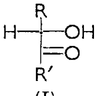
832. *Aliphatic Acids. Part I. Some Aliphatic Ketol-acids and Related Compounds.*

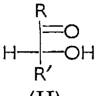
By W. A. Cramp, F. J. Julietti, J. F. McGhie, B. L. Rao, and W. A. Ross.

The preparation of 6(7)-hydroxy-7(6)-oxo and of 9(10)-hydroxy-10(9)-oxo-octadecanoic and of 13(14)-hydroxy-14(13)-oxo-docosanoic acids by three routes has been studied. The oxidation and reduction of these compounds and some intermediates, and the separation of the isomeric ketol-acids, have also been investigated.

The suggestion by Ellis[1] that α-ketol-acids such as (I) and (II) would be found amongst the autoxidation products of unsaturated acids has been supported by recent studies of the aerial oxidation of *cis*-octadec-9-enoic acid and its esters.[2,3] However, little attention has been paid to them.



(I)



(II)

$R = CH_3\cdot[CH_2]_7-$

$R' = -[CH_2]_7\cdot CO_2H$

Of the two preparative routes to α-ketol acids, one, the so-called " neutral " permanganate oxidation first reported by Holde and Marcusson,[4] and studied later by King[5] and by Coleman *et al.*[6], has the disadvantages that high dilutions must be used to obtain even moderate yields (30%) and purification is difficult. Swern and his co-workers,[6] realising that oxidation according to the scheme, $3{>}C{:}C{<} + 4KMnO_4 + H_2O \longrightarrow 3{>}C(OH)\cdot CO- + 4MnO_2 + 4KOH$, involves progressively increasing alkalinity, showed that the optimum pH for yields of ketol-acids was pH 9·0—9·5 and thus obtained 65—75% conversion of oleic acid into crude 9(10)-hydroxy-10(9)-oxo-octadecanoic acids. However, purification of the product proved difficult, the final yield of 90% pure material was 50%, and somewhat complicated apparatus and procedure are needed. We have obtained comparable results merely by using disodium hydrogen phosphate as a buffer to maintain the pH 9·0—9·5.

In our experience the methods described[6] for purification of the crude 9,10(10,9)-ketol-acids involve considerable losses and the final product still contains up to 10% of 9,10-dioxo-octadecanoic acid. We find that, after the easy removal of the accompanying dihydroxy-acids, reduction by zinc and acetic acid removes the dioxo-acids and leads to 60—65% yields of pure 9(10)-hydroxy-10(9)-oxo-octadecanoic acids from oleic acid, ultraviolet and infrared measurements then indicating absence of the dioxo-acid.

We have used this process also for preparation and purification of ketol acids from petroselenic and erucic acid, obtaining satisfactory yields.

Swern *et al.*[6] found that the yield (45%) of the mixed ketol acids from *trans*-octadec-9-enoic acid is approximately the same whether the pH of the reaction mixture is controlled or not. This appears to be a general property of *trans*-alkenoic acids, since we have observed similar behaviour with petroselaidic and brassidic acid.

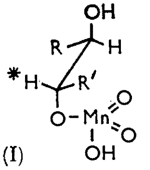
Permanganate oxidation of olefins has long been postulated to occur *via* a cyclic intermediate formed by *cis*-addition,[3,7] particularly since Criegee[8] isolated a number of intermediates in the hydroxylation of olefins employing osmium tetroxide. As a result

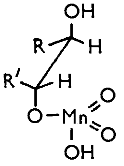
---

[1] Ellis, *J. Soc. Chem. Ind.*, 1926, **45**, 198T.
[2] Skellon, *J.*, 1948, 343; 1954, 3414; King, *J.*, 1956, 587.
[3] King, *J.*, 1954, 2114.
[4] Holde and Marcusson, *Ber.*, 1903, **36**, 2657.
[5] King, *J.*, 1936, 1788.
[6] Coleman, Ricciuti, and Swern, *J. Amer. Chem. Soc.*, 1956, **78**, 5342.
[7] Boëseken, *Rec. Trav. chim.*, 1922, **41**, 199; Drummond and Waters, *J.*, 1953, 435; Levesley and Waters, *J.*, 1955, 217.
[8] Criegee, *Annalen*, 1936, **522**, 75; *Angew. Chem.*, 1938, **51**, 519; Criegee, Marchand, and Wannowius, *Annalen*, 1942, **550**, 99.

of experiments with ^{18}O-labelled permanganate Wiberg and Saegebarth[9] evolved a detailed scheme for formation of fission of a cyclic manganese ester, but that scheme does not account for the differing behaviour of *cis*- and *trans*-alkenoic acids. This difference may be explained on the basis of conformation.

