

Synthesis of 7,7'-Deuterated Lycopene, 7,7'-Deuterated Rhodopin, and 7-Deuterated Apo-8'-lycopenal

JON EIGILL JOHANSEN and SYNNØVE LIAAEN-JENSEN

Organic Chemistry Laboratories, Norwegian Institute of Technology, University of Trondheim, N-7034 Trondheim-NTH, Norway

The synthesis of 7,7'-deuterated lycopene (8), 7,7'-deuterated rhodopin (9), and 7-deuterated apo-8'-lycopenal (7) is described. Deuterium was incorporated into geranyltriphenylphosphonium bromide (2) and (7-hydroxy-3,7-dimethyloct-2-en-1-yl) triphenylphosphonium bromide (3) through a base catalyzed exchange reaction.

As a model for the exchange reaction was studied the synthesis of undeuterated and deuterated 4,8-dimethyl-1-phenylnona-1,3,7-triene (14 and 15), followed by GLC-, PMR-, and IR characterization of the *cis-trans* isomeric products (14A, 14C, 15A and 15C).

Spectroscopic and other physical properties of intermediates, products and model compounds are reported.

IR absorption at 920 and 730 cm^{-1} in deuterated carotenoids is on an empirical basis ascribed to out-of-plane deformation of *trans*-CH = CD.

A number of deuterium labelled carotenoids have been prepared recently by partial or total synthesis.¹⁻⁵ Furthermore, fully deuterated carotenes have been isolated from algae grown in heavy water.⁶ Spectrometric studies on deuterated carotenoids have provided useful information especially on mass spectrometric fragmentations.¹⁻⁸

Generally two approaches are used for chemical synthesis of deuterium labelled organic compounds: reduction or hydrogen-deuterium exchange.^{9a} Reduction reactions have been used in all previous preparations of deuterium labelled carotenoids. In the present paper we report the first syntheses of deuterium labelled carotenoids using the exchange technique, in principle as discussed in the previous paper.⁵ The same type of exchange reaction has recently independently been used by Bestmann

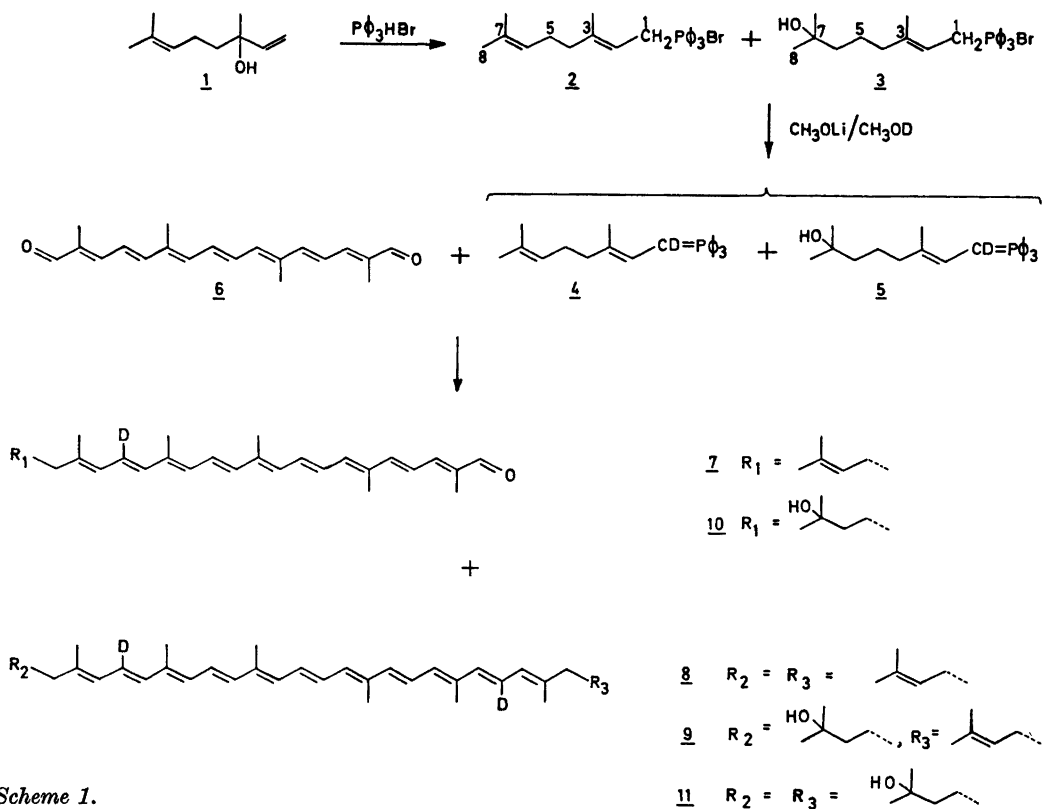
et al. for the preparation of a tritium labelled phosphorane.^{9b} The following paper¹⁰ deals with a related exchange reaction of enolizable hydrogen.

