

389. *A Contribution to the Chemistry, including the Stereochemistry, of the θ -Halogenohydroxystearic Acids.*

By GEORGE KING.

Improvements have been effected in the preparation and characterisation of the θ -chloro-, -bromo-, and -iodo-hydroxystearic acids. The identity of the halogenohydroxystearic acids prepared from elaidic acid by the addition of the appropriate hypohalogenous acid with those obtained from the epoxide by the addition of the corresponding hydrogen halide has been established. Significant amounts of oily by-products, consisting largely of *ester-acids*, with some dihalides, result by the former method, especially when oleic acid is the starting material.

The conversion of the halogenohydroxystearic acids into the corresponding oxides proceeds smoothly at room temperature in the presence of dilute alkali; however, some dihydroxystearic acid also results when concentrated alkali at 100° is used. Ketonic acids, presumably a mixture of θ - and ι -ketostearic acid, are formed in part by the action of mercuric oxide on the *iodo-hydroxystearic acids* in moist ether. The dichlorides of oleic and elaidic acids are much more stable towards alkali.

The stereochemical changes involved in the mutual transformations of the two (\pm)- θ -dihydroxystearic acids are discussed, and the author's original scheme of configurations is modified.

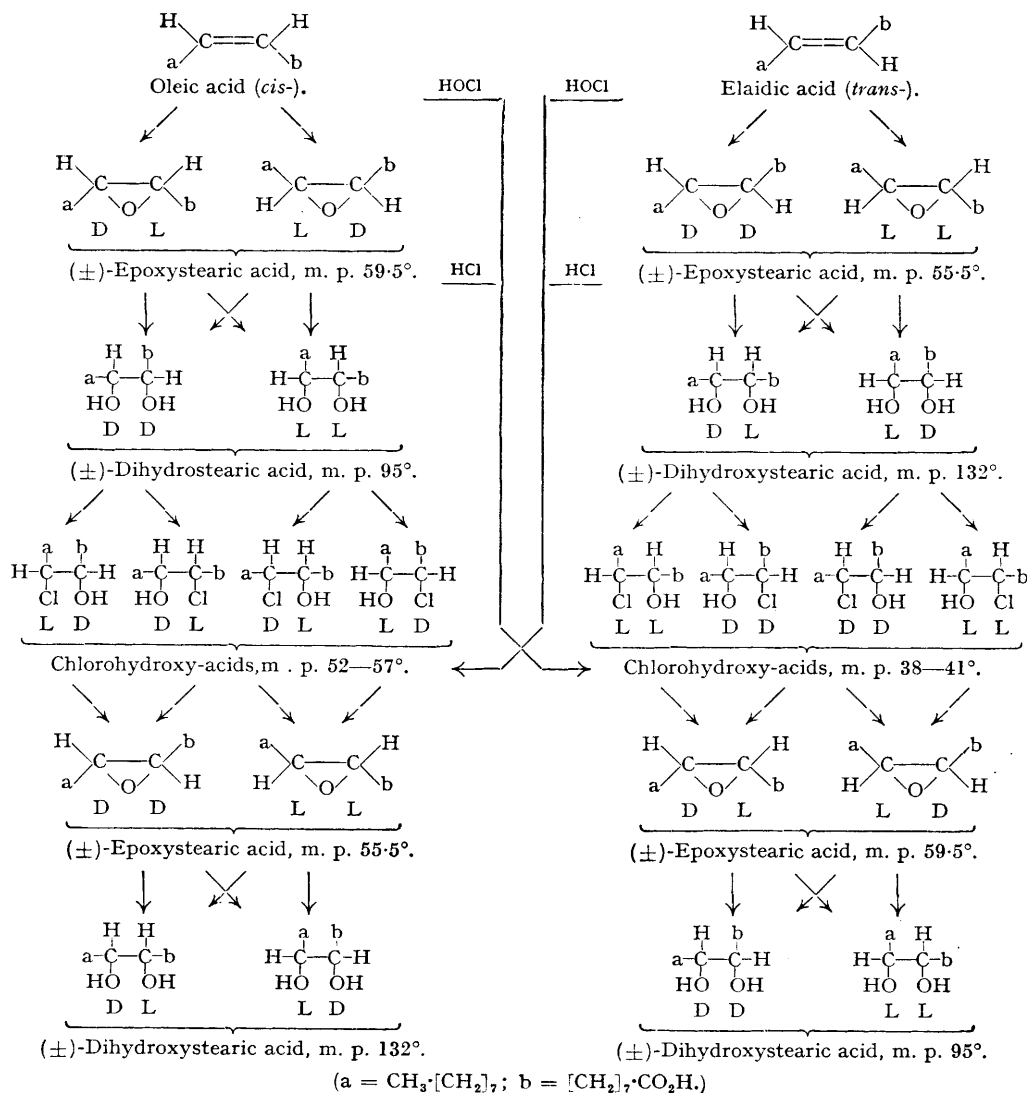
In a previous communication (J., 1942, 387) the mutual transformations of the (\pm)- θ -dihydroxystearic acids, m. p.s 132° and 95°, by way of the chlorohydroxy- and epoxy-stearic acids, were described, and the dihydroxystearic acid, m. p. 141°, occurring in castor oil was shown to be an optically active component of the acid, m. p. 132°. Configurational formulæ were provisionally assigned to these acids, reasons being adduced for the assumption that an inversion of configuration occurs on hydrolysis of the epoxy- to the dihydroxy-stearic acids. The literature abounds in similar instances of inversions accompanying the opening of the 1:2-oxide ring, typical of which are the hydrolyses of epoxycyclohexane (Brunel, *Bull. Soc., chim.*, 1903, **29**, 884; Derx, *Rec. Trav. chim.*, 1922, **41**, 318), crotonic acid oxide (Braun, *J. Amer. Chem. Soc.*, 1930, **52**, 3179), the anhydro-sugars (Peat, *Ann. Reports*, 1939, **36**, 262), and epoxy-steroids (Shoppee, *Ann. Reports*, 1946, **43**, 212).

