] E. C. Kleiderer and R. Adams, This Journal, **55**, 4219 (1933).

[20] This consists of a glass rod with a glass tube sealed across the bottom to form a T shaped stirrer; before cutting the tube to size, a hole is blown opposite to the end of the glass rod. The stirrer serves as a highly efficient centrifugal pump.

reaction by diazotizing 3.20 g. of *dl*-2-methyl-6-nitro-2′-aminobiphenyl in 15 ml. of 0.02 *M* hydrochloric acid with solid sodium nitrite, and stirring the solution of diazonium salt vigorously with 100 ml. of benzene at 5° while 20 ml. of 5% sodium hydroxide solution was added over a half-hour period. After another hour at room temperature the benzene layer was separated, dried over a small amount of magnesium sulfate, then passed through a column of F-20 alumina. The terphenyl derivative was eluted using another 140 ml. of benzene to give a crude yield of 0.77 g. of yellow solid. Two recrystallizations from ethanol gave 143 mg. (4%) of light yellow crystals, m.p. 100–100.5°.

Anal. Calcd. for $C_{19}H_{15}NO_2$: C, 78.87; H, 5.23; N, 4.84. Found: C, 79.12; H, 5.21; N, 4.98.

***d*-2-Methyl-6-nitro-2′-biphenyldiazonium Fluoborate.**—A sample of the amine of $[\alpha]^{25}_{\mathrm{D}}$ +164° in 1.2% solution in methanol (73% of max. rotation) and m.p. 69–72° was diazotized in hydrochloric acid and the diazonium fluoborate precipitated by addition of fluoboric acid giving 0.86 g. (51%) of the salt; $[\alpha]^{25}_{\mathrm{D}}$ +63° in 1.8% solution in dimethylformamide.

Gomberg–Bachmann Reaction on Optically Active Diazonium Salts.—A sample of *l*-2-methyl-6-nitro-2′-aminobiphenyl, (3.20 g.), $[\alpha]^{25}_{\mathrm{D}}$ −164° (73% of maximum), m.p. 65–72°, was diazotized and treated with benzene as described above for the *dl*-amine except that 200 ml. of benzene and 74 ml. of 10% sodium hydroxide were used. The product was isolated by evaporating the benzene from the organic layer; the residue was dissolved in 5 ml. of benzene and passed through a column of F-20 alumina of 30 ml. V-Volume.[21] The terphenyl derivative was eluted with 60 ml. of benzene, evaporation of which gave 0.422 g. of light orange semi-solid, $[\alpha]^{25}_{\mathrm{D}}$ −21° in 3% solution in benzene. The second 60 ml. of eluent contained 0.033 g. of an orange oil which was discarded. The first fraction was rechromatographed to give an 88% recovery of a light yellow solid, m.p. 55–70°, $[\alpha]^{30}_{\mathrm{D}}$ −24° in 3% solution in benzene. The yield of rechromatographed material was 13%. An analytical sample was prepared by drying over phosphorus pentoxide at room temperature, but without recrystallization.

Anal. Calcd. for $C_{19}H_{15}NO_2$: C, 78.87; H, 5.23. Found: C, 78.82; H, 5.19.

Recrystallization was omitted in the isolation procedure to avoid preferential removal of either active or racemic product. It was omitted in preparation of the analytical sample since this was a test for non-optically active impurities. The infrared spectra of a 10% solution in carbon disulfide of the 55–70° material was visually identical in all respects (location and shapes of peaks and valleys, relative heights of peaks, absence of shoulders) with the analytical sample of *dl*-2-methyl-6-nitro-2′-phenylbiphenyl. It was ascertained that the deamination product, 2-methyl-6-nitrobiphenyl, could not be distinguished even when present in amounts greater than 10% since its curve was too nearly the same as that of the terphenyl derivative. The carbon-hydrogen analysis shows that less than 5% of the 2-methyl-6-nitrobiphenyl can be present, for this compound contains 73.24% of carbon. It thus seems reasonably well established that the chromatographed product consists only of *l*- and of *dl*-2-methyl-6-nitro-2′-phenylbiphenyl.

