# Studies on the Synthesis of Linear Aliphatic Compounds. Part 4.[1] An Approach to Long-chain Paraffins with Lateral Side-chains

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The synthesis of 24-bromo-13-butyl-13-hydroxytetracosanal ethylene acetal is described. After dehydration, this compound allows chain extension in either direction using the methods given in Parts 1—3 in this series. A $C_{60}$ polyene (mixture of isomers) was thus obtained which was suitable for hydrogenation to the 12-butyl derivative of the $C_{56}$ n-paraffin previously described, so exemplifying a route to model compounds for low-density polyethylene.

Parts 1—3 of this series[1-3] described the synthesis of long-chain n-paraffins, which serve as models for linear, high-density polyethylene. We now describe preliminary work toward the synthesis of n-paraffins into which n-butyl side-chains (the commonest alkyl substituents in low-density polyethylene) can be inserted at any chosen position, by adapting methods already developed. A key intermediate was therefore 16-bromo-hexadecan-5-one. Before 12-bromododecanal became readily available[2] the following route was considered. The tertiary

reaction, and none with such long alkyl chains. When we employed the triphenylphosphonium salt derived from 12-bromododecanal ethylene acetal[3] the yield was even lower and no pure product was obtained.

12-Bromododecanal ethylene acetal was induced to form a Grignard reagent, and addition of the bromohexadecanone led to the isolation of a crystalline tertiary alcohol (2). This was readily dehydrated to the corresponding unsaturated bromo acetal (3) to give a presumed mixture of six isomers having

$$CH_2(CH_2)_{10}CO \xrightarrow{BuLi} CH_2(CH_2)_{10}C(OH)Bu \longrightarrow CH_2(CH_2)_9CH{=}CBu \longrightarrow BuCO(CH_2)_{10}CO_2H$$

$$\downarrow$$

$$BuCO(CH_2)_{10}CH_2Br$$
$$(1)$$

alcohol was obtained in fair yield, but 12-oxohexadecanoic acid could not be prepared in satisfactory yield either by direct oxidation with chromic acid or by dehydration (pyridine–phosphorus oxychloride; successful) followed by ozonolysis or chromic oxidation. However, conversion of 12-bromododecanal to the corresponding secondary alcohol with butyl-lithium or, better, butylmagnesium bromide, followed by mild (Jones) oxidation afforded a good yield of the desired ketone. Model experiments with the Wittig reagents derived from octyltriphenylphosphonium bromide showed this to be unreactive, the yellow colour surviving prolonged heating under reflux in ether. The best result (17% of bromo olefin) was obtained using a solution of the phosphonium salt plus potassium t-butoxide in t-butyl alcohol. In fact, the literature records few successful preparations of acylic trisubstituted olefines using the Wittig

nearly identical n.m.r. spectra. Alternatively, when the acetal group was hydrolysed on silica gel loaded with sulphuric acid in aqueous sulpholane, dehydration occurred simultaneously giving the unsaturated $C_{28}$ bromo aldehyde (4) together with isomers. This aldehyde was successfully chain-extended using the phosphonium salts (5; $n = 0$) and (5; $n = 1$) described in Part 2,[3] giving $C_{40}$ and $C_{52}$ bromo acetals (6), *i.e.* compounds related to the $C_{36}$ and $C_{48}$ bromo-acetals previously described, but having a butyl group near the halogen end of the molecule (Scheme). By treating acetal (3) with triphenylphosphine and condensing the product with an ω-bromo aldehyde form Part 2, it would be possible to place the butyl group near the other end of the molecule.

The conversion of the bromo acetals (6) to analogues of low-density polyethylene requires the processes of (*a*) deprotection,

$$Br(CH_2)_{11}COC_4H_9 + BrMgCH_2(CH_2)_{10}\overline{CHO(CH_2)_2O} \longrightarrow BrCH_2(CH_2)_{10}C(OH)(C_4H_9)(CH_2)_{11}\overline{CHO(CH_2)_2O}$$
$$(2)$$

$$BrCH_2(CH_2)_9CH{=}C(C_4H_9)(CH_2)_{11}CHO \longleftarrow BrCH_2(CH_2)_9CH{=}C(C_4H_9)(CH_2)_{11}\overline{CHO(CH_2)_2O}$$
$$(4) \qquad\qquad (3)$$

$$+ Ph_3\overset{+}{P}CH_2[(CH_2)_{10}CH{=}CH]_n(CH_2)_{10}\overline{CHO(CH_2)_2O}Br^-$$
$$(5)$$