The most stable conformational isomers of the intermediate derived from *cis*- and *trans*-olefins are respectively (I) and (II). In the latter, hydrogen bonding should be possible between both hydrogen atoms and the oxygen atoms attached to manganese, whereas in (I) only one such hydrogen–oxygen interaction is possible. Thus, compound (I) is more prone to attack at the hydrogen marked*, yielding the ketol; such a favourable arrangement is not possible in conformation (II) owing to hydrogen bonding.


(I)


(II)

The second of the routes[10] to α-ketol-acids involves reduction of an α-dioxo-acid by zinc and acetic acid. Two routes are available to the dioxo-acids: (*a*) $\rangle\text{C=C}\langle(+\text{Br}_2) \longrightarrow \rangle\text{CBr–CBr}\langle\ (+\text{NaNH}_2\text{–NH}_3) \longrightarrow \text{–C≡C–}\ (+\text{KMnO}_4) \longrightarrow \text{–CO–CO–}$; and (*b*) $\rangle\text{C=C}\langle(+\text{KMnO}_4;\ \text{OH}^-) \longrightarrow \rangle\text{C(OH)–C(OH)}\langle \longrightarrow \text{–CO–CO}$. Route (*b*) is the more attractive as it involves one stage fewer, and the purity of the olefinic acid is not critical, as it is in (*a*) and in the controlled oxidation experiments of Coleman *et al.*,[6] since dihydroxy-acids are readily purified.

Oxidation of *erythro*-9,10-dihydroxy-octadecanoic acid with chromic acid has already been reported,[11] and one of us[10] has shown that improved results are obtained by using Kiliani's chromic acid mixture, although even here the yields (25—30%) are far from satisfactory. We have now found that vicinal dihydroxy-acids are smoothly converted by *N*-bromosuccinimide into α-dioxo-acids in 80—90% yields. Although this reagent has been employed for oxidation of vicinal secondary-tertiary steroidal alcohols[12] and of α-hydroxy-acids,[13] this appears to be its first use for the oxidation of disecondary glycols, and it appears to be a general reagent for such oxidations. By this method 80—90% yields of 9,10- and 6,7-dioxo-octadecanoic and of 10,11- and 13,14-dioxodocosanoic acid have been obtained.

The quantitative reduction of such compounds[10] makes the desired α-ketol-acids easily accessible in excellent yields (based on the dihydroxy-acid as starting material) and high purity. In any pair of *erythro*–*threo*-dihydroxy acids, the *threo*-isomer is always the more readily oxidised, as is to be expected on conformational grounds, and from a preparative standpoint we prefer to use the *erythro*-isomer wherever possible.

Now bromine is rapidly liberated under the conditions we employed for the *N*-bromosuccinimide oxidations. Accordingly, we found that bromine might replace this reagent. However, yields of α-dioxo-acids prepared in this manner, though 80% under the most favourable conditions, were often not reproducible. This was traced as due in some measure to the influence of light, and if the reaction was catalysed by irradiation less erratic results were obtained. Nevertheless the *N*-bromosuccinimide method is to be preferred because of its reproducibility.

We also investigated the direct oxidation of vicinal dihydroxy-acids, by *N*-bromosuccinimide, to α-ketol-acids. Employing slightly less than the theoretical amount of

---

[9] Wiberg and Saegebarth, *J. Amer. Chem. Soc.*, 1957, **79**, 2822.
[10] Cf. McGhie, *Chem. and Ind.*, 1954, 131.
[11] Nicolet and Jurist, *J. Amer. Chem. Soc.*, 1922, **44**, 1139.
[12] Fieser and Rajagopalan, *J. Amer. Chem. Soc.*, 1949, **71**, 3935, 3938.
[13] Barakat and El-Wahab, *J. Amer. Chem. Soc.*, 1953, **75**, 5731.

the reagent for the oxidation of one hydroxyl group, we obtained 50—60% yields of α-ketol-acids, based on recovered starting material from the *erythro*-acids (not from *threo*-acids). Here, as in the case of the " neutral " permanganate oxidation, it was better to purify the crude product by reduction followed by crystallisation.

