VIII.—*The Condensation of* cyclo*Hexanealdehyde and Malonic Acid.*

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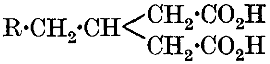
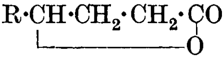
THE well-known condensation between aldehydes and compounds of the malonic acid type can proceed in three different directions, depending on the conditions employed, giving rise to products of the types (I), (II), and (III), but in very few cases have all three

(I.) $R{\cdot}CH_2{\cdot}CH{:}CH{\cdot}CO_2H$

$R{\cdot}CH{:}CH{\cdot}CH_2{\cdot}CO_2H$ (III.)

(II.) 

$R{\cdot}CH_2{\cdot}CH{<}\begin{matrix}CH_2{\cdot}CO_2H\\CH_2{\cdot}CO_2H\end{matrix}$

 (IV.)

$\underbrace{R{\cdot}CH{\cdot}CH_2{\cdot}CH_2{\cdot}CO}_{O}$

possibilities been realised. Products of type (I) are the most common and are obtained in the presence of pyridine and piperidine. Substances of the second type have been obtained from acetaldehyde and propaldehyde by Kommenos (*Annalen*, 1883, **218**, 145), using acetic anhydride as the condensing agent. Instances of the condensation of one molecule of an aldehyde with two molecules of malonic, acetoacetic or acetonedicarboxylic ester and allied compounds are, however, widely distributed in the literature (Claisen, Crismer, Kommenos, Knoevenagel).

Ott (*Ber.*, 1891, **24**, 2600), by heating propaldehyde and malonic acid in acetic acid, obtained a mixture of two unsaturated acids. The structures he assigned to them were corrected by Viefhaus (*Ber.*, 1893, **26**, 915) on the evidence of oxidation experiments. The presence of the unsaturated βγ-acid in the mixture obtained by Kommenos was detected by Fittig (*Ber.*, 1893, **26**, 2079), who also established the interconversion of the αβ- and βγ-acids in the presence of boiling alkali and suggested that the β-hydroxy-acid acts as the intermediate in the transformation. Weinstein (*Annalen*, 1885, **227**, 31) made a similar assumption. The isolation of the respective β-hydroxy-acids from the products obtained by treating phenyl*iso*crotonic acid (Luib), phenyl-Δ^{β}-pentenoic acid (Hoffmann), Δ^{β}-*iso*heptenoic acid (Fittig and Feuer), and hydrosorbic acid (Fittig and Baker) with boiling alkali supports the view that the β-hydroxy-acid is the first product of the condensation of propaldehyde and malonic acid, and that the two unsaturated acids are derived from it by dehydration proceeding in two different directions. The βγ-acid, however, is the sole product of the condensation of phenylacetaldehyde and malonic acid (Linstead and Williams, J., 1926, 1735).

The condensation of *cyclo*hexanealdehyde has now been found to give a substance of the type (I), (II), or (IV) as the main product according to the conditions of the experiment. In the presence of pyridine and piperidine (or diethylamine), β-cyclo*hexylacrylic acid* (type I) was almost exclusively obtained. When a mixture of the aldehyde and malonic acid was heated on the steam-bath with a few drops of diethylamine, β-cyclo*hexylglutaric acid* (type II) was formed in good yield together with a small quantity of the unsaturated αβ-acid. In the presence of alcohol and a larger quantity of diethylamine (1 mol.), the product consisted mainly of cyclo*hexane*-spiro*butyrolactone* (type IV) mixed with a little of the αβ-acid. The presence of this acid in all the mixtures is no doubt due to its great stability, which is also displayed in its behaviour towards acids and alkalis. For example, although the lactone on long boiling with alkali passed into the αβ-acid, the conversion of the latter into the βγ-form or into its own geometrical isomeride has not been detected. The structures of the two unsaturated acids have been established by preparing them from the corresponding ketones described by Kon (J., 1926, 1798).

