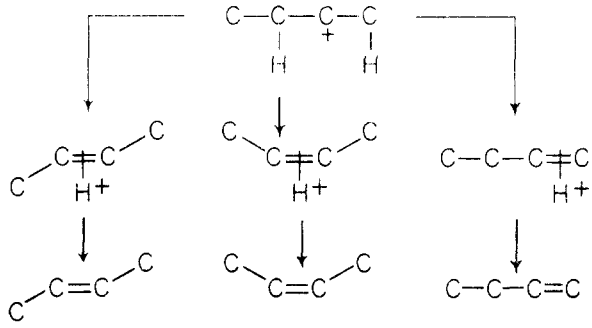


Fig. 11.—Loss of proton from carbonium ion *via* π-complex.

possible that the formation of the π-complex occurs *during* the formation of the carbonium ion.[38] To the extent that the transition states are approximated by the π-complexes (Fig. 11) it appears that the energies of the π-complexes are *cis* < *trans* = 1-butene. It is interesting to note that *cis*-olefins form more stable π-complexes with silver ions[39,40] than the corresponding *trans*-olefins. Recent studies on hydrogen bonding to olefins[41-43] have shown that 2-olefins (apparently mixture of *cis*- and *trans*-) are stronger bases than 1-olefins and form stronger hydrogen bonds. Thus, the relative stabilities of the π-complexes, and therefore the relative rates of formation of the olefins, seem to be governed by the basicities of the corresponding olefins.

(38) Neighboring hydrogen participation in the formation of carbonium ions by ionization has been demonstrated recently: W. B. Smith, R. E. Bowman and Th. J. Kmet, THIS JOURNAL, **81**, 997 (1959); D. J. Cram and J. Tadanier, *ibid.*, **81**, 2737 (1959); S. Winstein and J. Takahashi, *Tetrahedron*, **2**, 316 (1958).

(39) F. R. Hepner, K. N. Trueblood and H. J. Lucas, THIS JOURNAL, **74**, 1333 (1952).

(40) P. D. Gardner, R. L. Brandon and N. J. Nix, *Chemistry & Industry*, 1363 (1958).

(41) A. W. Baker and A. T. Shulgin, THIS JOURNAL, **80**, 5358 (1958).

(42) P. V. R. Schleyer, D. S. Trifan and R. Bacskai, *ibid.*, **80**, 6691 (1958).

(43) R. West, *ibid.*, **81**, 1614 (1959).

EVANSTON, ILL.

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

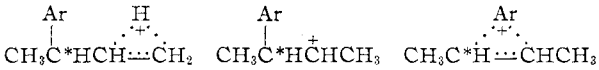
The Reactions of 3-Phenyl-1-butylamine-3-^{14}C and 3-*p*-Anisyl-1-butylamine-3-^{14}C with Nitrous Acid[1,2]

BY ARTHUR W. FORT AND ROBERT E. LEARY

RECEIVED OCTOBER 13, 1959

The diazotization of 3-phenyl-1-butylamine-3-^{14}C in acetic acid gives 3-phenyl-1-butene, 3-phenyl-1-butyl acetate and diastereoisomeric 3-phenyl-2-butyl acetates. 3-*p*-Anisyl-1-butylamine-3-^{14}C gives a similar product mixture. The secondary ester products of these reactions show extensive isotope-position rearrangement. The significance of these results is discussed.

The reactions of 3-phenyl-1-butylamine-3-^{14}C and 3-*p*-anisyl-1-butylamine-3-^{14}C with nitrous acid have been investigated with the objective of identifying the intermediates leading to secondary products in these and similar reactions. In the present work information was sought concerning the relative importance of the possible intermediates I, II and III.



Ar = C_6H_5– or *p*-$CH_3OC_6H_4$–

The symmetrical aryl-bridged ions III, if formed, will lead to secondary products showing isotope-position rearrangement. Secondary products formed by solvent attack on intermediates I and/or II will not show isotope-position rearrangement.

The reaction of 3-phenyl-1-butylamine-3-^{14}C with sodium nitrite in glacial acetic acid gave 3-phenyl-1-butene-X-^{14}C (IV), 10%, and a mixture of phenylbutyl-X-^{14}C acetates, which, after treatment with lithium aluminum hydride and distillation at reduced pressure, gave a 63% yield (based on unrecovered amine) of phenylbutanols. The ratio of alcohol products, estimated by gas chromatography, was 62 ± 2% 3-phenyl-1-butanol-X-^{14}C (V), 28 ± 2% *erythro*-3-phenyl-2-butanol-X-^{14}C (VI) and 10 ± 2% *threo*-3-phenyl-2-butanol-X-^{14}C (VII). Other isomeric phenylbutanols were not detected. The alcohol mixture was separated by fractional distillation into V and a mixture of the diastereoisomers VI and VII, from which pure *erythro*-3-phenyl-2-butanol was obtained by the procedure of Cram.[3] The absence of the conjugated olefins, *cis*-2-phenyl-2-butene and *trans*-2-phenyl-2-butene, from the crude olefin product was established by gas chromatography and by the similarity of its infrared spectrum with that of authentic 3-phenyl-1-butene. A control experiment showed that the conjugated olefins would have survived the reaction conditions, in large part, if they had been formed.

