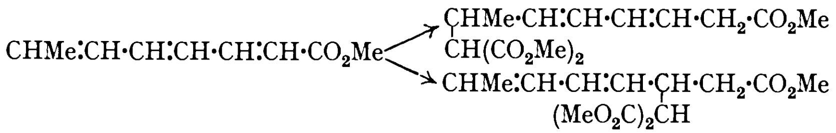
225. *Properties of Conjugated Compounds. Part XIX. The Michael Reaction Applied to a Triene Ester.*

By E. H. Farmer and S. R. W. Martin.

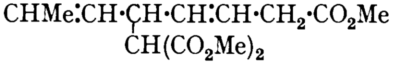
The manner in which esters of the malonic type add to conjugated butadiene-α-carboxylic esters of the sorbic acid series has already been extensively examined by one of the authors. Since in these additions the anionic component of the addendum can attach itself to either the β- or the δ-carbon atom of the conjugated ester, it is clearly to be expected that in conjugated hexatriene- or octatetraene-α-carboxylic esters attachment may be effected at one or more of the even carbon atoms (β-, δ-, ζ-, etc.) of the conjugated chain. Until recently, however, it has not been possible to test the correctness of the theoretical expectation owing to the non-availability of suitable triene and tetraene esters for experiment.

It has now been found that when methyl malonate is added to a typical conjugated triene ester, *viz.*, methyl $\Delta^{\alpha\gamma\epsilon}$-heptatriene-α-carboxylate (I), reaction takes place in two of the three possible ways to give a mixture of αζ- and αβ-addition products, (II) and (III)

(I.)  (II.) (III.)

$$\mathrm{CHMe{:}CH{\cdot}CH{:}CH{\cdot}CH{:}CH{\cdot}CO_2Me} \begin{cases} \xrightarrow{} \mathrm{\underset{CH(CO_2Me)_2}{CHMe}{\cdot}CH{:}CH{\cdot}CH{:}CH{\cdot}CH_2{\cdot}CO_2Me} & \text{(II.)} \\ \xrightarrow{} \mathrm{CHMe{:}CH{\cdot}CH{:}CH{\cdot}\underset{(MeO_2C)_2CH}{CH}{\cdot}CH_2{\cdot}CO_2Me} & \text{(III.)} \end{cases}$$

respectively, in yields up to 74% of the theoretical. Reaction in the third way is not totally excluded, but the presence of the αδ-product (IV) could not be detected. The αβ-product (II) is formed to the extent of roughly 67% and the αζ-product to at least 10% of the total product.

(IV.) 

$$\mathrm{CHMe{:}CH{\cdot}\underset{CH(CO_2Me)_2}{CH}{\cdot}CH{:}CH{\cdot}CH_2{\cdot}CO_2Me} \quad \text{(IV.)}$$

$$\mathrm{HO_2C{\cdot}CH_2{\cdot}CHMe{\cdot}(CH_2)_5{\cdot}CO_2H} \quad \text{(V.)}$$

The proof of constitution of the addition products rests upon the hydrogenation–hydrolysis procedure previously developed. The mixture of addition products, after being freed from unchanged reactants by distillation, was catalytically hydrogenated and then hydrolysed. The acids present in the hydrolysis product were converted into their anhydrides (after conversion of malonic into acetic groupings by heating), and these were separated by partial distillation. The anhydride derived from the αβ-addition product was the readily-distillable β-*n*-amylglutaric anhydride, whereas that from the αζ-product was the undistillable (polymolecular) anhydride of β-methylazelaic acid (V). The β-*n*-amylglutaric and β-methylazelaic acids derived from the anhydrides were authenticated by comparison with specimens synthesised for the purpose. Although there was little loss in isolating the former acid, the economical separation and purification of the latter acid was extremely troublesome and, consequently, only a minimal figure for the percentage of the αζ-product can be quoted.

Experimental.

Addition of Methyl Malonate to Methyl $\Delta^{\alpha\gamma\epsilon}$-Heptatriene-α-carboxylate.—The heptatrienecarboxylic acid was prepared by the method of Kuhn and Hoffer (*Ber.*, 1930, **63**, *B*, 2164); it was converted into the acid chloride by the action of thionyl chloride, and thence into the methyl ester by the action of methyl alcohol as recommended by these authors.

