175° although slight discoloration occurred in the latter two cases.

Condensation of Methacrylyl Chloride and Cyclopentadiene.—A mixture of 5.0 g. (0.048 mole) of methacrylyl chloride, prepared from glacial methacrylic acid and thionyl chloride, 6.6 g. (0.1 mole) of cyclopentadiene and 0.1 g. *p-t*-butylcatechol was kept in a sealed glass tube for a week at room temperature. Distillation of the black oil gave a 61% yield of heart fraction, b.p. 126° (95 mm.), $n^{22}D$ 1.4930, d^{29}_4 1.1227; lit.[3] for the chloride prepared from mixed acid adducts $n^{20}D$ 1.4950.

A mixture of 10 ml. of 10% aqueous potassium hydroxide and 1.12 g. (6.6 mmoles) of the acid chloride adduct was heated at 55–60° for 10 minutes. A small amount of tar was removed by filtration, and acidification gave 1.07 g. of acid, m.p. 60–63°. Recrystallization gave 0.85 g. of mixed crystals which were separated manually; 60% (0.51 g.) melted at 93–94° and this melting point was not depressed with samples of I previously obtained. The remaining 40% (0.34 g.) melted at 78–79° and showed no melting point depression when mixed with II.

2-Methylbicyclo[2.2.1]-5-heptene-2-carboxaldehyde.—A mixture of 285 g. (4.06 moles) of methacrolein, 225 g. (3.4 moles) of cyclopentadiene and 1 g. of *p-t*-butylcatechol was heated in a 2-l. steel bomb at 150–155° for 11 hours. An exothermic reaction occurred at about 95° when the reactants were heated. Distillation through an 18" Vigreux column gave 388.8 g. (84%) of adduct, b.p. 80–85° (31 mm.). Cooling and decantation gave three fractions: 22%, m.p. 55–60°; 28%, m.p. 20–45°, and 50%, m.p. −5 to +13°.

Anal. Calcd. for $C_9H_{12}O$: C, 79.37; H, 8.88. Found for the first fraction: C, 79.42; H, 8.80. For the last fraction: C, 79.41; H, 8.66.

Other preparations conducted at slightly higher temperatures gave products containing less of the higher melting (*exo*) isomer while runs conducted under less severe conditions gave increased amounts of this isomer.

When the crude product was heated at atmospheric pressure to a temperature of 180–195°, a distillate consisting of both methacrolein and cyclopentadiene came over at a head temperature of 58°.

A 2.72-g. (0.02 mole) sample of the third fraction above was oxidized with silver oxide, and 1.95 g. (65%) of crude I was obtained, m.p. 88–91°. Recrystallization from 50% acetic acid gave 1.4 g. (46%), m.p. 95–96°, which gave no melting point depression with I obtained previously.

Oxidation of the first fraction gave 2.3 g. of crude II, m.p. 70–76°. Recrystallization raised the melting point to 79–80°, yield 1.8 g. (60%). A mixed melting point with II was not depressed.

When 21 g. of methacrolein, 24 g. of cyclopentadiene and a tenth gram of inhibitor were heated in a sealed tube at 170° for 10 hours, more than the usual amount of methacrolein was recovered and a relatively small amount of adduct was obtained. In addition 3 g. of product was obtained, b.p. 170–178° (50 mm.), $n^{20}D$ 1.5242, d^{20}_4 1.0718. This was believed to be **2-methyl-1,2,3,4,5,8,9,10-octahydro-1,4,5,8-dimethanonaphthalene-2-carboxaldehyde.**

Anal. Calcd. for $C_{14}H_{18}O$: C, 83.12; H, 8.97; *MR*, 57.62. Found: C, 83.93; H, 8.71, *MR*, 57.75.

A 2,4-dinitrophenylhydrazone formed in 86% yield, m.p. 208–210°. After two recrystallizations from ethanol the m.p. was raised to 218–219°, yield 75%.