The Table summarises results obtained by the different methods. The second procedure is of general applicability, giving excellent yields of pure product. The other two routes both give a product difficult to separate from the accompanying dioxo-acid, though this may be overcome by our modified procedure. The pH-controlled oxidation, although rapid, requires the olefinic acid to be available in a high state of purity, and since, particularly in the case of oleic acid, this is rarely possible, routes B and C are to be preferred.

(A) *Oxidation by neutral permanganate at controlled* pH, (B) *reduction of the dioxo-acid, and* (C) *partial oxidation of the dihydroxy-acid.*

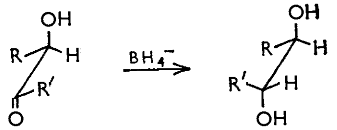
Acid	Yield (%) A	B	C *	M. p. of ketol-acid
6(7)-Hydroxy-7(6)oxo-octadecanoic	38	85	64	67—69°
9(10)-Hydroxy-10(9)oxo-octadecanoic ...	61	88	63	65—66
13(14)-Hydroxy-14(13)-oxodocosanoic ...	59	90	63	77

* Based on recovered dihydroxy-acid.

King[5] separated the two 9(10)-hydroxy-10(9)-oxo-octadecanoic acids as their semicarbazones by means of ethylene dichloride. We have repeated and confirmed these results: we draw attention to the need to use pure ethylene dichloride to avoid hydrolysis of the semicarbazones during their processing. We have also separated the isomeric 6-hydroxy-7- and 7-hydroxy-6-oxo-octadecanoic acids through their semicarbazones by a modification of this method. The semicarbazones, m. p. 109—125°, of the mixed 6(7)-hydroxy-7(6)-oxo-octadecanoic acids, on treatment with hot ethylene dichloride, was separated into less soluble and more soluble fractions, whence crystallisation afforded semicarbazones of m. p. 141—142° and 116—117° respectively. These on hydrolysis gave isomeric ketol-acids, m. p. 75—76° and 78—79°. The former acid was cleaved by periodic acid to dodecanal and adipic acid; under similar conditions the other isomer afforded dodecanoic acid and adipic semialdehyde. On this evidence, the former must be 7-hydroxy-6- and the latter 6-hydroxy-7-oxo-octadecanoic acid.

Since this work was completed[14] Gold and Skellon[15] reported briefly that, following King's procedure, they had isolated 6(7)-hydroxy-7(6)-oxo-octadecanoic acids of m. p. 74° and 75° through semicarbazones of m. p. 153° and 138°. Without other evidence, by analogy with the 9(10)-hydroxy-10(9)-oxo-octadecanoic acids they inferred that their acids were 6-hydroxy-7- and 7-hydroxy-6-oxo-octadecanoic acid respectively. In view of these discrepancies between their and our findings, we repeated our work, confirming our results.

In spite of numerous attempts we failed to separate the two isomeric 13(14)-hydroxy-14(13)-oxodocosanoic acids *via* their semicarbazones, although this has been reported in the literature.[16]



One of us has briefly reported[10] the reduction of dioxo- and ketol-acids with sodium borohydride to mixtures of *erythro*- and *threo*-dihydroxy-acids. We now find that the

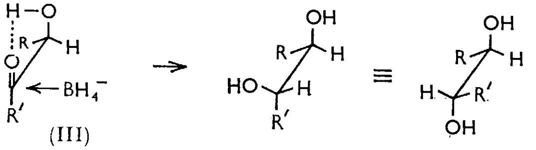
---

[14] Cramp, Thesis, London, 1958.

[15] Gold and Skellon, *J. Appl. Chem.*, 1959, **9**, 393.

[16] Dorée and Pepper, *J.*, 1942, 477.

threo-acid is in slight excess. On the basis of Cram's rule [17] it would be predicted that ketol-acids (also formed as intermediates in the reduction of dioxo-acids) would give predominantly the *threo*-acid, and we have shown that this is the case in the reduction of halogeno-oxo-acids where the *threo*-isomer is formed almost exclusively (*ca.* 80%). The simultaneous formation of the *erythro*-acid, in almost equal amounts, may be explained if hydrogen-bonding stabilises the ketol acids in the conformation (III).



Further oxidation of the ketol-acids with *N*-bromosuccinimide gave the expected dioxo-acids and these were cleaved by periodate or alkaline hydrogen peroxide to the expected products. For example, 9,10-dioxo-octadecanoic acid gave nonoic and azelaic acid.

