35. *The Oxidation of Hydroxyketostearic Acids in Presence of Alcoholic Alkali.*

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The disruptive oxidation of mixed 9 : 10-hydroxyketostearic acids in alcoholic alkaline solutions is shown to be mainly dependent upon the excess of potassium hydroxide present. The yields of azelaic acid obtained varied from about 50% in presence of 1 mol. of free caustic alkali to about 75% with 5 mols. of free caustic alkali per mol. of potassium ketolstearates, either at 21° or 50°. With increasing excess of alkali, increasing amounts of 9 : 10-dihydroxystearic acid, m. p. 132°, are found in the products; formation of the dihydroxystearic acid is more evident at 50° than at room temperature in presence of a moderate excess (1—2 mols.) of free alkali. The action proceeds in the absence of actual passage of a stream of oxygen through the solution, and no difference was found when a current of fresh oxygen was replaced by gas circulated through the system from a closed oxygen reservoir.

Experiments have been made with mixed 9 : 10- and 10 : 9-hydroxyketostearic acids prepared from oleic acid in order to ascertain the optimum conditions for the oxidation described by Morrell and Phillips (*J. Soc. Chem. Ind.*, 1938, **57**, 245), who state that continuous circulation of oxygen at room temperature through an alcoholic solution of the salts of the acids in presence of excess of caustic potash gives quantitative yields of azelaic and nonoic acids. We have not succeeded in obtaining quantitative oxidation under any of the conditions which we have tried, but have observed that the yield of azelaic and nonoic acids increases as the excess of alkali present is increased and that, moreover, scission into these acids takes place at 50° in presence of a substantial excess of alkali, without passage of oxygen, to almost the same extent as when oxygen is passed through the solution. We find, further, that the action is complete in 8 hours and does not require the 20 hours stated by Morrell and Phillips, and that little difference results from the use of a stream of fresh oxygen as compared with the recirculation of the same supply of the gas through the liquid system.

The oxidation products were isolated in the following manner. After removal of most of the alcohol the residue was diluted with water, made acid with sulphuric acid, and distilled in steam. The distillate was accurately neutralised with aqueous potash and excess of zinc sulphate solution was added, the precipitated zinc nonoate being filtered off, dried in a vacuum, and characterised by its melting point (133°) and mixed melting point.

The aqueous portion of the residue from the steam-distillation was separated from the oily layer, concentrated to a small bulk, and cooled. The azelaic acid which separated in an almost pure condition was collected, and the filtrate was extracted with ether to obtain the last traces of azelaic acid.

The oily portion of the steam-distillation residue was extracted with boiling light petroleum (b. p. 40—60°), which removed most of the unchanged hydroxyketostearic acids and left a residue which was shown to be mainly 9 : 10-dihydroxystearic acid, m. p. 132°.

The approximate yields of these various products obtained under different conditions of experiment are discussed below. The " percentage scission " is based upon the total yield of crude azelaic acid isolated as described (the recovery of zinc nonoate was insufficiently quantitative for this purpose). The " percentage of unchanged hydroxyketostearic acids " refers to the total material soluble in boiling light petroleum, and that of " crude dihydroxystearic acid " is the percentage of material insoluble in the latter medium.

Experiments at room temperature illustrate the extent to which the disruptive oxidation effected and the amount of dihydroxystearic acid produced are dependent upon the excess of alkali employed (Table I).

Table I.

Oxidation of hydroxyketostearic acids in alcoholic alkaline solution at room temperature.

Expt. No.	Excess KOH, mols.	Oxygen passed.	Temp.	Time (hrs.).	Scission, %.	Dihydroxy-stearic acid, %.	Unchanged material, %.
1	1	Fresh	21°	8	46	3	47
2	1	Circulated	22	20	55	5	41
3	3	Fresh	21	8	58	16	25
4	5	Circulated	21	20	73	16	7
5	5	Fresh	21	8	75	14	5

These results show that at the ordinary temperature the amount of disruptive oxidation into azelaic and nonoic acids is largely a function of the excess of alkali present, whilst the proportion of dihydroxystearic acid obtained also increases when a large excess of caustic potash is present. Experiments carried out at 50° led to the same conclusions, and also showed that the passage of gaseous oxygen is not essential for the production of azelaic and nonoic acids from the hydroxyketostearic acids (Table II).

TABLE II.

Oxidation of the hydroxyketostearic acids in alcoholic alkaline solution at 50°.

