[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF CALIFORNIA AT LOS ANGELES]

Macro Rings. VI. The Preparation of Three New Paracyclophanes[1a]

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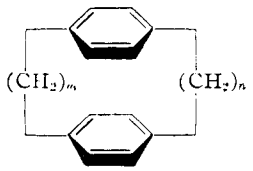
The three paracyclophanes (I) with 1- and 8-, 4- and 6-, and 6- and 6-membered methylene bridges have been prepared. Two attempts to prepare the paracyclophane with 1- and 6-membered bridges failed.

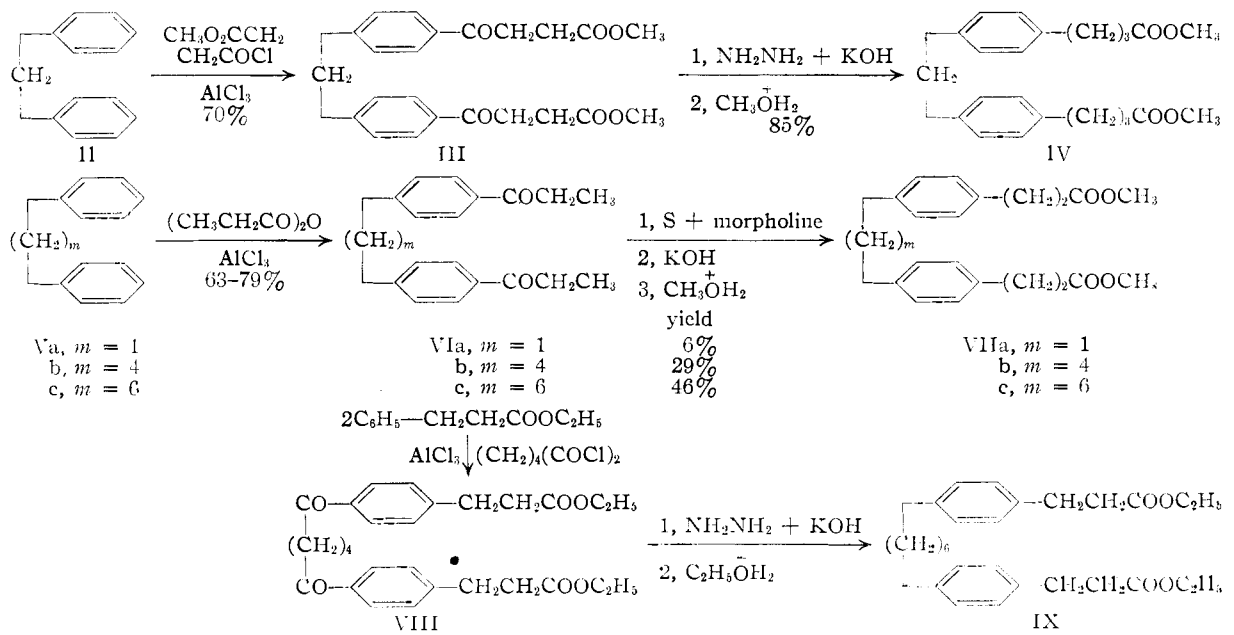
The preceding papers in this series[2] have reported the preparation of the compounds of class I that are formulated. The present study reports



n	m
2	2
2	3
2	4
3	4
3	6
4	4
4	5
5	5
5	6

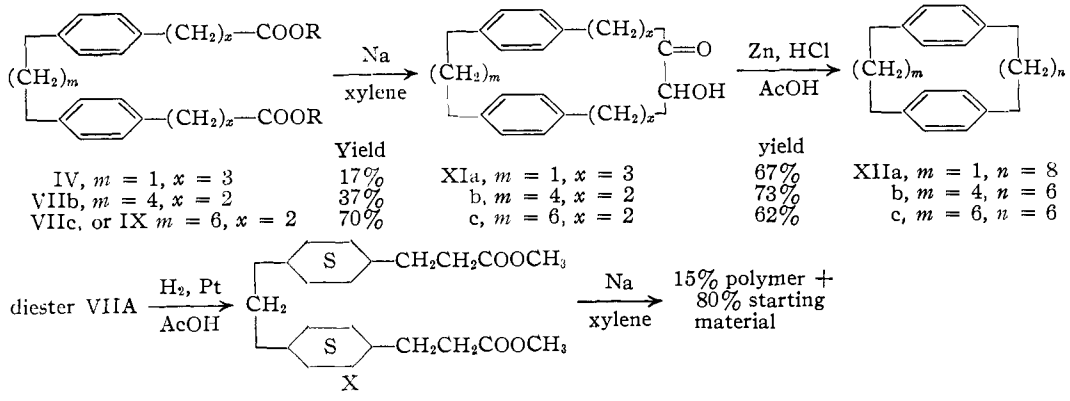
the synthesis of three new paracyclophanes (I) in which $m = 1, n = 8$; $m = 4, n = 6$ and $m = n = 6$. Two attempts to prepare the paracyclophane with $m = 1$, $n = 6$ are also described. The reason for preparing each of the hydrocarbons was different in each case. Thus the synthesis of I with $m = 1$, $n = 8$ as well as the attempts to synthesize I with $m = 1$, $n = 6$, was directed toward the determination of the smallest methylene bridge which can connect the *para* positions of diphenylmethane. In such a cycle the carbon atoms of the benzene rings which are separated by a single methylene group should be forced as close or closer than in the substance with $m = n = 2$.[2a] The ultraviolet absorption spectrum should be modified considerably, possibly in a fashion different from the modification found in those cycles in which the benzene rings occupy parallel planes (*e.g.*, in I, $n = m = 2$ or 3). The paracyclophane with $m = 4$, $n = 6$ was prepared to fill a gap between I with $m = 3$, $n = 6$ whose ultraviolet absorption spectrum shows some of the abnormalities characteristic of the smaller cycles,[2a] and the substance with $m = 5$, $n = 6$[2b] whose spectral properties duplicate those of the open-chain models in almost every way. Finally a compound of this class was desired for initial aromatic substitution experiments. This substance should be obtainable in reasonable amounts, should possess symmetry properties making all potential substitution sites equivalent, and should permit the two aromatic rings to turn over with respect to one another so that a minimum of disubstituted derivatives (one in each ring) might be obtained. Compound I with $m = n = 6$ fulfills these requirements.

The synthesis of the above compounds utilized the acyloin condensation in the critical ring-closing step, the appropriate diesters coming to hand by the sequences summarized in the formulation. Although the synthesis of diester VIIc (methyl ester) gave an over-all yield comparable to that obtained in the substitute synthesis of diester IX (ethyl ester), the latter preparation was more convenient since fewer steps were involved, and the intermediates and final product were purified more readily. The diethyl ester IX was also more desirable than



(1) (a) This work was sponsored by the Office of Naval Research. (b) Requests for reprints should be addressed to this author.

