Attempted dehydration[6] of N-[1-(hydroxymethyl)-cyclohexyl]acetamide (VIII) to 2-methyl-1-aza-3-oxaspiro[4.5]dec-1-ene (IX), a homolog of II (and an isomer of V), was unsuccessful. Unchanged VIII was obtained, either from attempted azeotropic removal of water with benzene in the presence or absence of a catalytic amount of hydrochloric acid, or from warming at 50° with 2,2-dimethoxypropane and acetic acid in benzene solution.

Experimental

Melting points were determined on a calibrated Fisher-Johns hot stage.

1-Aza-3-oxaspiro[4.5]dec-1-ene (II).—The procedure is adapted from that of Roberts and co-workers[3] for the reaction of aniline with triethyl orthoformate. A mixture of 1-aminocyclohexanemethanol[1a] (16.0 g., 0.124 mole) and 1-aminocyclohexanemethanol hydrochloride[1a] (0.25 g., 0.0015 mole) in freshly distilled triethyl orthoformate (41.0 g., 0.277 mole) was refluxed for 6 hr., during which time the ethanol which formed was periodically distilled (17.0 g., 97%). Distillation of the solution through a 10-cm. Vigreux column gave the following fractions: (1) triethyl orthoformate, b.p. 83–85° (110–80 mm.); (2) an intermediate fraction, b.p. 85–103° (60 mm.), assumed to be a mixture of triethyl orthoformate and product [crystals of N-[1-(hydroxymethyl)cyclohexyl]formamide (0.29 g., 1%), m.p. 124–126° (m.m.p. 125–127° with an authentic sample[1a]), formed when the liquid was kept in contact with the air]; (3) the product, as a colorless oil (9.50 g., 54%), b.p. 104–105° (60 mm.), having an infrared spectrum the same as the analytical sample; and (4) a residual brown oil (5.70 g.). Redistillation of the product yielded a sample, b.p. 104–105° (60 mm.), $n^{26}\text{D}$ 1.4701, $\nu_{\text{C=N}}$ 1634 s cm.$^{-1}$ on the liquid.

Anal. Calcd. for $C_8H_{13}NO$ (139.19): C, 69.03; H, 9.41; N, 10.06. Found: C, 68.91; H, 9.65; N, 9.72.

Care must be taken to protect the product from atmospheric moisture; otherwise, crystals of N-[1-(hydroxymethyl)cyclohexyl]formamide soon appear.

Hydrolysis to N-[1-(Hydroxymethyl)cyclohexyl]formamide (III).[6]—A sample of 1-aza-3-oxaspiro[4.5]dec-1-ene, obtained as a colorless distillate in the manner described above, was kept in contact with the air for several days. During this time, large colorless crystals formed (36% yield from 1-aminocyclohexanemethanol), m.p. 124.5–128.5°, lit.[1a] m.p. 124–125.5°. There was no depression in m.m.p. 124–127° with a sample[1a] prepared from 1-aminocyclohexanemethanol and formic acid, and the infrared spectra in Nujol were identical.

Hydrolysis to 1-Aminocyclohexanemethyl Formate Hydrochloride (IV).—Benzoyl chloride was added to a solution of 1-aza-3-oxaspiro[4.5]dec-1-ene (0.50 g., 0.0036 mole) in ether and the solution was kept overnight. The colorless crystals which had slowly formed were collected, giving a gummy white solid. Recrystallization from acetone yielded white crystals (0.14 g., 20%); m.p. 164–168° (not sharp, preceded by sweating); ν_{NH} 2620 w, 2560 vw, 2530 vw, 2480 vw, 2350 w, $\nu_{\text{C=O}}$ 1721 s cm.$^{-1}$ in Nujol. The compound, a water-soluble salt, is hygroscopic and gained weight on the balance during the weighing of the analytical sample.

Anal. Calcd. for $C_9H_{16}ClNO_2$ (193.67); C, 49.61; H, 8.33; N, 7.23. Found: C, 49.05; H, 8.57; N, 7.37.