Isotope-position rearrangement attending the formation of products in the deamination reaction of 3-phenyl-1-butylamine-3-^{14}C was determined by oxidizing each product to benzoic acid and comparing the ^{14}C-activity of the benzoic acid fragment with that of its parent compound. The measured ^{14}C-activities and percentage rearrangements are given in Table I.

The reaction of 3-*p*-anisyl-1-butylamine-3-^{14}C with sodium nitrite in acetic acid gave a product mixture that was similar to the one obtained from

(1) Presented at the Organic Division, A.C.S. Meeting, Atlantic City, N. J., September, 1959; abstracts, p. 27-P.

(2) Financial support by the U. S. Atomic Energy Commission is gratefully acknowledged.

(3) D. J. Cram, THIS JOURNAL, **71**, 3863 (1949).

TABLE I

^{14}C-ACTIVITY MEASUREMENTS ON THE 3-PHENYL-1-BUTYLAMINE-3-^{14}C– NITROUS ACID REACTION PRODUCTS

Compound	Counts/min.[a]	Rearrangement,[b] %
3-Phenyl-1-butene (IV)	(973 ± 7)[c]	1.5 ± 2.4 (3)[d]
Benzoic acid from IV	1370 ± 23	
3-Phenyl-1-butanol (V)	971 ± 4	0
Benzoic acid from V	1395 ± 28	
erythro-3-Phenyl-2-butanol (VI)	976 ± 9	34.6 ± 2.7
Benzoic acid from VI	926 ± 16	(35.4)[d](34.5)[d,e]

[a] Measured activity of "infinitely thick" barium carbonate of uniform area corrected for background with average deviation from the mean value. [b] Percentage loss of ^{14}C-activity from C-3. Measured activities of IV, V and VI must be multiplied by 10, and those of benzoic acid by 7 to adjust for relative carbon content before making comparisons. [c] Not measured. This value is the average of the activities of V and VI. [d] Result obtained from measurements made by New England Nuclear Assay Corp.; see footnotes *a* and *b*, Table II. [e] Contained 30% of the *threo* isomer VII.

3-phenyl-1-butylamine-3-^{14}C. Inactive 3-*p*-anisyl-1-butene (VIII), 3-*p*-anisyl-1-butanol (IX) and *erythro*-3-*p*-anisyl-2-butanol (X) were added to act as carriers. Treatment of the crude mixture with lithium aluminum hydride followed by fractional distillation gave 12% 3-*p*-anisyl-1-butene-X^{14}C (VIII),[4] 53% 3-*p*-anisyl-1-butanol-X-^{14}C (IX)[4] and a mixture of diastereoisomeric 3-*p*-anisyl-2-butanols from which 17% pure *erythro*-3-*p*-anisyl-2-butanol-X-^{14}C (X),[4] was obtained by the procedure of Winstein and Robinson.[5] Isotope-position rearrangement attending the formation of these products was determined by oxidizing each product to anisic acid and comparing the ^{14}C-activity of each anisic acid fragment with that of its parent compound. The ^{14}C-activities and percentage rearrangements for these compounds are given in Table II.

TABLE II

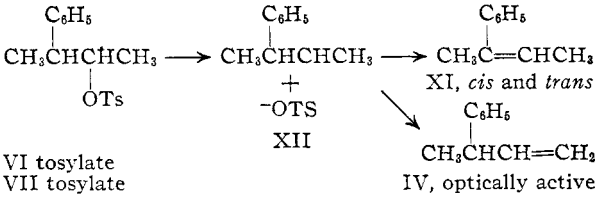
^{14}C-ACTIVITY MEASUREMENTS ON THE 3-*p*-ANISYL-1-BUTYLAMINE-3-^{14}C– NITROUS ACID REACTION PRODUCTS

Compound	μcuries/mmole[a,b]	Rearrangement,[c] %
3-*p*-Anisyl-1-butylamine·HCl	1.32 ± 2	5 (−1)[d]
Anisic acid from amine	1.26 ± 5	
3-*p*-Anisyl-1-butene (VIII)	1.10 ± 2	6 (2)[d]
Anisic acid fron VIII	1.03 ± 2	
3-*p*-Anisyl-1-butanol (IX)	1.04 ± 2	7 (3)[d]
Anisic acid from IX	0.965 ± 4	
erythro-3-*p*-Anisyl-2-butanol (X)	.836 ± 1	52 (49)[d]
Anisic acid from X	.404 ± 1	

[a] Measured activity with average deviation from the mean value, corrected for background and coincidence but not corrected for quenching. [b] Measurements were made on solutions of the compounds named using an internal scintillator by New England Nuclear Assay Corp., Boston, Mass. [c] Percentage loss of ^{14}C-activity from C-3. [d] Obtained by applying a reasonable correction for quenching effect to the individual measurements on anisic-^{14}C acid.