Anal. Calcd. for $C_{20}H_{22}N_4O_4$; N, 14.65. Found: N, 14.49.

Acknowledgment.—The analyses were performed by Galbraith Laboratories. The methacrylamide and methracylic acid were gifts of the Rohm and Haas Co. The authors wish to thank Dr. W. J. Potts of the Dow Chemical Co. for running and interpreting the spectrum of the hydroxy lactone.

BOULDER, COLORADO

[CONTRIBUTION FROM ABBOTT LABORATORIES]

Reactions of α,α-Diphenyl-β-propiolactone with Amines and Thiols

BY H. E. ZAUGG, H. J. GLENN, R. J. MICHAELS, R. U. SCHOCK AND L. R. SWETT

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The reactions of α,α-diphenyl-β-propiolactone with four heterocyclic secondary amines, two primary amines, with the sodium salts of ethyl mercaptan and of thiophenol and with thiourea are described and compared with analogous reactions of β-propiolactone itself. The conversion of products of these reactions to compounds of potential pharmacological interest is reported.

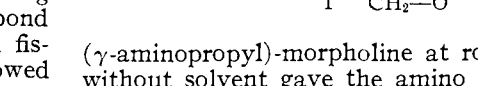
The seemingly capricious nature of the aminolysis reaction of β-propiolactone has been demonstrated by Gresham and co-workers.[1] Three principal factors, namely, solvent, mode of combination of the reactants and nature of the amine used, were found to be operative in determining whether hydroxy amides (carbonyl–oxygen bond fission) or β-amino acids (alkyl–oxygen bond fission) are formed. Hurd and Hayao[2] later showed that aromatic amines tend to react with β-propiolactone to give almost exclusively the corresponding amino acids. In contrast, a more recent study[3] with β-(*p*-nitrophenyl)-β-propiolactone showed that this β-hindered lactone reacts with most amines, regardless of conditions, to give β-hydroxy amides. Only benzylamine and cyclohexylamine give appreciable yields of the corresponding amino acids, and then only under carefully controlled conditions.

(1) T. Gresham, J. Jansen, F. Shaver, R. Bankert and F. Fiedorek, THIS JOURNAL, **73**, 3168 (1951).

(2) C. Hurd and S. Hayao, *ibid.*, **74**, 5889 (1952).

(3) A. Dornow and E. Schumacher, *Arch. Pharm.*, **286**, 205 (1953).

The present work extends the study of these reactions to the α-hindered lactone, α,α-diphenyl-β-propiolactone (I).[4] Reaction of I with excess N-

