readily reduced Fehling solution and gave D-xylose phenylosazone when allowed to react with phenylhydrazine in acetic acid at room temperature.

1-Imino-D-xyloascorbic Acid.—The sirupy osone from 12 g. of D-xylose was dissolved in water (250 ml.) and the solution neutralized by adding ammonium hydroxide. A solution of potassium cyanide (5 g.) in water was added whereupon the rotation changed from αD (2 dm.) −0.23° to −21.0° in ten minutes. Titration of a sample (1 ml.) of the reaction mixture with 0.01 *N* iodine after acidification with dilute hydrochloric acid showed that a total yield of 6.1 g. of imino-D-xyloascorbic acid had been produced. The solution containing the imino-ascorbic acid was made acid to congo red by adding dilute hydrochloric acid and then evaporated *in vacuo* until inorganic salts commenced to crystallize. (Here and elsewhere, unless stated otherwise, the concentration of solutions was carried out *in vacuo* in an atmosphere of carbon dioxide at 30–40° (bath temp.) to minimize the oxidation of the enediol system.) The residue was extracted with methanol (50 ml.), filtered, the salts being well washed with methanol, and the solution concentrated to about 30 ml. This solution of imino-D-xyloascorbic acid was adjusted to 100 ml. by adding water and kept in the cold room (3°) (solution A).

Conversion of 1-Imino D-Xyloascorbic Acid to D-Xyloascorbic Acid. (A) Hydrolysis with Formic Acid.—A 10-ml. aliquot of solution A containing 0.6 g. of imino D-xyloascorbic acid was treated with 88% formic acid (10 ml.) and the mixture heated on the boiling water-bath. The following changes in rotation were noted: αD (2 dm.) −4.05° (initial value); −2.88° (after 30 minutes); −2.15 (60 minutes); −1.75 (95 minutes); −1.58 (133 minutes); −1.43 (163 minutes); −1.33 (253 minutes); −1.30 (313 minutes); −1.25 (360 minutes) constant value. Titration of an aliquot with 0.01 *N* iodine showed that 0.17 g. of D-ascorbic acid was present in the solution after hydrolysis was complete.

(B) Hydrolysis with Hydrochloric Acid at 95°.—A 10-ml. aliquot of solution A was treated with water (25.5 ml.) to which had been added hydrochloric acid (1 ml., *d* 1.2) and the mixture heated on the boiling water-bath. The progress of the hydrolysis was followed polarimetrically, αD (2 dm.) −2.88° (initial value), −1.70° (60 minutes), −1.60° (120 minutes), −1.54° (180 minutes), constant value. At the end of the hydrolysis the solution contained 0.47 g. of D-ascorbic acid as shown by iodine titration.

(C) Hydrolysis with Hydrochloric Acid at 48°.—A 10-ml. aliquot of solution A was treated with water (40 ml.) to which had been added hydrochloric acid (2 ml. *d* 1.2). The mixture was warmed on a water-bath at 48° and the progress of the hydrolysis followed polarimetrically thus: αD (2 dm.) −1.06° (initial value); −0.70 (48 hours); −0.56 (55 hours) constant value. Titration of a portion of the final hydrolysis solution with 0.01 *N* iodine showed the presence of 0.43 g. of D-ascorbic acid.

Isolation of D-Xyloascorbic Acid.—A solution of imino-D-xyloascorbic acid, corresponding to solution A above and containing 3.8 g. of imino compound as shown by iodine titration, was adjusted to a *p*H of 1 by adding 6 *N* hydrochloric acid. The solution was heated on the boiling water-bath for 3 hours when the rotation was constant. The solution which then contained 2.2 g. of D-ascorbic acid (tested by iodine titration) was treated with lead acetate solution until no more precipitate of lead chloride was formed. Filtration, aided by the addition of charcoal, before and after treatment with hydrogen sulfide, followed by evaporation *in vacuo* gave a pale yellow sirup which was extracted with ethanol at room temperature. After again removing the solvent the residue was dissolved in ethanol (100 ml.) and treated with ether (250 ml.). After adding a little charcoal the flocculent inorganic precipitate was removed and the filtrate evaporated *in vacuo* to a sirup. The latter was dissolved in ethanol (250 ml.) and treated with a warm solution of lead acetate in 95% ethanol until no more lead D-ascorbate was precipitated (tested by centrifuging a portion of the solution and adding more lead acetate). The pale yellow precipitate was centrifuged, washed with ethanol, suspended in water (200 ml.) and treated with hydrogen sulfide to liberate the D-xyloascorbic acid. The solution was treated with a little charcoal, filtered to remove lead sulfide and concentrated *in vacuo* to a sirup. The latter was stirred with methanol (1 ml.), nucleated with a crystal of D- or L-xyloascorbic acid and when crystallization was complete, the crystals were triturated with dry acetone, filtered, washed with acetone and dried *in vacuo* (yield 720 mg.). A further amount (180 mg.) was obtained from the mother liquor (total yield 900 mg.). The crystals were colorless and appeared to be quite pure, m.p. and mixed m.p. 192° (with decomposition). After crystallization from the minimum of water the D-ascorbic acid showed m.p. 192° dec., $[\alpha]^{21}D$ −22° in water (*c* 2.0), 100 mg. reacted with 11.25 ml. 0.1 *N* iodine, corresponding to a purity of 99%.

Anal. Calcd. for $C_6H_8O_6$: C, 40.9; H, 4.6. Found: C, 41.0; H, 4.7.

Acknowledgment.—The authors wish to thank Dr. L. E. Schniepp of the Northern Regional Research Laboratory, Peoria, for a generous gift of D-xylose.

