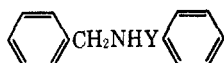


From an analysis of the results in Table III it appears in the reduction of compounds of the type



where Y is an aliphatic chain and chlorine is attached to either or both rings, that dehalogenation should be the expected reaction. Debenzylation which may accompany loss of halogen probably is a secondary reaction which takes place after dehalogenation.

Experimental Section⁴

The following is typical of the preparation of the Schiff bases. The ensuing reduction of III to XI is an example of the procedure used to obtain the secondary amines listed in Table II.

N-(4-Chlorobenzylidene)-2-phenethylamine (III).—4-Chlorobenzaldehyde (42.15 g, 0.3 mole), from an unopened bottle or freshly distilled, was added to a solution of 36.3 g (0.3 mole) of 2-phenethylamine in 200 ml of thiophene-free benzene. In a few minutes the solution became cloudy and globules of water began to appear. The mixture was heated and concentrated under reduced pressure until the removal of water was complete (about 1 hr). The residue was then distilled or recrystallized from a suitable solvent.

N-(4-Chlorobenzyl)-2-phenethylamine (XI).—A solution of 0.3 mole of III in 200 ml of 95% ethyl alcohol was hydrogenated in the presence of 3.0 g of 5% platinum on carbon⁵ at room temperature and 2-atm pressure. After uptake of hydrogen was complete (less than 2 hr), the solution was filtered from the catalyst and the catalyst was washed with alcohol. After concentration of the filtrates the residue was fractionated (see Table II for results).

The amines listed absorbed carbon dioxide and had to be analyzed shortly after distillation.

Hydrogenolyses of the Bases in Table II.—The reduction of XI is a typical example. A solution of 24.55 g (0.1 mole) of XI in 150 ml of glacial acetic acid was hydrogenated in the presence of 2.5 g of 5% palladium on activated carbon⁵ under 2.5 atm of pressure. Uptake of hydrogen was fairly rapid but slowed down at 75%. At this point the reaction was warmed to dissolve precipitated material. Uptake for 1 equiv was complete in about 3 hr. In most reductions a considerable amount of precipitate was present. It was necessary to heat the reaction mixture, filter hot, and extract the precipitate and catalyst further with hot aqueous or 95% alcohol. The combined filtrates were concentrated under reduced pressure. The residue was suspended in water and the mixture was stirred and made strongly basic with 40–50% sodium hydroxide solution. In some instances it was necessary to warm the mixture to completely convert the salt to base. After cooling, the mixture was thoroughly extracted with benzene and dried over anhydrous magnesium sulfate. After removal of the drying agent the solution was concentrated. A sample of the oily or sometimes solid residue was submitted for chromatographic analysis.

In a few experiments the reductions were run in 90–95% alcohol containing 3 molar equiv of hydrochloric acid. Work-up was essentially the same. However when hydrochloric acid was used heavy precipitation took place immediately upon the addition of it to the solution before reduction.

In the hydrogenation of 4-chlorodibenzylamine hydrochloride in methanol the material did not dissolve completely. When uptake of hydrogen was interrupted at 2 equiv some water was added to dissolve the precipitate. After removal of catalyst the solution was made strongly basic with sodium hydroxide and then submitted for chromatographic analysis. In the reduction of the base precipitation occurred as reduction proceeded. The same procedure was followed to get results of chromatography.

(4) Microanalyses were carried out by Mr. O. F. Kolsto and Mr. V. Rauschel and their associates. Chromatography (glpc) of the products of reduction were run by Mr. P. F. Helgren with known standards. The author is grateful to these men. The unit was an F and M Model 810-29 equipped with a thermal conductivity detector. Column, 4 ft, silicone SE 30, 10% on Anakrom A, 80–90 mesh; temperature, 250° (injector), 240° (detector); carrier, helium, 80 cc/min.

(5) Available from Engelhard Industries, Newark, N. J.