The 55–70° sample of *dl* + *l*-2-methyl-6-nitro-2′-phenylbiphenyl was recrystallized from ethanol: first crop m.p. 85–90°, $[\alpha]_{\mathrm{D}}$ nearly 0°; second crop m.p. 75–80°, $[\alpha]_{\mathrm{D}}$ −20°; third crop m.p. 50–56°, $[\alpha]_{\mathrm{D}}$ −40°. If 40° is taken as the maximum value for $[\alpha]_{\mathrm{D}}$, then $[\alpha]_{\mathrm{D}}$ −24° represents a sample with 60% of the maximum rotation and there is 83% of retention during the replacement process. This represents a crude maximum estimate.

Since oxygen was discovered to have a profound effect on the reaction of benzenediazonium salts with methanol under alkaline conditions,[22] a Gomberg–Bachmann reaction was carried out using solutions which had been boiled and swept with high purity nitrogen. The diazonium fluoborate sample described above was added to the stirred benzene (200 ml.)-water (50 ml.) mixture, and an "outgassed" solution of 0.60 g. of sodium hydroxide in 50 ml. of water was added. The product was isolated as described above using an alumina column of 35 ml. V-volume, giving 0.111 g. (16% yield) of residue, $[\alpha]^{27}_{\mathrm{D}}$ +17° in 4% solution in benzene, m.p. 70–85°. [This represents a crude maximum of 60% retention.] The infrared absorption curve in carbon disulfide was visually identical with the analytical sample of 2-methyl-6-nitro-2′-phenylbiphenyl.

***dl*-2-Methyl-6-nitro-2′-methoxybiphenyl and 2-Methyl-6-nitrobiphenyl.**—A solution of 2.12 g. of *dl*-2-methyl-6-nitro-2′-phenyldiazonium fluoborate was refluxed in 400 ml. of anhydrous methanol for an hour, the methanol removed by distillation, the residue extracted with benzene and chromatographed on Grade II alumina[23] giving 0.606 g. of yellow solid, m.p. 60–70°. This was rechromatographed on Grade I alumina, and the fractions were recrystallized to give bright yellow needles of 2-methyl-6-nitro-2′-methoxybiphenyl, m.p. 91.5–92° (estimated minimum yield 8%).

Anal. Calcd. for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.18; H, 5.56; N, 6.03.

The less strongly adsorbed fractions on recrystallization gave 46 mg. of colorless needles of 2-methyl-6-nitrobiphenyl, m.p. 104.5–105°, minimum yield 16%.

This decomposition was repeated with 2.58 g. of fluoborate prepared from amine with $[\alpha]^{25}_{\mathrm{D}}$ −207° in 1% solution in methanol. The first chromatographed fraction 0.42 g. was dissolved in 2.20 ml. of methanol and had zero rotation, a second 0.5 g. fraction likewise had zero rotation. After rechromatographing these two fractions, 0.23 g. of crystalline *dl*-2-methyl-6-nitro-2′-methoxybiphenyl, m.p. 93–94°, was obtained; estimated minimum yield 12%.

***d*-2-Methyl-6-nitro-2′-iodobiphenyl.**—A 1-g. sample of amine with $[\alpha]^{25}_{\mathrm{D}}$ +150° (67% of maximum), m.p. 62–77°, was diazotized in 15 ml. of hydrochloric acid solution and mixed with a 20% excess of potassium iodide solution; the mixture was then warmed for several minutes on a steam-bath. The mixture was extracted with benzene and the benzene passed through F-20 alumina of 35 ml. V-volume using 70 ml. of benzene as eluent. Evaporation of solvent gave 0.951 g. of light orange solid, m.p. 75–92°. Repetition of the chromatography gave 0.687 g. of light yellow solid (45% yield), m.p. 80–95°, $[\alpha]^{25}_{\mathrm{D}}$ +23° in 4% solution in methanol. Recrystallization from ethanol gave a 75% recovery of light yellow crystals, m.p. 90–105°, $[\alpha]^{25}_{\mathrm{D}}$ +20° in 2.5% solution in methanol.

