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THE PREPARATION AND PROPERTIES
OF THE MARGARINES

The margarines, as the name implies, are compounds formed by the chemical union of glycerol and margaric acid. The chemistry of this acid has enlisted the attention and interest of scientific investigators for a great many years. Since the classical researches of Chevreul on the fats in 1815, the subject has been the cause of a great deal of discussion, and a large number of chemists have contributed their share of patient toil and untiring energy in an effort to throw some light on the matter.

It would seem advisable at this point to outline briefly the history of margaric acid and trace the various vicissitudes it has experienced in the last hundred years.

THE LITERATURE OF MARGARIC ACID

The term "margaric acid" was formerly applied to an acid intermediate between stearic and palmitic acids, supposed to be produced, together with others, by saponification of solid natural fats, but it is now restricted to an artificially prepared fatty acid of the series $C_nH_{2n}O_2$, resulting from a definite reaction.

In a paper dealing with the properties of margaric acid, and published by Dr. R. F. Ruttan[1] in the records of the Eighth International Congress of Applied Chemistry, we find the following paragraph:-

"Chevreul[2] was the first to use the name "Margaric Acid". It is found in his early researches on the constitution of fats and soap formation, published in 1811. From pigs' fat he separated two fats of different melting points, the solid one he called "Stearin" and the liquid fat "Elaein". The acid obtained from the soap of the former he named "Acide Margarique", and from the oily fat he obtained an acid called by him "Acide Oleique". He subsequently resolved a large number of animal and vegetable fats into these acids and described Margaric Acid as the characteristic acid of Spermaceti. In 1820 he divided Margaric Acid into two acids of different melting points - "Acide Margarique" and "Acide Stearique".

Liebig[3] in 1840 quoted Chevreul's analytical figures for margaric acid as follows:-

Carbon	76.366%
Hydrogen	11.978%
Oxygen	11.656%

and indicated that this would correspond to the following formula, on the basis of the molecular weight of oxygen being equal to 100. -

	Mol.Weight		Percentage
70 atoms Carbon	5350.5	-	76.575
134 " H	836.1	-	11.967
8 " O	800.0	-	11.458
	6986.6		100.000

and by subtracting from this the elements of two molecules of water, he obtained the following formula for the "anhydrous" acid,

	Mol.Weight		Percentage
70 atoms Carbon	5350.50	-	79.132
130 " H	811.16	-	11.995
6 " O	600.00	-	8.873
	6761.66		100.000

The percentage of hydrogen determined in Chevreul's analysis agreed with the theoretical value. Liebig mentioned that there was the possibility of experimental error in Chevreul's analysis and that the hydrogen value was too high. The more probable formula for the non-anhydrous acid would, therefore, be $C_{70}H_{132}O_8$, and hence the "anhydrous" acid would possess the formula $C_{70}H_{128}O_6$. The latter he conceived to be constituted of one molecule of stearic acid, one of oleic acid and two of water, thus -

1 Molecule Stearic Acid	70 C + 136H + 7O
1 " Oleic "	70 C + 124H + 7O
2 " s Water	4H + 2O

The summation of these values would give -

$$140\ C + 264\ H + 16\ O = 2\ (70\ C + 132\ H + 8O) = 2 \text{ mol. margaric acid hydrate.}$$

He also stated that observations made on the distillation of oils and fats appeared to place beyond all doubt the relation between oleic and stearic acids on the one hand and margaric on the other. Ordinary mutton tallow was supposed to contain stearin, olein (both being compounds of "glyceryloxyd" and stearic or oleic acids), and a little margaric acid.

By the dry distillation of these, there was obtained a substance, which at ordinary temperature was a solid and contained no traces of stearic but only oleic and margaric acids, the latter being present to the extent of thirty per-cent of the weight of the original fat.

From the similarity of stearic and margaric acids, Berzelius concluded that there was a close relationship existing in the structure of both acids. He assumed the formula of margaric acid to be $C_{70}H_{132}O_5$.

These assumptions appeared to be confirmed by the experiments and observations of Von Varrentrapp[4] who subjected ox tallow, swine fat, olive oil and raw oleic acid to dry distillation. He stated that ox tallow and mutton tallow contained none, or only traces of margaric acid, and that Bussy had shown that these materials under the influence of high temperatures gave rise to products which represented mixtures of fatty acids from which, by recrystallization from alcohol, it was possible to remove all traces of stearic acid. Under these circumstances the stearic acid was supposed to decompose and there was obtained in its place margaric acid, which, in its melting point and other properties, was identical with the margaric acid recognized by the chemists of the time.

The product of the distillation consisted of two main portions, one an oil and the other a solid. The latter was separated from the oil by "pressing out" and repeated recrystallizations from alcohol. It was then saponified with sodium hydroxide, boiled up for some time in water and then reconverted to the acid. The product was a perfectly white crystalline substance melting at 55-56° C. It was recrystallized twice from alcohol, saponified, reconverted to the acid and distilled. During all these operations, the melting point did not change and he was convinced that the temperature cited ~~is~~ was the actual melting point of the so-called "Margaric Acid", and not of a mixture of lower melting or liquid substances. All the acids obtained from the different fats gave concurrent results and he therefore claimed that they were identical.

He performed several determinations of the molecular weight of the acid. The value obtained from the lead salt by combustion was 3522-3513 and that from the sodium salt 3700. The fact that the values did not agree very well was attributed by Varrentrapp, to the large difference between the atomic weight of sodium and the molecular weight of the acid. The value obtained by analysis of the silver salt was

3340 for the "anhydrous", and 3453 for the hydrated acid. This analysis showed a smaller percentage of carbon than that calculated for the hydrated acid. He prepared the calcium salt by the addition of calcium chloride to an aqueous solution of the sodium soap. On extracting the dry salt with ether, he obtained two substances, one liquid, and the other solid. These were richer in carbon and poorer in oxygen than the acid and this fact according to Varrentrapp, accounted for the low value of carbon in the silver salt, i.e.; when the latter was prepared in an alcoholic medium these substances remained in solution.

Varrentrapp then proceeded to purify all the acids in the same manner, and in this way obtained the acid melting at 60° C. On analysis it gave values which agreed with the following figures -

			In 100 Parts
34 Atoms	C	2598.79	- 75.92
68 "	H	424.30	- 12.39
4 "	O	400	- 11.69

Accordingly, he gave to the "anhydrous" acid, the formula - $C_{34}H_{66}O_3$ and to the hydrated, $C_{34}H_{66}O_3H_2O$, and to the silver salt, $C_{34}H_{66}O_3 \cdot Ag\,O$.

He then prepared "Margaron" by treating the acid with one-quarter its weight of lime and distilling, and obtained a substance melting at 76° C. By distilling the pure acid, he obtained a substance which he found to be identical with "margaron". He also prepared the acid by saponifying human fat, separating the oleic acid and recrystallizing the former to a constant melting point (60° C). This "margaric acid" on analysis agreed very closely with that obtained from the other fats.

He stated also that Meyer, in the same laboratory, prepared from olive oil a "margaric acid" possessing the same properties and melting at 60° C. He concluded by saying that,

> "The formation of margaric acid from stearic acid and its presence in all distillation products of fats, has been clearly demonstrated and the composition of the acid definitely established".

Bussy[5] in the same year treated one part of stearic acid (from ox tallow) in the warm with two to three parts of nitric acid, and found that a lively reaction took place. On heating the mixture, oxides of nitrogen were evolved accompanied by very pungent fumes. Finally, a product remained which melted at 35-45°C. "Margaric acid", he claimed, "is thus obtained combined with oily material. On saponification, there is obtained a blood red soap which, after separation of the acid, retains the deep colour". The mass was washed with water and after repeated saponifications and recrystallizations the acid melted at 60.5°C, and formed a brittle crystalline mass. Analysis of the substance agreed with the formula $C_{34}H_{66}O_{3}aq$, and hence with the values previously obtained.

He stated that the formation of margaric acid from stearic acid was clarified by this oxidation process in which stearic acid assumed two atoms of oxygen, one of which entered into the composition of the resulting acid and the other combined with two equivalents of hydrogen and separated as water. Consequently, if one subtracted from hydrated stearic acid, two atoms of hydrogen and added one atom of oxygen, there would be obtained;-

$$\begin{array}{rrr} 68\,C + & 138\,H & + 7\,O \\ - & 2\,H & + O \\ \hline 68\,C + & 136\,H & + 8\,O \end{array}$$

which would correspond exactly to the composition of two molecules of "hydrated" margaric acid.

He treated a small quantity of very pure stearic acid with concentrated nitric acid, whereby, he stated, the former was converted into pure "margaric acid". He also claimed to have obtained the acid from oleic acid which was not free from stearic acid. When using very pure olive oil, he obtained neither "margaric" or elaidic acids, but one melting at 80°C.

Redtenbacher[6] investigated the distillation products of stearic acid and considered "margaric acid" to be derived thereby, and as a result of his experiments and analyses ascribed the following formulae:-

Margaric Acid - $C_{34}H_{66} + 3O + H_2O$

Stearic Acid - $C_{34}H_{66} + 5O + H_2O$

Pelouze and F. Boudet[7] experimented with palm oil and obtained two different "oleins" from it. Both these "oleins" were supposed to contain "margarin" in solution. From these substances they obtained the acid melting at 60°C. They claimed that, "in the liquid portion of human fat is found the margarin in a dissolved state with olein, whereas in hog fat it is combined with stearic acid."

Von Fremy[8] saponified palm oil with potash and obtained a liquid fatty acid in small quantity accompanied by a solid acid. He heated the latter to 300° C and recrystallized it from alcohol. During this treatment the crystal structure changed but the composition remained the same. To this acid he gave the name "palmitic" acid, and he considered it to be dibasic.

He thus showed that the "margaric acid" obtained from palm oil by Pelouze and Boudet was a mixture of palmitic and oleic acids.

Stenhouse[9] also investigated the saponification products of palm oil and stated that his results corroborated those of Von Fremy. He found the acid to melt at 60° C. and palmitin at 48° C. He also saponified cacoabutter obtained from "Theobroma Cacoa". The mixed acids obtained melted at 51°C. After ten recrystallizations from alcohol, an acid melting at 69° C. was obtained, and from his analysis he considered it to be stearic acid. He claimed that, by distillation of cacoa-butter no appreciable quantity of fatty acids wereobtained. From the alcohol-soluble matter obtained by recrystallizing the stearic acid, he separated a small quantity of oleic acid and he was of the opinion that a third acid melting at 60°C. was also present in cacoa-butter and that it was, in all probability, margaric acid.

Chevreul had raised the question whether stearic and margaric acids were identical. Laurent and Gerhardt[10] were of the opinion that such was the case. They drew attention to the similarity of margaric and stearic acids in chemical relations, and to the fact that the composition of both acids, on the basis of their salts, were found to be very nearly the same. They compared the results of analysis of various preparations in the following manner:-

	Stearic Acid	Margaric Acid
C	75.40 - 75.60	75.55
H	12.53 - 12.61	12.56
O	11.79 - 12.06	11.89

The values they give for margaric acid were calculated from the formula. They concluded that stearic and margaric acids were identical, i.e.; they were different modifications of the same acid, and to stearic acid they ascribed the formula -

$$C_{34}H_{68}O_4$$

and to margaric acid the formula,

$$C_{17}H_{34}O_2$$

R. O. Thomson and E. T. Wood[11] in 1849 investigated the so-called "shea-butter", which is obtained from certain trees in West Africa - similar to the American oak, by extracting the fruit kernels with boiling water.

By saponification, separation of the soap by means of common salt and decomposing the latter with tartaric acid, they separated a fatty acid which, after repeated recrystallization from alcohol, was obtained in crystals possessing a nacreous lustre, and melting at 61.1° C. From the analysis of the silver salt, they considered it to be "margaric acid".

Chinese vegetable tallow from the juice of the "Stillingia Sebifera", contains an acid melting at 67.8° C. which Thomson and Wood consider to be a mixture of stearic and margaric acids.

The analysis of fats was directed into new channels by W. Heintz, who undertook to separate, by recrystallization, the fatty acids obtained by the saponification of fats. During his investigations on human fat[12] in 1851, he obtained three acids, the first margaric acid, $C_{17}H_{34}O_2$, melting at 60° C., secondly, palmitic acid, $C_{16}H_{32}O_2$, melting at 62° C., and thirdly, a new acid possessing the same formula as margaric acid, but melting at 56° C. He named the latter "Anthropinsaure", and maintained that it was identical with the "Madiasaure" found by Luck.

In 1852, during the course of his experimentation with spermaceti,[13] he found a margaric acid of melting point 60° C., besides palmitic and other acids, which formed the main constituents of the product.

Later on,[14] during his researches with mutton tallow, Heintz came to the conclusion that it was possible to obtain a substance composed of a mixture of palmitic and stearic acids, which exhibited the properties of an entirely different acid. It was not possible to separate the constituent acids of this mixture by recrystallization. The only manner in which separation could be accomplished was by fractional precipitation of the magnesium or barium salts of the acids by means of the metallic acetates.

The acid to which he gave the name "Anthropinsaure", he later identified as a mixture of five parts of stearic acid with seven parts of palmitic acid.

He issued the statement that acids containing an uneven number of carbon atoms in the molecule do not occur in nature. Accordingly, all the various acids up to this time considered as margaric acid were mixtures of palmitic and stearic acids.

Collet[15] in 1854, undertook to settle the question whether Chevreul's "margaric acid" was to be considered a mixture of palmitic and stearic acids. He desired to investigate the "margaric acid" obtained from a substance in which no stearic acid could be detected, and with this in view, he experimented with the solid acids of olive oil. The oil was saponified, and the soap solution treated with lead acetate. From this salt all oily material was separated by extraction with ether. The salt was decomposed with mineral acid and the fatty acid recrystallized from alcohol.

It showed the constant melting point of 60° C. and analysis gave the formula $C_{32}H_{32}O_4$.

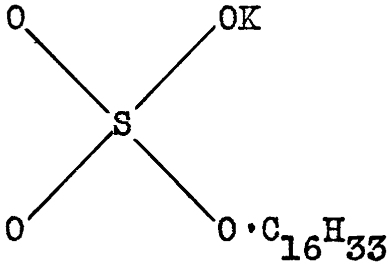
Collet was led to the conclusion that margaric and palmitic acids were identical, and that the former was by no means a mixture of palmitic and stearic acids. He emphasized the results of Varrentrapp's analysis of margaric acid, which, calculated according to the new equivalent weight of carbon, corresponded to the formula $C_{32}H_{32}O_4$, being identical with his own. He thought that the old nomenclature "margaric acid", should be retained for the acid of this composition. Berthelot[16] was of the same opinion.

Heintz[17] reiterated, however, that pure palmitic acid melts at 62° C and that it was demonstrated by his previous investigations that the so-called "margaric acid" melting at 60° C., could not be resolved into palmitic and stearic acids by recrystallization, but only by fractional precipitation. It was decided that the acid $C_{32}H_{32}O_4$ should still retain the name "palmitic acid", under which name it was described when first obtained in the pure state. He mentioned the researches of Hetzer on the solid fatty acids of olive oil, who obtained therefrom palmitic acid melting at 62° C. by mere recrystallization, without previously removing the oleic acid.

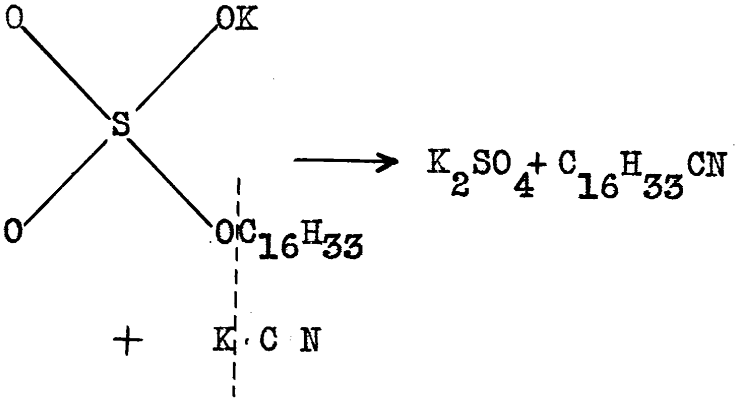
Heintz supposed that the less thorough method of purification, that is, recrystallization without previously removing the oleic acid, actually yielded a purer product; the oleic acid retaining the impurities in solution while the palmitic acid crystallized out. He supposed that stearic acid was detected among the saponification products of olive oil.

Since Heintz made the assertion that acids of the formula $C_{17}H_{34}O_2$ did not occur in natural fats there remained the problem of obtaining margaric acid synthetically. Then, almost simultaneously, yet independently of each other, Becker and Heintz synthetically prepared"margaric acid"from cetyl cyanide.

H. Koler[18] under the direction of Heintz, investigated the synthetical preparation of this acid. He prepared cetyl alcohol from spermaceti and by treatment with sulphuric acid, converted the alcohol into potassium cetyl sulphate,



which on treatment with potassium cyanide yielded cetyl cyanide,



The yield of cetyl cyanide was so small, however, that after saponification with alcoholic potash, no margaric acid could be detected in the reaction product.

Heintz[19] synthesised margaric acid in the following manner. Cetyl cyanide, prepared by the action of potassium cyanide on cetyl alcohol at 200° C., was continuously boiled with alcoholic potash, till ammonia was no longer given off and the residue had become solid. This residue was then decomposed with boiling hydrochloric acid; the separated fatty acid shaken up with aqueous ammonia, and the turbid solution precipitated with barium chloride. The precipitate, after being washed with water and alcohol, and repeatedly boiled with ether, yielded to this solvent an oil which solidified in the cold, melting below 40° C, and which had the composition of cetylic ether and cetylic aldehyde. The undissolved barium salt was decomposed by agitation with hydrochloric acid and ether, and by pipetting off the ethereal liquid and distilling off the ether, crude yellowish margaric acid was obtained, melting at 56.6° C. and solidifying in scales and fine needles. By several recrystallizations from alcohol, repeated partial precipitation from the solution of its sodium salt by acetate of magnesium and subsequent recrystallization of the portions of acid again separated, this acid was resolved into margaric and another acid containing a larger proportion of carbon, ($C_{19}H_{38}O_2$)- and which occurred chiefly in the portions first precipitated by magnesium acetate.

The final fractions yielded margaric acid, which, after its melting point had been raised by repeated recrystallization to 59.9° C. exhibited the characteristics of a pure fatty acid, and could not in any way be resolved into acids differing in melting point.

Becker[20] proceeded in the following manner;- By the saponification of spermaceti with alcoholic caustic potash, precipitation of the palmitic acid with barium chloride, distillation of the alcohol, washing of the residue with hot water, and dissolving in a little alcohol, he obtained cetyl alcohol. It was treated in the molten state with iodine and phosphorus until the colour of iodine remained, being thus transformed into cetyl iodide. The latter was poured off from the amorphous phosphorus, washed with water and freed from cetyl alcohol by boiling with ethyl alcohol. An impure specimen of cetyl cyanide was obtained by boiling the cetyl iodide for several days with an alcoholic solution of potassium cyanide, distilling off the alcohol, treatment of the residue with hot water to remove the potassium iodide, and recrystallization from alcohol. A small quantity of margaric acid crystallized out. To convert the cetyl cyanide into margaric acid, it was boiled for three days with aqueous alkali, ammonia being evolved during the process. After removal of the alcohol, the residue was decomposed with hydrochloric acid, the fatty acid dissolved in alcohol, and precipitated as a lead salt. This salt was extracted with alcohol and again decomposed by means of mineral acid.

The free acid was then recrystallized repeatedly from alcohol, and formed nacreous scales melting at 52-53° C. Analysis of the barium salt yielded values corresponding to the formula $C_{17}H_{34}O_2$. He prepared a larger sample of the acid and found it to possess the same composition and to melt at the same temperature, even after fractional precipitation.

Whereas Becker and Heintz approached the problem by attempting to build up margaric acid from compounds possessing fewer carbon atoms in their molecule, Krafft's[21] method of attack was directed in the opposite channel; that is to say, the breaking down of a compound possessing a larger number of carbon atoms. His starting point was stearic acid. He converted it into the barium salt,~~and~~ intimately mixed some barium acetate with it and obtained the corresponding ketone upon distillation. The product melted at 55.5° C. From this ketone, by oxidation with potassium bichromate in dilute sulphuric acid solution, he obtained margaric acid melting at 59.8° C. The silver salt contained 28.58 percent of silver. After extraction of the metallic salt with ether it showed the same silver content.

Ebert[22] carried out an investigation on adipocere. He saponified this substance,whereby ammonia was evolved to the extent of one percent and an insoluble residue, to the extent of six percent, remained, which consisted of tissue, etc. The acids were then fractionally precipitated by means of magnesium acetate. The chief constituent was palmitic acid (middle portion) and in smaller quantities margaric acid was present (in the first fraction). He stated that although the pure acid was obtained previously only by synthetical methods, he considered it to be present in adipocere in the pure state, inasmuch as he observed the melting point 59° C. which was not altered by the usual fractional precipitation methods. Analytical results agreed with the theoretical requirements. From the last fraction of the magnesium precipitation of the adipocere acids he obtained an acid melting at 80° C. which he called oxymargaric acid, and which he claimed possessed the formula $C_{17}H_{34}O_3$. His conslusions were based on the results of the analysis of the silver and magnesium salts.

Bomer[23] drew attention to the fact that it has remained unestablished whether the acid found by Ebert in adipocere is identical with the synthetical margaric acid.

