Researches on Polyenes. Part II. The Synthesis of Cosmene.*

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The structure, 2 : 6-dimethylocta-1 : 3 : 5 : 7-tetraene, (I), assigned to the dehydromonoterpene, " cosmene," is confirmed by total synthesis. Spectroscopic data for some natural and synthetic tetraenes are discussed, and deductions are made about their steric structures.

A HYDROCARBON, $C_{10}H_{14}$, named cosmene, was recently isolated by Sörensen and Sörensen (*Acta Chem. Scand.*, 1954, **8**, 284) from *Cosmos bipinnatus* Cav., and identified spectroscopically in eight other species (of seven different genera) of the family Compositae. On the basis of its ultra-violet and infra-red spectra, and of biogenetic considerations, the structure (I), with a *trans*-configuration at the –CH=CH– grouping, was proposed; it would thus be the first dehydroterpene, and incidentally the first acyclic terpenoid with an *iso*propenyl grouping known to occur in nature (cf. *inter al.*, Barnard, Bateman, Harding, Koch, Sheppard, and Sutherland, *J.*, 1950, 915).

Bates, Jones, Nayler, and Whiting (unpublished work) have observed the reduction of 1 : 4-diphenylbut-2-yne-1 : 4-diol to 1 : 4-diphenylbuta-1 : 3-diene in fair yield by lithium aluminium hydride. This reaction is synthetically equivalent to semihydrogenation followed by the action of phosphorus di-iodide (Kuhn and Wallenfels, *Ber.*, 1938, **71**, 1889); if general, it should make possible a very simple synthesis of (I) :

$$\mathrm{H_2C{=}CMe{\cdot}CHO + BrMg{\cdot}C{\equiv}C{\cdot}CMe(O{\cdot}MgBr){\cdot}CH{=}CH_2} \longrightarrow$$

$$\underset{\mathrm{(II)}}{\mathrm{H_2C{=}CMe{\cdot}CH(OH){\cdot}C{\equiv}C{\cdot}CMe(OH){\cdot}CH{=}CH_2}} \xrightarrow{\mathrm{LiAlH_4}} \underset{\mathrm{(I)}}{\mathrm{H_2C{=}CMe{\cdot}CH{=}CH{\cdot}CH{=}CMe{\cdot}CH{=}CH_2}}$$

3-Methylpent-1-en-4-yn-3-ol (Cymerman, Heilbron, and Jones, *J.*, 1945, 90; Oroshnik and Mebane, *J. Amer. Chem. Soc.*, 1949, **71**, 2062) was condensed with α-methylacraldehyde *via* the bisbromomagnesium derivative, giving the desired glycol (II) in 72% yield. This was treated with lithium aluminium hydride (4 mols.) in ether at 34°, whereby, in addition to hydroxylic by-products which were not investigated, a fragrant hydrocarbon, $C_{10}H_{14}$, was obtained in 35% yield. Final purification by recrystallisation at $-70°$ gave a product with m. p. $-1°$ to 0°, agreeing well with the melting point ($-2°$ to $-1°$) of cosmene. The infra-red spectra of the synthetic hydrocarbon, before and after recrystallisation, scarcely differed, and were identical, as far as could be ascertained, with the spectrum of cosmene determined by Professor Sörensen. A bis-maleic anhydride adduct, m. p. 198°, identical with that of cosmene, was obtained readily.