The Reaction of Cyanomethylenephosphoranes with Carbon Disulfide

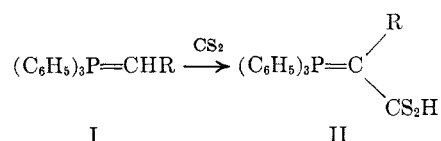
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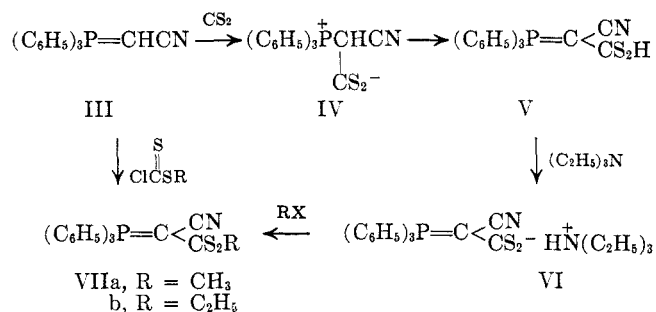
Although methylenephosphoranes have been studied extensively in recent years, little is known about the reaction of these compounds with carbon disulfide.¹ The only recorded examples involve disubstituted methylenetriphenylphosphoranes which are reported to give the Wittig products, namely, thioketenes and triphenylphosphine sulfide. Diphenylmethylenetriphenylphosphorane, for example, is converted to polymeric diphenylthioketene,² and fluorenylidetriphenylphosphorane gives the corresponding dimeric thioketene.³

The present report deals with the reaction of carbon disulfide with monosubstituted methylenephosphoranes (I) to give the dithiocarboxylic acids (II). When



phosphoranes of type I in which R = CO₂CH₃, CO₂-C₂H₅, CC₆H₅, C₆H₃(NO₂)₂, 2,4 were treated with excess carbon disulfide at room temperature for 24 hr, no reaction occurred. In the case where R = C₆H₅, reaction was immediate and complete under similar conditions; however, the only identifiable product was triphenylphosphine sulfide, indicating that a Wittig-type reaction had occurred. In no case was dithiocarboxylic acid II detected.

In contrast, cyanomethylenetriphenylphosphorane (III) gave a 98% yield of the dithiocarboxylic acid V. Presumably, the reaction proceeds *via* the zwitterion IV which then tautomerizes to V. Compound V dis-



solves readily in 0.1 N aqueous sodium hydroxide solution and is regenerated quantitatively on acidification with dilute hydrochloric acid. The infrared spectrum of V exhibits a sharp, strong band at 2200 cm⁻¹, characteristic for a conjugated nitrile function.

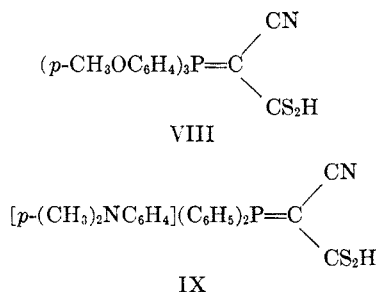
(1) A. Maercker, *Org. Reactions*, **14**, 385 (1965).

(2) H. Staudinger, G. Rathsam, and F. Kjelsberg, *Helv. Chim. Acta*, **3**, 853 (1920).

(3) A. Schönberg, E. Frese, and K.-H. Brosowski, *Chem. Ber.*, **95**, 3077 (1962).

When the reaction of phosphorane III with carbon disulfide was conducted in the presence of triethylamine, the triethylammonium salt VI was obtained. This salt is readily converted to alkyl esters of V on treatment with alkyl halides. Thus, with methyl iodide the ester VIIa is isolated in 99% yield. Confirmation of structure VII was obtained by an independent synthesis involving the condensation of III with alkyl chlorodithioformates (analogous to the method of Bestmann and Schulz⁴ using alkyl chloroformates).

