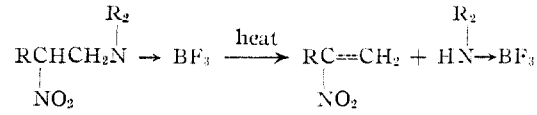

cases better than those reported with the Mannich base hydrochlorides.

In the initial experiments the boron trifluoride complexes were prepared from gaseous boron trifluoride and isolated prior to their pyrolysis (Experimental procedure B). It was found, however, that these complexes were not very stable and frequently decomposed on standing. Accordingly the boron fluoride adducts were prepared *in situ* by addition of an equivalent amount of boron trifluoride etherate to a solution of the Mannich base in an inert solvent. The resulting mixture was then heated under reduced pressure until pyrolysis was complete and the nitroölefin was removed by distillation as it was formed. The yields obtained with this procedure (procedure A) were much better and more reproducible than those obtained using procedure B. The nitroalkenes were identified by determination of physical constants, examination of infrared spectra, and conversion to the *p*-toluidine derivatives.

Experimental[4,5]

Mannich Bases of Nitroalkanes.—The Mannich bases were all prepared according to the directions of Blomquist and Shelley.[2] The physical constants of N-(2-nitropropyl)-piperidine (b.p. 87° (1 mm.), $n^{20}D$ 1.4469) which were determined and reported by these investigators were not confirmed in this Laboratory. Our values for this compound are: b.p. 67–68° (1–1.5 mm.), $n^{20}D$ 1.4650. This nitroamine was also converted to the picrate, m.p. 127–127.5° (recryst. from ethanol).

Anal. Calcd. for $C_{14}H_{19}N_5O_9$: C, 41.89; H, 4.74; N, 17.45. Found: C, 41.68; H, 4.99; N, 17.47.

2-Nitro-1-alkenes.—A summary of the pyrolysis experiments performed by both procedure A (use of inert diluent without isolation of the boron trifluoride complex) and procedure B (pyrolysis of the isolated boron trifluoride complex) is presented in Table I. The preparations of 2-nitropropene by procedure A and 2-nitro-1-butene by procedure B are described in detail. The nitroölefins obtained directly from the pyrolysis reactions were sufficiently pure for most purposes.

2-Nitropropene (Procedure A).—To a stirred solution of 17.2 g. (0.1 mole) of freshly distilled N-(2-nitropropyl)-piperidine in 150 ml. of di-2-ethylhexyl phthalate was added 15.6 g. (0.105 mole) of boron trifluoride etherate. A viscous white liquid separated out on the walls of the flask immediately. The ethyl ether formed in this reaction was removed under reduced pressure at room temperature. The mixture was then heated to 85° at a pressure of 1 mm. with continuous stirring. At this temperature the solution darkened and the 2-nitropropene began to form. The nitroolefin was distilled into a Dry Ice–acetone-cooled receiver as fast as it was formed. The solution was heated to 105° and was maintained at this temperature for one hour. There was obtained in the distillate receiver 6.7 g. (77%) of light green solid which melted on warming to room temperature, $n^{20}D$ 1.4296 (lit.[6] $n^{23}D$ 1.4292). The *p*-toluidine derivative of this nitroölefin was prepared and melted at 81–82° (lit.[2] 81.5–82.5°). The infrared spectrum of 2-nitropropene showed a conjugated nitro band at 1525 cm.$^{-1}$.

2-Nitro-1-butene (Procedure B).—A solution of 34.8 g. (0.2 mole) of freshly distilled N-(2-nitrobutyl)-diethylamine in 150 ml. of dry petroleum ether was saturated with gaseous boron trifluoride at 0–5°. The solid which separated was collected on a filter and washed with petroleum ether. It was then dried in a vacuum desiccator; yield 46.5 g. (96%) of slightly yellow solid, m.p. 50–53°. The boron trifluoride adduct (24.2 g., 0.1 mole) was then heated under a pressure of 1 mm. in a distillation apparatus with a distillate receiver packed in Dry Ice–acetone. Decomposition was observed at 35°. The distillation pot was slowly heated to 60° and was maintained at this temperature for one hour. There was obtained in the receiver 6.3 g. (63%) of 2-nitro-1-butene, $n^{20}D$ 1.4258 (lit.[2] $n^{20}D$ 1.4256). The *p*-toluidine adduct of this nitroölefin was prepared and melted at 68.5–69.5° (lit.[2] m.p. 67.5–68.5°). The infrared spectrum of 2-nitro-1-butene showed a conjugated nitro band at 1522 cm.$^{-1}$.