Repetition on 2.28 g. of amine with $[\alpha]^{25}_{\mathrm{D}}$ +224° (100% of maximum) gave 1.43 g. (42%) of once chromatographed *d*-2-methyl-6-nitro-2′-iodobiphenyl, m.p. 81–82°, $[\alpha]^{20}_{\mathrm{D}}$ 39°. An analytical sample obtained by recrystallization from ethanol had m.p. 90–90.5° $[\alpha]^{20}_{\mathrm{D}}$ +43°, +44°.

Anal. Calcd. for $C_{13}H_{10}NO_2I$: C, 46.02; H, 2.96; N, 4.14. Found: C, 46.15; H, 2.97; N, 4.04.

The once chromatographed samples of *d*-2-methyl-6-nitro-2′-iodobiphenyl contained a small amount (about 2%) of an impurity which is probably the deamination product, 2-methyl-6-nitrobiphenyl; this compound was estimated by means of the infrared peak at 14.40 μ.

***d*-2-Methyl-6-nitro-2′-bromobiphenyl.**—A 2.28-g. sample of *d*-2-methyl-6-nitro-2′-aminobiphenyl, $[\alpha]^{25}_{\mathrm{D}}$ +224°, was diazotized and heated with hydrobromic acid by the procedure described above for the iodo compound. Chromatography yielded 1.00 g. of a yellow glass which on crystallization from methanol gave 0.1 g. of light yellow crystals, m.p. 57–58°, $[\alpha]^{25}_{\mathrm{D}}$ +53° in 2% solution in methanol. On the basis of the infrared curve the chloro compound is absent (sensitive to about 2% of chloro compound).

Anal. Calcd. for $C_{13}H_{10}NO_2Br$: C, 53.42; H, 3.42; N, 4.82. Found: C, 53.60; H, 3.39; N, 4.70.

Another sample of amine, 1.27 g., m.p. 62–77°, $[\alpha]^{25}_{\mathrm{D}}$ +150°, was diazotized in hydrobromic acid and treated with a solution of cuprous bromide in hydrobromic acid. Extraction with benzene and chromatography gave 0.758 g. of yellow crystals, m.p. 35–52°, $[\alpha]^{25}_{\mathrm{D}}$ +29°. The infrared spectra of a carbon disulfide solution showed an extraneous peak at 14.40 μ which was attributed to 8% of 2-methyl-6-nitrobiphenyl; the corrected yield of bromo compound was 40%, and the corrected retention of optical activity was 90%. Recrystallization from ethanol gave a 50% recovery of almost colorless crystals, m.p. 60–70°, $[\alpha]^{25}_{\mathrm{D}}$ +22°.

***d*- and *l*-2-Methyl-6-nitro-2′-chlorobiphenyl.**—A 2.28-g. sample of *l*-2-methyl-6-nitro-2-aminobiphenyl, $[\alpha]^{25}_{\mathrm{D}}$ −180°, was diazotized and treated with a solution of cuprous chlo-

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(21) A. LeRosen, *ibid.*, **64**, 1905 (1942).

(22) D. F. DeTar and M. N. Turetzky, THIS JOURNAL, **77**, 1745 (1955).

(23) H. Brockmann and H. Schodder, *Ber.*, **74**, 73 (1941); *cf.* ref. 9.

ride in hydrochloric acid. In the first chromatographic purification there was obtained 1.58 g. (63%) of solid, m.p. 37–39°, $[\alpha]^{25}\mathrm{D}$ −63° in 1.6% solution in methanol. Recrystallization from ethanol gave an analytical sample, m.p. 53.5–54.5°, $[\alpha]^{25}\mathrm{D}$ −67° (*c* 0.6), −71° (*c* 1), −73° (*c* 3).

Anal. Calcd. for $C_{13}H_{10}NO_2Cl$: C, 62.90; H, 4.03; N, 5.65. Found: C, 62.98; H, 4.12; N, 5.70.