Few examples of the benzilic acid rearrangement of α-diketones have been reported in the aliphatic series, owing to aldol-type condensations. Nicolet and Jurist,[11] however, reported that 9,10-dioxo-octadecanoic acid is converted in 12% yield, by potassium hydroxide at 160°, into α-hydroxy-α-octylsebacic acid. If the reaction is carried out in an atmosphere of hydrogen yields up to 70% can be obtained.* Futher, the transformation also takes place under the described conditions [11] for the benzilic acid rearrangement, and it appears to be general for those aliphatic α-diketones that do not readily enolise.

EXPERIMENTAL

Ketol-acids.—(*a*) *cis*-Octadec-9-enoic acid (10 g.) was heated with water (100 ml.) on a steam-bath, and to the hot mixture 4% potassium hydroxide solution (50 ml.) was added, then ice water (1500 ml.) and 22% sodium dihydrogen phosphate solution (250 ml.) (giving pH 9·3). 8% Potassium permanganate solution (500 ml.) was then added during 10 min., the temperature being kept below 5°. Treatment with sodium hydrogen sulphite (15 g.) and 50% hydrochloric acid (100 ml.) gave a solid which was melted on the water-bath and, after cooling, filtered off, washed with water, dried azeotropically with benzene, and purified by one of three methods: (i) Extraction in a Soxhlet apparatus with light petroleum (b. p. 40—60°) for 9 hr. gave 5·2 g. of acid. The residue was *erythro*-9,10-dihydroxyoctadecanoic acid, (1·8 g.), m. p. 126—128°. Recrystallisation of the soluble material from light petroleum (b. p. 40—60°) gave 9(10)-hydroxy-10(9)oxo-octadecanoic acids (4·6 g.), m. p. 62—64°.

(ii) The product was extracted from dihydroxy-acids in a large volume of hot light petroleum (b. p. 40—60°), recovered, dissolved in hot acetic acid, and treated with an excess of zinc dust. The resulting solution was filtered and diluted with water, and the precipitate was filtered off and crystallised from aqueous ethanol, to yield ketol-acids (4·8 g.), m. p. 64—65°. *cis*-Octadec-6-enoic acid (10 g.) under similar conditions gave 6(7)-hydroxy-7(6)-oxo-octadecanoic acids (4·2 g.), m. p. 67—69°.

(iii) To the product (9·5 g.) in boiling acetic acid (200 ml.) zinc dust (20 g.) was added during 10 min. The zinc was filtered off and washed with boiling acetic acid (2 × 50 ml.). The combined filtrate and washings were diluted with water to crystallisation, then cooled to 0°. The crystals (9·0 g.) were digested with chloroform (50 ml.) and collected. The filtrate, after 30 min. at 0°, deposited a small amount of solid which was filtered off and combined with the main chloroform-insoluble residue. This on crystallisation gave *erythro*-9,10-dihydroxyoctadecanoic acid (1·4 g.), m. p. 131—132°. The oil remaining after evaporation of the chloroform crystallised from light petroleum (b. p. 40—60°), giving the ketol-acids (6·8 g.), m. p. 65—66°. Erucic acid (10 g.) under similar conditions gave 13(14)-hydroxy-14(13)-oxodocosanoic acids (6·5 g.), m. p. 77°, and *erythro*-13,14-dihydroxydocosanoic acid (1·6 g.), m. p. 131—132°.

---

* We thank Dr. B. C. L. Weedon for informing us before publication of similar results.

[17] Cram and Elhafez, *J. Amer. Chem. Soc.*, 1952, **74**, 5828.

(*b*) 9,10-Dioxo-octadecanoic acid (10 g.) in acetic acid (200 ml.) was treated with zinc dust as described above. The solid (10 g.) obtained on dilution with water was filtered off, washed with water, dried azeotropically with benzene, and crystallised from light petroleum (b. p. 60—80°), giving the ketol-acids (8·9 g.), m. p. 65—66°. Under similar conditions, 13,14-dioxodocosanoic acid (10 g.) gave ketol-acids (9·0 g.), m. p. 77°, and 6,7-dioxo-octadecanoic acid (10 g.) yielded 6(7)-hydroxy-7(6)-oxo-octadecanoic acids (8·5 g.), m. p. 67—69°.