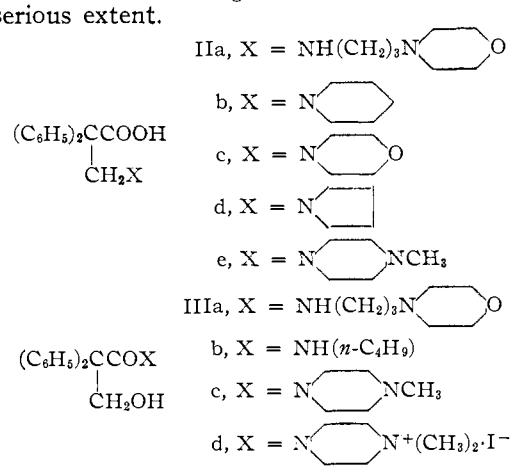


I

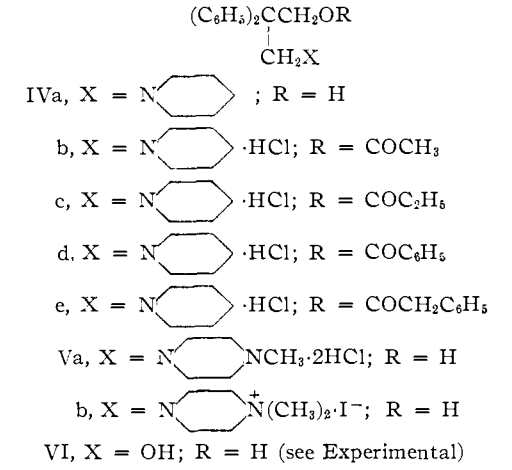
(γ-aminopropyl)-morpholine at room temperature without solvent gave the amino acid IIa in 60% yield and the hydroxy amide IIIa in 12% yield. From the reaction with *n*-butylamine, only the hydroxy amide IIIb could be isolated albeit in only 45% yield. The four heterocyclic amines piperidine, morpholine, pyrrolidine and N-methylpiperazine gave the corresponding amino acids, IIb, c, d and e, as the only isolable products, the first three in high yields (80–90%) but the last in only 46% yield. Employment of acetonitrile as solvent seemed to have little influence on the course of these amine reactions. However, non-polar media, such

(4) H. Zaugg, THIS JOURNAL, **72**, 2998 (1950).

as ether or even boiling benzene, retarded them to a serious extent.

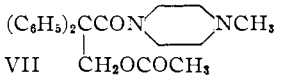


For the purpose of pharmacological evaluation, the two amino acids IIb and IIe were reduced with lithium aluminum hydride to the amino carbinols IVa and Va, respectively. The four O-acyl derivative IVb, c, d, and e were then prepared from IVa, and the methiodide Vb was made from Va.



VI, X = OH; R = H (see Experimental)

The hydroxy amide IIIc and its monomethiodide IIId were prepared from α-phenyltropic acid[5] by acetylation of the hydroxyl group followed by conversion to the acid chloride and reaction with N-methylpiperazine to give the acetoxy amide VII which readily hydrolyzed to IIIc. All attempts to prepare the acid chloride of O-acetyl-α-phenyltropic acid directly from the β-lactone I by treatment with acetyl chloride failed. Mild conditions gave only recovered lactone; and heating the reactants at 100° in an autoclave in the presence of a few drops of concentrated sulfuric acid as catalyst seemed to result in some reaction, but treatment of the crude product with N-methylpiperazine gave none of either amide VII or IIIc. In contrast, β-propiolactone itself reacts with acetyl chloride at only slightly elevated temperatures to give β-acetoxypropionyl chloride in 67% yield.[6]

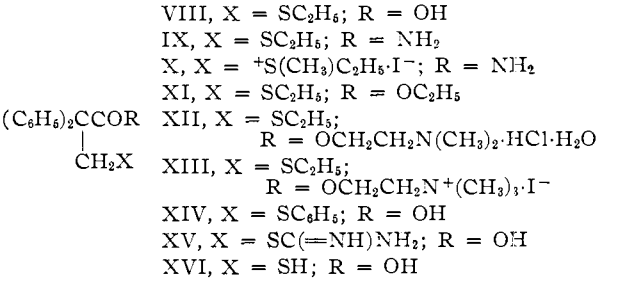


VII

(5) H. Zaugg, THIS JOURNAL, **72**, 3001 (1950).

(6) T. Gresham, J. Jansen and F. Shaver, *ibid.*, **72**, 72 (1950).

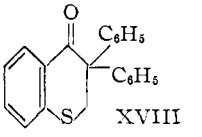
All reactions between β-propiolactone and organic sulfur compounds which have been reported thus far[7] involve alkyl–oxygen bond fission to give derivatives of β-thiolpropionic acid. Likewise, in the present work, treatment of the lactone I with the sodium salts of ethyl mercaptan and of thiophenol and with thiourea gave the acids VIII, XIV and XV in 43, 94 and 80% yields, respectively.