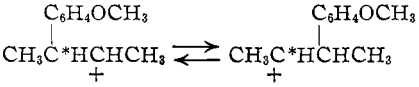
Discussion

In the acetolysis of the tosylates of optically active *erythro*- and *threo*-3-phenyl-2-butanol (VI and VII) Cram[6] observed, among other reactions, an E_i, non-stereospecific process leading to 3-phenyl-1-butene (IV) and *cis*- and *trans*-2-phenyl-2-butene (XI). It seems probable that this reaction proceeds through the "open" carbonium ion ion-pair



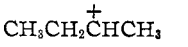
XII. In the present work the yield of 3-phenyl-1-butene (IV) from 3-phenyl-1-butylamine was approximately 10% and this product was free of *cis*- and *trans*-2-phenyl-2-butene. Less than 5% of the conjugated olefins in the 3-phenyl-1-butene product would have been detected by the methods used. Thus, the deamination of 3-phenyl-1-butylamine gave less than 0.5% of 2-phenyl-2-butenes, and it seems unlikely that the "open" carbonium ion (II, Ar = C_6H_5–) was an intermediate in this reaction.

2-*p*-Anisyl-2-butenes, if formed, would not have survived the reaction conditions in the deamination of 3-*p*-anisyl-1-butylamine, but the almost 50% isotope-position rearrangement that occurred in the formation of 3-*p*-anisyl-2-butyl acetate from 3-*p*-anisyl-1-butylamine-3-^{14}C shows that very little of this product could have arisen from the "open" carbonium ion (II, Ar = $CH_3OC_6H_4$–). That the extensive isotope-position rearrangement observed in the 3-*p*-anisyl-2-butyl-X-^{14}C acetate product of the present work could not have arisen by rearrangement of the "open" carbonium ion



follows from the stereospecificity observed in the solvolysis of optically active *erythro*- and *threo*-3-*p*-anisyl-2-butylsulfonic esters.[5] The isotope-position rearrangement observed in the present work is readily understandable in terms of the aryl-bridged intermediates II, essentially the same intermediates postulated to explain stereospecificity in the solvolysis of 3-phenyl-2-butyl-[3,7] and 3-*p*-anisyl-2-butyl[5]-sulfonic esters.

In favorable cases diazotization of amines might be expected to give "open" secondary carbonium ions by 1,2-shift of hydrogen. It is interesting to note in this connection that appreciable amounts of 2-butenes are obtained in the reaction of 1-butylamine with nitrous acid,[8] indicating the probable intervention of the "open" carbonium ion XIII.



XIII

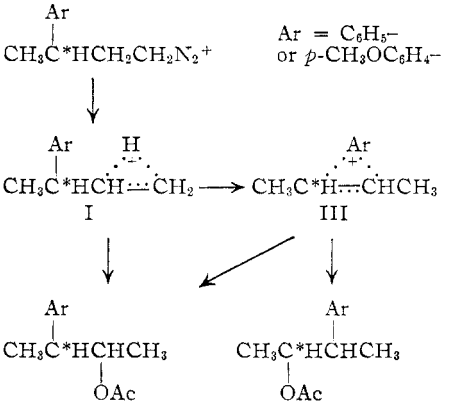
Migration of an α-phenylethyl group or an α-(*p*-anisyl)-ethyl group in the present reactions would have led to primary ester without isotope-position rearrangement and would not have been detected. However, benzyl and *p*-methoxybenzyl groups do not migrate in the reactions of 3-phenyl-1-propylamine-1-^{14}C and 3-*p*-anisyl-1-propylamine-1-^{14}C with nitrous acid,[9] and it is unlikely that there was

(4) Calculated by isotope-dilution analysis.
(5) S. Winstein and G. C. Robinson, THIS JOURNAL, **80**, 169 (1958).
(6) D. J. Cram, *ibid.*, **74**, 2137 (1952).
(7) D. J. Cram, *ibid.*, **74**, 2129 (1952).
(8) A. Streitwieser, Jr., and W. D. Schaeffer, *ibid.*, **79**, 2888 (1957).
(9) A. W. Fort and J. D. Roberts, *ibid.*, **78**, 584 (1956).

migration of α-arylethyl groups in the present reactions. Displacement of nitrogen with Walden inversion accounts for 69% of the primary acetate product in the deamination of 1-butylamine-1-*d* in acetic acid[8,10] and the reactions reported here are undoubtedly similar.

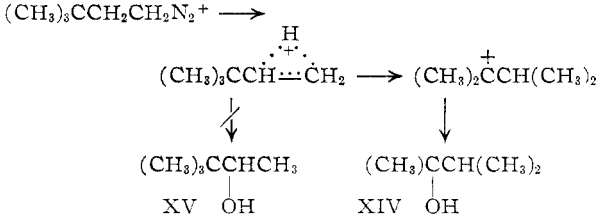
The low percentages of isotope-position rearrangement involved in the formation of 3-aryl-1-butenes indicate that the aryl-bridged intermediates III react with solvent to form ester much faster than they lose a proton to form olefin. This result is consistent with Cram's findings in the acetolysis of optically active *threo*-3-phenyl-2-butyl tosylate.[6]

The 35% isotope-position rearrangement that occurred in the formation of *erythro*-3-phenyl-2-butyl acetate indicates that 70% of this product arose from the *phenonium* ion (III, Ar = $C_6H_5^-$). The remaining 30% arose, possibly, from reaction of solvent with the hydrogen-bridged ion (I, Ar = $C_6H_5^-$).