The transformation, dihydroxystearic acid, m. p. 95° \longrightarrow chlorohydroxystearic acids \longrightarrow epoxystearic acid, m. p. 55·5° \longrightarrow dihydroxystearic acid, m. p. 132°, necessitates either one or three inversions. On the grounds that the epoxy-acids combine with hydrogen chloride to form chlorohydroxy-acids from which the original oxides are recoverable on treatment with alkali, Atherton and Hilditch (J., 1943, 204) deduced that a Walden inversion occurs during the first stage of the transformation. They favoured the view, though without cogent reason, that there is no inversion during either the opening or the closure of the oxide ring, an assumption which is clearly at variance with the observation that (+)-epoxystearic acid, m. p. 59·5°, undergoes an inversion of configuration on alkaline hydrolysis to form (\pm)-dihydroxystearic acid, m. p. 95° (King, *loc. cit.*, p. 389). A striking parallel is afforded by the *cis*-compound maleic acid oxide, which suffers a similar change of configuration on hydrolysis to furnish exclusively (\pm)-tartaric acid, yet combines with hydrogen chloride to form *r*-chloromalic acid, m. p. 153·5°, from which the original epoxide may be recovered by means of alkali (Kuhn and Ebel, *Ber.*, 1925, **58**, 919). Further, conversion of the optically active dihydroxy-acid, m. p. 141°, by way of the chlorohydroxy- into an *optically active* epoxy-stearic acid (King, *loc. cit.*) is difficult to reconcile with the view that a configurational change occurs only during the first stage of this conversion (cf. Lucas, Schlatter, and Jones, *J. Amer. Chem. Soc.*, 1941, **63**, 22; Lucas and Garner, *ibid.*, 1948, **70**, 990).

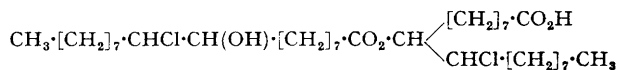
It appears highly probable, therefore, that an inversion accompanies *each* of the three stages involved in the mutual transformation of the (\pm)-dihydroxystearic acids, as suggested by Swern (*ibid.*, 1948, **70**, 1235) from purely general considerations. The annexed scheme, in which the symbols D and L have configurational significance only, indicates clearly the stereochemical changes occurring during these transformations and replaces that originally proposed by the author. It accords with the *trans*-addition of hypochlorous acid to the ethylenic acids and preserves the *erythro*-structure for the dihydroxy-acid, m. p. 132°.

In this connexion, considerable importance attaches to the identity of the chlorohydroxy-stearic acids resulting from the action of hydrogen chloride on the epoxy-acids with those obtained from the corresponding unsaturated acids by the addition of hypochlorous acid. According to Nicolet and Poulter (*ibid.*, 1930, **52**, 1186) these products differ, the former consisting, in their view, of θ -hydroxy- ι -chloro- and the latter of θ -chloro- ι -hydroxy-stearic acids. Moreover, the union of the oxides with hydrogen chloride in dry ether takes place under

conditions which may well favour the formation of oxonium salts of the type $\text{H}-\text{C}=\text{O} \xrightarrow{\text{Cl}} \text{CH}-$. In view of the fact that pure chlorohydroxystearic acids have not hitherto been isolated by the hypochlorous acid method, except in very small yield, it was felt desirable to make a further study of these products and of the bromo- and iodo-hydroxystearic acids obtained analogously.



As a result, it has now been found possible to obtain a 50—60% yield of a mixture, melting at 52—57°, of pure *o*-chlorohydroxystearic acids by the direct union of elaidic acid with hypochlorous acid in aqueous solution and to establish its identity with the product resulting in nearly theoretical yield from the action of hydrogen chloride on elaidic acid oxide, m. p. 55.5°, in ethereal solution. The former method, however, also furnishes appreciable amounts of oily by-products, consisting apparently of mixtures of *ester-acids*, such as



together with variable proportions of elaidic acid dichloride and other chlorinated products. The evidence for such esters consists largely of analytical values and of the fact that significant