E. Gerhardt[24] in 1890 extracted the fatty oil of the seeds of the Datura Stramonium with ether, converted the acids into the lead soap, dried the latter, and extracted with anhydrous ether to dissolve out the lead - oleate and linoleate. After decomposition of the salt and recrystallization, the acid melted at 56° C. and the mother liquor contained a substance melting at 58.5° C., the lower melting substance being the richer in carbon. By fractional precipitation with barium acetate, the higher melting acid yielded pure palmitic acid melting at 62° C. and the other, an acid to which he gave the name "Daturic Acid", which melted at 55° C. Analytical results agreed with the formula - $C_{17}H_{34}O_2$. The compound solidified at 53° C. He commented on the changeability of the silver salt in the presence of moisture and light; ~~has~~ prepared a number of salts, and also the substance, "Daturon", ($C_{16}H_{33}COC_{16}H_{33}$) by distillation of the acid with caustic lime.

The occurrence of this acid was doubted by Armand[25], who maintained that it was a mixture of palmitic and stearic acids. Von Gerhardt claimed to have shown its uniformity ~~of the acid~~ by the fractional recrystallization of the acid, its alkyl esters and salts. After regeneration from the esters and salts, it melted definitely at 54.5° C., whereas a mixture of palmitic and stearic acid, when submitted to the same treatment, yielded fractions melting anywhere from 55.5° to 63° C.

H. Nordlinger[26] in 1892 found palmitic and stearic acids among the fatty acids of palm oil and also, by fractional precipitation and distillation in vacuo, an acid possessing the formula - $C_{17}H_{34}O_2$, and which melted at 57° C. It distilled at 223-225° C. under 15 mm. pressure. He considered it to be identical with the Daturic Acid of Gerhardt.

Holde and Stange[27] in 1901 discovered in olive oil an acid of the constitution $C_{17}H_{34}O_2$, which, although it was not obtained in a perfectly pure state, they considered to be identical with Daturic Acid. These investigators affirm, however, that by exhaustive fractional precipitation of the acid with magnesium acetate, various fractions were obtained from a consideration of which it was very probable that the original acid consisted of a mixture of palmitic acid and two isomeric acids of the formula $C_{17}H_{34}O_2$. Holde[28], however, retained it for further study.

In the year 1904, Kreis and Haffner[29] in their publication, "On the naturally occurring and synthetically prepared mixed fatty acid glycerides", claimed that they obtained from hog fat an acid containing seventeen carbon atoms in its molecule. They exercised great care in the purification and determination of the acid, which melted at 55.5° C. Since they were undecided however, whether it was identical with Gerhardt's Daturic Acid, they named it Heptadecylic Acid.

In 1905, Holde[30] published the results of his investigation concerning the naturally occurring Heptadecylic Acid (Margaric Acid), which he exhaustively studied over a period of two years. He writes that, since the Heptadecylic Acid occurring in nature differs considerably from that prepared synthetically in melting point, the former melting at 53-57° C. and the latter at 59.9° C., there must at least be three or four iso-acids. This result would be surprising, owing to the fact that all acids of this type, whether of high or low molecular weight, possess a normal carbon chain. He investigated the margaric acid of Gerhardt, Kreis and Haffner, Nordlinger, and that obtained from Olive Oil. From the work of Holde, it would appear, according to Bomer, that, for the time being the assumption that Heptadecylic Acid occurs naturally, is not justified.

The facts concerning the supposedly naturally occurring Heptadecylic (margaric acid) which were brought to the fore by Holde's work, are the following:-

(1) Heptadecylic Acid from Olive Oil

The fractional precipitation gave, in fifteen series of fractionations, at first, a few fractions which agreed in melting point and molecular weight with Heptadecylic Acid. In the later fractions there was proved the presence of almost pure palmitic acid (melting point 61.8° C., molecular weight 256.3), stearic acid, and an acid of higher molecular weight (greater than 290) and melting at 74-76° C. He also obtained directly from olive oil an acid melting at 72-72.8° C. possessing a molecular weight of 368.7.

(2) The Heptadecylic Acid of Kreis and Haffner

By repeated precipitation of the magnesium salt of this specimen, Holde showed the presence of stearic acid, and hence it represented a mixture.

The Heptadecylic Acid of Gerhardt

(3) Holde stated that the proof of Gerhardt for the uniformity of this sample was not free from objection. New experiments performed by the former investigator, in which he employed

60 grams of acid freshly prepared from Datura Oil, demonstrated the fact that in the constant melting and apparently uniform fraction, the molecular weight of which corresponded to the formula - $C_{17}H_{34}O_2$, there was present an acid of higher molecular weight.

4. Nordlinger's Heptadecylic Acid

From 320 grams of acid from palm oil, by a series of fifteen fractional distillations and a subsequent fractional precipitation in four series, there apparently could be separated no trace of a homogeneous acid with the melting point at 56° C and a molecular weight of 270.

The leading points established by Heintz[31] in his researches, were the following:-

(a) All the acids obtained in the saponification of fats contain an even number of carbon atoms in their molecule.

(b) The margaric acid of most chemists is separable into palmitic and stearic acids.

(c) Fatty acids may be mixtures, and not definite compounds, even though neither their composition nor melting point can be altered by recrystallization.

(d) Such mixtures may, however, be resolved into the various components by partial precipitation.

(e) They differ from pure acids as regards their melting point and mode of solidifying.

Heintz has, moreover, determined with accuracy the melting point, composition, and many other properties of the fatty acids, and has also drawn up tables of constants of mixtures of fatty acids of known composition. Frem these, and the investigations of other chemists, the results of which were subsequently published, it appears that the nature of the bodies described as margaric acid was probably as follows:-

1. Margaric Acid of Chrevreul

This, according to Heintz, is to be regarded as a mixture of 90 percent of palmitic acid and 10 percent stearic acid, which is probable from the circumstance that it crystallizes in needles on cooling. Of similar nature, no doubt, are - the margaric acid of Varrentrapp, obtained from human fat; that from goose fat by Gottlieb; from shea-butter by Thomson and Wood, and many others.

During his investigation of the properties of margaric acid, Dr. R. F. Ruttan demonstrated the fact that a mixture of nine parts of palmitic acid and one part of stearic acid behaves very similarly to margaric acid in its general deportment. This similarity extends even to quantitative relationships.

2. Margaric Acid of Bromeis

The acid obtained by oxidation of stearic acid is undecomposed stearic acid, which owes its lower melting point to association with volatile acids.

Respecting the margaric acid which is obtained from impure oleic acid by the action of nitric acid, the following is significant, viz:- that strong nitric acid attacks oleic acid with violence, with the evolution of red nitrous vapours, and producing volatile acids of the series $C_nH_{2n}O_2$, viz:- acetic propionic, butyric, valeric, caproic, oenanthylic, caprylic, pelargonic and capric acids, and fixed acids of the series $C_nH_{2n-4}O_2$; viz:- suberic, pimelic, adipic, lipic and azelaic acids, the number and proportion of these varying with the duration of the action.

3. Margaric Acid of Redtenbacher and Varrentrapp

That of Redtenbacher was obtained by the dry distillation of stearic acid, when, according to Heintz, most of the stearic acid passes over unchanged.

That of Varrentrapp, obtained by the dry distillation of beef-suet, hog's lard, olive oil, or crude oleic acid, doubtless varied in composition according to the nature of the fat employed.

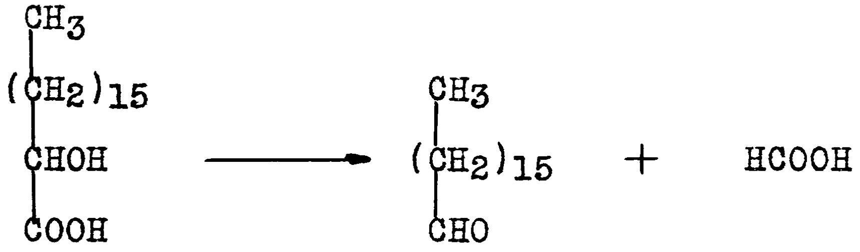
4. Anderson's Margaric Acid

This acid was obtained, together with sulphydric acid,[33] odmyl and other products, by the dry distillation of almond oil with sulphur. Apparently it was palmitic acid formed by the decomposition of oleic acid.

5. Margaric Acids of Poleck, Lewy and Others

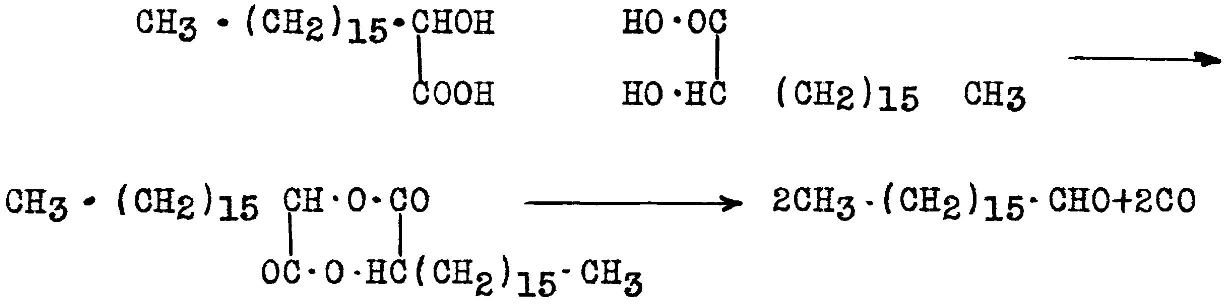
These acids were obtained by the dry distillation of wax and, doubtless, consisted of palmitic acid, more or less pure.

In 1904, H. Rondel Le S Lueur[34] synthesized margaryl aldehyde, $C_{16}H_{33}CHO$, by heating α hydroxy stearic acid obtained by the saponification of α brom stearic acid. By oxidation of this aldehyde he obtained a small quantity of margaric acid and prepared some of its salts. The aldehyde may be regarded as being formed directly from the α hydroxy acid, -



$$\begin{array}{l} CH_3 \\ | \\ (CH_2)_{15} \\ | \\ CHOH \\ | \\ COOH \end{array} \longrightarrow \begin{array}{l} CH_3 \\ | \\ (CH_2)_{15} \\ | \\ CHO \end{array} + HCOOH$$

or through the lactide, -



$$\begin{array}{l} CH_3\cdot(CH_2)_{15}\cdot CHOH \\ \qquad\qquad\quad | \\ \qquad\qquad\quad COOH \end{array} \quad \begin{array}{l} HO\cdot OC \\ \qquad\ | \\ HO\cdot HC \end{array} (CH_2)_{15}\ CH_3 \longrightarrow$$

$$\begin{array}{l} CH_3\cdot(CH_2)_{15}\ CH\cdot O\cdot CO \\ \qquad\qquad\quad |\qquad\ \ | \\ \qquad\qquad\quad OC\cdot O\cdot HC(CH_2)_{15}\cdot CH_3 \end{array} \longrightarrow 2CH_3\cdot(CH_2)_{15}\cdot CHO+2CO$$

The principle of this method offers a ready means of passing from an acid of the acetic series to the next lower homologue,

$R.CH_2.COOH \longrightarrow R.CH.Br.COOH \rightarrow R.CH(OH)COOH \rightarrow R.CHO \rightarrow R.COOH$

LeSeur also prepared margaramide, α brommargaric acid and α hydroxymargaric acid.

H. Meyer and A. Eckert[35] in 1910 claimed to have found in coffeeberry oil, one to one and a half percent of an acid, having the formula $C_{17}H_{34}O_2$ and melting at 57 °C., the magnesium salt of which melted at 137-142° C.

In 1912 Meyer and Beer[36] indicated that they had isolated from Datura Oil itself, a heptadecylic acid which they claimed to be identical with Krafft's synthetical margaric acid.

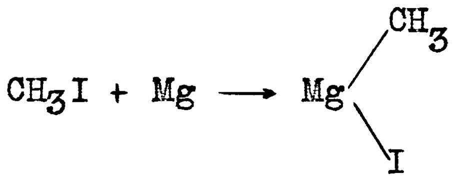
There is still no satisfactory evidence, however, of the occurrence in natural fats of acids with an odd number of carbon atoms.

We are indebted to Dr. R. F. Ruttan[37] for the development of the first practical method for the preparation of margaric acid in quantity.

Dr. Ruttan synthesized margaric acid conveniently and directly by an application of the Grignard reaction, determined a large number of its properties and has made a detailed comparison between the properties of margaric, palmitic and stearic acids. He has also prepared the margaryl esters of ethylene and propylene glycol and determined their properties.

Due to the circumstance that margaric acid employed in this investigation was prepared by Dr. Ruttan's modification of the Grignard reaction, it would appear advisable to review the salient features of this reaction, insofar as they bear upon the problem under consideration, before setting down in detail the method employed in the preparation of margaric acid.

Grignard[38] made the important observation that one molecular weight of monobrom and monoiodo derivatives of different hydrocarbons unite with one atomic weight of magnesium in the presence of absolute ether e.g.,



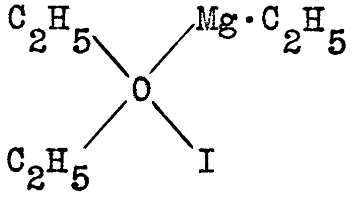
$$CH_3I + Mg \longrightarrow Mg\begin{matrix} \diagup CH_3 \\ \diagdown I \end{matrix} \qquad (1)$$

methyl magnesium iodide

With long carbon chains in the aliphatic series, saturated hydrocarbons are also formed, and the longer the chain the more readily will this reaction take place. With molecules containing six or more carbon atoms, the reaction consists largely in the removal of halogen and the formation of the hydrocarbon,

$$2\ C_6H_{13}Br + Mg \longrightarrow MgBr_2 + C_{12}H_{26} \qquad (2)$$

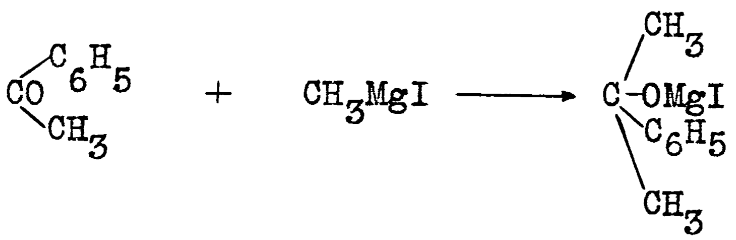
In an analagous way are formed C_6H_5MgBr, phenyl magnesium bromide and C_6H_5MgI, phenyl magnesium iodide, etc. Since these compounds are formed only in the presence of ether as a solvent, it appears probable that the ether not only serves as a solvent, but also plays an essential part in the reaction. In point of fact, a compound $C_2H_5MgI + (C_2H_5)_2O$ has been isolated which may be regarded as an oxonium derivative, -



The alkyl magnesium haloids or their ether derivatives are soluble in ether. On account of their unusual reactivity they may be used generally for the synthetical preparation of a large number of compounds.

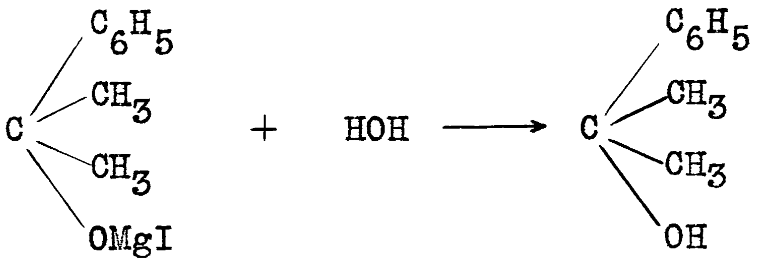
To illustrate two important types of reactions which are concerned in the synthesis which will be described later, we may consider the following:-

When acetophenone is subjected to the Grignard reaction, a tertiary alcohol is formed. The first stage of the reaction would be, -



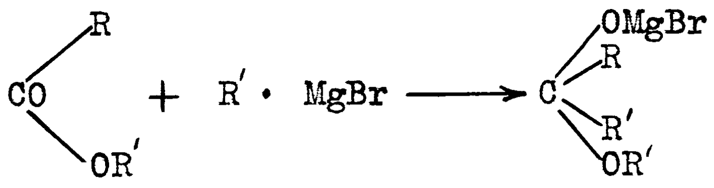
(3)

Then, on treatment with water or acids the MgI residue is substituted by hydrogen, -



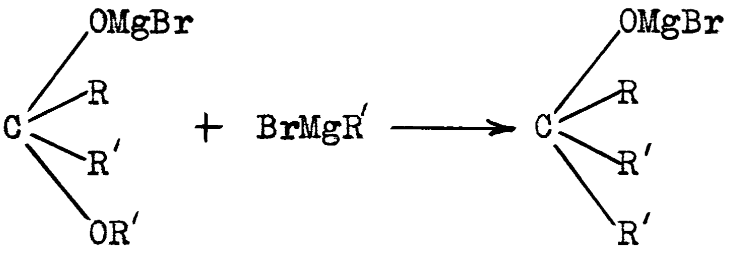
(4)

The esters of mono and polybasic carbonic acids also react readily with alkyl magnesium haloids with the formation of alcohols. In this case, two molecules of the magnesium compound react with one molecule of the ester, i.e.,



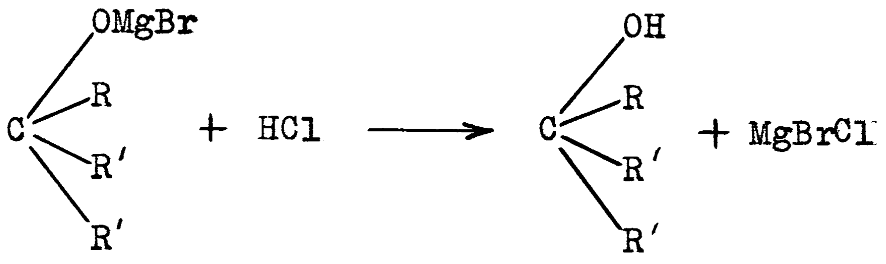
(5)

The next stage consists in the interaction of the product so formed with another molecule of alkyl magnesium haloid,



(6)

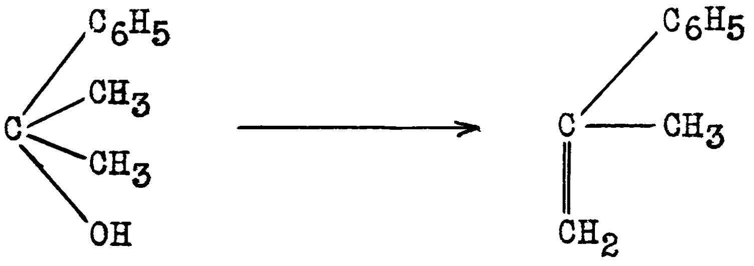
Then by removal of the MgBr residue by the action of an acid there is obtained the tertiary alcohol.



(7)

The reaction consists essentially in the replacement of the carbonyl oxygen of the corresponding free acid by two univalent hydrocarbon residues.

Tertiary alcohols possess the property of readily losing the elements of water, producing unsaturated or ethylene hydrocarbons, e.g., phenyl dimethyl carbinol loses the elements of water in the following manner;-



In the preparation of alcohols by means of the Grignard reaction, these unsaturated bodies may be produced either as by-products or may manifest themselves as the main products of the reaction.

When alkyl magnesium haloids are treated with dry carbon dioxide, the latter is absorbed, i.e., -

$$RMgI + CO_2 \longrightarrow R.COOMgI \qquad (8)$$

By the action of acids on the compounds so formed, carbonic acids are produced. -

$$R.COOMgI + HCl \longrightarrow R.COOH + MgICl \qquad (9)$$

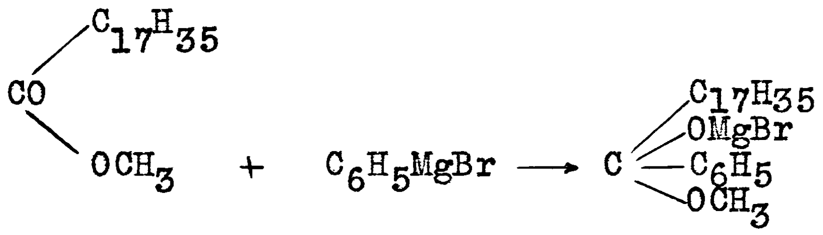
In the present investigation margaric acid was prepared by the method devised by Dr. R. F. Ruttan. Among the numerous applications of this reaction comparatively few studies have been made of the action of carbon dioxide upon the magnesium haloid compounds in the Grignard reaction. Dr. Ruttan was interested in ascertaining whether cetyl iodide would, with the constituents of the Grignard reaction, take up carbon dioxide and produce margaric acid. It seemed probable from Grignard's researches that magnesium, in the presence of anhydrous ether, would unite with cetyl iodide to produce the organo-metallic compound $C_{16}H_{33}MgI$ (Reaction 1), and this might absorb CO_2 (Reaction 8), and form such an intermediate unstable compound as $C_{16}H_{33}COOMgI$, which on acidification with hydrochloric acid would give margaric acid, $C_{16}H_{33}COOH$ (Reaction 9).

After a few preliminary experiments, Dr. Ruttan devised a method by which the Grignard reaction was applied as described above, and which gave 60-70 percent of the of the theoretical yield of margaric acid. The chief difficulty was found, not in obtaining the reaction, but in separating the acid from the other constituents resulting from the reaction.