RESULTS AND DISCUSSION

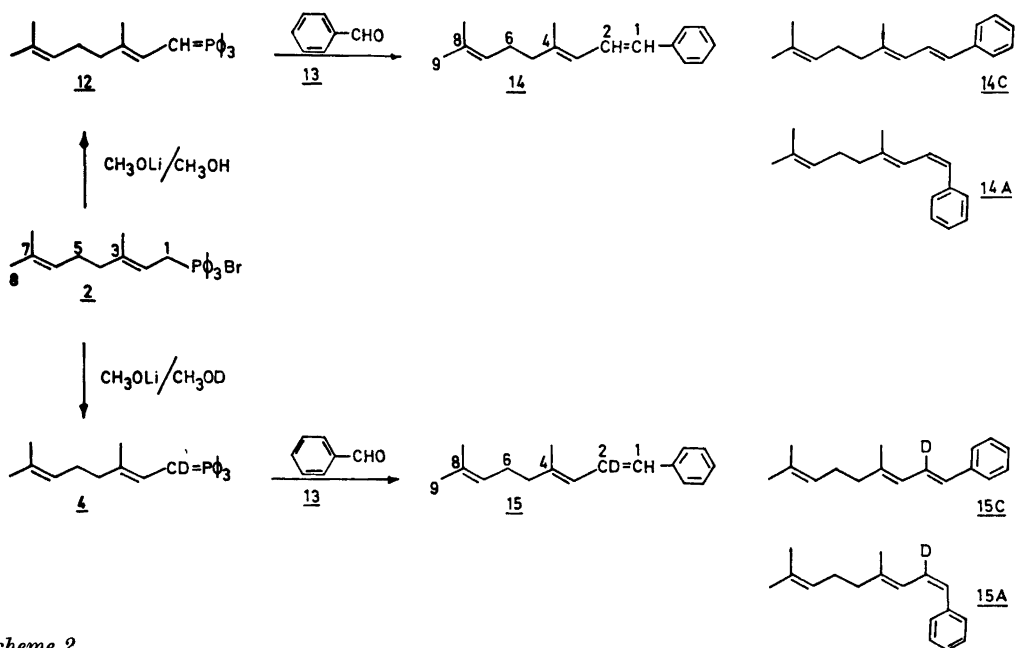
The synthesis of 7,7'-deuterated lycopene (8), 7,7'-deuterated rhodopin (9), and 7-deuterated apo-8'-lycopenal (7) was accomplished¹¹ by the route shown in Scheme 1 from linalool (1).

Hydrogen bromide catalyzed addition of methanol to the isopropylidene group of linalool (1) or geraniol has been reported.¹² Chloroform was therefore used as solvent in the first step. However, it is also known that geranyltriphenylphosphonium bromide (2) readily adds water.¹³ Since water is produced on formation of geranyltriphenylphosphonium bromide (2) from linalool (1) it is conceivable that water was subsequently added to the phosphonium salt 2, resulting in a mixture of geranyltriphenylphosphonium bromide (2, 76 %) and 7-hydroxy-3,7-dimethyloct-2-enyl)triphenylphosphonium bromide (3, 24 %), judged by the PMR spectrum.

Suitable conditions for the following exchange reaction of the mixed phosphonium salts (2 and 3) with deuteriomethanol and lithium methylate was studied by a model reaction (Scheme 2). Only products obtained from geranyltriphenylphosphonium bromide (2) were examined. In undeuterated methanol/lithium methylate the phosphorane 12 was readily obtained, judged by its further reaction with benzaldehyde (13) to the condensation product 14. Hydrogen-deuterium exchange during phosphorane (4)



Scheme 1.



Scheme 2.

formation from 2, followed by condensation with benzaldehyde (13) provided the deuterated hydrocarbon 15. Under the conditions used 80 % deuterium incorporation was achieved after 5 min. The stereochemistry of the model compounds prepared is discussed below.

The mixed deuterated phosphoranes 4 and 5 (Scheme 1) gave with crocetin dial (6) the monocondensation product 7 (15 % of carotenoid products) and 7,7'-deuterated lycopene (8, 59 %) and 7,7'-deuterated rhodopin (9, 26 %) as dicondensation products. The predicted minor condensation products 7-deuterated apo-8'-rhodopin (10) and the diol 11 were not isolated. Large excess of phosphorane was required to obtain high yield of dicondensation products (8 and 9) relative to the monocondensation product (7). Physical properties of the products 7, 8, and 9 are given in the Experimental Part.

Judged by electronic spectra crystalline 8 was the all-*trans* compound. *cis*-Bond formation during the Wittig reaction¹⁴ is in this case of 7(7') double bond(s) less favourable due to steric hindrance. Prior to crystallization two *cis* isomers of 7,7'-deuterated lycopene (8) were isolated. However, these *cis* isomers were

identical, judged by *R_F*-values and electronic spectra, to those present in the iodine catalyzed stereomutation mixture of all-*trans* 8, known to contain no isomers with sterically hindered double bonds.¹⁵ It consequently appears that the Wittig reactions leading to 7, 8, and 9 had *trans* stereospecificity.