As by-product in the formation of VIII, appreciable quantities of ethyl diphenylacetate, $(C_6H_5)_2CHCOOC_2H_5$, were formed. It might seem that this ester was produced primarily by reaction of the lactone I with the ethanol solvent to give ethyl α-phenyltropate, which readily would undergo aldol-reversal in alkaline medium to give the above cleavage product.[5] However, another possible route for this degradation reaction could involve initial carbonyl–oxygen bond fission of the lactone I to give the ethylthiol ester of α-phenyltropic acid, isomeric with VIII. This thiol ester would be expected to undergo aldol-reversal even more readily than the corresponding oxygen ester because its anionic fission product $[(C_6H_5)_2CCOSC_2H_5]^{\ominus}$, is a weaker base than is the anion $[(C_6H_5)_2CCOOC_2H_5]^{\ominus}$, formed initially by cleavage of ethyl α-phenyltropate. Once formed, the thiol ester would readily undergo ester interchange in the basic ethanolic medium to give the corresponding oxygen ester. The latter route for this cleavage reaction is given some credence by the fact that when water was substituted for ethanol as the solvent in the reaction of I with sodium ethyl mercaptide, a 42% yield of ethyl diphenylthiolacetate, $(C_6H_5)_2CHCOSC_2H_5$ (XVII), actually was isolated. At any rate, formation of XVII shows that a β-lactone can react with an organic sulfur compound by carbonyl–oxygen bond fission.

The thioacid VIII readily formed an acid chloride which gave the amide IX and the two esters XI and XII on treatment with the appropriate reactants. Reaction of the amide IX with methyl iodide gave, with difficulty, the sulfonium salt X. Treatment of the ester XII with methyl iodide likewise gave a methiodide, which is presumed to be the ammonium salt XIII rather than the sulfonium salt because of its relatively facile formation.

By the action of concentrated sulfuric acid on the thioacid XIV, ring-closure to the thiachromanone XVIII readily was effected.



XVIII

(7) H. Zaugg in Adams, "Organic Reactions," Vol. VIII, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 345.

Finally alkaline hydrolysis of the acid XV formed the thiolpropionic acid XVI.

Many of the products reported above were submitted for testing as potential analgesics, antipasmodics or local anesthetics. None showed more than minimal activity.

Acknowledgment.—Mr. E. F. Shelberg of the Abbott microanalytical laboratory was responsible for the elementary analyses.

Experimental

Reaction of α,α-Diphenyl-β-propiolactone with Amines. Method A. Without Solvent.—To 10 ml. of N-(γ-aminopropyl)-morpholine at room temperature was added 2.5 g. (0.011 mole) of I. After slight warming and standing overnight, the mixture became homogeneous. Completion of reaction was indicated by miscibility in water of an aliquot sample. The viscous colorless reaction mixture was triturated with 50–100 ml. of ether and, after cooling in ice, the precipitated amino acid IIa (2.45 g., 60%), m.p. 186–187° dec., was collected by filtration and dried. Recrystallization from methanol did not change the melting point.

Anal. Calcd. for $C_{22}H_{28}N_2O_3$ (IIa): C, 71.71; H, 7.66; N, 7.60. Found: C, 72.03; H, 7.68; N, 7.74.

The ether filtrate was washed with water and then extracted with dilute hydrochloric acid. The aqueous extract was made alkaline with sodium hydroxide, and the precipitated oil was taken up in ether, dried and concentrated. The hydroxy amide IIIa (0.50 g., 12%), m.p. 133–134°, slowly crystallized from the concentrated ether solution. Recrystallization from methanol did not raise the melting point.

Anal. Calcd. for $C_{22}H_{28}N_2O_3$ (IIIa): C, 71.71; H, 7.66. Found: C, 71.83; H, 7.34.

In like manner reaction of I with *n*-butylamine gave only the hydroxy amide IIIb, m.p. 70–72° (from hexane), in 45% yield.

Anal. Calcd. for $C_{19}H_{23}NO_2$: C, 76.73; H, 7.80. Found: C, 76.79; H, 7.84.

Reaction of I with piperidine gave only the amino acid IIb in 87% yield, m.p. 137–139° (from acetone). When mixed with an authentic specimen of IIb,[8] m.p. 137–138°, it produced no melting point depression.

