COMMUNICATION 14. PREPARATION OF POLYENIC ALDEHYDIC ESTERS, THEIR ACETALS, AND SYMMETRICAL AND UNSYMMETRICAL POLYENIC DICARBOXYLIC ESTERS

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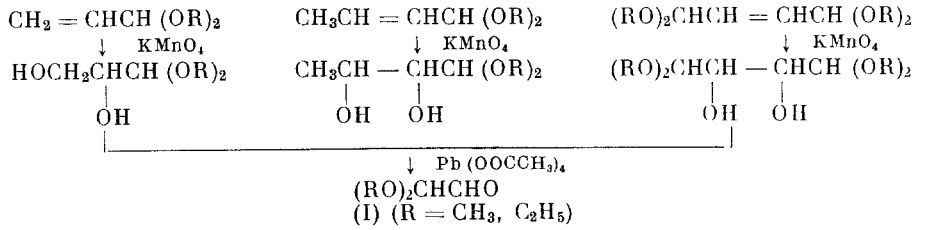
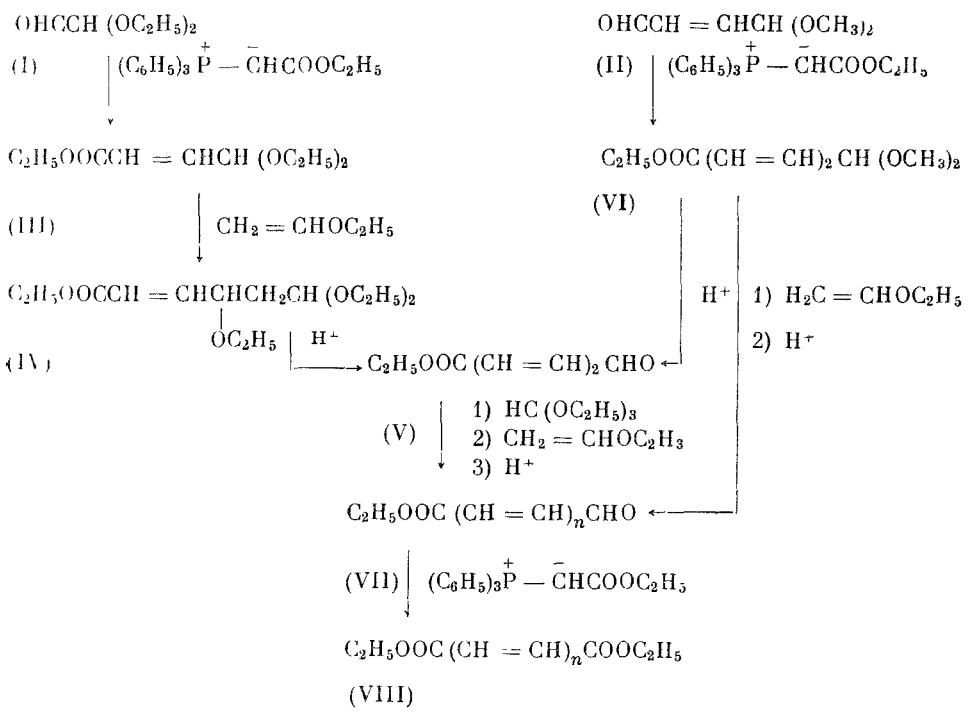
In our laboratory we have previously worked out ways of synthesizing polyenic dicarboxylic acids having even and odd numbers of double bonds on the basis of simultaneous symmetrical chain growth of the corresponding diacetals by reaction with vinyl ethers and subsequent hydrolysis and reaction of the unsaturated dialdehydes formed with a phosphoranylideneacetic ester [1, 2]. This method gave satisfactory results in some cases, but was inapplicable to the synthesis of unsymmetrical dicarboxylic acids, which may be of some interest as fragments of certain antibiotics [3].