In the same way, the dithiocarboxylic acids VIII and IX were prepared from the reaction of carbon disulfide



with the corresponding cyanomethylenetriarylphosphoranes. They dissolve readily in dilute, aqueous base and show strong absorption at 2200 cm^{-1} .

Experimental Section⁵

α -Dithiocarboxy- α -cyanomethylenetriphenylphosphorane (V).—To a solution of 7.08 g (0.0235 mole) of cyanomethylenetriphenylphosphorane⁶ (III) in 100 ml of chloroform was added 160 ml of carbon disulfide. The solution was allowed to stand at room temperature for 24 hr and then evaporated to dryness under vacuum. The bright yellow, crystalline, dithiocarboxylic acid V weighed 8.68 g (98%) and melted at 159–162° dec. A sample recrystallized from chloroform–petroleum ether (bp 30–60°) had a melting point of 162–164° dec.

Anal. Calcd for $\text{C}_{21}\text{H}_{18}\text{NPS}_2$: C, 66.82; H, 4.27; N, 3.71; P, 8.21; S, 16.99. Found: C, 66.64; H, 4.15; N, 3.89; P, 8.12; S, 16.88.

Triethylammonium Salt (VI) of V.—A solution of 4.52 g (0.015 mole) of cyanomethylenetriphenylphosphorane (III) in 40 ml of chloroform, to which had been added 2.8 ml (0.020 mole) of triethylamine and 1.2 ml (0.020 mole) of carbon disulfide, was allowed to stand overnight at room temperature. The solution was then evaporated to dryness under vacuum and the residue was slurried in benzene and filtered to give 5.38 g (75%) of the canary-yellow triethylammonium salt VI, mp 140–150° dec. An analytical sample was obtained by dissolving the salt in chloroform, reprecipitating with petroleum ether, filtering, and washing with benzene, mp 145–150° dec.

Anal. Calcd for $\text{C}_{27}\text{H}_{31}\text{N}_2\text{PS}_2$: N, 5.85; P, 6.47; S, 13.40. Found: N, 6.09; P, 6.41; S, 13.13.

α -Dithiocarbomethoxy- α -cyanomethylenetriphenylphosphorane (VIIa).—A solution of 3.00 g (0.00627 mole) of the triethylammonium salt VI and 1.07 g (0.00753 mole) of methyl iodide in 20 ml of chloroform was allowed to stand at room temperature overnight. The solvent was removed under vacuum and benzene was added to the residue. Triethylamine hydroiodide was removed by filtration and the benzene filtrate was evaporated to dryness to give 2.43 g (99%) of the pale yellow phosphorane VIIa, mp 228–235°. An analytical sample recrystallized from methanol and benzene–petroleum ether melted at 240–241°.

Anal. Calcd for $\text{C}_{22}\text{H}_{19}\text{NPS}_2$: C, 67.49; H, 4.63; N, 3.58; P, 7.91; S, 16.37. Found: C, 67.28; H, 4.66; N, 3.62; P, 8.01; S, 16.44.

A solution of 6.03 g (0.020 mole) of cyanomethylenetriphenylphosphorane (III) and 1.52 g (0.012 mole) of methyl chlorodithioformate⁷ in 150 ml of anhydrous benzene was heated on the steam bath for 2 hr. The phosphonium chloride was filtered off and the filtrate was evaporated to dryness. The residue was triturated with methanol and the solid which formed was filtered off to give 1.50 g (38%) of a product, mp 225–230°. Two recrystallizations from benzene–petroleum ether raised the melting point to 238–240°. The infrared spectrum of this compound was identical with that of VIIa and a mixture melting point with VIIa showed no depression.

α -Dithiocarbomethoxy- α -cyanomethylenetriphenylphosphorane (VIIb).—The ethyl ester was prepared in the same manner as that described for the methyl ester above. From 3.00 g (0.00627 mole) of VI and 1.17 g (0.00750 mole) of ethyl iodide in 20 ml of chloroform there was obtained 2.50 g (98%) of VIIb, mp 196–202°. Recrystallization from methanol and benzene–petroleum ether gave an analytical sample, mp 206–207°.