ST. PAUL, MINNESOTA

[CONTRIBUTION FROM THE GEORGE HERBERT JONES LABORATORY OF THE UNIVERSITY OF CHICAGO]

Free Radical Rearrangements. I. The Free β-Methyl-β-α-tolylpropyl (*p*-Methylneophyl) Radical[1]

BY W. H. URRY AND N. NICOLAIDES

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The free *p*-methylneophyl radical is postulated as the reactive intermediate in (1) the cobaltous chloride-catalyzed reaction of ethylmagnesium bromide with *p*-methylneophyl chloride, and (2) the peroxide-induced decarbonylation of β-*p*-tolylisovaleraldehyde. The rearranged and unrearranged products (*p*-tolyl derivatives) were obtained in approximately the same yields as the corresponding ones (phenyl derivatives) from the reactions of the free neophyl radical generated in the same ways (1 and 2). The free 2,2-dimethylbutyl radical prepared as in (1) gave 2,2-dimethylbutane and a dimer. In these free radical rearrangements it is concluded that: (1) no β-alkyl migration occurs, (2) the β-aryl group undergoes a 1,2-shift, and (3) the migratory aptitudes of the phenyl and *p*-tolyl groups are approximately equal.

Introduction

The rearrangement of the free neophyl (β,β-dimethylphenethyl) radical is postulated as the mechanism leading to rearranged products in two reactions: (1) the cobaltous chloride-catalyzed reaction of phenylmagnesium bromide with neophyl chloride to give isobutylbenzene, β,β-dimethylstyrene and 2-methyl-3-phenylpropene-1[2a]; and (2) the decarbonylation of β-phenylisovaleraldehyde with *t*-butyl peroxide (10 mole %) to give isobutylbenzene.[2b] It is characteristic of these free-radical reactions that unrearranged products are also formed: reaction 1, *t*-butylbenzene and bineo-

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[1] The material of this paper (taken from the Ph.D. thesis of N. Nicolaides, University of Chicago, 1950) was presented in summary before the Organic Division of the American Chemical Society at Chicago, September, 1950; and at the Twelfth National Organic Symposium. Denver, Colorado, June, 1951.

[2] (a) W. H. Urry and M. S. Kharasch, THIS JOURNAL, **66**, 1438 (1944); (b) S. Winstein and F. H. Seubold, *ibid.*, **69**, 2916 (1947).

phyl; and reaction 2, *t*-butylbenzene. This investigation provides partial answers to interesting questions regarding the scope, the detailed mechanism and migratory aptitudes of groups in these free radical rearrangements (see Discussion). In the present study of the free *p*-methylneophyl (β-methyl-β-*p*-tolylpropyl) radical, both methods of generation outlined above were employed. The behavior of the free 2,2-dimethylbutyl radical was observed in the cobaltous chloride-catalyzed reaction of 2,2-dimethylbutyl chloride with ethylmagnesium bromide.

The Reactions of *p*-Methylneophyl Chloride (β-Methyl-β-*p*-tolylpropyl Chloride) and 1-Chloro-2,2-dimethylbutane with Ethylmagnesium Bromide in the Presence of Cobaltous Chloride.—The experiment with *p*-methylneophyl chloride performed with conditions identical to those of Urry and Kharasch[2] gave the following products (see Fig. 1): (1) *p*-*t*-butyltoluene (30.6%), (2) *p*-isobutyltoluene (13%), (3) 2-methyl-3-*p*-tolylpropene-1 (7%), (4) *p*-β-β-trimethylstyrene (4%), (5) hydrocarbon $C_{13}H_{20}$ probably 2-methyl-2-*p*-tolylpentane (2.3%), (6) ether $C_{13}H_{20}O$ probably ethyl *p*-methylneophyl ether (2.7%), (7) a mixture of dimers of molecular weight 294 $(C_{11}H_{15})_2$ (35.6%), (8) polymers (6.1%) and (9) a mixture of ethane (54%) and ethylene (46%). The products (1 to 8) account for all the *p*-methylneophyl chloride consumed (75%), and the yield of ethane and ethylene (73%), on the basis of the Grignard reagent consumed, is almost quantitative (97%).

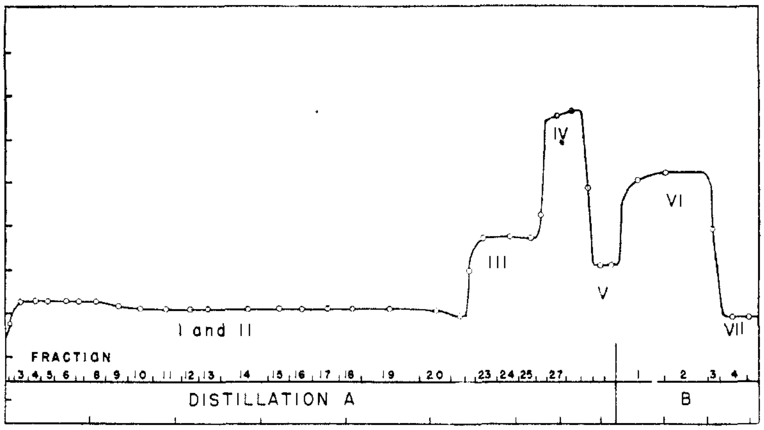


Fig. 1.—Fractional distillation–index of refraction curve: I, *p*-*t*-butyltoluene; II, *p*-isobutyltoluene; III, 2-methyl-3-*p*-tolylpropene-1; IV, *p*-β-β-trimethylstyrene; V, hydrocarbon $C_{13}H_{20}$; VI, recovered *p*-methylneophyl chloride; and VII, ether $C_{13}H_{20}O$.

