

781. *Unsaturated Fatty Acids. Part II.* The Synthesis of Linolenic Acid.*[†]

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The first synthetical confirmation of the long-accepted structure of linolenic acid is presented.

Condensation of 1-bromo-octa-2 : 5-diyne (prepared from 1-bromopent-2-yne and propargyl alcohol) with the Grignard reagent of the ethylene acetal of dec-9-ynal (prepared from dec-9-ynoic acid) gave the triacetylenic acetal (IX). This was converted by partial hydrogenation, bromination, hydrolysis, and oxidation, into the solid 9 : 10 : 12 : 13 : 15 : 16-hexabromostearic acid from which it is known that linolenic acid can be regenerated.

An important class of natural acids contains unsaturated centres separated by a methylene group. Unsaturated systems of this type are highly reactive; they rearrange readily in the presence of alkalis, and autoxidise with great ease on exposure to air. The most familiar of these acids with "methylene interrupted conjugation" are the diene linoleic (octadeca-9 : 12-dienoic) acid and the triene linolenic (octadeca-9 : 12 : 15-trienoic) acid.¹ Several related compounds are also known, and acids with up to six methylene-separated double bonds have been reported. These occur mainly in brain and liver phosphatides, and in fish-liver oils.² Of the natural acids with methylene-interrupted conjugation only linoleic, the simplest member of the series, has previously been synthesised.³⁻⁵ A synthetical confirmation of the structure (XII) assigned to linolenic acid on the basis of degradative studies is described in this paper.

Linolenic acid is the most abundant and widespread triene acid in Nature. It occurs principally in the vegetable drying oils, and is largely responsible for the ease with which these harden on exposure to air. It is usually isolated from linseed oil, in which it may comprise 50% or more of the total acids present,¹ as a solid hexabromide. This on debromination with zinc⁷ gives "α-linolenic acid" which has been used in most investigations and structural studies. Although originally thought to be identical with the natural compound, the α-acid has been shown to contain small amounts of isomers.^{8,9} These artefacts can, however, be removed by low-temperature crystallisation.⁸ As linolenic acid is an unstable liquid, the present studies were aimed at the synthesis of the solid hexabromide.

One of the two key intermediates required, the nonynylidioxolan (III), has previously been prepared from deca-1 : 9-diyne by Walborsky, Davies, and Howton.⁴ A convenient alternative route has now been developed which avoids the use of sulphur compounds, and hence the risk of catalyst poisoning in subsequent hydrogenations of materials prepared from the nonynylidioxolan. The readily-available dec-9-ynoic acid (I)¹⁰ was converted into its *N*-methylanilide, which was reduced with lithium aluminium hydride¹¹ to dec-9-ynal (II). Reaction of the latter with ethylene glycol then gave the nonynylidioxolan (III) in 40% overall yield.

* Part I, *J.*, 1953, 1785.

† Submitted in honour of the seventieth birthday of Sir Ian Heilbron, D.S.O., F.R.S.

¹ Hilditch, "The Chemical Constitution of Natural Fats," Chapman and Hall, London, 1956.

² Klenk and Bongard, *Z. physiol. Chem.*, 1952, **291**, 104; Klenk and Lindlar, *ibid.*, 1955, **299**, 74; 1955, **301**, 156; Klenk and Dreike, *ibid.*, 1955, **300**, 113; Silk and Hahn, *Biochem. J.*, 1954, **57**, 582.

³ Raphael and Sondheimer, *J.*, 1950, 2100.

⁴ Walborsky, Davies, and Howton, *J. Amer. Chem. Soc.*, 1951, **73**, 2590.

⁵ Gensler and Thomas, *ibid.*, p. 4601.

⁶ Erdmann, Bedford, and Raspe, *Ber.*, 1909, **42**, 1334.

⁷ Rollett, *Z. physiol. Chem.*, 1909, **62**, 422; McCutcheon, *Org. Synth.*, 1942, **22**, 82.

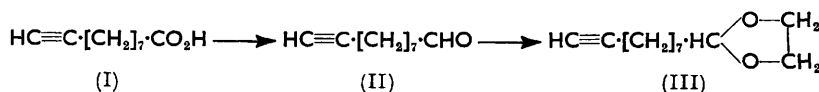
⁸ Matthews, Brode, and Brown, *J. Amer. Chem. Soc.*, 1941, **63**, 1064.