Reduction to VI, Isolated as N-[1-(Benzoyloxymethyl)cyclohexyl]-N-methylbenzamide (VII). A. From 1-Aza-3-oxaspiro-[4.5]dec-1-ene (II).—Lithium aluminum hydride (0.35 g., 0.0092 mole) was added to a solution of 1-aza-3-oxaspiro[4.5]dec-1-ene (1.0 g., 0.0072 mole) in dry ether (30 ml.), causing an initially vigorous reaction. The mixture was refluxed for 5 hr. and then the excess lithium aluminum hydride was decomposed by addition of acetone, followed by a solution of water in acetone. The ethereal layer was treated with benzoyl chloride (1.0 g., 0.0071 mole), producing within 5 min. a water-soluble, white solid (0.45 g.), m.p. 155–164°, assumed to be a hydrochloride salt (of VI or of the benzoate ester of VI), which was removed by filtration. The filtrate was treated with aqueous 20% sodium hydroxide solution (20 ml.), and the resulting mixture was warmed on a steam bath for 20 min., causing evaporation of the ether and acetone, and formation of a gummy white solid (0.65 g., 26%). Crystallization of this solid from ethanol–water gave colorless crystals, m.p. 105–107°. Two recrystallizations from ethanol–water yielded colorless flakes; m.p. 112–113°; $\nu_{\text{OH,NH}}$ none, $\nu_{\text{C=O}}$ 1700 s and 1628 s cm.$^{-1}$ in Nujol.

Anal. Calcd. for $C_{22}H_{25}NO_3$ (351.43): C, 75.18; H, 7.17; N, 3.99. Found: C, 75.20; H, 7.20; N, 3.82.

B. From N-[1-(Hydroxymethyl)cyclohexyl]formamide (III).—N-[1-(Hydroxymethyl)cyclohexyl]formamide (2.5 g., 0.0159 mole) was placed in the thimble of a Soxhlet extractor and extracted into refluxing ether containing lithium aluminum hydride (0.5 g., 0.013 mole). After 4 days of refluxing, 0.25 g. (10%) of the formamide remained in the thimble undissolved. The excess lithium aluminum hydride was then decomposed by addition of acetone, followed by a solution of water in acetone. The ethereal layer was dried over magnesium sulfate and evaporated, leaving a white solid (0.75 g., 30% recovery), m.p. 123–124°, m.m.p. 123–125° with formamide starting material, and an oil having an amine odor. The oil was washed out with ether, the ether was evaporated, and the residual oil was shaken with benzoyl chloride and aqueous sodium hydroxide solution. The white solid which formed was crystallized from ethanol–water, giving colorless crystals (0.80 g., 24% based on unrecovered formamide), m.p. 105–110°. One recrystallization from ethanol–water yielded colorless plates (0.60 g., 18%), m.p. 109–111°. There was no depression in m.m.p. 109–111° with the sample prepared from 1-aza-3-oxaspiro[4.5]dec-1-ene (A, above), and the infrared spectra in Nujol were identical.

N-[1-(Hydroxymethyl)cyclohexyl]acetamide (VIII).[6]—A solution of 1-aminocyclohexanemethanol[1a] (14.76 g., 0.114 mole) in acetic anhydride (11.65 g., 0.114 mole) was warmed on a steam bath for 1 hr. The acetic acid formed was then evaporated under reduced pressure. The residual, viscous, dark brownish red liquid was made slightly basic with dilute aqueous sodium bicarbonate solution, and extracted five times with ether. Evaporation of the ether and crystallization of the residue from 1:1 methylene chloride–petroleum ether (b.p. 60–68°) gave two crops of small white needles (3.17 g., 16%), m.p. 118–119.5°, lit.[1a] m.p. 121–123°.

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[6] Taken from the senior thesis of Thomas E. Huntley, University of Minnesota, 1960, to whom we are indebted.

Photochemical Transformations. XVII.[1] The Photochemistry of Palustric Acid[2]

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Received March 19, 1964

The photochemical ring scission of 1,3-cyclohexadienes to triene derivatives is now a widespread and well-documented reaction.[4] This process has, in fact, been synthetically employed as a new entry into medium-sized ring systems.[5] The behavior of cyclohexadienes is in contrast to the ring-formation reactions which commonly occur from the irradiation of the seven- and eight-membered ring analogs.[4] Although the ring cleavage reaction appears to be a fairly general phenomenon with cyclohexadienes, there exist a few exceptional compounds, namely, the pyrocalciferols[6] and

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[1] For the previous paper in this series, see W. G. Dauben and Robert M. Coates, *J. Am. Chem. Soc.*, **86**, 2490 (1964).