7,7'-Deuterated lycopene (8) prepared here had 92 % deuterium incorporation (D₀:D₁:D₂ = 3:10:87, calculated from the mass spectrum as in a preceding paper⁵) when using 160 times excess of CH₃OD and 87 % incorporation (D₀:D₁:D₂ = 5:16:79) when using 40 times excess of CH₃OD relatively to exchangeable hydrogen in the phosphonium bromide. A previously synthesized 7,7'-deuterated lycopene (8) obtained *via* a different route involving lithium aluminium deuteride reduction had 80 % incorporation (D₀:D₁:D₂ = 5:30:65).⁴

Relatively few IR data are available for deuterated carotenoids.⁴⁻⁶ IR data for products 7, 8, and 9 are discussed in connection with data for the products of the model reaction, Scheme 2.

The olefinic region in the PMR spectra of hydrocarbons 14 and 15 were very complex due to a mixture of *cis* and *trans* isomers. GLC analysis revealed three components for 14

Table 1. Infrared absorptions of some deuterated and undeuterated carotenoids and hydrocarbon model compounds.

Compound	a	b	c	d
Lycopene	961	—	—	—
7,7'-Deuterated lycopene (8) ⁴	960	925	727	—
7,7'-Deuterated lycopene (8) ⁵	961	927	730	—
11,11'-Deuterated ϵ -carotene ⁵	965	922	732	—
7-Deuterated apo-8'-lycopenal (7)	966	920	729	—
Rhodopin	960	—	—	—
7,7'-Deuterated rhodopin (9)	960	925	728	—
14 (stereoisomeric mixture)	960s	—	—	772m
14A (1- <i>cis</i> -14)	(965w)	—	—	775s
14C (1- <i>trans</i> -14)	965s	—	—	—
15 (stereoisomeric mixture)	(960w)	918m	727s	(770w) 671w
15A (1- <i>cis</i> -15)	(960w)	(920m)	(730w)	(770w) 671m
15C (1- <i>trans</i> -15)	—	918s	727s	—
<i>cis</i> EtCH = CHEt ¹⁸	—	—	—	709
<i>cis</i> EtCH = CDEt ¹⁸	—	—	—	641

a = C—H out-of-plane deformation of *trans*-CH=CH.

b = C—H(D) out-of-plane deformation of *trans*-CD=CH.

c = C—H out-of-plane deformation of *cis*-CH=CH.

d = C—H(D) out-of-plane deformation of *cis*-CD=CH.

s = strong, m = medium, w = weak.

Parentheses indicate that these absorptions might be explained by incomplete separation on GLC or incomplete deuteration.