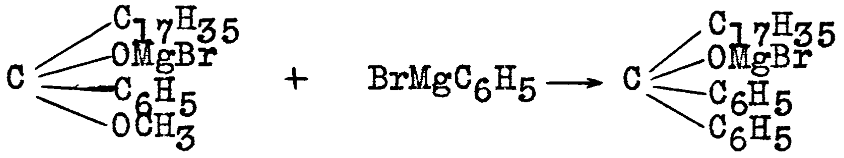
Another method of preparation of margaric acid is the following.[38a] This synthesis also depends upon certain properties of the Grignard reagent as embodied in the preceding discussion. Magnesium is allowed to act upon brombenzene in the presence of absolute ether, -

$$C_6H_5Br + Mg \longrightarrow C_6H_5MgBr \qquad \text{Reaction (1)}$$

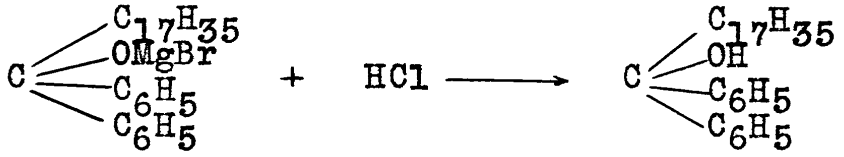
The aryl magnesium haloid so obtained reacts with methyl stearate, -



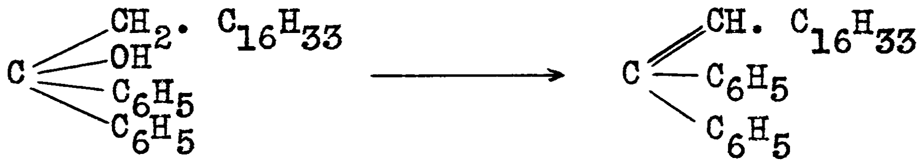
The compound so formed reacts with another molecule of the aryl magnesium haloid, -



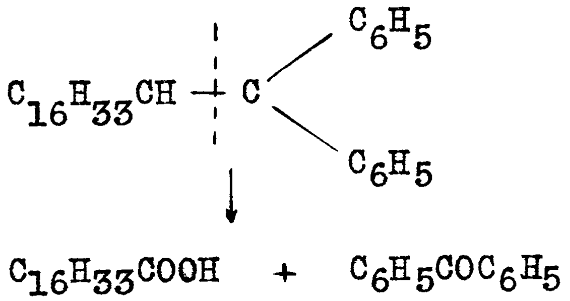
The product is then treated with hydrochloric acid,



This compound is a tertiary alcohol and loses the elements of water to form an unsaturated compound, -



which is hexadecydiphenylethylene. This compound on oxidation with suphuric acid and sodium bichromate assumes three atoms of oxygen and the molecule is ruptured at the double bond, with the production of benzophenone as a by-product, and margaric acid, according to the reaction, -

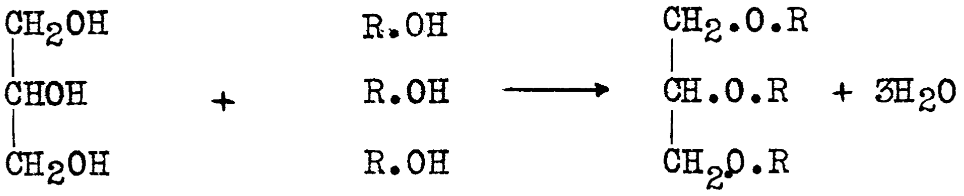


$$C_{16}H_{33}COOH + C_6H_5COC_6H_5$$

Margaric Acid Benzophenone

The Chemical Constitution of Fats

Fats are the products of the chemical combination of glycerol and fatty acids. Glycerol, being a tryhydric alcohol, and consequently deporting itself like a trihydric base, is capable of combining with three radicals of fatty acids, as illustrated in the following equation, in which "R" represents any fatty acid residue:-



$$\begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + \begin{array}{l} R.OH \\ \\ R.OH \\ \\ R.OH \end{array} \longrightarrow \begin{array}{l} CH_2.O.R \\ | \\ CH.O.R \\ | \\ CH_2O.R \end{array} + 3H_2O$$

The resulting compounds are termed "triglycerides" or "neutral glycyl esters", and may be compared to neutral salts. Therefore, the triglycerides are also termed "neutral fats", and the nomenclature employed for salts has been adopted for them by some authors. Thus we speak of glyceryl stearate, glyceryl margarate or stearic glyceride and margaric glyceride.

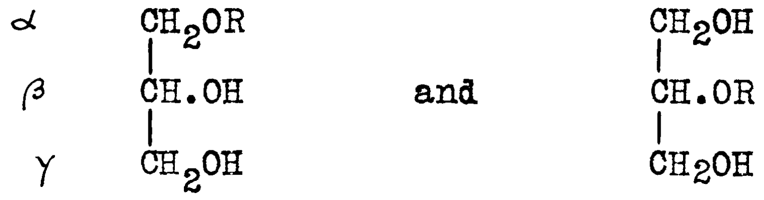
This constitution of fats has been established by the classical researches of Chevreul.

Adopting this constitution of neutral fats, theory predicts the possible existence of monoglycerides and diglycerides in which, respectively, only one or two acid residues are present in the molecule of the fat.

In nature, apparently, only the triglycerides occur. Mono- and diglycerides are, as a rule, not met with in freshly prepared fats.

Monoglycerides

These compounds have the general formula $C_3H_5.OR(OH)_2$, R having the same significance as previously indicated. According to the position which the fatty acid radicle occupies in the molecule, two isomeric monoglycerides are theoretically possible, i.e. -



$$\begin{array}{ll} \alpha & CH_2OR \\ & \quad | \\ \beta & CH.OH \\ & \quad | \\ \gamma & CH_2OH \end{array} \quad \text{and} \quad \begin{array}{l} CH_2OH \\ \quad | \\ CH.OR \\ \quad | \\ CH_2OH \end{array}$$

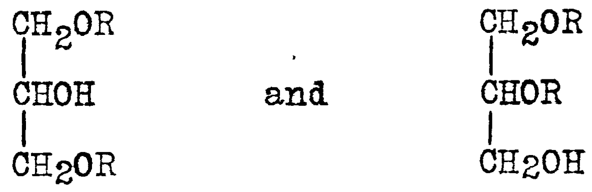
It will be observed from a consideration of the formulae, that the α and γ positions are identical. Compounds corresponding to the first formula are denoted α monoglycerides.

They contain an asymmetric carbon atom and may, therefore, represent racemic compounds.

Monoglycerides in which the fatty acid radicle is attached to the carbon atom occupying the central position are known as β monoglycerides and are symmetrical in structure.

Diglycerides

These glycerides possess the general formula $C_3H_5(OR)_2OH$. Theoretically there are two possible isomeric modifications of diglycerides, according as the two fatty acid radicles are adjacent, i.e., attached to the carbon atoms in the α and β position, or to the two terminal carbon atoms in the α and γ positions. The $\alpha\beta$ and $\beta\gamma$ modifications are structurally identical. This is illustrated by the following formulae, -

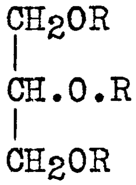


$$\begin{array}{l} CH_2OR \\ | \\ CHOH \\ | \\ CH_2OR \end{array} \quad \text{and} \quad \begin{array}{l} CH_2OR \\ | \\ CHOR \\ | \\ CH_2OH \end{array}$$

The compounds conforming to the first formula are denoted $\alpha\gamma$ and the second $\alpha\beta$ diglycerides, or simply α diglycerides and β diglycerides. Those of the second type possess an asymmetric carbon atom and, hence, may represent racemic compounds.

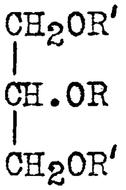
Triglycerides

Theory predicts the existence of two main classes of triglycerides according to whether all three fatty acid radicles in the molecule have the same or different composition. Those possessing the former configuration are known as "simple triglycerides", whereas the latter are suitably denominated "mixed tryglicerides". Of the former class only one representative can exist for each fatty acid, namely, -



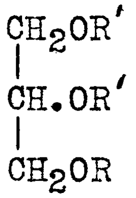
$$\begin{array}{l} CH_2OR \\ | \\ CH.O.R \\ | \\ CH_2OR \end{array}$$

There are, however, two isomeric triglycerides of the second type, one having a symmetrical and the other an unsymmetrical structure, -



$$\begin{array}{l} CH_2OR' \\ | \\ CH.OR \\ | \\ CH_2OR' \end{array}$$

and



$$\begin{array}{l} CH_2OR' \\ | \\ CH.OR' \\ | \\ CH_2OR \end{array}$$

For a long time most of the natural fats were considered to consist of mixtures of simple triglycerides of the fatty acids, although Berthelot[386] had pointed out that the complexity of the natural fats and oils might be best explained by the existence of mixed glycerides.

The first mixed triglyceride to be isolated was an oleodistearin, obtained by Heise from Mkanyi fat and from Kokum butter, and stated also to occur in cacoa butter (Fritsweiler[39]) and in Borneo tallow (Klimont[40]). Hansen[41] in 1902 separated from mutton tallow by repeated recrystallizations from ether products which he regarded as a palmitodistearin and a stearodipalmitin. Kreis and Hafner[42] in 1903 also obtained a β—palmitodistearin from beef fat, from mutton fat and from lard[43]. More recently Bomer has carried out some praiseworthy pieces of work, in which he has subjected mutton tallow, beef tallow and lard to laborious fractional crystallizations, and, as a result, has isolated what he regards as homogeneous products, representing from beef fat[44] and from mutton fat[45] stearodipalmitin, palmitodistearin and tristearin, and from lard[46] stearodipalmitin and palmitodistearin.

Kreis and Hafner also obtained from lard a product which they regarded as a glyceride of margaric (heptadecylic or daturic) acid. More recent work by Bomer and Limprich[46a], who prepared the triglyceride of margaric acid renders it improbable that Kreis and Hafner's product was in fact trimargarine. It may be remarked that the free acid derived from their material is stated to melt at 55.6°C, whereas the melting point of margaric acid as found by Dr. R. F. Ruttan is 59.9° C.

The preparation of pure glycerides from natural products is a very laborious task and has not always been accomplished satisfactorily, owing to the great difficulty of separating the various triglycerides.

Thus, Duffy[47] on recrystallization of 2000 grams of mutton tallow from large quantities of ether, obtained after thirty-two successive crystallizations, no more than eight grams of substance which even then could not be considered to be pure tristearin.

Again, Krafft[48] showed that whilst trilaurin and trimyristin could be obtained (by fractional distillation in a perfect vacuum) from laurel oil and nutmeg butter, respectively, in such a state of purity that after one recrystallization glycerides of normal melting point are obtained, higher triglycerides underwent decomposition, so that, e.g., pure tripalmitin could not be prepared from Japan wax by this method. Hence, for the preparation of pure triglycerides synthetical methods must be employed.

As already stated, the margarines are the glyceryl esters of margaric acid, and in view of the fact that this relationship expresses chemical constitution, they represent true fats, just as the stearins and palmitins, which are the glyceryl esters of stearic and palmitic acids.

Margaric acid has the formula $C_{17}H_{34}O_2$, and by virtue of its possessing seventeen carbon atoms in the molecule it occupies the position intermediate between palmitic and stearic acids in the fatty acid series.

The fundamental distinguishing characteristic, and the one of prime importance between the margarines on the one hand and the stearins, palmitins or the glyceryl esters of other acids possessing an even number of carbon atoms in their molecule, on the other, is the fact that the latter exist in nature, whereas the margarines do not. It is probably more than a coincidence that odd numbered carbon atom fatty acids do not exist in nature.

The present investigation had for its object the synthesis and determination of the properties of the margarines, that is to say - fats in which the acid radicle consisted solely of margaric acid, and, in addition, the synthesis of various mixed triglycerides containing residues of margaric, palmitic and stearic acids.

The following compounds have been prepared and their more important properties determined; -

α Monomargarine
β Monomargarine
α Dimargarine
β Dimargarine
Trimargarine
α Margaro-β-γ-dipalmitin
α Margaro-β-γ-distearin
β Margaro-α-γ-dipalmitin
β Margaro-α-γ-distearin
α Palmito-β-γ-dimargarine
α Stearo-β-γ-dimargarine
β Palmito-α-γ-dimargarine
β Stearo-α-γ-dimargarine
β Margaryl-α-γ-dichlorhydrin
γ Margaryl-α-β-dibromhydrin
Margaryl-acetone-glycerol

With the exception of Trimargarine none of these compounds have been prepared previously. The following properties of these compounds have been determined, namely, melting point, saponification value, refractive indices at various temperatures, and solubilities in absolute alcohol and ether at 0° C and 15° C.

The synthesis of the margarines is of particular interest in view of the fact that this region of the domain of organic chemistry has hitherto remained unexplored, and, also from considerations applicable to the study of fat metabolism, and, consequently, also to the disease of diabetes.

When fats are introduced into the animal organism, cleavage of the molecule takes place with the separation of the fatty acid and glycerol. The fatty acid then undergoes oxidation on the beta carbon atom.

Palmitic acid has the formula $C_{16}H_{32}O_2$ or,

$$CH_3.\ (\ CH_2\ )_{12}.\ CH_2.\ CH_2.\ COOH$$

and oxidation on the beta carbon atom gives rise to the follow- compound,

$$CH_3.\ (\ CH_2\ )_{12}.\ CO.\ CH_2.\ COOH$$

Acid hydrolysis then takes place with the production of myristic and acetic acids, in the following manner,

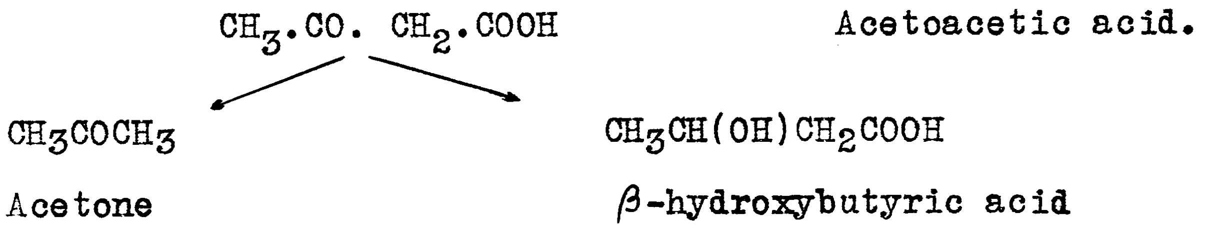
$$CH_3.\ (\ CH_2\ )_{12}.\ CO.\ CH_2.\ COOH$$

$$CH_3.\ (\ CH_2\ )_{10}.\ CH_2CH_2\ COOH\ +\ CH_3.\ COOH$$

Oxidation again occurs on the beta carbon atom, followed by acid hydrolysis, whereupon is obtained lauric and acetic acids.

$$CH_3.\ (\ CH_2\ ).{}_8.CH_2.\ CH_2.\ COOH\ +\ CH_3.COOH$$

This process continues through the acids capric, caprylic, caproic, butyric and acetoacetic acid. The latter breaks down into acetone and β hydroxybutyric acid, in the following manner, -



$CH_3.CO.\ CH_2.COOH$ Acetoacetic acid.

CH_3COCH_3 Acetone

$CH_3CH(OH)CH_2COOH$ β-hydroxybutyric acid

Due to the fact that Knoop in 1905 indicated that this process was involved in fat metabolism, it is known as the "Beta Oxidation Theory of Knoop".

The compounds, CH_3COCH_3, CH_3COCH_2COOH, and $CH_3CH(OH)CH_2COOH$ are known as acetone bodies.

Diabetes is one of the more common ailments of man. The diabetic is not capable of assimilating starches and sugars. The fats are partially digested in the diabetic organism, but there is formed the objectionable group of acids containing four carbon atoms, butyric, oxybutyric and acetoacetic acids. It is this latter which breaks down to form acetone, which shows in the breath and urine of diabetics. The presence of these acids gives rise to acidosis (ketosis), and this condition is accompanied by diminished ability of the blood to absorb CO_2 and carry it to the lungs for elimination. When death occurs, it is ordinarily due to acidosis and is generally preceded by a state of coma. Acidosis is due to the incomplete metabolism fats.

In a normal individual when the fats are digested they are oxidized to carbon dioxide and water. In the diabetic the fat is partially burned in the system but the process stops at the four carbon atom acid particularly acetoacetic acid.

According to the beta oxidation theory of Knoop, if one would start not with a fat containing a fatty acid of even number of carbon atoms ($C_{18}H_{36}O_2$) but with an acid containing an odd number of carbon atoms ($C_{17}H_{34}O_2$, Margaric Acid) there should not be obtained on digestion an acid containing four carbon atoms, that is, the objectionable acetoacetic acid.

These principles are involved in the preparation of Intarvin, which is claimed to be essentially glyceryl margarate, $C_3H_5(C_{17}H_{33}O_2)_3$, a product developed by Dr. Max. Kahn.[49]

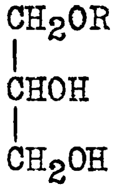
Trials of this artificial fat showed that it could be digested by diabetic patients without difficulty and that there were no undesirable effects. The patient promptly lost the acidosis of the blood, the gnawing hunger, and improved in general mental and physical health.

It has been pointed out, however, by Hurtley (1916),[49a] who has made a careful analysis of available data, including those from his own valuable investigations of diabetic patients, that there is no absolutely direct proof that the β-hydroxybutyric acid and acetoacetic acid, together with acetone which arises from the hydrolysis of the latter, which are found normally in such cases, are derived from fat. There is, however, a considerable amount of indirect evidence. Normal, healthy individuals excrete a small amount of acetone in the urine, usually less than 100mgrms. in twenty-four hours. The amount increases when large amounts of fats are taken,and butter fat appears to cause the greatest increase. The increases are, however, not great, the absolute amount of acetone excreted represents only a minute fraction of the fat given, and in some cases no increase has been obtained. Other evidence in favour of the origin of "acetone bodies" from fat comes from a quantitative study of the excretion of these substances in severe diabetes. This was first carried out by Magnus Levy (1901), and the results have been extended and confirmed by others. The amount of carbon in the "acetone bodies" excreted over a given period is sometimes greater than that of the carbon in the protein catabolised during the same time, so that the whole of these substances cannot arise from protein. But it is well established that in severe cases of diabetes such as Magnus Levy investigated, a considerable amount of the protein which is catabolised gives rise to the formation of glucose, so that only a part is left for "acetone body" formation. The evidence for the participation of fat in the formation of these substances is therefore strengthened. Some collateral evidence on this point has been furnished by the publication of Kahn (1923), which has already been referred to. The latter investigator found that trimargarine is absorbed to the extent of about 95 percent. Sevringhaus (1924) has, however, not been able to find any diminution of "acetone body" excretion when glyceryl margarate in amounts up to 100 grms. daily was taken by a normal person who was excreting acetone bodies owing to a deficiency of carbohydrate in the diet. The results of further experiments on this interesting and important question will be awaited with interest.

CRITIQUE OF THE SYNTHETICAL METHODS FOR THE PREPARATION OF GLYCERIDES

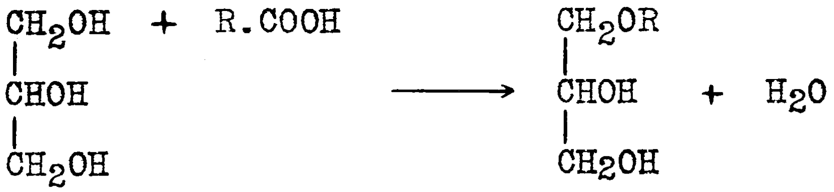
Reviewing, insofar as they bear on the present problem, the synthetical methods which have been employed for the preparation of glycerides, simple and mixed, the following discussion embodies the salient features.

α Monoglycerides



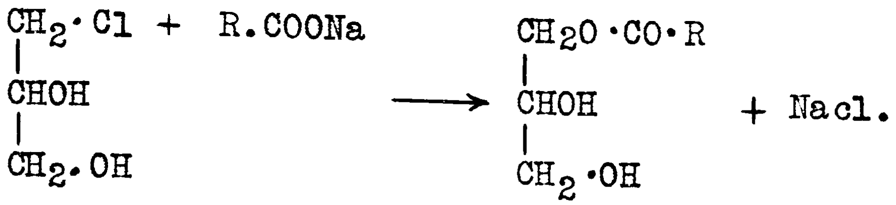
$$\begin{array}{l} CH_2OR \\ | \\ CHOH \\ | \\ CH_2OH \end{array}$$

Berthelot's[50] classic method consisted in heating together the fatty acid with an excess of glycerol in a sealed tube.



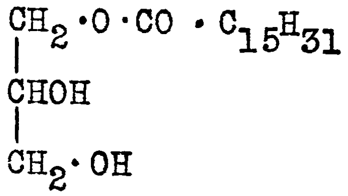
$$\begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + R.COOH \longrightarrow \begin{array}{l} CH_2OR \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + H_2O$$

Inasmuch as it is difficult to control the reaction in such a manner that only a monoglyceride (without any diglyceride) be formed - Romburg[51], Guth[52], and Krafft[53], mixed equivalent quantities of α monochlorhydrin or bromohydrin with the finely powdered sodium salt of the fatty acid and heated the mixture to a relatively high temperature, i.e., -



$$\begin{array}{l} CH_2\cdot Cl \\ | \\ CHOH \\ | \\ CH_2\cdot OH \end{array} + R.COONa \longrightarrow \begin{array}{l} CH_2O\cdot CO\cdot R \\ | \\ CHOH \\ | \\ CH_2\cdot OH \end{array} + Nacl.$$

In the preparation of α monopalmitin,



$$\begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{15}H_{31} \\ | \\ CHOH \\ | \\ CH_2\cdot OH \end{array}$$

Krafft heated together two molecular equivalents of potassium palmitate and one part of monochlorhydrin for several hours at a temperature of 180-190° C. The product, after cooling, was extracted with ether, recrystallized from isobutyl alcohol and separated from the last traces of di- and tripalmitin by recrystallization from hot benzene.