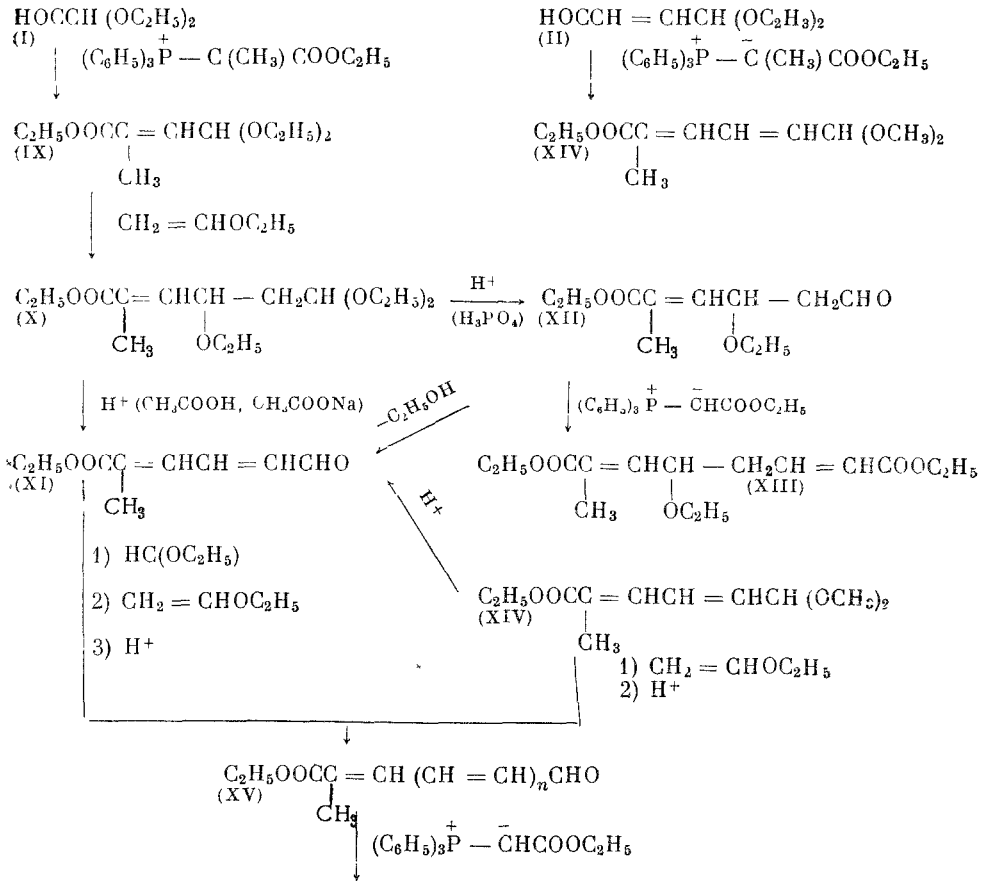
In the present work we succeeded in developing a new general method of synthesis, which permits the preparation of symmetrical and unsymmetrical dicarboxylic acids both with even and with odd numbers of double bonds of the types $C_2H_5OOC(CH_3) = CH(CH = CH)_nCOOC_2H_5$ and $C_2H_5OOC(CH = CH)_nCOOC_2H_5$. As in previous investigations [1, 2] we used a combination of chain growth of acetals with a vinyl ether and the Wittig reaction. However, as starting materials we used such unsymmetrical compounds as glyoxal monoacetal (I) and fumaraldehyde monoacetal (II). The monoacetal (I) was prepared by the oxidation of acrolein acetal by the method described in [4] with slight improvements. With the object of increasing the yield we studied the possibility of synthesizing (I) from crotonaldehyde acetal and fumaraldehyde diacetal [5] in accordance with the general scheme:

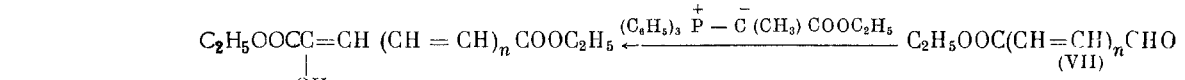


However, the results of the variants that we tried were no better than the method from the literature, and the total yield of (I) by all three methods was about 15-20% on the original acetals. The reaction of the glyoxal monoacetal (I) with ethyl (triphenylphosphoranylidene)acetate and the further growth of the resulting ethyl fumaraldehydate diethyl acetal (III) under the action of ethyl vinyl ether led to ethyl 4-ethoxy-4-formyl-2-pentenoate diethyl acetal (IV), whose hydrolysis with acetic acid in presence of sodium acetate gave ethyl 5-formyl-2,4-pentadienoate (V). The same ester (V) was obtained by the reaction of fumaraldehyde monoacetal (II) with ethyl (triphenylphosphoranylidene)acetate and the subsequent hydrolysis of the intermediate dimethyl acetal (VI) of ethyl 5-formyl-2,4-pentadienoate with 6% phosphoric acid. From the ester (V) in three stages – acetalization with orthoformic ester, growth of the resulting acetal with ethyl vinyl ether, and hydrolysis of the product with acetic acid in presence of sodium acetate – we obtained ethyl 7-formyl-2,4,6-heptatrienoate (VII, n = 3). The same aldehyde (VII, n = 3) was formed from the ethyl ester (VI) by growth with ethyl vinyl ether and subsequent hydrolysis with 6% phosphoric acid. Further successive use of the reactions of acetalization and chain growth with ethyl vinyl ether followed by hydrolysis enabled us to obtain aldehydic esters (VII, n = 4 and 5). By the action of ethyl (triphenylphosphoranylidene)acetate these aldehydic esters (VII, n = 3, 4, and 5) were converted into the corresponding dicarboxylic esters. In this way we prepared diethyl 2,4,6,8-decatetraenedioate (VIII, n = 4) and diethyl fully-trans-2,4,6,8,10,12-tetradecahexaenedioate (VIII, n = 6) (diethyl ester of crocetrocine). The latter was found to be identical with the preparation that we obtained earlier [2].



