The Intramolecular Nature of the Rearrangement of Benzimidates

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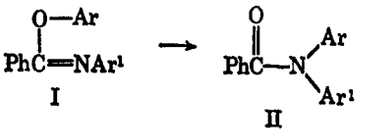
The Chapman rearrangement of a mixture of ^{14}C-4-bromophenyl N-phenylbenzimidate and 4-bromophenyl N-4-tolylbenzimidate showed that the reaction was intramolecular. Tritium-labeled allyl N-phenylbenzimidate similarly rearranged exclusively intramolecularly with inversion of the allyl group.

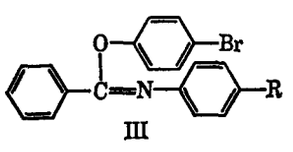
Aryl N-arylbenzimidates I are transformed by heating, either alone or in a solvent, to 250–280°, into N-aroyldiphenylamines II (the Chapman rearrangement).[2]



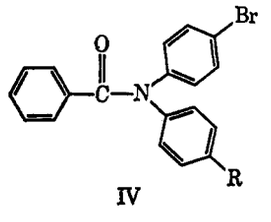
I II

Chapman presented evidence, based on melting point determinations, that the rearrangement was intramolecular.[3] Wiberg and Rowland rearranged a mixture of phenyl N-phenylbenzimidate and 4-chlorophenyl N-4-chlorophenylbenzimidate and concluded from an infrared and X-ray analysis of the mixture of products that no crossing over had occurred.[4] This evidence, while strongly supporting an intramolecular mechanism, does not entirely exclude some intermolecular participation, particularly since the substituted and unsubstituted benzimidates will rearrange at different rates.

A mixture of ^{14}C-4-bromophenyl N-phenylbenzimidate (III, R = H) and 4-bromophenyl N-4-tolylbenzimidate (III, R = Me) were rearranged by heating in boiling tetraglyme.[5] The carbon-14-labeled benzimidate was synthesized by brominating uniformly labeled phenol, and then treating the resulting ^{14}C-4-bromophenol with phenylbenziminyl chloride. The two benzimidates should rearrange at comparable rates since the methyl group can exert only a small electronic effect, and the migrating group is 4-bromophenyl in both cases.



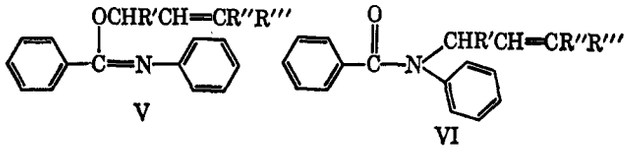
III



IV

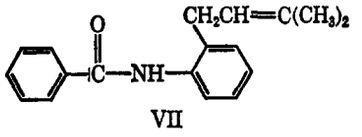
The rearranged mixture of benzoyl-4-bromodiphenylamines IV was separated by oxidizing the benzoyl-N-(4-bromophenyl)-4-toluidine (IV, R = Me) to N-benzoyl-N-(4-bromophenyl)-4-aminobenzoic acid (IV, R = CO_2H). Experiments with the unlabeled compound showed that the optimum conditions for oxidation were boiling with a 10 molar excess of potassium permanganate in pyridine for 10 hr.[6] Oxidation with a larger excess of permanganate for shorter periods gave benzoic acid, and no reaction occurred in aqueous magnesium sulfate solution.[7] Repeated recrystallization of the nonacidic fraction from the oxidation gave a benzoyl-4-bromodiphenylamine of constant specific activity. Comparison with the specific activity of the labeled benzimidate showed that rearrangement had occurred with 96.4 ± 3.4% retention of the activity of the original compound. An *ortho* rearrangement of the migrating group could result in the formation of some N-benzoyl-3-bromodiphenylamine. The presence of this compound in the N-benzoyl-4-(^{14}C-bromo)diphenylamine was tested by mixing the two compounds, and subjecting the mixture to a fractional recrystallization. The recovered N-benzoyl-4-(^{14}C-bromo)diphenylamine had 93.5 ± 2.5% of the activity of the original compound. The Chapman rearrangement must then proceed through an intramolecular transfer of the migrating group.