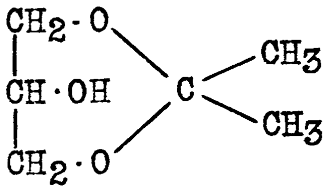
Fischer[54], synthesized α monoglycerides utilizing acetone-glycerol or isopropylidene-glycerol as a starting point.

In view of the fact that this method was utilized in the present investigation for the preparation of α monomargarine, it is advisable at this point to discuss the theoretical considerations involved.

Isopropylidene-glycerol is a condensation product of glycerol and acetone. Its structure has been elucidated by Irvine, MacDonald and Soutar[55].

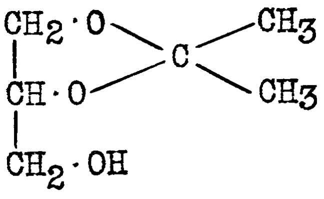
Definite condensation compounds of polyhydric alcohols with acetone or benzaldehyde were first isolated by Fisher in the course of his earlier work in the sugar group and a considerable amount of research has been devoted to elucidate the structure of the substances thus produced. Owing to the extreme ease with which they are hydrolysed into their components (an instability emphasized in the course of Fischer's papers), it was a matter of some difficulty to obtain direct experimental evidence bearing on this question. Irvine, MacDonald and Soutar carried out an investigation which had as its original object a study of the condensation of glycerol with acetone and benzaldehyde, evidence regarding the mechanism of this reaction being highly desirable in view of the nature of their work in the sugar group. In the earlier speculations on this subject, it was recognized that on account of its relatively simple structure, glycerol is an extremely suitable compound in which to study the reaction in question, particularly as the hydroxyl groups do not differ widely in their reactivity.

As indicated by Fischer, the isopropylidene glycerol (acetone-glycerol) formed by the interaction of glycerol and acetone in the presence of a catalyst, may possess either of the structures



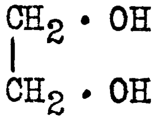
(10)

or



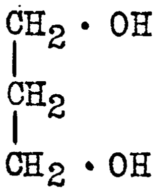
(11)

and no other alternatives need be considered. From the fact that ethylene glycol



$$\begin{array}{l} CH_2\cdot OH \\ | \\ CH_2\cdot OH \end{array}$$

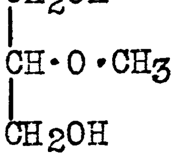
fails to react with ketones, whilst trimethylene glycol



$$\begin{array}{l} CH_2\cdot OH \\ | \\ CH_2 \\ | \\ CH_2\cdot OH \end{array}$$

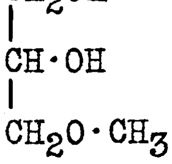
gives a positive result, the opinion has been expressed that the condensation involves hydroxyl groups attached to β carbon atoms and that, accordingly, isopropylidene glycerol should be represented by formula (10) . In the case of compounds formed with difficulty and hydrolysed with extraordinary ease, negative evidence of this nature is not conclusive, and ultimately the entire question of constitution was left quite open by Fischer, who termed the compound "acetone-glycerol".

The methylation process adopted by Irvine and his co-workers offered a ready means of solving the problem. By methylation and subsequent hydrolysis, compounds constituted according to formulae (10) and (11) should yield respectively β or α monomethyl ethers of glycerol, formulae (12) and (13)



$$\begin{array}{l} CH_2OH \\ | \\ CH\cdot O\cdot CH_3 \\ | \\ CH_2OH \end{array}$$

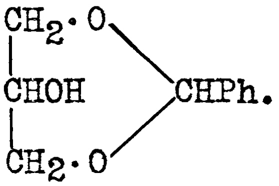
(12)

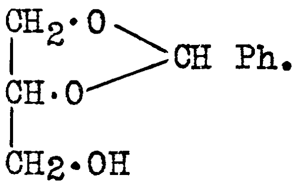


$$\begin{array}{l} CH_2OH \\ | \\ CH\cdot OH \\ | \\ CH_2O\cdot CH_3 \end{array}$$

(13)

and, of course, a similar series of reactions should be applicable to benzylidene-glycerol, and thus discriminate between the two formulae -


(14)


(15)

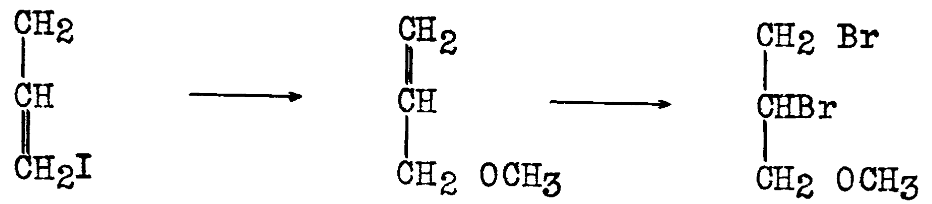
and as a consideration of this compound is contributory to the final proof of the structure of acetone-glycerol,we shall discuss it later.

On methylating isopropylidene-glycerol by the silver oxide reaction (methyl iodide and silver oxide), these investigators discovered that only one methyl group could be introduced and the product obtained consisted of the corresponding monomethyl ether (b.p.57 C/13 mm). This result disposed of all structural schemes based on the reaction of acetone in the enolic modification. Hydrolysis of the isopropylidene-glycerol methyl ether yielded glycerol-mono-methyl ether (b.p.110-111 C/13 mm), and Irvine, MacDonald and Soutar directed their effort to the allocation of the methyl group in this compound.

This was by no means an easy task. C. F. Boehringer and Sohne[56] have described and patented a glycerol-methyl ether, but the description is imperfect and according to Irvine and his collaborators the physical constants quoted are evidently rough approximations unsuitable for the purposes of comparison and identification of the compound. If, as these investigators suspected, the methylated glycerol obtained from isopropylidene-glycerol corresponded with formula (13) the compound possesses an asymmetric carbon atom and should be capable of resolution into active forms, and with this object in view, they attempted to prepare an acid phthalate according to the method of Pickard and Kenyon[57]. In the case of a glycol, such as glycerol methyl ether, condensation with phthalic anhydride may give rise to several compounds, and Irvine failed to isolate a pure product or to obtain satisfactory alkaloidal salts. Accordingly, he attempted an alternative process. By condensation of a dl-glycol with an active ketone two compounds should result, which should be separable by recrystallization. From these in turn, by the action of hydrolysts, the active glycols should be regenerated. In the case of glycerol methyl ether, the desired reaction was carried out with laevo-menthone and with camphor, but in each case the products were liquids and, therefore, useless for the particular object in view.

Recourse was, therefore, had to synthetical and decomposition methods of determining the constitution of the methylated glycerol. Starting from allyliodide (16) the corresponding methyl allyl ether (17) was prepared and converted into β-γ-dibromo-α-methoxy propane (18).

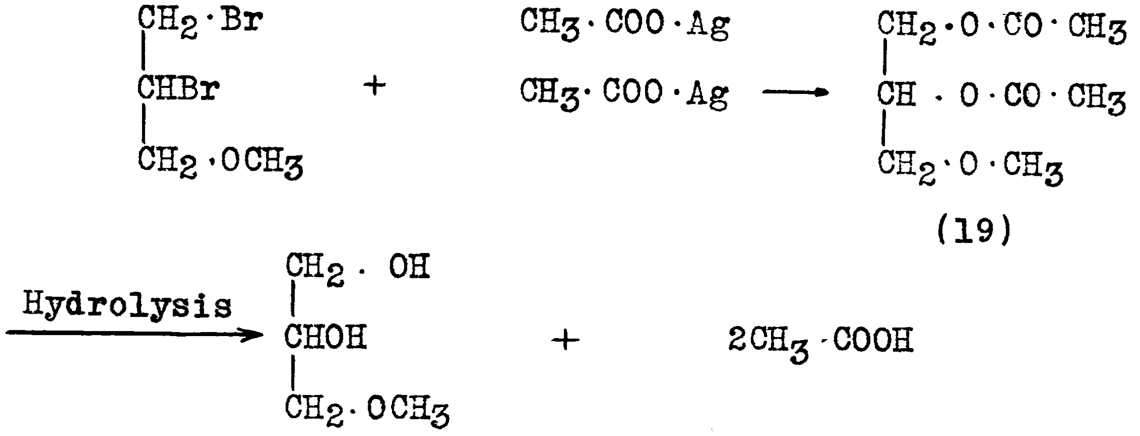
The reaction is as follows;-



$$\begin{array}{l}CH_2\\ |\\ CH\\ \Vert\\ CH_2I\end{array} \longrightarrow \begin{array}{l}CH_2\\ \Vert\\ CH\\ |\\ CH_2\ OCH_3\end{array} \longrightarrow \begin{array}{l}CH_2\ Br\\ |\\ CHBr\\ |\\ CH_2\ OCH_3\end{array}$$

(16) (17) (18)

The replacement of the halogen atoms in this compound could not be accomplished directly, but by the action of silver acetate the bromide was converted into β-γ-diacetin methyl ether (19) which on hydrolysis yielded glycerol α methyl ether (20)



$$\begin{array}{l}CH_2\cdot Br\\ |\\ CHBr\\ |\\ CH_2\cdot OCH_3\end{array} + \begin{array}{l}CH_3\cdot COO\cdot Ag\\ CH_3\cdot COO\cdot Ag\end{array} \longrightarrow \begin{array}{l}CH_2\cdot O\cdot CO\cdot CH_3\\ |\\ CH\cdot O\cdot CO\cdot CH_3\\ |\\ CH_2\cdot O\cdot CH_3\end{array}$$

(19)

$$\xrightarrow{\text{Hydrolysis}} \begin{array}{l}CH_2\cdot OH\\ |\\ CHOH\\ |\\ CH_2\cdot OCH_3\end{array} + 2CH_3\cdot COOH$$

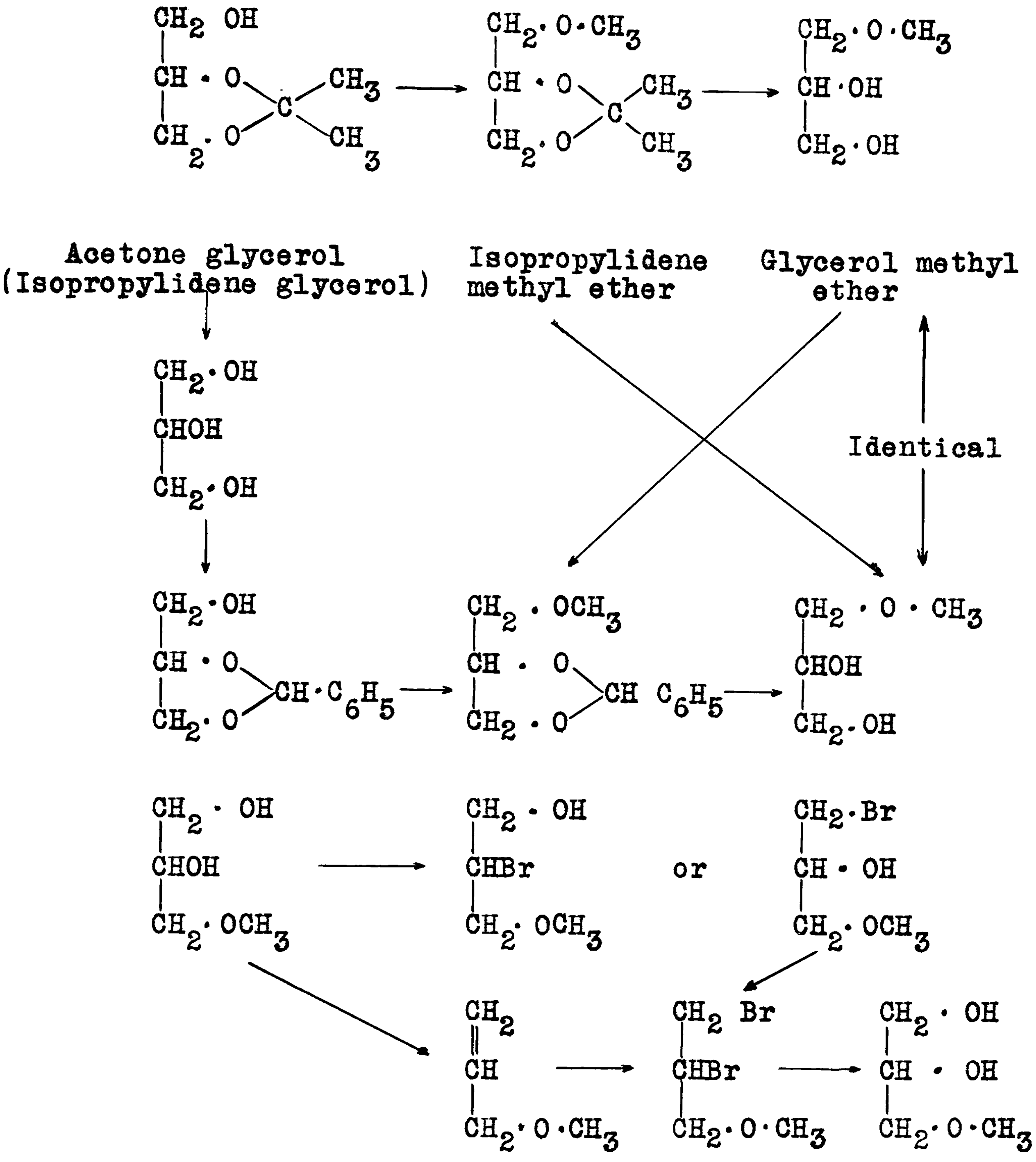
(20)

This product proved to be identical with the methylated glycerol obtained from isopropylidene glycerol, the constitution of the latter compound being thereby solved. To obtain confirmatory evidence the glycerol methyl ether derived from the isopropylidene compound was heated with excess of anhydrous oxalic acid, and thus converted into methyl allyl ether, from which in turn, the corresponding dibromide was prepared. The specimen isolated was identical in every respect with that obtained as described above from allyl iodide, the identity being established by boiling point determinations at different pressures, the valuation of refractive index, density and molecular refraction.

The proof that benzaldehyde condenses with glycerol in precisely the same manner as does acetone, was arrived at in the course of a parallel series of reactions performed by the same investigators. Benzylidene-glycerol, prepared by the process patented by Gerhardt[58] gave, on methylation, benzylidene glycerol methyl ether. and this, on hydrolysis, was converted into a glycerol methyl ether, which proved to be identical with the mono methyl ether prepared through the agency of isopropylidene glycerol.

Further confirmatory evidence of the structure of this compound was obtained in the following manner:-

Glycerol methyl ether derived from the isopropylidene compound, was condensed with benzaldehyde, thus forming benzylidene glycerol methyl ether. Similarly, in a parallel experiment, the methylated glycerol obtained from the original benzylidene compound was successfully condensed with acetone. The respective product proved to be identical with those previously prepared. The schemes of reaction involved in the structural study and in determining the constitution of glycerol α methyl ether and hence of isopropylidene glycerol or acetone-glycerol are summarized as follows:-



Irvine states that, of course, it is possible that isomeric forms of isopropylidene glycerol and of benzylidene glycerol exist in which the substituting residues are attached to the terminal carbon atoms, formulae (10) and (14), and, in this connection, it may be noted that Hornitzki and Menschutkin[59] describe a "benzoglycerol" which is apparently different from Fischer's "benzol glycerin".

There is, however, little doubt that all the compounds described by Irvine are individual substances and not mixtures,as in each preparation involving distillations, fractions were collected at frequent intervals even when the boiling point showed no change. In no case was there any appreciable variation in the refractive indices determined and, as all the compounds described have been prepared on several occasions without any irregularity being observed in the physical constants, it would appear that they are pure substances.

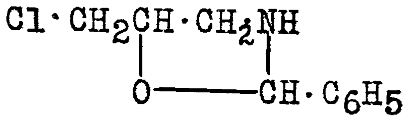
As a result of these investigations, it has been definitely established that isopropylidene glycerol, or acetone glycerol,has the structure shown in formula(11) .

Irvine further claims that,in all probability the methods described by him will be capable of extension to the problems connected with the constitution of fats and glycerophosphates. By alkylation of a mono- or di-glyceride followed by hydrolysis, a glycerol dimethyl, or monomethyl ether should result, and identification of the positions occupied by the alkyl groups would give direct evidence as to the structure of the parent compound. Moreover, much important research on the fats has shown that the hydrolysis of mixed glycerides by acids or enzymes can be controlled to give the intermediate di- and monoglycerides, so that the allocation of definite positions to the acyl groups in the glycerol residue should not be a matter of great difficulty. It would, of course, be necessary as a preliminary to such work, to determine the constants of all the possible methylated glycerols or to obtain derivatives from them suitable for the purpose of identification, and with this object in view, Irvine stated that it was his intention to make a complete examination of the two glycerol monomethyl ethers and of the two corresponding dimethyl ethers so that it would be possible to utilize these substances in determining the structure of mixed glycerides and glycerophosphates.

The "biochemical" synthesis of monoolein by means of pancreas ferment (Pottevin[60]) should be mentioned here. The action of the ferment appears to exhibit the same catalytic nature as the Twitchell reagent[61] possesses. If the latter, which is a sulpho-aromatic compound, be added to a mixture of glycerol and fatty acids, glycerol being in excess and care being taken to remove the water as it is formed, monoglycerides (together with diglycerides) are obtained.

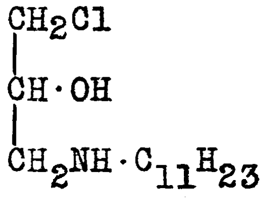
Another synthesis of an α-monoglyceride that is worthy of note, was the preparation of α-monobutyrin by Harriot, who obtained it by allowing lipase to act on a mixture of glycerin and butyric acid.

Bergman[62] synthesizes α monoglycerides using as the initial substance -



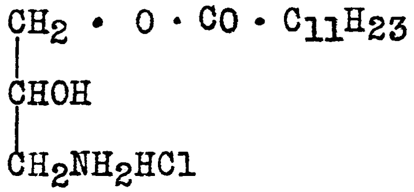
Phenylchloromethyl oxazolidine.

By treating this compound in chloroform with pyridine and lauryl chloride at 0° C and eliminating the elements of benzaldehyde by means of hydrochloric acid, he obtained the compound α chloro-β-hydroxy-propyl-γ-laurylamide.



$$\begin{array}{l} CH_2Cl \\ | \\ CH \cdot OH \\ | \\ CH_2NH \cdot C_{11}H_{23} \end{array}$$

On heating this compound with water and shaking, the elements of water are assumed by the molecule and simultaneous migration of the lauryl residue to the α position and the chlorine atom to the γ-position occurs with the production of α lauryloxy-β-hydroxypropyl-γ-amine-hydrochloride.



$$\begin{array}{l} CH_2 \cdot O \cdot CO \cdot C_{11}H_{23} \\ | \\ CHOH \\ | \\ CH_2NH_2HCl \end{array}$$

Nitrous acid reacts with this compound and,as a consequence an hydroxyl group is substituted for the amino and hydrochloric acid residues in the γ position, thus yielding the α monoglyceride.

In the present investigation it was originally intended to prepare the margarines, utilizing the appropriate chlorhydrins and the silver salt of margaric acid. The latter was chosen in preference to the alkali salts in order to avoid any possibility of hydrolytic phenomena due to free alkali complicating the reaction. It was shown by Dr. Whitby that the silver salts of palmitic and stearic acids are not appreciably subject to hydrolysis by water and it was quite reasonable to assume the same to be true of margaric acid.

The stability of silver margarate was tested by heating a small portion of the salt in the electric oven at 110°C for six hours. At the end of this time the decomposition amounted to only six-tenths of one percent.

Silver salts have been employed but little in the synthetical preparation of glycerides, except in the case of simple triglycerides. They have been utilized by Dr. R.F.Ruttan in the syntheses of various fatty acid esters of ethylene glycol, and also by Dr. G. S. Whitby in the preparation of mixed glycerides containing palmitic, stearic and butyric acid residues.

The use of silver salts in the syntheses of the margarines would seem to commend itself, therefore, owing to the considerations already described. With regard to the experimental procedure in effecting reaction between the chlorhydrins and the silver salts of margaric acid, the following observations may be made: -

Reaction may, in most cases, be brought about at a reasonably rapid rate by heating at any temperature above, say 130° C. The temperature actually selected in any particular case was decided by several considerations, such as the following:-

(a) The temperature must not be so high as to induce decomposition in the fat which results from the reaction, or to volatilize the chlorhydrin.

(b) The silver salts might suffer some decomposition on prolonged heating, with the formation of free acid. In general, it appeared best to bring about reaction by heating for a short time at a higher temperature than for a long time at a lower temperature.

Berthelot in 1854, stated that he had synthesized α mono-margarine by heating glycerol and margaric acid to 200° C for twenty-one hours and then at 100° C for an extended period. The product was neutral, white, difficultly soluble in ether and melted at 56°C. The acid he used, however, was obtained from human fat and consisted of a mixture of acids.

As determined in the present investigation, pure α monomargarine melts at 76.4° C.

In the case of α-monomargarine, reaction was induced by mixing together the chlorhydrin and dry silver salt as thoroughly as possible, in a cylindrical reaction vessel by means of a glass stirring rod and heating slowly in an oil bath to 135° C for about three hours. Considerable difficulty was encountered in eliminating colloidal silver chloride and silver from the reaction product. This phenomenon was previously reported by Dr. Ruttan and Roebuck in 1915, in connection with the investigation of the esters of ethylene glycol.