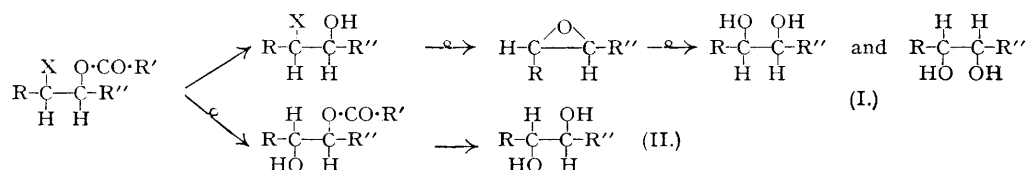
yields of epoxystearic acid can be obtained within a few hours by hot, but not by cold, saponification. If chlorine water is used as a source of hypochlorous acid (cf. Read and Andrews, *J.*, 1921, 1774; Read and Reid, *J.*, 1928, 745, 1487), the dichloride is the principal product, but appreciable amounts of chlorohydroxystearic acids are also formed. Repeated crystallisation of the mixed chlorohydroxy-acids from methanol affords a *product*, melting sharply at 73°, which is probably pure θ -chloro- ι -hydroxy- or ι -chloro- θ -hydroxy-stearic acid. These chlorohydroxystearic acids are quantitatively converted into the oxide, m. p. 55·5°, within two hours by cold aqueous sodium hydroxide.

Similarly, oleic acid oxide, m. p. 59·5°, and ethereal hydrogen chloride furnish a mixture of chlorohydroxy-acids, m. p. 38—41°, stereoisomeric with those prepared from elaidic acid or its oxide, from which the original oxide can readily be recovered by the action of cold alkali. On the other hand, oleic acid and aqueous hypochlorous acid react to give oily products containing less than 40% of free chlorohydroxystearic acid, the remainder consisting of ester-acids of the type already mentioned, oleic acid dichloride, and possibly other chlorinated products. No solid constituent could be isolated from this mixture (cf. Atherton and Hilditch, *loc. cit.*, p. 207), and only small amounts of the oxide are isolable after treatment with alkali, even at 100°.

The chlorohydroxystearic acids crystallise in needles and are very sparingly soluble in hexane or light petroleum at 0°, but those from oleic acid oxide are moderately soluble at room temperature. In contrast, oleic acid dichloride is a viscous oil, m. p. 12—15°, soluble in light petroleum at 0°, whereas elaidic acid dichloride crystallises in well-defined rhombic or six-sided plates, m. p. 47·5° (Piotrowski, *Ber.*, 1890, **23**, 2531, gave m. p. 32°), sparingly soluble in light petroleum at 0°. Further, elaidic acid dichloride is virtually unaffected by prolonged treatment with aqueous alkali at 100° and even oleic acid dichloride is only slowly attacked, forming dihydroxystearic acid, m. p. 95°.

The strictly anhydrous conditions used by Nicolet and Poulter in the preparation of the chlorohydrins from oleic and elaidic acid oxides have been adapted by Swern *et al.* (*Analyt. Chem.*, 1947, **19**, 414) for the quantitative determination of oxirane oxygen ($\begin{smallmatrix} \text{C} \\ \diagup \text{O} \diagdown \\ \text{C} \end{smallmatrix}$), but are unnecessary for preparative purposes. More conveniently, an ethereal solution of the oxide may be shaken with a moderate excess of concentrated aqueous halogen acid for 15—60 minutes. This method has been successfully applied also to the preparation of the bromohydroxystearic acids (m. p. 15—18·5°, from oleic acid oxide; m. p. 56—63°, from elaidic acid oxide) and the *iodohydroxystearic acids* (an oil from oleic acid oxide; needles, m. p. 54—60°, from elaidic acid oxide), thus avoiding the possible reduction of the oxides to unsaturated acids by the prolonged action of anhydrous hydrogen iodide (Morrell and Phillips, *J. Soc. Chem. Ind.*, 1939, **58**, 160r). The iodo-compounds, especially those derived from oleic acid oxide, are rather unstable and slowly lose iodine. When shaken in moist ether with freshly precipitated mercuric oxide, they are partly converted into a mixture, m. p. 73—74·5°, of ketonic (probably θ - and ι -ketostearic) acids.

The preparation of the bromo- and iodo-hydroxystearic acids from the ethylenic acids by the action of hypobromous and hypoiodous acid, respectively, is less satisfactory, and the subsequent isolation and purification of the oleic acid derivatives appear impracticable (the elaidic acid derivatives are more tractable). The yields of free halogenohydroxy-acids are relatively small, the principal products being oily ester-acids, with variable amounts of dihalide. As might be expected, the hydrolysis of these esters leads to different products according to the firmness with which the halogen is held :



Thus, whilst the more firmly held chlorine yields exclusively the oxide and its hydrolysis product (I), the less stable bromo- and iodo-compounds give rise in addition to significant amounts of the stereoisomeric dihydroxy-acid (II), the oxide normally predominating. Accordingly, the products of the action of hypochlorous acid on oleic acid afford on hydrolysis the oxide, m. p. 59·5°, with a small amount of the corresponding dihydroxystearic acid, m. p. 95°; those from elaidic acid afford the oxide, m. p. 55·5°, and the dihydroxy-acid, m. p. 132°. On

the other hand, the crude products of the action of hypobromous and hypoiodous acids on oleic acid yield the oxide, m. p. 59·5°, and a mixture of the two dihydroxy-acids, whilst those from elaidic acid give the oxide, m. p. 55·5°, and the two dihydroxy-acids.