Expt. No.	Excess KOH, mols.	Oxygen passed.	Time (hrs.).	Scission, %.	Dihydroxy-stearic acid, %.	Unchanged material, %.
6	1	Fresh	8	50	41	7
7	2	None	8	61	30	8
8	5	Fresh	8	72	17	10

It will be noted that, with only 1 mol. excess of caustic alkali, the yield of scission products remains at about the same level at 50° as at 21° (expt. 1, Table I), but that nearly all the hydroxyketostearic acids disappeared at 50°, considerable proportions of dihydroxystearic acid being produced. With higher concentrations of alkali at 50°, the total amount of hydroxyketostearic acids attacked remained little altered, but more scission products and less dihydroxystearic acid were obtained. The passage of gaseous oxygen seems to be of little importance.

In order to ascertain whether the low yields of azelaic and nonoic acids obtained in presence of a comparatively small excess of free caustic alkali were due to preferential oxidation of one of the two isomeric hydroxyketostearic acids, the unchanged residue from one of the experiments (Table I, no. 2) was used in a subsequent experiment (no. 3); it was then found that the action proceeded normally. This is in accordance with the statement by Morrell (*Fette u. Seifen*, 1939, **46**, 546) that, whilst 9-hydroxy-10-ketostearic acid is preferentially oxidised in alkaline solution, tautomeric change of the 10-hydroxy-9-ketostearic acid to the 9-hydroxy-10-keto-form (cf. Stevens, *J. Amer. Chem. Soc.*, 1939, **61**, 1714) proceeds under these conditions, and disruptive oxidation of the whole of the acids eventually takes place.

It is clear that, even with 5 mols. excess of potassium hydroxide per mol. of the potassium salts of the hydroxyketostearic acids, not more than 75% of the latter are broken down into azelaic and nonoic acids; and it would appear that an excess of at least 10—12 mols. of free alkali would be required before quantitative conversion into the scission products could be effected under these conditions.

The formation of dihydroxystearic acid, which is clearly also favoured by increased proportions of caustic potash in the reacting system, may possibly be explained as the result of a reaction: $2\text{-CH(OH)}\cdot\text{CO}\cdot \longrightarrow \text{-CO}\cdot\text{CO-} + \text{-CH(OH)}\cdot\text{CH(OH)-}$, whilst the further breakdown into azelaic and nonoic acids may result from decomposition either of the original hydroxyketostearic acids or of diketostearic acid produced in the manner suggested. It appears reasonable to suggest that the 9 : 10-dihydroxystearic acid, m. p. 132°, which has frequently been observed to form a small proportion of the products of atmospheric oxidation of oleic acid (cf., *e.g.*, Skellon, *J. Soc. Chem. Ind.*, 1931, **50**, 382T) may arise from a similar decomposition of hydroxyketostearic acids produced from the peroxides initially formed (Ellis, *J. Soc. Chem. Ind.*, 1926, **45**, 193T). It is known that diketostearic acid derivatives are simultaneously produced, and give rise to a yellowish colour in oxidised oil films. Further, this appears to offer a reasonable explanation of the well-established fact that the 9 : 10-dihydroxystearic acid of m. p. 132° is produced during atmospheric oxidation, whereas the lower-melting form (m. p. 95°) would be expected to result by direct addition of oxygen [the form melting at 132° being produced directly from oleic acid only as the result of alkaline (permanganate) oxidation].

EXPERIMENTAL.

Preparation of the Mixed Hydroxyketostearic Acids.—This was essentially the same as that recommended by King (J., 1936, 1788), based on the earlier work of Holde and Marcusson (*Ber.*, 1903, **36**, 2657), but modifications in detail were made in order to reduce the large volumes of solution requisite in the preparation of more than small specimens of the α-ketolstearic acids; this involved some loss in yield of the latter as compared with the conditions used by King.

Purified oleic acid (50 g.) was neutralised with aqueous potassium hydroxide, and the solution of potassium oleate diluted with water and crushed ice to 7500 c.c. A 2% solution of potassium permanganate (2500 c.c.) was then added to the mechanically stirred solution at 0°, with further crushed ice (1000 c.c.) during 10 minutes. Stirring was continued for a further 10 minutes, and the solution allowed to stand at 0° for 18 hours; it was then decolourised by addition of sodium bisulphite (300 g.) in water (750 c.c.), and the acids liberated by addition of concentrated hydrochloric acid (500 c.c.). The white, flocculent precipitate of solid acids was collected, washed with a little water, and dried in a vacuum. The dried product was digested with chloroform (500 c.c.), and the solution cooled at 0°; a little 9 : 10-dihydroxystearic acid (0·6 g.) then separated and was removed. The residue (34·9 g.) from the evaporated chloroform filtrate was dissolved in boiling light petroleum (b. p. 40—60°, 3500 c.c.), yielding a yellow solution which deposited crude α-ketolstearic acids (21·2 g., m. p. 66—69·5°) on keeping at 0°. The light petroleum mother-liquors gave a solid yellow residue (12·8 g.) on evaporation.