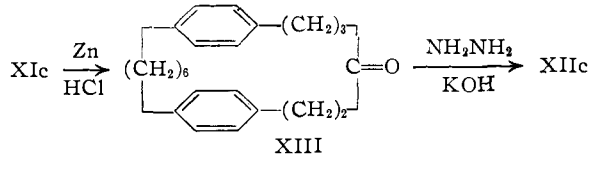
(2) (a) D. J. Cram and H. Steinberg, THIS JOURNAL, **73**, 5691 (1951); (b) H. Steinberg and D. J. Cram, *ibid.*, **74**, 5388 (1952); (c) D. J. Cram and N. L. Allinger, *ibid.*, **76**, 726 (1954); (d) N. L. Allinger and D. J. Cram, *ibid.*, **76**, 2362 (1954); (e) D. J. Cram and H. U. Daeniker, *ibid.*, **76**, 2743 (1954).



the dimethyl ester VIIc because the former was considerably more soluble in xylene, a property allowing the acyloin ring-closing reaction (xylene solvent) to be carried out on a larger scale than with the dimethyl ester.

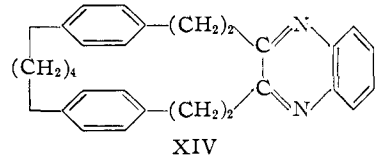
The diesters VII and IX were subjected to the usual acyloin condensation,[2] and crystalline acyloins were obtained from diesters IV, VIIb and VIIc or IX in yields of 17, 37 and 70%, respectively. Since attempts to cyclize diester VIIa failed (only polymer and 5% of unreacted ester was obtained), the compound was reduced catalytically to give a mixture of diastereomeric products X in which the *cis, cis* isomer was presumed to predominate.[2c] This material also failed to undergo the acyloin ring closure, 80% of the starting material surviving the conditions of the experiment. In neither case was any acyloin detected in the product with the sensitive acyloin test with bismuth trioxide.[3]

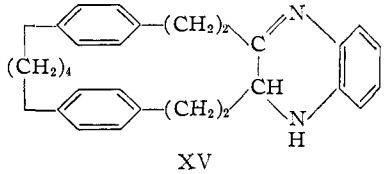
The acyloins XI were reduced by a modified Clemmensen reduction[4] to the hydrocarbons XII, the acyloin XIc being reduced by two additional methods. A modified Wolff–Kishner reduction[5] of XIc gave a rather poor yield of the hydrocarbon XIIc, whereas the stepwise reduction of XIc to ketone XIII by the method of Stoll[6] with the subsequent reduction of XIII to XIIc (Wolff–Kishner reaction) also provided an inferior over-all yield of hydrocarbon. The production of XIIc by the last



two sequences substantiates the fact that the Clemmensen reduction of XIc to give the same hydrocarbon (XIIc) proceeds without any carbon-skeleton modifying rearrangements.

The crude acyloins described here and in previous studies[2] are yellow in color and contain varying amounts of diketone derived from the ketol function. In some cases the diketones have been isolated.[2c] The mother liquors from the purification of acyloin XIb were intensely yellow in color, suggesting the presence of a considerable amount of diketone. Treatment of these mother liquors with *o*-phenylenediamine gave not only the expected quinoxaline XIV but also another derivative whose analysis suggests the dihydroquinoxaline derivative XV, which probably arose directly from the acyloin. The ultraviolet absorption spectrum of XIV (Fig. 1) is very similar to that of the quinoxaline derivative of 3,3,7,7-tetramethylene-1,2-cycloheptanedione[7] (λ_{max} 235 mμ, log ϵ 4.78; λ_{max} 323 mμ, log ϵ 3.90), and to that of 2,3-dimethylquinoxaline[8] (λ_{max} 237 mμ, log ϵ 4.39; λ_{max} 315


XIV


XV

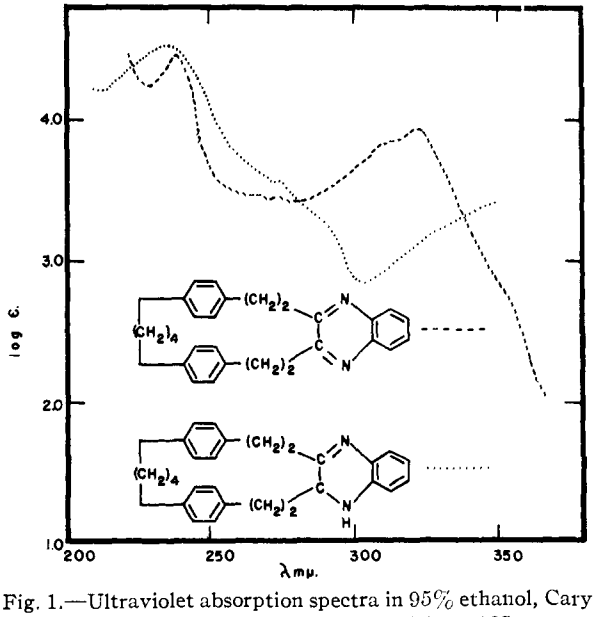
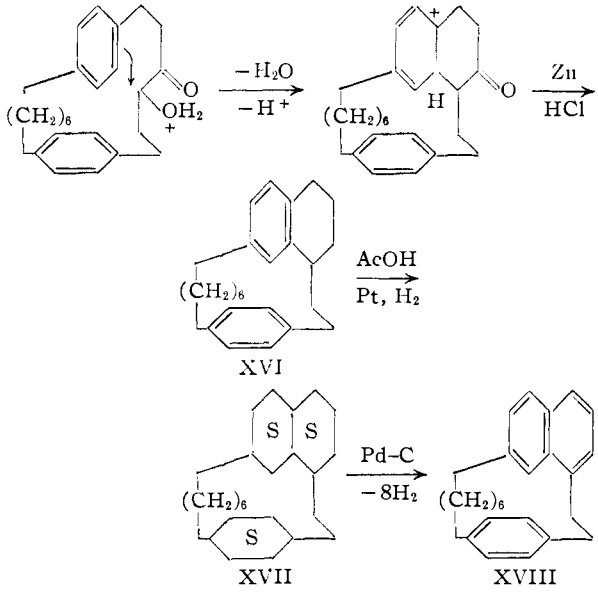


Fig. 1.—Ultraviolet absorption spectra in 95% ethanol, Cary recording spectrophotometer, model 11PMS.