[2] This investigation was supported in part by PHS Grant No. A-709, National Institute of Arthritis and Metabolic Diseases, U. S. Public Health Service.

[3] National Science Foundation Cooperative Fellow, 1960–1963.

[4] For a summary of the pertinent literature, see ref. 1.

[5] E. J. Corey and A. G. Hortmann, *J. Am. Chem. Soc.*, **85**, 4033 (1963).

[6] W. G. Dauben and G. J. Fonken, *ibid.*, **81**, 4060 (1959).

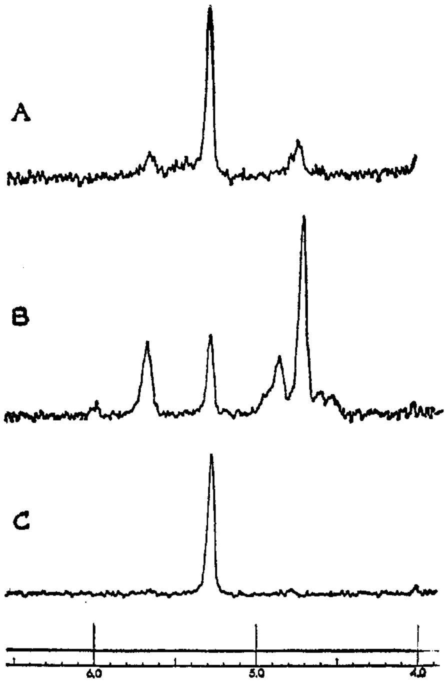
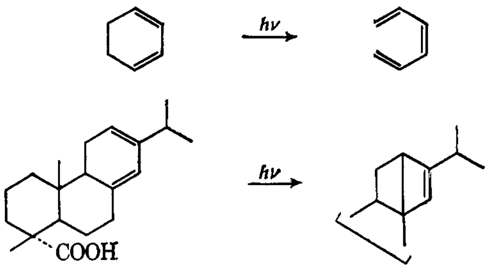


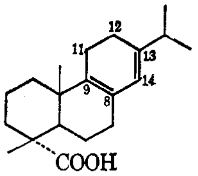
Fig. 1.—N.m.r. spectra of A, product from heating photomethyl palustrate; B, photostationary-state mixture of methyl palustrate (**2**) and methyl photopalustrate (**3**); C, methyl palustrate (**2**). Spectra were taken in deuteriochloroform with tetramethylsilane as internal standard and band positions expressed in τ-units.

levopimaric acid (**1**),[1,7] which furnish bicyclo[2.2.0]-hexene derivatives instead of trienes.



I

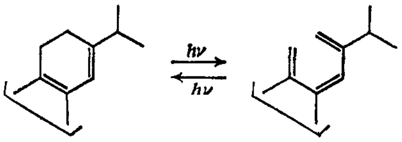
The unexpected photochemical behavior of levopimaric acid directed our attention to its oleoresin companion, palustric acid (**2**), which possesses instead an 8,13-diene in ring C.[8] It was of interest to determine what effect this subtle structural change might have upon the photochemistry of the molecule.[9]



2

The irradiation of palustric acid, as its methyl ester in pentane solution, was followed by the changes in both the ultraviolet spectrum and the optical rotation. During the course of the photolysis the initial ultraviolet maximum at 265 mμ disappeared and a new maximum at a 248 mμ grew in with the concomitant appearance of an isosbestic point at 249 mμ. After 2 hr. of exposure, a stationary state was reached. The specific rotation underwent a change from +70 to −85° which paralleled the decrease in ultraviolet absorption at 265 mμ.

The observation of a stationary state at which considerable ultraviolet absorption remained suggested that a photoequilibrium between methyl palustrate and the ring-opened triene (**3**) had occurred. This supposition was borne out by inspection of the nuclear magnetic resonance (n.m.r.) spectrum. Whereas methyl palustrate shows a single, sharp vinyl proton at τ 4.70 (see Fig. 1C), the irradiated material displayed the complex absorption (Fig. 1B) to be expected from a mixture of the diene and triene. The new higher field pattern centered at τ 5.27 integrated to precisely four times the area of the new peak at τ 4.30. The middle band at τ 4.70 coincided exactly with the vinyl proton absorption of the starting diene. The total area of the vinyl region of the mixture corresponded to approximately three protons (measured relative to the carbomethoxyl signal), a result which conclusively demonstrates that ring opening has taken place to the extent of about 50%.