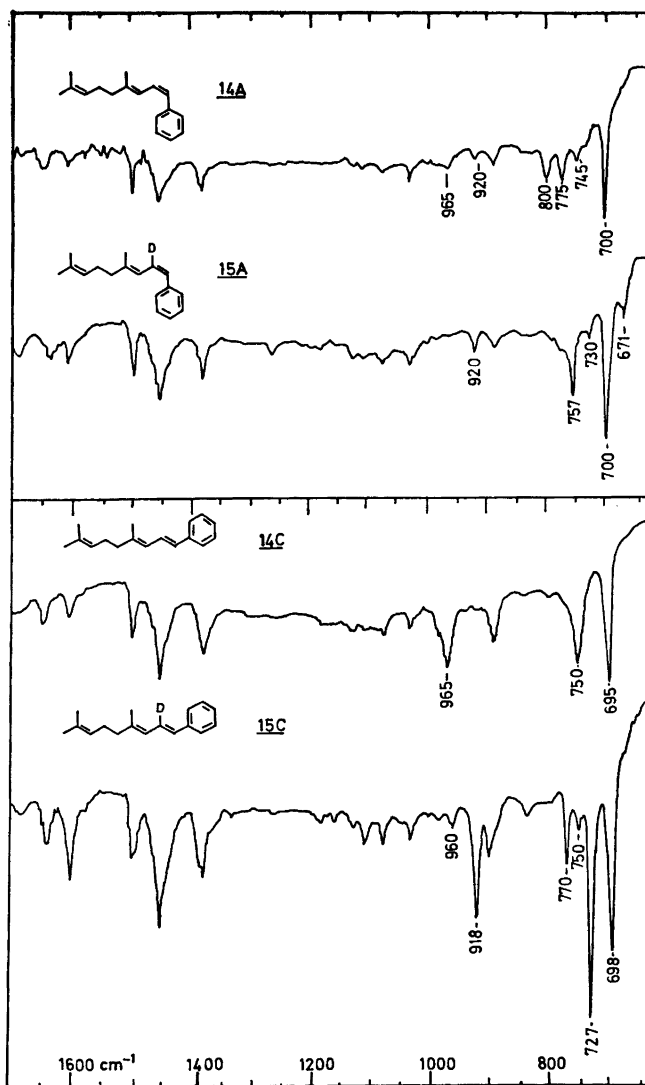


Fig. 1. Infrared spectra (liq.) of 1-*cis*-4,8-dimethyl-1-phenylnona-1,3,7-triene (14A), 1-*trans*-4,8-dimethyl-1-phenylnona-1,3,7-triene (14C), 1-*cis* 2-deuterated 4,8-dimethyl-1-phenylnona-1,3,7-triene (15A), and 1-*trans* 2-deuterated 4,8-dimethyl-1-phenylnona-1,3,7-triene (15C).

(14A–C) and four for 15 (15A–D). By preparative GLC 14A and 14C, and 15A and 15C were separated and isolated. IR data and PMR spectra revealed that 14A and 15A had *cis* configuration and 14C and 15C had *trans* configuration around the disubstituted double bond. The interpretation was supported by a computer-simulated (Program NMR 01¹⁶) ABC spectrum with assumed chemical shifts and coupling constants. Available data do not

permit definition of the stereochemistry of the adjacent double bond in these isomers (arbitrarily presented as *trans* in Scheme 2).

Characteristic IR data for the hydrocarbons 14 (stereoisomeric mixture), 14A, 14C, 15 (stereoisomeric mixture), 15A and 15C are given in Table 1, together with relevant data for the deuterated all-*trans* carotenoids here or previously prepared (7, 8, and 9) and undeuterated analogues. Assignments of the

~920 and ~730 cm⁻¹ absorptions in deuterated carotenoids to *trans*-CD=CH is supported by data for the *trans* model compounds 14C (undeuterated) and 15C (deuterated). Absorption at 920–927 cm⁻¹ has previously been considered characteristic of a monodeuterated *trans* double bond whereas absorption at 727–730 cm⁻¹, first considered due to an impurity,⁴ later has been ascribed to this same group.¹⁷ Data for the model compounds further suggest that absorption at 775 cm⁻¹ (14A) is connected with C–H out-of-plane deformation of *cis*-CH=CH, whereas the corresponding vibration for *cis*-CD=CH occurs at 671 cm⁻¹ (14C). Absorption at 641 cm⁻¹ in *cis* EtCD=CH₂Et has previously been ascribed to such deformation at *cis*-CD=CH.¹⁸

The PMR spectra of 7,7'-deuterated lycopene (8), 7,7'-deuterated rhodopin (9), and 7-deuterated apo-8'-lycopenal (7) were as expected.

Discussion of the mass spectrometric data will be published separately.¹⁹

EXPERIMENTAL

Materials and methods. Methylene chloride (Merck *p.a.*) used in the exchange reactions had passed through a column of Al₂O₃ (Merck basic, activity grade 1²⁰). Ether had passed through a column of Al₂O₃ (Spence type H, activity grade 1²⁰). Technical grade acetone was distilled. Technical grade petroleum ether was distilled (b.p. 40–65°C) and then passed through a column of Al₂O₃ (Merck neutral, activity grade 1²⁰). Deuterated methanol (CH₃OD) was from Koch-Light (>99% deuterated). Other solvents used were of analytical grade.

For column chromatography was used Merck, Spence or Woelm Al₂O₃, activity grade 1–3,²⁰ and Merck kieselgel (0.05–0.2 mm). TLC was performed on Merck Al₂O₃ or kieselgel (type 60) with or without indicator as stated in each case. Paper chromatography was carried out on Schleicher and Schüll Nos. 287 (kieselguhr) and 288 (aluminium oxide).

GLC was carried out on a Perkin Elmer F 11 flame ionization gas chromatograph. Other instruments used were as specified previously.²¹ Complete spectra are available elsewhere.¹¹

Deuterated carotenoids

Geranyltriphenylphosphonium bromide (2) and *(7-hydroxy-3,7-dimethyloct-2-enyl)triphenylphosphonium bromide* (3). Linalool (1, 145 g) and triphenylphosphonium bromide [286 g; m.p. 187–193°C; δ (CDCl₃) 7.50–8.15 (15 aromatic H) and 12.15 s (1 H); prepared by the procedure