Slight differences in the ultra-violet spectra of the synthetic hydrocarbon before and after recrystallisation are illustrated in the Figure; the data for the natural hydrocarbon, which had also been recrystallised repeatedly, actually agree better with the former. There is no doubt that the increase in intensity of absorption following recrystallisation is real, since values of 61,200 and 62,500 were obtained in duplicate experiments starting with

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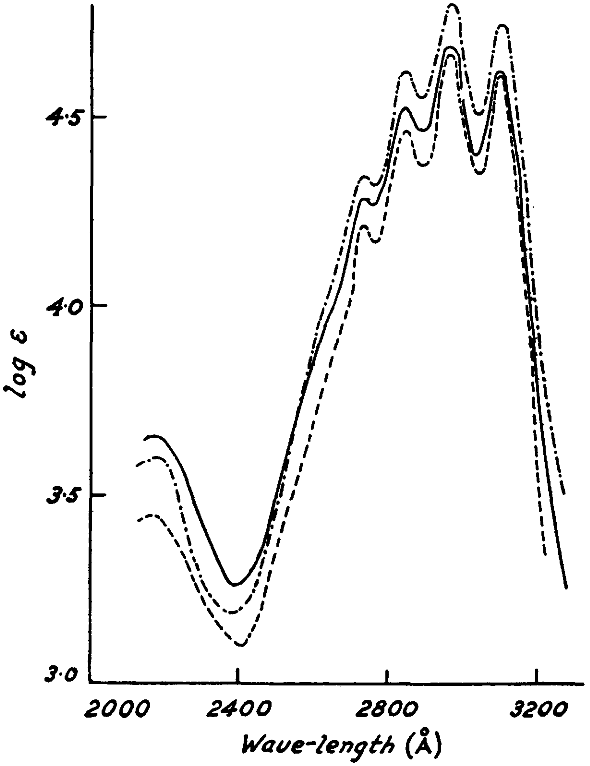
* Part I, *J.*, 1954, 3217.

material with ε 49,500 (values refer to the 2965-Å band). It therefore seems likely that the (analytically pure) hydrocarbon obtained by reduction was nevertheless a mixture of stereoisomers about the trisubstituted ethylenic linkage. The two isomers of (I) with a *cis*-ethylenic linkage would have absorbed intensely in the infra-red below 750 cm.$^{-1}$ and therefore cannot have been present in quantity. Since identical maleic anhydride adducts were obtained, the natural hydrocarbon and the recrystallised synthetic hydrocarbon must have been the same isomer, almost certainly that with an all-*trans*-system of ethylenic bonds (cf. Craig, *J. Amer. Chem. Soc.*, 1950, **72**, 1678). The lower intensity of absorption observed for the natural hydrocarbon may have been the result of an impurity, *e.g.*, ocimene, more difficult to separate by crystallisation than the mono-*cis*-stereoisomer of (I). More probably it was merely a consequence of the great experimental difficulty of working with easily polymerised liquids on a small scale.



Absorption spectrum of cosmene in n-*hexane.*

- - - - - - Natural (Sörensen and Sörensen, *loc. cit.*).

———— Synthetic (before crystallisation).

—·—·— Synthetic (after crystallisation).

The ultra-violet absorption spectra of cosmene and a number of other conjugated tetraenes are summarised in the Table; several conclusions may be drawn. In all cases marked fine-structure is present, the interval between bands being constant at *ca.* 1450 cm.$^{-1}$, provided that Blout and Fields's data for deca-2 : 4 : 6 : 8-tetraene (which we have confirmed) are accepted in preference to Kuhn and Grundmann's older values (*Ber.*, 1938, **71**, 446). The bathochromic effect of substituent methyl groups is about +30 Å each compared with about +45 Å in dienes, and appears to be independent of their location on the tetraene system, as has often been assumed. The considerable discrepancy between " isomerised arachnidonic acid," *i.e.*, an octadecatetraenoic acid of unknown structure, probably all-*trans*, and β-parinaric acid (Ahlers, Brett, and McTaggart, *J. Appl. Chem.*, 1953, **3**, 433), *i.e.*, all-*trans*-octadeca-9 : 11 : 13 : 15-tetraenoic acid, on the one hand, and (all-*trans*-)deca-2 : 4 : 6 : 8-tetraene, on the other, points to a larger " weight effect " [$\Delta\lambda(C_6H_{13}$, approx.) — $\Delta\lambda(CH_3)$ = 20—25 Å] on the absorption spectra of conjugated tetraenes than is encountered with dienes (cf. Bates, Jones, and Whiting, *J.*, 1954, 1854).