3

These n.m.r. data coupled with the observation of an isosbestic point indicate that the principal photochemical pathway involved in the irradiation of palustric acid is the reversible ring cleavage to the triene (**3**). It is estimated from the n.m.r. spectra that the composition at the stationary state is 45–50% diene and 55–50% triene. A number of attempts were made to isolate the triene from the photomixture, but without success. Further irradiation slowly gave rise to a great number of products.[10]

When the photomixture was heated for 4 hr. in refluxing diglyme (162°), the n.m.r. spectrum of methyl palustrate was regenerated to a large extent (Fig. 1A). The original diene was isolated from the pyrolysate and identified by spectral comparison.

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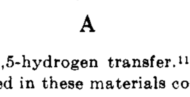
(7) W. H. Schuller, R. N. Moore, J. E. Hawkins, and R. V. Lawrence, *J. Org. Chem.*, **27**, 1178 (1962).

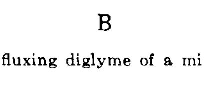
(8) W. H. Schuller, R. N. Moore, and R. V. Lawrence, *J. Am. Chem. Soc.*, **82**, 1734 (1960).

(9) W. H. Schuller and R. V. Lawrence [U. S. Patent 3,086,989 (April 23, 1963); *Chem. Abstr.*, **59**, 11,575 (1963)] have reported that palustric acid upon irradiation afforded a small yield of the bridged valence isomer. However, until the detailed properties of this material are published, this structural assignment must be regarded as tentative.

(10) Two products were formed first and were frequently present as impurities (5–10%) in the mixtures of **2** and **3**. One of these is considered likely to be the *trans* triene (A) while the other appears to be B, derived from A



A



B

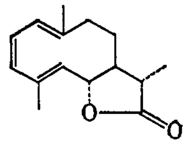
by a 1,5-hydrogen transfer.[11] Pyrolysis in refluxing diglyme of a mixture enriched in these materials converted A to B.

(11) J. Wolinsky, B. Chollar, and M. D. Baird, *J. Am. Chem. Soc.*, **84**, 2775 (1962); J. W. H. Watthey and S. Winstein, *ibid.*, **85**, 3715 (1963); K. J. Crowley, *Proc. Chem. Soc.*, 17 (1964).

The valence isomerization of conjugated trienes to their cyclohexadiene isomers has previously been encountered.[12] *cis*-1,3,5-Hexatriene is said to be transformed into 1,3-cyclohexadiene at temperatures as low as 100°.[13] The thermal re-formation of the ring C diene from the phototriene suggests that the central (8–14) double bond probably has the *cis* configuration (*i.e.*, substituents bearing the other double bonds are *cis*) as written.

In addition to the contrast in behavior between levopimaric acid and palustric acid previously pointed out,[1] there are two other aspects of the above results worthy of note. The relatively high proportion of diene at photoequilibrium is rather unusual. In most cases the triene is favored to a large extent.[12] This observation may be reasonably attributed to the presence of the isopropyl side chain, which must surely destabilize the transoid rotamer of the *cis* triene (**3**). Hence, the population of the cisoid conformer would be expected to be enhanced, a circumstance which should render the photocyclization of the triene more favorable than usual. This same argument may be applied to explain the slow rate of *cis–trans* isomerization.

The other point to be made is that the ultraviolet maximum of the triene, 240 mμ (ϵ 7000), obtained by subtraction, is quite low for a chromophore containing three conjugated double bonds. This evidence is, however, not considered to be inconsistent with the structural assignment since the *cis* triene cannot assume a planar configuration owing to the steric interference between the terminal methylene groups. With the consequent decrease in effective orbital overlap, reduced ultraviolet absorption is not surprising. That a diene having both double bonds exocyclic to a six-membered ring displays anomalous absorption curves is well known.[14] The *cis* triene **4** also exhibits a quite low ultraviolet maximum (211 mμ).[5]



4

Experimental[15]

Irradiation of Methyl Palustrate.[16]—The pentane used for irradiation was purified by several washings with first concentrated sulfuric acid, then 30 and 65% fuming sulfuric acid, followed by thorough rinsing with concentrated aqueous potassium hydroxide and water. Distillation from phosphorus pentoxide and passage over a column of basic alumina (activity I) provided pentane of suitable quality (optical density of 0.3 at 200 mμ.