of Schwieter *et al.*²²] in chloroform (0.7 l) were stirred at room temperature for 20 h. This gave a mixture of 2 (76%) and 3 (24%), yield 358 g (77% based on 1), on crystallization from methylene chloride-ethyl acetate; m.p. 164–165°C; λ_{max} (MeOH) 214, 261, 267, and 274 nm [*E*(1%, 1 cm) 575, 31, 37 and 30]; ν_{max} (KBr) 3040–2770 (CH), 1660 (C=C), 1585, 1480 and 1445 (phenyl, CH₂, CH₃), 1435 (P-phenyl), 995 (*trans*-CH=CH), 750, 725 and 690 cm⁻¹ (monosubst. phenyl and bromine); δ (CDCl₃) 1.17 s (H-8, CH₃-7 in 3), 1.35 s and 1.42 s (3 H, CH₃-3 in 2 and 3), 1.52 s and 1.59 s (H-8, CH₃-7 in 2), 1.17, 1.52, and 1.59 counting for 6 H, 1.77 (H-6 in 2?), 1.9–2.0 (4 H, H-3,4), 2.52 s (*ca.* 1/4 H, OH in 3), 4.54 dd (2 H, J_{P-1} = 14 Hz, J₁₋₂ = 8 Hz, H-1), 5.00 m (H-6 in 2?), 5.08 t (J₁₋₂ = 8 Hz, H-2?) and 7.7–8.05 (15 aromatic H). An aliquot, after recrystallization from methylene chloride-ethyl acetate, melted at 177–178°C (reported 189°C for 2¹³ and 194°C for 3¹³).

7-Deuterated apo-8'-lycopenal (7), *7,7'-deuterated lycopene* (8) and *7,7'-deuterated rhodopin* (9). Conditions for formation of the deuterated phosphoranes were investigated in model experiments described below.

(i). A solution of the phosphonium bromides 2 and 3 (35 mg) in CH₃OD (1.1 ml) and 0.28 N CH₃OLi (see below) was stirred at room temperature for 5 min. Crocetinial (6, 10 mg) in methylene chloride (5 ml) was added slowly, and the reaction mixture stirred at 30°C for 3 h. The reaction mixture was taken to dryness, the residue dissolved in chloroform and chromatographed by TLC on kieselgel G (chloroform), yield 0.34 mg (2% based on 6) of 8; λ_{max} (acetone) 446, 472, and 504 nm (most intense maximum is italicized); *m/e* (200°C) 538 (M); D₀:D₁:D₂ = 3:10:87; 92% deuterium incorporation and 7.8 mg (52% based on 6) of 7; λ_{max} (acetone) 446 nm; *m/e* (200°C) 417 (M); D₀:D₁ = 6:94; 94% deuterium incorporation.

(ii). To a mixture of 2 and 3 (1.44 g) in CH₃OD (10.8 ml) and 0.28 N CH₃OLi, stirred for 5 min at room temperature, was added methylene chloride (3 ml). Crocetinial (6, 20 mg) in methylene chloride (4 ml) was added slowly, and the mixture stirred at 30°C for 3 h. The mixture was taken to dryness, the residue dissolved in 90% methanol, extracted with petroleum ether and washed with aqueous 5% NaCl-solution and water. The solution was taken to dryness, dissolved in ether, and the pigments purified by TLC on kieselgel G (15% acetone in petroleum ether = 15% APE). This gave 7,7'-deuterated lycopene (8); yield 12.1 mg (31% based on 6), 7,7'-deuterated rhodopin (9); yield 5.6 mg (14% based on 6) and 7-deuterated apo-8'-lycopenal (7); yield 2.5 mg (8% based on 6).

7-Deuterated apo-8'-lycopenal (7) was rechromatographed by TLC on kieselgel G (15% APE). Chromatography on paper (SS 287, 5% APE) gave two zones: neo¹⁵ a; R_F = 0.90; λ_{max}

(acetone) 348 and 357 nm and all-*trans*; $R_F = 0.76$; λ_{\max} (acetone) 466 nm. 7 was crystallized from acetone; m.p. 122–124°C (reported 141°C for the undeuterated analogue²³); λ_{\max} (acetone) 350 and 469 nm (reported λ_{\max} (acetone) 470 nm²⁴); ν_{\max} (KBr) 3030–2850 (CH), 1670 (conj. CH=O), 1610 (CH₂), 1185, 1005, 966 (*trans*-CH=CH), 920 and 729 cm⁻¹ (*trans*-CD=CH); δ (CDCl₃) 0.88 and 1.28 (imp.), 1.64 s and 1.70 s (isopropylidene CH₃), 1.85 s (end-of-chain CH₃), 1.90 (end-of-chain CH₃ at CHO), 2.02–2.40 (allylic CH₂) and 9.42 (aldehyde H); m/e (190°C), 417 (M), 348 (M–69), 325 (M–92), 322 (M–95) and 311 (M–106); D₀:D₁:D₂ = 12:88; 88 % deuterium incorporation.