Reaction of I with morpholine gave a 95% yield of the morpholinium salt of the amino acid IIc, m.p. 173° dec.

Anal. Calcd. for $C_{23}H_{30}N_2O_4$: C, 69.32; H, 7.59; N, 7.03. Found: C, 69.53; H, 7.45; N, 7.23.

When this salt was heated for 5 hr. at 110° under reduced pressure (20 mm.), the free amino acid IIc, m.p. 163–164°, was obtained.

Anal. Calcd. for $C_{19}H_{21}NO_3$: C, 73.29; H, 6.80; N, 4.50. Found: C, 73.19; H, 7.03; N, 4.63.

Method B. In Acetonitrile.—The reaction of I with piperidine did not take place in ether solution at room temperature nor even in refluxing benzene to give IIb. A more polar solvent seemed necessary.

To a stirred solution of 2.65 g. (0.0307 mole) of piperidine in 10 ml. of acetonitrile was added 4.6 g. (0.0205 mole) of the lactone I. In about an hour at room temperature, the reaction mixture set to a solid mass. After standing overnight, the solid was collected and washed with pentane. There was obtained 5.5 g. (87%) of the amino acid IIb, m.p. 138–139° dec.

In like manner, the reaction of I with pyrrolidine gave the amino acid IId in 83% yield, m.p. 133°.

Anal. Calcd. for $C_{19}H_{21}NO_2$: C, 77.26; H, 7.17; N, 4.74. Found: C, 77.08; H, 7.34; N, 4.81.

Similarly, N-methylpiperazine with I in acetonitrile gave the amino acid IIe in 46% yield, m.p. 175–176° (from 95% ethanol).

Anal. Calcd. for $C_{20}H_{24}N_2O_2$: C, 74.04; H, 7.46; N, 8.64. Found: C, 74.28; H, 7.58; N, 8.56.

A crude by-product also was obtained from this reaction, possibly the hydroxy amide IIIc, but it could not be purified.

2,2-Diphenyl-3-piperidinopropanol (IVa).—To a stirred suspension of 9.4 g. (0.25 mole) of lithium aluminum hydride in 700 ml. of tetrahydrofuran was added, dropwise at such a rate as to maintain reflux, a solution of 34 g. (0.11 mole) of the amino acid IIb in 500 ml. of tetrahydrofuran. After completion of the addition (1 hr.), the mixture was stirred for 2 hr. at reflux and then was decomposed by addition of a saturated solution of sodium potassium tartrate. The purple colored solution was decanted from solid salts and was then dried over anhydrous magnesium sulfate. After filtration, and removal of the solvent by distillation, the residue was distilled *in vacuo* to give 11.4 g. (35%) of the amino alcohol IVa, as a viscous yellow oil, b.p. 165–166° (0.7 mm.).

Four ester hydrochloride derivatives of IVa were prepared by treatment with the appropriate acid chloride in ether solution:

Acetate IVb, m.p. 173–175° (from methanol–ether). *Anal.* Calcd. for $C_{22}H_{28}ClNO_2$: C, 70.66; H, 7.55. Found: C, 70.87; H, 7.40.

Propionate IVc, m.p. 155–157° (from ethanol–ether). *Anal.* Calcd. for $C_{23}H_{30}ClNO_2$: C, 71.21; H, 7.80. Found: C, 71.25; H, 7.68.

Benzoate IVd, m.p. 218–219° (from ethanol–ether). *Anal.* Calcd. for $C_{27}H_{30}ClNO_2$: C, 74.38; H, 6.94. Found: C, 74.32; H, 6.66.

Phenylacetate IVe, m.p. 174–176° (from ethanol–ether). *Anal.* Calcd. for $C_{28}H_{32}ClNO_2$: C, 74.73; H, 7.17. Found: C, 74.47; H, 7.13.

