Chem. Phys. Lipids 7 (1971) 108–120 © North-Holland Publishing Company

CHEMICAL SYNTHESIS OF HIGHLY UNSATURATED FATTY ACIDS, II.*

PREPARATION OF SUBSTITUTED PROPARGYL HALIDES**

WOLF-H. KUNAU

Ruhr-Universität Bochum, Institute für Physiologische Chemie,
Lehrstuhl I, Bochum-Querenburg, Germany

Received January 22, 1971
Accepted April 17, 1971

A method for the preparation of substituted propargyl halides is described. Nine substituted propargyl bromides and twelve substituted propargyl iodides with up to four triple bonds are prepared by ether cleavage of substituted propargyl methyl ethers with acetyl bromide and acetyl iodide. The yields of bromides are higher than those obtained by other methods. The corresponding iodides are synthesized for the first time. The synthesis of thirteen substituted propargyl methyl ethers with up to four triple bonds is reported.

I. Introduction

The exclusive utilisation of substituted propargyl bromides in the various Grignard condensations²) proved to be an important factor responsible for the low overall yield in the total chemical synthesis of polyenoic fatty acids. So far bromides with more than three triple bonds were prepared in relative low yields from the corresponding alcohols by reaction with phosphorus tribromide²⁻⁵). The condensation of these bromides with the bis-Grignard derivatives of $(n-1)$-acetylenic acids very often gave yields of only 30–50%³⁻⁹).

The present communication reports an improved method of preparing substituted propargyl bromides and a procedure for synthesizing substituted propargyl iodides. The latter compounds are more reactive in the condensation with bis-Grignard derivatives of $(n-1)$-acetylenic acids than the former.

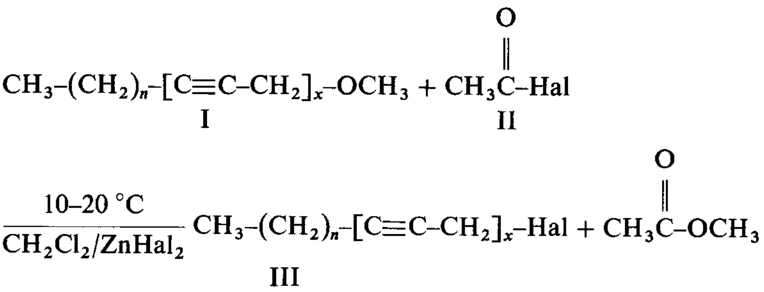
The procedure described by Marszak and Epsztein for the preparation of 1-chloro-2-alkynes¹⁰,¹¹) and by Couffignal et al. for the synthesis of 1-bromo-2-alkynes¹²) were modified to suit the synthesis of substituted

---

* Communication I: ¹).

** The position of triple bonds is stated in the form $(n-x)$ according to the recommendation of the IUPAC-IUB Commission on Biochemical Nomenclature, where n indicates the number of carbon atoms in the chain.

propargyl bromides and iodides with up to four triple bonds. These authors converted 1-methoxy-2-alkynes to 1-chloro- and 1-bromo-2-alkynes with acetyl chloride and acetyl bromide, respectively, at 60 °C without a solvent in the presence of the appropriate zinc halide. In the course of the present study it was found that by using dichloromethane as solvent this ether cleavage can be carried out at room temperature. Under these conditions substituted propargyl methyl ethers (I) with up to four triple bonds were cleaved not only by acetyl bromide (II), but also by acetyl iodide (II) thus furnishing substituted propargyl bromides and iodides (III) in very good yields. See fig. 1.



$$\underset{I}{CH_3-(CH_2)_n-[C\equiv C-CH_2]_x-OCH_3} + \underset{II}{CH_3\overset{\overset{O}{\|}}{C}-Hal} \xrightarrow[CH_2Cl_2/ZnHal_2]{10-20\,^\circ C} \underset{III}{CH_3-(CH_2)_n-[C\equiv C-CH_2]_x-Hal} + CH_3\overset{\overset{O}{\|}}{C}-OCH_3$$

Fig. 1. Preparation of substituted propargyl halides. Hal = Br, J.

The yields of the bromides were in fact better than those published previously, syntheses of substituted propargyl iodides have not been reported so far.

II. Results and discussion

The experiments described in this paper show that it has been possible to improve the preparation of substituted propargyl bromides and to synthesize substituted propargyl iodides for the first time. The latter compounds proved to be more reactive than the corresponding bromides in the condensation with bis-Grignard derivatives of $(n-4)$, $(n-1)$-alkadiynoic acids[1]), as reported elsewhere[13]). They are therefore useful new building blocks for the synthesis of highly unsaturated fatty acids. Our studies revealed, that substituted propargyl methyl ethers were easily cleaved at room temperature, if dichloromethane was used as solvent. Propargyl methyl ethers with one triple bond were splitted within few hours, whereas cleavage of propargyl methyl ethers with more triple bonds proceeded more slowly. The course of the reaction could be followed by thin layer chromatography. Purification of the crude bromides was achieved with good yields by fractional distillation at pressures at which the boiling points were within the range of 40–60 °C.