7,7'-Deuterated lycopene (8) was rechromatographed by TLC on kieselgel G (5 % APE). Paper chromatography (SS 287, 2 % APE) gave three zones: neo b, $R_F = 0.90$, λ_{\max} (ether) 361, (440), 464, and 493 nm; neo a, $R_F = 0.80$, λ_{\max} (ether) 360, 442, 467, and 497.5 nm, and all-*trans* $R_F = 0.73$, λ_{\max} (ether) 360, 445, 471, and 503.5 nm. The all-*trans* isomer was inseparable from authentic lycopene. The same isomers were obtained on iodine catalyzed stereomutation of each isomer.²⁵ 8 was crystallized from acetone-petroleum ether, yield 6.0 mg; m.p. 157–158°C (reported 140–160°C for the deuterated⁴ and 171°C for the undeuterated analogue¹³), undeepressed on admixture with authentic lycopene; λ_{\max} (acetone) 446, 473, and 505 nm; % D_B/D_{II}²⁶ = 6, % III/II²⁶ = 78 (reported λ_{\max} (acetone) 363, 446.5, 475, and 506 nm²⁵ for undeuterated lycopene); ν_{\max} (KBr) 3040–2855 (CH), 1625 (C=C), 1450 (CH₂), 1375 (CH₂), 961 (*trans*-CH=CH), 927 (*trans*-CD=CH), 825 (>C=CH-) and 730 (*trans*-CD=CH); δ (CDCl₃) 1.62 and 1.70 (4 isopropylidene CH₃), 1.83 (2 end-of-chain CH₃), 1.97 (4 in-chain CH₃), 2.10 and 2.15 (4 allylic CH₂), 5.13 (2 H, H-2,2'), 5.96 (2 H, H-6,6') and 6.78–6.25 (12 olefinic H); m/e (190°C) 538 (M), 469 (M–69), 446 (M–92), and 432 (M–106); D₀:D₁:D₂ = 5:16:79; 87 % deuterium incorporation.

7,7'-Deuterated rhodopin (9) was rechromatographed by TLC on kieselgel G (15 % APE). Paper chromatography (SS 287, 2 % APE) gave three zones: neo b, $R_F = 0.69$, neo a, $R_F = 0.66$, and *trans* $R_F = 0.46$. The *trans* isomer could not be separated from synthetic undeuterated rhodopin.²³ 9 had λ_{\max} (ether), 360, 441, 467, and 498; λ_{\max} (acetone) 446, 471, and 502 nm (reported λ_{\max} (acetone) 365, 447.5, 477, and 508 nm for the *trans* isomer²⁵); ν_{\max} (KBr) 3420 (OH), 3030–2850 (CH), 1630, 1450 (CH₂), 1375 (CH₂), 960 (*trans*-CH=CH), 925 and 728 cm⁻¹ (*trans*-CD=CH); δ (CDCl₃) 0.88 and 1.27 (imp.), 1.60 and 1.67 s (isopropylidene CH₃), 1.82 s (end-of-chain CH₃), 1.96 s (in-chain CH₃), 2.10–2.15 (allylic CH₂), 5.13 m (isopropylidene), 5.96 (H-6,6'), and 6.0–6.9 (olefinic H); m/e (200°C) 556 (M), 538 (M–18), 464 (M–92), and 450 (M–106); D₀:D₁:D₂ = 7:13:80; 87 % deuterium incorporation.

Model compounds

Conditions for formation of undeuterated and deuterated phosphoranones. A 0.28 N solution of CH₃OLi in CH₃OH was prepared by addition of 20 % BuLi in hexane (9.6 ml) to CH₃OH (100 ml).

A 0.28 N solution of CH₃OLi in CH₃OD was prepared by addition of 20 % BuLi in hexane (1.2 ml) to CH₃OD (10 g).

Equivalent amounts of base and phosphonium bromide were used for phosphorane formation, unless otherwise stated. The reactions were monitored by TLC.

4,8-Dimethyl-1-phenylnona-1,3,7-triene (14). To a mixture of the phosphonium salts 2 and 3 (0.72 g) in CH₃OH (5.5 ml) and 0.28 N CH₃OLi, stirred for 5 min at 20°C, was added freshly distilled benzaldehyde (13, 0.16 g). The mixture was stirred at 20°C for 2 h and taken to dryness. TLC twice on kieselgel PF 254+366 (petroleum ether) gave 14; yield 0.162 g (63 % based on 2); λ_{\max} (hexane) 287 nm; ν_{\max} (liq.) 3080–2710 (CH), 1675, 1637 (conj. phenyl), 1598 (conj. C=C), 1491, 1448 (CH₂), 1374 (CH₂), 1180–1030 (phenyl), 960 (*trans*-CH=CH), 885, 827 (>C=CH-), 800, 772 (*cis*-CH=CH), 748 and 698 cm⁻¹ (monosubst. benzene); δ (CDCl₃) 1.61 s, 1.70 s (6 H, H-9, CH₃-8), 1.84 s (3 H, CH₃-4), 2.11–2.24 (4 H, H-5,6), 5.13 m (1 H, H-7), 5.90–7.15 (3 H, H-1,2,3, complex coupling) and 7.15–7.42 (5 aromatic H); m/e (110°C) 226 (M), 157 (100 %) and 69 (98 %). 14, analyzed on GLC (column OV-17) gave three peaks (14A, 14B and 14C) with retention time (210°C) 15, 17, and 22 min and relative integral 45:12:43, respectively. 14A and 14C were separated preparatively in the same GLC system.