2,2-Diphenyl-3-(N-methylpiperazino)-propanol (Va).—Twenty-two and four-tenths grams (0.1 mole) of the amino acid IIe was placed in a Soxhlet extractor from which it was slowly dissolved by 1500 ml. of stirred refluxing ether containing 15.2 g. (0.4 mole) of lithium aluminum hydride. After 48 hr. some of the amino acid remained undissolved, so it was added in several portions to the ether solution which was then stirred and refluxed for another 24 hr. The cooled reaction mixture was decomposed by the dropwise addition of 200 ml. of water. The ethereal layer was separated and dried and after removal of the drying agent, it was treated with excess ethereal hydrogen chloride. The crude precipitate was recrystallized twice from 95% ethanol to give 21.7 g. (57%) of the amino alcohol Va, m.p. 244–246°.

Anal. Calcd. for $C_{20}H_{28}Cl_2N_2O$: C, 62.66; H, 7.36; N, 7.31. Found: C, 62.63; H, 7.55; N, 7.43.

Monomethiodide Vb, m.p. 278–279° (from methanol). *Anal.* Calcd. for $C_{21}H_{29}IN_2O$: C, 55.75; H, 6.46; N, 6.19. Found: C, 55.97; H, 6.58; N, 6.19.

2,2-Diphenyl-1,3-propanediol (VI).—When the β-lactone I (22.5 g., 0.1 mole) was reduced with lithium aluminum hydride (0.25 mole) in ethereal solution in the usual way, the diol VI, m.p. 101–103°,[9] was obtained in 84% yield.

Anal. Calcd. for $C_{15}H_{16}O_2$: C, 78.92; H, 7.06. Found: C, 78.77; H, 7.15.

N-Methylpiperazides of Acetyl-α-phenyltropic Acid (VII) **and of α-Phenyltropic Acid** (IIIc).—A mixture of 6.9 g. (0.03 mole) of α-phenyltropic acid[5] and 5.5 g. (0.07 mole) of acetyl chloride was refluxed on the steam-bath for 3 hr., and the excess acetyl chloride was removed by distillation. Then 7.1 g. (0.06 mole) of thionyl chloride was added, and the mixture was refluxed for 4 hr. The excess thionyl chloride was also removed by distillation and the residual oil (acetoxy acid chloride) was taken up in 50 ml. of dry ether. This solution, previously chilled in ice, was then added slowly to an ice-cold solution of 7.0 g. (0.07 mole) of N-methylpiperazine in 50 ml. of dry ether. After standing at room temperature overnight, the reaction mixture was extracted with excess dilute hydrochloric acid. The separated aqueous extract was made alkaline with cold 40% sodium hydroxide solution, and the precipitated oil was taken up in chloroform. Removal of the chloroform gave an oily free base which could not be crystallized. This material was dissolved in ether and the hydrochloride was fractionally precipitated by the slow addition of a solution of hydrogen chloride in isopropyl alcohol. Two fractions of the hydrochlorides were obtained. The first (hygroscopic) gave a crude crystalline base (3.5 g.), m.p. 95–100°, and the second hydrochloride fraction gave a purer base, which after two recrystallizations from aqueous ethanol yielded 2.3 g. of VII, m.p. 111–112°.

(8) H. Zaugg, B. Horrom and M. Vernsten, THIS JOURNAL, **75**, 288 (1953).

(9) J. Burr, Jr., *ibid.*, **73**, 5170 (1951), reports m.p. 102–103° for compound VI.

Anal. Calcd. for $C_{22}H_{26}N_2O_3$: C, 72.10; H, 7.15; N, 7.65; O, 13.10. Found: C, 71.93; H, 6.88; N, 7.80; O, 13.80.

The 3.5 g. of crude base (m.p. 95–100°) was dissolved in a solution of 25 ml. of concentrated hydrochloric acid in 25 ml. of water and allowed to stand for 60 hr. After heating for 1 hr. on the steam-bath, the mixture was cooled in ice and made strongly alkaline with 40% sodium hydroxide solution. The liberated base was extracted with benzene, which was removed by distillation to leave a solid residue which was recrystallized from aqueous ethanol to give 2.5 g. (80%) of the hydroxy amide IIIc, m.p. 141–142°.