The substituted propargyl iodides with one triple bond could be obtained in quantitative yields. It was not necessary to purify the crude products, because by-products could not be detected by gas chromatography and thin layer chromatography. The 1-iodo-2-alkynes are light yellow liquids.

Due to the presence of by-products the other substituted propargyl halides had to be purified by distillation or cristallisation. The amount of by-product increased with the number of triple bonds. A large number of ether cleavage revealed that the yield depends on the purity of acetyl iodide and bromide, the distillation temperature or the solvent mixture used for cristallisation.

The refraction indices of the substituted propargyl halides, especially of the iodides differed from fraction to fraction during distillation, even when the result of all chromatographic and spectroscopic methods for the different fractions were identical. Therefore the refraction indices, given in the experimental part, are average values of several fractions. A comparison of the analogous bromides and iodides reveals that with the exception of compounds with one triple bond the bromides can be obtained with slightly better yield. Therefore for reactions where both bromides and iodides are equally reactive, preference is given to bromides, for example in case of condensation of substituted propargyl halides with the Grignard derivatives of propargyl methyl ethers. However, in reactions where the iodides proved to be more reactive compounds, one has to consider the lower yields in the preparation of the iodides and the higher yields in the subsequent Grignard condensation. An example for the usefullness of the iodides is the final condensation of substituted propargyl halides with the bis-Grignard derivatives of $(n-4)$, $(n-1)$-alkadiynoic acids[13]).

Of all the substituted propargyl methyl ethers necessary to prepare the halides only the substances with one triple bond had been described[12]). Analogous to the preparation of the corresponding propargyl alcohols[2]) the higher unsaturated ethers could also be easily prepared when 1-methoxy-2-propyne and 1-methoxy-2,5-hexadiyne were used insted of 2-propyn-1-ol[2]) and 2,5-hexadiyn-1-ol[3]), respectively. The condensations were completed after 3–4 hr of stirring at room temperature.

III. Experimental

Reactions were carried out in an atmosphere of pure nitrogen. Purified tetrahydrofuran and diethyl ether were distilled over $LiAlH_4$ before use.

Melting points were determined on a "Leitz-Mikroskop-Heiztisch 350", all temperatures are uncorrected. Gas-chromatographic (GLC) analyses were performed on a Packard, Model 835, instrument, or a Hewlett-Packard, Model 5750, instrument, both equipped with a flame-ionization detector. The following column packings were used: 8% DEGS on Anakrom A-SD

60–70 mesh, 10% Apiezon L on Anakrom/ A 60–70 mesh, 3% OV-1 on Anakrom A 60–70 mesh, 1% SE-30 on Anakrom A 60–70 mesh. Infrared (IR) spectra were recorded with a Perkin-Elmer spectrophotometer, Model 337, as films. Nuclear magnetic resonance (NMR) spectra were measured with Varian T 60, A 60 and A 100 instruments using no solvent and tetramethylsilan as reference compound. Thin-layer chromatography (TLC) was carried out on thin layers of silica gel H (Merck) and with the developing system hexan and diisopropyl ether (90:10).

A. Substituted propargyl methyl ethers

1. 1-Methoxy-2-alkynes

These compounds were prepared according to the method of Couffignal et al.$^{12)}$. The synthesis of the homologous series of 1-methoxy-2-alkynes was described by these authors with the exception of 1-methoxy-2-nonyne and 1-methoxy-2-decyne.

a. 1-Methoxy-2-nonyne

Yield: 84%, purity 98% (GLC), b.p. 81–82 °C (8 mm Hg), $n_D^{20} = 1.4393$. IR spectrum: 2230, 2290 cm^{-1}(–C≡C–), 1095 cm^{-1} (–O–CH_3), other bands at 905, 1130, 1185 cm^{-1}. NMR spectrum: triplet at δ3.98 (2) (–CH_2O–), singlet at δ3.25 (3) (–OCH_3), complex at δ2.0–2.4 (2) (–CH_2–C≡C–), complex at δ1.1–1.7 (8) (–CH_2–), distorted triplet at δ0.90 (3) (CH_3–).

b. 1-Methoxy-2-decyne

Yield: 83%, purity 98% (GLC), b.p. 99–100 °C (10 mm Hg), $n_D^{20} = 1.4442$. IR spectrum: 2230, 2290 cm^{-1} (–C≡C–), 1095 cm^{-1} (–O–CH_3), other bands at 905, 1130, 1185 cm^{-1}. NMR spectrum: triplet at δ3.95 (2) (–CH_2O–), singlet at δ3.23 (3) (–OCH_3), complex at δ2.0–2.4 (2) (–CH_2–C≡C–), complex at δ1.1–1.7 (10) (–CH_2–), distorted triplet at δ0.89 (3) (CH_3–).