(3) W. Rigby, *J. Chem. Soc.*, 793 (1951).
(4) K. Wiesner, D. M. MacDonald, R. B. Ingram and R. B. Kelly, *Can. J. Research*, **B28**, 561 (1950).
(5) Huang-Minlon, THIS JOURNAL, **68**, 2487 (1946).
(6) M. Stoll, *Helv. Chim. Acta*, **30**, 1837 (1947).
(7) N. J. Leonard and P. M. Mader, THIS JOURNAL, **72**, 5388 (1950).
(8) F. Bohlmann, *Ber.*, **84**, 860 (1951).

mμ, log ε 3.84). The spectrum of the dihydro-compound XV is also included in Fig. 1.

The Clemmensen reduction of acyloin XIc gave not only the desired hydrocarbon (XIIc in 62% yield) but also a 5% yield of a second hydrocarbon (XVI) whose analysis and molecular weight corresponded to XIIc minus one mole of hydrogen. The two hydrocarbons when mixed gave a substantial melting point depression. No double bond could be detected in XVI spectrally (*e.g.*, the ultraviolet absorption spectra of XVI and XIIc were very similar) or by the use of the usual chemical tests. On hydrogenation of XVI in acetic acid with a platinum catalyst exactly six moles of hydrogen were absorbed to give an oil (XVII) whose analysis corresponded to a dodecahydro-derivative of XVI. These data suggested that the anomalous hydrocarbon XVI contained one more ring than hydrocarbon XIIc. The nature of this ring became clear from the following results. The dodecahydro-derivative XVII was dehydrogenated at 300° with a palladium–carbon catalyst, eight moles of hydrogen being liberated to produce a new hydrocarbon XVIII whose analysis indicated a structure carrying four hydrogen atoms less than the starting anomalous hydrocarbon XVI. The ultraviolet absorption spectrum of XVIII is recorded in Fig. 2 along with that of 1,7-dimethylnaphthalene,[9] and the two curves are very similar to one another. These observations lead to unique structures for XVI, XVII and XVIII, the original anomalous hydrocarbon XVI apparently arising by an electrophilic attack of an incipient carbonium ion (formed from the acyloin XIIc) on one of the benzene rings. The formulation of the reaction is illustrative of a number of possible mechanistic schemes that readily can be envisioned.



The ultraviolet absorption spectra of the cyclic hydrocarbons, XIIb, XIIc and XVI were determined, and found to be normal in every respect as compared with that of open-chain model compounds. The abnormal spectrum of paracyclophane (XIIa) will be recorded and discussed in a future communication.

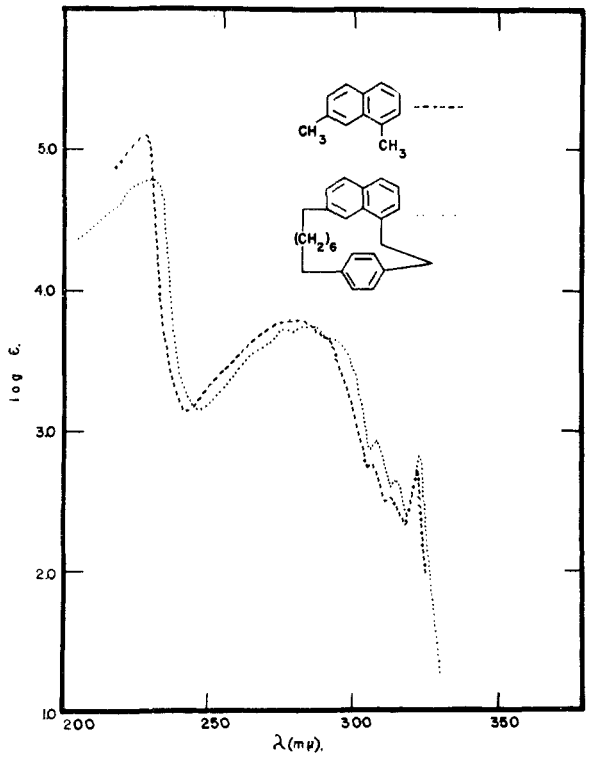


Fig. 2.—Ultraviolet absorption spectra of 1,7-dimethylnaphthalene in isooctane and of hydrocarbon XVIII in 95% ethanol, Cary recording spectrophotometer, model 11PMS.

(9) American Petroleum Institute Research Project 44, Spectral Serial No. 220.

Experimental[10]

1,6-Bis-(4-propionylphenyl)-hexane (VI).—The 1,6-diphenylhexane (Vc) used as starting material was produced in 93% yield by reducing 1,6-diphenylhexane-1,6-dione[11] by the modified Wolff–Kishner method[5] to give material, b.p. 153–154° (2 mm.), $n^{25}D$ 1.5440 (literature b.p. 142° (1 mm.), $n^{25}D$ 1.5409).[12] This material was propionylated as follows. Aluminum chloride (106 g.) was dissolved in 150 ml. of nitrobenzene, the temperature rising to 60°. Propionic anhydride (44 ml.) was then added over a period of 30 minutes followed by 40 g. of 1,6-diphenylhexane (15 minutes), the temperature remaining at 60°. The dark red solution was held at 60° for 2 hours and then stirred into a mixture of 1 kg. of ice and 75 ml. of concentrated hydrochloric acid. The mixture which was allowed to warm to 25° during one hour, was extracted with ether, and the organic layer was washed with water, with dilute base and again with water. The ether solution was dried, evaporated, and the nitrobenzene was distilled at 4 mm. pressure until a pot temperature of 125° was reached. The brown residual oil was dissolved in benzene and passed through 100 g. of activated alumina. The brown column filtrates (the column was washed with benzene) were combined, decolorized with charcoal, and the benzene was evaporated. The remaining brown solid was recrystallized from hexane to give 35 g. (63% yield) of yellow product, m.p. 94–95° (uncor.). Five recrystallizations of this material from hexane gave white needles, m.p. 96–97° (uncor.).

Anal. Calcd. for $C_{24}H_{30}O_2$: C, 82.24; H, 8.64. Found: C, 82.28; H, 8.53.

(10) All melting points are corrected unless otherwise stated, boiling points are uncorrected.

(11) "Organic Syntheses," Coll. Vol. 2, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 169.

(12) K. T. Serijan and P. H. Wise, THIS JOURNAL, **73**, 5691 (1951).

The use of carbon disulfide as solvent and other variations of conditions gave product in inferior yields.

1,6-Bis-[4-(β-carboxyethyl)-phenyl]-hexane.—A mixture of 38 g. of 1,6-bis-(4-propionylphenyl)-hexane, 11.5 g. of sulfur and 95 ml. of morpholine was held at reflux for 22 hours, and poured into water, the resulting mixture being extracted with chloroform. The dark extract was washed with water, dried and the solvent was evaporated to leave 60.5 g. of a dark red oil. This crude thiomorpholide was hydrolyzed by refluxing with 100 ml. of 50% sodium hydroxide and 375 ml. of 70% ethanol for 23 hours. The reaction mixture was diluted with water, acidified with concentrated hydrochloric acid, and the brown precipitate that formed was collected in a large funnel and partially dried under a rubber dam. The moist solid was dried at 100° under 2 mm. of pressure to a constant weight of 36 g. (88% yield) of crude acid, m.p. 180–193°. This acid was converted without purification to the methyl ester (see next section).