The 49% isotope-position rearrangement that occurred in the formation of *erythro*-3-*p*-anisyl-2-butyl acetate indicates that the hydrogen-bridged ion (I, Ar = $CH_3OC_6H_4^-$) is converted into the aryl-bridged ion (III, Ar = $CH_3OC_6H_4^-$) much faster than it reacts with solvent to form ester. The increased degree of isotope-position rearrangement in the formation of secondary ester in this reaction was anticipated on the basis of the known influence of a *p*-methoxyl substituent in stabilizing an aryl-bridged cation like III.[11]

The course of reaction of 3-*p*-anisyl-1-butylamine-3-^{14}C with nitrous acid is similar to the results reported by Saunders[12] for the deamination of 3,3-dimethyl-1-butylamine-1-^{14}C in aqueous solution. The latter reaction gave 2,3-dimethyl-2-butanol (XIV) as a major product, but no detectable amount of 3,3-dimethyl-2-butanol (XV). Thus,



(10) A. Streitwieser, Jr., *J. Org. Chem.*, **22**, 861 (1957).

(11) J. D. Roberts and C. M. Regan, THIS JOURNAL, **75**, 2069 (1953).

(12) W. H. Saunders, Jr., *ibid.*, **78**, 6127 (1956).

the hydrogen-bridged intermediate undergoes 1,2-shift of methyl faster than it reacts with water to form XV.

Acknowledgment.—We are indebted to Dr. Claire J. Collins, Oak Ridge National Laboratory, for a gift of standard benzoic-^{14}C acid, used to prepare self-absorption curves for barium carbonate.

Experimental

All melting points reported are corrected. Microanalyses are by Drs. Weiler and Strauss, Oxford, England.

3-Phenylbutanoic Acid.—To a solution of 40 g. of 3-phenyl-2-butenoic acid[13] in 150 ml. of absolute ethanol was added 1 g. of 5% palladium–charcoal and the mixture was shaken at room temperature under a low pressure of hydrogen until the calculated quantity of hydrogen was absorbed. Distillation of the combined product from several runs gave a 95% yield of 3-phenylbutanoic acid, b.p. 120–126° (2 mm.) (lit.[14] b.p. *ca.* 160° (16 mm.)).

3-Phenylbutanamide was prepared by the general method of Boissonnas.[15] Ethyl chloroformate (43.5 g., 0.401 mole) was added to a stirred solution of 63.3 g. (0.386 mole) of 3-phenylbutanoic acid and 40.5 g. (0.401 mole) of triethylamine in 900 ml. of chloroform at 0°. The solution was stirred for 15 minutes, then a stream of ammonia was passed into the reaction mixture for 10 minutes. The mixture was stirred and allowed to warm to room temperature over a period of one hour, filtered and the chloroform evaporated. The residue was recrystallized twice from benzene and once from aqueous ethanol to give 41.0 g. (65%) of 3-phenylbutanamide, m.p. 104–105° (lit.[16] m.p. 105°).

3-Phenyl-1-butylamine.—Lithium aluminum hydride (20 g., 0.53 g.f. wt.) and 450 ml. of dry ether were placed in a flask equipped with a mechanical stirrer and an extraction bulb surmounted by a reflux condenser. In the bulb was placed 41.0 g. (0.252 mole) of 3-phenylbutanamide and the mixture was heated under reflux until all of the amide was extracted. Distillation of the product gave 22 g. (59%) of 3-phenyl-1-butylamine, b.p. 98° (11 mm.).

The phenylurea derivative was prepared without solvent and recrystallized from 90% ethanol, m. p. 115–116°.

Anal. Calcd. for $C_{17}H_{20}N_2O$: C, 76.08; H, 7.51; N, 10.44. Found: C, 76.33; H, 7.52; N, 10.20.

3-Phenyl-1-butanol.—3-Phenylbutanoic acid (51.0 g., 0.311 mole) was reduced with excess lithium aluminum hydride. Distillation gave 38.0 g. (81%) of 3-phenyl-1-butanol, b.p. 104–105° (4 mm.) (lit.[17] b.p. 117° (8 mm.)).

The N-(α-naphthyl)-carbamate of 3-phenyl-1-butanol was recrystallized from ligroin, m.p. 90–91°.

Anal. Calcd. for $C_{21}H_{21}NO_2$: C, 78.97; H, 6.63; N, 4.39. Found: C, 79.09; H, 6.84; N, 4.39.