The well-dried triene ester, m. p. 74·5° (20 g.; 1 mol.), was dissolved in redistilled methyl malonate (36 g.; 2 mols.), and a solution of sodium (0·3 g.; 1/10 atom) in *dry* methyl alcohol (3 c.c.) added thereto. The mixture was diluted with just insufficient ether (about 3 c.c.) to produce a precipitate, and then gently refluxed for 16 hours. The reaction product was cooled, diluted with much ether, and washed free from alcohol by shaking with small quantities of water. Evaporation of the ether and distillation of the mixture of esters yielded much unchanged material and only a small quantity of addition product. As frequently happens in carrying out the Michael reaction with a fractional molecular proportion of sodium ethoxide, the yield of addition product never exceeded 10% when the reactants were used for the first time; but when the *recovered* reactants were re-heated with sodium, methyl alcohol, and ether in precisely the same way as before, the yield rose to 74%. The addition product, after distillation of unchanged reactants (b. p. 60—120°/1—2 mm.), passed over at 152—170°/1—2 mm., leaving a small undistillable residue (about 3% of the total material); on redistillation it was obtained as a colourless oil, b. p. 154—159°/1—2 mm., which was shown to be a mixture of *methyl* β-*methylheptadiene*-ααη-*tricarboxylate* (in which the double bonds doubtless occupied the γε-positions) and *methyl* $\Delta^{\gamma\epsilon}$-*heptadiene*-α-*carboxylate*-β-*malonate* (Found: C, 59·0; H, 7·0. $C_{14}H_{20}O_6$ requires C, 59·15; H, 7·0%).

Catalytic Reduction of the Addition Product.—The addition product (16 g.), when dissolved in alcohol (100 c.c.) and shaken with hydrogen at room temperature and atmospheric pressure, absorbed the gas very rapidly at first and suffered complete reduction (2 mols. of hydrogen absorbed) in 10 hours. The reduction product, after being freed from catalyst and solvent, was obtained as a colourless oil which completely distilled at 142—165°/1—2 mm. (mainly 142—150°). This was a mixture of *methyl* β-*methylheptane*-ααη-*tricarboxylate* and *methyl heptane*-α-*carboxylate*-β-*malonate* (Found: C, 58·55; H, 8·1. $C_{14}H_{24}O_6$ requires C, 58·7; H, 8·0%); yield, 98%.

The distilled reduction product (15·8 g.) was hydrolysed by refluxing on a steam-bath with an alcoholic solution of sodium hydroxide (sodium, 4·5 g., in sufficient methyl alcohol, and water, 16 c.c.). The sodium salts of the derived acids were rapidly precipitated, and after 4 hours were filtered off; a little of the mixed salts which remained dissolved in the alcoholic liquor was recovered by saturating the latter with carbon dioxide, and evaporating off the alcohol. The mixture of sodium salts was refluxed for 9 hours with five times its weight of a 15% hydrochloric acid solution in order to promote decarboxylation of the malonic acid groupings in the reduced acids; as, however, this process was far from complete, the mixture of acids was extracted with ether, dried, and decarboxylated by heating cautiously at 170° until no further evolution of carbon dioxide occurred. The crude mixture of acids which contained β-methylazelaic acid and β-*n*-amylglutaric acid was thus obtained as a rather viscous brownish liquid.

Separation of Reduced Acids.—The mixture of acids was boiled with about eight times its bulk of acetic anhydride for 2 hours. The excess of acetic anhydride was distilled off at ordinary pressure, and the acidic residue was heated cautiously at reduced pressure until all remaining traces of acetic acid had been expelled. The residue was then heated at reduced pressure (precautions being taken against the access of moisture to the apparatus when letting in air) until the distillable portion had completely passed over (b. p. 135—150°/2—3 mm.) and further heating tended only to the decomposition of the residual material. The distillate was a colourless oil (b. p. 138°/2 mm. on redistillation) which consisted of the pure *anhydride* of β-*n*-amylglutaric acid (Found: C, 65·05; H, 8·75. $C_{10}H_{16}O_3$ requires C, 65·2; H, 8·7%); from this anhydride the corresponding *anilic acid*, $HO_2C{\cdot}CH_2{\cdot}CH(C_5H_{11}){\cdot}CH_2{\cdot}CO{\cdot}NHPh$, was readily obtained in the form of a white crystalline powder, m. p. 81° (Found: C, 69·1; H, 8·3. $C_{16}H_{23}O_3N$ requires C, 69·3; H, 8·3%), and the corresponding free acid as a colourless non-solidifiable oil. The anhydride, the anilic acid, and the free acid agreed in all respects with authentic specimens of these substances, which were specially synthesised for comparison (see below). The yield of amylglutaric anhydride amounted to at least 67% of the anhydride mixture.

