339. *The Oxidation of the* 9 : 10-*Dihydroxystearic Acids with Periodic Acid.* η-*Aldehydo-octoic Acid.*

By George King.

Oxidation of the 9 : 10-dihydroxystearic acids with periodic acid affords a convenient method of preparing pure nonaldehyde and η-aldehydo-octoic acid (azelaic semialdehyde) in satisfactory yields. The latter substance, which is practically unknown, has been examined in some detail. It deteriorates on keeping, owing partly to susceptibility to atmospheric oxidation and partly to spontaneous polymerisation to a well-defined trimeride.

In a previous communication (J., 1936, 1791) it was shown that 9-hydroxy-10-ketostearic acid could be oxidised smoothly by periodic acid under suitable conditions to nonoic acid and η-aldehydo-octoic acid. No attempt was made, however, to isolate the latter, which was separated in the form of its 2 : 4-dinitrophenylhydrazone. η-Aldehydo-octoic acid has been reported as occurring among the products of hydrolysis of oleic acid ozonide (Harries and Thieme, *Annalen*, 1905, **343**, 354; Harries and Türk, *Ber.*, 1906, **39**, 3732; Molinari and Barosi, *Ber.*, 1908, **41**, 2794; see also Haller and Brochet, *Compt. rend.*, 1910, **150**, 496; Erdmann, Bedford, and Raspe, *Ber.*, 1909, **42**, 1338; Noller and Adams, *J. Amer. Chem. Soc.*, 1926, **48**, 1074), but it is clear from the indefinite melting point (*ca.* 63—70°) assigned to it, and from the lack of uniformity in its description, that the material isolated was highly impure.

It has now been shown that the periodic acid method of Malaprade (*Compt. rend.*, 1928, **186**, 382; *Bull. Soc. chim.*, 1934, **1**, 833) may be successfully applied to the more readily accessible 9 : 10-dihydroxystearic acids for the preparation of both nonaldehyde and η-aldehydo-octoic acid in a state of purity. The yield of semialdehyde is never theoretical, owing partly to spontaneous polymerisation to a crystalline trimeride and partly to its atmospheric oxidation to azelaic acid, changes which are accelerated by heat.

A more rapid polymerisation is induced when η-aldehydo-octoic acid is heated with aqueous sodium hydroxide, but the product is a sticky oil of high molecular weight. Providing the temperature and concentration of the reactants are kept low, the yield of nonaldehyde from dihydroxystearic acid is nearly quantitative, but under other conditions changes may subsequently occur as a result of which much of the nonaldehyde polymerises to a crystalline trimeride, the factors governing the formation of which are not yet fully understood.

EXPERIMENTAL.

Oxidation of 9 : 10-*Dihydroxystearic Acid, m. p.* 132°, *with Periodic Acid.*—Potassium periodate (6 g.), dissolved in N-sulphuric acid (300 ml.) at 20°, was rapidly added to a solution of dihydroxystearic acid (8 g.) in alcohol (400 ml.) at 40°. After 10 minutes the clear solution was cooled to 15° and diluted with sufficient water to dissolve the precipitated potassium sulphate. Extraction with ether gave an oily product, which was submitted to steam-distillation. Extraction of the distillate with ether gave nonaldehyde (3·2 g.) as a colourless oil, b. p. 76—77°/11 mm. (Found: C, 76·3; H, 13·1. Calc. for $C_9H_{18}O$: C, 76·0; H, 12·8%). The 2 : 4-dinitrophenylhydrazone crystallised from alcohol in golden-yellow needles, m. p. and mixed m. p. with an authentic specimen, 106·5°. The semicarbazone, m. p. 100°, crystallised in needle-like plates from light petroleum and in slender plates from alcohol (Bagard, *Bull. Soc. chim.*, 1907, **1**, 351, gives m. p. 100°; cf. Harries and Thieme, *loc. cit.*). The sodium bisulphite compound separated from saturated sodium bisulphite solution in thin rectangular plates, from which nonaldehyde was easily regenerated by distillation with water.

The aqueous solution of non-volatile products remaining after steam-distillation (about 180 ml.) was cooled to room temperature, filtered from a little insoluble matter, and cooled in ice-water. The somewhat impure η-aldehydo-octoic acid (3·33 g.) which separated was collected, dried, and extracted with boiling light petroleum (400 ml., b. p. 40—60°), in which all but a small fraction (0·5 g.) dissolved. When the petroleum solution was cooled in ice–salt, the semialdehyde separated in plates, which, recrystallised several times from 50 parts of warm water, gave pure η-aldehydo-octoic acid (1·5 g.) in colourless, rhombic plates, m. p. 38° [Found: C, 63·0; H, 9·3; *M* (Rast), 181; equiv., 172. Calc. for $C_9H_{16}O_3$: C, 62·8; H, 9·4%; *M*, 172]. The solubility in water was about 1·9% at 20°, 0·3—0·4% at 0°. The alkali and alkaline-earth salts were soluble in water (cf. Harries and Türk, *loc. cit.*), the zinc salt moderately, the lead salt slightly, and those of copper, silver, and iron sparingly soluble. The *p*-nitrophenylhydrazone crystallised from alcohol in orange rods, m. p. 144° (Harries and Franck, *Annalen*, 1910, **374**, 365, give m. p. 130°) (Found: C, 58·8; H, 7·0; N, 13·4. Calc. for $C_{15}H_{21}O_4N_3$: C, 58·6; H, 6·9; N, 13·7%). The 2 : 4-dinitrophenylhydrazone crystallised from methyl alcohol in orange prisms, m. p. 122·5° (cf. J., 1936, 1791). The semicarbazone separated at once in the cold, and crystallised from alcohol and from hot water in small colourless plates, m. p. 166·5° (Harries and Thieme, *loc. cit.*, give m. p. 163°), insoluble in ether and light petroleum (Found: C, 52·7; H, 8·1; N, 18·0; equiv., 226. Calc. for $C_{10}H_{19}O_3N_3$: C, 52·4; H, 8·3; N, 18·3%; equiv., 229).