3-Phenyl-1-butene.—Crude 3-phenyl-1-butanol, obtained from 40 g. (0.24 mole) of 3-phenylbutanoic acid by reduction with lithium aluminum hydride, was acetylated by heating under reflux for one hour with excess acetic anhydride in the presence of pyridine. The reaction mixture was cooled and dissolved in ether. The ether solution was washed with water, then with dilute sulfuric acid, dried and the ether removed by evaporation. The crude ester was passed over beryl saddles heated at 520°, using a slow stream of purified nitrogen as a carrier gas. The pyrolysate was dissolved in ether, washed with water, then with dilute sodium carbonate solution, dried and distilled at atmospheric pressure. The yield of 3-phenyl-1-butene, b.p. 170–172°, was 11.7 g. (36% over-all (lit.[18] b.p. 157–162° (630 mm.)). The infrared spectrum of this product was identical with that reported[6] for (−)-3-phenyl-1-butene.

threo-**3-Phenyl-2-butanol.**—*threo*-3-Phenyl-2-butyl acid phthalate was obtained by the procedure of Cram[3]; m.p. 130–131° (lit.[3] m.p. 130–131°). Saponification of 10 g. of the acid phthalate gave 3.5 g. of *threo*-3-phenyl-2-butanol, b.p. 69° (2 mm.), $n^{25.7}$D 1.5160 (lit.[3] b.p. 108° (10 mm.), n^{25}D 1.5159).

(13) S. Lindenbaum, *Ber.*, **50**, 1270 (1917).

(14) E. Fischer and W. Schmitz, *ibid.*, **39**, 2208 (1906).

(15) R. A. Boissonnas, *Helv. Chim. Acta*, **34**, 874 (1951).

(16) E. P. Kohler and M. Reimer, *Am. Chem. J.*, **33**, 333 (1905).

(17) B. Wojcik and H. Adkins, THIS JOURNAL, **55**, 4939 (1933).

(18) S. J. Cristol, W. C. Overhults and J. S. Meek, *ibid.*, **73**, 813 (1951).

erythro-**3-Phenyl-2-butanol.**—*erythro*-3-Phenyl-2-butyl acid 3-nitrophthalate was obtained by the procedure of Cram[3]; m.p. 156–157° (lit.[3] m.p. 156–157°). Saponification of 10 g. of the 3-nitrophthalate gave 4.0 g. of *erythro*-3-phenyl-2-butanol, b.p. 78° (3.5 mm.), n^{28}D 1.5177 (lit.[3] b.p. 105° (10 mm.), n^{25}D 1.5167).

The Reaction of 3-Phenyl-1-butylamine with Nitrous Acid.—A mixture of 26.7 g. (0.387 g.f. wt.) of sodium nitrite, 31.5 g. (0.211 mole) of freshly distilled 3-phenyl-1-butylamine and 134 ml. of glacial acetic acid was stirred overnight at 2°. The mixture was allowed to warm to room temperature and stirring was continued for 14 hours more. The reaction mixture was poured into a mixture of ice and water containing 95 g. of sodium hydroxide and extracted four times with pentane and twice with ether. The combined extracts were washed with dilute hydrochloric acid to remove unreacted amine (14% recovery, b.p. 88–90° (8 mm.)), then with water and dried. The residue from evaporation of solvent was distilled under reduced pressure to give 2.56 g. (11% based on unrecovered amine) of 3-phenyl-1-butene, b.p. 55° (10 mm.) to 60° (12 mm.), identified by its infrared spectrum, which was identical with that of authentic 3-phenyl-1-butene in all major respects; 1.5 g. of an intermediate fraction, b.p. 70–105° (7.5 mm.); 21.5 g. (62%) of phenylbutyl acetates, b.p. 105–120° (7.5 mm.); and 2.0 g. of column holdup and pot residue. The ester fraction was treated with excess lithium aluminum hydride to convert the esters into the corresponding carbinols. Fractional distillation of the carbinol mixture through a 75 × 0.8 cm. column equipped with a wire spiral gave 3.1 g. of a mixture of diastereoisomeric 3-phenyl-2-butanols, b.p. 104–111° (9.2 mm.), identified by its infrared spectrum, which was identical in all major respects with that of a mixture of *erythro*- and *threo*-3-phenyl-2-butanols obtained by reaction of hydrotropaldehyde with methylmagnesium iodide, except for a band at 5.8 μ indicating the presence of unreduced acetate; and by preparation of *erythro*-3-phenyl-2-butyl acid 3-nitrophthalate, m.p. 156–157°; and 7.5 g. of 3-phenyl-1-butanol, b.p. 113–115° (8.5 mm.), identified by preparation of its N-(α-naphthyl)-carbamate, m.p. 90–91°. The infrared spectrum of the 3-phenyl-1-butanol fraction had bands at 5.80 and 8.10 μ which corresponded to intense bands in the spectrum of 3-phenyl-1-butyl acetate.

The conjugated olefins, *cis*- and *trans*-2-phenyl-2-butene and 2-phenyl-1-butane, were shown to be absent from low-boiling fractions by comparison of their infrared spectra and gas chromatography retention times with those of authentic samples of the conjugated olefins.

In a control experiment a sample of *trans*-2-phenyl-2-butene in glacial acetic acid was allowed to stand in the presence of sodium nitrite for 36 hours at 2° then for 36 hours at room temperature. Distillation gave olefin (60% recovery), shown by gas chromatography retention times to be a mixture of *cis*- and *trans*-2-phenyl-2-butene and 2-phenyl-1-butene.