The amount of decomposition occurring during the reaction was found to be extremely large, over half of the reaction product consisting of free margaric acid. It was suspected that the large percentage of decomposition might be due to the possibility of the presence of a trace of moisture in the reactants. The chlorhydrin, distilling at a high temperature under reduced pressure, was water-free. Accordingly, the silver salt was very carefully dried in the electric oven at 110° C and then at a lower temperature under reduced pressure, the test of stability of the silver salt having demonstrated that this treatment effects no change in silver margarate, providing no liquid phase is present. The reaction was then repeated and it was found that this modification of procedure improved matters but little. The free acid, due to the decomposition of the silver salt, amounted to one-half of the reaction product.

It was thought that the excessive decomposition might be due to incomplete mixing of the reacting constituents. This presented a little difficulty due to the fact that the proportions employed involved intimate contact between a small volume (about 4 cc.) of a relatively viscous liquid and a large volume (about 60 cc.) of a light powder.

It was thought that if incomplete mixing were the cause of the large amount of decomposition, when this condition obtained, reaction would occur locally and those molecules of silver margarate having none of chlorhydrin in their vicinity with which to react, entered upon side reactions involving the production of relatively large amount of by-products and considerable decomposition, with the formation of free acid.

To accomplish thorough mixing, the chlorhydrin was dissolved in a suitable volume of ether, the silver salt suspended in the solution, and the whole thoroughly stirred. The ether was then slowly evaporated in the electric oven at a low temperature, and the mixture stirred at intervals as the consistency changed from a suspension to a thick paste. When the solvent had been completely removed, the product was heated in the usual manner. Even with these precautions, however, the free margaric acid in the resulting mixture amounted to fifty percent of the total.

It was then attempted to synthesize the compound, employing a medium which would be capable of dissolving both the reacting substances. Such a medium is phenyl ethyl ether, or phenetole.

$$C_6H_5OC_2H_5$$

This method has been employed successfully by Dr. Whitby in the synthesis of mixed triglycerides of palmitic and stearic acids. In choosing a solvent to act as a medium for the conduction of the reaction, the boiling point is an important consideration. Dr. Whitby obtained a satisfactory reaction between palmityl-dichlorhydrin and silver stearate, in phenetole (b.p.172° C), but the reaction between butyryl-dichlorhydrin and silver stearate in xylene (b.p.135°C) was not very satisfactory, owing to the fact that at the lower temperature of boiling xylene a much longer period of heating was required to bring about reaction than at the higher temperature of boiling phenetole and that during such longer heating much decomposition of the silver salts occurred.

In the case of margaric acid, the decomposition of the silver salt in phenetole medium, after heating at 155° C for two and a half hours amounted to 97.5 percent. Taking into account the fact that impurities were present in the reaction product, it is quite evident that in phenetole solution at the temperature specified, the silver margarate was practically completely decomposed before any interaction occurred with the chlorhydrin. It was obvious from this experiment that this method of procedure, although quite satisfactory in the case of palmitic and stearic acids, was entirely inapplicable to margaric acid.

It was discovered ultimately that of all the methods tried in attempts to obtain complete mixing of the substances, on the average, the preliminary treatment with anhydrous ether proved to be the most feasible and gave consistently lower decomposition percentages than the others. The percentage decomposition of the silver salt varied considerably from experiment to experiment, the lowest value obtained being 33.61 percent.

The free acid due to the decomposition of the silver salt during the reaction was determined by weighing an aliquot portion of the substance into a beaker, and adding a suitable volume, about 50 cc. , of ethyl alcohol, which had previously been exactly neutralized with tenth normal sodium hydroxide, using phenolphthalein as an indicator. The alcohol was warmed until the substance had dissolved completely, allowed to cool and then the fatty acid titrated with standard alkali.

Various methods of separating the free acid from the glyceride in the reaction product were tried. The principle involved was the addition of the exact amount of alkali necessary to neutralize the acid, thus converting it into the corresponding soap, and finally, the separation of the soap from the fat by means of a suitable solvent, which would dissolve the latter and not the former. The quantity of alkali required in each case was determined from the analysis of the free acid in the reaction product.

The first method attempted involved the fusion of the fat in a porcelain dish on the water bath, and the addition of the calculated quantity of sodium bicarbonate. The mixture was then heated for a definite period, allowed to cool, extracted in a Soxhlet, and finally, the solvent was evaporated. It was found, however, that this did not completely remove the acid. More sodium bicarbonate was added and the process repeated. This procedure eliminated a further quantity of margaric acid but the removal was not complete. Calcium hydroxide was substituted for sodium bicarbonate with no better results. The method finally adopted, and one which yielded entirely satisfactory results, was to dissolve the reaction product in ethyl alcohol and add the required quantity of caustic potash, also dissolved in alcohol, thus precipitating the corresponding soap. The solvent was then evaporated at a low temperature (40°C) under a pressure of about 20 mm. of mercury. The dry residue was extracted with ether in order to dissolve the fat, and thus separated from the soap. The employment of this solvent did not lead, however, to satisfactory results. It was invariably found that the ether dissolved a small quantity of the soap in addition to the glyceride. Petroleum ether was then used as a solvent but it appeared to have a detrimental effect on the fat, as a result of which the product obtained after evaporation of this solvent was considerably darker in color than the original substance. Chloroform was ultimately employed as the solvent at this stage of the purification and proved very suitable. The general procedure for purification of the glyceride was, then, to extract the raw product withether and evaporate to dryness, analyse the residue for free margaric acid, dissolve the product in alcohol, add the required quantity of alcoholic potash, remove the alcohol, extract with chloroform, evaporate to dryness and recrystallize the product to a constant melting point.

In order to facilitate mixing of the reacting constituents in addition to the preliminary ether treatment, in later experiments, a considerable excess of chlorhydrin was employed above that required for actual interaction with the quantity of silver margarate present. Under these circumstances there was obtained ultimately, on evaporation of the chloroform used to separate fat from soap, a product which exhibited an alkaline reaction.

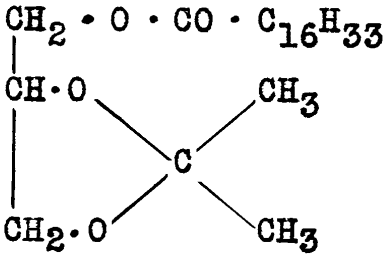
After some experimentation, it was discovered that the potassium soap of margaric acid was soluble in the chlorhydrin employed. This phenomenon offered the explanation as to why the fat, as obtained, possessed an alkaline reaction. This discovery led to a modification of procedure. The crude product after separation from silver chloride by means of ether was subjected to a preliminary series of recrystallizations from alcohol in order to remove the excess dichlorhydrin. It was then tested for free acid and the subsequent treatment was identical with that already described.

The behaviour of the reaction mixture varied considerably in different experiments. In some cases the contents of the reaction vessel assumed a liquid consistency shortly after the commencement of the heating process. In other cases, the product became liquid only after the elapse of anywhere from one to two hours. The fact was established that the quantity of silver margarate decomposed was greater in those experiments during which the reaction product assumed a liquid consistency shortly after the initiation of the reaction. In all cases very pungent fumes were evolved during the experiment.

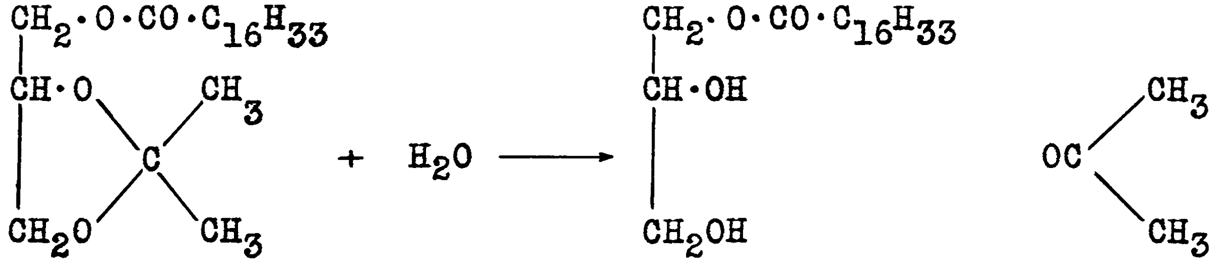
In these reactions, employing the silver salt of margaric acid, the yields of glycerides obtained were small. This circumstance is readily understood when one takes into account the excessive decomposition of silver margarate which occurred during the reaction and the possibility of side reactions. Two phenomena point to the occurrence of side reactions. Firstly, the evolution of pungent fumes during the reaction. These fumes had an intensely irritating effect on the eyes and mucous membrane and were found to be more pronounced in those experiments in which a bromhydrin was employed, i.e; in the synthesis of $\alpha\beta$-dimargarine. The second indication of side reactions was the production of a large amount of low melting and greasy material which was removed during the process of recrystallization. Apart from these considerations, the actual portion of the reaction confined to the formation of glyceride was not limited to the production of the mono variety. During the recrystallization, there were separated substances which possessed melting points corresponding to trimargarine and dimargarine, as was determined later in the investigation. Taking these considerations into account, together with the fact that due to decomposition during reaction, approximately only half of the margaric acid originally employed functioned as such in the synthesis, the low yields are readily accounted for. The highest melting specimen obtained by these methods fused at 73°C, which proved to be considerably below the melting point (76.4°C) of pure monomargarine.

The glyceride was finally obtained in a pure state by means of acetone-glycerol. The latter compound was obtained by the condensation of anhydrous glycerol and acetone in the presence of hydrochloric acid and sodium sulphate. In this reaction, which was carried out at room temperature, the hydrochloric acid functioned as a catalyst and the sodium sulphate as a dehydrating agent, removing the water formed during the process from the sphere of action, thus permitting the condensation to proceed to completion.

The interaction of acetone-glycerol and margaryl chloride was accomplished in chloroform solution in the presence of quinoline, and the system allowed to stand for several days. The chloroform solution was taken up in ether, the latter washed successively with sulphuric acid, potassium bicarbonate and water, and then dried over anhydrous sodium sulphate. The solution was evaporated and the product recrystallized. There was thus obtained the new compound margaryl-acetone-glycerol, -



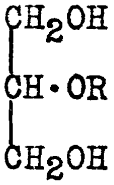
a white crystalline compound melting at 35.5° C. The molecule of this compound was then ruptured by the hydrolytic effect. of concentrated hydrochloric acid, whereby the elements of water partook in the reaction with the elimination of acetone and the production of α monomargarine, in the following manner:-



α monomargarine

By means of this method it has been possible to block two of the hydroxyl groups in the glycerol molecule, those in the β and γ positions, while the third was substituted with the margaryl residue. The hydroxyl groups were then replaced. In this manner the margaryl residue has been substituted in the glycerol molecule in the α position and in that position only, giving rise to α monomargarine whose identity and structure are thus quite definitely established.

β-Monoglycerides.



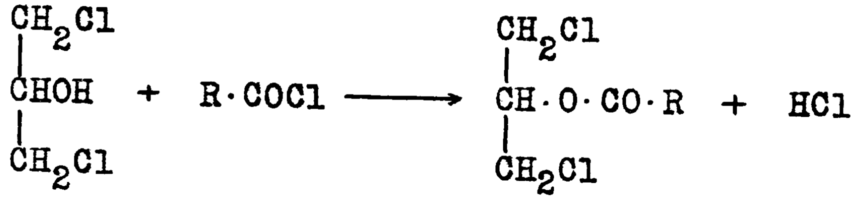
$$\begin{array}{l} CH_2OH \\ | \\ CH\cdot OR \\ | \\ CH_2OH \end{array}$$

The method employed in the syntheses of glycerides of this type, i.e., symmetrical monoglycerides, is due to Grun[63] who prepared β-monolaurin.

The literature concerning these compounds is comparatively meagre, as, apparently very few have been made. Lewkowitsch records only three syntheses of β monoglycerides, that of β-monolaurin and β-monopalmitin by Grun, and β-monomyristin by Weyrauch[64].

The syntheses involved in the formation of these compounds consist of three stages:-

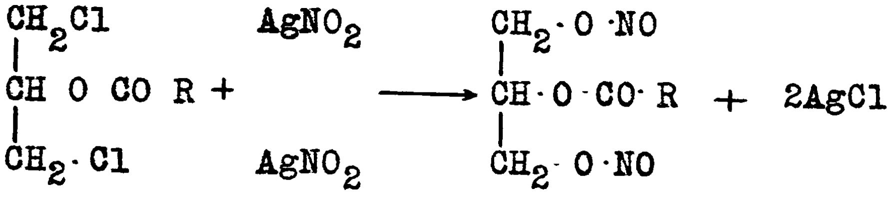
First, the condensation of the chloride of the fatty acid with α dichlorhydrin (1·3 -dichloro-propanol-2). This treatment converts the latter compound into a dichloro-ester,



$$\begin{array}{l} CH_2Cl \\ | \\ CHOH \\ | \\ CH_2Cl \end{array} + R\cdot COCl \longrightarrow \begin{array}{l} CH_2Cl \\ | \\ CH\cdot O\cdot CO\cdot R \\ | \\ CH_2Cl \end{array} + HCl$$

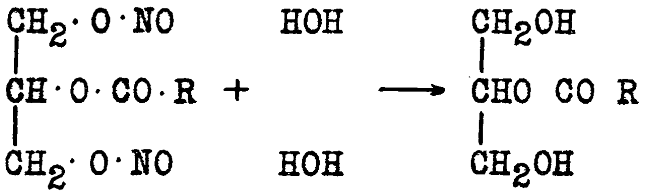
A dichloro-ester.

Second, the dichloro-ester is subjected to the action of silver nitrite at a relatively high temperature. The silver nitrite reacts with the chlorine atoms in the α and γ positions, giving rise to a labile nitrite, in the following manner,



$$\begin{array}{l} CH_2Cl \\ | \\ CH\ O\ CO\ R \\ | \\ CH_2\cdot Cl \end{array} + \begin{array}{l} AgNO_2 \\ \\ \\ \\ AgNO_2 \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot NO \\ | \\ CH\cdot O\cdot CO\cdot R \\ | \\ CH_2\cdot O\cdot NO \end{array} + 2AgCl$$

Third, the nitrite is converted into the β-monoglyceride by the substitution of hydroxyl groups in the two terminal positions. The labile nitrites are hydrolysed by traces of acids or even by water, and are thereby converted into the corresponding hydroxylated compound, thus yielding the desired monoglyceride.

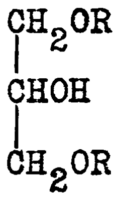


$$\begin{array}{l} CH_2\cdot O\cdot NO \\ | \\ CH\cdot O\cdot CO\cdot R \\ | \\ CH_2\cdot O\cdot NO \end{array} + \begin{array}{l} HOH \\ \\ \\ \\ HOH \end{array} \longrightarrow \begin{array}{l} CH_2OH \\ | \\ CHO\ CO\ R \\ | \\ CH_2OH \end{array}$$

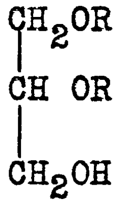
B. W. Van Eldik Thieme claims that pure monolaurins are obtained by employing iodohydrins in Grun's silver nitrite method.

The method just outlined was employed in this investigation for the preparation of β-monomargarine. The synthesis of this compound presented considerable difficulty, due to the decomposition of β-margaryl-dichlorhydrin (as evidenced by the presence of free margaric acid in the reaction product) and to the fact that the β monoglyceride was not the sole product of the reaction. A large amount of by-product of a pasty consistency was formed, which was separated from the desired glyceride by a long process of recrystallization from ether, alcohol, and low boiling petrolic ether. The occurrence of the large percentage of foreign matter in the reaction product detracted very much from the yield of β monomargarine, and it was necessary to perform three complete syntheses before obtaining a sufficient quantity of the glyceride for the investigation of its properties.

Diglycerides



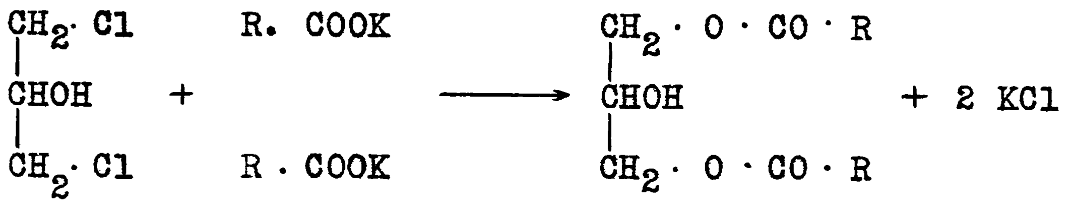
$$\begin{array}{l} CH_2OR \\ | \\ CHOH \\ | \\ CH_2OR \end{array}$$



$$\begin{array}{l} CH_2OR \\ | \\ CH\ OR \\ | \\ CH_2OH \end{array}$$

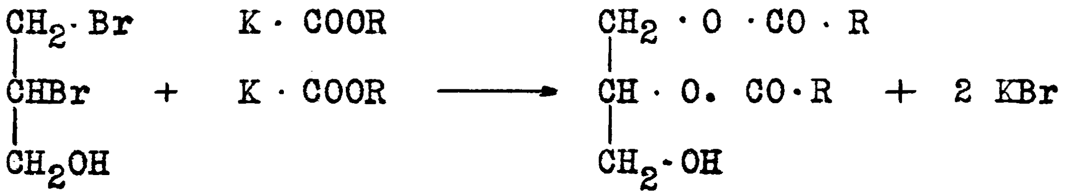
With the exception of the isopropylidene-glycerol reaction, these compounds are prepared synthetically by the same methods that are employed in the preparation of monoglycerides, with the obvious modifications that a larger proportion of fatty acids must be used and that instead of monochlorhydrin (or monobromhydrin), dichlorhydrin (or dibromhydrin) must be employed.

If it is desired to prepare a symmetrical diglyceride, dichlorhydrin is caused to react with the sodium or potassium salt of the particular acid in question,



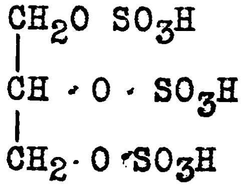
$$\begin{array}{l} CH_2\cdot Cl \\ | \\ CHOH \\ | \\ CH_2\cdot Cl \end{array} + \begin{array}{l} R.\ COOK \\ \\ \\ \\ R\cdot COOK \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot R \\ | \\ CHOH \\ | \\ CH_2\cdot O\cdot CO\cdot R \end{array} + 2\ KCl$$

Similarly, in order to synthesize an unsymmetrical or diglyceride[65] the alkali salt of the acid would be condensed with dibromhydrin, as is illustrated in the following equation:-



$$\begin{array}{l} CH_2\cdot Br \\ | \\ CHBr \\ | \\ CH_2OH \end{array} + \begin{array}{l} K\cdot COOR \\ \\ K\cdot COOR \\ \\ \\ \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot R \\ | \\ CH\cdot O.\ CO\cdot R \\ | \\ CH_2\cdot OH \end{array} + 2\ KBr$$

Grun has stated that by treating a solution of higher fatty acids in concentrated sulphuric acid (one part of fatty acids in 1.5 parts of sulphuric acid) with glyceroldisulphuric acid, $C_3H_5\ (OH)(OSO_3H)_2$ at a temperature of 70°C for three hours, diglycerides are formed exclusively, neither triglycerides nor monoglycerides having been found in the product of the reaction. The lower the molecular weight of the fatty acid employed, the smaller was the yield of diglyceride. This is explained by Grun and Schacht by their observation that the once formed diglycerides combined with free fatty acids to form an addition product. Thus, on allowing myristic acid to react with glyceroldisulphuric acid, an addition compound of the formula $C_3H_5\ (OH)\ (OC_{14}H_{27}O)_2 + 2C_{14}H_{28}O_2$ could be isolated. The glycerol disulphuric acid employed was prepared by the action of hot water on glycerol trisulphuric acid,

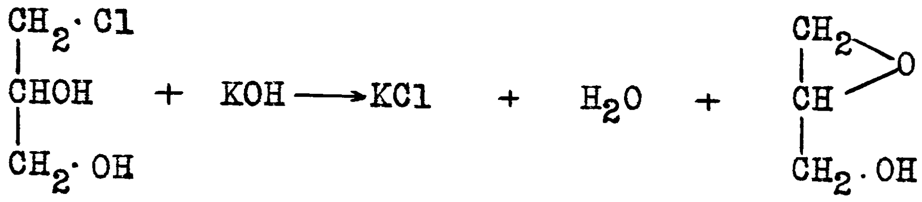


$$\begin{array}{l} CH_2O\ SO_3H \\ | \\ CH\cdot O\cdot SO_3H \\ | \\ CH_2\cdot O\cdot SO_3H \end{array}$$

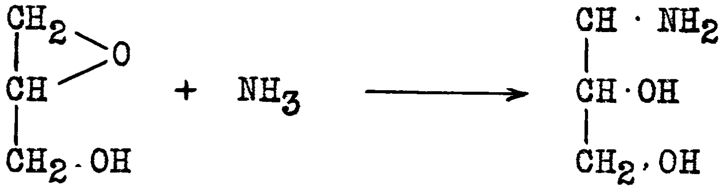
the latter being obtained as a result of the interaction of chlorosulphuric acid($SO_2(OH)Cl$), on glycerol at 0° C. (Claesson)[66]

B. W. Van Eldik Thieme disputed the correctness of Grun's statements, and showed, in conformity with the theoretical postulate, that mono-, di-, and tri- glycerides should be obtained, that triglycerides are indeed formed, and that subsequently, by the hydrolysing action of water, both diglyceride and monoglyceride are obtained. It would thus appear that under the conditions which Grun and Schacht maintained during their experiments, the sulphuric acid contained sufficient water to convert triglyceride into diglyceride.