A pure sample of this acid was obtained by saponification of the pure methyl ester in the usual way, and was recrystallized twice from methanol, m.p. 198–200° (uncor.).

Anal. Calcd. for $C_{24}H_{30}O_4$: C, 75.36; H, 7.91. Found: C, 75.13; H, 7.90.

1,6-Bis-[4-(β-carbomethoxyethyl)-phenyl]-hexane (VIIc).—A mixture of 84 g. of crude 1,6-bis-[4-(β-carboxyethyl)-phenyl]-hexane, 100 ml. of absolute methanol, 250 ml. of ethylene dichloride and 5 ml. of concentrated sulfuric acid was held at reflux for 18 hours. The brown reaction mixture was cooled, washed with water, with sodium bicarbonate solution and again with water. The solution was dried, the solvent was evaporated, and the brown residual solid (80 g.) was dissolved in benzene. This solution was passed through a column of 400 g. of activated alumina, 4 l. of benzene being required for elution of the ester. The column eluate was evaporated to give a yellow solid which was recrystallized from a mixture of hexane and benzene to give 46 g. (52% yield) of yellow crystals, m.p. 120.5–123.5° (uncor.). Five recrystallizations from the same solvent gave white plates of the desired ester (VIIc), m.p. 126.3–127°.

Anal. Calcd. for $C_{26}H_{34}O_4$: C, 76.06; H, 8.35. Found: C, 75.84; H, 8.44.

1,4-Bis-[4-(β-carbethoxyethyl)-benzoyl]-butane (VIII).—A mixture of 12.2 g. of adipic acid and 33.3 g. of thionyl chloride was held at reflux for three hours, the excess thionyl chloride was distilled under reduced pressure, and the light brown adipyl chloride that remained was used without further purification. This material was added over a period of 10 minutes to a well-stirred mixture of 50 g. of powdered aluminum chloride and 100 ml. of carbon disulfide. To this mixture was added with vigorous stirring over a 20-minute period 28.5 g. of ethyl hydrocinnamate. The reaction mixture became reddish-brown in color and hydrogen chloride was evolved. Carbon disulfide (50 ml.) was distilled over a period of 30 minutes, and the residual dark red oil was stirred into a mixture of 500 g. of cracked ice and 100 ml. of concentrated hydrochloric acid. Benzene (500 ml.) was added and the mixture was allowed to stand for 1.5 hours. The mixture was shaken, the phases were separated, and the aqueous phase was again extracted with benzene. The combined organic extracts were washed with water, with sodium bicarbonate solution and again with water. The solution was then dried, the benzene was evaporated, and when cooled, the residual brown oil crystallized. This material was recrystallized from a mixture of benzene and hexane to give 18.5 g. (50% yield) of ketoester VIII, m.p. 89.5–92.0°. A small sample was recrystallized five times from the same solvent to yield white needles, m.p. 93.6–94.1°.

Anal. Calcd. for $C_{28}H_{36}O_6$: C, 72.08; H, 7.35. Found: C, 72.05; H, 7.46.

1,6-Bis-[4-(β-carbethoxyethyl)-phenyl]-hexane (IX).—A mixture of 138 g. of 1,4-bis-[4-(β-carbethoxyethyl)-benzoyl]-butane, 100 ml. of 85% hydrazine hydrate, 120 g. of potassium hydroxide and 1.5 l. of diethylene glycol was held at reflux for 2 hours. Distillate was then allowed to escape until the pot temperature rose to 190°, the mixture being held at this temperature for 16 hours. The mixture was then cooled somewhat and 1.5 l. of water was added. With the clear yellow solution at about 60°, 200 ml. of concentrated hydrochloric acid was added with vigorous stirring. The fluffy white precipitate that separated was allowed to stand for a day and then collected in a large funnel and allowed to partially dry under a rubber dam. The virtually white solid was further dried for 20 hours at 80° at 25 mm. of pressure, and then recrystallized from a mixture of chloroform and methanol to give 68 g. of white solid, an additional 29.5 g. being obtained as a second crop (yield of 85% of crude material). This acid was converted to its ethyl ester without further purification as follows.

A mixture of 55 g. of the above acid, 75 ml. of absolute ethanol, 175 ml. of ethylene chloride and 3.5 ml. of concentrated sulfuric acid was held at reflux for 16 hours. After cooling, the mixture was diluted with water and extracted with ether. The ether solution was washed with water, dilute sodium bicarbonate solution, and again with water. The solution was dried, evaporated, and the remaining white solid was recrystallized from a mixture of benzene and hexane to give 40.5 g. (64% yield) of white plates, m.p. 91.0–92.5°. Three recrystallizations of this material from the same solvents yielded white plates, m.p. 92.2–92.9°.

Anal. Calcd. for $C_{28}H_{36}O_4$: C, 76.67; H, 8.74. Found: C, 76.49; H, 8.79.

A sample of the methyl ester was prepared in a similar fashion in 70% yield, m.p. 124.7–125.7°, undepressed by admixture with the sample previously prepared by another route (see above).

3-Keto-4-hydroxy-p,p′-hexamethylene-1,6-diphenylhexane (XIc).—The acyloin reaction was carried out under high dilution conditions using the apparatus previously described.[2a] The 1,6-bis-[4-(β-carbethoxyethyl)-phenyl]-hexane (153 g.) in 1925 ml. of pure xylene was added to 33.5 g. of clean molten sodium (dispersed in 1 l. of xylene) during 51 hours. The mixture was stirred and heated for an additional hour, cooled to 0°, and acetic acid (100 g.) was slowly added. The polymer and sodium acetate that separated were collected, the xylene was distilled from the filtrates, and the residual yellow solid was recrystallized from a mixture of hexane and benzene to yield 75.1 g. of yellow rosettes, m.p. 136–142°, and a second crop of 8.3 g., m.p. 137–142°. The mother liquors were combined, the solvent was evaporated, and the residual oil was distilled at 1 mm. and a pot temperature of 250–260° to yield 18.3 g. of a light yellow solid as distillate. Recrystallization of this material from hexane gave 13.0 g. of white rosettes, m.p. 139–142.5°. The total yield of crude acyloin (XIc) amounted to 84.3 g. (70%). A small sample was recrystallized three times from hexane to give white rosettes, m.p. 143.6–144.1°.

Anal. Calcd. for $C_{24}H_{30}O_2$: C, 82.24; H, 8.63. Found: C, 82.06; H, 8.85.