In an analogous way, using the reactions of glyoxal monoacetal (I, R = C_2H_5) and of fumaraldehyde monoacetal (II) with ethyl 2-(triphenylphosphoranylidene)propionate, subsequent growth with ethyl vinyl ether, and hydrolysis with acetic acid in presence of sodium acetate, we obtained a series of aldehydic carboxylic ester of the type $C_2H_5COOC(CH_3) = CH(CH = CH)_nCHO$ by the general scheme (see below).





(XVI) (VII)

In connection with some of our other investigations it was of interest to us to hydrolyze the ester acetal (X) without elimination of the ethoxy group. The selection of the conditions for such hydrolysis was carried out using, for control purposes, the method of gas-liquid chromatography in a column containing 1% of a silicone elastomer supported by common salt, which, as shown previously [6], is very effective for the separation of acetals. It was found that ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate (XII) is formed smoothly in the hydrolysis when 6% phosphoric acid is used. Hydrolysis with acetic acid in presence of sodium acetate gave, as would be expected, ethyl 5-formyl-2-methyl-2,4-pentadienoate (XI), whereas the use of 3% p-toluenesulfonic acid led to a mixture of (XI) and (XII). Ethyl5-formyl-2-methyl-2,4-pentadienoate(XI) and ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate (XV, n = 2) were prepared also from fumaraldehyde monoacetal (II).

By the reaction of ethyl 9-formyl-2-methyl-2,4,6,8-nonatetraenoate (XV, n = 3) with ethyl (triphenylphosphoranylidene)acetate and of ethyl 9-formyl-2,4,6,8-nonatetraenoate (VII, n = 4) with ethyl 2-(triphenylphosphoranylidene)propionate we obtained one and the same diethyl 2-methyl-2,4,6,8,10-dodecapentaenedioate (XVI, n = 4), identical with the product of the degradation of natural fungichrome [3]. In this way we developed two new methods of synthesizing unsymmetrical polyenic dicarboxylic esters.

To confirm the trans configurations of all the above-described compounds, as in previous investigations [1, 2] we made use of infrared spectra (analysis from the deformation vibrations of hydrogen at cis- and trans-double bonds in the ranges 700-800 and 900-1000 cm^{-1}, respectively). It was found that the compounds (V, VII, n = 3, 4, 5) and (VIII, n = 4, 6) have strong absorption bands in the region 900-1000 cm^{-1}, which, in absence of strong bands in the region 700-800 cm^{-1}, indicates that they have a fully trans configuration. For the unsymmetrical aldehydic esters (XI) and (XV, n = 2, 3) and diethyl 2-methyl-2,4,6,8,10-dodecapentaenedioate (XVI, n = 4) there are two strong absorption bands in the range 700-1000 cm^{-1}: one at 750 cm^{-1}, and the other in the range 900-1000 cm^{-1}. This result is in accord with data in the literature for fully-trans-dimethylcrocetin,which contains a methyl group in the 2-position [7]. It should be noted that at all stages of the above-described schemes the reaction products are formed in fairly high yields, exceeding those attained previously [1, 2]. Moreover, as intermediate products of the synthesis aldehydic carboxylic esters and the aldehydic carboxylic acids themselves are formed, and these may be used for the preparation of various functionally substituted polyenic acids, we are currently investigating this.