Bergman[67] utilized the following scheme in the preparation of $\alpha\beta$ diglycerides. By the action of cold aqueous caustic potash on monochlorhydrin, a molecule of hydrochloric acid is eliminated, and glycide is formed,

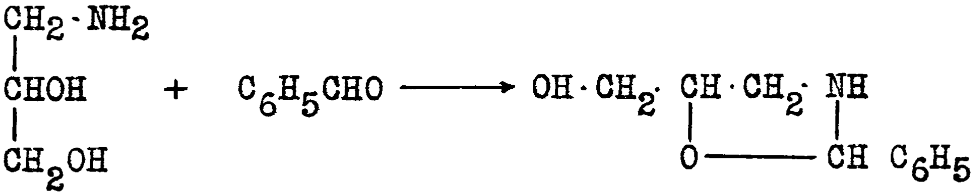


If glycide is treated with aqueous ammonia, there is formed γ-amino-propylene glycol,



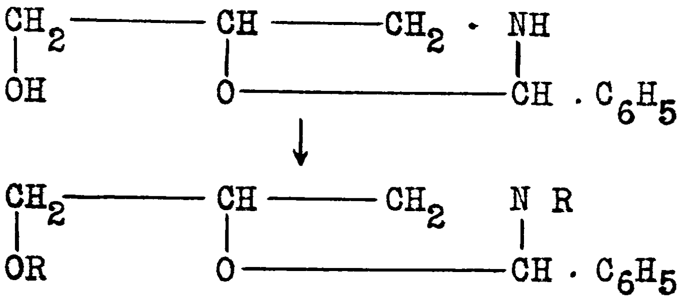
γ-amino propylene glycol

When γ-amino propylene glycol is treated with benzaldehyde in the presence of ethyl acetate, the following reaction takes place with the formation of 2-Phenyl-5-methylol-oxazolidin,



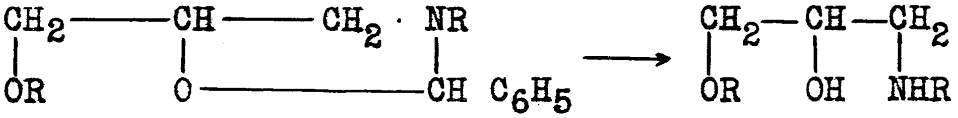
If this compound is treated with two molecular equivalents of an acyl chloride R CO·Cl substitution occurs for the hydroxylic hydrogen in position 5 and the imino hydrogen.

In this way the following compound (20) is obtained:-



(20)

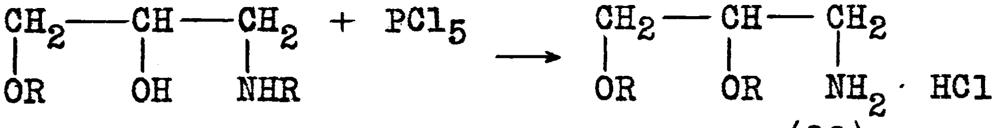
By the hydrolytic action of hydrochloric acid on this compound, the elements of benzaldehyde are eliminated from the molecule, in the following manner:-



(21)

$$\underset{OR}{CH_2}-\underset{OH}{CH}-\underset{NHR}{CH_2}$$

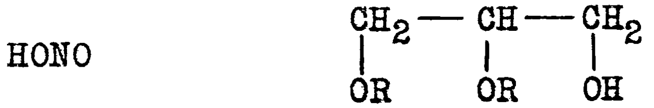
On treatment with phosphorus pentachloride, compound (21) undergoes molecular rearrangement, giving rise to(22),



$$\underset{OR}{CH_2}-\underset{OH}{CH}-\underset{NHR}{CH_2} + PCl_5 \longrightarrow \underset{OR}{CH_2}-\underset{OR}{CH}-\underset{NH_2 \cdot HCl}{CH_2}$$

(22)

Finally, the amino group is replaced by hydroxyl on treatment with nitrous acid, yielding the diglyceride (23),

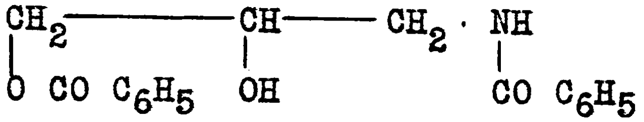


$$HONO \qquad \underset{OR}{CH_2}-\underset{OR}{CH}-\underset{OH}{CH_2}$$

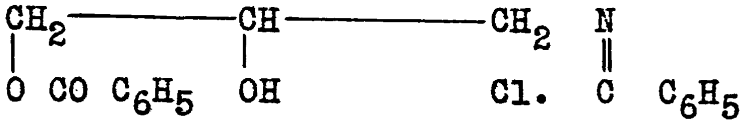
(23)

Concerning the rearrangement which Bergman assumes occurs on subjecting compound (21) to the action of phosphorus pentachloride, he states that he has not been able to isolate the necessary intermediate compounds, but he considers a rearrangement of the following type to take place. Consider the case in which R stands for the benzoic acid residue.

The first stage consists of the formation of an imide-chloride body (24),



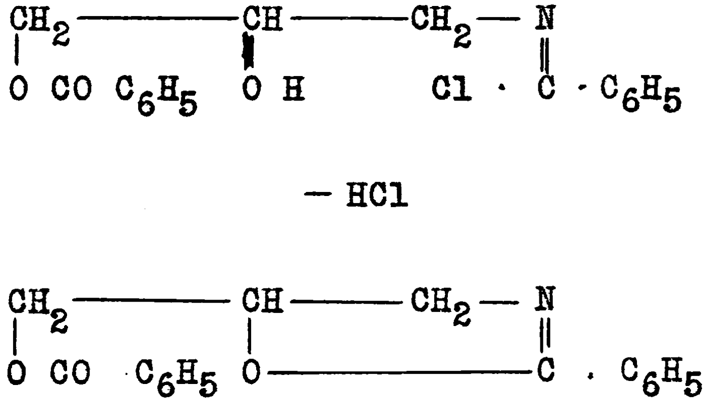
$$\begin{array}{llll} CH_2\text{———} & CH\text{———} & CH_2\cdot & NH \\ | & | & & | \\ O\;CO\;C_6H_5 & OH & & CO\;C_6H_5 \end{array}$$



$$\begin{array}{lllll} CH_2\text{———} & CH\text{———} & CH_2 & N & \\ | & | & & \| & \\ O\;CO\;C_6H_5 & OH & Cl. & C & C_6H_5 \end{array}$$

(24)

The halogen of the intermediate imide-chloride is very reactive, and the proximity of an alcoholic hydroxyl group on the carbon atom induces reaction to occur between the halogen and the hydrogen of this group, with the elimination of hydrochloric acid, and the formation of a cyclic iminoether (25),



$$\begin{array}{llll} CH_2\text{———} & CH\text{———} & CH_2\text{—} & N \\ | & | & & \| \\ O\;CO\;C_6H_5 & O\;H & Cl\cdot & C\cdot C_6H_5 \end{array}$$

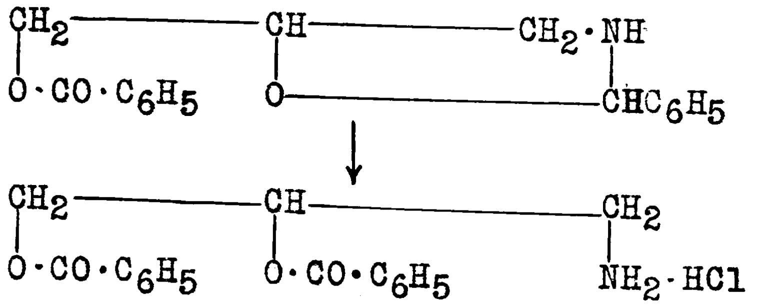
$$-\;HCl$$

$$\begin{array}{llll} CH_2\text{———} & CH\text{———} & CH_2\text{—} & N \\ | & | & & \| \\ O\;CO\;C_6H_5 & O\text{————} & & C\;.\;C_6H_5 \end{array}$$

(25)

The action of dilute warm hydrochloric acid on compound (25) is sufficient to produce partial rupture of the molecule at the double bond, the assumption of the elements of water, and

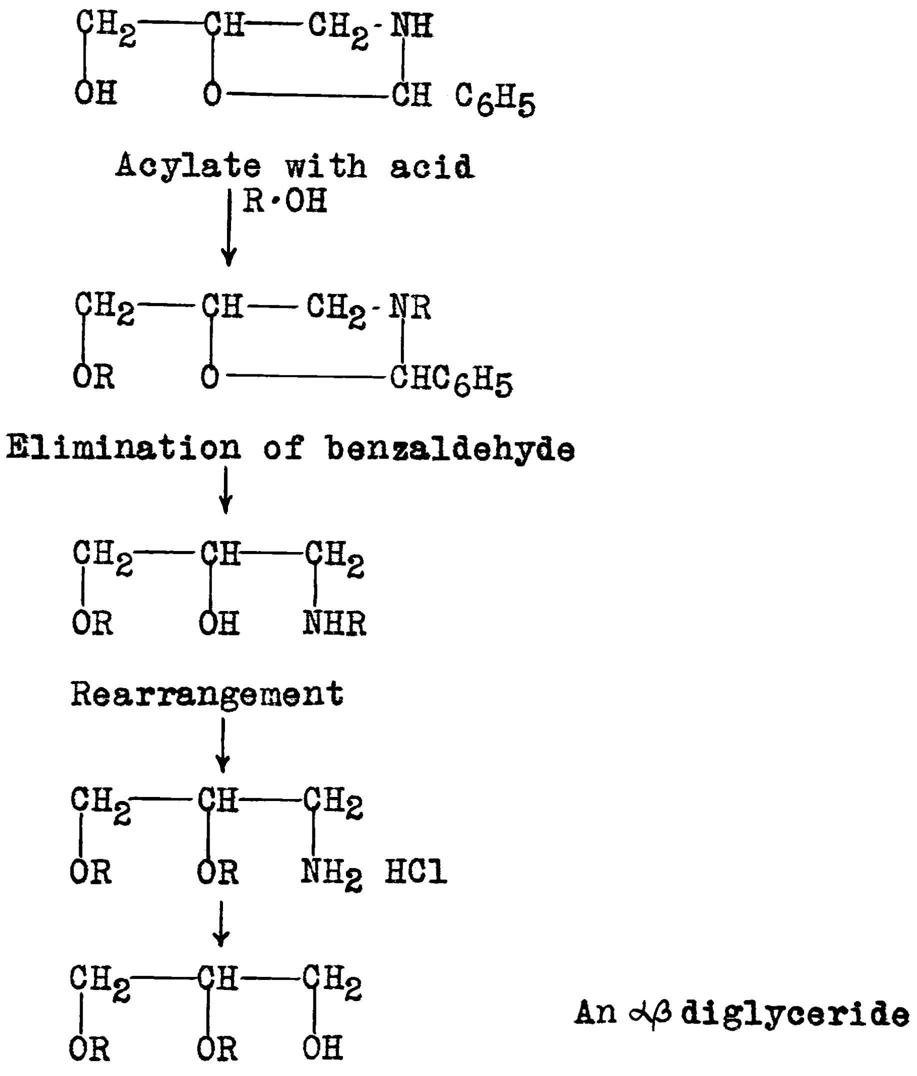
and the formation of the hydrochloride (26) of the base,



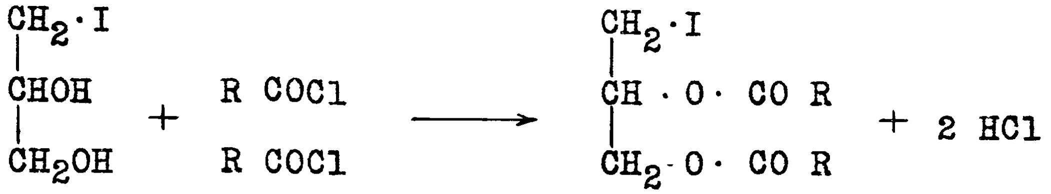
(26)

in which the amino group may be replaced by hydroxyl in the manner described.

These considerations may be summed up in the following manner.



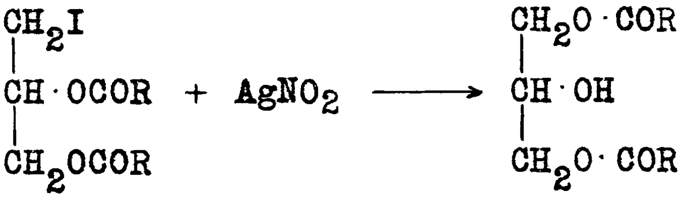
Fischer[68] prepared α diglycerides by the interaction of the desired acid chloride and α iodohydrin, at room temperature,



$$\begin{array}{l} CH_2 \cdot I \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + \begin{array}{l} R\ COCl \\ \\ R\ COCl \end{array} \longrightarrow \begin{array}{l} CH_2 \cdot I \\ | \\ CH \cdot O \cdot CO\ R \\ | \\ CH_2 \cdot O \cdot CO\ R \end{array} + 2\ HCl$$

(27)

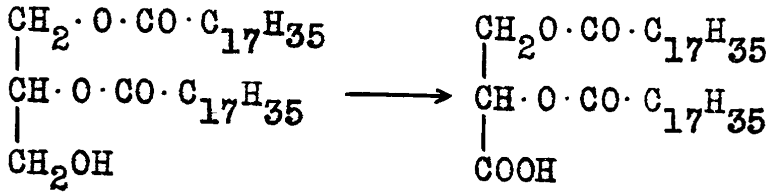
giving rise to the β-γ-diacyl-α-iodohydrin (27) This compound is treated with silver nitrite in aqueous alcoholic solution at a temperature of 60° C, and there occurs a migration of an acyl group from the β to the α position with the production of the α diglyceride.



$$\begin{array}{l} CH_2I \\ | \\ CH \cdot OCOR \\ | \\ CH_2OCOR \end{array} + AgNO_2 \longrightarrow \begin{array}{l} CH_2O \cdot COR \\ | \\ CH \cdot OH \\ | \\ CH_2O \cdot COR \end{array}$$

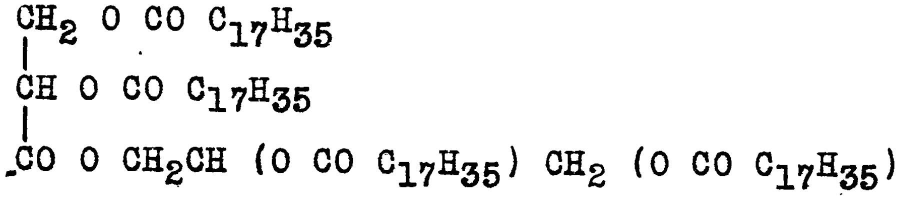
Grun and Witka[69] investigated various reactions involving the formation of diglycerides in order to determine whether migration occurred during reaction.

To determine the constitution of diglycerides, Grun states that the most satisfactory method and that which yields the most promising results, is the observation and examination of the oxidation products of glycerides. Diglycerides when subjected to oxidation should form, finally, diacyl glyceric acid (28) through the intermediate aldehyde; thus for $\alpha\beta$ distearin the total reaction would be,



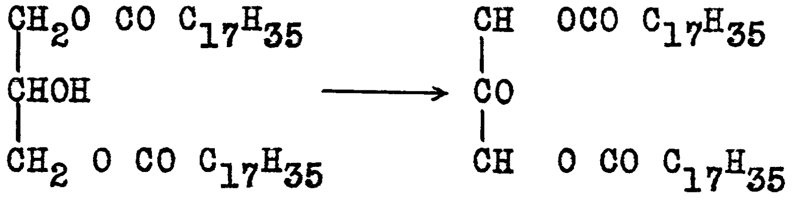
$$\begin{array}{l}CH_2\cdot O\cdot CO\cdot C_{17}H_{35}\\ |\\ CH\cdot O\cdot CO\cdot C_{17}H_{35}\\ |\\ CH_2OH\end{array} \longrightarrow \begin{array}{l}CH_2O\cdot CO\cdot C_{17}H_{35}\\ |\\ CH\cdot O\cdot CO\cdot C_{17}H_{35}\\ |\\ COOH\end{array} \qquad (28)$$

In the experiments performed with $\alpha\beta$ diglycerides they obtained this acid in the form of its distearo-ester,



$$\begin{array}{l}CH_2\ O\ CO\ C_{17}H_{35}\\ |\\ CH\ O\ CO\ C_{17}H_{35}\\ |\\ CO\ O\ CH_2CH\ (O\ CO\ C_{17}H_{35})\ CH_2\ (O\ CO\ C_{17}H_{35})\end{array}$$

Again, the moderate oxidation of the α diglycerides should yield dioxy-acetone derivatives. As an example, α-distearin would, theoretically, give rise to distearyl-dioxy-acetone



$$\begin{array}{l}CH_2O\ CO\ C_{17}H_{35}\\ |\\ CHOH\\ |\\ CH_2\ O\ CO\ C_{17}H_{35}\end{array} \longrightarrow \begin{array}{l}CH\ \ OCO\ C_{17}H_{35}\\ |\\ CO\\ |\\ CH\ \ O\ CO\ C_{17}H_{35}\end{array} \qquad (29)$$

Actually, they were not able to isolate the compound (29) but its presence among the oxidation products was demonstrated by the carbonyl determination according to the method of Strache.

The quantitative determination of the carbonyl residue in the oxidation product was performed by the method of Benedict and Strache[70]. The procedure is as follows:-

A measured excess of phenylhydrazine is allowed to act on the substance, combination with the carbonyl group taking place with the elimination of the elements of water. The product is then treated with Fehlings' solution whereby the unused phenylhydrazine is oxidized with the evolution of nitrogen, thus,

$$2C_6H_5\ NH\ NH_2 + O_2 \rightarrow 2C_6H_5 + 2N_2 + 2H_2O$$

The volume of the nitrogen is measured, and a blank experiment performed. The difference corresponds to the quantity of phenylhydrazine used, and hence the percentage of carbonyl residue can be calculated.

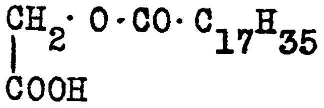
The oxidation of β-monostearin leads to less promising results. A summation of all the products which, theoretically, may be formed by the oxidation of these compounds is unnecessary. An intermediate product would be stearyl-oxy-pyruvic acid (30) and finally, stearyl glycollic acid (31).

On the other hand monostearin would give rise to stearyl tartronic acid (32). It was expected that this acid would be very unstable and revert to stearyl glycollic acid.

The following scheme illustrates these considerations:-

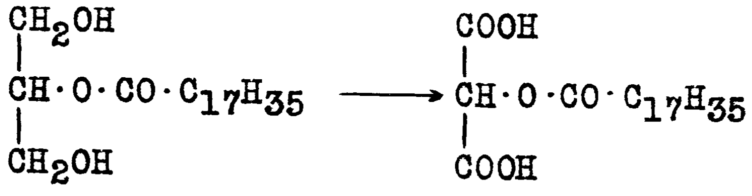
$$\begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ CHOH \\ | \\ CH_2OH \end{array} \longrightarrow \begin{array}{l} CH_2O\cdot CO\cdot C_{17}H_{35} \\ | \\ CO \\ | \\ COOH \end{array}$$

(30)



$$\begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ COOH \end{array}$$

(31)



$$\begin{array}{l} CH_2OH \\ | \\ CH\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ CH_2OH \end{array} \longrightarrow \begin{array}{l} COOH \\ | \\ CH\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ COOH \end{array}$$

(32)

Stearyl tartronic acid was found to be very unstable, thus confirming the suspicions of the investigators. They attempted to prepare it synthetically on several occasions, but the product obtained was, in each case, stearyl glycollic acid. The latter method, therefore, is inapplicable as a means of determining the constitution of monoglycerides.

As a result of his investigations Grun arrives at the conclusion that migration occurs only under certain conditions and with certain groups. Reactions carried out in solution and at somewhat elevated temperatures, such as Fischer used in connection with the α iodohydrin in the preparation of diglycerides, are favorable for migration phenomena.

He states that when reactions of this type are performed in the absence of a solvent, that there is little possibility of migration of the groups occurring. In the case of the synthesis of β-diglycerides, he showed that wandering occurred to a small extent, but that in the synthesis of α diglycerides by means of α dichlorhydrin and potassium stearate, no migration whatever occurred. He further emphasizes his idea by referring to the fact that the mixed triglyceride, α-Lauro-β-γ-distearin, obtained by Fischer from α-monolaurin and stearyl chloride is identical with the compound obtained by himself, employing $\alpha\beta$-distearo-chlorhydrin and potassium laurate.

The synthesis of α dimargarine was conducted in this work simultaneously with that of α monomargarine, and consequently, the reaction conditions and methods of purification of the resulting glyceride were the same as those employed in the case of the mono compound.

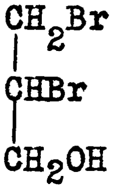
The silver salt of margaric acid was employed in the earlier attempts to prepare the diglyceride and various methods of mixing the reactants were tried, including ordinary mixing, the preliminary ether treatment and finally another method, involving the mixing of the chlorhydrin and silver salt with sufficient xylene to produce a thick paste. In spite of these precautions, the amount of decomposition varied between 44 and 56 percent.

It was finally decided to employ the potassium salt in the synthesis. A small preliminary experiment was performed with this soap and γ dichlorhydrin, and the free margaric acid in the reaction product amounted to only 8.6 percent, as compared with the decomposition in the case of the silver salts which varied from 40 to 60 percent of the final product of the reaction. In view of the promising results obtained in the preliminary experiment, it was performed on a larger scale with results that were even better than in the preliminary trial.

In this case, the decomposition was only 3.24 percent. In addition to this, the color of the resulting margarine after purification was perfectly white. In the case of experiments performed with silver salts, there invariably remained with the compound a certain amount of color which could be eliminated only with considerable difficulty.