A small sample of the acyloin (0.30 g.) was converted to the phenylosazone by refluxing it with 0.4 g. of phenylhydrazine hydrochloride and 0.6 g. of sodium acetate in 20 ml. of ethanol for 20 hours. The product was recrystallized three times from a mixture of ethanol and ethyl acetate to yield 0.080 g. of straw-colored needles, m.p. 198.7–200.7°.

Anal. Calcd. for $C_{36}H_{40}N_4$: C, 81.77; H, 7.63; N, 10.60. Found: C, 81.78; H, 7.55; N, 10.75.

3-Keto-p,p′-hexamethylene-1,6-diphenylhexane (XIII).—The acyloin was reduced according to the method of Stoll.[6] A mixture of 3.0 g. of acyloin XIc, 20 g. of mossy zinc, 100 ml. of dioxane and 5 ml. of water was held at reflux for 6 hours while a gentle stream of dry hydrogen chloride was bubbled through the solution. The dark reaction mixture was diluted with water, extracted with ether, and the ether extract was washed with water, with dilute sodium bicarbonate solution and again with water. The solution was dried, the solvent was evaporated, and the 3.8 g. of yellow solid that remained was dissolved in 50% benzene–pentane. This solution was adsorbed on a chromatograph column of 75 g. of very active neutral alumina, and elution with the same solvent gave 2.1 g. of pale yellow solid. Recrystallization of this material from hexane gave 0.75 g. (26%) of XIII, m.p. 111–114°, which was recrystallized once from hexane, once from methanol and again from hexane to give white needles, m.p. 115.0–115.3°.

Anal. Calcd. for $C_{24}H_{30}O$: C, 86.17; H, 9.04. Found: C, 86.41; H, 8.88.

A semicarbazone was prepared and recrystallized five times from a mixture of ethanol and ethyl acetate to yield white plates, m.p. 203.5–204.3°.

Anal. Calcd. for $C_{26}H_{33}ON_3$: C, 76.69; H, 8.50. Found: C, 76.47; H, 8.67.

p,p'-Hexamethylene-1,6-diphenylhexane (XIIc).—Zinc (500 g.) was amalgamated with 50 g. of mercuric chloride, 1 l. of water and 100 ml. of concentrated hydrochloric acid. A mixture of 68.4 g. of 3-keto-4-hydroxy-*p,p'*-hexamethylene-1,6-diphenylhexane (XIc), 1 l. of glacial acetic acid and 1 l. of concentrated hydrochloric acid was added, and the resulting mixture was refluxed for 70 hours, during which time five 100-ml. portions of concentrated hydrochloric acid were added. The reaction mixture was then cooled, diluted with water and extracted with pentane. The pentane extract was washed with water, dried, and evaporated to give 62 g. of white solid. Three recrystallizations of this material from methanol gave 27.8 g. of white needles, m.p. 99.0–100.6°. On standing, the mother liquors deposited a small crop of rhombohedral crystals, which were collected and recrystallized from methanol to yield 0.4 g. of material, m.p. 95.2–96.7°. A mixed melting point of the two materials gave 68–80°. Through the use of extensive fractional crystallization and chromatographic separation (very active neutral alumina with pentane developer) the mother liquors were made to give an additional 10.9 g. of needles, m.p. 99.0–100.6°, and 2.7 g. of rhombohedra, m.p. 95.2–96.6°. The total yield of the desired hydrocarbon (XIIc) was 38.7 g. (62%); the total yield of the anomalous hydrocarbon (rhombohedra) amounted to 3.1 g. (5%). A small sample of the needles (XIIc) was recrystallized twice from methanol to give m.p. 99.6–100.6°.

Anal. Calcd. for $C_{24}H_{32}$: C, 89.93; H, 10.07; mol. wt., 320. Found: C, 90.17; H, 10.07; mol. wt., 328 (Rast).

A small sample of the anomalous hydrocarbon XVI was recrystallized twice from methanol to give material, m.p. 95.7–96.6°.

Anal. Calcd. for $C_{24}H_{30}$: C, 90.50; H, 9.50; mol. wt., 318. Found: C, 90.27, 90.22; H, 9.57, 9.60; mol. wt., 314 (Rast).

A Wolff–Kishner reduction of acyloin XIc patterned after the procedure described for the preparation of IX resulted in a product that after extensive purification (fractional crystallization and chromatography on alumina) a 7% yield of XIIc, m.p. 98–100°, undepressed by admixture with XIIc prepared by the Clemmensen reduction of XIc.

A similar Wolff–Kishner reduction of 3-keto-*p,p'*-hexamethylene-1,6-diphenylhexane (XIII) gave hydrocarbon XIIc in 58% yield, m.p. 97.6–98.6°, undepressed by admixture with XIIc prepared by the Clemmensen reduction.

Identification of the Anomalous Hydrocarbon (XVI).—The lower melting hydrocarbon XVI from the Clemmensen reduction of acyloin XIc gave negative tests for unsaturation with bromine, with potassium permanganate, and with hydrogen in the presence of either Raney nickel or platinum in ethanol. When hydrogenated with platinum in acetic acid, exactly six moles of hydrogen was absorbed, the procedure being as follows.

A mixture of 300 mg. of XVI, 300 mg. of XVI, 300 mg. of prereduced platinum, and 50 ml. of acetic acid was stirred for 9 hours in an atmosphere of hydrogen during which time 139 ml. of hydrogen was consumed. The catalyst was collected and the filtrate was shaken with a mixture of water and pentane. The pentane layer was washed with water, dried, evaporated, and the residual 300 mg. of oil was distilled at 1 mm. and a bath temperature of 225–228° to give 250 mg. of viscous colorless oil (XVII).

Anal. Calcd. for $C_{24}H_{42}$: C, 87.19; H, 12.81. Found: C, 87.47; H, 12.90.

This hydrogenation product (XVII) (0.50 g.) was heated with 50 mg. of 10% palladium-on-carbon. Hydrogen (250 ml.) was evolved at a temperature of 280 to 300° over a period of 2 hours. Pentane was added to the cooled material, the resulting mixture was filtered, and the filtrate was evaporated to give a colorless oil. This material was distilled at 1 mm. and a bath temperature of 235–240° to give 0.30 g. of a viscous colorless oil (XVIII).

Anal. Calcd. for $C_{24}H_{26}$: C, 91.66; H, 8.34. Found: C, 91.46; H, 8.48.

1,4-Diphenylbutane (Vb).—Catalytic reduction of 105 g. of 1,4-diphenyl-1,3-butadiene[13] in 500 ml. of methylcyclohexane with Raney nickel under 65 atmospheres of hydrogen at 45° gave a mixture that was filtered. Distillation of the solvent left a white solid that was recrystallized from ethanol to give 94 g. (89%) of white rectangular prisms, m.p. 52.0–52.7° (uncor.), literature[2a] m.p. 51.5–53°.