EXPERIMENTAL

Preparation of 2,3-Dihydroxybutyraldehyde Diethyl Acetal. A solution of 34 g of potassium permanganate in 650 ml of water was added dropwise at 0° to a well stirred mixture of 30 g of crotonaldehyde diethyl acetal and 250 ml of water. The reaction mixture was stirred at room temperature for three hours and then left overnight. The manganese dioxide formed was centrifuged off and washed with water several times with separation by centrifugation on each occasion. The aqueous solution was evaporated down to low bulk in a rotary evaporator under the vacuum of a water pump, and the diol was salted out with potassium carbonate. The oily layer was separated, and the aqueous layer was extracted with ether. The oily layer and the ether extracts were combined and dried with calcium chloride, ether was distilled off, and by fractionation we isolated 12.5 g (34%) of 2,3-dihydroxybutyraldehyde diethyl acetal, b.p. 78-80° (4 mm); $n_D^{17.5}$ 1.4364 [8]. Found: C 53.74; 53.47, H 9.87, 10.09%. $C_8H_{18}O_4$. Calculated: C 53.91, H 10.18%.

Preparation of Tartraldehyde Bis[Dimethyl Acetal]. Analogously, by the oxidation of 60.4 g of fumaraldehyde bis[dimethyl acetal] in water with a solution of 54.5 g of potassium permanganate in 1 liter of water at 5° we obtained 29.3 g (41%) of tartraldehyde bis[dimethyl acetal], b.p. 113-118° (12 mm), n_D^{19} 1.4450 [9].

Preparation of Glyoxal Mono[Diethyl Acetal] (I, R = C_2H_5). 50 g of lead tetraacetate was added in small portions at 16-27° to a stirred solution of 25 g of 2,3-dihydroxybutyraldehyde diethyl acetal in 250 ml of dry benzene (if after the addition of the reagent a test with starch-iodide paper is positive it is necessary to add a few more drops of the diol). The mixture was stirred at room temperature for two hours and filtered, 40 g of finely ground potassium carbonate was added to the filtrate, which was then vacuum-evaporated in a rotary evaporator. The residue was carefully extracted with ether. The extract was dried with magnesium sulfate, ether was removed, and the residue was fractionated. We obtained 11.46 g (61%) of glyoxal monoacetal, b.p. 46-47° (13 mm) [4].

Preparation of Glyoxal Mono[Dimethyl Acetal] (I, R = CH_3). Analogously, from 19 g of tartraldehyde bis[dimethyl acetal] in 180 ml of dry benzene and 40.5 g of lead tetraacetate at 18-32° we obtained 4.6 g (44%) of glyoxal mono[dimethyl acetal], b.p. 58-61° (30 mm), $n_D^{16.5}$ 1.4250 [10].

Preparation of Ethyl Fumaraldehydate Diethyl Acetal (III). A mixture of 9.3 g of glyoxal mono[diethyl acetal] (I, R = C_2H_5) and 24.5 g of ethyl (triphenylphosphoranylidene)acetate in 150 ml of dry benzene was boiled for 12 hours. Benzene was removed by vacuum evaporation in a rotary evaporator, the product was extracted with petroleum ether, the residue remaining after the removal of solvent was fractionated, and we isolated 9.9 g (70%) of ethyl fumaraldehydate diethyl acetal (III); b.p. 70-73° (3 mm), $n_D^{18.5}$ 1.4345; infrared spectrum (in CCl_4) 1730, 1669 cm^{-1}. Found: C 59.38, 59.62; H 9.05, 9.14%. $C_{10}H_{18}O_4$. Calculated: C 59.38, H 8.97%.

The 2,4-dinitrophenylhydrazone prepared from (III) had m.p. 155-157° (from alcohol), which corresponds to data in the literature for the 2,4-dinitrophenylhydrazone of ethyl fumaraldehydate diethyl acetal [11].

Preparation of Ethyl 2-Methylfumaraldehydate Diethyl Acetal (IX). A mixture of 5.3 g of glyoxal mono[diethyl acetal] and 17.4 g of ethyl 2-(triphenylphosphoranylidene)propionate in 100 ml of dry benzene was boiled for 16 hours. The product was treated as described above, and fractionation gave 7.67 g (87.5%) of ethyl 2-methylfumaraldehydate diethyl acetal, b.p. 62° (2 mm), $n_D^{14.2}$ 1.4423, infrared spectrum (in CCl_4) 1721, 1652 cm^{-1}. Found: C 61.45, 61.22, H 9.20, 9.30%. $C_{10}H_{20}O_4$. Calculated: C 61.09, H 9.32%.

Preparation of Ethyl 5-Formyl-2,4-pentadienoate Dimethyl Acetal (VI). Analogously (boiling for 14 hours), from 32 g of fumaraldehyde mono[dimethyl acetal] (II) [6] and 95 g of ethyl (triphenylphosphoranylidene)acetate in 300 ml of dry benzene we obtained 29.5 g (61%) of ethyl 5-formyl-2,4-pentadienoate dimethyl acetal, b.p. 84-86° (1.5 mm), n_D^{19} 1.4840. Found. C 60.34, 60.15, H 7.89, 8.22%, $C_{10}H_{16}O_4$. Calculated: C 59.98; H 8.05%.