2. 1-Methoxy-2,5-alkadiynes

a. 1-Methoxy-2,5-octadiyne

A solution of ethyl magnesium bromide was prepared from 36.45 g magnesium (1.5 g atom), 174 g ethyl bromide (1.6 mole) and 600 ml tetrahydrofuran. After adding 400 ml tetrahydrofuran, a solution of 105 g 1-methoxy-2-propyne (1.5 mole) in 100 ml tetrahydrofuran was added during 45 min at 0 °C. The mixture was stirred for 2 hrs at room temperature. Subsequently, it was cooled again to 0 °C and 1.0 g cuprous chloride was added. After stirring the solution during 15 min, 194.0 g 1-iodo-2-pentyne was added dropwise. The mixture was stirred at room temperature for about 5 hrs, was then poured in ice and 2 N sulfuric acid and both layers were filtered over kieselgur, the residue was washed with ether. Subsequently, the layers were separated, the aqueous phase was extracted twice with ether, and the combined ether phases were washed with sat. NH_4Cl sol./25% NH_4OH (10:1) until free from copper ions, with water until neutral, dried over Na_2SO_4 and evaporated, leaving 138 crude 2,5-octadiynyl methyl ether. Distillation yielded 125 g (92%), purity > 97% (GLC), b.p. of 45–46 °C (0.4 mm Hg), $n_D^{20} = 1.4688$. IR spectrum: 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1325 cm^{-1} ($-CH_2-C{\equiv}C$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 905, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.00 (2) ($-CH_2O-$), singlet at δ3.26 (3) ($-OCH_3$), complex at δ3.15 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ2.1–2.4 (2) ($-CH_2-C{\equiv}C-$), triplet at δ0.97 (CH_3-).

In the same way were prepared:

b. 1-Methoxy-2,5-nonadiyne

Yield: 89%, purity 98% (GLC), b.p. 55–56 °C (7×10^{-2} mm Hg), $n_D^{20} = 1.4680$. IR spectrum: 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1320 cm^{-1} ($-CH_2-C{\equiv}C-$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 910, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.04 (2) ($-CH_2O-$), singlet at δ3.31 (3) ($-OCH_3$), complex at δ3.18 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.2–1.7 (4) ($-CH_2-$), triplet at δ0.91 (3) (CH_3-).

c. 1-Methoxy-2,5-decadiyne

Yield: 87%, purity > 98% (GLC), b.p. 60–61 °C (3×10^{-2} mm Hg), $n_D^{20} = 1.4670$. IR spectrum: 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1320 cm^{-1} ($-CH_2-C{\equiv}C-$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 905, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.00 (2) ($-CH_2O-$), singlet at δ3.30 (3) ($-OCH_3$), complex at δ3.19 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at 1.2–1.8 (4) ($-CH_2-$), distorted triplet at δ0.97 (3) (CH_3-).

d. 1-Methoxy-2,5-undecadiyne

Yield: 92%, purity > 98% (GLC), b.p. 40–43 °C (10^{-4} mm Hg), $n_D^{20} = 1.4678$. IR spectrum: 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1320 cm^{-1} ($-CH_2-C{\equiv}C-$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 905, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.06 (2) ($-CH_2O-$), singlet at δ3.31 (3) ($-OCH_3$), complex at δ3.17 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.2–1.7 (6) ($-CH_2-$), distorted triplet at δ0.93 (3) (CH_3-).

e. 1-Methoxy-2.5-dodecadiyne

Yield: 89%, purity 98% (GLC), b.p. 63–65 °C (5×10^{-3} mm Hg), $n_D^{20} = 1.4670$. IR spectrum: 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1320 cm^{-1} ($-CH_2-C{\equiv}C-$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 905, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.04 (2) ($-CH_2O-$), singlet at δ3.30 (3) ($-OCH_3$), complex at 3.17 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ1.9–2.4 (2) ($-CH_2-C{\equiv}{\equiv}C-$), complex at 1.1–1.7 (8) ($-CH_2-$), distorted triplet at δ0.91 (3) (CH_3-).

f. 1-Methoxy-2,5-tridecadiyne

Yield: 90%, purity>98% (GLC), b.p. 76–78 °C (10^{-2} mm Hg), $n_D^{20} = 1.4670$. IR spectrum 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1320 cm^{-1} ($-CH_2-C{\equiv}-C$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 910, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.03 (2) ($-CH_2O-$), singlet at δ3.29 (3) ($-OCH_3$), complex at δ3.16 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ1.9–2.4 (2)($-CH_2-C{\equiv}{\equiv}C-$), complex at δ1.1–1.7 (10) ($-CH_2-$), distorted triplet at δ0.89 (3) (CH_3-).