A 1.00-g. sample of *d*-amine, m.p. 62–77°, $[\alpha]^{25}\mathrm{D}$ +164°, gave 0.450 g. (41%) of chloro compound, m.p. 32–43°, $[\alpha]^{30}\mathrm{D}$ +61°. Assuming that the reaction goes with 90% retention of optical activity, the −63° corresponds to a rotation of −87° for the pure chloro compound and +61° corresponds to +93° for the pure chloro compound.

Racemization of *l*-2-Methyl-6-nitro-2′-chlorobiphenyl.—A sample of the chloro compound was kept at 100° for 23 hours (no solvent); the initial rotation was −67° and that after the heating period was −43°. Another sample was refluxed for 24 hours in carbon tetrachloride solution and showed no change in rotation.

Peroxide of *d*-2-Methyl-6-nitro-2′-biphenylcarboxylic Acid.—A 9-g. sample of *d*-2-methyl-6-nitro-2′-biphenylcarboxylic acid, $[\alpha]^{25}\mathrm{D}$ +62°, was converted to the acid chloride (8.12 g.) as described above. A solution of the acid chloride in 100 ml. of benzene was added slowly to a solution of 2.29 g. of sodium peroxide in 70 ml. of 50% aqueous ethanol with vigorous stirring at a temperature of 0–5°. The reaction mixture was extracted with methylene chloride, the solution dried, and the solvent removed at room temperature. The 6.78 g. of yellow crystalline peroxide was dissolved in chloroform and colorless crystals of the diacyl peroxide precipitated with methanol; yield 6.02 g., m.p. 137° dec., $[\alpha]^{25}\mathrm{D}$ +48° in 1.5% solution in chloroform.

Anal. Calcd. for $C_{28}H_{20}N_2O_8$: C, 65.62; H, 3.93; N, 5.47. Found: C, 65.50; H, 3.90; N, 5.97; peroxide 99%.

The peroxide value was determined by the method of Siggia[24] using isopropyl alcohol as the solvent.

A 10-g. sample of acid, $[\alpha]^{23}\mathrm{D}$ −50°, was converted to *l*-peroxide, $[\alpha]^{25}\mathrm{D}$ −49° in 1.5% solution in chloroform, in 62% yield.

Thermal Decomposition of the Peroxide in Benzene.—A 1.97-g. sample of peroxide, $[\alpha]^{25}\mathrm{D}$ −49°, 99% pure by iodometric titration, was refluxed for 23 hours in 200 ml. of reagent grade benzene. The solvent was removed by distillation, and a test for peroxide was negative. The residue was extracted with aqueous ammonia, and the neutral portion chromatographed to give 0.100 g. of solid, m.p. 80–90°, $[\alpha]^{25}\mathrm{D}$ −20° in 3% solution in benzene. The infrared spectra curve of a carbon disulfide solution matched the curve of the analytical sample of *dl*-2-methyl-6-nitro-2′-phenylbiphenyl with no extraneous peaks. The yield was 5% and the optical retention 50% as a crude maximum value.

A 1.66-g. sample of peroxide, $[\alpha]^{25}\mathrm{D}$ +48° and of 99% iodometric purity was similarly decomposed; the carbon dioxide was swept into an Ascarite adsorption bulb with purified nitrogen; 13% yield based on two moles of carbon dioxide per mole of peroxide. The yield of neutral chromatographed 2-methyl-6-nitro-2′-phenylbiphenyl was 0.089 g. (5%), m.p. 65–80°, $[\alpha]\mathrm{D}$ +10° (minimum).

Thermal Decomposition of the Peroxide in Carbon Tetrachloride.—A 1.64-g. sample of peroxide, $[\alpha]^{25}\mathrm{D}$ +48°, iodometric purity 99%, was refluxed for 24 hours with 250 ml. of dry carbon tetrachloride (peroxide test negative). After removal of the solvent and extraction of the residue with aqueous ammonia, the neutral material was dissolved in benzene and chromatographed to give 0.116 g. of an oil which solidified, m.p. 44–60°, $[\alpha]^{24}\mathrm{D}$ +39°, infrared curve identical with that of an analytical sample of *l*-2-methyl-6-nitro-2′-chlorobiphenyl, analytical sample prepared without crystallization.