Allyl N-phenylbenzimidate (V, R′ = R″ = R‴ = H) has been reported to rearrange on heating to give N-allylbenzanilide (VI, R′ = R″ = R‴ = H), and 1-



V VI

methallyl N-phenylbenzimidate (V, R′ = Me, R″ = R‴ = H), rearranged to N-crotylbenzanilide (VI, R′ = R‴ = H; R″ = Me).[8] However, 3,3-dimethylallyl N-phenylbenzimidate (V, R′ = H; R″ = R‴ = Me) afforded N-benzoyl-2-(3,3-dimethylallyl)aniline (VII).[9] The course of the rearrangement of allyl N-



VII

phenylbenzimidate (V, R′ = R″ = R‴ = H) has now been studied using the α-tritioallyl compound

(1) On leave of absence from the Economic Development Administration Laboratory Government of the Commonwealth of Puerto Rico.

(2) R. Roger and D. Neilson, *Chem. Rev.*, **61**, 190 (1961).

(3) A. W. Chapman, *J. Chem. Soc.*, **127**, 1992 (1925).

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(5) O. H. Wheeler, F. Roman, M. Santiago, and F. Quiles, *Can. J. Chem.*, **47**, 503 (1969).

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(V, R′ = T; R″ = R‴ = H). Acrolein was reduced smoothly to 1-tritioallyl alcohol with tritiated sodium borohydride. Reduction with lithium aluminum hydride gave low yields of the carbinol. Reaction of the carbinol with phenylbenzimiminyl chloride afforded the α-tritioallyl benzimidate (V, R′ = T; R″ = R‴ = H). This compound was rearranged by heating alone to 210–215°. The resulting tritio-N-allylbenzanilide [VI, R′ = R″ = H (or T)] was hydroxylated with hydrogen peroxide in the presence of osmium tetroxide. The glycol obtained was then cleaved with periodic acid, and the formaldehyde formed was converted into the dimedone derivative. Comparison of the specific acrivity of the allyl alcohol, allyl benzimidate, allylbenzanilide, and the glycol showed that no loss of activity had occurred during the reactions. The specific activity of the formaldehyde–dimedone derivative was 99.0 ± 1.5% of that of the allyl N-phenylbenzimidate. Thus the activity in the allylbenzanilide was located exclusively in the γ position. The rearrangement must then be entirely intramolecular, proceeding with inversion of the allyl chain, and is analogous to that of the Claissen rearrangement.[10]

Experimental Section[11]

^{14}C-4-Bromophenyl N-Phenylbenzimidate.—Phenol (50 g), dissolved in carbon disulfide (50 ml), was added to ^{14}C-labeled phenol (6.3 mg, 0.1 mCi), dissolved in carbon disulfide (5 ml). Bromine (25.3 ml), in carbon disulfide (25 ml), was added slowly with stirring, and cooling to −10°. After the mixture warmed to room temperature, the carbon disulfide was distilled off. The residual liquid was slowly distilled under reduced pressure through a good fractionating column.[12] The 4-bromophenol obtained had bp 135–138° (25 mm), and crystallized on cooling, mp 63–64° (lit.[12] mp 66°), specific activity (151.9 ± 2.7) × 10^3 cpm/mmol.

A solution of N-phenylbenzimidoyl chloride (5 g) in absolute ether (10 ml) was treated with the dry ^{14}C-labeled 4-bromophenol (4.2 g) in absolute ethanol (15 ml) containing sodium (0.6 g). The reaction mixture was stirred for 15 hr. The solution was then distilled to about half its original volume. The residue was poured into cold water (50 ml) and refrigerated overnight. The solid was filtered and recrystallized from ethanol giving an almost white precipitate (5 g, 75%), mp 80–90° (lit.[4] mp 83–84°), specific activity (150.9 ± 3.2) cpm/mmol.