Since the brownish viscous mass left on distilling the amylglutaric anhydride might contain the anhydride of *n*-propylpimelic acid in addition to that of β-methylazelaic acid (both anhydrides being polymolecular and undistillable), the whole mass was heated with aqueous NaOH and the alkaline solution filtered, cooled, and extracted with ether. The brown oily acid derived from the ethereal extract largely solidified on standing for several days over concentrated sulphuric acid in an evacuated desiccator. The solid material was thoroughly drained on a tile and was thus obtained in the form of clean white crystals, m. p. 43—44°. These crystals could not be satisfactorily recrystallised from ordinary solvents, but since their m. p. and general properties corresponded closely with those of β-methylazelaic acid (Freer and Perkin, J., 1888, **53**, 218) they were analysed without further crystallisation and were directly compared with a specimen of β-methylazelaic acid derived by repetition of Freer and Perkin's synthesis. The identity of the acid as β-methylazelaic acid was fully confirmed (Found: C, 59·05; H, 8·85. Calc. for $C_{10}H_{18}O_4$: C, 59·4; H, 8·9%). Of the original mixture of anhydrides, 8% was isolated in the form of solid β-methylazelaic acid; from the oily residue extracted from the tile, a further small quantity of solid β-methylazelaic acid was isolated, but owing to the low m. p. and inferior crystallising capacity of this acid no decision could be reached as to whether the final oily residue consisted entirely of the same acid (rendered somewhat impure by the slight decomposition which occurred during the separation of the amylglutaric anhydride) or whether it contained some proportion of *n*-propylpimelic acid, derived from the αδ-addition product (IV).

Several degradations of the original ester mixture with (*a*) alkaline permanganate, (*b*) ozone, and (*c*) ozone followed by permanganate, were carried out in order to determine whether any quantity of the original addition product consisted of the ester (IV), but in all cases the result was unsatisfactory, since not only was succinic acid (the decomposition product arising uniquely from the αδ-addition product) not formed, but the expected decomposition products of the αβ- and αζ-addition products could not all be isolated. Apparently oxidation did not bring about normal scission at all the original double bonds.

Synthesis of β-n-*Amylglutaric Acid.*—*n*-Hexyl alcohol was converted into *n*-hexaldehyde with potassium dichromate and dilute sulphuric acid. The pure aldehyde, b. p. 131°, was condensed with cyanoacetamide under the conditions employed for this type of reaction by Day and Thorpe (J., 1920, **117**, 1465). The resulting white precipitate of αα′-dicyano-β-*n*-amylglutarimide was washed well with water and triturated with dilute hydrochloric acid to remove impurities; it was then hydrolysed by 5 hours' boiling with 15% hydrochloric acid. The oily hydrolysis product was extracted from the cooled aqueous liquor with ether; it yielded directly on distillation pure β-n-*amylglutaric acid*, a colourless, viscous, non-solidifiable oil, b. p. 208°/2 mm. (Found: C, 59·5; H, 9·1. $C_{10}H_{18}O_4$ requires C, 59·4; H, 8·9%). From the acid the corresponding anhydride was obtained by boiling with acetic anhydride. This was a colourless liquid, b. p. *ca.* 140°/2 mm., which on treatment with aniline in ethereal solution yielded the corresponding anilide as a white crystalline powder, m. p. 81°.

The authors acknowledge their indebtedness to the Chemical Society for a grant to one of them (S. R. W. M.).

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
LONDON, S.W. 7.

[*Received, May* 31*st*, 1933.]