TABLE I

PYROLYSIS OF MANNICH BASE–BORON TRIFLUORIDE COMPLEXES

Boron trifluoride complex	Nitroolefin, 2-nitro-	Procedure A Yield, %	Procedure A Pyrolysis temp., °C.	Procedure B Yield, %	Procedure B Pyrolysis temp., °C.
N-(2-Nitropropyl)-piperidine	Propene	77	105	48	70
N-(2-Nitrobutyl)-diethylamine	1-Butene	78	100	62	60
N-(2-Nitrobutyl)-dimethylamine	1-Butene	86	100	72	90
N-(2-Nitropentyl)-diethylamine	1-Pentene	90	110	40	80

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(4) All melting and boiling points are uncorrected.

(5) We are indebted to Dr. Keith S. McCallum and Mr. Al Kennedy for infrared interpretations and microcombustion data. The Commercial Solvents Corporation generously supplied us with a sample of 1-nitrobutane.

(6) A. T. Blomquist, W. J. Tapp and J. R. Johnson, THIS JOURNAL, 67, 1519 (1945).

Optical Enantiomorphs of α-Aminoadipic Acid

BY JESSE P. GREENSTEIN, SANFORD M. BIRNBAUM AND M. CLYDE OTEY

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A resolution of racemic α-aminoadipic acid into its optical enantiomorphs has not been recorded. Borsook, *et al.*, reported a preparation of L-α-aminoadipic acid with $[\alpha]^{25}D$ +33.9° for a 5.49% solution in 6 *N* HCl by treating carbobenzoxy-DL-α-aminoadipic acid with aniline and papain, followed by hydrolysis of the anilide and removal of the carbobenzoxy group from the separated L-enantiomorph.[1] No mention was made of the D-enantiomorph.

We have resolved the racemic aminodicarboxylic acid into its optical enantiomorphs by the acylase procedure developed in this Laboratory.[2,3] Chloroacetyl-DL-α-aminoadipic acid was prepared and subjected at *p*H 7.0 to the asymmetric action of hog kidney acylase I to yield L-α-aminoadipic acid and chloroacetyl-D-α-aminoadipic acid. The latter compound yielded D-α-aminoadipic acid after HCl hydrolysis followed by adjustment to *p*H 3.2. For 2% solutions in 5 *N* HCl the $[\alpha]^{25}D$ for the L-isomer was +25.0°, and for the D-isomer −25.0°. The $[\alpha]^{25}D$ for a 6% solution of the D-isomer in 6 *N* HCl was −24.9°. L-α-Aminoadipic acid was

(1) H. Borsook, C. L. Deasy, A. J. Haagen-Smit, G. Keighley and P. H. Lowy, *J. Biol. Chem.*, **176**, 1383 (1948).

(2) S. M. Birnbaum, L. Levintow, R. B. Kingsley and J. P. Greenstein, *ibid.*, **194**, 455 (1952).

(3) J. P. Greenstein, S. M. Birnbaum and L. Levintow, in "Biochemical Preparations," Vol. III, in press.

found to be oxidized by relatively large amounts of *Crotalus adamanteus* L-amino acid oxidase and the optical purity of the D-isomer could be readily determined by the procedure now routine in this Laboratory.[4,5] The D-α-aminoadipic acid was found to contain less than 1 part in 1,000 of the L-isomer. Furthermore, the L-isomer was quantitatively oxidized by the oxidase, thus excluding any appreciable contamination by piperidonecarboxylic acid. We have no explanation for the discrepancy between our rotation values and that of Borsook, *et al.*