In the synthesis of the glyceride by means of potassium margarate, low melting by-products were also formed to a certain extent, but much less than in the case of the silver salt. These by-products, and others of higher melting points, were eliminated by systematic recrystallization from ether and fractional solution in a mixture of alcohol and chloroform.

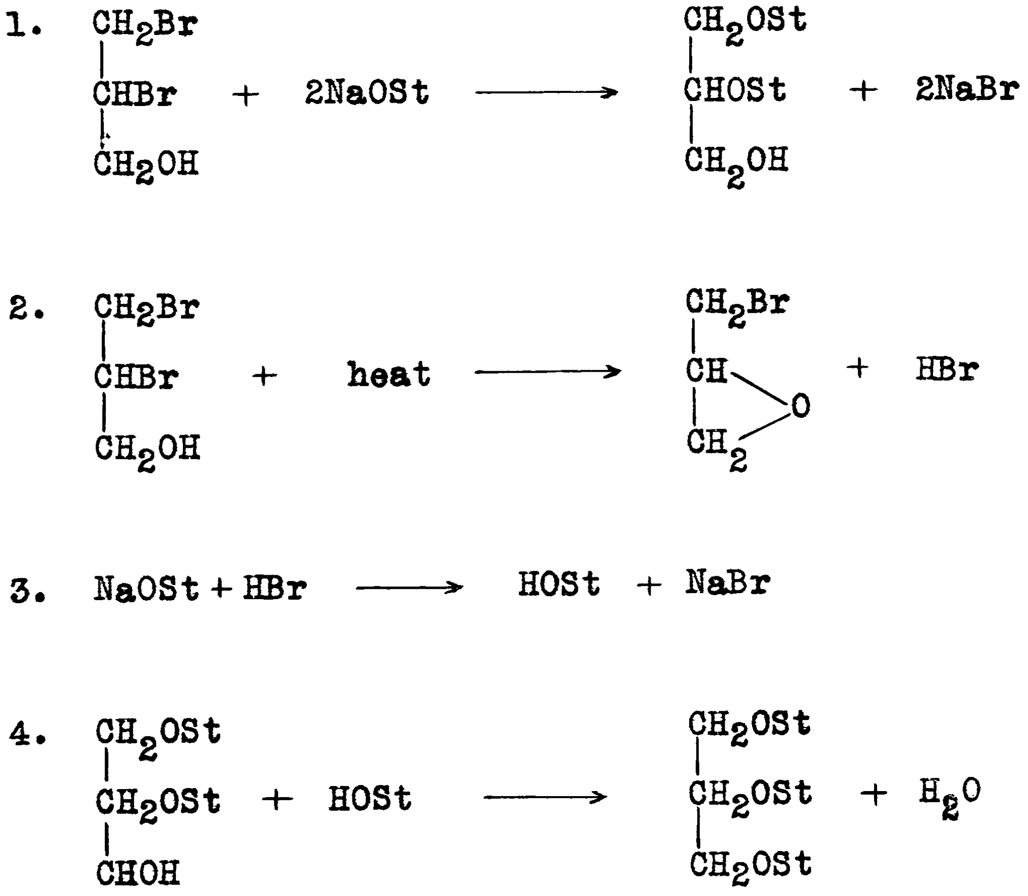
It was attempted to prepare β dimargarine by the interaction of αβ dibrompropyl alcohol,



$$\begin{array}{l} CH_2Br \\ | \\ CHBr \\ | \\ CH_2OH \end{array}$$

and silver margarate. The period of heating was in the neighborhood of three hours and the temperature about 150° C, the mixture being stirred thoroughly during the entire process. Pungent fumes were evolved and the product obtained was highly coloured. In the reaction, a large excess of bromhydrin was employed. The decomposition was very high in this case, also, amounting in the crude product to nearly half the weight of the residue, and on removal of the excess bromhydrin, by recrystallization from alcohol, the value increased to double the amount, demonstrating the fact that the crude product obtained after separation of silver chloride, consisted almost entirely of bromhydrin, margaric acid and by-product, all in a very impure state. The results of this experiment are comparable to those in which it was attempted to prepare α monomargarine in phenetole solution. Consequently, this method was abandoned and the employment of the silver salts definitely discontinued as a synthetical agent in obtaining pure "simple margarines". Recourse was then had to the potassium salt, this method having proved successful in the case of α dimargarine. Relatively large quantities of reactants were employed and the decomposition of the potassium salt was only moderately high, amounting to about twenty percent. It was anticipated that there would be a larger decomposition in this case than in those experiments in which the chlorine compounds were utilized, and the results justified the preliminary conjecture. Among other by-products, there was separated from the reaction product, a quantity of material melting at 62-66 C, which consisted largely of trimargarine.

Some idea of the difficulty involved in the preparation of pure glycerides of this type may be obtained from a consideration of the work of R. R. Renshaw[71] . He conducted a series of experiments dealing with the preparation of $\alpha\beta$-distearin from $\alpha\beta$-dibromhydrin, employing the sodium and lead salts. As a result of his investigations, he came to the conclusion that, under the conditions employed by him, the following reactions probably occurred.



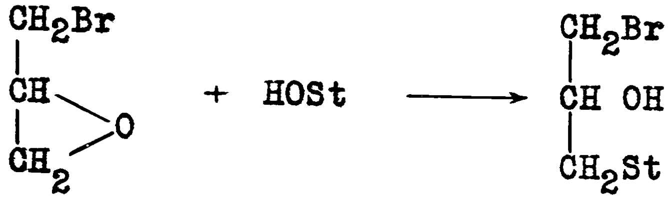
1. $$\begin{array}{l} CH_2Br \\ | \\ CHBr \\ | \\ CH_2OH \end{array} + 2NaOSt \longrightarrow \begin{array}{l} CH_2OSt \\ | \\ CHOSt \\ | \\ CH_2OH \end{array} + 2NaBr$$

2. $$\begin{array}{l} CH_2Br \\ | \\ CHBr \\ | \\ CH_2OH \end{array} + \text{heat} \longrightarrow \begin{array}{l} CH_2Br \\ | \\ CH \diagdown \\ | \quad\;\; O \\ CH_2 \diagup \end{array} + HBr$$

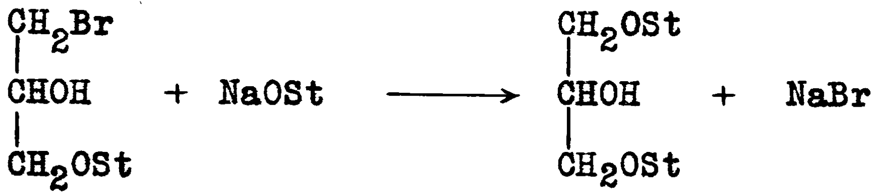
3. $$NaOSt + HBr \longrightarrow HOSt + NaBr$$

4. $$\begin{array}{l} CH_2OSt \\ | \\ CH_2OSt \\ | \\ CHOH \end{array} + HOSt \longrightarrow \begin{array}{l} CH_2OSt \\ | \\ CH_2OSt \\ | \\ CH_2OSt \end{array} + H_2O$$

Since large quantities of stearic acid were formed, it would seem likely that considerable amounts of epibromhydrin would also be present and react thus, -

5. 

Renshaw isolated from the reaction products a substance containing bromine and stearic acid. The presence of such a compound would be explained by the last reaction, or by the action of one molecule of stearic acid in reaction No.1. The following reaction, involving the formation of the isomer, might also be expected, -

6. 

$$\begin{array}{l} CH_2Br \\ | \\ CHOH \\ | \\ CH_2OSt \end{array} + NaOSt \longrightarrow \begin{array}{l} CH_2OSt \\ | \\ CHOH \\ | \\ CH_2OSt \end{array} + NaBr$$

None of the latter compound was isolated, and Renshaw concluded that no more than traces of it were formed.

It is quite evident from the foregoing that the isolation of a pure glyceride of this type is a matter of considerable difficulty.

Triglycerides

Pure triglycerides were first obtained by Berthelot[72] who heated glycerol with fatty acids. As has been mentioned previously, mono- and diglycerides are formed simultaneously in the reaction. In order to exclude the formation of these lower glycerides, and with a view to obtaining complete esterification by removing the water as it was formed, Scheij[73] heated glycerol with an excess of fatty acid in a slow current of air. In the case of the triglycerides of the fatty acids of low molecular weight, i.e., up to acids having ten atoms in their molecule, a small quantity of fatty acid distills over simultaneously with the water, and it is therefore necessary to add from time to time, a fresh quantity of the fatty acid. In the case of the acids of higher molecular weight, the reaction is complete when water ceases to be evolved.

The pure glyceride may also be prepared by heating together the sodium or silver salts with tribromhydrin (Guth; Parthiel and v. Velsen[74]).

Trimargarine has been prepared by Bomer and Limprich[75] They undertook to determine whether the glyceride obtained by Kreis and Hafner[76] from hog fat, and which the latter investigators claimed to be trimargarine, was actually the compound they supposed it to be. With this object in view, Bomer and Limprich endeavored to prepare the compound synthetically.

They obtained margaric acid by the application of Krafft's reaction, starting from stearic acid.

The acid resulting from the saponification of the glyceride obtained by Kreis and Hafner melted at 55.6° C, whereas the melting point of margaric acid as found by Dr. R. F. Ruttan, is 59.9° C.

Bomer prepared the triglyceride by heating together 5.48 grams of the dry potassium soap of margaric acid, and 1.67 grams of tribromhydrin in the presence of a little xylol. The mixture was heated to 180-190° C for two hours, and on cooling, the brown reaction product was extracted with ether. The soluble material amounted to 1.71 grams. There was obtained from this, 0.45 grams of glyceride melting at 60.7° C. The greatest portion of the ether insoluble material consisted of undecomposed potassium margarate. This was converted to the acid, purified and used in another experiment of the same type. In the second experiment he obtained 0.38 grams of triglyceride, melting at 60.0° C. Finally, a small amount of trimargarine melting at 62.7° C was obtained. He mentions no saponification value of the glyceride, apparently the quantity obtained being too small to permit of an analysis being made.

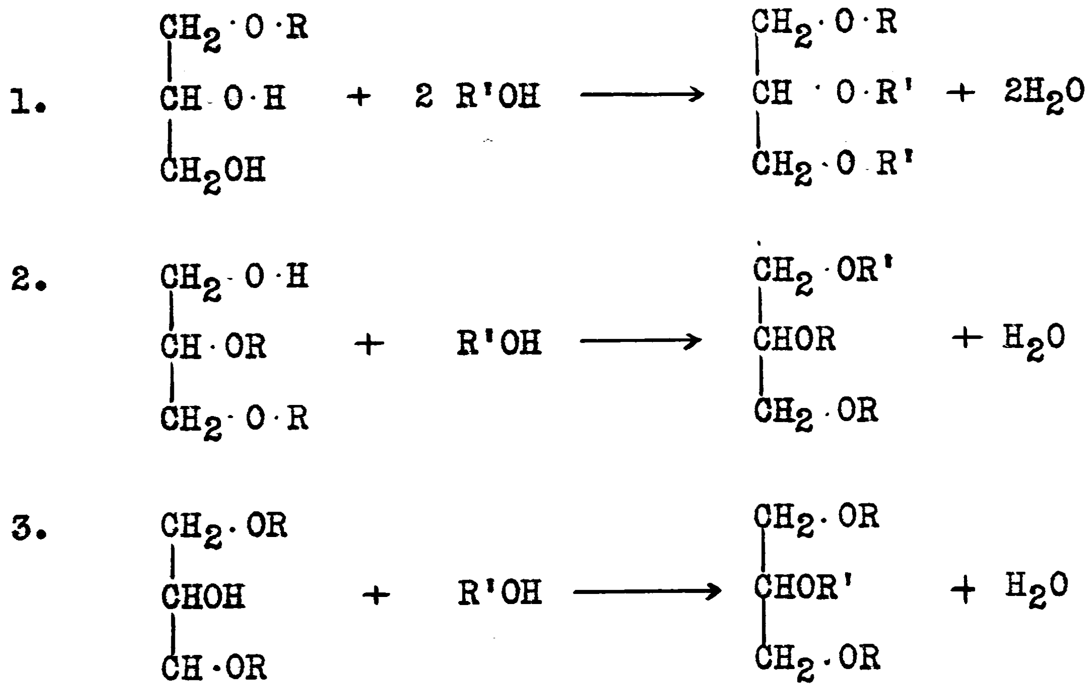
The melting point of the triglyceride obtained in this work corresponds with that of Bomer and its saponification value demonstrated that it consisted of pure trimargarine, and hence it has been definitely identified in the present investigation, and some additional properties determined.

Berthelot[77] claimed to have prepared trimargarine by heating αmonomargarine with an excess of margaric acid at 270° C for some hours. The product obtained melted at 60 C. As stated already, the acid he employed was not margaric acid, but a mixture.

In the present syntheses trimargarine was prepared by the direct esterification of glycerol with margaric acid, employing a temperature of 190° C.

Mixed Triglycerides

Mixed triglycerides of the even carbon atom fatty acids have been prepared by the interaction of a free acid and a mono- or diglyceride of the other acid , according to the following reactions;-



1.
$$\begin{array}{l} CH_2\cdot O\cdot R \\ | \\ CH\cdot O\cdot H \\ | \\ CH_2OH \end{array} + 2\ R'OH \longrightarrow \begin{array}{l} CH_2\cdot O\cdot R \\ | \\ CH\cdot O\cdot R' \\ | \\ CH_2\cdot O\ R' \end{array} + 2H_2O$$

2.
$$\begin{array}{l} CH_2\cdot O\cdot H \\ | \\ CH\cdot OR \\ | \\ CH_2\cdot O\cdot R \end{array} + R'OH \longrightarrow \begin{array}{l} CH_2\cdot OR' \\ | \\ CHOR \\ | \\ CH_2\cdot OR \end{array} + H_2O$$

3.
$$\begin{array}{l} CH_2\cdot OR \\ | \\ CHOH \\ | \\ CH\cdot OR \end{array} + R'OH \longrightarrow \begin{array}{l} CH_2\cdot OR \\ | \\ CHOR' \\ | \\ CH_2\cdot OR \end{array} + H_2O$$

Kreis and Hafner in 1902 prepared[78] palmito-distearin by subjecting a mixture of distearin and palmitic acid to the somewhat drastic treatment of heating at 200° C for 16 hours.

Bomer and Limprich in 1913, employing this method of synthesis for the preparation of βpalmito-distearin, found that the product of the interaction of αdistearin and palmitic acid, which Guth[79] had assumed to be βpalmito-distearin, contained twelve percent of tristearin and probably some stearo-dipalmitin. This result makes it clear that the interaction of a mono- or diglyceride with a free acid is not satisfactory for the synthesis of pure mixed glycerides.

The action of oleic acid on distearin and palmitin was examined by Kreis and Hafner[80] with the object of preparing oleo-distearin and oleo-dipalmitin. It was found that considerable quantities of tristearin and tripalmitin were formed, while the yield of the mixed triglycerides was small.

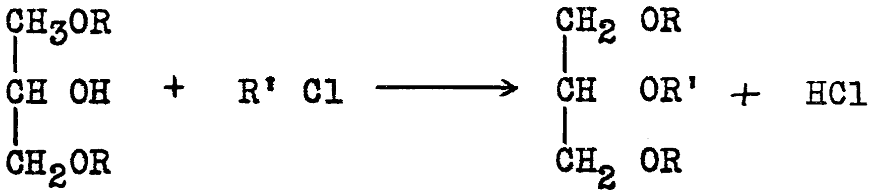
In 1912, Van Eldik Thieme[81] showed that the interaction of a chlorhydrin and the sodium salt of the fatty acid, a method largely used in the synthesis of glycerides, yields a mixture of substances. Working with sodium laurate and mono- and dichlorhydrin, he found that mono- di- and triglycerides were formed at the same time. In explanation of this result, he found that the alkali salt of the acid reacts with the glycerol hydroxyl leading to partial esterification.

Bomer and Limprich found, similarly, that the interaction of α dichlorhydrin and sodium stearate lead to the production, in addition to α-distearin, of some tristearin.

In all these reactions involving the interaction of the potassium salt of the acid and the appropriate chlorhydrin, although by-products are formed due to esterification other than that expected, the compound desired forms the main portion of the reaction product and can be isolated by careful and systematic methods of purification.

Reactions involving the use of concentrated sulphuric acid hardly commend themselves, due to the theoretical considerations described when dealing with the diglycerides.

A method, involving the use of diglycerides, which has been used for the preparation of mixed triglycerides containing residues lower than palmitic acid, is the action of an acyl chloride on a diglyceride, at a relatively high temperature.

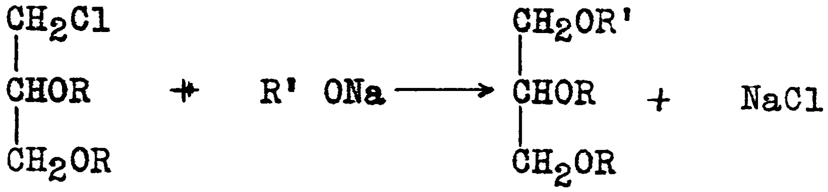


$$\begin{array}{l} CH_3OR \\ | \\ CH\ OH \\ | \\ CH_2OR \end{array} + R'\,Cl \longrightarrow \begin{array}{l} CH_2\ OR \\ | \\ CH\ \ OR' \\ | \\ CH_2\ OR \end{array} + HCl$$

This method appears to yield a mixture of products. Thus, from myristyl chloride and α dilaurin was obtained not only β myristodilaurin (in two modifications), but also, to the extend of fifty percent, lauro-dimyristin[82].

The direct interaction of glycerol and fatty acids is an unsuitable method for the purpose of preparing pure specimens of mixed triglycerides. If a mixture of two acids were in question, the possible products are so numerous (17) that the possibility of separating a homogeneous material would be very small indeed.

One of the most satisfactory methods which has hitherto been followed for the preparation of mixed triglycerides, would appear to be the interaction of the alkali salt of an acid with a diacyl chlorhydrin,

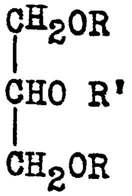


$$\begin{array}{l} CH_2Cl \\ | \\ CHOR \\ | \\ CH_2OR \end{array} + R'\ ONa \longrightarrow \begin{array}{l} CH_2OR' \\ | \\ CHOR \\ | \\ CH_2OR \end{array} + NaCl$$

a method which was employed by Grun and Theimer[83] in the case of certain glycerides containing lauro residues. Waiving for the moment the question of the method employed by these investigators for the preparation of the diacylchlorhydrins, the only objection that could be made to this method would be on the groundsof the possible presence of sodium hydroxide in the sodium salts of the fatty acids. The presence of even a trace of caustic alkali might lead to side reactions.

The following discussion embodies the methods employed for the preparation of mixed triglycerides of margaric, palmitic and stearic acids.

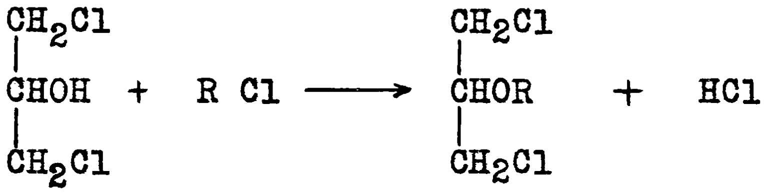
Symmetrical Mixed Triglycerides



$$\begin{array}{l} CH_2OR \\ | \\ CHO\ R' \\ | \\ CH_2OR \end{array}$$

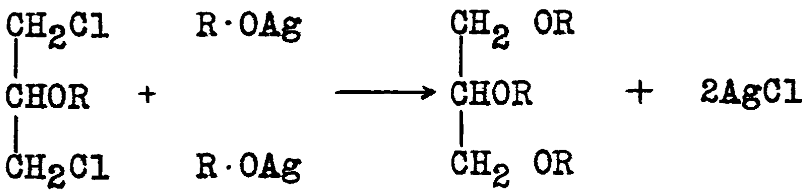
The syntheses of compounds of this type consisted of two steps in each of which the reaction, it would seem, must be strictly limited to one course.

Firstly, the preparation of the β-acyldichlorhydrin by the interaction of αγ dichlorhydrin and the acylchloride



$$\begin{array}{l} CH_2Cl \\ | \\ CHOH \\ | \\ CH_2Cl \end{array} + R\ Cl \longrightarrow \begin{array}{l} CH_2Cl \\ | \\ CHOR \\ | \\ CH_2Cl \end{array} + HCl$$

This reaction occurred readily in most cases, there being a loss of hydrochloric acid corresponding with the theoretical. Secondly, interaction of the acyl-dichlorhydrin with two molecules of the silver salt of the other acid.



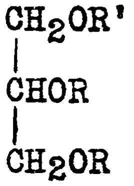
$$\begin{array}{l} CH_2Cl \\ | \\ CHOR \\ | \\ CH_2Cl \end{array} + \begin{array}{l} R\cdot OAg \\ \\ \\ \\ R\cdot OAg \end{array} \longrightarrow \begin{array}{l} CH_2\ OR \\ | \\ CHOR \\ | \\ CH_2\ OR \end{array} + 2AgCl$$

This method was employed for the preparation of β-palmito-dimargarine and β-stearo-dimargarine. The decomposition of silver margarate in these experiments was less than that in the preparation of the "simple margarines". This was to be expected, due to the fact that the reacting constituents involved in the second phase of the reaction consisted of approximately equal amounts of solid materials, thus enabling thorough mixing to be obtained.

The lead salt of margaric acid was substituted for the silver salt in the preparation of β-margaro-dipalmitin and β-margaro-distearin.