In the light of these results, it seems highly probable that the rise in the proportion of the lower-melting dihydroxy-acid, reported by Esafov (*J. Gen. Chem., Russia*, 1937, **7**, 1403) to occur when the concentration of alkali used to hydrolyse the iodohydrin of oleic acid is increased, may be ascribed to the progressive hydrolysis of the epoxide, m. p. 59·5°, and that the presence of the higher-melting dihydroxy-acid among the products arises from saponification of esters in his "iodohydrin" preparation. There is no evidence that mixtures of the two oxides or of the dihydroxystearic acids result from the hydrolysis, however effected, of the pure halogenohydroxystearic acids obtained by the action of the halogen acid on an epoxystearic acid, and the latter reaction may be regarded as substantially homogeneous in the stereochemical sense.

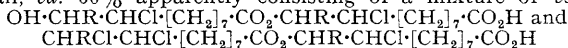
Careful re-examination of the oxides of oleic and elaidic acids has confirmed the accuracy of the m. p.s and crystalline appearances recorded by Ellis (*Biochem. J.*, 1936, **30**, 756). Ethyl oleate oxide, prepared from ethyl oleate and peracetic acid, was found to melt at 21°, in agreement with the value found by Pigulevski and Rubaschko (*J. Gen. Chem. Russia*, 1939, **9**, 830).

EXPERIMENTAL.

Chlorohydroxystearic Acids from Elaidic Acid.—(a) 0·3M-Sodium hypochlorite solution (150 ml.; prepared by passing chlorine into saturated aqueous sodium hydrogen carbonate) was added to a solution of elaidic acid (10 g.) in 0·04N-potassium hydroxide (1 l.). The solution was saturated with carbon dioxide, set aside overnight, and then slowly acidified with dilute sulphuric acid, excess of hypochlorous acid being destroyed by sodium sulphite. Crystallisation of the semi-solid product from *n*-hexane gave a mixture of nearly pure chlorohydroxystearic acids (6·8 g.) as needles, m. p. and mixed m. p. with the similar product prepared from elaidic acid oxide 52—57° (Found: C, 64·1; H, 10·5; Cl, 11·1; equiv., 335. Calc. for $C_{18}H_{35}O_3Cl$: C, 64·5; H, 10·5; Cl, 10·6%; equiv., 335). Recrystallisation from light petroleum-benzene and repeated crystallisation from methanol gave a product, melting sharply at 73·5°, which was probably pure θ -chloro- ι -hydroxy- or ι -chloro- θ -hydroxystearic acid (Found: C, 64·5; H, 10·3; Cl, 10·8%).

The mixed chlorohydroxystearic acids (2 g.) were dissolved in an excess of cold 0·1N-sodium hydroxide; after 2 hours acidification afforded a nearly theoretical yield (1·78 g.) of elaidic acid oxide, which separated from ethanol in small rhombic plates, m. p. and mixed m. p. 55·5° (Found: C, 72·2; H, 11·4; equiv., 299. Calc. for $C_{18}H_{34}O_3$: C, 72·4; H, 11·5%; equiv., 298).

On evaporation, the hexane mother-liquor left a viscous oil (4 g.), which was completely soluble in cold, very dilute alkali, *ca.* 60% apparently consisting of a mixture of ester-acids of the types



($R = CH_3\cdot [CH_2]_7\cdot$), 35% of elaidic acid dichloride, and 1·3% of elaidic acid (Found: C, 65·8; H, 10·3; Cl, 11·0; equiv., 500; I.V., 1·2. $C_{36}H_{69}O_5Cl_2$ requires C, 66·3; H, 10·5; Cl, 10·9; equiv., 652. $C_{36}H_{67}O_4Cl_3$ requires C, 64·5; H, 10·1; Cl, 15·9; equiv., 670. Calc. for $C_{18}H_{34}O_3Cl_2$: C, 61·2; H, 9·7; Cl, 20·1%; equiv., 353). The following data were also used in computing the probable composition of the oil, since α -chlorohydrin groups are quantitatively converted into epoxy-groups by cold alkali, and hot saponification of the esters leads to the transitory generation of α -chlorohydrins without measurably affecting the dichloride: (i) sodium hydroxide required for immediate neutralisation, 1·998; (ii) total alkali neutralised in 2 hours at 20°, 2·900; (iii) total alkali neutralised in 2 hours at 100°, 4·802; (iv) chlorine saponified in 2 hours at 20°, 0·930; (v) chlorine saponified in 2 hours at 100°, 1·947 milli-equivs./g. No significant amount of epoxystearic acid was isolated after saponifying the oil in the cold for 2 hours, but hot saponification furnished a fatty solid, which was resolved by light petroleum (b. p. 40—60°) into (i) very sparingly soluble dihydroxystearic acid (3%), crystallising from methanol in rhombic and hexagonal plates, m. p. 125—127·5°, (ii) nearly pure elaidic acid oxide (50%), m. p. and mixed m. p. 54—55°, which separated from the solvent at 0°, and (iii) a soluble, semi-crystalline fraction, the nature of which was not determined.