The 2,4-dinitrophenylhydrazone of ethyl 5-formyl-2,4-pentadienoate prepared from (VI) had m.p. 179-181° (from alcohol), λ_{max} (in alcohol) 390 mμ. Found. N 16.67, 16.58%. $C_{14}H_{14}N_4O_6$. Calculated: N 16.76%.

Preparation of Ethyl 7-Formyl-2,4,6-heptatrienoate (VII, n = 3). To 3.3 g of ethyl 5-formyl-2,4-pentadienoate dimethyl acetal (VI) and 0.05 ml of boron trifluoride etherate we added with stirring 1.2 g of ethyl vinyl ether at such a rate that the temperature did not rise above 40-45°. The mixture was stirred for one hour at 50° and one hour at room temperature. The product was diluted with ether and washed with 5% sodium bicarbonate solution, the ether layer was dried with potassium carbonate. By fractionation we isolated 3 g of ethyl 7-formyl-6-methoxy-2,4-heptadienoate methyl ethyl acetal (b.p. 95-130° (1.5 mm); n_D^{19} 1.4850, which without further purification was hydrolyzed by boiling it in a water bath for 2.5 hours with a mixture of 1 g of fused sodium acetate, 10 ml of acetic acid, and 0.64 ml of water in a stream of nitrogen. The mixture was poured onto 30 g of ice. The crystalline precipitate was separated by filtration. We obtained 1.2 g (41%) of yellow crystals of ethyl 7-formyl-2,4,6-heptatrienoate, m.p. 65-66° (from petroleum ether), λ_{max} (in alcohol) 310 mμ (ε 45500). Found: C 66.59, 66.58, H 6.77, 6.77%. $C_{10}H_{12}O_5$. Calculated: C 66.65, H 6.71%.

The 2,4-dinitrophenylhydrazone prepared from this had m.p. 201-203°, λ_{max} (in alcohol) 407.5 mμ. Found: N 14.81%. $C_{16}H_{16}N_4O_6$. Calculated: N 15.55%.

Preparation of Diethyl 2,4,6,8-Decatetraenedioate (VIII, n = 4). By a procedure analogous to that described above, from 0.5 g of ethyl 7-formyl-2,4,6-heptatrienoate (VII, n = 3) and 1.2 g of ethyl (triphenylphosphoranylidene)-acetate in 100 ml of dry benzene by boiling for eight hours we obtained 0.43 g (62%) of diethyl 2,4,6,8-decatetraenedioate (VIII, n = 4), m.p. 131-132° (from methanol); λ_{max} (in benzene) 338.5; 356 mμ (ε 61100, 58700), infrared spectrum: 1012, 1654, 1700 cm^{-1}. Found: C 67.45, 67.40, H 7.34, 7.14%. $C_{14}H_{18}O_4$. Calculated: C 67.18; H 7.23%.

Preparation of Ethyl 9-Formyl-2,4,6,8-nonatetraenoate (VII, n = 4). 9.76 g of ethyl 7-formyl-2,4,6-heptatrienoate (VII; n = 3) was dissolved in 25 ml of absolute alcohol, and 19.5 ml of orthoformic ester and a warm solution of 0.2 g of ammonium nitrate in 25 ml of absolute alcohol were added. The mixture was heated for 30-40 minutes at 70° and then set aside for 24 hours, it was then washed with 5% sodium bicarbonate solution and extracted with ether; the extract was dried with magnesium sulfate. By fractionation we isolated 8.14 g (62.5%) of ethyl 7-formyl-2,4,6-heptatrienoate diethyl acetal, b.p. 122-127° (0.4 mm) and n_D^{18} 1.5300, which was used without further purification in the chain-growth reaction.

By the method described for the experiment on the preparation of (VII, n = 3) from 7.89 g of ethyl 7-formyl-2,4,6-heptatrienoate in presence of 0.1 ml of boron trifluoride etherate and 3.2 g of ethyl vinyl ether we obtained ethyl 8-ethoxy-9-formyl-2,4,6-nonatrienoate diethyl acetal, which without purification was hydrolyzed with a

mixture of 32 ml of acetic acid, 2 ml of water, and 3.2 g of fused sodium acetate, with which it was heated for 75 minutes in a water bath in a stream of nitrogen. The treatment was as described for the preparation of (VII, n = 3), and we obtained 5.1 g [46%, based on (VII, n = 3)] of crystalline ethyl 9-formyl-2,4,6,8-nonatetraenoate, m.p. 113-115° (from petroleum ether); λ_{max} (in alcohol) 250, 341, 356.5 mμ (ε 3600, 46600, 46600). Found : C 69.24; 69.42; H 6.89, 6.98%. $C_{12}H_{14}O_3$. Calculated: C 69.88, H 6.84%.