g. 1-Methoxy-2.5-tetradecadiyne

Yield: 88%, purity>96% (GLC), b.p. 84–87 °C (10^{-3} mm Hg), $n_D^{20} = 1.4671$. IR spectrum: 2260 (w) cm^{-1} ($-C{\equiv}C-$), 1320 cm^{-1} ($-CH_2-C{\equiv}C-$), 1090, 1110 cm^{-1} ($-O-CH_3$), other bands at 910, 1185, 1475 cm^{-1}. NMR spectrum: triplet at δ4.02 (2) ($-CH_2O-$), singlet at δ3.30 (3) ($-OCH_3$), complex at δ3.16 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex δ1.9–2.4 (2) ($-CH_2-C{\equiv}{\equiv}C-$), complex at δ1.1–1.8 (12) ($-CH_2-$), distorted triplet at δ0.90 (3) (CH_3 -).

3. 1-Methoxy-2,5,8-alkatriyne

a. 1-Methoxy-2,5,8-undecatriyne

This compound was synthesized by two different ways:

(a) by elongating 1-iodo-2-pentyne with 1-methoxy-2,5-hexadiyne,

(b) by elongating 1-iodo-2,5-octadiyne with 1-methoxy-2-propyne.

Both reactions were carried out as described for 1-methoxy-2,5-octadiyne.

(a) Short-path distillation (10^{-5} mm Hg) at a bath temperature of 50–100 °C, yield: 55%, purity 96% (GLC), $n_D^{20} = 1.4962$.

(b) Short-path distillation (10^{-5} mm Hg) at a bath temperature of 50–80 °C, yield 91%, purity 96% (GLC), $n_D^{20} = 1.4960$.

IR spectrum: 2260 (w), 2290 (w) cm^{-1} ($-C{\equiv}C-$), 1330 cm^{-1} ($-CH_2-C{\equiv}{\equiv}C-$), 1090, 1105 cm^{-1} ($-O-CH_3$), other bands at 905, 1185 cm^{-1}. NMR spectrum: triplet at δ4.06 (2) ($-CH_2O-$), singlet at δ3.29 (3) ($-OCH_3$), complex at 3.18 (4) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ1.9–2.4 (2) ($-CH_2-C{\equiv}C-$), triplet at δ1.09 (3) (CH_3-).

b. 1-Methoxy-2,5,8-tetradecatriyne

This substance was prepared

(a) by elongating 1-iodo-2-octyne with 1-methoxy-2,5-hexadiyne,

(b) by elongating 1-iodo-2,5-undecadiyne with 1-methoxy-2-propyne.

(a) Short-path distillation (10^{-5} mm Hg) at a bath temperature of 70–120°C, yield: 60%, purity 96% (GLC), $n_D^{20} = 1.4905$.

(b) Short-path distillation (10^{-5} mm Hg) at a bath temperature of 70–120°C, yield: 88%, purity 97% (GLC), $n_D^{20} = 1.4895$.

IR spectrum: 2260 (w), 2290 (w) cm^{-1} (–C≡C–), 1325 cm^{-1} (–CH_2–C≡C–), 1090, 1105 cm^{-1} (–O–CH_3), other bands at 905, 1185 cm^{-1}. NMR spectrum: triplet at δ4.07 (2) (–CH_2O–), singlet at δ3.32 (3) (–OCH_3), complex at δ3.18 (4) (–C≡C–CH_2–C≡C–), complex at δ1.9–2.4 (2) (–CH_2–C≡C–), complex at δ1.1–1.7 (6) (–CH_2–), distorted triplet at δ0.90 (3) (CH_3–).

4. 1-Methoxy-2,5,8,11-alkatetrayne

a. 1-Methoxy-2,5,8,11-tetradecatetrayne

This substance was prepared by two different ways:

(a) by elongation of 1-iodo-2,5-octadiyne with 1-methoxy-2,5-hexadiyne,

(b) by elongation of 1-bromo-2,5,8-undecatriyne with 1-methoxy-2-propyne.

(a) Short-path distillation (10^{-5} mm Hg) at a bath temperature of 100–130°C, yield: 61%, purity 95% (GLC), $n_D^{20} = 1.5128$.

(b) Short-path distillation (10^{-5} mm Hg) at a bath temperature of 70–110°C, yield: 90%, purity 95% (GLC), $n_D^{20} = 1.5138$.