N-Benzoyl-N-^{14}C-4-bromodiphenylamine.—^{14}C-4-Bromophenyl N-phenylbenzimidate (2 g), dissolved in tetraethylene glycol dimethyl ether (50 ml), was heated at 275° for 4 hr. At the end of this period the solution was poured into water. White crystals were obtained (1.6 g, 80%): mp 178–180° (lit.[5] mp 180–181°); specific activity (1.48.5 ± 2.1) × 10^3 cpm/mmol.

N-Benzoyl-N-(4-bromophenyl)-4-aminobenzoic Acid.—N-Benzoyl-N-4-bromophenyl-4-toluidine (1.7 g)[5] was dissolved in pyridine (3 ml) and water (2 ml), and potassium permanganate (3 g) was added. The resulting mixture was refluxed while stirring for 8 hr when the purple color disappeared. An additional solution of potassium permanganate (3 g) in water (2 ml) was added and the mixture heated for a further 2 hr.[13] The solution was filtered hot, and the precipitated manganese dioxide washed with hot water. The filtrate was concentrated under reduced pressure to about half its volume and filtered again. The filtrate was acidified with 10% hydrochloric acid to pH 6 and allowed to cool, when crystals were obtained (1.0 g, 60%), mp 210°.

Anal. Cald for $C_{20}H_{14}BrNO_3$: C, 60.62; H, 3.56; Br, 20.17; N, 3.54. Found: C, 60.52; H, 3.64; Br, 19.83; N, 3.38.

Oxidation with nine times the above amount of potassium permangante in aqueous pyridine for 6 hr gave only a small amount of benzoic acid. The original compound was recovered unchanged from an oxidation with twice its weight of potassium permanganate in an aqueous solution of magnesium sulfate for 2 or 5 hr.[14]

Mixed Rearrangement.—A mixture of ^{14}C-4-bromophenyl N-phenylbenzimidate (1 g) and 4-bromophenyl N-4-tolylbenzimidate (1 g) in tetraglyme (50 ml) was heated under reflux at 275–280° for 4 hr. The cooled reaction mixture was poured into water, and the precipitate separated and dried. The solid (1.5 g) was dissolved in pyridine (1.5 ml) and water (1 ml), and potassium permanganate (1.5 g) was added. The resulting mixture was refluxed while stirring for 8 hr. An additional solution of potassium permanganate (1.5 g) in water (2 ml) was added and the mixture again heated for 2 hr. The solution was filtered while hot, and the precipitated manganese dioxide washed with hot water. The filtrate was extracted twice with chloroform (5 ml). The chloroform layer was then extracted three times with 5% sodium hydroxide (5 ml). The aqueous layer was acidified with hydrochloric acid giving crystals: mp 298–210°; specific activity (13.9 ± 1.1) × 10^3 cpm/mmol. The residue in the chloroform solution was recrystallized from ethanol to constant mp 178–180° and specific activity (143.2 ± 4.9) × 10^3 cpm/mmol.

^{14}C-Labeled N-benzoyl-4-bromodiphenylamine was mixed with an equal weight of unlabeled N-benzoyl-3-bromodiphenylamine. The mixture was then separated by fractionally crystallizing from ethanol containing a small amount of water, until the melting point and specific activity was constant. The recovered N-benzoyl-N-4-bromodiphenylamine had mp 178–180° and a specific activity of (133.1 ± 3.1) × 10^3 cpm/mmol. The recovered N-benzoyl-3-bromodiphenylamine could not be obtained pure, since its melting point remained at 130° (lit.[5] mp 132–134°) and the specific activity could not be reduced below (10.6 ± 1.1) × 10^3 cpm/mmol.

α-H^3-Allyl N-Phenylbenzimidate.—A solution of tritiated sodium borohydride (1.5 g, 0.1 mC) in triglyme (5 ml) and water (2 ml) was added dropwise to acrolein (2.0 g) in triglyme (20 ml). The mixture was stirred at room temperature for 10 hr, filtered and the mixture fractionally distilled to give α-^{3}H-allyl alcohol (1.5 g, 75%): bp 95–96°; specific activity (703.1 ± 9.2) × 10^3 cpm/mmol.