The 2,4-dinitrophenylhydrazone had m.p. 216-218° (from alcohol); λ_{max} (in alcohol) 430 mμ. Found: N 14.14; 14.32%. $C_{18}H_{18}N_4O_6$. Calculated: N 14.50%.

Preparation of Diethyl 2,4,6,8,10,12-Tetradecahexaenedioate (Diethyl Ester of Crocin) (VIII, n = 6). From 3.5 g of ethyl 9-formyl-2,4,6,8-nonatetraenoate (VII, n = 4) in 30 ml of absolute alcohol and 15 ml of orthoformic ester in presence of a solution of 0.4 g of ammonium nitrate in 20 ml of absolute alcohol by the method described for the preceding experiment we obtained ethyl 9-formyl-2,4,6,8-nonatetraenoate diethyl acetal, which was used without isolation in the further reactions. By its reaction with ethyl vinyl ether (5 ml) in presence of 0.1 ml of boron trifluoride etherate, as described for the experiment on the preparation of (VII, n = 3), we isolated ethyl 10-ethoxy-11-formyl-2,4,6,8-undecatetraenoate diethyl acetal, which without further purification was hydrolyzed by heating in a water bath for 30 minutes in a stream of nitrogen with a mixture of 33 ml of acetic acid, 3.3 g of fused sodium acetate, and 2.1 ml of water. After the treatment described above we obtained yellow crystals of ethyl 11-formyl-2,4,6,8,10-undecapentaenoate (VII, n = 5), which was used without purification in the next stage.

A mixture of this aldehydic ester and 15 g of ethyl (triphenylphosphoranylidene)acetate in 150 ml of dry benzene was boiled in a stream of nitrogen for six hours, solvent was removed by vacuum-evaporation in a rotary evaporator, the residue was treated with methanol, and we obtained 0.5 g [13%, based on the original (VII, n = 4)] of diethyl 2,4,6,8,10,12-tetradecahexaenedioate (diethyl ester of crocin) (VIII, n = 6), m.p. 201-203°, undepressed by admixture of a preparation obtained earlier [2].

Preparation of Ethyl 4-Ethoxy-5-formyl-2-methyl-2-pentenoate Diethyl Acetal (X). From 3.6 g of ethyl 2-methylfumaraldehydate diethyl acetal (IX) and 4.7 ml of ethyl vinyl ether in presence of 0.1 ml of boron trifluoride etherate we obtained 8 g (56%) of ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate diethyl acetal; b.p. 111-115° (2 mm); n_D^{18} 1.4447. Found: C 62.04; H 9.57%. $C_{15}H_{28}O_5$. Calculated: C 62.47; H 9.79%.

Preparation of Diethyl 4-Ethoxy-2-methyl-2,6-octadienedioate (XIII). A mixture of 9.9 g of ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate diethyl acetal (X) and 30 ml of 6% phosphoric acid was heated with vigorous stirring in a water bath for one hour with removal of alcohol by distillation. A little calcium carbonate was added to the mixture, which was stirred at room temperature for 90 minutes. The reaction product was extracted with ether, and the extract was washed with 5% sodium bicarbonate solution and dried with magnesium sulfate. Fractionation gave 5.2 g (73%) of ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate (XII); b.p. 75° (0.35 mm), n_D^{20} 1.4662. The product gave one peak on the gas-liquid chromatogram (column with 1% of silicone elastomer on common salt, length 5 meters; carrier gas helium, consumption 75 ml/min, 152°) with an efflux time of 11.2 minutes. Under the same conditions the chromatography of ethyl 5-formyl-2-methyl-2,4-pentadienoate (XI) gave a peak with an efflux time of 8.8 minutes. On the gas-liquid chromatogram of a mixture of the two substances there were two clear peaks; the original acetal (X) had an efflux time of 31 minutes.

From 4.5 g of the above ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate (XII) and 14 g of ethyl (triphenylphosphoranylidene)acetate in 150 ml of dry benzene we obtained, in the usual way (boiling for 16 hours), 5.4 g [69% on (X)] of diethyl 4-ethoxy-2-methyl-2,6-octadienedioate (XIII), b.p. 128-133° (0.5 mm), $n_D^{18.5}$ 1.4840. Found: C 63.44; 63.26; H 8.32; 8.84%. $C_{15}H_{24}O_5$. Calculated: C 63.36; H 8.51%.