EXPERIMENTAL.

β-cyclo*Hexylacrylic acid* was prepared by the method described by Haworth, Perkin, and Rankin (J., 1924, **125**, 1693), *cyclo*hexanealdehyde being used in place of piperonal. It separated as an oil when the reaction product was poured into dilute hydrochloric acid, and, after solidifying, crystallised from dilute alcohol in scales, m. p. 57—58°, b. p. 153—154°/11 mm. (yield, 12 g. from 10 g. of aldehyde). It is very soluble in the usual organic solvents, including petroleum (b. p. 40—60°), very sparingly soluble in water, and can be purified by steam distillation (Found : C, 70·0 ; H, 9·1. $C_9H_{14}O_2$ requires C, 70·1 ; H, 9·1%. Found in the *silver* salt : Ag, 41·1. $C_9H_{13}O_2Ag$ requires Ag, 41·4%). The *acid chloride* boils at 142°/12 mm., the *methyl* ester at 92—93°/15 mm. (Found : C, 71·3 ; H, 9·8. $C_{10}H_{16}O_2$ requires C, 71·5 ; H, 9·5%) and the *ethyl* ester at 119°/11 mm. The *amide* melts at 158—159° (Found : C, 70·5 ; H, 9·9. $C_9H_{15}ON$ requires C, 70·6 ; H, 9·8%), and the *anilide* at 142°.

When the acid (1 mol.) was boiled for 24 hours with 64% caustic potash solution (20 mols.) or concentrated hydrochloric acid, little or no change occurred. Treatment with three parts of 50% sulphuric acid for 15 minutes gave rise to tarry products, but no lactone indicating conversion into the βγ-form could be isolated from the steam distillate.

The *dibromide*, formed in glacial acetic acid, was a thick colourless liquid which could not be distilled (9 mm.) without losing hydrogen bromide (Found : Br, 50·5. $C_9H_{14}O_2Br_2$ requires Br, 50·95%).

The unsaturated acid is immediately oxidised by dilute permanganate solution, and in a current of steam *cyclo*hexanealdehyde is obtained in good yield (semicarbazone, m. p. 175°).

β-cyclo*Hexylglutaric Acid.*—A mixture of *cyclo*hexanealdehyde (10 g.), malonic acid (20 g.), and diethylamine (1 c.c.) was kept for 12 hours, the acid gradually dissolving and the mixture separating into two layers, the lower of which increased in volume at the expense of the upper. The mixture was then heated on the steam-bath until effervescence ceased (1 hour) and finally gently refluxed for 10 minutes. The cooled product was poured into dilute hydrochloric acid, and the somewhat pasty solid obtained, after being removed and dried in ether, was extracted twice with petroleum (b. p. 40—60°) at the ordinary temperature. The residue crystallised from benzene or dilute alcohol in needles, m. p. 153—154° (yield, 12 g.). From the petroleum solution 3 g. of *cyclo*hexylacrylic acid were isolated by extraction with aqueous sodium bicarbonate and acidification.

β-cyclo*Hexylglutaric acid* is sparingly soluble in benzene, less so in water, and almost insoluble in petroleum. It crystallises from hot hydrochloric acid in scales (Found: C, 61·35; H, 8·6. $C_{11}H_{18}O_4$ requires C, 61·7; H, 8·4%. Found in the *silver* salt: Ag, 49·65. $C_{11}H_{16}O_4Ag_2$ requires Ag, 50·0%). The *acid chloride* boils at 159—160°/12 mm., the *methyl* ester at 106—108°/17 mm. (Found: C, 64·1; H, 9·4. $C_{13}H_{22}O_4$ requires C, 64·5; H, 9·1%), and the *ethyl* ester at 118—120°/17 mm. The *diamide* melts at 190° (Found: C, 62·05; H, 9·2. $C_{11}H_{20}O_2N_2$ requires C, 62·3; H, 9·4%). The *dianilide* is very sparingly soluble in ordinary solvents and crystallises in needles, m. p. 237° (decomp.), from methyl alcohol–acetone. The *anhydride* is a liquid which solidifies in ice. The *anilic acid* crystallises from dilute alcohol in needles, m. p. 151° (Found: C, 70·8; H, 7·9. $C_{17}H_{23}O_3N$ requires C, 70·6; H, 8·0%). It does not lose water below 185°, but when kept at 200° for a few minutes it changes into the *anil* (probably polymolecular; compare Auwers, *Annalen*, 1896, **292**, 132), which crystallises from dilute acetone in needles, m. p. 181°.