⁹ McCutcheon, Crawford, and Welsh, *Oil and Soap*, 1941, **18**, 9; Ahlers, Brett, and McTaggart, *J. Appl. Chem.*, 1953, **3**, 433.

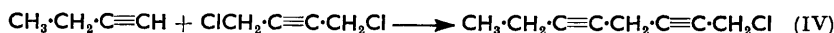
¹⁰ Black and Weedon, *J.*, 1953, 1785.

¹¹ Weygand and Eberhardt, *Angew. Chem.*, 1952, **64**, 458; Weygand, Eberhardt, Linden, Schäfer, and Eigen, *ibid.*, 1953, **65**, 525; Weygand and Mitgau, *Chem. Ber.*, 1955, **88**, 301; Nigam and Weedon, to be published.

As second component a 1-halogeno-octa-2 : 5-diyne was required. Reaction of the Grignard reagent of but-1-yne ¹² with an excess of 1 : 4-dichlorobut-2-yne ¹³ gave 1-chloro-

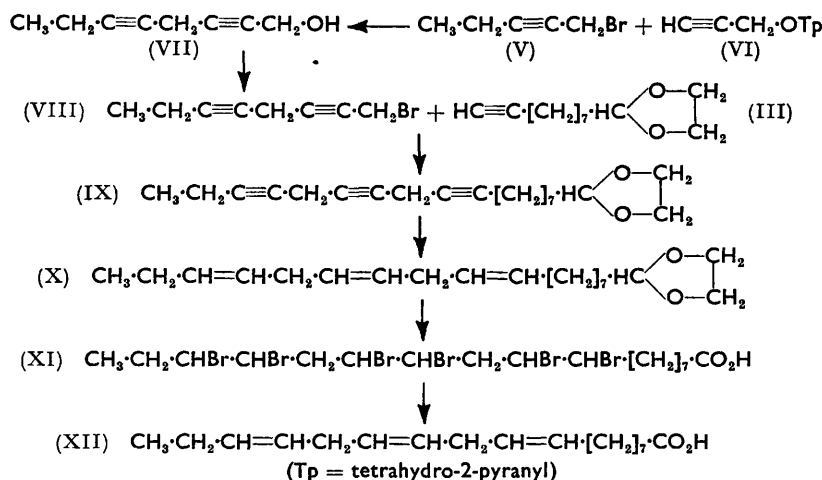


octa-2 : 5-diyne (IV) in 11% yield. (A cuprous chloride catalyst ¹⁴ was used in this and subsequent condensations of Grignard reagents with acetylenic halides.) An attempt



to cause the chloride to react with the Grignard reagent of the nonynylidioxolan gave only traces of the required product. Attention was therefore directed to the corresponding bromide which was prepared in the following way.

Condensation of 1-bromopent-2-yne (V) ¹⁵ with the Grignard reagent of the tetrahydropyranyl ether (VI) ¹⁶ derived from propargyl alcohol, and alcoholysis ¹⁷ of the initial product, gave octa-2 : 5-diyn-1-ol (VII) (α -naphthylurethane) in 50% overall yield. (Deca-2 : 5-diyn-1-ol was similarly prepared from 1-bromohept-2-yne.^{5,18}) The structure of the octadiynol, an acetylenic alcohol of new type, was confirmed by its light-absorption properties, and by catalytic reduction to octan-1-ol (88%). Treatment of the octadiynol with phosphorus tribromide gave (58%) 1-bromo-octa-2 : 5-diyne (VIII).



A Grignard condensation of the two intermediates (III) and (VIII) gave the triyne (IX) (2 : 4-dinitrophenylhydrazone) in 33% yield. Partial reduction over Lindlar catalyst ¹⁹ then led to the corresponding triene (X). From the known stereochemical course of reductions with this catalyst,²⁰ the triene was assumed to consist mainly, if not exclusively, of the "all-*cis*" isomer, and thus to have the same configuration as that assigned to linolenic acid on the basis of Raman and infrared absorption studies.⁹

Bromination of the triene produced a mixture of bromo-acetals, which was converted

¹² Aston, Mastrangelo, and Moessen, *J. Amer. Chem. Soc.*, 1950, **72**, 5287.

¹³ Johnson, *J.*, 1946, 1009.

¹⁴ Danehy, Killian, and Nieuwland, *J. Amer. Chem. Soc.*, 1936, **58**, 611; Nigam and Weedon, to be published.