When a *cis*-linkage is introduced, as in α-parinaric acid, the intensity of adsorption is reduced, and the maxima are displaced to *longer* wave-lengths. These effects are analogous to those observed in 1 : 4-disubstituted dienes (Nichols, Herb, and Riemenschneider, *J. Amer. Chem. Soc.*, 1951, **73**, 247) and in the hexa-2 : 4-dienoic acids (Allan, Jones, and Whiting, unpublished work). Zechmeister's rule (*Experientia*, 1954, **10**, 1), that an all-*trans*-polyene absorbs maximally at longer wave-lengths than any of its stereoisomers, is thus untrue for simple *unbranched* polyenes; though his generalisation that the all-*trans* compound shows the highest extinction coefficient does hold within this group.

From the Table it is clear that the Centaur Y compounds of Hellström and Löfgren (*Acta Chem. Scand.*, 1952, **6**, 1024) must be tri- or tetra-substituted tetraenes or, more probably, possess one or more *cis*-linkages.

*Absorption spectra of conjugated tetraenes.**

Substance	Sol-vent †	$\lambda_{max.}$	$10^{-3}\,\varepsilon$	$\lambda_{max.}$	$10^{-3}\,\varepsilon$	$\lambda_{max.}$	$10^{-3}\,\varepsilon$	$\lambda_{max.}$	$10^{-3}\,\varepsilon$	Ref.
Octa-1 : 3 : 5 : 7-tetraene	CH	3040	(9*x*) ‡	2905	(10*x*)	2780	(8*x*)	2680	(6*x*)	1
	H	3200	56	2970	56	2830	33	2720	20	2
Deca-2 : 4 : 6 : 8-tetraene	H	3100	—	2950	—	2830	—	2720	—	3
	H	3100	76·5	2960	84·5	2830	51	2730	25	4
Cosmene (natural)	H	3097	42·7	2960	47·5	2830	30	2720	16·9	5
Cosmene (synthetic)	H	3105	55·5	2965	62·5	2845	41·6	2740	21·8	6
α-Parinaric acid	A	3200	61·7	3050	66	2915	42·7	—	—	7
β-Parinaric acid	A ?	3160	—	3010	73·5	2880	—	—	—	8
" Isomerised arachnidonic acid "	A	3150	67	3000	73	2860	58	2715	21·3	9
Centaur Y_1 and Y_2	CH	3195	—	3045	—	2915	—	2800	—	10
Deca-1 : 3 : 5 : 7 : 9-pentaene	IO	3343	118	3180	112	3039	63	2908	25	11

* Wave-lengths are in Å. † H, hexane or heptane : CH, *cyclo*hexane; IO, *iso*octane : A, absolute ethanol. For polyene hydrocarbons the solvent shifts within this group are small; see reference 11. ‡ *x* is unknown; intensities quoted are relative.

References: (1) Woods and Schwartzman, *J. Amer. Chem. Soc.*, 1949, **71**, 1396; (2) Kuhn and Grundmann, *Ber.*, 1938, **71**, 446; (3) Blout and Fields, *J. Amer. Chem. Soc.*, 1948, **70**, 189; (4) Nayler and Whiting, unpublished work; (5) Sörensen and Sörensen, *Acta Chem. Scand.*, 1954, **8**, 284; (6) present work; (7) Riley, *J.*, 1950, 14; (8) Ahlers, Brett, and McTaggart, *J. Appl. Chem.*, 1953, **3**, 433; (9) Mowry, Brode, and Brown, *J. Biol. Chem.*, 1942, **142**, 671; (10) Hellström and Löfgren, *Acta Chem. Scand.*, 1952, **6**, 1024; (11) Mebane, *J. Amer. Chem. Soc.*, 1952, **74**, 5527.