(b) Chlorine water (900 ml.; 0·184N) was added gradually, with vigorous shaking, to elaidic acid (20 g.) emulsified with water (200 ml.) at 50°, and mechanical shaking was continued for 1 hour. The product (23·9 g.) was isolated with ether (Found: Cl saponified by 0·1N-sodium hydroxide in 2 hours at 20°, 2·7%; equiv., 434). When dissolved in light petroleum (200 ml.) and kept at 0° for several days, it deposited chlorohydroxystearic acids, which crystallised from light petroleum-benzene in needles (3·5 g.), m. p. 52—60° (Found: equiv., 333). Repeated crystallisation from aqueous methanol gave the pure chlorohydroxystearic acid, m. p. and mixed m. p. 73·5° (Found: equiv., 334), from which elaidic acid oxide, m. p. 55·5°, was obtained in 96% yield after treatment with cold aqueous sodium hydroxide.

Removal of solvent from the light petroleum mother-liquor left an oil (18·8 g.), which became semi-crystalline within several weeks and appeared to contain about 60% of ester-acids (Found: Cl saponified by N-sodium hydroxide in 2 hours at 20°, 1·2, and in 2 hours at 100°, 5·1%; equiv., 456; I.V., 1·3). It afforded a 12% yield of elaidic acid oxide, m. p. 54°, on hot saponification. The semi-crystalline product (5 g.) was drained on a porous plate, and the solid (1·45 g.) was crystallised successively from acetic acid and acetone, giving elaidic acid dichloride (0·65 g.) in elongated hexagonal or nearly rectangular plates, m. p. and mixed m. p. 47° (Found: equiv., 357).

Chlorohydroxystearic Acids from Elaidic Acid Oxide.—Elaidic acid oxide (3 g., m. p. 55.5°) in ether (30 ml.) was shaken vigorously from time to time during 1 hour with 10N-hydrochloric acid (2 ml.). Evaporation of the washed and dried ethereal solution left a residue of chlorohydroxystearic acids, which crystallised from light petroleum-benzene in needles (2.85 g.), m. p. and mixed m. p. with the similar product prepared from elaidic acid 52—57° (Found: C, 64.5; H, 10.3; Cl, 10.6%; equiv., 334). The product gave no precipitate when boiled for a short time with alcoholic silver nitrate, which indicates the absence of an oxonium chloride. It afforded a nearly theoretical yield of the original oxide on treatment with 0.1N-sodium hydroxide for 2 hours at room temperature.

Chlorohydroxystearic Acids from Oleic Acid Oxide.—An ethereal solution of oleic acid oxide (3 g.; m. p. 59.5°), shaken with concentrated hydrochloric acid as above, gave a mixture of chlorohydroxystearic acids (3.3 g.), which crystallised (from light petroleum containing 5% of ether) in minute rectangular plates or tablets, m. p. 38—41° (Found: C, 64.3; H, 10.4; Cl, 10.9%; equiv., 333). With cold alkali the product afforded a 95% yield of the original oxide, separating from acetone in characteristic long, thin laminae, m. p. 59.5°.

Action of Hypochlorous Acid on Oleic Acid.—(a) A solution of oleic acid (5 g.; I.V., 90.5; equiv., 283) in the theoretical amount of aqueous sodium hydroxide was treated with sodium hypochlorite and carbon dioxide according to Atherton and Hilditch's method (*J.*, 1943, 207). The oily product (5.83 g.) became very viscous at 0°, but did not crystallise. It was resolved by light petroleum at 0° into (i) a sparingly soluble fraction (2.73 g.) (Found: C, 61.5; H, 9.6; Cl, 13.6%; equiv., 425; I.V., 1.9) and (ii) a soluble fraction (3.1 g.) (Found: C, 66.0; H, 10.8; Cl, 11.5%; equiv., 398; I.V., 1.5), neither of which furnished any crystalline matter. After saponification with N-sodium hydroxide for 2 hours at 100°, both fractions gave semi-solid products, which were separated by light petroleum into (i) a trace of sparingly soluble dihydroxystearic acid, which crystallised from methanol in nearly rectangular plates, m. p. and mixed m. p. 93—94°, (ii) crude oleic acid oxide (9—12%), m. p. 54—56°, lowered to 48—49° by elaidic acid oxide, raised to 57—58.5° by pure oleic acid oxide, and (iii) a semi-solid fraction, soluble in light petroleum at 0° and containing a little halogen.

(b) Oleic acid (5 g.), treated with hypochlorous acid as in the case of elaidic acid [method (a)], yielded an oil, of which a fraction (2.24 g.) separated from light petroleum at room temperature (Found: C, 61.5; H, 9.7; Cl, 15.6%; equiv., 427; I.V., 1). Saponification of this fraction at 100° yielded only 4% of oleic acid oxide. Quantitative data obtained by saponification at room temperature and at 100° indicated that the oil consisted mainly of ester-acids, with oleic acid dichloride and possibly other chlorinated products.