¹⁵ Tchao Yin Lai, *Bull. Soc. chim. France*, 1933, **53**, 1533.

¹⁶ Henbest, Jones, and Wells, *J.*, 1950, 3646.

¹⁷ Ahmad and Weedon, *J.*, 1953, 3286; Dauben and Bradlow, *J. Amer. Chem. Soc.*, 1952, **74**, 559.

¹⁸ Wotiz, *ibid.*, 1950, **72**, 1639.

¹⁹ Lindlar, *Helv. Chim. Acta*, 1952, **35**, 446.

²⁰ Baker, Linstead, and Weedon, *J.*, 1955, 2218.

by hydrolysis and oxidation into a mixture of hexabromostearic acids (XI) in 50% overall yield. Bromination of linolenic acid gives a similar mixture of hexabromo-acids, from which one of the four possible racemates can be isolated as a solid in *ca.* 25% yield.²¹ Crystallisation of the synthetic mixture gave the same solid in 16% yield. The identity was confirmed by direct comparison of the acid and its methyl ester with authentic samples derived from natural linolenic acid. No depressions were observed in the mixed melting point determinations, and the infrared absorption spectra were identical. Since, as mentioned above, the solid hexabromide can be converted into linolenic acid (XII) by debromination and low-temperature crystallisation,⁸ the results now reported constitute a formal synthesis of this natural acid.

EXPERIMENTAL

M. p.s were determined on a Kofler block and are corrected.

Ultraviolet light absorption measurements were determined on alcoholic solutions. Infrared absorption measurements were made on liquid films, unless stated otherwise.

All operations were carried out in an inert atmosphere, usually of nitrogen. Freshly purified solvents were used to ensure the absence of peroxides. Tetrahydrofuran was dried over solid potassium hydroxide and then over sodium wire, and was redistilled immediately before use. Compounds containing methylene-interrupted conjugation were used as soon as possible after preparation, to minimise the losses due to polymerisation and oxidation.

To ensure the absence of ethyl bromide in the copper-catalysed Grignard reactions, a slight excess of magnesium was used in the preparations of ethylmagnesium bromide, and the resulting solutions were decanted from the excess of metal.

Intermediates.—1-Bromopent-2-yne¹⁵ was prepared from but-1-yne¹² *via* pent-2-yn-1-ol.²² Infrared absorption: maxima, 4.320 and 4.460 μ (for C \equiv C); no allene band was observed. The pentynol α -naphthylurethane crystallised from light petroleum (b. p. 100–120°) in needles, m. p. 109° (Found: C, 75.35; H, 6.2; N, 5.65. C₁₆H₁₅O₂N requires C, 75.85; H, 5.95; N, 5.55%).

1-Bromohept-2-yne^{5, 18} was prepared similarly from hex-1-yne. Hept-2-yn-1-yl methane-sulphonate was prepared by the method of Raphael and Sondheimer,³ and 1:4-dichlorobut-2-yne by that of Johnson.⁴

Dec-9-ynoic acid¹⁰ was prepared from commercial undec-10-enoic acid. The latter was converted into undec-10-ynoic acid in 80% yield by Khan's method,²³ and thence in 74% yield into 1:1-diphenylundec-1-en-10-yne¹⁰ which crystallised from *n*-pentane and had m. p. 35°. Chromic acid oxidation of the hydrocarbon gave dec-9-ynoic acid, m. p. 22°, in 58% yield, and a neutral fraction (*ca.* 20%). The latter partly solidified; recrystallisation from light petroleum (b. p. 40–60°) gave a material, m. p. 112–113°. Infrared light absorption: maxima 2.86, 3.08 (OH), 5.835 (CO), 6.23, 13.38, and 14.32 μ (Ph). Oxidation of the solid with periodic acid gave benzophenone, which was isolated in 30% yield as its 2:4-dinitrophenylhydrazone, m. p. and mixed m. p. 238°.

2-Non-8'-ynyl-1:3-dioxolan (III).—A solution of dec-9-ynoic acid (23.7 g.) in thionyl chloride (48 c.c.) was heated under reflux until the evolution of hydrogen chloride ceased, and then evaporated. Distillation of the residue gave the acid chloride (22.5 g., 86%), b. p. 58–64°/0.1 mm., n_D^{21} 1.4610.