Anal. Calcd. for $C_{13}H_{10}NO_2Cl$: C, 62.90; H, 4.03. Found: C, 62.98; H, 4.08.

The yield was 7%, and the retention of optical activity a maximum of 55%.

Another peroxide sample, 1.124 g., with $[\alpha]^{25}\mathrm{D}$ +48°, of 99% iodometric purity, was treated similarly, giving 0.126 g. of semi-solid chromatographed material containing an extraneous peak at 11.20 μ, $[\alpha]^{24}\mathrm{D}$ +37°; rechromatographed material was free of this impurity, $[\alpha]^{23}\mathrm{D}$ +38°; 4% yield, 50% maximum retention of optical activity.

Thermal Decomposition of the Peroxide in Bromotrichloromethane.—A 1.476-g. sample of peroxide, $[\alpha]^{24}\mathrm{D}$ −49°, iodometric purity 99%, was refluxed for eight hours with 250 ml. of bromotrichloromethane; 57% of carbon dioxide was evolved, based on two moles per mole of peroxide. The solution gave no test for peroxide. The solvent was removed by distillation, the remaining gum taken up in ether and extracted with aqueous ammonia. The neutral residue (0.794 g.) was chromatographed on F-20 alumina with a 30 ml. V-volume, and the first 70 ml. of eluent contained 0.486 g. of a semi-solid material, $[\alpha]^{25}\mathrm{D}$ −37°, the infrared curve of which matched that of 2-methyl-6-nitro-2′-bromobiphenyl except for extraneous peaks at 11.20, 12.75 and 13.05 μ. When the material was rechromatographed an initial fraction, 16% by weight, consisted of an oil with a sharp odor and with peaks corresponding to the extraneous ones. Other fractions amounting to 0.295 g. consisted of a solid, m.p. 50–54°, $[\alpha]^{24}\mathrm{D}$ −47° (89% of maximum), and an infrared curve identical with that of an analytical sample of 2-methyl-6-nitro-2′-bromobiphenyl. (No chloro compound was detectable in either the crude or in the recrystallized materials; the limits of detection are probably about 2%.) The 0.295 g. corresponds to an 18% yield and to a maximum of 90% retention of optical activity.

A second sample of 1.53 g. of peroxide, $[\alpha]^{25}\mathrm{D}$ +48°, iodometric purity 99%, was treated in similar fashion giving a 49% yield of carbon dioxide, and 0.577 g. of chromatographed semi-solid neutral material $[\alpha]\mathrm{D}$ +38°, having an infrared curve similar to that of the corresponding fraction of the previous run. A recrystallized sample had m.p. 56.5–58° and $[\alpha]^{25}\mathrm{D}$ +45°. These results are similar to those obtained above except that the yield of once chromatographed material is 15% higher. The estimated yield of 2-methyl-6-nitro-2′-bromobiphenyl is 20%, and the maximum retention of optical activity is about 90%.

***l*-2-Methyl-6-nitro-2′-biphenylcarboxamide.**—A 2-g. sample of the acid, $[\alpha]^{25}\mathrm{D}$ −69°, was converted to the acid chloride and to the amide: m.p. 140–141, $[\alpha]^{25}\mathrm{D}$ −76° in 1.5% solution in methanol.

Anal. Calcd. for $C_{14}H_{12}N_2O_3$: C, 65.62; H, 4.72; N, 10.94. Found: C, 65.46; H, 4.62; N, 11.06.

***dl*-2-Methyl-6-nitro-2′-cyanobiphenyl.**—The amide prepared as above was refluxed for an hour with thionyl chloride, and the resulting nitrile crystallized by adding pentane to the solution; m.p. 103–104°.

Anal. Calcd. for $C_{14}H_{10}N_2O_2$: C, 70.58; H, 4.23; N, 11.76. Found: C, 70.59; H, 4.17; N, 11.83.

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(24) S. Siggia, "Quantitative Organic Analysis Via Functional Groups," John Wiley and Sons, Inc., New York, N. Y., 1949, p. 100.