(*c*) *erythro*-9,10-Dihydroxyoctadecanoic acid (6·4 g.), ethyl acetate (200 ml.), water (150 ml.), and *N*-bromosuccinimide (6·0 g.) were heated under reflux for 10 min. The bromine was then removed by distillation of ethyl acetate, the volume of the solution being kept constant by addition of solvent. The ethyl acetate layer was separated, washed, and evaporated. The residue (6·1 g.), which contained dihydroxy-, ketol-, and dioxo-acids was separated and purified as described above. The ketol-acids were obtained in varying yields (1·3—4·0 g.) together with varying amounts of starting material, typical figures being ketol-acids (3·5 g.), m. p. 64—65°, and dihydroxy-acid (2·6 g.). *erythro*-13,14-Dihydroxydocosanoic acid (6·4 g.) under the same conditions gave ketol-acids (2·6 g.), m. p. 77°, and unchanged starting material (2·3 g.). *erythro*-6,7-Dihydroxyoctadecanoic acid (6·4 g.) similarly yielded ketol-acids (2·5 g.), m. p. 64—67°, and unchanged starting material (2·5 g.). Under similar conditions *threo*-6,7- and 9,10-dihydroxyoctadecanoic acids gave no evidence of ketol-acid formation.

threo-9,10-Dihydroxyoctadecanoic acid (10 g.) in ethyl acetate (500 ml.) was treated with *N*-bromosuccinimide (5 g.) in water (200 ml.) at room temperature. The suspension was stirred overnight, being shielded from light, then sodium hydrogen sulphite solution was added and the ethyl acetate layer separated. Purification in the usual way yielded 9(10)-hydroxy-10(9)-oxo-octadecanoic acids (2·4 g.), m. p. 65—67°. *threo*-6,7-Dihydroxyoctadecanoic acid under the same conditions gave the same yield of ketol-acids.

Dioxo-acids.—(*a*) *erythro*-9,10-Dihydroxyoctadecanoic acid (6·4 g.), ethyl acetate (250 ml.), water (200 ml.), and *N*-bromosuccinimide (14·4 g.) were heated under carbon dioxide. After 15 min., the bromine was distilled out with ethyl acetate, the volume being maintained by addition of fresh solvent. The ethyl acetate layer was separated, washed repeatedly with water, concentrated to small bulk (not to dryness), and diluted with hot methanol (100 ml.). The solid which separated at 0° was filtered off and recrystallised from methanol (at 0°), to give 9,10-dioxo-octadecanoic acid (5·7 g.), lemon-yellow plates, m. p. 84—85°. Other experiments, in which the mixture was irradiated with light from a 200 w bulb, gave similar yields.

The *threo*-isomer (10 g.) gave the same dioxo-acid (7·4 g.). *erythro*-13,14-Dihydroxydocosanoic acid (10 g.) and the *threo*-isomer (10 g.) under the same conditions yielded 13,14-dioxodocosanoic acid (8·5 and 6·8 g.), m. p. 94°. *erythro*-6,7-Dihydroxyoctadecanoic acid (10 g.) and the *threo*-isomer (10 g.) likewise gave 6,7-dioxo-octadecanoic acid (7·3 g. and 7·0 g.), m. p. 98—100°.

(*b*) *erythro*-9,10-Dihydroxyoctadecanoic acid (5 g.), ethyl acetate (150 ml.), and water (100 ml.) were heated under reflux on a steam-bath, and bromine (1·9 ml.) was added. After 30 min. the remaining bromine was distilled off with ethyl acetate. Working up as above yielded the dioxo-acid (3·9 g.), m. p. 81—83°. The *threo*-isomer (5 g.) under similar conditions yielded the dioxo-acid (2·1 g.), m. p. 82°. Under the same conditions *erythro*- and *threo*-13,14-dihydroxydocosanoic acids (5 g.) yielded 13,14-dioxodocosanoic acid (2·8 g. and 1·9 g.), m. p. 91°.