A solution of methylaniline (16.1 g.) in an equal volume of pyridine was slowly added to one of the acid chloride in benzene (90 c.c.) cooled in an ice-bath. The mixture was shaken occasionally and kept at 20° for $\frac{1}{2}$ hr. Water was added, and the product was extracted with benzene. The extract was washed thoroughly with 2*N*-hydrochloric acid and then with water, dried (Na₂SO₄), and evaporated. Distillation of the residue gave the *methylanilide* (26.4 g., 85%), b. p. 155–165° (bath temp.)/10^{–4} mm., n_D^{23} 1.5190 (Found: C, 78.8; H, 8.85; N, 5.55. C₁₇H₂₃ON requires C, 79.35; H, 9.0; N, 5.45%).

A solution of lithium aluminium hydride (1.53 g.) in ether (150 c.c.) was added slowly to a cooled (0°) and well-stirred solution of the *methylanilide* (21 g.) in ether (150 c.c.). After the mixture had been stirred at 0° for 3 hr., a small volume of ethyl acetate was added (to decompose the excess of hydride), followed by 2*N*-hydrochloric acid. The product was extracted with ether and the extract was washed thoroughly with 2*N*-hydrochloric acid and then with water,

²¹ Shinowara and Brown, *J. Amer. Chem. Soc.*, 1938, **60**, 2734.

²² Tchao Yin Lai, *Bull. Soc. chim. France*, 1933, **53**, 682.

²³ Khan, *Org. Synth.*, 1952, **32**, 104.

dried (Na_2SO_4), and evaporated, giving crude dec-9-ynal (10.5 g.). The 2:4-dinitrophenylhydrazone crystallised in golden-yellow plates, m. p. 73.5° , undepressed on admixture with the specimen described below.

A mixture of the crude aldehyde (3.5 g.), benzene (100 c.c.), ethylene glycol (30 c.c.), and concentrated sulphuric acid (2 drops) was stirred vigorously and heated under reflux for 4.5 hr., the water formed being removed by azeotropic distillation. The mixture was cooled and diluted with 5% aqueous sodium hydroxide. The benzene layer was separated, washed with water, dried (Na_2SO_4), and evaporated. Distillation of the residue gave 2-non-8'-ynyl-1:3-dioxolan (2.9 g.), b. p. $120\text{--}122^\circ/8\text{ mm.}$, n_D^{25} 1.4570 (Found: C, 73.95; H, 10.55. Calc. for $\text{C}_{12}\text{H}_{20}\text{O}_2$: C, 73.45; H, 10.25%). Treatment with Brady's reagent gave a 2:4-dinitrophenylhydrazone, m. p. 73.5° undepressed on admixture with the derivative from a specimen of the acetal prepared by the method of Walborsky, Davies, and Howton⁴ (who give m. p. $73\text{--}74^\circ$).

1-Chloro-octa-2:5-diyne (IV).—A solution of 1:4-dichlorobut-2-yne¹⁸ (74 g.) in ether (50 c.c.) was added slowly to a cooled (0°), well-stirred ethereal solution (125 c.c.) of butynylmagnesium bromide [prepared from magnesium (6.1 g.), ethyl bromide (21.8 g.), and but-1-yne (19 g.)], containing cuprous chloride (0.75 g.). The mixture was stirred at 20° overnight, and then under reflux for 8 hr. The mixture was cooled, 2*N*-hydrochloric acid was added, and the product was isolated with ether. Distillation gave 1:4-dichlorobut-2-yne (53 g.), and 1-chloro-octa-2:5-diyne (3 g.), b. p. $42\text{--}44^\circ/10^{-2}\text{ mm.}$, n_D^{18} 1.4985 (Found: C, 68.25; H, 6.6; Cl, 25.65. $\text{C}_8\text{H}_6\text{Cl}$ requires C, 68.35; H, 6.4; Cl, 25.25%. Hydrogen number, 29.7; equivalent to 4.7 double bonds). Ultraviolet light absorption: no maximum with $E_{1\text{cm}}^{1\%} > 20$ in the region 200—400 m μ . Infrared light absorption: maxima, 4.310, 4.375, 4.440 (for $\text{C}\equiv\text{C}$), 5.135 μ (allenic impurity).