Preparation of Ethyl 5-Formyl-2-methyl-2,4-pentadienoate Dimethyl Acetal (XIV). In the usual way [see experiment on the preparation of (III) in [5]], by boiling 30.6 g of fumaraldehyde monoacetal (II) and 84.5 g of ethyl 2-(triphenylphosphoranylidene)propionate in 350 ml of dry benzene, we obtained 24.35 g (48.5%) of ethyl 5-formyl-2-methyl-2,4-pentadienoate dimethyl acetal (XIV); b.p. 99-106° (3 mm); n_D^{20} 1.4885. Found· C 61.57; 61.85; H 8.57, 8.51%. $C_{11}H_{18}O_4$. Calculated: C 61.66, H 8.47%.

Preparation of Ethyl 5-Formyl-2-methyl-2,4-pentadienoate (XI). a) From ethyl 5-formyl-2-methyl-2,4-pentadienoate dimethyl acetal (XIV). A mixture of 4.3 g of (XIV) and 5 ml of 6% phosphoric acid was heated in a boiling water bath with good stirring and treated as described for the experiment on the preparation of (XIII). We isolated yellow crystals of ethyl 5-formyl-2-methyl-2,4-pentadienoate (XI), m.p. 32-33° (from petroleum ether). Found: C 64.01; 64.08, H 6.89; 6.68%. $C_9H_{12}O_3$. Calculated: C 64 28; H 7.19%. The 2,4-dinitrophenylhydrazone had m.p. 211-214° (from alcohol), λ_{max} (in alcohol) 395 mμ. Found: N 15.98, 16.20%. $C_{15}H_{16}N_4O_6$. Calculated: N 16.09%.

b) From ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate (XII): A mixture of 4.9 g of (XII), 87 ml of dry toluene, and 43 mg of p-toluenesulfonic acid was heated at 120-145° (in the bath) for two hours with removal of an azeotropic mixture of toluene and alcohol until a test (Tserevitinov) for alcohol in the distillate was negative. The mixture was washed with 5% sodium bicarbonate solution and dried with magnesium sulfate. Solvent was driven off, and we then obtained 3.82 g (80%) of ethyl 5-formyl-2-methyl-2,4-pentadienoate, m.p. 31-33° and identical with the sample described above.

c) From ethyl 4-ethoxy-5-formyl-2-methyl-2-pentenoate diethyl acetal (X); In the usual way by the hydrolysis of 4 g of (X) with a mixture of 13.3 ml of acetic acid, 0.85 ml of water, and 1.33 g of sodium acetate (boiling for five hours), we obtained and isolated 1.4 g (60%) of ethyl 5-formyl-2-methyl-2,4-pentadienoate, identical with the sample described above.

Preparation of Ethyl 7-Formyl-2-methyl-2,4,6-heptatrienoate (XV, n = 2). a) Preparation of ethyl 5-formyl-2-methyl-2,4-pentadienoate diethyl acetal: The acetalization of 4.28 g of ethyl 5-formyl-2-methyl-2,4-pentadienoate (XI) with 5.2 ml of orthoformic ester in presence of a solution of 0.1 g of ammonium nitrate in 2 ml of absolute alcohol in the usual way gave 5 g (83.5%) of ethyl 5-formyl-2-methyl-2,4-pentadienoate diethyl acetal; b.p. 120-125° (2.5 mm), n_D^{18} 1.4852, λ_{max} (in alcohol) 282.5 mμ (ε 22300).

b) Preparation of ethyl 7-formyl-6-methoxy-2-methyl-2,4-heptadienoate ethyl methyl acetal. 21.07 g of ethyl 5-formyl-2-methyl-2,4-pentadienoate dimethyl acetal (XIV) was given the usual chain-growth treatment with 7.1 g of ethyl vinyl ether in presence of 0.1 ml of boron trifluoride etherate [see experiment with (VII, n = 3)]. We obtained 22.72 g (81%) of a product of b.p. 124-135° (1.5 mm) and n_D^{17} 1.4862, which was used in the next stage without further purification.

c) 11.2 g of the product obtained as above was hydrolyzed with a mixture of 37.4 ml of acetic acid, 2.4 ml of water, and 3.74 g of fused sodium acetate in the usual way. The crystals precipitated were extracted with chloroform, the extract was dried with magnesium sulfate, and solvent was removed. We then obtained 4.2 g (55%) of ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate, m.p. 47-49° (from petroleum ether), λ_{max} (in alcohol) 319.5 (ε 44500). Found: C 67.94, 67.90, H 7.55, 7.35%. $C_{11}H_{14}O_3$. Calculated: C 68.02; H 7.27%. The 2,4-dinitrophenylhydrazone had m.p. 239-241.5° (from alcohol); λ_{max} (in alcohol) 410.5 mμ. Found N 14.90; 14.96%. $C_{17}H_{21}N_4O_6$. Calculated: N 14.97%.