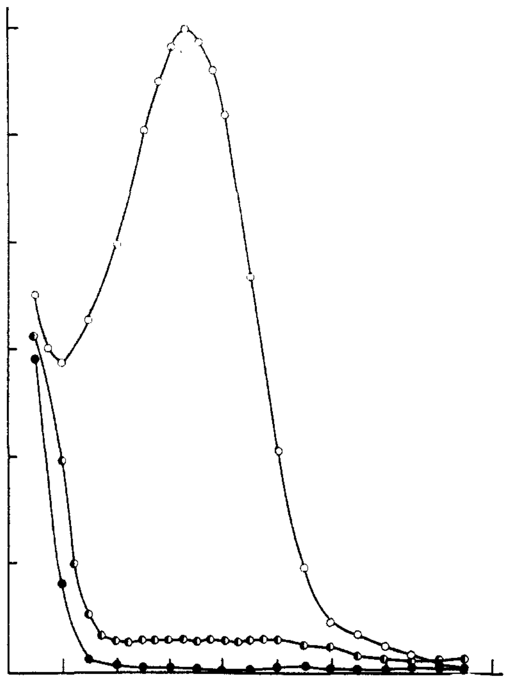


Fig. 2.—Absorption spectra in isoöctane: ○, *p*-β-β-trimethylstyrene; ◐, 2-methyl-3-*p*-tolylpropene-1; ●, *p*-*t*-butyltoluene.

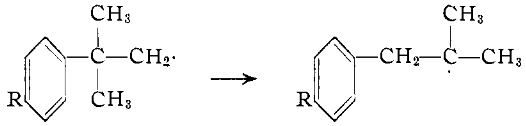
The *p*-*t*-butyltoluene was identified by comparison of its boiling point, refractive index, ultraviolet absorption spectrum (Fig. 2), and the melting point of its known 2,6-dinitro derivative with identical observations upon known *p*-*t*-butyltoluene prepared in two ways—by hydrolysis of *p*-methylneophylmagnesium chloride, and by the reaction of toluene with *t*-butyl chloride in the presence of aluminum chloride. *p*-Isobutyltoluene was identified by comparison of the same physical properties, and the melting point of its sulfonamide derivative with identical observations upon known *p*-isobutyltoluene prepared by the Clemmensen reduction of *p*-methylisobutyrophenone. The two unsaturated compounds (3 and 4) were identified by their boiling points, indices of refraction and ultraviolet absorption spectra (Fig. 2). The results of their ozonolyses confirmed the assigned structures: the 2-methyl-3-*p*-tolylpropene-1 gave formaldehyde and methyl *p*-methylbenzyl ketone, and the *p*-β-β-trimethylstyrene gave acetone and *p*-toluic acid. The same solid dimer (m.p. 76°; molecular weight 294; probably 2,5-dimethyl-2,5-di-*p*-tolylhexane) was obtained from the dimeric mixture (7) and as a by-product in the reaction of *p*-methylneophyl chloride with magnesium.

When 1-chloro-2,2-dimethylbutane was added to a solution of ethylmagnesium bromide and cobaltous chloride in *n*-butyl ether, a vigorous reaction, which consumed 74% of the chloride, ensued. A quantitative yield (based upon the Grignard reagent used) of a mixture of ethane (55%) and ethylene (45%) was obtained. A careful distillation of the reaction mixture gave: (1) 2,2-dimethylbutane (45%), (2) 1-chloro-2,2-dimethylbutane (21% recovery), and (3) dimer (19%, probably 3,3,6,6-tetramethyloctane). No products of rearrangement were found.

The Peroxide-initiated Decarbonylation of β-*p*-Tolylisovaleraldehyde.—A reaction mixture containing this aldehyde (0.346 mole) and *t*-butyl peroxide (0.039 mole) was held at 130°. A gaseous product (64% yield of carbon monoxide) was obtained, and a careful distillation of the reaction mixture gave *p*-*t*-butyltoluene (31%), *p*-isobutyltoluene (28%) and unchanged aldehyde (25%) A similar experiment at 141° gave *p*-*t*-butyltoluene (31%) and *p*-isobutyltoluene (30%). The two hydrocarbons were identified in the manner previously described.

Discussion

Free-radical chain-reaction mechanisms have been proposed for cobaltous chloride-catalyzed Grignard reactions[1] and aldehyde decarbonylation reactions[2] of the type studied here. Three general conclusions regarding the postulated free-radical rearrangements (I → III; II → IV) seem justified by the present work: (1) no migration of alkyl groups occurs, (2) rearrangement of the free neophyl I or *p*-methylneophyl II radicals proceeds *via* a



I, R = H
II, R = CH_3

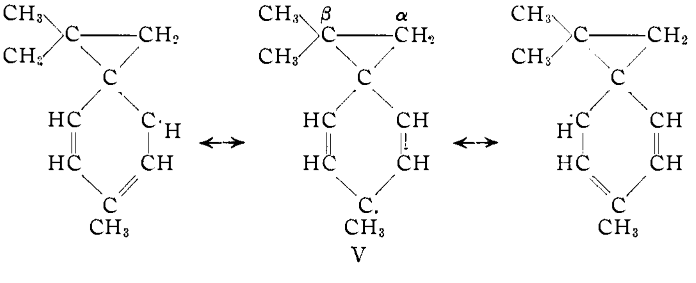
III, R = H
IV, R = CH_3

1,2-shift of the aryl group, and (3) migratory aptitudes of the phenyl and *p*-tolyl groups are approximately equal.

The first conclusion is supported by two experimental results. First, no rearranged products were found in the cobaltous chloride-catalyzed reaction of 1-chloro-2,2-dimethylbutane with ethylmagnesium bromide. The expected products of rearrangement (2-methylpentane, 2-methylpentene-1, 2-methylpentene-2, 3-methylpentane and 3-methylpentene-2) would have distilled in the range between 2,2-dimethylbutane and the unchanged 1-chloro-2,2-dimethylbutane. The small amount of distillate in the boiling range (49–112°) gave no evidence of the presence of these substances (no b.p. plateaus, and all fractions were saturated; bromine test). Second, no *p*-*s*-butyltoluene was obtained in the decarbonylation of β-*p*-tolylisovaleraldehyde, and Winstein and Seubold[2] observed no *s*-butylbenzene in the analogous reaction with β-phenylisovaleraldehyde. Apparently no β-methyl migration occurs in these rearrangements of free neophyl and *p*-methylneophyl radicals. These results suggest that it is unlikely that β-methyl migration occurs in the cobaltous chloride-catalyzed Grignard reactions of the neophyl and *p*-methylneophyl chlorides. The evidence from these two experiments upon this question is inconclusive since the compositions of the dimeric mixtures are unknown (free α-methyl-α-ethylbenzyl radicals would probably give the dimer, 3,4-dimethyl-3,4-diphenylhexane).