The chloro-octadiyne (2.8 g.), the Grignard reagent of 2-non-8'-ynyl-1:3-dioxolan (3.7 g.), and cuprous chloride (0.25 g.) in ether (50 c.c.) were stirred at 20° overnight, and then under reflux for 18 hr. Isolation of the product in the usual way gave an oil (4.3 g.). To determine whether this contained any of the highly unstable triacetylene (IX), it was hydrogenated in ethyl acetate over Adams catalyst, and the product was examined for a derivative of octadecanal. Distillation gave: (i) 2-Nonyl-1:3-dioxolan (1.4 g.), b. p. $68\text{--}70^\circ/10^{-2}\text{ mm.}$, n_D^{22} 1.4390 (Found: C, 72.0; H, 12.2. $\text{C}_{12}\text{H}_{24}\text{O}_2$ requires C, 71.95; H, 12.1%). Treatment with Brady's reagent yielded decanal 2:4-dinitrophenylhydrazone, m. p. 108° undepressed on admixture with an authentic specimen prepared from decanoic acid;¹¹ (ii) A fraction (0.15 g.), b. p. $175\text{--}180^\circ$ (bath temp.)/ 10^{-5} mm. , which with Brady's reagent gave a crude derivative (80%). This, after chromatography from benzene on bentonite-kieselguhr, and crystallisation from alcohol, yielded (52%) a solid, m. p. 108° undepressed on admixture with a specimen, m. p. 110° , of octadecanal 2:4-dinitrophenylhydrazone prepared from stearic acid.¹¹ At this stage the route described below to 1-bromo-octa-2:5-diyne was developed, and further work with the chloro-octadiyne was abandoned.

Octa-2:5-diyne-1-ol (VII).—A solution of ethylmagnesium bromide was prepared in ether (50 c.c.), from magnesium (3.6 g.) and ethyl bromide (15 g.), and was then diluted with tetrahydrofuran (130 c.c.). Tetrahydro-2-prop-2'-ynyloxypyran¹⁶ (21 g.), dissolved in tetrahydrofuran (50 c.c.), was added slowly to the well-stirred solution of the Grignard reagent. The mixture was boiled under reflux for 3 hr., cooled to 20° , and then cuprous chloride (0.36 g.) was added. After the mixture had been stirred for 15 min., 1-bromopent-2-yne¹⁵ (20.3 g.) in tetrahydrofuran was added dropwise. Stirring was continued for 3 hr. at 20° and then for 16 hr. under reflux. After the mixture had been cooled to 0° , an excess of saturated ammonium chloride solution was added, and the product was isolated with ether. The ethereal extract was washed thoroughly with water, dried (K_2CO_3), and evaporated. The residue (32.1 g.) was dissolved in alcohol (170 c.c.), toluene-*p*-sulphonic acid (1.1 g.) was added, and the solution was boiled under reflux for 2.5 hr., then cooled, and diluted with water. The product was extracted with ether, and the extract washed with saturated sodium hydrogen carbonate solution then with water, dried (K_2CO_3), and evaporated. Distillation of the residue gave octa-2:5-diyne-1-ol (8.5 g.), b. p. $68^\circ/10^{-3}\text{ mm.}$, n_D^{24} 1.4900 (Found: C, 78.3; H, 8.45. $\text{C}_8\text{H}_{10}\text{O}$ requires C, 78.65; H, 8.25%. Hydrogen number, 29.2; equivalent to 4.2 double bonds). Ultraviolet light absorption: maximum at 262 m μ , $E_{1\text{cm}}^{1\%}$ 6, suggesting the presence of a trace of an impurity with a dienyne chromophore. Infrared light absorption: maxima, 3.095 (OH), 4.360, 4.410, 4.480 ($\text{C}\equiv\text{C}$), 7.585 and 9.860 μ (OH and C—O); no allene band was observed. The α -naphthylurethane (ca. 90% yield), crystallised from light petroleum (b. p. $80\text{--}100^\circ$) and had m. p. 126° (Found: C, 78.05; H, 6.15; N, 4.95. $\text{C}_{19}\text{H}_{17}\text{O}_2\text{N}$ requires C, 78.35; H, 5.9; N, 4.8%).

Reduction of the alcohol (1.1 g.) in ethyl acetate (30 c.c.) over Adams catalyst, and isolation of the product in the usual way, gave octan-1-ol (1.02 g.), b. p. 92°/12 mm., n_D^{24} 1.4290. The α -naphthylurethane (ca. 90% yield) crystallised from light petroleum (b. p. 80–100°) in needles, m. p. and mixed m. p. 66° (Adamson and Kenner²⁵ give m. p. 66°).