Experimental Part

N-Chloroacetyl-DL-α-aminoadipic Acid.—One hundred and sixty-eight grams of aminoadipic acid[6] was treated with chloroacetyl chloride and chilled NaOH in the usual manner. The reaction mixture was acidified to a *p*H of about 0.5 with concd. HCl and extracted several times with ethyl acetate. The combined extracts were dried over Na_2SO_4 and evaporated to dryness *in vacuo*. The residual sirup was dissolved in dry ether from which crystals separated on chilling. The yield of N-chloroacetyl-DL-α-aminoadipic acid was 74 g., m.p. 127° (cor.). After recrystallization from ethyl acetate the m.p. was 129° (cor.). The yield was 31%, but from the aqueous layer 46 g. of unaltered DL-α-aminoadipic acid (N, calcd. 8.7, found 8.6) could be recovered.

Anal.[7] Calcd. for $C_8H_{12}O_5NCl$: N, 5.9; Cl, 14.9. Found: N, 5.8; Cl, 14.6.

Enzymatic Resolution of Chloroacetyl-DL-α-aminoadipic Acid.—Eighty-six and a half grams of chloroacetyl-DL-α-aminoadipic acid was suspended in 2 liters of water and brought into solution at *p*H 7.0 by addition of 2 *N* LiOH. Water was added to bring the final volume to 3,640 cc. (0.1 *M*) and 2.8 g. of acylase I powder was dissolved in the solution. The latter was brought back to *p*H 7.0 by addition of a few drops of LiOH, and placed in a water-bath at 38°.[8] After 10 hours of incubation, manometric ninhydrin analyses on an aliquot of the digest revealed 50% hydrolysis of the racemate. Further incubation of the digest up to 24 hours did not result in a change of this figure. Accordingly, acetic acid was added to *p*H 5, and the protein filtered off with the aid of Norit. The filtrate was evaporated to about 400 cc. *in vacuo*, and the small amount of protein which flocculated was again removed by filtration. The filtrate was treated dropwise with concd. HCl to *p*H 3.2. A copious crystallization of L-α-aminoadipic acid quickly ensued. Twice the volume of absolute ethanol was added, and the mixture chilled at 5° for several hours. The L-isomer was filtered and washed with ethanol, and the mother liquor and washings combined and set aside for the preparation of the D-isomer. The yield of L-α-aminoadipic acid was 27 g. or 93%; $[\alpha]^{25}D$ +24.6° (2% in 5 *N* HCl). It was recrystallized by adding sufficient boiling water to dissolve the solid, filtering rapidly through a heated filter, and chilling quickly in a −20° alcohol–water-bath to 5°. The final yield of pure L-α-aminoadipic acid was 22 g. or 76%; $[\alpha]^{25}D$ +25.0° (2% in 5 *N* HCl).

Anal. Calcd. for $C_6H_{11}NO_4$: C, 44.7; H, 6.9; N, 8.7. Found: C, 44.8; H, 6.9; N, 8.7.

The combined alcoholic mother liquor and washings contained chloroacetic acid, chloroacetyl-D-α-aminoadipic acid, and traces of unprecipitated L-α-aminoadipic acid. It was evaporated *in vacuo* nearly to dryness, concd. HCl was added with careful cooling to a *p*H of about 0.5, and the acid solution extracted several times with ethyl acetate. The combined extracts were dried over Na_2SO_4 and evaporated *in vacuo* to a residual oil. The oil was taken up in a liter of dry acetone, filtered, the acetone removed by a stream of air, and the residue dissolved in 500 cc. of 2 *N* HCl. The solution was refluxed for 2 hours, decolorized with a little Norit, and evaporated *in vacuo* to a thick sirup. The sirup was dissolved in 400 cc. of H_2O, and the solution treated dropwise with pyridine to *p*H 3.2. The D-α-aminoadipic acid which appeared was recrystallized from water as described for the L-isomer. Yield of pure product was 12 g. or 42%; $[\alpha]^{25}D$ was −25.0° for a 2% solution, and −24.9° for a 6% solution, in 6 *N* HCl.