Preparation and Diazotization of 3-Phenyl-1-butylamine-3-^{14}C.—Acetophenone-7-^{14}C (60.0 g., 0.500 mole, containing 1.0 mcurie of ^{14}C-activity) was converted by the procedure of Lindenbaum[13] to 3-phenyl-2-butenoic-3-^{14}C acid, 56.0 g. (69%), m.p. 97–98° (lit.[13] m.p. 97°). Catalytic hydrogenation of 3-phenyl-2-butenoic-3-^{14}C acid, carried out as reported above for the inactive acid, gave 55 g. (97%) of 3-phenylbutanoic-3-^{14}C acid, b.p. 120–126° (2 mm.), which was diluted with 20 g. of inactive acid.

3-Phenylbutanoic-3-^{14}C acid (63.3 g., 0.386 mole) was converted, as described above for the inactive acid, into 3-phenylbutanamide-3-^{14}C, 44.5 g. (70%), m.p. 104–105°. Reduction of the active amide with lithium aluminum hydride was carried out by the extraction procedure described above for the reduction of 3-phenylbutanamide. Distillation gave 36.3 g. (89%) of 3-phenyl-1-butylamine-3-^{14}C, b.p. 82° (3 mm.).

Sodium nitrite (28.8 g., 0.417 g.f. wt.) and 34.0 g. (0.228 mole) of 3-phenyl-1-butylamine-3-^{14}C were stirred for a period of *ca.* 30 hours at 2° in 145 ml. of glacial acetic acid. The reaction mixture was allowed to warm to room temperature and stirring was continued for 30 hours more. The reaction mixture was poured into a mixture of ice and water containing excess sodium hydroxide and extracted with four portions of pentane. The combined extracts were washed with dilute hydrochloric acid to remove unreacted amine (7% recovery), with dilute sodium carbonate solution, then with water, dried and evaporated. Partial distillation of the oily residue gave 3-phenyl-1-butene-X-^{14}C. The crude undistilled phenylbutyl acetates were treated with excess lithium aluminum hydride in ether and the ratio of carbinol products was estimated by comparison of the gas chromatography profile with those of known mixtures of 3-phenyl-1-butanol and *threo*- and *erythro*-3-phenyl-2-butanol. Other isomeric phenylbutanols were not detected. 3-Phenyl-1-butanol was separated from 3-phenyl-2-butanol by fractional distillation. A colored impurity was removed from the 3-phenyl-1-butene-X-^{14}C product by adsorption on activated alumina and elution of the olefin with pentane. Pure *erythro*-3-phenyl-2-butanol-X-^{14}C was obtained from the secondary alcohol fraction as described above for the inactive alcohol. Traces of secondary alcohols were removed from the primary alcohol fraction by preferential esterification of the primary alcohol with phthalic anhydride. Each of the purified products gave a single peak in gas chromatography and the infrared spectrum of each was identical with that of the corresponding authentic compound. A portion of each of the purified products was oxidized to benzoic-7-^{14}C acid with potassium permanganate in refluxing 10% sodium hydroxide solution.

3-*p*-**Anisyl-2-butenoic Acid.**—A solution of 90 g. (0.60 mole) of *p*-methoxyacetophenone and 104 g. (0.62 mole) of ethyl bromoacetate in 450 ml. of dry benzene was added with stirring to 40 g. (0.62 g. atom) of #20-mesh zinc at reflux temperature. When the addition was completed the mixture was boiled under reflux for two hours more than hydrolyzed with dilute sulfuric acid and ice. The benzene layer was washed with water, dilute sodium carbonate solution, again with water and evaporated. The oily residue was heated at about 170° for a period of 5 minutes to dehydrate the hydroxyester product. The crude unsaturated ester was saponified with aqueous ethanolic sodium hydroxide and the sodium salt was collected by filtration, washed with ethanol, then with ether and dissolved in water. Acidification of the aqueous solution and recrystallization of the crude acid from ethanol–water gave 105 g. (90%) of 3-*p*-anisyl-2-butenoic acid, m.p. 156–157°.

Anal. Calcd. for $C_{11}H_{12}O_3$: C, 68.73; H, 6.29. Found: C, 68.43; H, 6.60.

3-*p*-**Anisylbutanoic Acid.**—To a solution of 30 g. of 3-*p*-anisyl-2-butenoic acid in 150 ml. of absolute ethanol was added 1 g. of 5% palladium–charcoal and the mixture was shaken under a low pressure of hydrogen at room temperature until the calculated quantity of hydrogen was absorbed. The catalyst was removed by filtration, the solvent evaporated and the residue distilled under reduced pressure. Reduction of 103 g. (0.54 mole) of 3-*p*-anisyl-2-butenoic acid by this procedure gave 70 g. (67%) of 3-*p*-anisylbutanoic acid, b.p. 154–155° (1 mm.). The product slowly crystallized, m.p. 67–68° after recrystallization from ligroin.

Anal. Calcd. for $C_{11}H_{14}O_3$: C, 68.02; H, 7.27. Found: C, 67.97; H, 7.28.