1-*cis*-4,8-Dimethyl-1-phenylnona-1,3,7-triene (14A) had ν_{\max} (liq.) 3080–2730 (CH), 1640 (conj. phenyl), 1600 (conj. C=C), 1570, 1490, 1450 (CH₂), 1375 (CH₂), 1180–1030 (phenyl), 965 (imp. from 6b, c?), 885, 825 (>C=CH-), 800, 775 (*cis*-CH=CH), 745 and 700 cm⁻¹ (monosubst. benzene); δ (CDCl₃) 1.61 s and 1.70 s (6 H, H-8, CH₃-8), 1.83 s (3 H, CH₃-4), 2.11–2.24 (4 H, H-5,6), 5.12 m (1 H, H-7), 6.39 (3 H, H-1,2,3) and 7.20–7.40 (5 aromatic H).

1-*trans*-4,8-Dimethyl-1-phenylnona-1,3,7-triene (14C) exhibited ν_{\max} (liq.) 3080–2720 (CH), 1640 (conj. phenyl), 1598 (conj. C=C), 1575, 1495, 1449 (CH₂), 1375 (CH₂), 1180–1030 (phenyl), 965 (*trans*-CH=CH), 890, 845, 805, 750 and 695 cm⁻¹ (monosubst. benzene); δ (CDCl₃) 1.63 s and 1.70 s (6 H, H-9, CH₃-8), 1.87 s (3 H, CH₃-4), 2.13–2.25 (4 H, H-5,6), 5.17 m (1 H, H-7), 5.92, 6.09, 6.28, 6.53, 6.82, 6.99, 7.12 (3 H, H-1,2,3), and 7.2–7.4 (5 aromatic H); the spectrum showed good agreement with a computer-simulated ABC spectrum assuming the given coupling constants and chemical shifts of the H-1, H-2, and H-3, protons, confirming the *trans* 1-double bond.

2-Deuterated 4,8-dimethyl-1-phenylnona-1,3,7-

triene (15). (i). To a mixture of the phosphonium bromides 2 and 3 (0.72 g) in CH₃OD (5.5 ml) and 0.28 N CH₃OLi stirred for 1 h at 20°C was added freshly distilled benzaldehyde (13, 0.16 g). The reaction mixture was stirred for 2 h at 30°C, and taken to dryness under vacuum. TLC as above gave 0.029 g (11% based on 2) of 15; D₀:D₁=20:80; 80% deuterium incorporation.

(ii). To a mixture of 2 and 3 (0.72 g) in CH₃OD (5.5 ml) and 0.28 N CH₃OLi stirred for 5 min at 20°C was added freshly distilled benzaldehyde (13, 0.16 g) and then treated as above. This gave 7, yield 0.202 g (78% based on 2); λ_{max} (hexane) 287 nm; ν_{max} (liq.) 3080–2710 (CH), 2250 (CD), 1715, 1680, 1633 (conj. phenyl), 1595 (conj. C=C), 1491, 1447 (CH₂), 1376 (CH₃), 1180–1030 (phenyl), 960 (imp. from 14?), 918 (*trans*-CD=CH), 899, 837 (>C=CH-), 770 (imp. from 14?), 756, 727 (*trans*-CD=CH), 702–692 (monosubst. benzene), and 671 cm⁻¹ (*cis*-CD=CH); δ (CDCl₃) 1.63 s, 1.69 s (6 H, H-9, CH₃-8), 1.82 (3 H, H-4), 2.10–2.23 (4 H, H-5,6), 5.13 m (1 H, H-7), 6.00 and 6.39 (2 H, H-1,3) and 7.05–7.35 (5 aromatic H); *m/e* (110°C) 227 (M), 158 (96%) and 69 (100%); D₀:D₁=18:82; 82% deuterium incorporation. 15 was analyzed by GLC (column OV-17) and gave four peaks (15A, 15B, 15C and 15D) with retention time (210°C) 15, 18, 24, and 27 min and relative integrals 28:19:43:10, respectively. 15A and 15C were separated preparatively in the same GLC system.

I-cis 2-Deuterated 4,8-dimethyl-1-phenylnona-1,3,7-triene (15A) showed ν_{max} (liq.) 3080–2720 (CH), 2240 (CD), 1680, 1630 (conj. phenyl), 1600 (conj. C=C), 1492, 1447 (CH₂), 1376 (CH₂), 1180–1030 (phenyl), 920 (imp. from 15B, C?, C?), 885, 840 (>C=CH-), 757, 730 (imp. from 15B, C?), 700 (monosubst. benzene), and 671 cm⁻¹ (*cis*-CD=CH); δ (CDCl₃) 1.60 s and 1.68 s (6 H, H-9, CH₃-8), 1.83 (3 H, H-4), 2.06–2.25 (4 H, H-5,6), 5.16 (1 H?, H-7), 6.32–6.39 (2 H?, H-1,3) and 7.25–7.50 (5 aromatic H).