The fact that an aryl group attached to the neocarbon atom is a necessary condition for this rearrangement might suggest that it was involved in some fundamental way. For example, the structural change might proceed through an ortho shift on the benzene ring. The observation that all the rearranged products obtained in this work were *p*-methyl derivatives excludes this mechanism, and strongly suggests that a 1,2-shift of the aryl group occurs (I → III; II → IV).

Recent work with ionic rearrangements would suggest the intermediate V in the rearrangement of the free *p*-methylneophyl radical.[3] If V is formed, however, it is probably only an intermediate in the conversion from II to IV. This interpretation is supported by the fact that isobutylbenzene is the only hydrocarbon product of the *t*-butyl peroxide-initiated decarbonylation of α,α-dimethyl-β-phenyl propionaldehyde.[4] The intermediate free α,α-dimethylphenethyl radical III formed in this reaction does not rearrange, and hence probably does not form V. This evidence excludes the possibility of typical neighboring group behavior in these free-radical reactions (the exclusive formation of V and its subsequent reactions at either carbon atom Vα or Vβ). It suggests that the rearrangement is unidirectional, and that the reactions observed are those of II and IV.



V

Within experimental error the relative yields of rearranged and unrearranged products obtained in the present work (approximately 50% rearrangement in the aldehyde decarbonylations, and also in the C_{11} products of the Grignard reaction of *p*-methylneophyl chloride) are the same as those observed in previous studies of the free neophyl radical.[1,2] These results suggest that in these free-radical rearrangements the phenyl and *p*-tolyl groups are of approximately equal migratory aptitude.[5] In supposed ionic rearrangements, the stereospecificity observed by Curtin and Pollak[6,7] in the rearrangements of 1-aryl-1,2-diphenyl-2-aminoethanols and other aminoalcohols casts doubt upon previous determinations of intrinsic migratory aptitudes with substances having two asymmetric centers (symmetrical diaryl diphenyl

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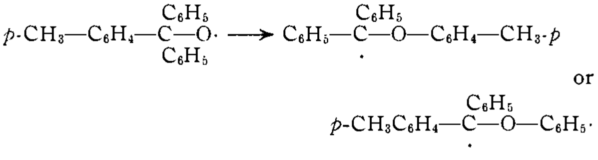
(3) The relative migratory aptitudes of aryl groups and the reaction rates observed in a recent study of the rearrangements of aryl diphenylmethyl peroxides are best interpreted by the postulation of such an intermediate (W. H. Urry and R. M. McNeer, unpublished work). The following type of rearrangement is involved in the latter reaction



$$p\text{-}CH_3\text{—}C_6H_4\text{—}\underset{C_6H_5}{\overset{C_6H_5}{C}}\text{—}O\cdot \longrightarrow C_6H_5\text{—}\underset{\cdot}{\overset{C_6H_5}{C}}\text{—}O\text{—}C_6H_4\text{—}CH_3\text{-}p$$

or

$$p\text{-}CH_3C_6H_4\text{—}\underset{\cdot}{\overset{C_6H_5}{C}}\text{—}O\text{—}C_6H_5\cdot$$

(4) W. H. Urry and N. Nicolaides, unpublished work.

(5) Admittedly this assignment of migratory aptitudes is not as rigorous as would be obtained if a choice of phenyl *versus* *p*-tolyl migration in the same free radical were studied. The above interpretation is supported in such a case. however. by the observation that these two groups are of equal migratory aptitude in the rearrangement of *p*-tolyl diphenylmethyl peroxide (W. H. Urry and R. M. McNeer, unpublished work).

(6) P. I. Pollak and D. Y. Curtin, This Journal, **72**, 961 (1950).

(7) D. Y. Curtin and P. I. Pollak. *ibid.*, **73**, 992 (1951).

pinacols). Other work, however, in which the rearrangement is not so influenced by the geometry of the molecules indicates that in ionic rearrangements the *p*-tolyl group has a greater migratory aptitude than the phenyl group.[8,9]

Experimental Work

Reagents.—Ethylmagnesium bromide solution was prepared in the usual manner, and suspended matter was removed on a sintered glass filter. Aliquot portions were titrated acidimetrically for Grignard reagent concentration, and by the Volhard method for halide concentration. Anhydrous cobaltous chloride was prepared by heating its hexahydrate (Merck and Co., Inc., Reagent Grade) at 120° under high vacuum.

β-Methyl-β-*p*-tolylpropyl (*p*-methylneophyl) chloride (950 g., b.p. 87–88° at 4 mm., $n^{20}\mathrm{D}$ 1.5226, 78% yield) prepared by the reaction of methallyl chloride (607 g., b.p. 70–71°, $n^{20}\mathrm{D}$ 1.4265) with toluene (1862 g.) and concentrated sulfuric acid (106 g.) was distilled through a 12-plate Fenske column.[10,11]

Anal. Calcd. for $C_{11}H_{15}Cl$: C, 72.31; H, 8.28; Cl, 19.41. Found: C, 72.40; H, 8.30; Cl, 19.45.

Its purity was confirmed by two experiments. A reaction mixture containing the chloride (0.1105 molar) and potassium hydroxide (1.84 molar) in aqueous ethanol gave less than 1% hydrolysis (Volhard titration) after 2.5 days at 29° followed by 2.5 days at 60°. The *p*-methylneophyl chloride (90 g., 0.493 mole) was converted to its Grignard reagent which was hydrolyzed with aqueous acetic acid (20%). *p*-*t*-Butyltoluene[12] (68.9 g., b.p. 90–91° at 27–29 mm.; n^{20}_{D} 1.4917, 94% yield) of constant refractive index in distillation through a 100-plate Podbielniak Heligrid column was obtained. Nitration of this hydrocarbon gave a nearly quantitative yield of 2,6-dinitro-4-*t*-butyltoluene[13] (m.p. 96°). The distillation residue (3.5 g.) solidified, and gave white platelets after recrystallization from methanol (m.p. 77°). This substance is presumed to be 2,5-dimethyl-2,5-di-*p*-tolylhexane.