A 606-mg. (2.0 mmoles) portion of palustric acid was esterified with diazomethane. The oily methyl ester [$\lambda_{\max}^{\mathrm{EtOH}}$ 265 mμ (ϵ 8100), $[\alpha]^{22}\mathrm{D}$ +69.9° (*c* 2.09)] was transferred with the purified pentane to a three-necked, 350-ml. irradiation vessel. In the center neck was placed the standard water-cooled Hanovia quartz probe no. 19434. A stopper was placed in one side arm and a water condenser in the other side arm. The system was flushed thoroughly with a stream of helium admitted through a narrow inlet tube on the side of the irradiation flask. A magnetic stirrer was employed to agitate the solution. The light source was a 100-w. medium-pressure mercury lamp (Hanovia, type 608A36) inserted into the core of the water-cooled quartz probe. The temperature of the reaction solution did not rise above 30° and aliquots were taken at the indicated time intervals (Table I) for measurement of both the ultraviolet absorption and the optical rotation. For the latter purpose, 5-ml. portions were removed, the solvent was evaporated, and the residue was diluted to 1 ml. with chloroform.

TABLE I

Time, min.	Optical density, 265 mμ	Observed rotation, degree
0	13.7	+0.62
5	13.0	+0.33
15	11.0	−0.22
30	10.1	−0.55
60	9.0	−0.69
90	8.3	−0.75
120	8.0	−0.75

The solvent was evaporated and the unpurified photoproduct was submitted to v.p.c. analysis.[15] The tracings showed mainly one peak at 9 min., preceded by two small ones at 5.5 (secondary product A) and 6.5 min. (secondary product B), respectively. The latter two materials represented about 5% of the total material.

The n.m.r. spectrum displayed increased absorption in the vinyl region (see center of Fig. 1 for a typical spectrum). In addition to the rather sharp singlet at τ 4.70 corresponding to the vinyl hydrogen of methyl palustrate, there appeared a new band at τ 4.30 and a complex pattern centered at τ 5.27. The high-field multiplet had an area four times the area of the low field absorption at τ 4.30. The area ratio of the bands at τ 4.30 and 4.70 varied from 50:50 to 45:55 in several runs. The total area of the vinyl region when compared to the methyl ester signal indicated an average of three vinyl protons in the mixture. Weak absorption was also noted in the vicinity of τ 3 and attributed to the presence of a small amount of methyl dehydroabietate.

A 540-mg. portion of the photoproduct was obtained free of the low-retention impurities (secondary products A and B) and methyl dehydroabietate by chromatography on neutral alumina (activity II). The material was adsorbed on a 20-g. column (H/D 13) and eluted with 10-ml. portions of pentane. The first three fractions (total content, 82 mg.) were considerably enriched in the contaminants A and B according to v.p.c. analysis. The next four 10-ml. fractions were combined with the following four 50-ml. fractions, which upon evaporation furnished 300 mg. of the photomixture, $\lambda_{\max}$ 250 mμ (ϵ 6000), $[\alpha]\mathrm{D}$ −92.0° (*c* 1.93).

N.m.r. analysis showed the mixture to be composed of 57% of the triene (**3**) and 43% methyl palustrate. From the rotation of the latter (+69.9°), the optical rotation of the pure triene is calculated to be −214 ± 10°. The ultraviolet spectrum, $\lambda_{\max}$ 240 mμ (ϵ 6800), was determined by subtraction of the absorption due to methyl palustrate. The photomixture displayed enhanced infrared absorption at 3085, 1629, 1134, and 870 cm.$^{-1}$ compared with a spectrum of methyl palustrate.

A number of attempts to isolate the triene in a pure state were to no avail. Chromatography of the photomixture on a column with a H–D ratio of 75 and an alumina to substrate ratio of 100 gave only slight enrichment. When the free acid was photolyzed, efforts to effect purification by either direct crystallization or use of the various amine salts were not promising. The use of a Cortex filter during the irradiation did not appear to affect the equilibrium significantly.