1,4-Bis-(4-propionylphenyl)-butane (VIb).—Propionic anhydride (46 ml.) was added to a stirred mixture of 100 g. of aluminum chloride and 200 ml. of carbon disulfide over a period of 10 minutes. A solution of 35.5 g. of 1,4-diphenylbutane in 50 ml. of disulfide was added over a 25-minute period, and then 210 ml. of carbon disulfide was distilled from the mixture (30 minutes) to leave a dark red oil. This oil was stirred into 1 kg. of ice and 50 ml. of concentrated hydrochloric acid, chloroform was added, and the resulting mixture was warmed slowly to 30°. The chloroform layer was separated, washed with water, dilute sodium hydroxide, again with water, dried and evaporated. The residual white solid was recrystallized from a mixture of hexane and benzene to give 38.7 g. (70%) of white needles, m.p. 127.3–128.8°. A small sample was twice recrystallized from the same solvent, m.p. 129.4–130.0°.

Anal. Calcd. for $C_{22}H_{26}O_2$: C, 81.95; H, 8.13. Found: C, 82.23; H, 7.89.

1,4-Bis-[4-(β-carbethoxyethyl)-phenyl]-butane (VIIb).—A mixture of 98.0 g. of 1,4-bis-(4-propionylphenyl)-butane (VIb), 32 g. of sulfur and 260 ml. of morpholine was subjected to the conditions of the Willgerodt reaction described above for the preparation of the homologous acid, 1,6-bis-[4-(β-carboxyethyl)-phenyl]-hexane. The crude thiomorpholide was hydrolyzed with 1070 ml. of 70% ethanol and 285 ml. of 50% sodium hydroxide. The crude acid finally obtained was dried by dissolving it in chloroform and drying the solution. The crude acid thus obtained (105 g.) was esterified by refluxing it in a solution of 200 ml. of absolute ethanol, 400 ml. of ethylene dichloride and 5 ml. of concentrated sulfuric acid for 23 hours. The resulting solution was cooled and shaken with a mixture of ether and water. The organic layer was washed with water, dried, evaporated, and the residual black oil was dissolved in benzene and adsorbed on a column of 300 g. of very active neutral alumina. The column was treated with 6 l. of benzene, and the solvent was evaporated from the column filtrate to give 70 g. of orange crystals. These were dissolved in 20% pentane–80% benzene and adsorbed on another column of 300 g. of fresh alumina. The ester was eluted with 4 l. of 20% pentane in benzene, and evaporation of the solvent from the column filtrate gave a yellow solid. This material was dissolved in ethanol and the solution was refluxed for 6 hours with 10 g. of Raney nickel. The catalyst was collected, the solvent was evaporated from the filtrate, and the residual solid was recrystallized from hexane–benzene (charcoal treatment) to give 29.5 g. of white plates, m.p. 72–73°. A second crop (5.5 g.) was also taken to bring the total yield of ester to 29%. A small sample was recrystallized three times from the same solvent to give white plates, m.p. 72.8–73.8°.

Anal. Calcd. for $C_{26}H_{34}O_4$: C, 76.06; H, 8.35. Found: C, 76.00; H, 8.18.

3-Keto-4-hydroxy-*p,p'*-hexamethylene-1,4-diphenylbutane (XIb).—The reaction was carried out in the usual apparatus,[2a] 34.5 g. of 1,4-bis-[4-(β-carbethoxyethyl)-phenyl]-butane (VIIb) in 1 l. of xylene being added over a period of 51.5 hours to 8.3 g. of sodium dispersed in 1 l. of refluxing xylene. The reaction mixture was worked up in the usual way (see preparation of XIc), 24 g. of yellow crystals being obtained from the xylene solution. This solid was distilled at 0.3 mm. and a pot temperature of 210–230° to give 13.8 g. of pale yellow crystals. Recrystallization of this material from hexane gave 10.4 g. (37%) of white rosettes, m.p. 96–97°. A small sample was recrystallized three times from hexane to give white rosettes, m.p. 97.9–98.6°.

Anal. Calcd. for $C_{22}H_{26}O_2$: C, 81.95; H, 8.13. Found: C, 82.00; H, 8.07.

The solvent was evaporated from the mother liquors from the crystallization of the acyloin, and the residual oil was heated at 100° for one hour with 2.16 g. of *o*-phenylenediamine in 20 ml. of acetic acid. The mixture was diluted with water, extracted with ether, and the ether layer was dried and evaporated. The residual solid was dissolved in benzene and chromatographically adsorbed on 100 g. of neutral activated alumina. Elution of the column with benzene gave two fractions.

(13) Ref. 11, p. 229.

Fraction One: Quinoxaline Derivative of Diketone XIV.—Evaporation of the solvent from this fraction gave material that was recrystallized from ethanol to yield 1.5 g. of material, m.p. 151.5–155.0°. Three more recrystallizations from ethanol gave needles, m.p. 154.3–155.2°.

Anal. Calcd. for $C_{28}H_{28}N_2$: C, 85.67; H, 7.19; N, 7.14. Found: C, 85.43; H, 7.33; N, 7.21.

Fraction Two: Dihydroquinoxaline Derivative of Acyloin (XV).—Evaporation of the solvent from this fraction gave material that was recrystallized from ethanol to give 1.4 g. of yellow plates, m.p. 167–177° dec. Three more recrystallizations of the material from the same solvent yielded yellow plates, m.p. 168–177° dec.

Anal. Calcd. for $C_{28}H_{30}N_2$: C, 85.24; H, 7.67; N, 7.10. Found: C, 85.24; H, 7.50; N, 7.09.

***p,p'*-Hexamethylene-1,4-diphenylbutane (XIIb).**—A mixture of 1.35 g. of 3-keto-4-hydroxy-*p,p'*-hexamethylene-1,4-diphenylbutane, 12.3 g. of amalgamated zinc, 40 ml. of glacial acetic acid and 40 ml. of concentrated hydrochloric acid was refluxed for 48 hours during which time four 5-ml. portions of concentrated hydrochloric acid were added. The reaction mixture was treated as in the preparation of XIIc, 0.7 g. of white needles of XIIb being obtained, m.p. 93.2–95.2° (methanol). Three more recrystallizations of this material gave 0.5 g. of needles (methanol), m.p. 94.5–95.4°, 0.4 g. being obtained as second crops, m.p. 94–95°, to give a total yield of 73%.

Anal. Calcd. for $C_{22}H_{28}$: C, 90.35; H, 9.65. Found: C, 90.33; H, 9.73.