Anal. Calcd. for $C_{22}H_{30}$: C, 89.73; H, 10.27. Found: C, 89.51; H, 10.50.

Reaction of *p*-Methylneophyl Chloride with Ethylmagnesium Bromide in the Presence of Cobaltous Chloride.—Ethylmagnesium bromide (1930 ml. of 1.42 *N* solution in ether, 2.74 moles) was placed in a 3-liter, 3-necked flask equipped through ground glass joints with a dropping funnel, a Tru-Bore stirrer and a Friedrich condenser. Cobaltous chloride (5 g.) was added, and then *p*-methylneophyl chloride (421 g., 2.30 moles) was dropped in over a period of five hours. Additional cobaltous chloride (about 2 g.) was added every hour (total used, 18.75 g.), and the reaction mixture was held under reflux for three hours after the addition was complete.

Gaseous products passed through the condenser into a gas train consisting of three traps cooled to −80° and a pneumatic trough. Gas (37.7 liters S.T.P., mol. wt. 29.1) collected in the latter was shown to be a mixture of ethane (54%) and ethylene (46%) by analysis according to Kharasch, Lewis and Reynolds.[14]

The reaction mixture was treated with dilute acetic acid solution (20%). The ether solution was washed with sodium carbonate solution (10%) and with water, and was dried over anhydrous calcium chloride. Aqueous washings were diluted to a known volume, and a Volhard halide determination of this solution showed that the reaction had been 75% complete.

Ether was removed by distillation through a 12-plate Fenske column, and the reaction product was distilled rapidly (b.p. 70–100° at 2 mm.) to give two distillate fractions and a residue. The first fraction was carefully distilled through the 100-plate column. The results are given in Fig. 1 (distillation A; a graph of refractive index *versus* distillate weight is used because the pressure was reduced as the distillation progressed). The second fraction was carefully redistilled through the Fenske column (Fig. 1, distillation B). This distillation procedure was used because *p*-methylneophyl chloride decomposes slowly upon distillation through the Heligrid column.

Analysis of the distillation curve (Fig. 1) indicates the following products: fractions A2 to A21, *p*-*t*-butyltoluene (76.6 g., b.p. 84–85° at 22 mm., $n^{20}\mathrm{D}$ 1.4919); fractions A10 to A22, *p*-isobutyltoluene (31.9 g., b.p. 85.5–87° at 22 mm., $n^{20}\mathrm{D}$ 1.4871); fractions A22 to A26, 2-methyl-3-*p*-tolylpropene-1 (17.4 g., b.p. 90.1–90.4° at 22 mm., $n^{20}\mathrm{D}$ 1.5069); fractions A27 and A28, *p*-methyl-β,β-dimethylstyrene (9.7 g., b.p. 100–101° at 22 mm., $n^{20}\mathrm{D}$ 1.5359); fractions A29 to A31, hydrocarbon $C_{13}H_{20}$ (6.1 g., b.p. 90° at 7 mm., $n^{20}\mathrm{D}$ 1.4980); fraction B1 to B2, recovered *p*-methylneophyl chloride (98.6 g., b.p. 87–88° at 4 mm., $n^{20}\mathrm{D}$ 1.5220); fraction B4 and B5, substance $C_{13}H_{20}O$ (8.8 g., b.p. 61–62° at 1 mm., $n^{20}\mathrm{D}$ 1.4880). *p*-*t*-Butyltoluene and *p*-isobutyltoluene were not completely separated in the fractional distillation. The quantity of each was calculated from the refractive index of each fraction. The refractive indices of the pure hydrocarbons were determined from samples obtained by independent synthesis (see Preparation of Reference Substances).

The high-boiling residues from the preliminary distillation and B were distilled at high vacuum, and a mixture of dimers (90.2 g., b.p. 126–160° at 1 mm., mol. wt. calcd. for $C_{22}H_{30}$, 294, found 294) was obtained. When this mixture was cooled to 10° it partially solidified. Crystalline material (m.p. 76.5–77.5° after recrystallization from 95% ethanol) isolated on a clay plate was shown to be identical with the supposed 2,5-dimethyl-2,5-di-*p*-tolylhexane obtained as a product of the reaction of *p*-methylneophyl chloride with magnesium (m.p. of mixture 76.5–77.5°). A residue (20 g.) remained.

Identification of Reaction Products.—Fraction A7 (Fig. 1) was shown to be *p*-*t*-butyltoluene by its conversion to 2,6-dinitro-4-*t*-butyltoluene, m.p. 96°, 90% yield, m.p. of its mixture with an authentic sample 96–97°.[13] The same derivative was formed in low yield from fraction A18. This substance was also converted to the diacetamide (m.p. 300°) by the method of Ipatieff and Schmerling.[15]

Anal. Calcd. for $C_{15}H_{22}O_2N_2$: C, 68.66; H, 8.45; N, 10.68. Found: C, 68.53; H, 8.33; N, 10.71.

Some of a high *p*-isobutyltoluene fraction (A21) was converted to the sulfonamide derivative (m.p. 91–92°, "mixed m.p." with authentic sample 91–92°) according to Procedure I of Huntress and Autenrieth.[16,17] To be certain that this derivative was satisfactory for the identification, the sulfonamide of *p*-*t*-butyltoluene (m.p. 140°) was prepared.

Anal. Calcd. for $C_{11}H_{17}O_2NS$: N, 6.16. Found: N, 6.17.