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(12) G. J. Fonken, *Tetrahedron Letters*, 549 (1962); E. Havinga and J. L M. A. Schlatmann, *Tetrahedron*, **16**, 146 (1961); E. Havinga, *Chimia* (Aarau), **16**, 145 (1962).

(13) E. Vogel, *Angew. Chem., Intern. Ed. Engl.*, **2**, 1 (1963).

(14) A. T. Blomquist and D. T. Longone, *J. Am. Chem. Soc.*, **79**, 3916 (1957); E. E. van Tamelen, S. H. Levin, G. Brenner, J. Wolinsky, and P. E. Aldrich, *ibid.*, **81**, 1666 (1959).

(15) Optical rotations were measured in chloroform unless otherwise specified. The n.m.r. spectral data are relative to tetramethylsilane as an internal standard. Chromatography was performed on Woelm neutral alumina which had been deactivated to the desired activity by the addition of distilled water. The v.p.c. analyses were conducted at 210° on a column containing 5% SE-30 silicone oil using a Wilkens Aerograph Model 600 apparatus.

(16) The palustric acid was isolated from the rosin of *Pinus palustris* by fractional crystallization of the 2,6-dimethylpiperidine salt. The rosin and isolation procedure were kindly supplied by Dr. R. V. Lawrence of the Naval Stores Laboratory, Olustee, Fla.

The triene would not form an adduct with maleic anhydride. The photomixture (201 mg.) was quantitatively recovered by chromatography on silica gel after exposure to 62 mg. of maleic anhydride in 4 ml. of benzene for 48 hr. at room temperature.

Extension of the irradiation period led to complex mixtures (v.p.c. analysis). It is noteworthy that cautious exclusion of atmosphere seemed to inhibit the formation of methyl dehydroabietate. When all joints were greased and the solution thoroughly degassed (heated to reflux while flushing with helium), little if any dehydrogenation was observed. A small amount of methyl dehydroabietate was isolated by column chromatography after a prolonged irradiation in which such precautions had not been taken. Infrared comparison with an authentic sample confirmed the identity of this material.

Pyrolysis of the Photomixture.—A solution of 435 mg. of unpurified photomixture (containing totally 15% of A and B) in 22 ml. of diglyme was heated at reflux temperature (160°) under a nitrogen atmosphere for 4 hr. Aliquots (0.50 ml.) were removed periodically by means of a syringe and diluted to 1 ml. with diglyme, and the optical rotation was measured (Table II).

TABLE II

Time, min.	Observed rotation, degree
0	−0.82
15	+0.03
30	+0.08
60	+0.12
120	+0.19
240	+0.22

The final three aliquots were recombined with the solution, and then pentane and cold water were added. The aqueous phase was extracted twice more with pentane. The combined pentane extracts were washed four times with cold water, dried in the usual manner, and finally evaporated to dryness, 381 mg. (94%). The n.m.r. spectrum of the unpurified pyrolysate is shown in Fig. 1C.

The material was chromatographed on alumina to remove the contaminants (mainly A), as in the previous experiment. After separation of the earlier fractions enriched in the impurities (total content, 122 mg.), the column was stripped with 50 ml. of benzene. Evaporation of the benzene eluate furnished 230 mg. (57%) of material of 93% purity (v.p.c. analysis), λ_{max} 265 mμ (ϵ 7000), $[\alpha]_D$ +30°. With the exception of a few minor differences, the infrared spectrum was superimposable with that of methyl palustrate. The n.m.r. spectrum exhibited the characteristic singlet (τ 4.70) associated with the vinyl hydrogen of methyl palustrate.

Secondary Product A.—From the irradiation of 1.80 g. of methyl palustrate to the steady state there was obtained after two alumina chromatographies 23 mg. of a mixture, which by v.p.c. analysis proved to be 90% A and B. Although the v.p.c. traces indicated 50% A and 40% B, the n.m.r. spectrum showed 70% and 20% to be more nearly correct. This estimate was obtained by comparison of the τ 8.76 methyl signal of B with the τ 8.85 signal of A. The allylic method of B could also be distinguished. The mixture had $[\alpha]_D$ −140°, λ_{sh} 241 mμ (ϵ 7600), and ν_{max} 1630 and 900 cm.$^{-1}$.