Bromohydroxystearic Acids from Elaidic Acid.—(a) 0.35M-Sodium hypobromite (100 ml.; prepared from bromine and aqueous sodium carbonate) was added to a solution of elaidic acid (5 g.) in 0.1N-potassium hydroxide (200 ml.), and after 30 minutes the solution was acidified with dilute sulphuric acid, free bromine being destroyed by sodium sulphite. Ether extraction gave an oil, which was dissolved in light petroleum (75 ml.) and cooled at 0° for 2 days. The deposit of bromohydroxystearic acids (1.64 g.) crystallised from *n*-hexane in needles, m. p. and mixed m. p. with the similar product prepared from elaidic acid epoxide 57—61° (Found: Br, 20.9; equiv., 376. Calc. for $C_{18}H_{35}O_3Br$: Br, 21.1%; equiv., 379), and afforded pure elaidic acid oxide, m. p. 55.3°, in 95% yield on treatment with 0.2N-sodium hydroxide for 1 hour at room temperature.

Evaporation of the light petroleum mother-liquor left a semi-crystalline residue (4.3 g.) (Found: Br saponified by N-potassium hydroxide in 2 hours at 100°, 9.8%; equiv., 390; I.V., 38), of which the crystalline component was elaidic acid, m. p. and mixed m. p. 43.5°. The products of saponification of the semi-crystalline residue were resolved by *n*-hexane into (i) about 4% of dihydroxystearic acids, consisting almost entirely of the acid, m. p. 95°, (ii) 14% of elaidic acid oxide, m. p. and mixed m. p. 54—55°, and (iii) a large fraction, soluble in hexane, composed of crude elaidic acid.

(b) 1.08M-Hypobromous acid (25 ml.; prepared by adding 10 ml. of bromine to a suspension of 30 g. of freshly precipitated mercuric oxide in 50 ml. of water and filtering) was added gradually, with cooling and shaking, to elaidic acid (5.64 g.) in ether (50 ml.). The ethereal layer was washed, dried, and evaporated, and the residual oil was dissolved in light petroleum (50 ml.) and cooled at 0° for 24 hours. The deposit of bromohydroxystearic acids (1.02 g.) crystallised from light petroleum-benzene in needles, m. p. 66—68°, raised by repeated crystallisation from hexane to 70—71° (Found: equiv., 369; Br, 20.9%).

The light petroleum mother-liquor left an oil on evaporation (Found: equiv., 651; Br saponified by 0.1N-sodium hydroxide in 2 hours at 20°, 7.0, and in 4 hours at 100°, 18.5%. $C_{18}H_{35}O_3Br_2$ requires equiv., 741; Br, 21.6. $C_{18}H_{35}O_4Br_2$ requires equiv., 804; Br, 29.8. Calc. for $C_{18}H_{34}O_4Br_2$: equiv., 442; Br, 36.1%). Quantitative data obtained by saponification at room temperature and at 100° indicated that the oil consisted mainly of ester-acids, with a small amount of elaidic acid dibromide. Saponification for 2 hours in the cold gave an insignificant amount of elaidic acid oxide, but after hot saponification the oil (3.6 g.) afforded a solid product, resolved by *n*-hexane into (i) an insoluble fraction (0.77 g.), crystallising from acetic acid and from methanol in rectangular plates (dihydroxystearic acid), m. p. 93°, from whose mother-liquors a few mg. of dihydroxystearic acid, m. p. 127°, were isolated, and (ii) nearly pure elaidic acid oxide (1.23 g.), m. p. 54—55°, depressed to 49—51° by oleic acid oxide. No oleic acid oxide was detected and, when the epoxide was heated with 2½ parts of acetic acid at 100° for 1 hour and the resulting solution was diluted and heated with an excess of 10% aqueous sodium hydroxide for 1 hour, a good yield of nearly pure dihydroxystearic acid, m. p. 130°, was obtained.

Bromohydroxystearic Acids from Elaidic Acid Oxide.—The epoxide (3 g.), m. p. 55.5°, in ether (30 ml.) was shaken frequently during 1 hour with 46—48% hydrobromic acid (3 ml.). The bromohydroxystearic acids (3.79 g.) crystallised from *n*-hexane in needles, m. p. 56—63° (Found: equiv., 376; Br, 21.2%), raised by repeated crystallisation to 70—71° (cf. Morrell and Phillips, *J. Soc. Chem. Ind.*, 1940, 59, 144r), unchanged on admixture with the similar product from elaidic acid and hypobromous acid. Cold alkali afforded a nearly theoretical yield of the original oxide.

Bromohydroxystearic Acids from Oleic Acid Oxide.—The oxide (3 g.), m. p. 59.5°, gave an oily mixture of bromohydroxystearic acids (3.76 g.), which, when cooled, set to a mass of colourless crystals,

m. p. 15–18.5° (Found: equiv., 379; Br, 21.1%), slightly soluble in light petroleum at 20°. The original oxide was recovered in good yield after treatment with cold aqueous alkali.