The structures of 2-methyl-3-*p*-tolylpropene-1 and 1-*p*-tolyl-2-methylpropene were proved by ozonolysis. A portion of fraction A25 in ethyl acetate solution at −80° was treated with ozone in an apparatus similar to that described by Church, Whitmore and McGrew.[18] The ozone consumption indicated 94% unsaturation. The effluent oxygen was bubbled through a trap containing aqueous alcohol. The methone derivative of formaldehyde (m.p. 191–192°, "mixed m.p." with authentic sample 191–192°)[19] was prepared from this solution. The ethyl acetate was removed from the reaction mixture under vacuum, and the residue was warmed with water. The 2,4-dinitrophenylhydrazone of *p*-tolylacetone (m.p. 134–135° after recrystallization from 95% ethanol; m.p. of mixture with an authentic sample, 134–135°) was prepared from the oil.

Anal. Calcd. for $C_{16}H_{16}N_4O_4$: N, 17.06. Found: N, 17.33.

Fraction A28 was ozonized in the same way. The ozone

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used indicated 88% unsaturation. Water used in the hydrolysis of the ozonide was separated, and the oil was extracted with sodium carbonate solution. Aqueous extracts were combined and distilled. The 2,4-dinitrophenyl hydrazone of acetone (m.p. 126–127°, m.p. of mixture with authentic sample 127°) was obtained in good yield from the distillate. *p*-Toluic acid (m.p. 179° after recrystallization from 95% ethanol; m.p. of mixture with authentic sample, 179°) precipitated when the distillation residue was acidified.

Ultraviolet absorption spectra (Fig. 2) of the two olefins obtained with a Beckman photoelectric quartz spectrophotometer gave corroborative structural evidence. The spectrum of *p*-β,β-trimethylstyrene resembles that of β,β-dimethylstyrene with an absorption maximum at 2475 Å.[2] Fraction A24 gives an absorption spectrum resembling that of *p*-*t*-butyltoluene, as would be expected if it were 2-methyl-3-*p*-tolylpropene-1.

Fractions A30 and A31 were washed with concentrated sulfuric acid. Distillation of the recovered oil at reduced pressure gave an unidentified hydrocarbon $C_{13}H_{20}$ (6.1 g., b.p. 76–7° at 3 mm., $n^{20}\mathrm{D}$ 1.4980).

Anal. Calcd. for $C_{13}H_{20}$: C, 88.56; H, 11.44; mol. wt., 176.3. Found: C, 88.92; H, 11.30; mol. wt., 177 (freezing point depression in benzene).

Another substance of unidentified structure was obtained (fractions B4 and B5). It gave a negative test for halogen and was soluble in concentrated sulfuric acid. It is possibly an ether $C_{13}H_{20}O$ (8.8 g., b.p. 61–62° at 1 mm., $n^{20}\mathrm{D}$ 1.4880, molecular weight by the ebullioscopic method in carbon tetrachloride 192).

Anal. Calcd. for $C_{13}H_{20}O$: C, 81.20; H, 10.48. Found: C, 81.84; H, 10.55.

Preparation of 1-Chloro-2,2-dimethylbutane.—A reaction mixture containing 2,2-dimethylbutane (1890.5 g., Phillips Petroleum Company, b.p. 49°), sulfuryl chloride (307.2 g., redistilled, b.p. 69°) and benzoyl peroxide (3 g.) was held under reflux for 4 hours. The reaction mixture was rapidly distilled to separate unreacted 2,2-dimethylbutane, monochloro derivatives and higher boiling products. The chlorohexane fraction was then carefully distilled through the 100-plate column. The products 2-chloro-3,3-dimethylbutane (109 g., b.p. 51° at 110 mm., $n^{20}\mathrm{D}$ 1.4185), 1-chloro-2,2-dimethylbutane (155.3 g., b.p. 56.5° at 110 mm., $n^{20}\mathrm{D}$ 1.4207) and 1-chloro-3,3-dimethylbutane (42 g., b.p. 57° at 110 mm., $n^{20}\mathrm{D}$ 1.4171) were obtained.

The combined fractions containing 1-chloro-2,2-dimethylbutane were heated under reflux with ethanolic potassium hydroxide solution (300 ml., 20 g. of potassium hydroxide) for two days. The recovered halide was distilled through the 100-plate column to give pure 1-chloro-2,2-dimethylbutane (144.5 g., b.p. 59° at 115 mm., $n^{20}\mathrm{D}$ 1.4207, d^{25} 0.8782).

Reaction of 1-Chloro-2,2-dimethylbutane with Ethylmagnesium Bromide in the Presence of Cobaltous Chloride.—1-Chloro-2,2-dimethylbutane (144.5 g., 1.19 moles) was dropped over a period of four hours into a *n*-butyl ether solution of ethylmagnesium bromide (1.41 moles, 820 ml. of 1.72 *N* solution) with multiple addition of cobaltous chloride (11 g.) as before. The gaseous reaction product (24.6 liters at S.T.P., mol. wt. 29.1) was ethane (55%) and ethylene (45%).

The reaction mixture was treated with aqueous acetic acid. The butyl ether solution was separated and extracted with sodium carbonate solution and with water, and was dried over anhydrous calcium chloride. Volhard analyses indicated that 74% of the organic halide had been brought into reaction. The butyl ether solution was distilled rapidly through a 12-plate Fenske column until the distillation temperature reached 140°. Redistillation (100-plate column) of distillate gave 2,2-dimethylbutane (45.2 g., b.p. 49.3°, $n^{20}\mathrm{D}$ 1.3690, 45% yield) and recovered 1-chloro-2,2-dimethylbutane (29.8 g., b.p. 112–113°, $n^{20}\mathrm{D}$ 1.4203). Intermediate fractions (total wt. 6.7 g., b.p. 49–112°) were probably mixtures of these two substances. Boiling points and the refractive indices of successive fractions showed a steady increase. These fractions did not decolorize bromine in carbon tetrachloride solution.