The vinyl region of the n.m.r. spectrum of this mixture had bands at τ 4.30, 5.08, and a complex pattern from 5.25 to 5.50. Three methyl signals were observed at τ 8.85, 8.93, and 9.03. Another sample of A which was uncontaminated with B had essentially the same infrared and n.m.r. spectra; the minor bands attributed to B were absent in the latter.

Secondary Product B.—A mixture of 60% A and B (79 mg.) obtained by judicious combination of various enriched fractions from preceding chromatographies was heated under reflux in 4 ml. of diglyme for 4 hr. The course of the pyrolysis was followed by v.p.c. analysis which demonstrated that A was being converted into B. The pyrolysate was isolated by pentane extraction, then chromatographed on neutral alumina (activity II) with pentane as the eluent.

A series of fractions were collected which contained, for the most part, variable proportions of methyl palustrate and B, from which the physical properties of B could be obtained. The optical rotation was calculated to be about −140°, correcting for the per cent of methyl palustrate. The infrared spectrum had absorption at 893 cm.$^{-1}$. In the vinyl region of the n.m.r. spectrum, there were broad bands at τ 4.33 and 4.50 as well as a rather sharp band τ 5.26. The lower field peaks had approximately the same area as the higher field absorption. A sharp doublet ($J \sim 1$ c.p.s.) was discerned at τ 8.42. Signals from saturated methyl groups were found at τ 8.76, 8.90, 8.98, and 9.00.

Preparation of New Amino Acids and 2,5-Oxazolidinediones

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In the course of preparing some novel peptides by the Leuchs-anhydride route, two new amino acids, DL-2-(*o*-ethoxyphenyl)glycine and 1-aminocyclooctanecarboxylic acid, were prepared by variants of the Strecker synthesis. In addition, 1-aminocyclobutanecarboxylic acid and DL-2-phenylsarcosine were prepared by improved procedures. New 2,5-oxazolidinediones were prepared from these acids as well as from D- and L-2-phenylglycine by direct phosgenation. The preparation and properties of these compounds are described in this paper.

In working with 2,5-oxazolidinediones, we have found that for many of them the admonitions in the literature[1] as to the observance of strict anhydrous conditions in their preparation and to the need of utilizing them within a few hours are not necessary. Air-dried glassware and a commercial source of dioxane were adequate. Storage of the pure compounds at 5° over silica gel resulted in little or no polymerization for extended periods.

The anhydride groupings showed two characteristic absorption peaks at 5.37–5.45 and 5.62–5.77 μ corresponding to carbon–oxygen stretching. If the ring nitrogen was unsubstituted, nitrogen–hydrogen stretching gave peaks at 2.97–3.10 μ.

Experimental

All melting points are corrected. Analyses were run by members of the Microbiological and Physical Chemistry Departments of this laboratory; infrared spectra were determined on a Perkin-Elmer Model 21 spectrophotometer.

The preparation of D-4-phenyl-2,5-oxazolidinedione is typical for all of the oxazolidinediones.

D-4-Phenyl-2,5-oxazolidinedione.—D-2-Phenylglycine[2] (350 g., 2.32 moles) was suspended in 3 l. of dioxane (Fisher Scientific Co., D-111, certified grade) in a 5-l. four-necked flask fitted with a heating mantle, gas-inlet tube, thermometer, solid carbon dioxide condenser with drying tube, and sealed stirrer. Phosgene was slowly introduced *via* a safety flask until about 460 g. (4.67 moles) was added. The rate of addition was adjusted to maintain the temperature at 50°. When the reaction rate fell off, heating was started to keep the temperature at this level. At the end of 4 hr. from the initial addition of phosgene, solution had occurred. The solid carbon dioxide condenser was replaced with an air condenser, and dry nitrogen was passed through overnight. The dioxane solution was concentrated to an oil on a rotary evaporator. The oil was taken up in ethyl acetate

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(1) *Cf.* J. P. Greenstein and M. Winitz, "Chemistry of the Amino Acids," Vol. 2, John Wiley and Sons, Inc., New York, N. Y., 1961, p. 861.

(2) From L. Perrigo Co., Allegan, Mich.