The small fraction insoluble in boiling light petroleum separated from alcohol or acetone in colourless needles, m. p. 113·5°, and was identified as the trimeride of η-aldehydo-octoic acid [Found: C, 62·8; H, 9·1%; equiv., 173; *M* (Rast), 515. Calc. for $(C_9H_{16}O_3)_3$: *M*, 516]. It was sparingly soluble in water and cold benzene, but readily in ether. Heated at 100° with 2N-sulphuric acid, the trimeride was largely depolymerised in 10 minutes, the semialdehyde being conveniently recovered in the form of its dinitrophenylhydrazone.

Oxidation of 9 : 10-*Dihydroxystearic Acid, m. p.* 95°.—The oxidation of dihydroxystearic acid, m. p. 95°, with periodic acid differed from the above only in that (a) the dihydroxy-acid was dissolved in alcohol at 20°, and (b) the reaction was allowed to proceed for 15 minutes. The products were the same, and the yields equally as good as those obtained from the acid of m. p. 132°.

Oxidation of η-Aldehydo-octoic Acid.—Potassium permanganate (2 g.) in warm water (100 ml.) was slowly added to the semialdehyde (0·73 g.) in water (100 ml.) at 50° acidified with sulphuric acid (3·5 g.), until the permanganate colour persisted for some minutes. After being decolorised with sodium bisulphite, the clear solution was cooled. The deposited azelaic acid (0·58 g.) was recrystallised once from hot water, giving characteristic, nearly rectangular plates, m. p. 107°, unchanged by an authentic specimen.

Polymerisation of η-Aldehydo-octoic Acid.—(a) Spontaneous polymerisation and oxidation occurred slowly when the semialdehyde was kept under ordinary conditions or in a desiccator. Thus the m. p. of a specimen rose from 37° to 75—95° during 10 months, with loss of crystalline form, the equiv. then being 151·5, corresponding to a content of some 16% of azelaic acid. The product, extracted with hot water and filtered, left an insoluble residue (about 10% of the whole), which crystallised from acetone in needles, m. p. 113·5°, and was identified as the trimeride. The aqueous filtrate was concentrated, and cooled in ice-water. The crude azelaic acid which separated was recrystallised from ether–light petroleum, then from water, giving colourless plates, m. p. 107°, not depressed by an authentic specimen. The aqueous mother-liquors contained unchanged semialdehyde.

(b) The semialdehyde (1·5 g.) in 2N-sodium hydroxide (20 ml.) was heated at 100° for 1 hour. The solution was cooled, acidified, and extracted with ether. The extract was washed with aqueous sodium bisulphite, then with water, dried, and evaporated, leaving a nearly colourless sticky *oil* (1·02 g.), which dissolved in acetone, alcohol, and (less readily) ether, but not in light petroleum, benzene, or chloroform [Found: C, 63·4; H, 8·9%; equiv., 168; *M* (Rast), 709. $(C_9H_{16}O_3)_4$ requires *M*, 688]. The oil had no aldehydic properties, and was not depolymerised when heated with dilute sulphuric acid. Its alkaline-earth, silver, and lead salts were sparingly soluble in water.

Polymerisation of Nonaldehyde.—Nonaldehyde prepared by the periodic acid method, but under more concentrated conditions and at higher temperatures (50—55°) than those described above, contained traces of volatile iodine compounds, and soon polymerised to a large extent, occasionally setting to a mass of crystals. In a typical case, a fraction of nonaldehyde (3·37 g.), collected at 85—90°/20 mm., was submitted to steam-distillation after standing for 48 hours. The non-volatile solid residue crystallised from alcohol in colourless needles of the trimeride of nonaldehyde (1·1 g.), m. p. 33·5° (cf. Molinari and Barosi, *loc. cit.*), soluble in ether and light petroleum [Found: C, 75·9; H, 12·6%; *M* (Rast), 464. Calc. for $(C_9H_{18}O)_3$: *M*, 426]. Depolymerisation was effected by slow distillation with 30% sulphuric acid. Further experiments showed that trimerisation was probably not due to the presence of traces of free iodine or of hydriodic acid.

The author gratefully acknowledges his indebtedness to Dr. G. W. Ellis, O.B.E., for his helpful interest and advice, and to the Chemical Society for a grant.

ST. MARY'S HOSPITAL MEDICAL SCHOOL, LONDON, W. 2. [*Received, September 30th, 1938.*]