3-*p*-**Anisylbutanamide** was prepared by the general procedure of Boissonnas.[15] A solution of 96 g. (0.49 mole) of 3-*p*-anisylbutanoic acid, 60 g. (0.60 mole) of triethylamine and 66 g. (0.60 mole) of ethyl chloroformate in 1300 ml. of chloroform was stirred at 0° for one hour. Ammonia was bubbled into the stirred solution for 20 minutes and the reaction mixture was allowed to warm to room temperature over a period of one hour. The mixture was filtered, the filtrate evaporated and the residue was recrystallized from chloroform to give 60 g. (63%) of 3-*p*-anisylbutanamide, m.p. 115–116°.

Anal. Calcd. for $C_{11}H_{15}NO_2$: C, 68.37; H, 7.82. Found: C, 68.31; H, 7.92.

3-*p*-**Anisyl-1-butylamine.**—3-*p*-Anisylbutanamide was reduced with excess lithium aluminum hydride in ether by the extraction procedure used for 3-phenyl-1-butylamine. Distillation under reduced pressure gave 30 g. (54%) of 3-*p*-anisyl-1-butylamine, b.p. 116° (4 mm.), n^{26}D 1.5220.

The hydrochloride was prepared in ether and recrystallized from ethanol–pentane, m.p. 178.5–179°.

Anal. Calcd. for $C_{11}H_{18}ClNO$: C, 61.24; H, 8.41. Found: C, 61.01; H, 8.19.

The phenylthiourea derivative was recrystallized from 95% ethanol, m.p. 121–121.5°.

Anal. Calcd. for $C_{18}H_{22}N_2OS$: C, 68.75; H, 7.05. Found: C, 68.73; H, 7.10.

3-*p*-Anisyl-1-butanol.—3-*p*-Anisylbutanoic acid (15 g., 0.077 mole) was reduced with excess lithium aluminum hydride in ether. Distillation at reduced pressure gave 11 g. (79%) of 3-*p*-anisyl-1-butanol, b.p. 130° (3 mm.) (lit.[19] b.p. 158° (14 mm.)).

The *p*-bromobenzenesulfonate was recrystallized from ethanol–water; m.p. 72–73°.

Anal. Calcd. for $C_{17}H_{19}BrO_4S$: C, 51.13; H, 4.80. Found: C, 51.28; H, 4.88.

The N-phenylcarbamate of 3-*p*-anisyl-1-butanol[20] was recrystallized from ligroin, m.p. 56–57°.

Anal. Calcd. for $C_{18}H_{21}NO_3$: C, 72.21; H, 7.07. Found: C, 72.15; H, 7.04.

3-*p*-Anisyl-1-butene.—The crude 3-*p*-anisyl-1-butanol obtained by reduction of 50 g. (0.26 mole) of 3-*p*-anisylbutanoic acid with lithium aluminum hydride was acetylated by boiling under reflux with a slight excess of acetic anhydride in the presence of pyridine. Distillation under reduced pressure gave 46 g. (81% over-all) of 3-*p*-anisyl-1-butyl acetate, b.p. 132–134° (2.5 mm.). The ester was passed over glass helices heated at 525° using argon as a carrier gas. The pyrolysate was freed of acetic acid and distilled at reduced pressure to give 14.5 g. (40% based on unrecovered ester) of 3-*p*-anisyl-1-butene, b.p. 97° (9.5 mm.).

A sample of the olefin was hydrogenated in the presence of palladium–charcoal to **2-*p*-anisylbutane**, b.p. 100° (10 mm.).

Anal. Calcd. for $C_{11}H_{16}O$: C, 80.44; H, 9.83. Found: C, 80.54; H, 9.89.

3-*p*-Anisyl-2-butanol was prepared in 86% yield from 2-*p*-anisylpropanal and methylmagnesium iodide. The mixture of diastereoisomeric alcohols boiled at 102–104° (1 mm.) (lit.[5] b.p. 149° (14 mm.)).

***erythro*-3-*p*-Anisyl-2-butanol** was obtained from the diastereoisomeric mixture by recrystallization of the acid phthalate from benzene as reported by Winstein and Robinson.[5] Saponification of *erythro*-3-phenyl-2-butyl acid phthalate, m.p. 137–138° (lit.[5] m.p. 137–138°), gave, after distillation, *erythro*-3-phenyl-2-butanol, m.p. 60–61° (lit.[5] m.p. 60–61°).