Anal. Calcd. for $C_{20}H_{24}N_2O_2$: C, 74.04; H, 7.46; N, 8.64. Found: C, 74.35; H, 7.63; N, 8.82.

Methiodide IIId, m.p. 234–235° (from methanol–ether). *Anal.* Calcd. for $C_{21}H_{27}IN_2O_2$: C, 54.08; H, 5.84; N, 6.01. Found: C, 54.37; H, 5.78; N, 6.07.

2,2-Diphenyl-3-ethylthiopropionic Acid (VIII).—Sodium ethoxide was prepared from 4.6 g. (0.2 mole) of sodium in 40 ml. of dry ethanol. A solution of 12.4 g. (0.2 mole) of ethyl mercaptan in 10 ml. of ethanol was then added dropwise with cooling and stirring, followed by a solution of 33.6 g. (0.15 mole) of α,α-diphenyl-β-propiolactone in 100 ml. of ethanol. After standing at room temperature for 48 hr., the mixture was refluxed for 20 hr., cooled and poured into 200 ml. of water. Non-acidic material was eliminated by an ether extraction, and the aqueous layer was acidified with hydrochloric acid. The liberated acid was taken up in ether and dried. Removal of the ether by distillation gave the crude product, which after one recrystallization from dilute ethanol yielded 18.5 g. (43%) of VIII, m.p. 146–147°.

Anal. Calcd. for $C_{17}H_{18}O_2S$: C, 71.30; H, 6.33. Found: C, 71.07; H, 6.30.

From the neutral fraction was obtained 2.4 g. of ethyl diphenylacetate, m.p. 55–57°, identified by analysis and by mixed melting point with an authentic specimen.

When the β-lactone was treated with sodium ethylmercaptide in aqueous rather than alcoholic solution, the desired acid VIII was obtained in very poor yield together with a 42% yield of ethyl diphenylthiolacetate (XVII), m.p. 48–49°.

Anal. Calcd. for $C_{16}H_{16}OS$: C, 74.97; H, 6.29; S, 12.51. Found: C, 75.11; H, 6.33; S, 12.51.

Mixed with an authentic specimen, m.p. 49°,[10] there was no depression of melting point.

2,2-Diphenyl-3-ethylthiopropionamide (IX).—To a solution of 6.3 g. (0.031 mole) of the acid VIII in 40 ml. of dry benzene was added 4.8 g. of thionyl chloride dissolved in 10 ml. of dry benzene. After refluxing for 3 hr., the excess thionyl chloride and benzene were removed under reduced pressure. To the cooled residue of acid chloride was added 30 ml. of concentrated ammonium hydroxide. The oil which resulted was taken up in ether. Removal of the ether by distillation left a solid which after two recrystallizations from 75% ethanol gave 3.4 g. (54%) of the amide IX, m.p. 84–85°. (In another experiment a second dimorph, m.p. 95–96° was obtained.)

Anal. Calcd. for $C_{17}H_{19}NOS$: C, 71.56; H, 6.71; N, 4.91. Found: C, 71.53; H, 6.46; N, 5.04.

Methiodide X, m.p. 158–160° (from ethanol), was obtained by the reaction of methyl iodide with IX in refluxing acetone.

Anal. Calcd. for $C_{18}H_{22}INOS$: C, 50.59; H, 5.19; N, 3.28. Found: C, 51.10; H, 5.22; N, 3.41.

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

Ethyl 2,2-Diphenyl-3-ethylthiopropionate (XI).—By substituting ethanol for the ammonium hydroxide in the above procedure, the ester XI, b.p. 202° (2.5 mm.), $n^{26}D$ 1.5685, was obtained in 52% yield.

Anal. Calcd. for $C_{19}H_{22}O_2S$: C, 72.59; H, 7.05. Found: C, 72.40; H, 6.92.