The synthetic method described above appears to be easily the most convenient yet found for aliphatic polyenes of moderate chain-length, providing that the grouping >CH=CH·CH=C< is present in the molecule. It is not, however, applicable to 2 : 5-dimethylhexa-2 : 4-diene (unpublished work).

EXPERIMENTAL

2 : 6-*Dimethylocta*-1 : 7-*dien*-4-*yne*-3 : 6-*diol*.—A solution of ethylmagnesium bromide was prepared from magnesium (2·5 g.) in ether under nitrogen, and ether was replaced by benzene until the b. p. of the distillate reached 70° (final volume 150 c.c.). The mixture was cooled to 0° while a solution of 3-methylpent-1-en-4-yn-3-ol (Oroshnik and Mebane, *loc. cit.*) (1·4 g.) in ether (10 c.c.) was added; stirring was continued for 3 hr. at room temperature. After the mixture had been cooled to 0°, α-methylacraldehyde (3·5 g.) in benzene (25 c.c.) was added, and the mixture was stirred for 5 hr. at room temperature; the originally insoluble viscous complex then dissolved. Addition of ammonium chloride solution, isolation of the neutral fraction, and distillation gave the *glycol* (5·7 g.), b. p. 75—80° (bath-temp.)/10^{-3} mm., n_D^{16} 1·4946 (Found: C, 72·05; H, 8·65. $C_{10}H_{14}O_2$ requires C, 72·25; H, 8·5%).

2 : 6-*Dimethylocta*-1 : 3 : 5 : 7-*tetraene* (*Cosmene*).—The glycol (3·0 g.) in ether (50 c.c.) was added to a solution of lithium aluminium hydride (2·5 g.) in ether (200 c.c.), and the mixture was heated under reflux for 4 hr. Cautious addition of ice and aqueous tartaric acid, and ether-extraction gave a solution which was dried ($MgSO_4$) at −4° under nitrogen. Removal of ether at 0° gave a residue which was extracted with light petroleum (b. p. 40–60°; 5 × 30 c.c.) at 20° and passed through activated alumina. Solvent was again removed at 0°, and the residue was distilled, giving the *tetraene* (0·9 g.), b. p. 50° (bath-temp.)/0·2 mm., n_D^{18} 1·5852, m. p. −7°

to −5° (Found: C, 89·3; H, 10·7. $C_{10}H_{14}$ requires C, 89·5; H, 10·5%). Four recrystallisations from pentane at −70° raised the m. p. to −1° to 0°, and the intensity of absorption as illustrated; the refractive index was almost unchanged, n_D^{18} now 1·5850. Sörensen and Sörensen (*loc. cit.*) give b. p. 30°/0·3 mm., n_D^{20} 1·584, m. p. −2° to −1°. The synthetic hydrocarbon polymerised and oxidised rapidly in air, but could be stored for several months at −60° in nitrogen.

5 : 6′-*Dimethyl*-1 : 2 : 3 : 4 : 1′ : 2′ : 3′ : 4′-*octahydrodiphenyl*-2 : 3 : 2′ : 3′-*tetracarboxylic Dianhydride.*—A solution of maleic anhydride (0·65 g.) in benzene (10 c.c.) was cooled until mainly solid, and the tetraene (0·3 g.) was added, whereupon a yellow colour developed at once. The mixture was warmed to room temperature, then set aside at 0° for 3 days. Evaporation of the benzene and extraction with light petroleum (b. p. 60—80°) left a residue which was crystallised repeatedly from benzene–light petroleum, then acetone–light petroleum, giving needles, m. p. 198°, undepressed on admixture with a specimen of the maleic anhydride adduct of cosmene, for which Sörensen and Sörensen (*loc. cit.*) give m. p. 198—199° (Found: C, 65·3; H, 5·5. Calc. for $C_{18}H_{18}O_6$: C, 65·45; H, 5·5%).

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