Separation of Ketol-acids.—A solution of semicarbazide hydrochloride (16·6 g.), sodium acetate trihydrate (25 g.), and absolute ethanol (200 ml.) was heated under reflux for 10 min. and filtered. 9(10)-Hydroxy-10(9)-oxo-octadecanoic acids (20 g.), m. p. 64—67°, were added to the filtrate, and the solution was heated to the b. p., cooled to room temperature, and diluted to turbidity with water. After 2 days, filtration gave the mixed semicarbazones (16 g.), m. p. 132—144°. The mixture of semicarbazones (15·8 g.) was treated with purified ethylene dichloride (500 ml.), 100 ml. of solvent were distilled off, and the suspension was filtered hot, leaving an insoluble residue (6·05 g.), m. p. 150—152°. The bulked residues after recrystallisation from aqueous ethanol gave the semicarbazone (4·6 g.), m. p. 152·5°, as flat prisms. Evaporation of the ethylene dichloride filtrates afforded products (5·75 g.), m. p. ~132—136°, recrystallisation of which yielded the isomeric semicarbazone (4·9 g.), m. p. 138—138·5°. Hydrolysis of the "soluble" and "insoluble" semicarbazones gave 10-hydroxy-9-oxo- (m. p. 75·5°) and 9-hydroxy-10-oxo-octadecanoic acid (m. p. 74°) respectively.

A mixture of semicarbazide hydrochloride (25 g.), sodium acetate trihydrate (34 g.), and ethanol (250 ml.) was heated under reflux for 5 min., then filtered, and the solid was washed with hot ethanol (2 × 25 ml.). 6(7)-Hydroxy-7(6)-oxo-octadecanoic acids (30 g.) in hot ethanol (100 ml.) were added to the filtrate and washings, the volume was reduced to 200 ml., and water added to turbidity. The solid which had separated after 40 hr. was filtered off and dissolved in hot benzene–ethanol, the water layer was removed, the solution concentrated, and light petroleum (b. p. 40—60°; 500 ml.) added. After cooling in ice, the separated solid (32 g.), m. p. 106—115°, was filtered off. Reprecipitation with light petroleum (b. p. 40—60°) from ethanol raised m. p. to 109—125°. The dried product (25 g.) was heated to the b. p. with ethylene dichloride (150 ml.), filtered hot, and washed with ethylene dichloride (20 ml.). The insoluble residue, m. p. 138—140°, crystallised from ethanol–light petroleum (b. p. 40—60°) and then from ethanol as needles (8·1 g.), m. p. 141—142°. The ethylene dichloride filtrate was concentrated to *ca.* 10 ml., ethanol was added and then light petroleum (b. p. 40—60°; 200 ml.). The resulting suspension was heated under reflux for 15 min. and then cooled in ice. The sticky solid obtained on filtration was heated under reflux with light petroleum, b. p. 40—60° (500 ml.), for 1 hr., cooled, and filtered. Repeated crystallisation from ethanol–light petroleum (b. p. 40—60°) gave needles (7·4 g.), m. p. 116—117°.

The higher-melting semicarbazone (8 g.) was heated under reflux with 2N-hydrochloric acid (400 ml.) and 40% aqueous formaldehyde (8 ml.) for 15 min. On cooling, a pale yellow oil separated (6·5 g.) which solidified at 0°. Crystallisation from methanol–light petroleum (b. p. 40—60°) gave 7-*hydroxy*-6-*oxo-octadecanoic acid* (5·6 g.), plates, m. p. 75—76° (Found: C, 68·8; H, 10·7. $C_{18}H_{34}O_4$ requires C, 68·8; H, 10·9%). Similar decomposition of the lower-melting semicarbazone and crystallisation from methanol–light petroleum (b. p. 40—60°) gave 6-*hydroxy*-7-*oxo-octadecanoic acid* (3·8 g.), prisms, m. p. 78—79° (Found: C, 69·0; H, 10·9%).

The lower-melting acid (2 g.) in ethanol (175 ml.) was added to periodic acid (2 g.) in water (200 ml.). After 3 hr., the product was poured into water (500 ml.) and extracted with ether (10 × 30 ml.). The product obtained on evaporation of the ether was distilled in steam. The distillate gave dodecanal 2,4-dinitrophenylhydrazone (650 mg.), orange needles (from methanol), m. p. 106°. The aqueous residue from the steam-distillation was concentrated, and on repeated extraction with ether gave adipic acid (850 mg.).

Periodic acid oxidation of the higher-melting acid (2 g.) gave a steam-volatile product, which with zinc sulphate solution gave zinc dodecanoate, m. p. 129°. The residue from the steam-distillation gave the 2,4-dinitrophenylhydrazone, m. p. 134°, of adipic semialdehyde.