The Reaction of 3-*p*-Anisyl-1-butylamine with Nitrous Acid.—A mixture of 28 g. (0.16 mole) of 3-*p*-anisyl-1-butylamine and 23 g. (0.33 g.f. wt.) of sodium nitrite in 125 ml. of glacial acetic acid was stirred at 2° for *ca.* 17 hours then at room temperature for *ca.* 25 hours and poured into a mixture of ice and water containing 100 g. of sodium hydroxide. The basic mixture was extracted four times with pentane and once with ether. The combined extracts were washed with dilute hydrochloric acid to remove unreacted amine (3% recovery), with dilute sodium carbonate solution, then with water, dried and evaporated. Partial distillation of the oily residue gave 1.15 g. of 3-*p*-anisyl-1-butene, b.p. 82° (5 mm.), which had a single peak in gas chromatography corresponding in retention time to that of authentic 3-*p*-anisyl-1-butene. The crude, undistilled acetate mixture was treated with excess lithium aluminum hydride and the alcohol mixture distilled to give 0.98 g. (9% total yield based on unrecovered amine) of 3-*p*-anisyl-1-butene, b.p. 105° (14 mm.); 6.63 g. (24%) of a mixture of diastereoisomeric 3-*p*-anisyl-2-butanols, infrared spectrum like that of a synthetic mixture of authentic *threo*- and *erythro*-3-*p*-anisyl-2-butanol, acid phthalate, m.p. 137–138°; and 11.5 g. (42%) of 3-*p*-anisyl-1-butanol, b.p. 153–154° (10 mm.), N-phenylcarbamate, m.p. 56–57°, infrared spectrum like that of a synthetic 3-*p*-anisyl-1-butanol except for a weak peak at 8.70 μ and a medium peak at 11.0 μ which indicate the presence of some 3-*p*-anisyl-2-butanol. Column holdup and pot residue amounted to *ca.* 3 g.

Preparation and Diazotization of 3-*p*-Anisyl-1-butylamine-3-^{14}C.—*p*-Methoxyacetophenone-7-^{14}C was obtained by the acylation[21] of anisole with acetyl-1-^{14}C chloride in carbon disulfide at 0° using anhydrous aluminum chloride as catalyst. Distillation at reduced pressure gave a 71% yield of *p*-methoxyacetophenone-7-^{14}C, b.p. 123–124° (7 mm.) (lit.[21] b.p. 139° (15 mm.)).

3-*p*-Anisyl-2-butenoic-3-^{14}C acid was obtained from 90 g. (0.60 mole, containing *ca.* 2 mcuries of ^{14}C-activity) of *p*-methoxyacetophenone-7-^{14}C by the procedure used for the inactive acid. Catalytic hydrogenation was carried out as reported for the inactive acid to give 82 g. (70% over-all) of 3-*p*-anisylbutanoic-3-^{14}C acid, b.p. 176–178° (5 mm.).

3-*p*-Anisylbutanoic-3-^{14}C acid (50 g., 0.26 mole) was converted into the corresponding amide by the procedure used for the inactive acid. 3-*p*-Anisylbutanamide-3-^{14}C was reduced with lithium aluminum hydride by the extraction procedure reported above. Inactive 3-*p*-anisyl-1-butylamine (19 g.) was added to act as a carrier and the product was distilled to give 42 g. (49% over-all) of 3-*p*-anisyl-1-butylamine-3-^{14}C, b.p. 99° (1.2 mm.).

3-*p*-Anisyl-1-butylamine-3-^{14}C was diazotized as reported for the inactive amine. Inactive 3-*p*-anisyl-1-butene (0.734 g.), *erythro*-3-*p*-anisyl-2-butanol (3.39 g.) and 3-*p*-anisyl-1-butanol (5.06 g.) were added to act as carriers, the mixture was treated with excess lithium aluminum hydride to convert acetates into the corresponding carbinols and the products were isolated by distillation. The 3-*p*-anisyl-1-butene-X-^{14}C product showed a single peak in gas chromatography and had an infrared spectrum identical with that of authentic 3-*p*-anisyl-1-butene after one redistillation. *erythro*-3-*p*-Anisyl-2-butanol-X-^{14}C, m.p. 60–61°, was obtained by recrystallization of the acid phthalate and saponification. 3-*p*-Anisyl-1-butanol-X^{14}-C was purified by recrystallization of the brosylate, m.p. 72–73°, followed by formolysis and saponification of the formate. Anisic-7-^{14}C acid, m.p. 184°, was obtained from a portion of each of the purified products by oxidation with excess potassium permanganate in refluxing 5% sodium hydroxide solution.

(19) A. Sosa, *Ann. chim.*, [11] **14**, 5 (1940).

(20) Sosa, ref. 19, reported obtaining an oil.

(21) C. R. Noller and R. Adams, THIS JOURNAL, **46**, 1889 (1924).

LEXINGTON, KY.

[CONTRIBUTION FROM THE MCPHERSON CHEMISTRY LABORATORY OF THE OHIO STATE UNIVERSITY, COLUMBUS 10, OHIO]

The Synthesis and Some Reactions of Di-*t*-butylacetic Acid and Di-*t*-butylketene[1]

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Di-*t*-butylacetic acid is prepared in good over-all yield from hexamethylacetone as shown in the chart, I → VI. On treatment of the acid chloride with sodium amide in liquid ammonia di-*t*-butylketene is formed. This ketene is stable and relatively unreactive compared to other known aliphatic ketenes. The possible intervention of di-*t*-butylketene in reactions of di-*t*-butylacetyl chloride raises the general question as to the importance of ketenes in reactions of acid chlorides having a hydrogen on the α-carbon.

In continuation of a program designed to develop methods for the synthesis of highly branched aliphatic compounds and to study the reactions thereof, we wished to prepare di-*t*-butylacetic acid. This compound was especially desired because it could be the parent of a series of highly hindered trisubstituted acetic acids. In this paper we re-

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(2) The material herein presented was taken from the Ph.D. theses of A. Arkell, 1958, and T. Fukunaga, 1959.