IR spectrum: 2260 (w) cm^{-1} (–C≡C–), 1330 cm^{-1} (–CH_2–C≡C–), 1095 cm^{-1} (–O–CH_3), other bands at 905, 1185 cm^{-1}. NMR spectrum: triplet at δ4.07 (2) (–CH_2O–), singlet at 3.32 (3) (–OCH_3), complex at δ3.20 (6) (–C≡C–CH_2–C≡C–), complex at δ1.9–2.5 (2) (–CH_2–C≡C–), triplet at δ1.1 (CH_3–).

B. Substituted propargyl iodides

1. 1-Iodo-2-alkynes

a. 1-Iodo-2-pentyne

A solution of 187 g acetyl iodide (1.1 mole) in 100 ml dichloromethane was added dropwise at 10°C to a solution of 98 g 2-pentynyl methyl ether (1.0 mole), 10 g anhydrous zinc iodide and 250 ml dichloromethane during 30 min. The mixture was allowed to stir at room temperature until methyl ether could not be detected by GLC. This took about 4–5 hrs. Subsequently, the mixture was poured into ether and water, the layers were separated, and the aqueous layer extracted twice with ether. The combined ether phases were washed with 10% $Na_2S_2O_3$-solution, sat. $NaHCO_3$-solution and water, dried over Na_2SO_4 and evaporated leaving 196 g of light yellow liquid. The crude 1-iodo-2-pentyne had a purity of 97% (GLC) and a refraction index of $n_D^{20} = 1.5670$. Distillation yielded 159 g (82%) 1-iodo-2-pentyne with a purity of 97% (GLC) and a b.p. of 52–54 °C (8 mm Hg) and a refraction index of $n_D^{20} = 1.564$. IR spectrum: 2230 cm^{-1} (–C≡C–), 1330 cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170, a small C=O-impurity at 1750 cm^{-1}. NMR spectrum: triplet at δ3.72 (2) ($-CH_2-J$), complex at δ2.0–2.5 (2) ($-CH_2-C{\equiv}C-$), triplet at δ1.12 (3) (CH_3-).

In the same way were prepared:

b. 1-Iodo-2-hexyne

Crude product: yield: 102%, purity 96% (GLC), $n_D^{20} = 1.554$. IR spectrum: 2235 cm^{-1} (–C≡C–), 1340 cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}, a small C=O-impurity at 1750 cm^{-1}. NMR spectrum: triplet at δ3.70 (2) ($-CH_2-J$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}{\equiv}C-$), complex at δ1.3–1.9 (2) ($-CH_2-$), triplet at δ0.96 (3) (CH_3-).

c. 1-Iodo-2-heptyne

Crude product: yield: 99%, purity 96% (GLC), $n_D^{20} = 1.539$. Distilled product: yield: 91%, purity 98%, b.p. 42–44 °C (0.4 mm Hg), $n_D^{20} = 1.5375$. IR spectrum: 2230 cm^{-1} (–C≡C–), 1330 (w) cm^{-1} ($CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1130 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.70 (2) ($-CH_2-J$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.3–1.7 (4) ($-CH_2-$).

d. 1-Iodo-2-octyne

Crude product: yield: 100%, purity 96% (GLC), $n_D^{20} = 1.536$. Distilled product: yield: 92%, purity 98% (GLC), b.p. 30–32 °C (5×10^{-3} mm Hg), $n_D^{20} = 1.5320$. IR spectrum: 2230 cm^{-1} (–C≡C–), 1330 (w) cm^{-1} ($-CH_2-C{\equiv}{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.71 (2) ($-CH_2-J$), complex at δ2.0–2.4 (2) ($-CH_2-{-}C{\equiv}C-$), complex at 1.2–1.7 (6) ($-CH_2-$), triplet at δ0.90 (3) (CH_3-).

e. 1-Iodo-2-nonyne

Crude product: 102%, purity 96% (GLC), $n_D^{20} = 1.528$. Distilled product: yield: 90%, purity 98% (GLC), b.p. 39–40 °C (10^{-4} mm Hg), $n_D^{20} = 1.5254$. IR spectrum: 2230 cm^{-1} (–C≡C–), 1330 cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.68

(2) ($-CH_2-J$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.1–1.7 (8) ($-CH_2-$), distorted triplet at 0.88 (3) (CH_3-).

f. 1-Iodo-2-decyne

Crude product: Yield: 99%, purity 95% (GLC), $n_D^{20} = 1.523$. IR spectrum: 2230 cm^{-1} ($-C{\equiv}C-$), 1320 (w) cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.68 (2) ($-CH_2-J$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.1–1.7 (10) ($-CH_2-$), distorted triplet at δ0.88 (CH_3-).

g. 1-Iodo-2-undecyne

Crude product: yield: 101%, purity 95% (GLC), $n_D^{20} = 1.518$. Distilled product: Short-path distillation (10^{-3} mm Hg) at a bath temperature of 45–60°C, yield: 94%, purity > 97% (GLC) $n_D^{20} = 1.5164$. IR spectrum: 2230 cm^{-1} ($-C{\equiv}C-$), 1330 (w) cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.68 (2) ($-CH_2-J$), complex at δ2.0–2.4 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.1–1.7 (12) ($-CH_2-$), distorted triplet at δ0.89 (3) (CH_3-).