^{3}H-Allyl alcohol (0.7 g) was added to a suspension of sodium hydride (0.25 g) in dry benzene (10 ml). A solution of N-phenylbenziminyl chloride (2 g) in benzene (10 ml) was added dropwise with stirring. After stirring overnight, water was added, and the product isolated in the usual manner, giving an oil (1.5 g, 70%): bp 118–120° (0.2 mm) [lit.[8] bp 196–198° (112 mm)]; specific activity (702.8 ± 15.1) × 10^3 cpm/mmol.

N-^{3}H-Allyl-N-benzoylaniline.—^{3}H-Allyl N-phenylbenzimidate (1.2 g) was heated without solvent, by means of a silicone oil bath, for 3 hr at 210–215°. The product (1 g, 85%) had bp 188–190° (8 mm) [lit.[8] bp 196–198° (12 mm)], specific activity (702.7 ± 17.6) × 10^3 cpm/mmol.

Degradation of N-^{3}H-Allyl-N-benzoylaniline.—A solution of N-^{3}H-allyl-N-benzoylaniline (1 g) in absolute ether (9 ml) was treated with osmium tetroxide (0.8 g) in ether (16 ml) and anhydrous pyridine (0.7 ml) and then left overnight. The solvent was evaporated under reduced pressure, and the residue was mixed with chloroform (10 ml), and a solution of sodium hydroxide (0.25 g), and mannitol (1 g) in water (30 ml) was added. The mixture was stirred for 1 hr when the chloroform layer was colorless. The brown oil (9.65 g, 56%) obtained by ether extraction had bp 214–215° (12 mm), specific activity (702.7 ± 6.3) × 19^1 cpm/mmol. A solution of the glycol (9.5 g) in water (10 ml) containing periodic acid (0.25 g) was neutralized with sodium bicarbonate, and allowed to stand overnight at room temperature. The mixture was then extracted several times with ether and the organic extract was washed with water. From the aqueous phase formaldehyde was obtained as the dimedone derivative: mp 189–190° (lit.[15] mp 190°), specific activity (6.96.0 ± 6.3) × 10^3 cpm/mmol. An oil was obtained on acidifying the sodium

(10) D. Y. Curtin and H. W. Johnson, *ibid.*, **76**, 2276 (1954).

(11) The ^{14}C and ^{3}H activities were determined with solutions in toluene containing 0.4% PPO and 0.1% POPOP, using a Beckman Model 6860 liquid scintillation counter.

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(13) R. L. Malan and P. M. Dean, *J. Amer. Chem. Soc.*, **69**, 1797 (1947).

(14) C. B. Kremer, *J. Chem. Educ.*, **33**, 71 (1956).

(15) E. C. Horning and M. G. Horning, *J. Org. Chem.*, **11**, 95 (1946).

bicarbonate extract. The oil could not be recrystallized and did not form a solid 2,4-dinitrophenylhydrazone.

Registry No.—^{14}C-4-Bromophenyl N-phenylbenzimidate, 18746-06-0; ^{14}C-4-bromophenol, 18746-07-1; N-benzoyl-N-^{14}C-4-bromodiphenylamine, 18746-08-2; N-benzoyl-N-(4-bromophenyl)-4-aminobenzoic acid, 18753-77-0; α-^{3}H-allyl N-phenylbenzimidate, 18753-78-1; α-^{3}H-allyl alcohol, 18753-79-2; N-^{3}H-allyl-N-benzoylaniline, 18753-80-5.

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Reactions of *t*-Butylperoxy Esters. VIII. The Preparation of Dialkyl *t*-Butylperoxy Phosphates[1]

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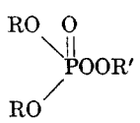
Analytically pure *t*-butylperoxy phosphates, $(RO)_2P(O)OOCMe_3$ (**1**, R = Me, Et, *n*-Pr, *i*-Pr, *n*-Bu, *i*-Bu, *n*-octyl, Ph, $PhCH_2$), are prepared by reaction of the corresponding dialkylchlorophosphates (**2**) with an aqueous potassium hydroxide solution of *t*-butyl hydroperoxide in the presence of petroleum ether (bp 20–40°). Only peroxy esters **1** (R = *n*-Pr, *i*-Pr) are distillable; other methods of purification are presented.