Anal. Found: C, 44.5; H, 7.0; N, 8.7.

Optical Purity of D-α-Aminoadipic Acid.—One thousand micromoles of D-α-aminoadipic acid at *p*H 7.2, and in the presence of catalase, was practically inert to 30 mg. of *Crotalus adamanteus* venom. When, under the same conditions, 1 micromole of the L-isomer was mixed at the beginning of the run with the 1,000 micromoles of the D-isomer, there was an oxygen consumption equivalent to that of the 1 micromole of L-isomer added. The reaction reached completion in about 1 hour. There was evidently less than 1 part of the L-isomer present in 1,000 parts of the D. Ten micromoles of the L-isomer alone in the presence of large amounts of the venom and catalase, also consumed close to the theoretical amount of oxygen. The D-isomer itself was completely inert to hog kidney D-amino acid oxidase, and therefore the optical purity of the L-isomer could not be determined in this fashion.[4]

D-Piperidonecarboxylic Acid.—A solution of 2 g. of D-α-aminoadipic acid in 100 cc. of H_2O was refluxed, and aliquots removed at intervals for manometric ninhydrin analyses. After two hours an equilibrium value was established of 73% piperidonecarboxylic acid and 27% aminodicarboxylic acid. The *p*H of the solution was 3.2. On chilling, about half of the aminoadipic acid crystallized. It was filtered off, and the mother liquor evaporated to dryness. The residue was extracted several times with hot alcohol, the extracts were combined, filtered and evaporated to a low bulk from which the D-piperidonecarboxylic acid crystallized as large prisms. The yield was 80%; $[\alpha]^{25}D$ − 16.5° (2% in H_2O) and −41.5° (2% in 6 *N* HCl).

Anal. Calcd. for $C_6H_9O_3N$: C, 50.4; H, 6.3; N, 9.8. Found: C, 50.3; H, 6.3; N, 9.8.

No racemization of the piperidonecarboxylic acid occurred for when 250 mg. was refluxed for 2 hours with 25 cc. of 2 *N* HCl, and the resulting D-α-aminoadipic acid isolated by treatment with pyridine to *p*H 3.2 (yield 230 mg.), the latter possessed $[\alpha]^{25}D$ − 25.1° (2% in 6 *N* HCl).

Anal. Found: C, 44.5; H, 7.0; N, 8.7.

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(4) A. Meister, L. Levintow, R. B. Kingsley and J. P. Greenstein, *J. Biol. Chem.*, **192**, 535 (1952).

(5) S. M. Birnbaum and J. P. Greenstein, *Archiv. Biochem. Biophys.*, **39**, 108 (1952).

(6) Donated by Dr. Alton Meister.

(7) Analyses by R. J. Koegel and staff of this Laboratory.

(8) At *p*H 7.0 and 38°, the rate of hydrolysis of this substrate by crude hog kidney aqueous homogenate is 1.5 micromoles per hour per mg. *N*; with acylase I this rate is 45. Since the reaction is zero order, the amount of acylase added to the solution should be sufficient to hydrolyze the L-component of the racemate in about 8 hours.

C^{14} Tracer Studies in the Rearrangements of Unsymmetrical α-Diketones. III. *p*-Methoxybenzylideneacetophenone Oxide[1]

BY EDWARD C. HENDLEY[2a] AND O. KENTON NEVILLE[2b]

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Benzylideneacetophenone oxide, labeled with carbon-14 in the carbonyl group was found to rearrange in alkaline medium to 2-hydroxy-2,3-diphenylpropionic acid, labeled exclusively in the carbinol group.[3] These results if interpreted as due to a benzilic acid type of rearrangement of intermediate benzyl phenyl diketone suggest either a very

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(2) (a) Member of the Research Participation Program sponsored jointly by the Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies; permanent address, Dept. of Chemistry, Mississippi State College, State College, Miss. (b) Nuclear Instrument and Chemical Corp., Chicago, Ill.

(3) C. J. Collins and O. K. Neville, THIS JOURNAL, **73**, 2471 (1951).