2. *1-Iodo-2,5-alkadiynes*

The preparation of 1-iodo-2,5-alkadiynes was carried out in general as described for 1-iodo-2-alkynes, but an excess of 20% acetyl iodide was used instead of 10%, and it took about 6–10 hours until the reaction was completed.

a. 1-Iodo-2,5-octadiyne

Yield: 72%, purity 96% (GLC), b.p. 47–49°C (2×10^{-2} mm Hg), $n_D^{20} = 1.569$. IR spectrum: 2230 (w) cm^{-1} ($-C{\equiv}C-$), 1330 cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}, a small C=O-impurity at 1750 cm^{-1}. NMR spectrum: triplet at δ3.65 (2) ($-CH_2-J$), complex at δ3.12 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ2.0–2.4 ($-CH_2-C{\equiv}C-$), triplet at δ1.1 (3) (CH_3-).

b. 1-Iodo-2,5-undecadiyne

Short-path distillation (10^{-3} mm Hg) at a bath temperature of 50–75°C, yield: 83%, $n_D^{20} = 1.541$. IR spectrum: 2230 cm^{-1} ($-C{\equiv}C-$), 1325 cm^{-1} ($-CH_2-C{\equiv}C-$), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}, a C=O-impurity at 1750 cm^{-1}. NMR spectrum: triplet at δ3.64 (2) ($-CH_2-J$), complex at δ3.12 (2) ($-C{\equiv}C-CH_2-C{\equiv}C-$), complex at δ2.15 (2) ($-CH_2-C{\equiv}C-$), complex at δ1.1–1.6 (6) ($-CH_2-$), distorted triplet at δ0.90 (3) (CH_3-).

3. *1-Iodo-2,5,8-alkatriynes*

The 1-iodo-2,5,8-alkatriynes were prepared in analogy to iodides having less triple bonds, but the reaction time was longer and very often it was necessary to add after 24 hrs another 10% of acetyl iodide.

a. 1-Iodo-2,5,8-undecatriyne

Yield: 73%, m.p. 24.5–25.5 °C (cristallized from ether at −50 °C). IR spectrum: 2240 cm^{-1} (–C≡C–), 1330 cm^{-1} (–CH$_2$–C≡C–), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.65 (2) (–CH$_2$–J), complex at δ3.10 (4) (–C≡C–CH$_2$–C≡C–), complex at δ2.15 (2) (–CH$_2$–C≡C–), triplet at δ1.1 (3) (CH$_3$–).

b. 1-Iodo-2,5,8-tetradecatriyne

Yield: 71%, m.p. 15.5–16.5 °C (cristallized form ether/ethanol at −50 °C). IR spectrum: 2240 cm^{-1} (–C≡C–), 1330 cm^{-1} (–CH$_2$–C≡C–), 560 cm^{-1} (C–J), other bands at 1140 and 1170 cm^{-1}. NMR spectrum: triplet at δ3.65 (2) (–CH$_2$–J), complex at δ3.15 (4) (–C≡C–CH$_2$–C≡C–), complex at δ1.9–2.4 (2) (–CH$_2$–C≡C–), complex at δ1.1–1.7 (6) (–CH$_2$–), distorted triplet at δ0.90 (3) (CH$_3$–).

4. 1-Iodo-2,5,8,11-alkatetraynes

a. 1-Iodo-2,5,8,11-tetradecatetrayne

Yield: 60%, m.p. 49–50 °C (cristallized from ether at 0 °C). IR spectrum: 2230 (w) cm^{-1} (–C≡C–), 1330 cm^{-1} (–CH$_2$–C≡C–), 560 cm^{-1} (C–J), other bands at 1140 and 470 cm^{-1}. NMR spectrum: triplet at δ3.65 (2) (–CH$_2$–J), complex at δ3.20 (6) (–C≡C–CH$_2$–C≡C–), complex at δ1.9–2.5 (2) (–CH$_2$–C≡C–), triplet at δ1.1 (CH$_3$–).

C. Substituted propargyl bromides

The different bromides were synthesized as described for the corresponding iodides.