Bis-(4-propionylphenyl)-methane (VIa).—This preparation was carried out by the method used for the preparation of the homolog VIb. From 27 ml. of propionic anhydride, 60 g. of aluminum chloride and 125 ml. of carbon disulfide was ultimately obtained upon evaporation of the extraction solvent (ether) 28 g. of orange oil. This oil was distilled at 1 mm., the fraction distilling at a pot temperature of 205–225° (21.9 g. or 79%) being collected. Crystallization of this light yellow solid distillate from a mixture of hexane and benzene gave 12.8 g. of white crystals, m.p. 53.6–60.6°. A small sample was recrystallized 5 times from the same solvent to give white needles, m.p. 62–63°.

Anal. Calcd. for $C_{19}H_{20}O_2$: C, 81.40; H, 7.19. Found: C, 81.49; H, 6.97.

Bis-[4-(β-carboxyethyl)-phenyl]-methane.—A mixture of crude bis-(4-propionylphenyl)-methane (228 g.), 80 g. of sulfur and 650 ml. of morpholine was held at reflux for 21 hours, and the resulting thiomorpholide was hydrolyzed to the corresponding acid by the method recorded for the preparation of the above homologous acids. The resulting grossly impure acid was purified as follows. It was dissolved in dilute sodium hydroxide solution, and sufficient acid was added to precipitate about 10% of the total solid which had been collected. The filtrate was made strongly acid, the dark yellow solid that separated was collected, dissolved in chloroform (2 l.) and the solution was dried. The solvent was evaporated to give 237 g. of dark red oil (crude acid) which was esterified by refluxing with 2 l. of absolute ethanol and 100 ml. of concentrated sulfuric acid for 16 hours. The crude ester was isolated in the usual way and distilled at a pot temperature of 227–231° (2 min.). The dark yellow distillate (134.5 g.) was refluxed with ethanol and 20 g. of Raney nickel for 3 hours, the mixture was filtered, the solvent was evaporated, and the ester was distilled at 1 mm. to give 109 g. of light yellow distillate, b.p. 200–220°. This material was hydrolyzed by refluxing for one hour with 250 ml. of ethanol and 600 ml. of water containing 16 g. of sodium hydroxide and 22.4 g. of potassium hydroxide. The resulting solution was filtered, cooled and acidified with concentrated hydrochloric acid. The white precipitate that formed was collected and recrystallized twice from glacial acetic acid to yield 26 g. of white solid, m.p. 185.0–193.5°. A second crop was obtained (5.1 g.), m.p. 187–194°. The two crops were combined and recrystallized twice from methanol to yield 21 g. (8.2% yield) of acid, m.p. 191.5–196.5°. A small sample was recrystallized five times from methanol to give white plates, m.p. 196.5–198.5°.

Anal. Calcd. for $C_{19}H_{20}O_4$: C, 73.06; H, 6.45. Found: C, 72.87; H, 6.52.

Bis-[4-(β-carbomethoxyethyl)-phenyl]-methane (VIIa).—A mixture of 21 g. of bis-[4-(β-carboxyethyl)-phenyl]-methane, 200 ml. of absolute methanol and 10 ml. of concentrated sulfuric acid was refluxed for 2 hours and was then treated in the usual way (see preparation of VIIc) to give 234 g. of a pale yellow solid (impure diester). This material was recrystallized from hexane to give 17.2 g. of white plates, m.p. 46.8–48.8°. Another recrystallization of this material from hexane gave 15.7 g. (68%) of white plates, m.p. 47.2–48.8°. A small sample was twice recrystallized from hexane to yield white plates, m.p. 47.5–48.8°.

Anal. Calcd. for $C_{21}H_{24}O_4$: C, 74.13; H, 7.11. Found: C, 73.91; H, 7.11.

Attempted Acyloin Condensation of Bis-[4-(β-carboxyethyl)-phenyl]-methane (VIIa).—The reaction was carried out in the usual way with 10 g. of ester VIIa. Only polymer and 0.2 g. of starting ester was obtained as demonstrated by a mixed melting point determination.

Bis-[4-(β-carbomethoxyethyl)-cyclohexyl]-methane (X).—A mixture of ester VIIa (11.3 g.), 50 ml. of glacial acetic acid and 0.5 g. of platinum oxide was shaken in an atmosphere of hydrogen for 8 hours, the theoretical amount of gas being taken up. The mixture was filtered, and the filtrate was shaken with a mixture of water and ether. The ether layer was washed with water, dilute sodium bicarbonate solution, again with water, and was dried. The ether was evaporated to give 11.5 g. of colorless oil which was distilled at 1 mm. and a bath temperature of 235–237° to yield 10.75 g. (93%) of colorless oil (X), $n^{25}D$ 1.4812.

Anal. Calcd. for $C_{21}H_{36}O_4$: C, 71.55; H, 10.30. Found: C, 71.53; H, 10.47.

Attempted Acyloin Condensation of Bis-[4-(β-carbomethoxyethyl)-cyclohexyl]-methane (X).—The reaction was carried out in the usual way with 10.75 g. of diester X, the addition time being 24 hours. The reaction mixture was worked up in the usual way to give polymer and 9.9 g. of a yellow oil. This material was distilled at 1 mm. pressure and a pot temperature of 245–255° to yield 8.5 g. of colorless oil, $n^{25}D$ 1.4815. The recovery of starting material was 80%.

Dimethyl-bis-(4-succinylphenyl)-methane (III).—A mixture of 16.8 g. of diphenylmethane, 30 g. of β-carbomethoxypropionyl chloride[14] and 200 ml. of tetrachloroethane was cooled to 0° in an ice–salt bath. Aluminum chloride (60 g.) was added to the stirred mixture in six portions during 0.5 hour, and the resulting mixture was stirred for an additional 0.5 hour at 0°. The material was allowed to warm to 27° over a period of 1.5 hours, the dark viscous oil was poured over ice, and the mixture was extracted with chloroform. The extract was washed with 2 *N* hydrochloric acid, water, dilute sodium carbonate solution and again with water. The solution was dried, evaporated and the residual yellow oil was recrystallized from a mixture of benzene and hexane to give 27.7 g. (70%) of white plates, m.p. 87.2–92.2°. A small sample was recrystallized five times from the same solvent to yield white plates, m.p. 92.8–93.8°.

Anal. Calcd. for $C_{23}H_{24}O_6$: C, 69.68; H, 6.10. Found: C, 69.91; H, 5.94.

Bis-[4-(γ-carbomethoxypropyl)-phenyl]-methane (IV).—Diketone III (72 g.) was reduced in the usual way with hydrazine (see procedure for preparation of IX from VIII) to give upon final acidification 62 g. of crude diacid. This material was esterified in the usual way (see preparation of VIIa) to give 64 g. of a yellow oil. This material was distilled at 1 mm. and a bath temperature of 275–276° to give 60.5 g. (85%) of colorless oil, $n^{25}D$ 1.5345. A small sample was redistilled to give an oil, $n^{25}D$ 1.5345, m.p. 13.8–15.1°.