Reductions with Sodium Borohydride.—Mixed methyl 13(14)-hydroxy-14(13)-oxodocosanoates, m. p. 50—51° (Found: C, 72·1; H, 11·6. Calc. for $C_{23}H_{44}O_4$: C, 71·8; H, 11·5%) were prepared by reduction of the diketo-ester with zinc and acetic acid. These esters (0·8 g.) in methanol (25 ml.) were treated with sodium borohydride (0·7 g.). After 10 hr. the solution was neutralised with acetic acid and diluted with water. The precipitated solid was filtered off; recrystallisation from methyl acetate (50 ml.) gave *methyl* erythro-13,14-*dihydroxydocosanoate* (0·2 g.), m. p. 108° (Found: C, 71·5; H, 11·8. $C_{23}H_{46}O_4$ requires C, 71·4; H, 12·0%). The filtrate yielded the threo-*ester* (0·37 g.), m. p. 78° (Found: C, 71·1; H, 11·7%). The methyl esters were saponified with alcoholic potassium hydroxide to the respective acids.

Methyl 9(10)-hydroxy-10(9)-oxo-octadecanoates, m. p. 35—36° (Found: C, 69·4; H, 10·9. Calc. for $C_{19}H_{36}O_4$: C, 69·4; H, 11·0%), were prepared by similar reduction of the diketo-ester. These esters (0·8 g.) were reduced with sodium borohydride (0·7 g.) as above. Fractional crystallisation of the product from methyl acetate afforded methyl *erythro*-9,10-dihydroxyoctadecanoate (0·15 g.), m. p. 105°, and the *threo*-ester (0·3 g.), m. p. 71°.

9,10-Dioxo-octadecanoic acid (5 g.) in methanol (300 ml.) was treated with sodium borohydride (5 g.) added during 10 min. After 3 hr., the solid (5·1 g.), m. p. 103—109°, which was precipitated when the solution was diluted with water and acidified with acetic acid, was filtered off. The dried product (5·0 g.) was repeatedly extracted with boiling ether; the insoluble residue, on crystallisation from ethyl acetate, gave *erythro*-9,10-dihydroxyoctadecanoic acid (1·5 g.), m. p. 130—131°. Concentration of the ether extracts gave a solid (2·0 g.), which after several crystallisations from ethyl acetate gave *threo*-9,10-dihydroxyoctadecanoic acid (0·9 g.), m. p. 93—94°. The same products resulted on reduction of 9(10)-hydroxy-10(9)-oxo-octadecanoic acids.

Reduction of either 13,14-dioxodocosanoic acid (5 g.) or 13(14)-hydroxy-14(13)-oxodocosanoic acids (5 g.) by the same procedure gave *erythro*-13,14-dihydroxydocosanoic acid (2·0 g.), m. p. 131°, and the *threo*-acid (1·0 g.), m. p. 99—100°.

Benzilic Acid Rearrangements.—13,14-Dioxobehenic acid (2·5 g.), ethanol (25 ml.), and potassium hydroxide (10 g.) were heated for 30 min. The solution was cooled, acidified with 50% hydrochloric acid, and extracted with ether. Washing of the extract with water, drying (Na_2SO_4), evaporation, and crystallisation from acetone gave 2-hydroxy-2-octyltetradecanedioic acid (1·6 g.), m. p. 115—116° (lit.,[18] 115—116°).

9,10-Dioxo-octadecanoic acid (13 g.) and potassium hydroxide (65 g.), moistened with water, were heated at 160° for 5 min., then poured into water and acidified with dilute sulphuric acid. Next day, the product was extracted with ether [to remove azelaic acid (0·4 g.)] and then with chloroform. The chloroform extract was distilled in steam, and the residue was basified, concentrated, and re-acidified. After crystallisation from chloroform–benzene the 2-hydroxy-2-octylsebacic acid (1·6 g.) had m. p. 110°. In a second experiment with an atmosphere of hydrogen, the temperature was raised to 210—220°, and the product (3·6 g. from 5·0 g. of starting material) had m. p. 111—112°.

We thank the Governors of Chelsea College of Science and Technology for the award of a Research Assistantship (to B. L. R.) and the D.S.I.R. for a maintenance award (to W. A. C.).

DEPARTMENT OF CHEMISTRY, CHELSEA COLLEGE OF SCIENCE AND TECHNOLOGY,
MANRESA ROAD, LONDON, S.W.3. [*Received, April 8th,* 1960.]

---

[18] Le Sueur and Withers, *J.*, 1914, 2815.