After *n*-butyl ether (b.p. 48° at 30 mm.) was distilled from the higher boiling reaction product, a constant boiling fraction (19.1 g., b.p. 54–55° at 2 mm., $n^{20}\mathrm{D}$ 1.4219) was obtained. This substance is presumed to be 3,3,6,6-tetramethyloctane.

Preparation of β-*p*-Tolylisovaleraldehyde.—This aldehyde was prepared by the hydrolysis (with sulfuric acid, 20%, 2400 g.; reflux, 24 hr.) of the acetal formed in the reaction of ethyl orthoformate (344 g., b.p. 87° at 112 mm., $n^{20}\mathrm{D}$ 1.3905) with *p*-methylneophylmagnesium chloride (prepared by the reaction of *p*-methylneophyl chloride, 530 g., with magnesium, 71.5 g., in ether, 2.5 l.). Purification in the usual manner through its bisulfite addition product and distillation through a 50-plate column gave β-*p*-tolylisovaleraldehyde (165 g., b.p. 71–73° at 1 mm.; $n^{20}\mathrm{D}$ 1.5116, 41% yield).

Anal. Calcd. for $C_{11}H_{16}O$: C, 81.79; H, 9.15. Found: C, 81.75; H, 9.18.

This aldehyde oxidized in air to give β-*p*-tolylisovaleric acid (m.p. 77–78°). This acid was also prepared by the reaction of *p*-methylneophylmagnesium chloride with carbon dioxide.

Anal. Calcd. for $C_{12}H_{16}O_2$: C, 74.97; H, 8.38. Found: C, 75.00; H, 8.45.

The 2,4-dinitrophenylhydrazone of this aldehyde (m.p. 131–132.5°) was prepared.

Anal. Calcd. for $C_{18}H_{20}O_4N_4$: C, 60.55; H, 5.66; N, 15.73. Found: C, 60.62; H, 5.60; N, 15.64.

The Reaction of β-*p*-Tolylisovaleraldehyde with *t*-Butyl Peroxide.—A mixture of β-*p*-tolylisovaleraldehyde (60.8 g., 0.346 mole) and *t*-butyl peroxide (5.71 g., 0.039 mole, b.p. 37.5° at 46 mm., $n^{20}\mathrm{D}$ 1.3886) was held under reflux at 130° for 7 hours. Gaseous product (5.31 l. at S.T.P.) passed through the reflux condenser, a trap held at −80°, and a calcium chloride tube into a pneumatic trough. Its composition was determined in a Burrell gas analysis apparatus: 92.7% CO, 1.8% O_2, 3.2% CH_4 and 2.2% N_2.

The reaction product was distilled through the 100-plate Podbielniak column. Fractions 1 to 3 were *p*-*t*-butyltoluene (6.83 g., b.p. 85.5 at 22 mm., $n^{20}\mathrm{D}$ 1.4916) and fractions 9 to 12 were *p*-isobutyltoluene (8.11 g., b.p. 76° at 13 mm., $n^{20}\mathrm{D}$ 1,4871). The compositions of the intermediate fractions 4 (3.19 g., $n^{20}\mathrm{D}$ 1.4909), 5 (3.31 g., $n^{20}\mathrm{D}$ 1.4908), 6 (2.60 g., $n^{20}\mathrm{D}$ 1.4904), 7 (2.40 g., $n^{20}\mathrm{D}$ 1.4900), and 8 (3.65 g., $n^{20}\mathrm{D}$ 1.4887) were calculated from their refractive indices with the assumption that they contain only the above hydrocarbons. This assumption was supported by the yields of 2,6-dinitro-4-*t*-butyltoluene obtained by nitration of portions of these fractions. After two other intermediate fractions 13 (0.33 g., $n^{20}\mathrm{D}$ 1.4886, b.p. 69° at 7.5 mm.), and 14 (2.52 g., $n^{20}\mathrm{D}$ 1.5103, b.p. 62° at 1.5 mm.) unreacted β-*p*-tolylisovaleraldehyde was obtained (12.35 g., $n^{20}\mathrm{D}$ 1.5122, b.p. 63° at 1.5 mm.). A residue (8.3 g.) remained in the distilling flask.

Fraction 3 was identified as *p*-*t*-butyltoluene by its conversion to the dinitro derivative (m.p. 95°) and the sulfonamide (m.p. 140–141°) as previously described. Fraction 11 was identified as *p*-isobutyltoluene by preparation of its sulfonamide (m.p. 91–92°). The residue had an average mol. wt. of 344 determined in carbon tetrachloride in the ebullioscope.

Preparation of Reference Substances.—A reaction mixture containing toluene (211.6 g., 2.30 moles, $n^{20}\mathrm{D}$ 1.4961), *t*-butyl chloride (44 g., 0.476 mole, $n^{20}\mathrm{D}$ 1.3850) and ferric chloride (20.4 g.) was held at room temperature for 18 hours. Dilute hydrochloric acid was then added, and the organic layer was separated. It was washed with water, and was dried over anhydrous calcium chloride.

The reaction product was distilled at reduced pressure through the 100-plate column. *m*-*t*-Butyltoluene (38.5 g., b.p. 91–92° at 32 mm., $n^{20}\mathrm{D}$ 1.4940, 54% yield) and *p*-*t*-butyltoluene (7.5 g., b.p. 93.5° at 32 mm., $n^{20}\mathrm{D}$ 1.4916, 10% yield) were obtained. *m*-*t*-Butylbenzoic acid (m.p. 127°, 80% yield) was obtained by the reaction of alkaline permanganate with *m*-*t*-butylbenzene, and nitration of the *p*-*t*-butyltoluene gave 2,6-dinitro-4-*t*-butyltoluene (m.p. 96°).

p-Isobutyltoluene (b.p. 88° at 23 mm., $n^{20}\mathrm{D}$ 1.4873, 78% yield) was prepared by the Clemmensen reduction of *p*-methylisobutyrophenone according to the method of Martin.[20] The required *p*-methyl isobutyrophenone (b.p. 114–115° at 13 mm., $n^{20}\mathrm{D}$ 1.5188, 68% yield) was obtained from

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[20] R. Adams, "Organic Reactions," Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1934, p. 1.

the aluminum chloride-catalyzed reaction of isobutyryl chloride with toluene.[21]

p-Tolylacetone (b.p. 108–112° at 12 mm., 45% yield) was prepared by the reaction of di-*p*-xylylcadmium with acetyl chloride according to the method of Gilman and Nelson.[22]

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[21] C. F. H. Allen, *Org. Syntheses*, **14**, 1 (1934).