Anal. Calcd for $\text{C}_{23}\text{H}_{20}\text{NPS}_2$: N, 3.45; P, 7.64; S, 15.81. Found: N, 3.63; P, 7.60; S, 15.95.

Similarly, a solution of 3.01 g (0.010 mole) of cyanomethylenetriphenylphosphorane (III) and 0.77 g (0.0055 mole) of ethyl chlorodithioformate⁷ in 50 ml of anhydrous benzene, when heated on the steam bath for 2 hr, gave 0.51 g (25%) of a solid, mp 202–205°. Recrystallization from methanol gave a product, mp 206–207°, identical by infrared and mixture melting point with VIIb.

Cyanomethyltris(*p*-methoxyphenyl)phosphonium Chloride.—A mixture of 9.25 g (0.0262 mole) of tris(*p*-methoxyphenyl)phosphine⁸ and 3.16 g (0.0419 mole) of chloroacetonitrile in 100 ml of anhydrous benzene was refluxed for 2 days. The phosphonium salt was filtered off and recrystallized from methanol–ether to give 8.76 g (78%) of the phosphonium chloride, mp 204–206°.

Anal. Calcd for $\text{C}_{23}\text{H}_{23}\text{ClNO}_3\text{P}$: Cl, 8.29; N, 3.27; P, 7.24. Found: Cl, 8.06; N, 3.53; P, 7.43.

Cyanomethylenetris(*p*-methoxyphenyl)phosphorane.—To a solution of 5.50 g (0.0129 mole) of cyanomethyltris(*p*-methoxyphenyl)phosphonium chloride in 50 ml of water cooled to 10° was added just enough of a cooled solution of 2 *N* sodium hydroxide to make the reaction mixture slightly basic. The gum which separated was taken up in chloroform and the chloroform was washed, dried, and evaporated. The residue was triturated with ether and the solid that formed was filtered to give 3.69 g (73%) of the phosphorane, mp 109–113°. An analytical sample recrystallized from benzene–ether melted at 118–120°.

Anal. Calcd for $\text{C}_{23}\text{H}_{22}\text{NO}_3\text{P}$: N, 3.58; P, 7.91. Found: N, 3.70; P, 7.69.

α -Dithiocarboxy- α -cyanomethylenetris(*p*-methoxyphenyl)phosphorane (VIII).—A solution of 0.70 g (0.00179 mole) of cyanomethylenetris(*p*-methoxyphenyl)phosphorane in 12 ml of chloroform, to which had been added 20 ml of carbon disulfide, was allowed to stand at room temperature for 24 hr. The mixture was evaporated to dryness under vacuum and the residue was triturated with petroleum ether and filtered to give 0.76 g (91%) of the yellow dithiocarboxylic acid VIII, mp 100–120° dec. Recrystallization from benzene–petroleum ether gave a sample melting at 125–128° dec.

Anal. Calcd for $\text{C}_{24}\text{H}_{22}\text{NO}_3\text{PS}_2$: P, 6.62; S, 13.71. Found: P, 6.66; S, 13.60.

Cyanomethyl(*p*-dimethylaminophenyl)diphenylphosphonium Chloride.—A solution of 15.0 g (0.049 mole) of *p*-dimethylaminophenyldiphenylphosphine⁹ and 4.2 g (0.056 mole) of chloroacetonitrile in 200 ml of anhydrous benzene was refluxed for 16 hr. The solid was filtered and recrystallized from chloroform–benzene to give 14.9 g (80%) of the phosphonium salt, mp 279–281°.

Anal. Calcd for $\text{C}_{22}\text{H}_{22}\text{ClN}_2\text{P}$: Cl, 9.31; N, 7.35; P, 8.13. Found: Cl, 9.66; N, 7.27; P, 7.94.