Preparation of Ethyl 9-Formyl-2-methyl-2,4,6,8-nonatetraenoate (XV, n = 3). a) Preparation of ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate diethyl acetal: A mixture of 3.5 g of ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate (XV, n = 2) in 20 ml of absolute alcohol, 6.5 g of orthoformic ester, and 5 mg of p-toluenesulfonic acid in 10 ml of absolute alcohol was heated in a boiling water bath for 30 minutes. On the next day the mixture was treated as in the experiment with (VII, n = 4), and we obtained 3.7 g (72.5%) of ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate diethyl acetal, b.p. 149-154° (2 mm); $n_D^{20.5}$ 1.5325.

From 4.15 g of ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate in 25 ml of absolute alcohol and 7.6 g of orthoformic ester in presence of a solution of 0.25 g of ammonium nitrate in 10 ml of absolute alcohol in the usual way (heating at 70° for one hour and then standing at room temperature for 36 hours) we obtained [see experiment with (VII, n = 4)] 4.5 g (76%) of the same ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate diethyl acetal, b.p. 120-123° (0.15 mm), n_D^{18} 1.5355.

b) 5.5 g of the above-described ethyl 7-formyl-2-methyl-2,4,6-heptatrienoate diethyl acetal was given the usual chain-growth treatment with 1.48 g of ethyl vinyl ether in presence of 0.05 ml of boron trifluoride etherate [see experiment with (VII, n = 3)]. We obtained 4.5 g (65%) of ethyl 8-ethoxy-9-formyl-2-methyl-2,4,6-nonatrienoate diethyl acetal, b.p. 150-180° (0.3 mm) and $n_D^{21.5}$ 1.5248, which without purification was hydrolyzed in the usual way (heating for two hours) with a mixture of 15 ml of acetic acid, 1 ml of water, and 1.5 g of sodium acetate. We obtained 3.2 g [82%, based on (XV, n = 2)] of ethyl 9-formyl-2-methyl-2,4,6,8-nontetraenoate (XV, n = 3), m.p. 95-98° (from petroleum ether); λ_{max} (in alcohol) 251.5, 349.5, 364 mμ (ε 3160, 68500, 68300). Found: C 70.71; 70.51; H 7.38, 7.37%. $C_{13}H_{16}O_3$. Calculated C 70.89, H 7.32%.

The corresponding 2,4-dinitrophenylhydrazone had m.p. 216.5-218° (from alcohol); λ_{max} (in alcohol) 430 mμ. Found. N 13.85, 13.08%. $C_{19}H_{20}N_4O_6$. Calculated: N 13.99%.

Preparation of Diethyl 2-Methyl-2,4,6,8,10-dodecapentaenedioate (XVI, n = 4). a) By boiling 0.6 g of ethyl 9-formyl-2-methyl-2,4,6,8-nonatetraenoate (XV, n = 3) and 1.75 g of ethyl (triphenylphosphoranylidene)acetate in

100 ml of dry benzene for four hours in the usual way we obtained 0.4 g (40%) of diethyl 2-methyl-2,4,6,8,10-dodecapentaenedioate, m.p. 87.5-88.5°, λ_{max} (in alcohol) 266, 370, 389 mμ (ε 2930, 32600, 31000). Found: C 69.89; 69.92; H 7.67, 7.57%. $C_{17}H_{22}O_4$. Calculated: C 70.32, H 7.64%.

b) By boiling 1.2 g of ethyl 9-formyl-2,4,6,8-nonatetraenoate (VII, n = 4) and 3 g of ethyl 2-(triphenylphosphoranylidene)propionate in 100 ml of benzene for four hours, in the usual way, we obtained the above-described diethyl 2-methyl-2,4,6,8,10-dodecapentaenedioate, m.p. 87-88°, yield 0.85 g (50%).

SUMMARY

A new general method was developed for the synthesis of symmetrical and unsymmetrical polyenic dicarboxylic acids with even and odd numbers of double bonds, starting with glyoxal monoacetal and fumaraldehyde monoacetal.

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