1. 1-Bromo-2-alkynes

a. 1-Bromo-2-pentyne

Yield: 84%, purity 97%, b.p. 40–42 °C (13 mm Hg), $n_D^{20} = 1.498$ (lit. 45.8–46 °C (18 mm Hg[3])). IR spectrum: 2240 cm^{-1} (–C≡C–), 1325 cm^{-1} (–CH$_2$–C≡C–), 610, 1205 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.95 (2) (–CH$_2$–Br) complex at δ2.27 (2) (–CH$_2$–C≡C–), triplet at δ1.12 (3) (CH$_3$–).

b. 1-Bromo-2-octyne

Yield: 93%, purity 97% (GLC), b.p. 46–48 °C (5×10^{-2} mm Hg), $n_D^{20} =$ 1.487 (lit. b.p. 89–90 °C (12 mm Hg), $n_D^{20} = 1.4866$[5])), b.p. 55–58 °C (0.6 mm

Hg), $n_D^{20} = 1.4882$[9]. IR spectrum: 2240 cm^{-1} ($-C\equiv C-$), 1330 (w) cm^{-1} ($-CH_2-C\equiv C-$), 610, 1205 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.93 (2) ($-CH_2-Br$), complex at δ2.23 (2) ($-CH_2-$), distorted triplet at δ0.90 (3) (CH_3-).

c. 1-Bromo-2-undecyne

Yield: 95%, purity 97% (GLC), b.p. 48–51 °C (5×10^{-3} mm Hg), $n_D^{20} = 1.483$. IR spectrum: 2240 cm^{-1} ($-C\equiv C-$), 1340 (w) cm^{-1} ($-CH_2-C\equiv C-$), 610, 1205 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.85 (2) ($-CH_2-Br$), complex at δ2.19 (2) ($-CH_2-C\equiv C-$), complex at δ1.29 (12) ($-CH_2-$), distorted triplet at δ0.88 (3) (CH_3-).

2. *1-Bromo-2,5-alkadiynes*

a. 1-Bromo-2,5-octadiyne

Yield: 90%, b.p. 34–36 °C (5×10^{-3} mm Hg), $n_D^{20} = 1.524$. IR spectrum: 2240, 2280 cm^{-1} ($-C\equiv C-$), 1340 cm^{-1} ($-CH_2-C\equiv C-$), 610, 1205 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.82 (2) ($-CH_2-Br$), complex at δ3.15 (2) ($-C\equiv C-CH_2C\equiv C-$), complex at δ2.10 (2) ($-CH_2-C\equiv C-$), triplet at δ1.1 (3) (CH_3-).

b. 1-Bromo-2,5-undecadiyne

Yield: 88%, purity 97% (GLC), b.p. 63–66 °C (10^{-4} mm Hg) $n_D^{20} = 1.509$ (lit. 64 °C (10^{-5} mm Hg), $n_D^{20} = 1\ 5109$[3], 100–102 °C (10^{-1} mm Hg), $n_D^{20} = 1.5115$[14]). IR spectrum: 2240, 2280 cm^{-1} ($-C\equiv C-$), 1325 cm^{-1} ($-CH_2-C\equiv C-$), 615, 1210 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.94 (2) ($-CH_2-Br$) complex at δ3.22 (2) ($-C\equiv C-CH_2-C\equiv C-$), complex at δ1.9–2.3 (2) ($-CH_2-C\equiv C-$), complex at δ1.1–1.7 (6) ($-CH_2-$), distorted triplet at δ0.90 (3) (CH_3-).

c. 1-Bromo-2,5-tetradecadiyne

Short-path distillation (10^{-5} mm Hg) at a bath temperature of 50–80 °C, yield: 87%, purity 97% (GLC), $n_D^{20} = 1.499$. IR spectrum: 2240, 2280 cm^{-1} ($-C\equiv C-$), 1325 cm^{-1} ($-CH_2-C\equiv C-$), 615, 1210 cm^{-1} (C–Br), a small C=O-impurity at 1750 cm^{-1}. NMR spectrum: triplet at δ3.89 (2) ($-CH_2-Br$), complex at 3.17 (2) ($-C\equiv C-CH_2-C\equiv C-$), complex at δ1.9–2.3 (2) ($-CH_2-C\equiv C-$), complex at δ1.27 (12) ($-CH_2-$).

3. *1-Bromo-2,5,8-alkatriynes*

a. 1-Bromo-2,5,8-undecatriyne

Short-path distillation (10^{-5} mm Hg) at a bath temperature of 60–90 °C, yield: 83%, $n_D^{20} = 1.541$ (lit. b.p. 62–66 °C (10^{-3} mm Hg), $n_D^{20} = 1.5422$[3]).