1-trans 2-Deuterated 4,8-dimethyl-1-phenylnona-1,3,7-triene (15C) had ν_{max} (liq.) 3080–2720 (CH), 2250 (CD), 1680, 1630 (conj. phenyl), 1595 (conj. C=C), 1496, 1447 (CH₂), 1376 (CH₂), 1180–1030 (phenyl), 918 (*trans*-CD=CH), 895, 835 (>C=CH-), 770, 750, 727 (*trans*-CD=CH), and 693 cm⁻¹ (monosubst. benzene); δ (CDCl₃) 1.65 s and 1.71 s (6 H, H-9, CH₃-8), 1.87 s (3 H, CH₃-4), 2.10–2.25 (4 H, H-5,6), 5.13 m (1 H, H-7), 5.87 s (1 H, H-3), 6.45 s (1 H, H-1), and 7.2–7.5 (5 aromatic H).

Acknowledgement. Crocetinialdehyde was provided by Dr. J. D. Surmatis, Hoffman-La Roche, Nutley, New Jersey.

REFERENCES

- Schwietter, U., Englert, G., Rigassi, N. and Vetter, W. *Pure Appl. Chem.* 20 (1969) 365.
- Francis, G. W. and Liaaen-Jensen, S. *Acta Chem. Scand.* 24 (1970) 2705.
- Budzikiewicz, H., Brzezinka, H. and Johannes, B. *Monatsh. Chem.* 101 (1970) 579.
- Kjøsen, H., Liaaen-Jensen, S. and Enzell, C. R. *Acta Chem. Scand.* 25 (1971) 85.
- Eidem, Å. and Liaaen-Jensen, S. *Acta Chem. Scand. B* 28 (1974) 273.
- Strain, H. H., Thomas, M. R., Crespi, H. L. and Katz, J. J. *Biochim. Biophys. Acta* 52 (1961) 517.
- Vetter, W., Englert, G., Rigassi, N. and Schwietter, U. In Isler, O., Ed., *Carotenoids*, Birkhäuser, Basel 1971.
- Svec, W. A., Harkness, A. L., Strain, H. H. and Katz, J. J. *Org. Mass Spectrom.* 6 (1972) 843.
- a. Thomas, A. F. *Deuterium Labelling in Organic Chemistry*, Appleton, New York 1971; b. Bestmann, H. J., Kratzer, O., Armsen, R. and Maekawa, E. *Ann. Chem.* (1973) 760.
- Johansen, J. E. and Liaaen-Jensen, S. *Acta Chem. Scand. B* 28 (1974) 349.
- Johansen, J. E. *Graduation work*, Norwegian Institute of Technology, University of Trondheim, Trondheim 1972.
- Kjøsen, H. and Liaaen-Jensen, S. *Acta Chem. Scand.* 24 (1970) 1488.
- Surmatis, J. D. and Ofner, A. *J. Org. Chem.* 28 (1963) 2735.
- Johnson, A. W. *Ylid Chemistry*, Academic, New York 1966.
- Zechmeister, L. *cis-trans Isomeric Carotenoids, Vitamins A, and Arylpolyenes*, Springer, Wien 1962.
- Borgen, O. and Skaugset, P. T. *Unpublished results*.
- Kjøsen, H. *Thesis*, Norwegian Institute of Technology, University of Trondheim, Trondheim 1972.
- Schrötter, H. W. and Hoffmann, E. G. *Justus Liebigs Ann. Chem.* 672 (1964) 44.
- Johansen, J. E., Eidem, Å. and Liaaen-Jensen, S. *Acta Chem. Scand. B* 28 (1974). *In press*.
- Brockmann, H. and Schodder, H. *Ber. Deut. Chem. Ges.* 74 (1941) 73.
- Kjøsen, H. and Liaaen-Jensen, S. *Acta Chem. Scand.* 26 (1972) 4121.
- Schwietter, U., Planta, C. v., Rüegg, R. and Isler, O. *Helv. Chim. Acta* 45 (1962) 541.
- Surmatis, J. D., Ofner, A., Gibas, J. and Thommen, R. *J. Org. Chem.* 31 (1966) 186.
- Kjøsen, H. and Liaaen-Jensen, S. *Phytochemistry* 8 (1963) 483.
- Liaaen-Jensen, S. *Kgl. Nor. Vidensk. Selsk. Skr.* (1962) No. 8.
- Ke, B., Imsgard, F., Kjøsen, H. and Liaaen-Jensen, S. *Biochim. Biophys. Acta* 210 (1970) 139.

Received November 20, 1973.