[22] H. Gilman and J. F. Nelson, *Rec. trav. chim.*, **55**, 518 (1936).

[CONTRIBUTION FROM THE GRASSELLI CHEMICALS DEPARTMENT, EXPERIMENTAL STATION, E. I. DU PONT DE NEMOURS & CO., INC.]

The Synthesis of DL-*threo*- and DL-*erythro*-1-(5-Nitro-2-thienyl)-2-dichloroacetamido-1,3-propanediols and Related Compounds

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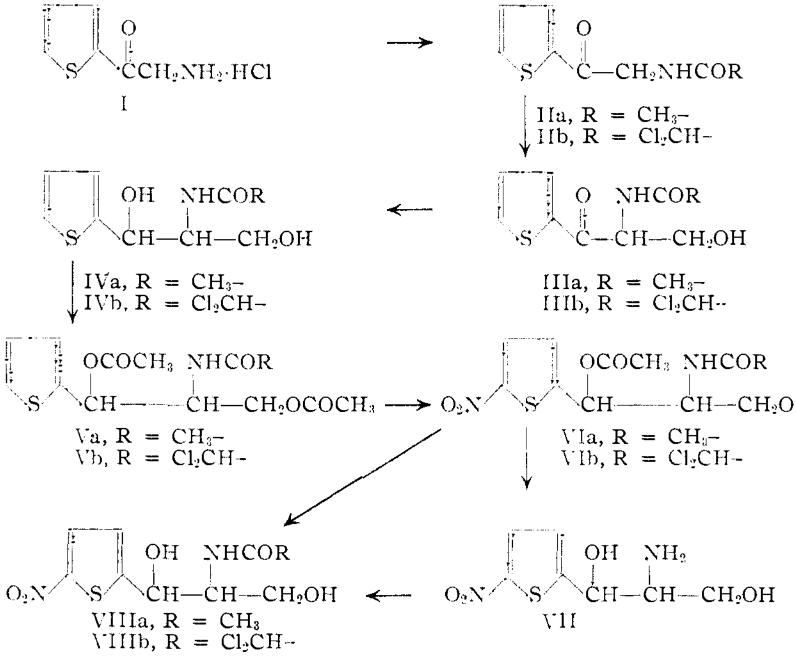
Two syntheses of both diastereoisomeric racemates of 1-(5-nitro-2-thienyl)-2-dichloroacetamido-1,3-propanediol have been described. Both syntheses, which start with 2-acetylthiophene, include reductions of intermediate DL-N-[2-hydroxy-1-(2-thenoyl)-ethyl]-acylamides with sodium borohydride. The mixtures of isomeric racemates formed in this reduction have been separated and have led to a series of pure *threo*- and pure *erythro*-racemates.

This paper describes two syntheses of both diastereoisomeric racemates of 1-(5-nitro-2-thienyl)-2-dichloroacetamido-1,3-propanediol (VIIIb) starting from 2-acetylthiophene.

Carrara and Weitnauer[1] have reported the preparation of DL-*threo*-1-(5-nitro-2-thienyl)-2-dichloroacetamido-1,3-propanediol by a route similar to those described in this paper. Keskin, Mason and Nord[2] have recorded a partial synthesis of this same compound which terminated with the preparation of DL-*threo*-1-(2-thienyl)-2-acetamido-1,3-propanediol (IVa).



Some of these steps have been described for the benzene series in connection with the synthesis of Chloramphenicol.[3,4]

In the present work DL-N-[2-hydroxy-1-(2-thenoyl)-ethyl]-acetamide (IIIa) was reduced with sodium borohydride, rather than with aluminum isopropoxide as reported by the previous workers. This reduction has led to both the *threo*- and *erythro*-racemates and the previously unreported *erythro* series is described here. In addition, a second synthesis involving dichloroacetylation rather than acetylation of the intermediate N-2-thenoylmethylamine hydrochloride (I) has led to an entirely new series of compounds.

The first synthesis of the two diastereoisomeric racemates of (VIIIb) involved initially the bromination of 2-acetylthiophene and conversion of the resulting 2-bromoacetylthiophene to N-2-thenoylmethylamine hydrochloride (I) by means of a Delépine reaction through the intermediate N-2-thenoylmethylhexamethylenetetraminium bromide. The aminoketone hydrochloride (I) was next acetylated and the resulting N-2-thenoylmethylacetamide (IIa) was hydroxymethylated with aqueous formaldehyde in the presence of sodium bicarbonate to give IIIa. This synthesis to this point has been described by the previous workers[1,2] and consequently has not been described in detail in the experimental part of this paper.

Next, IIIa was reduced in 94% yield with sodium borohydride in methanol solution. This reduction was rapid and very convenient to carry out and appears to be the first case in which sodium borohydride has been used to reduce compounds of this type. The reduction product was a mixture of the *threo*- and *erythro*-racemates of IVa. The exact ratio of *threo* to *erythro* forms produced in this reaction was not determined, but it appeared to be

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(1) G. Carrara and G. Weitnauer, *Gazz. chim. ital.*, **81**, 142 (1951).

(2) H. Keskin, C. D. Mason and F. F. Nord, *J. Org. Chem.*, **16**, 1333 (1951).

(3) J. Controulis, M. C. Rebstock and H. M. Crooks, Jr., THIS JOURNAL, **71**, 2463 (1949).

(4) L. M. Long and H. D. Troutman, *ibid.*, **71**, 2469 (1949); **71**, 2473 (1949).