A methiodide of XI, m.p. 125–126°, was obtained, but it could not be purified completely.

Anal. Calcd. for $C_{20}H_{25}IO_2S$: C, 52.63; H, 5.52; S, 7.02. Found: C, 54.07; H, 5.70; S, 6.68.

β-Dimethylaminoethyl 2,2-Diphenyl-3-ethylthiopropionate Hydrochloride (XII).—Treatment of the acid chloride of VIII with excess β-dimethylaminoethanol in benzene gave a 46% yield of the ester XII in the form of the monohydrate, m.p. 117–119° (from acetone–ether).

Anal. Calcd. for $C_{21}H_{30}ClNO_3S$: C, 61.22; H, 7.34; N, 3.40. Found: C, 61.39; H, 7.57; N, 3.45.

Methiodide XIII, m.p. 151–152° (from isopropyl alcohol). *Anal.* Calcd. for $C_{22}H_{30}INO_2S$: C, 52.90; H, 6.05; N, 2.81. Found: C, 52.83; H, 6.19; N, 2.95.

2,2-Diphenyl-3-phenylthiopropionic Acid (XIV).—To a solution of 2.20 g. (0.02 mole) of thiophenol in 50 ml. of dry methanol containing sodium methoxide (prepared from 0.46 g. of sodium) was added 4.48 g. (0.02 mole) of the lactone I. After standing at room temperature for two weeks (a shorter time probably would suffice), the methanol was removed under reduced pressure and the residue was taken up in 75 ml. of water. After extraction with two 50-ml. portions of ether, the aqueous solution was acidified with concentrated hydrochloric acid. The precipitated oil crystallized slowly, was removed by filtration and washed with water to give 6.33 g. (94%) of the acid XIV, m.p. 95–100°. Two recrystallizations from hexane (Skellysolve B) raised the melting point to 103–104°.

Anal. Calcd. for $C_{21}H_{18}O_2S$: C, 75.42; H, 5.42. Found: C, 75.57; H, 5.54.

3,3-Diphenylthiachromanone (XVIII).—To 5 ml. of concentrated sulfuric acid at room temperature was added 0.97 g. of 2,2-diphenyl-3-phenylmercaptopropionic acid. After constant swirling for 10 minutes, the deep red solution was poured onto ice, the resulting solid was collected at the filter and washed with water. The crude dry product (0.9 g.) was recrystallized twice by dissolving in acetone and adding hexane (Skellysolve B) to the warm solution. The pure thiachromanone XVIII melted at 163–164°.

Anal. Calcd. for $C_{21}H_{16}OS$: C, 79.72; H, 5.10. Found: C, 79.94; H, 5.36.

Reaction of the β-Lactone I with Thiourea. Preparation of XV.—To a boiling solution of 0.40 g. (0.0053 mole) of thiourea in 10 ml. of dry ethanol was added 1.12 g. (0.005 mole) of the lactone I. Refluxing for 3 hr. resulted in the precipitation of a colorless, crystalline solid, which after refrigeration overnight was collected at the filter and dried. There was obtained 1.20 g. (80%) of XV, m.p. 159.5–162°.

Anal. Calcd. for $C_{16}H_{16}N_2O_2S$: C, 63.97; H, 5.37; N, 9.33; S, 10.67. Found: C, 63.96; H, 5.57; N, 8.51; S, 10.37.

2,2-Diphenyl-3-thiolpropionic Acid (XVI).—Approximately 13.3 g. of crude XV was warmed with a 10% sodium hydroxide solution until most of it dissolved. After filtering and allowing to stand several hours, the alkaline solution was acidified and the precipitated product (7.3 g., m.p. 180–190°) was dried. Two recrystallizations from methanol gave colorless prisms of XVI, m.p. 200–202.5°.

Anal. Calcd. for $C_{15}H_{14}O_2S$: C, 69.74; H, 5.46; S, 12.39. Found: C, 69.91; H, 6.02; S, 12.68.

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