The chemistry of phosphoric acid peroxy esters of general structure **1** has to date received little attention.[2]



1

This scarcity of results is not surprising in view of the lack of suitable methods for preparation of these compounds and the difficulties encountered in their handling.

The first reported peroxy esters of phosphoric acid (**1**) were prepared by Rieche, Hilgetag, and Schramm.[3] Thus dimethyl or diethyl chlorophosphate (**2**, R = Me, Et) were allowed to react with *t*-butyl hydroperoxide (**3**) in the presence of excess anhydrous pyridine at −10 to −20° to produce dimethyl or diethyl *t*-butylperoxy phosphate (**1**, R = Me, Et).

$$\underset{\substack{\mathbf{2}\\ \text{R = Me, Et}}}{(RO)_2P(O)Cl} + \underset{\mathbf{3}}{Me_3COOH} \xrightarrow[-10 \text{ to } -20^\circ]{\text{pyridine}} \underset{\mathbf{1}}{(RO)_2P(O)OOCMe_3} + Py\cdot HCl$$

Harrison and Mageli[4] described a series of peroxy esters (**1**, R = Et, *n*-Bu, *n*-octyl, Ph; R′ = CMe_3, hexyl, cumyl, pinanyl) prepared by the reaction of **2** with hydroperoxides in the presence of aqueous solutions of alkali metal hydroxides. However, satisfactory analyses were obtained only for **1** (R = *n*-Bu, *n*-octyl; R′ = CMe_3).

As part of a general investigation of the chemical and biological properties of **1** it was necessary to develop methods for preparation of analytically pure peroxy ester in quantity.

Rieche and coworkers[3] successfully prepared **1** (R = Me, Et). Although we have been able to reproduce their work, this method is not generally applicable. Distillation of **1** is difficult. Only in the case of **1** (R = *i*-Pr) is it possible to distil 5 g or larger portions in good yield. Therefore, it is requisite that the crude peroxy ester be obtained in a form that is readily purified without distillation. Attempts to remove the excess pyridine by vacuum distillation, washing with water or sulfuric acid, and column chromatography were either unsuccessful or produced low yields of product. Several experiments in which a stoichiometric amount of 2,6-lutidine was substituted for the pyridine were tried. Since lutidine hydrochloride is less soluble than pyridine hydrochloride, removal of the organic base was not so difficult. However, yields of peroxy ester were low and an unidentified contaminant prevented purification.

The procedure of Harrison and Mageli[4] which eliminated the organic base seemed to be advantageous. However, in our hands the reported procedure has failed to yield products free of impurities.

We now report a generally applicable sequence that permits synthesis of **1** (R = Me, Et, *n*-Pr, *i*-Pr, *n*-Bu, *i*-Bu, *n*-octyl, Ph, $PhCH_2$) in yields varying from 30 to 80%. Reaction of chlorophosphate **2** with an aqueous potassium hydroxide solution of *t*-butyl hydroperoxide (**3**) in the presence of petroleum ether (bp 20–40°) produces the corresponding dialkyl *t*-butylperoxy

(1) (a) This investigation was supported by a grant from the Public Health Service, U. S. Department of Health, Education, and Welfare (GM 14932-01). (b) The results were presented in part in a talk at the International Symposium on the Chemistry of Organic Peroxides in Berlin, DDR, Sept 1967.

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(3) (a) A. Rieche, G. Hilgetag, and G. Schramm, *Chem. Ber.*, **95**, 381 (1962); (b) *Angew. Chem.*, **71**, 285 (1959); (c) German Patent (East) 21,489 (1959); (d) German Patent 1,082,895 (1960).

(4) J. B. Harrison and O. L. Mageli, U. S. Patent 2,960,526 (1960).