$$BrCH_2(CH_2)_9CH{=}C(C_4H_9)CH_2[(CH_2)_{10}CH{=}CH]_{(n+1)}(CH_2)_{10}\overline{CHO(CH_2)_2O}$$
$$(6)$$

$$\downarrow C_8H_{17}\text{-}PPh_3Br^-$$

$$HCH_2(CH_2)_9CH{=}C(C_4H_9)CH_2[(CH_2)CH{=}CH]_2(CH_2)_{10}CH{=}CHC_7H_{15}$$
$$(7)$$

**Scheme.**

(b) a Wittig reaction with an alkyltriphenylphosphonium salt, (c) removal of bromine by hydride reduction, and (d) hydrogenation. The deprotection of (6; $n = 2$) gave the corresponding $C_{52}$ aldehyde. Condensation with octylphosphonium bromide led to a crude $C_{60}$-bromide which was directly reduced with lithium aluminium hydride.[1] A hydrocarbon (7) resulted, with analytical and n.m.r. properties as expected. There is little doubt that hydrogenation would have given the 12-butyl derivative of the hexapentacontane described in Part 2, but time did not permit this investigation.

## Experimental

I.r. spectra were measured in $CCl_4$ or $CS_2$ solutions. [1]H n.m.r. spectra were determined at 200 MHz using $CDCl_3$ solutions, and signal positions are given in δ values relative to $Me_4Si$; [13]C n.m.r. spectra were obtained similarly. Ether refers to diethyl ether.

16-*Bromohexadecan-5-ol.*—(a) Butyl-lithium (1.44M solution, standardised by double titration; 16.25 cm³) was added dropwise to a solution of 12-bromododecanal (see Part 1) (6.16 g) in dry ether maintained at 5 °C. Water (60 cm³) was added and the organic product (6.24 g) was isolated as a low-melting solid, m.p. 38 °C after chromatography and recrystallisation (Found: C, 60.8; H, 11.7; Br, 24.0, 23.6. $C_{16}H_{33}BrO$ requires C, 59.8; H, 10.35; Br, 24.85%; it is possible that a little bromine was lost through metal–halogen exchange reaction). When the initially formed ether solution of the lithium complex was allowed to stand overnight before work-up, a non-polar liquid, tentatively identified as 1-oxa-2-butylcyclotridecane, was the main product.

(b) A solution of butylmagnesium bromide in ether was prepared under nitrogen from magnesium (1.84 g) and 1-bromobutane (10.51 g). 12-Bromododecanal (17.0 g) in dry ether (50 cm³) was added during 10 min with cooling. Stirring was continued for 15 min, then work-up with dilute HCl and ether gave, after drying, evaporation, and recrystallisation, the *alcohol* (19.0 g, 91%), m.p. 35 °C, with an i.r. spectrum as expected.

16-*Bromohexadecan-5-one.*—The foregoing alcohol [16.5 g, method (b)] in acetone (AnalaR) was treated dropwise with 3M chromic acid in sulphuric acid with cooling to below 24 °C. Water was added and the neutral product was isolated, giving, after recrystallisation from light petroleum (b.p. 30—40 °C), the *ketone* (13.6 g, 83%), m.p. 22 °C (Found: C, 60.9; H, 9.8; Br, 25.0. $C_{16}H_{31}BrO$ requires C, 60.2; H, 9.8; Br, 25.0), $v_{max.}$(CCl₄) 1 720, 1 160, 1 000, and 650 cm⁻¹.

20-*Bromo-9-butylicos-8-ene.*—A solution of octyltriphenylphosphonium bromide (3.2 g) in THF (25 cm³) was added to dry t-butyl alcohol (200 cm³) and potassium t-butoxide (12 cm³ of 0.69M solution in t-butyl alcohol), followed by 16-bromohexadecan-5-one (2.0 g) in THF under nitrogen. The solution was heated under reflux for 20 h after which acetic acid (2 drops) was added, removing a pale yellow colour. The solvent was evaporated under reduced pressure and the residue extracted with light petroleum (4 × 30 cm³). The extracts were washed with acetonitrile and the petroleum layer was evaporated, giving a mixture of hydrocarbon and unchanged ketone (1.7 g) which was chromatographed on silica-gel using 5% ether–light petroleum. The early fractions (0.45 g, 17%) gave $v_{max.}$ 3 040 (=CH) and 650 cm⁻¹ ($CH_2Br$) but no carbonyl absorption; $\delta_H$ 0.84 (3 H, t, Me), 1.30 (2 H, t, C$H_2$Me), 1.85 (2 H, m, C$H_2$CH=), 3.4 (2 H, t, BrC$H_2$), and 5.1 (1 H, t, =C$H$CH₂); $\delta_C$ 14.141 ($CH_3$), 22.517 ($CH_2$Me), 28.71 [$CH_2$($CH_2$)₃Br], 28.0 [$CH_2$($CH_2$)₂Br],

33.92 ($CH_2$Br), 61.2 (=CHCH₂) and 68.00 [$CH_2$($C$=)CH₂] of about the expected intensity confirmed the structure.