Cyanomethylene(*p*-dimethylaminophenyl)diphenylphosphorane.—To a cooled solution of 1.69 g (0.00443 mole) of cyanomethyl(*p*-dimethylaminophenyl)diphenylphosphonium chloride in 20 ml of water was added 50 ml of a 0.1 *N* sodium hydroxide solution. The resulting solid was filtered, washed thoroughly with water, and dried to give 1.12 g (73%) of the phosphorane, mp 198–202°. An analytical sample recrystallized from chloroform–petroleum ether had mp 202–204°.

(4) H. J. Bestmann and H. Schulz, *Ann.*, **674**, 11 (1964).

(5) Melting points are uncorrected. Infrared spectra were determined in chloroform solution using a Perkin-Elmer Model 137 Infracord.

(6) S. Trippett and D. M. Walker, *J. Chem. Soc.*, 3874 (1959).

(7) H. C. Godt, Jr., and R. E. Wann, *J. Org. Chem.*, **26**, 4047 (1961).

(8) O. Neunhoeffer and L. Lamza, *Chem. Ber.*, **94**, 2514 (1961).

(9) S. Trippett and D. M. Walker, *J. Chem. Soc.*, 2130 (1961).

Anal. Calcd for $C_{22}H_{21}N_2P$: N, 8.13; P, 9.00. Found: N, 8.17; P, 8.98.

α -Dithiocarboxy- α -cyanomethylene(*p*-dimethylaminophenyl)-diphenylphosphorane (IX).—A solution of 1.50 g (0.00435 mole) of cyanomethylene(*p*-dimethylaminophenyl)diphenylphosphorane in 25 ml of chloroform, to which had been added 40 ml of carbon disulfide, was allowed to stand at room temperature for 24 hr. Upon evaporation of the solvents under vacuum 1.79 g (98%) of the yellow dithiocarboxylic acid IX was obtained, mp 125–135° dec. An analytical sample recrystallized from benzene-ether melted at 136–139° dec.

Anal. Calcd for $C_{23}H_{21}N_2PS_2$: N, 6.66; P, 7.37; S, 15.25. Found: N, 6.65; P, 7.30; S, 15.39.

Acknowledgment.—The authors wish to express their gratitude to Professor Nathan Kornblum, Purdue University, for reading and commenting upon the original manuscript. We are also greatly indebted to Mrs. Barbara Artman of the Analytical Chemistry Department for the microanalyses.

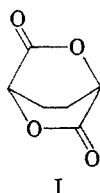
On the Ring Closure of Some 2,5-Dibromoadipic Acids

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Le Sueur² heated *meso*-2,5-dihydroxyadipic acid and obtained water and a lactone-lactide. However, heating racemic-2,5-dihydroxyadipic acid afforded the racemic dilactone (I). Marvel and collaborators³ also

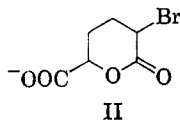


I

prepared I by heating the racemic acid.

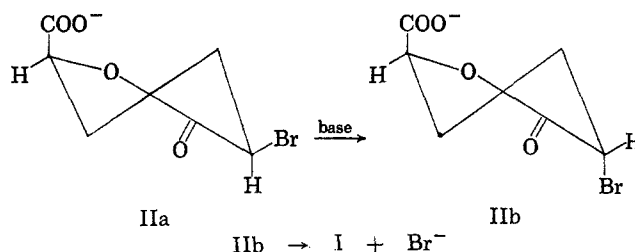
In connection with some biological studies of derivatives of the 2,5-dibromoadipic acids, the behavior of these acids with sodium carbonate in refluxing acetonitrile has been examined. It has been found that, irrespective of the acid (racemic, *meso*, active), the reaction mixture affords as one of the end products the dilactone I in 43% yield.