IR spectrum: 2240 cm^{-1} ($-C\equiv C-$), 1330 cm^{-1} ($-CH_2-C\equiv C-$), 615, 1210 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.99 (2) ($-CH_2-Br$), complex at δ3.0–3.5 (4) ($-C\equiv C-CH_2-C\equiv C-$), complex at δ1.9–2.5 (2) ($-CH_2-C\equiv C-$), triplet at δ1.11 (3) (CH_3-).

b. 1-Bromo-2,5,8-tetradecatriyne

Short-path distillation (10^{-4} mm Hg) at a bath temperature of 80–120°C, yield: 81%, $n_D^{20} = 1.5221$ (lit. 110–125°C (2×10^{-3} mm Hg), $n_D^{20} = 1.5245$3)), b.p. 140°C (1×10^{-1}), $n_D^{20} = 1.5252$14))). IR spectrum: 2240 cm^{-1} ($-C\equiv C-$), 1325 cm^{-1} ($-CH_2-C\equiv C-$), 615, 1210 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.97 (2) ($-CH_2-Br$), complex at δ2.9–3.4 (4) ($-C\equiv C-CH_2-C\equiv C-$), complex at δ1.9–2.5 (2) ($-CH_2-C\equiv C-$), complex at δ1.1–1.7 (6) ($-CH_2-$), distorted triplet at δ0.91 (3) (CH_3-).

4. 1-Bromo-2,5,8,11-alkatetraynes

a. 1-Bromo-2,5,8,11-tetradecatetrayne

Yield: 74%, m.p. 51–52°C (cristallized from ether at 20°C) (lit. m.p. 49–52°C4))). IR spectrum: 2240 cm^{-1} ($-C\equiv C-$), 1325 cm^{-1} ($-CH_2-C\equiv C-$), 615, 1210 cm^{-1} (C–Br). NMR spectrum: triplet at δ3.95 (2) ($-CH_2-Br$), complex at δ2.9–3.5 (6) ($-C\equiv C-CH_2-C\equiv C-$), complex at δ1.9–2.5 (2) ($-CH_2-C\equiv C-$), triplet at δ1.1 (CH_3-).

D. 1-Methoxy-2,5-hexadiyne

1-Methoxy-2,5-hexadiyne was prepared in analogy to the synthesis of 2,5-hexadiyne-1-ol3) by using 1-methoxy-2-propyne and propargyl tosylate instead of 2-propyne-1-ol and 1-bromo-2-propyne, respectively. Furthermore the reaction mixture was not refluxed, but stirred at room temperature.

Yield: 82%, b.p. 49–50°C (7 mm Hg), $n_D^{20} = 1.4604$. IR spectrum: 640, 3310 cm^{-1} ($HC\equiv C-$), 1320 cm^{-1} ($-C\equiv C-CH_2-$), 1095 cm^{-1} ($-OCH_3$), an allenic impurity was present as shown by a very weak band at 1935 cm^{-1}. NMR-spectrum: triplet at δ4.1 (2) ($-CH_2-O-$), singlet at δ3.36 (3) ($-OCH_3$), complex at δ3.20 (2) ($-C\equiv C-CH_2-C\equiv C-$), triplet at δ2.13 (1) ($HC\equiv C-$).

Acknowledgements

Helpful discussions with Prof. H. Faillard are gratefully acknowledged. I am also indebted to Dr. E. G. Hoffmann and G. Schroth, Max-Planck-Institut für Kohleforschung, Mülheim/Ruhr, who recorded the NMR spectra. The excellent technical assistance of Helga Lehmann and Reinhard Gross is highly appreciated.

References

1) W.-H. Kunau, Chem. Phys. Lipids 7 (1971) 101
2) J.M. Osbond, P.G. Philpott and J.C. Wickens, J. Chem. Soc. (London) (1961) 2779
3) D. van der Steen, H.J.J. Pabon and D.A. van Dorp, Rec. Trav. **82** (1963) 1015
4) H.J.J. Pabon, D. van der Steen and D.A. van Dorp, Rec. Trav. **84** (1965) 1319
5) W.-H. Kunau, Hoppe-Seyler's Z. physiol. Chem. **349** (1968) 333
6) C.B. Struijk, R.K. Beerthuis, H.J.J. Pabon and D.A. van Dorp, Rec. Trav. **85** (1966) 1233
7) R.K. Beerthuis, D.H. Nugteren, H.J.J. Pabon and D.A. van Dorp, Rec. Trav. **87** (1968) 461
8) H. Sprecher, Biochim. Biophys. Acta **144** (1967) 296
9) H. Sprecher, Biochim. Biophys. Acta **152** (1968) 519
10) I. Marszak and R. Epsztein, C.R. Acad. Sci. **240** (1955) 883
11) I. Marszak and R. Epsztein, Bull. Soc. chim. France (1956) 160
12) R. Couffigual, M. Gaudemar and P. Perriot, Bull. Soc. chim. France (1967) 3909
13) W.-H. Kunau, Hoppe-Seyler's Z. physiol. Chem. 352 (1971) 542
14) W. Stoffel and E. Bierwirth, Angew. Chem. **74** (1962) 905