Action of Hypobromous Acid on Oleic Acid.—Oleic acid (5.64 g.) in ether (50 ml.) was treated with hypobromous acid as for elaidic acid, method (b). Removal of the ether left an oil (7.38 g.) (Found: equiv., 514; I.V., 1.9; Br saponified by 0.1N-sodium hydroxide in 2 hours at 20°, 9.2, and in 4 hours at 100°, 17.8%), which appeared to contain a considerable proportion of ester-acids and could not be purified by fractionation from light petroleum. Oily products were obtained after cold saponification, but hot saponification of the oil (4.05 g.) furnished a solid (3.21 g.), from which were isolated (i) dihydroxystearic acid (0.2 g.), m. p. and mixed m. p. 130–131°, (ii) dihydroxystearic acid (0.1 g.), m. p. and mixed m. p. 93–94°, and (iii) slightly impure oleic acid oxide (0.7 g.), m. p. and mixed m. p. 58–58.5°. No elaidic acid oxide was found.

Iodo-hydroxystearic Acids from Elaidic Acid.—Iodine (3.08 g.) was added gradually, with shaking, to elaidic acid (5.64 g.) in moist ether (30 ml.), containing freshly precipitated mercuric oxide (2.3 g.) in suspension, and shaking was continued for a further 15 minutes. The ethereal solution was washed successively with aqueous sodium sulphite and water, and then saturated with hydrogen sulphide to remove mercury. The filtered solution was washed with aqueous potassium iodide and with water, dried, and freed from solvent. The residual oil, dissolved in light petroleum (80 ml.) and cooled at 0° for several days, deposited mixed *iodo-hydroxystearic acids* (2.37 g.), crystallising from *n*-hexane in colourless needles (1.22 g.), m. p. 61–64°, raised by repeated crystallisation from aqueous methanol to 64.5–65.5° (Found: I, 28.2; equiv., 414. $C_{18}H_{33}O_3I$ requires I, 29.8%; equiv., 426). The *iodo-hydroxy-acids* were rapidly attacked by an excess of cold 0.1N-sodium hydroxide, making an accurate determination of the equivalent weight difficult, and after 1 hour acidification afforded a nearly theoretical yield of elaidic acid oxide.

Evaporation of the light petroleum mother-liquor left an unstable oil (Found: equiv., ca. 438; I saponified by 0.1N-sodium hydroxide in 1½ hours at 20°, 17.5, and by 0.5N-alkali in 2½ hours at 100°, 24.1%). Saponification of the oil (1 g.) at 100° gave a solid product, from which were isolated (i) dihydroxystearic acid (0.09 g.), m. p. 94–95°, with traces only of the higher-melting dihydroxy-acid, (ii) elaidic acid oxide (0.12 g.), m. p. and mixed m. p. 54–55°, and (iii) elaidic acid (0.1 g.), m. p. and mixed m. p. 43–44°. The oil became dark brown and semi-solid in several weeks and was not further examined.

In this method of preparing the *iodo-hydroxystearic acids*, prolonged contact with an excess of mercuric oxide was avoided, since this led to the formation of appreciable amounts of ketonic acids (see below).

Iodo-hydroxystearic Acids from Elaidic Acid Oxide.—66% Hydriodic acid (3 ml.) was added gradually, with cooling and shaking, to the oxide (3 g.), m. p. 55.5°, in ether (30 ml.), and the solution was then shaken occasionally during 1 hour. The recovered *iodo-hydroxystearic acids* (4.16 g.) crystallised from *n*-hexane in small needles, m. p. 54–60°, not depressed by the similar product (m. p. 61–64°) prepared from elaidic acid (Found: C, 51.2; H, 8.2; I, 29.8; equiv., 398; I.V., 2. Calc. for $C_{18}H_{33}O_3I$: C, 50.7; H, 8.3; I, 29.8%; equiv., 426). Treatment of the product with cold 0.1N-sodium hydroxide for 30 minutes afforded the original oxide in 95% yield.

Iodo-hydroxystearic Acids from Oleic Acid Oxide.—When oleic acid oxide (3 g.) in ether was treated with hydriodic acid as above, the product consisted of a viscous oily mixture of *iodo-hydroxystearic acids* (4.12 g.), which did not solidify at 0° (Found: C, 51.8; H, 8.4; I, 29.4%; equiv., 418; I.V., 3). It became a dark brown semi-solid mass after several weeks, with loss of iodine. Treatment of the oil with cold aqueous alkali for 30 minutes furnished the original oxide in more than 90% yield. Saponification of the oil (1 g.) with 0.5N-potassium hydroxide at 100° for 9 hours led, on acidification, to a solid (0.72 g.), from which dihydroxystearic acid (0.17 g.), m. p. 93–94°, and oleic acid oxide (0.4 g.), m. p. 58–58.5°, were isolated. The same products were obtained when 8N-potassium hydroxide was used for saponification, and no higher-melting dihydroxy-acid was detected (cf. Esavof, *loc. cit.*).