When the crude hydroxyketostearic acids were again treated with chloroform, a further 0·8 g. of 9 : 10-dihydroxystearic acid was separated; the chloroform-soluble portion, after another crystallisation from light petroleum, gave 18·1 g. of still impure α-ketolstearic acids (m. p. 67—71°). Crystallisation of this from 60% alcohol finally yielded four fractions: diketostearic acid (1·5 g., m. p. 84—86°), a mixture of α-ketol- and diketostearic acids (2·8 g., m. p. 66—85°), somewhat impure α-ketolstearic acids (6·3 g., m. p. 59—63°), and a comparatively pure specimen of the mixed α-ketolstearic acids (4·6 g., m. p. 63—65°) (Found: OH, 5·1, 5·3; CO, 8·7, 9·4. Calc.: OH, 5·4; CO, 8·9%).

Oxidation of the Mixed 9 : 10-*Hydroxyketostearic Acids.*—The general description already given of the isolation of the products of oxidation may be illustrated by details of two experiments carried out respectively at room temperature and at 50° with fresh oxygen.

(a) *Oxidation at* 21° *with fresh oxygen* (Expt. 1, Table I). The mixed α-ketolstearic acids (2·5 g.) were dissolved in 0·25N-alcoholic potassium hydroxide solution (64 c.c., 100% excess), and the solution diluted with alcohol (66 c.c.) and placed in a three-necked flask fitted with a mechanical stirrer, thermometer and gas inlet and outlet tubes. Fresh oxygen was bubbled through the mechanically stirred solution at room temperature (21°) for 8 hours; the temperature rose to 24° during the first hour and subsequently slowly returned to that of the room. The product was worked up according to the scheme previously described (p. 204). The aqueous distillate (4 l.) from the steam-distillation was exactly neutralised with potassium hydroxide solution; excess of zinc sulphate solution then precipitated zinc nonoate (0·32 g.). The hot aqueous portion of the residue in the steam-distillation flask, together with the liquor from two washings of the oily portion with boiling water, after concentration and cooling, deposited azelaic acid (0·61 g.); the cold filtrate yielded to ether a further amount (0·08 g.) of azelaic acid. The total weight of azelaic acid recovered was 46% of that demanded for complete scission of the ketolstearic acids originally present. Boiling light petroleum (b. p. 40—60°) left undissolved 0·07 g. of material from the oily layer; the solution on cooling deposited crude hydroxyketostearic acids (0·99 g., m. p. 58—63°) and retained 0·18 g. of less pure, yellowish solid acids. The approximate yield of dihydroxystearic acid was thus less than 3%, and of unchanged material (including any uncharacterised by-products soluble in light petroleum) 47%.

(b) *Oxidation at* 50° *with fresh oxygen* (Expt. 6, Table II). The mixed α-ketolstearic acids (5 g.) were dissolved in 0·25N-alcoholic potassium hydroxide solution (130 c.c., 100% excess) and placed in the reaction-flask, which was maintained at 50° in an oil-bath, a current of fresh oxygen being bubbled through the mechanically stirred solution as described above for 8 hours. After steam-distillation of the acidified products, the amount of zinc nonoate deposited from the neutralised aqueous distillate was 1·07 g.; the hot aqueous portion (and washings) of the residue from the steam-distillation, on cooling, deposited 1·27 g. of azelaic acid and then yielded a further 0·23 g. of the acid on extraction of the cold mother-liquors with ether (total yield of azelaic acid 1·5 g., equivalent to 50% of the theoretical). From the oily portion of the residue (2·74 g.) there were obtained 2·05 g. of material insoluble in light petroleum, which on recrystallisation from ethyl acetate melted at 132° and was 9 : 10-dihydroxystearic acid (mixed m. p. unchanged); the light petroleum solution deposited 0·13 g. of crude ketolstearic acids and yielded on evaporation a further 0·23 g. of viscous residue (yield of dihydroxystearic acid, *ca.* 41%; of unchanged or indefinitely characterised products, 7%).

In the experiments (Table I, nos. 2 and 4) in which the oxygen was re-circulated through the solution, the oxygen inlet and outlet tubes were connected with a closed oxygen reservoir and a circulation pump, by means of which the same supply of oxygen was made to flow continuously through the alkaline solutions.

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