Deca-2 : 5-diyn-1-ol.—(a) Condensation of 1-bromohept-2-yne^{5, 18} with the Grignard reagent of tetrahydro-2-prop-2'-ynyloxyran, and alcoholysis of the initial product, gave deca-2 : 5-diyn-1-ol (33%) as a very unstable liquid, b. p. 86°/10⁻³ mm., n_D^{21} 1.4860. Ultraviolet light absorption : maximum, 266 m μ , $E_{1\%}^{1\text{cm}}$ 18. Infrared light absorption : maxima at 3.020, 4.415, 4.480, 7.630, and 9.855 μ . The α -naphthylurethane (75% yield) crystallised from light petroleum (b. p. 80–100°) and had m. p. 102° (Found : C, 79.3; H, 7.0; N, 4.6. $C_{21}H_{21}O_2N$ requires C, 78.95; H, 6.65; N, 4.4%). Catalytic hydrogenation of the alcohol gave decan-1-ol (70%) [α -naphthylurethane, m. p. and mixed m. p. 71° (Talvitie²⁶ gives m. p. 71.4°)].

(b) A solution of the Grignard reagent of tetrahydro-2-prop-2'-ynyloxyran [from magnesium (0.7 g.) and the acetylene (4.2 g.)] in tetrahydrofuran (70 c.c.) was added during 2 hr. to a well-stirred, boiling solution of hept-2-ynyl methanesulphonate³ (11.6 g.) in the same solvent (125 c.c.). The resulting suspension was heated under reflux for 16 hr. and then cooled. An excess of 2N-sulphuric acid was added, and the mixture was stirred vigorously for 30 min. Isolation of the product with ether and distillation gave : (i) 1-Bromohept-2-yne (4.3 g., 80%) and (ii) crude deca-2 : 5-diyn-1-ol (3 g., 65%), n_D^{21} 1.4720. The α -naphthylurethane (40% yield) and its mixture with a specimen from (a), both had m. p. 102°.

1-Bromo-octa-2 : 5-diyn-1-ol (VIII).—Phosphorus tribromide (5.7 g.) was added to a stirred solution of octa-2 : 5-diyn-1-ol (7.1 g.) and pyridine (0.11 g.) in ether (30 c.c.) at such a rate that the mixture boiled gently. The mixture was heated under reflux for a further 3 hr. and then cooled. The upper layer was decanted on ice, and the product was extracted with ether. The extract was washed with saturated sodium carbonate solution, dried (CaCl₂), and evaporated. Distillation of the residue gave 1-bromo-octa-2 : 5-diyn-1-ol (6.3 g.), b. p. 50–52°/10⁻⁴ mm., n_D^{20} 1.5250 (Found : C, 51.35; H, 5.1. C_8H_9Br requires C, 51.9; H, 4.9%). Ultraviolet light absorption : maxima, 216 and 290 m μ , $E_{1\%}^{1\text{cm}}$ 70 and 4, respectively. Infrared light absorption : maxima, 4.395, 4.463 (C \equiv C) and 5.155 μ (allenic impurity).

2-(Heptadeca-8 : 11 : 14-triynyl)-1 : 3-dioxolan (IX).—A well-stirred solution of ethylmagnesium bromide [from magnesium (0.6 g.) and ethyl bromide (2.5 g.)] in ether (25 c.c.) was diluted with tetrahydrofuran (65 c.c.), and a solution of 2-8'-nonyl-1 : 3-dioxolan (5.0 g.) in tetrahydrofuran (25 c.c.) was added slowly. The mixture was stirred vigorously at 20° for 4 hr., and then under reflux for 1.5 hr. The resulting acetylenic Grignard solution was cooled and added during 2 hr. to a warm (35°), vigorously-stirred mixture of 1-bromo-octa-2 : 5-diyn-1-ol (4.3 g.), tetrahydrofuran (75 c.c.), and cuprous chloride (0.25 g.). The mixture was boiled for 16 hr., more cuprous chloride (0.25 g.) being added after 10 hr., and then cooled. Water was added, the inorganic salts were removed by filtration, and the product was extracted with ether. The extract was washed with water, dried (Na₂SO₄), and evaporated. Distillation of the residue from a short-path still gave (i) a mixture of starting materials and (ii) the tri-yne (2.3 g., 33%), b. p. 165–175° (bath temp.)/10⁻⁵ mm. The product was very unstable, and no attempt was made to analyse it. On treatment with Brady's reagent it gave *octadeca-9 : 12 : 15-triynal* 2 : 4-dinitrophenylhydrazone (ca. 80%), which crystallised from alcohol and had m. p. 102° (Found : N, 13.25. $C_{24}H_{28}O_4N_4$ requires N, 12.85%).