24-*Bromo-13-butyl-13-hydroxytetracosanal Ethylene Acetal* (2).—A Grignard reagent was prepared from magnesium turnings (0.021 mol), dry ether (10 cm³) and a solution of 12-bromododecanal ethylene acetal (6.4 g, 0.02 mol) in dry ether (20 cm³), and stirred for 9 h under nitrogen. 16-Bromohexadecan-5-one (4.0 g, 0.01 mol) in dry ether (30 cm³) was added during 5 min and stirring was continued for a further 5 h. Saturated aqueous sodium sulphate (1.2 cm³) was added with stirring, followed by solid sodium sulphate. The mixture was filtered, the solid washed with fresh ether and the washings combined with the filtrate. The solvent was evaporated to give an oily solid (9.0 g) which was chromatographed on silica gel (400 g, 60—120 mesh) using ether–light petroleum (b.p. 30—40 °C) as eluant (30:70). The middle fractions were recrystallized from light petroleum to give the title compound (3.5 g), m.p. 54 °C, $R_F$ [SiO₂, ether–light petroleum (10:90), I₂] 0.29; $v_{max.}$(CCl₄), 3 620 (OH), 1 140, 1 040, 940, (CHO₂C₂H₄*), and 640 cm⁻¹ (BrCH₂); $\delta_H$ 0.9 (3 H, t, Me), 3.6 (1 H, s, COH), 3.4 (2 H, t, C$H_2$Br), 3.81 (4 H, m, CH₂CHO₂C₂H₄), and 4.81 (1 H, t, C$H$O₂C₂H₄); $\delta_C$(CDCl₃), 20.8 (C$H_2$CHO₂C₂H₄), 24.8 (C$H_2$CH₂CHO₂C₂H₄), 52.1 (COH), 76.48 (CHO₂$C_2$H₄), and 184.70 (CHO₂$C_2$H₄).

24-*Bromo-13-butyltetracos-12-enal Ethylene Acetal* (3) (*and Isomers*).—Toluene-*p*-sulphonic acid (0.5 g), was added to a solution of the above hydroxy acetal (2.60 g) in toluene (125 cm³), and the mixture heated under reflux for 2 h. The toluene was evaporated using a rotary evaporator and the residual solvent was removed by adding a little CCl₄ and distilling under reduced pressure. The crude product (3.0 g) was chromatographed on a silica-gel column, using ether–light petroleum. The best fractions were combined and evaporated to give a colourless, viscous liquid, the title compound (3) (and isomers) (1.80 g, 72%), which on t.l.c. [SiO₂ in ether–light petroleum (1:9)] gave one spot, $R_F = 0.67$; $v_{max.}$(CCl₄) 3 040 (=CH), 1 660 (C=C), and 650 (BrCH₂) cm⁻¹; $\delta_H$(CDCl₃), 0.91 (3 H, t, CH₂$Me$), 3.40 (2 H, t, BrC$H_2$), 3.81 (4 H, m, CHO₂C₂H₄), 4.8 (1 H, t, CH₂C$H$O₂C₂H₄), 5.08 (1 H, m, $\overset{Bu}{>}$C=C$H$CH₂); $\delta_C$(CDCl₃), 13.99 ($CH_3$), 21.21 ($CH_2$Me), 32.80 ($CH_2$CH₂Br), 33.82 ($CH_2$Br), 4.70 (CHO₂$C_2$H₄), 139.41 (C=CH), 184.6 (CHO₂C₂H₄).