Action of Hypoiodous Acid on Oleic Acid.—Freshly precipitated mercuric oxide (3.25 g.) was added gradually, with cooling and shaking, to a solution of oleic acid (8.46 g.) and iodine (7.62 g.) in moist ether (50 ml.). After further shaking for 30 minutes, the solution was filtered, washed, dried, and evaporated under reduced pressure. The residual oil (11 g.) soon began to decompose and purification was impracticable (Found: equiv., 487; I saponified by 0.1N-sodium hydroxide in 1 hour at 20°, 12.9, and by 0.5N-alkali in 3½ hours at 100°, 20.2%). It probably contained less than 43% of free *iodo-hydroxystearic acids*, but an appreciable proportion of ester-acids. Cold saponification gave oily products, but saponification of the oil (5 g.) at 100° furnished a pale yellow, sticky solid (4.15 g.), which was resolved into (i) dihydroxystearic acid (0.2 g.), m. p. 130°, (ii) dihydroxystearic acid (0.15 g.), m. p. 93°, (iii) oleic acid oxide (0.4 g.), m. p. 58°, and (iv) a pale yellow fatty material containing ketonic substances, which gave an oily precipitate with Brady's reagent. No elaidic acid oxide was found.

Elaidic Acid Dichloride.—A 2.1N-solution (34 ml.) of chlorine in dry carbon tetrachloride was added gradually, with cooling, to elaidic acid (9.2 g.) in carbon tetrachloride (30 ml.). After a few minutes, excess of chlorine was destroyed by sodium sulphite. Removal of the solvent left elaidic acid dichloride (11.5 g.), which crystallised from acetic acid and then from acetone, in elongated hexagonal or nearly rectangular plates, m. p. 47.5°, soluble in light petroleum at room temperature, but rather sparingly so at 0° (Found: C, 61.4; H, 9.7; Cl, 19.1; equiv., 354. Calc. for $C_{18}H_{31}O_2Cl_2$: C, 61.2; H, 9.7; Cl, 20.1%; equiv., 353). When the dichloride was boiled with 0.5N-potassium hydroxide for 4 hours, the amount of chlorine saponified was negligible; even after 30 hours' boiling with 2N-alkali, most of the dichloride was recovered unchanged.

Oleic Acid Dichloride.—Oleic acid dichloride, prepared similarly, consisted of a viscous oil, m. p. 12–15°, soluble in light petroleum at 0° (Found: C, 62.7; H, 9.7; Cl, 18.4%; equiv., 402; I.V., 4). Saponification of the dichloride with 2N-potassium hydroxide at 100° for 30 hours afforded a semi-solid product, containing a little dihydroxystearic acid, m. p. 95°, but no significant amount of oxide. The amount of chlorine saponified was 6.2%, or about one-third of the total chlorine.

Action of Mercuric Oxide on the Iodo-hydroxystearic Acids.—Freshly precipitated mercuric oxide

(2.5 g.) was shaken for 4 hours with a solution of iodohydroxystearic acids (2.5 g.), m. p. 54—60° (prepared from elaidic acid oxide), in moist ether (50 ml.). The filtered solution was washed, dried, and evaporated, leaving a solid (0.5 g.) which crystallised from alcohol in ill-defined plates, m. p. 52—55°, containing elaidic acid oxide and some ketonic material. The insoluble residue of mercury compounds and mercuric oxide was shaken vigorously with ether and dilute sulphuric acid at frequent intervals during several hours. The material (0.87 g.) from the ethereal extract was resolved by *n*-hexane into (i) a few mg. of dihydroxystearic acid, m. p. 130°, (ii) ketonic acids (presumably θ - and ι -ketostearic acids) (0.4 g.), which separated from the solvent at room temperature and crystallised from alcohol in rhombic plates, m. p. 73—74.5° (Found: C, 71.6; H, 10.9; equiv., 296. Calc. for $C_{18}H_{34}O_3$: C, 72.4; H, 11.5%; equiv., 298) (cf. Robinson and Robinson, *J.*, 1926, 2204), and (iii) elaidic acid oxide (0.33 g.), m. p. and mixed m. p. 54—55°, which separated from the cooled solvent.

Repeated crystallisation of the semicarbazones of the ketonic acids from acetone and from alcohol gave hexagonal tablets or short prisms, m. p. 120° (Found: N, 11.4. Calc. for $C_{18}H_{37}O_3N_3$: N, 11.8%). No ketonic acids were obtained when elaidic acid oxide in ether was shaken with mercuric oxide, and there was no evidence of isomerisation of the oxide under these conditions.

The oily iodohydroxystearic acids (2.5 g.), prepared from oleic acid oxide, similarly afforded (i) ketonic acids (0.5 g.), m. p. and mixed m. p. 73° (semicarbazone, m. p. and mixed m. p. 120°), and (ii) somewhat impure oleic acid oxide (0.5 g.), m. p. 55—56°, lowered to 49—50° by admixture with elaidic acid oxide.

Ethyl Oleate Oxide.—Ethyl oleate (30 g.; b. p. 179—182°/3.5 mm.; I.V., 83) was stirred for 2½ hours at 25—30° with 1.3M-peracetic acid (100 ml.) (Findley, Swern, and Scanlan, *J. Amer. Chem. Soc.*, 1945, **67**, 412), and after a further 3½ hours the solution was poured into cold water (1.5 l.). The oil was crystallised twice from ether at –50° and then from light petroleum at the same temperature, giving the pure, crystalline oxide (13 g.), m. p. 21° (Found: C, 73.6; H, 11.6; sap. val., 174. Calc. for $C_{20}H_{38}O_3$: C, 73.6; H, 11.7%; sap. val., 172).

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ST. MARY'S HOSPITAL MEDICAL SCHOOL, LONDON, W.2.

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