Anal. Calcd. for $C_{23}H_{28}O_4$: C, 74.97; H, 7.66. Found: C, 74.92; H, 7.44.

4-Keto-3-hydroxy-*p,p'*-octamethylenediphenylmethane (XIa).—The reaction was carried out in the usual way (see preparation of XIc) utilizing 47 g. of diester IV and an addition time of 60 hours. The orange oil obtained by evaporation of the xylene was distilled at 1 mm. pressure and a bath temperature of 245–260° to give 9.7 g. of a pale yellow solid. This material was recrystallized twice from hexane and twice from aqueous methanol to give 1.8 g. of white plates, m.p. 121–122.3°, second crops yielding 2.0 g., m.p. 120.2–122°. The final mother liquors by chromatography on alumina gave an additional 2.8 g. of acyloin, m.p. 120.2–122.0° (total yield 6.6 g. or 17%). A small sample was recrystallized once from aqueous methanol, once from hexane

(14) *Org. Syntheses*, **25**, 19 (1945).

and twice more from aqueous methanol to give white plates, m.p. 121.3–122.6°.

Anal. Calcd. for $C_{21}H_{24}O_2$: C, 81.78; H, 7.84. Found: C, 81.97; H, 7.86.

p,p'-Octamethylenediphenylmethane (XIIa).—Acyloin XIa (1.9 g.) was reduced by the method outlined for XIc → XIIc, 1.6 g. of crude product remaining when the extraction solvent was evaporated. Recrystallization of this material from methanol gave 0.90 g. of hard white crystals, m.p. 118.8–121.5°. Two additional recrystallizations of this material from methanol gave 0.40 g. of XIIa, m.p. 120.3–121.5°. The mother liquors yielded an additional 0.75 g. of XIIa by chromatographic purification on alumina, m.p. 119.5–121.0°. The total yield amounted to 1.21 g. (67% yield).

Anal. Calcd. for $C_{21}H_{26}$: C, 90.59; H, 9.41. Found: C, 90.64; H, 9.16.

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[CONTRIBUTION FROM THE IPATIEFF HIGH PRESSURE AND CATALYTIC LABORATORY, DEPARTMENT OF CHEMISTRY, NORTHWESTERN UNIVERSITY]

Studies in the Terpene Series. XX.[1] The Thermal Isomerization of Pinane at Atmospheric Pressure

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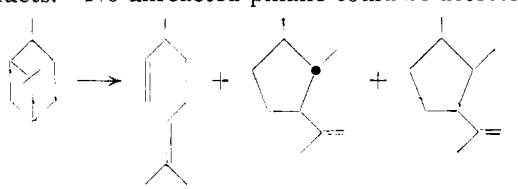
At 500° and atmospheric pressure pinane isomerizes to a diolefin, 3,7-dimethyl-1,6-octadiene, and two cyclic monoölefins, 1-*trans*-2-dimethyl-*cis*-3-isopropenylcyclopentane and 1-*cis*-2-dimethyl-*cis*-3-isopropenylcyclopentane. The diolefin at 500° and atmospheric pressure cyclizes to the two monoölefins produced in the pinane reaction. A free radical mechanism is proposed for the reaction.

The thermal isomerization of pinane at high pressure has been investigated,[4] and it was found that the products of the reaction were 1-*trans*-2-dimethyl-*cis*-3-isopropenylcyclopentane and a bicyclic dihydroterpene of unknown structure, among others.[5] Rummelsburg studied the atmospheric pressure thermal isomerization of pinane but without proving the structures of the products, he suggested that the monocyclic dihydroterpenes consisted mostly of menthenes.[6] The present study was undertaken to determine the structures of the products of the atmospheric thermal reaction of pinane and to compare these products with those produced by the high pressure thermal reaction of pinane.

Results

At 500° and atmospheric pressure pinane (I) isomerizes to a diolefin, 3,7-dimethyl-1,6-octadiene (II), a low boiling cyclic monoölefin, 1-*trans*-2-dimethyl-*cis*-3-isopropenylcyclopentane (III), and a high boiling cyclic monoölefin, 1-*cis*-2-dimethyl-*cis*-3-isopropenylcyclopentane (IV). Under the flow conditions used, the distribution was 13% II, 57% III, 19% IV and 11% high and low boiling products. No unreacted pinane could be detected.



I II III IV

Furthermore, under conditions used for the pinane reaction, the diolefin II cyclizes to the monoölefins III and IV. The formation of 1,2-dimethyl-3-isopropenylcyclopentane rather than 1,2-dimethyl-3-isopropylidenecyclopentane is interesting in view of the observation that an *exo* double bond stabilizes a 5-membered ring.[7]

The method used in investigating the reaction was the following. The products of the reaction were fractionally distilled into many small cuts, and samples of these cuts were hydrogenated quantitatively to determine the degree of unsaturation of each. The distillation curve is in Fig. 1 and the results of the hydrogenations are in Table I. From hydrogenation and elemental analyses it was found that all the products were isomers of pinane of two types, monoölefin and diolefin. The first cuts from distillation contained a mixture of diolefin and low boiling cyclic monoölefin; the final cuts were pure high boiling cyclic monoölefin. Chromatographic separation over silica gel[8] was used successfully to obtain the pure diolefin. The distillation and hydrogenation data were used in the quantitative analysis of the products. The refractive indices of the distillation cuts checked well with the analy-

TABLE I

QUANTITATIVE HYDROGENATIONS OF PRODUCTS FROM THE 500° ISOMERIZATION OF PINANE

Distilled, %	H number[a]	B.p., °C.	$n^{20}D$
7	1.40	157.0	1.4452
16	1.26	158.7	1.4441
38	1.25	160.4	1.4462
50	1.18	161.1	1.4475
61	1.10	161.3	1.4485
90	0.99	170.3	1.4547
95	0.98	171.2	1.4555

[a] Defined as moles of hydrogen absorbed per mole of pinane isomer.

(1) For the previous paper of this series, see H. Pines, A. Rudin, G. Bo and V. N. Ipatieff, THIS JOURNAL, **76**, 2740 (1954).

(2) Universal Oil Products Company Predoctoral Fellow, 1950–1953.

(3) Deceased, November 29, 1952.

(4) V. N. Ipatieff, W. D. Huntsman and H. Pines, THIS JOURNAL, **75**, 6222 (1953).

(5) During the present study it was shown that a third pinane isomer is produced in the high pressure reaction which on hydrogenation gives 1-*cis*-2-dimethyl-*cis*-3-isopropylcyclopentane.

(6) A. L. Rummelsburg, THIS JOURNAL, **66**, 1718 (1944).

(7) H. C. Brown, J. H. Brewster and H. Shechter, *ibid.*, **76**, 467 (1954).

(8) B. J. Mair and A. F. Forziati, *J. Research Natl. Bur. Standards*, **32**, 151, 165 (1944).