When the reaction mixture was refluxed for only 5 hr., the yield of the tri-yne was reduced to 7%.

9 : 10 : 12 : 13 : 15 : 16-Hexabromostearic Acid (XI).—A solution of the tri-yne (2.3 g.), freshly distilled, in *n*-hexane (100 c.c.) was shaken in hydrogen in the presence of Lindlar catalyst (2.3 g.) until there was a marked diminution in rate of absorption (400 c.c. of hydrogen were taken up at 17°/763 mm., equivalent to 73% of the theoretical for 3 mol.; this low figure is attributed to loss of material by polymerisation). The catalyst was filtered off, and a solution of bromine (4 g.) in *n*-hexane (4 c.c.) was added dropwise until a permanent red coloration indicated a slight excess of bromine. The solution was kept at 0° overnight, and then shaken with 10% aqueous sodium thiosulphate (to remove excess of bromine), with dilute sodium carbonate, and finally with water. The solution was dried (Na₂SO₄) and evaporated, giving a viscous residue (4.2 g.) which deposited a small amount of a solid.

To a warm (55–60°), well-stirred solution of the crude product in glacial acetic acid (120

²⁴ Elvidge and Whalley, *Chem. and Ind.*, 1955, 589.

²⁵ Adamson and Kenner, *J.*, 1934, 838.

²⁶ Talvitie, *Ann. Acad. Sci. Fennicae*, 1927, **26**, A, 1.

c.c.), a solution of chromium trioxide (2.2 g.) in 2N-sulphuric acid (40 c.c.) was added dropwise. The mixture was stirred at 20° overnight, and then concentrated to a small volume under reduced pressure. 2N-Sulphuric acid (130 c.c.) was added. The mixture was warmed (steam-bath) for 1 hr., then cooled, diluted with saturated brine (95 c.c.), and extracted with chloroform. Evaporation of the extract gave a mixture of bromo-acids (3 g.) which was extracted with light petroleum (b. p. 80—100°). The residual solid (0.5 g., 16%) had m. p. 177°. Extraction with benzene and crystallisation from dioxan yielded 9 : 10 : 12 : 13 : 15 : 16-hexabromostearic acid, m. p. 181—182°, undepressed on admixture with the solid hexabromide, m. p. 181—182°, prepared from natural linolenic acid (Rollett⁷ gives m. p. 180—181°). The infrared spectra of Nujol mulls of the "natural" and the synthetic acid were identical.

In another experiment the mixture of bromo-acids was esterified in ethereal suspension with diazomethane. Chromatography of the methyl esters on alumina (Savory and Moore), pentane-ether being used as eluant,²⁷ and crystallisation from alcohol, gave (10%) methyl 9 : 10 : 12 : 13 : 15 : 16-hexabromostearate, m. p. 157—158°, undepressed on admixture with a specimen from natural linolenic acid (Stanfield and Schierz²⁸ give m. p. 157—158°). The infrared spectra of carbon tetrachloride solutions of the "natural" and the synthetic ester were identical. No lower or higher bromo-stearates were detected in the chromatogram. Model experiments showed that methyl tetra- and hexa-bromostearate are readily separated on alumina, but that the recovery of each ester is only *ca.* 50%.

Hydrolysis of methyl hexabromostearate for $\frac{1}{2}$ hr. in a boiling mixture (1 : 5) of 2N-hydrochloric acid and dioxan, and evaporation of the resulting solution gave (90%) a solid, m. p. 180°. Recrystallisation from dioxan gave hexabromostearic acid, m. p. and mixed m. p. 181—182°.

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A brief account of some of the work described in this paper has been published previously.²⁹

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²⁷ Howton, *Science*, 1955, **121**, 704.

²⁸ Stanfield and Schierz, *J. Amer. Chem. Soc.*, 1932, **54**, 4357.

²⁹ Nigam and Weedon, *Chem. and Ind.*, 1955, 1555.