These results can be rationalized by a reaction scheme which must involve the intermediate δ -lactone (II)⁴



II

which would probably adopt the half-chair conformation⁵ to give the final product. By a backside dis-



placement with inversion of configuration, IIb is changed into I. Epimerization at the brominated carbon in IIa *via* base-catalyzed enolization could give rise to IIb. Such an epimerization is conformationally reasonable and involves quasi-axial Br \rightarrow quasi-equatorial Br in a half-chair ring. Experimentally it was found that dilactone formation is slower for the *meso* acid.

Freudenberg and collaborators⁶ heated (+)-2,5-dihydroxyadipic acid and obtained the (+)-dilactone. In view of this work it was of interest to carry out reactions with the active dibromoadipic acids. We have found that (+)-2,5-dibromoadipic acid yields some (+)-dilactone and, similarly, (-)-2,5-dibromoadipic acid affords some (-)-dilactone. Based on the *assumption* that the dibromo acids and the dihydroxy acids with the same sign of optical rotation have the same configuration an interesting mechanism can be considered for the formation of the active dilactones from the active dibromo acids. It would involve a double inversion (the first inversion brought about by neighboring group participation by the carboxylate ion to form an α -lactone) with retention of configuration⁷ to give the δ -lactone IIb. The active dilactone is then formed from IIb through a backside displacement. The *meso* acid would also undergo a double inversion (the first inversion brought about by neighboring group participation by the carboxylate ion to form an α -lactone) with retention of configuration to give the δ -lactone IIa. By means of a base-catalyzed enolization and epimerization at the brominated carbon, IIa is converted to IIb. Experimentally it happens that there is also retention of the sign of rotation for the optically active dibromo acids.

For the active dihydroxy acid two intramolecular esterifications afford the active dilactone. No inversion of configuration is possible because bonds to the asymmetric carbon atoms are not involved and again there is retention of the sign of rotation. This also explains the fact that the *meso*-dihydroxy acid is not a suitable material for making the dilactone, since inversion would be necessary.

Experimental Section

Materials.—The racemic and *meso*-2,5-dibromoadipic acids were prepared by the procedure of Holmberg and Muller.⁸ The resolution of *rac*-2,5-dibromoadipic acid was carried out according to Holmberg and Muller.⁸ The acetonitrile was certified reagent from Fisher Scientific Co.

Dilactone from *rac*-2,5-Dibromoadipic Acid.—Powdered, anhydrous sodium carbonate (1.75 g) was slowly added to a solu-

(5) It has been suggested that δ -lactones will adopt a half-chair conformation whenever possible [K. K. Cheung, K. H. Overton, and R. A. Sim, *Chem. Commun.*, 634 (1965)], permitting the resonance of OC(=O) system.

(6) K. Freudenberg, W. F. Bruce, and E. Gauf, *Ann.*, **510**, 209 (1934).

(7) W. A. Cowdrey, E. D. Hughes, and C. K. Ingold, *J. Chem. Soc.*, 1208 (1937); E. Grunwald and S. Winstein, *J. Am. Chem. Soc.*, **70**, 841 (1958).

(8) B. Holmberg and E. Muller, *Ber.*, **58B**, 1601 (1925); see also, C. K. Ingold, *J. Chem. Soc.*, **119**, 951 (1921).

(1) (a) To whom correspondence should be addressed at the Union Carbide Corp., Chemicals Division, Tarrytown, N. Y.; (b) Department of Chemistry, University of Saskatchewan, Regina Campus.

(2) H. R. Le Sueur, *J. Chem. Soc.*, **93**, 718 (1908).

(3) C. S. Marvel, E. D. Weil, L. B. Wakefield, and C. W. Fairbanks, *J. Am. Chem. Soc.*, **75**, 2327 (1953).

(4) This lactone was not isolated. The infrared spectrum of the reaction mixture supports the structure of an intermediate δ -lactone.