36-*Bromo-25-butylhexatriaconta*-12,25-*dienal Ethylene Acetal* (6; n + 1 = 1).—The $C_{30}$ hydroxy acetal (2), (6.0 g) was deprotected by passing a solution in dichloromethane (20 cm³) containing bromoethane (4 cm³) through a column containing silica-gel impregnated with 10% of a 25:37.5:37.5 mixture of toluene-*p*-sulphonic acid–sulpholane–water (100 g), and using 3:1 light petroleum–dichloromethane as eluant. The product (3.31 g) had undergone dehydration as well as hydrolysis, as shown by the loss of absorption at *ca.* 3 600 cm⁻¹ as well as the usual substitution of C=O for C–O stretching bands, and by its non-polar behaviour on t.l.c. 11-(Dioxolan-2-yl)undecyltriphenylphosphonium bromide (4.65 g) was dissolved in hot toluene (20 cm³) and the solution was evaporated under reduced pressure. Dry potassium carbonate (1.74 g), 18-crown-6 (97 mg) and a solution of the foregoing $C_{28}$ bromo aldehyde (4.65 g) in dry THF (30 cm³) were added, and the mixture was heated under reflux in nitrogen for 5 days. Isolation of the non-polar product by extraction with light petroleum, washing with acetonitrile and evaporation gave a crude product (2.7 g), which was dissolved in dry ether (30 cm³) and bromoethane (3 cm³)

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* Implies the dioxolan-2-yl group.

and treated with lithium aluminium hydride (44 mg) for 10 min at 20 °C. Isolation of the neutral product and chromatography gave an oil (2.24 g) which was chromatographed on silica-gel. Ether–light petroleum eluted fractions which were homogeneous on t.l.c., though certainly a statistical mixture of six isomers at the ($-CH_2CH_2)_2C=CHCH_2-$ centre, as well as a 4:1 *cis-trans* mixture at $-CH=CH-$, including the named dienal acetal, as a colourless oil (1.43 g, 30%), with i.r. and n.m.r. spectra as expected.

*48-Bromo-37-butyloctatetraconta*-12,24,37-*trienal* *Ethylene Acetal.*—Compound (**6**; $n + 1 = 2$) was prepared in the same way (except that sodium borohydride replaced lithium aluminium hydride, *cf.* Part 3) from the hydroxy acetal (**2**) *via* dehydration-deprotection to the aldehyde (**4**) (2.68 g) and crystalline *trans*-24-(dioxolan-2-yl)tetracos-12-enyltriphenylphosphonium bromide (5.0 g).[1] The product (1.40 g, 29%) again must have been a mixture of isomers with the same carbon skeleton. It gave a single spot, $R_F$ 0.58, on t.l.c., $\nu_{max.}$ 3 000 (*cis*-CH=CH), 1 140, 1 040 (dioxolanyl group), and 650 cm$^{-1}$ (CH$_2$Br); $\delta_H$ 5.10 (1 H, t, $>$C=C*H*CH$_2$), other $\delta_H$ and $\delta_C$ signals as expected.

*45-Butylhexaconta*-8,20,32,45-*tetraene.*—The foregoing acetal (1.075 g) was deprotected using the toluenesulphonic acid–aqueous sulpholane–silica method described above to give the corresponding aldehyde, in which the strong acetal bands at 1 140 and 1 040 cm$^{-1}$ were replaced by carbonyl and H(CO) bands. Corresponding changes were observed in the n.m.r.

spectrum ($\delta$ 9.8, 1 H, t for CHO rather than signals at 3.81 and 4.81). Octyltriphenylphosphonium bromide (417 mg), anhydrous potassium carbonate (190 mg), 18-crown-6 (3 mg) and dry THF (25 cm$^3$) were added and the mixture was heated under reflux for 5 days. Work-up involved lithium aluminium hydride reduction without the addition of ethyl bromide, and the conditions used led to simultaneous removal of primary bromine, giving, after chromatographic isolation of the least polar fraction, a syrup (320 mg, 30%) which when analysed was found to be the expected mixture of isoskeletal tetraenes including the named isomer (Found: C, 86.15; H, 13.45. $C_{60}H_{114}$ requires C, 86.35; H, 13.65%). I.r. bands were as expected but none were attributable to functional groups believed to be absent. The $^1$H n.m.r. spectrum also showed only the signals expected for an unsaturated hydrocarbon of this structure.

## References
1 Part 3, preceding paper.
2 I. Bidd, D. J. Kelly, P. M. Ottley, O. I. Paynter, D. J. Simmonds, and M. C. Whiting, *J. Chem. Soc., Perkin Trans. 1*, 1983, 1369.
3 E. Igner, O. I. Paynter, D. J. Simmonds, and M. C. Whiting, *J. Chem. Soc., Perkin Trans. 1*, 1987, 2447.