Oxidation of Hexahydrobenzylideneacetone.—The two unsaturated ketones (αβ and βγ) obtained by the condensation of *cyclo*hexanealdehyde with acetone (Kon, *loc. cit.*) were each oxidised with alkaline hypobromite solution as described by Barbier and Léser (*Bull. Soc. chim.*, 1905, **33**, 815). From 10 g. of the αβ-ketone (b. p. 103°/9 mm.), after removal of bromoform and excess of hypobromite, and acidification, 3 g. of unchanged ketone and 5 g. of an oily acid were obtained. The latter, after crystallising from dilute alcohol, was identical with *cyclo*hexylacrylic acid, m. p. 57—58° (Found: C, 69·65; H, 8·8; Ag in silver salt, 41·15. Calc.: C, 70·1; H, 9·1; Ag, 41·4%). On treatment with dilute permanganate solution it at once generated *cyclo*hexanealdehyde.

From the βγ-ketone (5 g., b. p. 101°/9 mm.), 2 g. of a liquid acid and 1·5 g. of unchanged ketone were obtained. The *βγ-acid* was purified through the *silver* salt but failed to solidify in a freezing mixture (Found in a sample that had been kept in a vacuum desiccator for 2 days : C, 69·7 ; H, 8·7. $C_9H_{14}O_2$ requires C, 70·1 ; H, 9·1%. Found in the silver salt : Ag, 41·5. $C_9H_{13}O_2Ag$ requires Ag, 41·4%). The acid had an odour resembling that of the lactone described below, but could not be distilled owing to the small quantity available. When kept in contact with dilute permanganate solution for a few minutes, it generated *cyclo*hexanone.

cyclo*Hexane*spiro*butyrolactone*.—A mixture of *cyclo*hexanealdehyde (10 g.), malonic acid (10 g.), diethylamine (10 c.c.), and alcohol (12 c.c.), after being warmed until the white solid first formed redissolved, was kept over-night and then heated on the steam-bath until effervescence ceased (1 hour). The cooled product was poured into dilute hydrochloric acid and the precipitated oil was taken up in ether, washed with bicarbonate solution, dried over potassium carbonate, and distilled. The *lactone* was obtained as a colourless, mobile oil, b. p. 152—155°/15 mm., together with a small quantity of a lower-boiling fraction (120—125°/15 mm.) containing the ester of the αβ-acid (Found : C, 69·8 ; H, 9·25. $C_9H_{14}O_2$ requires C, 70·1 ; H, 9·1%. Found for the *silver* salt of the corresponding hydroxy-acid : Ag, 39·4. $C_9H_{15}O_3Ag$ requires Ag, 38·7%).

The lactone is very sparingly soluble in water and unusually stable towards ammonia and dilute alkali solutions ; even after 4—5 hours' refluxing with concentrated aqueous ammonia, a portion was undissolved. In making the silver salt, this portion was removed in ether before silver nitrate was added. The salts of the hydroxy-acid tend to lose water and pass into the salts of the unsaturated acid ; this accounts for the high value of silver in the estimation. When a 10% solution of sodium hydroxide was boiled for 24 hours with the lactone and then acidified, the unsaturated αβ-acid, m. p. 57—58°, was isolated in good yield.

The exact conditions for the formation of the lactone are difficult to define, as in one or two experiments this was not produced, the unsaturated acid being obtained instead.

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