Unsymmetrical Mixed Triglycerides

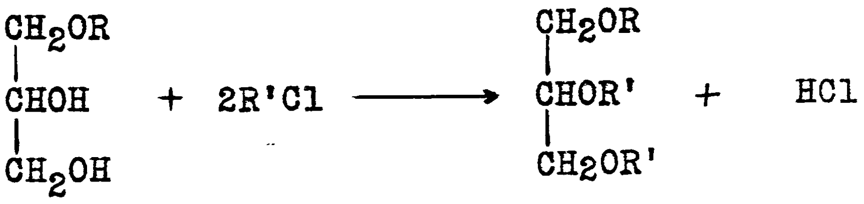
The method adopted for the preparation of triglycerides of this type,



$$\begin{array}{l} CH_2OR' \\ | \\ CHOR \\ | \\ CH_2OR \end{array}$$

in this investigation is due to Fischer[84]. It has also been used by Amberger and Brownig,[85] who have prepared a considerable number of mixed triglycerides of palmitic and stearic acids.

The method, theoretically, is the same as that already described, involving the interaction of an α-monoglyceride with an acid chloride.



$$\begin{array}{l} CH_2OR \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + 2R'Cl \longrightarrow \begin{array}{l} CH_2OR \\ | \\ CHOR' \\ | \\ CH_2OR' \end{array} + HCl$$

The conditions under which the reaction was performed differed materially, however. In the former method a relatively high temperature was employed, about 160°C, whereas the method employed here consisted in treating a solution of the α-monoglycerides (prepared by the isopropylidene-glycerol reaction) in chloroform, with the desired acid chloride in the presence of pyridine or quinoline at room temperature. The function of the tertiary bases was to remove the hydrochloric acid evolved in the reaction and thus enable it to proceed to completion. The reaction mixture was allowed to stand for two or three days at room temperature. It was taken up in ether, washed with sulphuric acid, with potassium bicarbonate, and finally with distilled water to remove any soap formed that may have passed into solution in the ether. The ethereal solution was dried over sodium sulphate for some hours, the ether evaporated and the residue recrystallized.

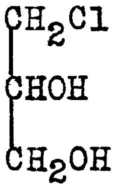
Glycerol Chlorhydrins

Considering the formula for glycerol,

$$\begin{array}{l} \mathrm{CH_2OH} \\ | \\ \mathrm{CHOH} \\ | \\ \mathrm{CH_2OH} \end{array}$$

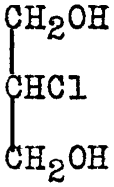
it will be seen that there are five chlorhydrins that may be formed by the replacement of one or more hydroxyl groups by chlorine atoms.

Two isomeric monochlorhydrins are theoretically possible,



$$\begin{array}{l} \mathrm{CH_2Cl} \\ | \\ \mathrm{CHOH} \\ | \\ \mathrm{CH_2OH} \end{array}$$

Glycerol α-monochlorhydrin.



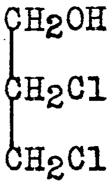
$$\begin{array}{l} \mathrm{CH_2OH} \\ | \\ \mathrm{CHCl} \\ | \\ \mathrm{CH_2OH} \end{array}$$

Glycerol β-monochlorhydrin.

and two isomeric dichlorhydrins,

$$\begin{array}{l} \mathrm{CH_2Cl} \\ | \\ \mathrm{CHOH} \\ | \\ \mathrm{CH_2Cl} \end{array}$$

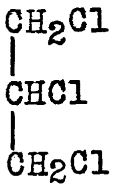
Glycerol α-dichlorhydrin.



$$\begin{array}{l} \mathrm{CH_2OH} \\ | \\ \mathrm{CH_2Cl} \\ | \\ \mathrm{CH_2Cl} \end{array}$$

Glycerol β-dichlorhydrin.

and finally, one trichlorhydrin -



$$\begin{array}{l} \mathrm{CH_2Cl} \\ | \\ \mathrm{CHCl} \\ | \\ \mathrm{CH_2Cl} \end{array}$$

Preparation of Monochlorhydrin.

Barely warm glycerol is saturated with dry hydrochloric acid gas and then heated in a sealed tube at 100 C for thirty-six hours. The viscous liquid is saturated with sodium bicarbonate, extracted with ether, and the latter distilled off. The residue is fractionated under reduced pressure and the portion boiling at 113°C/10 mm. is collected. It is a neutral oil with more or less of an ethereal odor, soluble in water, alcohol and ether.

Preparation of α Dichlorhydrin.

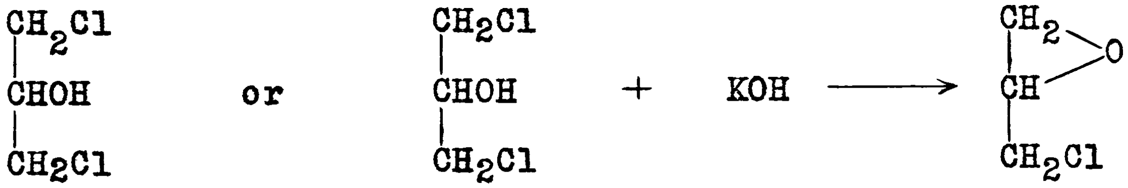
Symmetrical dichlorhydrin, or α dichlorhydrin (1.3 Dichlor-propanol-2) is prepared in the following manner:-

Glycerol is dehydrated by heating slowly to a temperature of 175° C in an evaporating dish on a sand bath. It is then mixed with an equal volume of acetic acid and dry hydrochloric acid gas is passed into the cold liquid until the gas ceases to be absorbed. The mixture is then heated on the water bath and after standing twenty-four hours, the current of gas is continued for an additional six hours. The liquid is then distilled, hydrochloric acid being driven off first, together with acetic acid, and finally the dichlorhydrin distills over at 176°C.

In the case of glycerol α monochlorhydrin and α dichlorhydrin obtained by the methods just described, the possibility exists of obtaining small quantities of the isomeric β monochlorhydrin and β dichlorhydrin as by-products, and although it is possible to separate these by fractional distillation under atmospheric or reduced pressure, depending upon which one is considered, the following method was adopted in this work in order to obtain perfectly pure chlorhydrins.

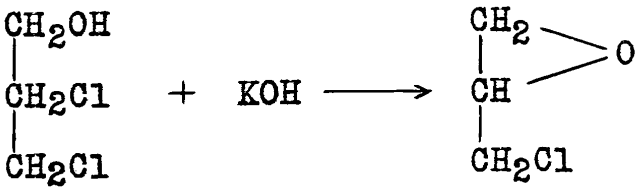
If α dichlorhydrin or β dichlorhydrin be treated at a low temperature with caustic potash, the formation of one product only is possible from either compound. This will be made clear by considering the following formulae. By such treatment the substances lose a molecule of hydrochloric acid in this manner -

(a) In the case of α dichlorhydrin -



(1) (2) (3)

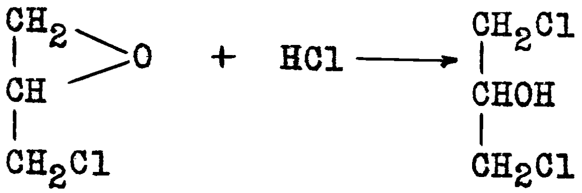
(b) In the case of β dichlorhydrin -



(4) (5)

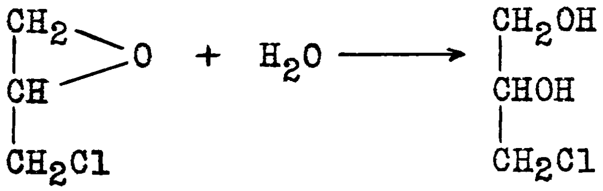
Formulae (3) and (5) are identical and the compound is epichlorhydrin. This substance reacts in the following manner;-

When treated with hydrochloric acid, the oxygen linkage is ruptured and the elements of mineral acid attach themselves to the molecule,



yielding pure ∝ dichlorhydrin, and this is the only product formed in the reaction. Thus, it is possible to obtain this compound in an exceedingly pure state from a mixture of the two isomers, by converting the latter into epichlorhydrin and its subsequent transformation into the symmetrical dichlorhydrin desired.

Similarly, epichlorhydrin can be caused to assume the elements of water, thus:-



and the compound obtained is ∝ monochlorhydrin. It is perfectly pure, as there is no possibility of the presence of the β isomer.

Preparation of the Silver Salts.

The method[86] originally employed for the preparation of the silver salts of the fatty acids was the double decomposition of the sodium salt of the acid and silver nitrate - in alcoholic solution, in the case of the higher acids and an aqueous solution in the case of the lower acids. This method possesses several disadvantages:

(a) The initial material in hand is generally the free acid and thus the method, as usually employed, involves as a preliminary step, the preparation and isolation of the sodium salt.

(b) In the case of the higher fatty acids, the silver salt has a tendency to separate in an inconvenient form - as a gelatinous precipitate.

(c) The yield may be comparatively poor. Dr. G. S. Whitby applied these methods to the preparation of the silver salts of palmitic and stearic acid in 2-4% solutions and obtained a yield of silver salt amounting to less than 50% of the theoretical.

Krafft[87] described a method of obtaining the silver salt of palmitic acid in a crystalline condition. The procedure is as follows;-

An ammoniacal alcoholic solution of the acid is mixed with a similar solution of silver nitrate, and to the resulting clear liquid, water is added. The addition of water precipitates the silver salt as fine shining crystals. Dr. Whitby found this method to give an almost theoretical yield and to be applicable to other higher fatty acids.

It was found, however, that it was possible to modify the method in such a manner as to render it simpler and more convenient. Instead of ammoniacal solutions of the acid in question, and silver nitrate, a simple alcoholic solution of the acid and an aqueous ammoniacal solution of silver nitrate could be employed. If the ammoniacal silver nitrate is prepared with the minimum amount of NH_3 to take up the first formed precipitate of silver oxide, an immediate precipitate is produced on adding it to the alcoholic solution of the fatty acid. Water is added in order to complete the precipitation of the silver salt. When this method is adopted, the salt is thrown out in a readily filterable condition in a comparatively small volume of liquid, whereas, according to Krafft's procedure, large quantities of water are required to throw the precipitate out completely, and filtration is thereby rendered tedious.

The method just described, however, has the disadvantage that the products obtained are not absolutely pure. The silver salt is contaminated with a small amount (usually less than one percent) of the free acid. As a consequence of the dilution with water, there is the occurrence of a small amount of hydrolysis, and the product, unless well washed with alcohol and ether, finally exhibits a silver content which is slightly low. (Krafft makes no record of the silver content of his product.)

It is possible to utilize an ethereal solution of the acid instead of an alcoholic, but the product obtained was found to be contaminated with the free acid to a greater extent than when an alcoholic solution was used. The following procedure, due to Dr. G. S. Whitby,[88] was employed in the present investigation. This method is even simpler than the first one adopted; it avoids the hydrolytic effect of dilution with water and it yields a pure product in a satisfactory form - a dry powder:

To the acid, dissolved in alcohol, one equivalent of ammonia is added in the form of the ordinary aqua ammonia (sp.gr. 0.9). By the addition, with constant stirring, to this solution of one equivalent of silver nitrate in an aqueous alcoholic medium, the silver salt of the fatty acid is precipitated in practically theoretical amount. The silver nitrate solution is most suitably prepared by dissolving the salt in a small quantity of water and then diluting with alcohol. The precipitated silver salt is filtered off on the pump, washed with alcohol and dried on a porous plate. Perfectly white products, which can readily be ground to fine powders suitable for the various synthetical purposes to which the salts are applicable, can easily be obtained.

All melting points recorded in the present paper were determined in narrow capillary tubes with thin walls, the temperature being raised with extreme slowness when the melting point was approached. The melting-point bath consisted of two beakers, a smaller one inside a larger, both provided with vertical stirrers operated by a hot-air engine, so that a continual and thorough mixing of the liquid was obtained, and thus a very gradual increase in temperature resulted.

The solubilities were determined by saturating the solvent for four hours with the material whose solubility was desired, at a temperature three degrees above that at which the solubility was required. The temperature was then lowered to that specified and maintained at that point for an additional six hours, the solution being continually stirred. The latter was then filtered rapidly, a definite volume pipetted into a weighed beaker, and the solvent evaporated in the electric oven. The beaker was weighed and warmed alternately until a constant weight was obtained.

The identity of the various compounds was established by saponifying a known weight of the glyceride in a definite volume of alcoholic potash, titrating the excess alkali with standard acid and comparing the observed amount of alkali required to saponify one gram of the fat with the amount demanded by theory.

The refractive indices were obtained by means of the Zeiss refractometer.

EXPERIMENTAL

Method of drying the various reagents employed in the syntheses of Margaric Acid.

Ether

Anhydrous ether was obtained in the following manner;- One litre was agitated thoroughly with 200 cc. of distilled water and separated from the latter by means of a separating funnel. This procedure was carried out three times in order to remove the last traces of alcohol present. The ether was then allowed to stand over one-third its volume of anhydrous granular calcium chloride for a period of twenty-four hours. It was then filtered into a clean, perfectly dry flask and metallic sodium was added either in wire form or as thin bright scales. When the ebullition had ceased, which required standing over night, more sodium was added and the whole allowed to stand for a further period. This treatment was repeated a number of times. Finally, the day before experiment was contemplated, the ether was distilled off from the sodium into a dry flask and allowed to stand over phosphorus pentoxide over night. Just before the reaction was carried out, the ether was distilled off the phosphorus pentoxide, and was then ready for use. On other occasions the ether was allowed to remain over sodium until conditions were suitable for a synthesis and then distilled off from this metal on to the phosphorus pentoxide, and then directly off the latter, the fifteen hour period of standing over phosphorus pentoxide being dispensed with. This modification of procedure was resorted to in order to eliminate certain undesirable changes which the ether sometimes underwent on standing overnight in the presence of phosphorus pentoxide.

Magnesium

The magnesium used was of two kinds, ribbon and turnings. Previous to its employment in a reaction, the magnesium was brightly polished by means of emery paper and dried for several hours in the electric oven at 110° C.

Cetyl Iodide - $C_{16}H_{33}I$

The product used was Schuchardt's preparation. It was dried for several weeks over granular calcium chloride after a preliminary very gentle warming over the same substance.

Carbon Dioxide

The carbon dioxide employed was obtained by the action of HCl on marble in a Kipp generator. The gas was passed successively through two sulphuric acid wash bottles, two calcium chloride towers and finally through a long tube containing phosphorus pentoxide. This treatment insured a thoroughly dry product.

Purification of Palmitic Acid.

The palmitic acid as obtained melted at 60°C. It was purified in the following manner:-

To 60 grams dissolved in 400 cc. of 95% alcohol were added 40 cc. of the same solvent containing 15 grams of potassium hydroxide in solution. The liquid was boiled for three hours under a reflux. Barium palmitate was then precipitated by the addition of an aqueous solution of 24.2 grams of barium chloride to the alcoholic solution of potassium palmitate. The precipitate was filtered off, boiled up with 600 cc. of alcohol, filtered and washed. The latter operation was carried out three times. After the final filtering and washing, the barium palmitate was decomposed and the free acid liberated by boiling with hydrochloric acid. The molten acid was allowed to cool, filtered, washed free from mineral acid and recrystallized four times from 300 cc. of alcohol. The palmitic acid then melted at 62.2°C.

Purification of Stearic Acid.

This acid was obtained in a pure state in the same manner as that described in the case of palmitic acid and when pure, it melted at 69.5°C.

Preparation of Margaric Acid by Dr. Ruttan's modification of the Grignard Reaction

The reaction was conducted in a well dried distilling flask of one litre capacity. The side tube of the flask was bent upwards and connected to a long water-cooled condenser, to the top of which was attached a U-tube filled with granular calcium chloride to prevent access of atmospheric moisture to the system.

In the neck of the flask a triple bored stopper carried a tube to the bottom of the flask through which the carbon dioxide was passed. This tube was of 3/16" bore but was widened out to 1.5 cm. in diameter where it dipped below the liquid, to prevent blocking by the solid products of the reaction. The cetyl iodide was introduced by a short stemmed 100 cc. separating funnel, which was inserted through another opening in the cork of the flask. The third hole of the stopper carried a mercury seal stirring apparatus which allowed the system to be thoroughly stirred during the entire reaction and at the same time excluded any possibility of moisture coming into contact with the reacting constituents. The stirrer was operated by a water-cooled hot-air engine. Carbon dioxide was generated in a Kipp generator. The gas then passed successively through two sulphuric acid wash bottles, two calcium chloride towers and finally through a phosphorus pentoxide tube about 60 cm. in length, and then into the reaction flask, that portion not being absorbed escaping through the condenser and calcium chloride U-tube.

Experiment No.1.

Reacting Constituents	Quantity Employed
Cetyl Iodide	35.2 gr.
Magnesium	2.5 "
Ether	200 cc.

The flask and connections were placed upon the water bath, 200 cc. of anhydrous ether and 2.5 grams of dry polished magnesium ribbon, or bright granulated magnesium, were introduced and the flask closed. About one-half the total quantity of cetyl iodide was then added with a crystal of iodine to act as a catalyser. The reaction first manifested itself by a bleaching of the iodine and a gentle ebullition of the ether in the vicinity of the magnesium. The ether was maintained in a state of ebullition by raising the water bath and immersing the flask in the warm water and then removing the bath. After thirty minutes the water bath was removed completely and a towel was wrapped around the bottom of the flask, in order to utilize the heat of the reaction. The cetyl iodide was then introduced in quantities of about one cc. After each addition of the latter, the ebullition became very brisk, then subsided somewhat in a short time until the next addition of cetyl iodide. The mixture became whitish opalescent, then dark grey and finally very dark, and carried black particles of the traces of iron in the magnesium. The reaction never became violent. The addition of cetyl iodide covered a period of two hours. When the reaction had nearly ceased, the contents of the flask were refluxed on the water bath for one hour, the temperature of the surrounding water being maintained at 42°C, and the flask being immersed to a depth of 1.5 inches. The liquid was allowed to cool and a copious precipitate of the organic metallic compound separated in bright mica-like crystals. About 200 cc. of ether were gradually added as required, to maintain the contents in liquid form while the carbon dioxide was being passed through the mixture. The temperature was kept at 21° C. Small oily bubbles gathered on the surface of the solution. As the contents of the flask became thick, the temperature was raised to the boiling point of ether. The slow stream of carbon dioxide was passed in for four hours.

When the reaction was finished, the flask was well cooled, broken ice slowly added with a dilute solution of HCl (10-7) until a faint but permanent acid reaction was obtained. The thick ethereal mixture was washed with cold water and filtered to remove most of the hydrocarbon. A portion of the ether was distilled off the filtrate and the latter filtered again after cooling. The last filtrate containing the margaric acid, some hydrocarbon, together with undecomposed cetyl iodide,was evaporated to dryness, leaving a yellowish coloured solid. This residue was washed with warm dilute alcohol in which the hydrocarbon was almost insoluble, but which dissolved the soluble acid and cetyl iodide. The liquid separated into two layers. On filtering, there was no change in the appearance of the mixture. It was evaporated to dryness. The residue consisted of 11.6 grams of a yellow solid. It was dissolved in 90 cc. of alcohol, two grams of an alcohol solution of NaOH added and the solution refluxed for three hours. The alcohol was evaporated and the dry powdered soap extracted in a Soxhlet for four hours with ether. This treatment removed cetyl iodide, traces of cetyl alcohol and any remaining hydrocarbon. The acid was liberated in a beaker by means of warm sulphuric acid, the solid fatty acid removed after cooling, washed with water until the washings gave a neutral reaction, and then recrystallized from alcohol. By washing the hydrocarbon, filtered off at different stages, with warm dilute alcohol, more acid could be recovered. After a number of recrystallizations the margaric acid melted at 59.9° C.

Ditria-contane or Dicetyl.

The hydrocarbon obtained as a by-product has been identified by Dr. R. F. Ruttan as Dicetyl $C_{32}H_{66}$, formed by the action of magnesium on the iodide,

$$2C_{16}H_{33}I + Mg \longrightarrow MgI_2 + C_{32}H_{66} .$$

It recrystallizes from ether or hot alcohol in shining white waxy plates, melting at 70.5° C, and has a refractive index of 1.4334 at 72°C. It is almost insoluble in cold alcohol and petrolic ether, but very soluble in hot ether. It is somewhat soluble in the soaps of margaric acid, from which it is extracted with difficulty. The slightest trace of moisture in the reacting mixture greatly increases the amount of this hydrocarbon formed. It is very essential, therefore, to especially dry both the cetyl iodide and carbon dioxide to minimize the formation of this hydrocarbon which is removed from the mixture with such difficulty.

Experiment No.2.

In this experiment the same molecular proportions of reacting constituents were used as in Experiment No.1, with the exception of the magnesium, a slight excess of which was employed. Vigorous stirring was maintained during the entire course of the reaction. The solution bleached quickly and towards the end, the reaction became vigorous. After two hours the reaction had practically ceased. The solution was refluxed for three hours. The stream of dry CO_2 was allowed to pass through the system for eight hours with vigorous stirring and then for four hours without stirring. The flask was well cooled with ice, the contents acidified slowly at a low temperature and washed with cold water. The mixture was filtered and the filtrate evaporated. The yield of crude product was 10 grams. This was dissolved in alcohol, saponified for four hours with the theoretical amount of sodium hydroxide and extracted in a Soxhlet apparatus with petroleum ether for eight hours. The sodium salt was decomposed and the acid recrystallized repeatedly from alcohol.

Experiment No.3.

The quantities employed were as outlined previously. The duration of the initial reaction was 1.5 hours. Refluxing was carried on for 1.5 hours without stirring, then for 2.5 hours with stirring. The stream of CO_2 was allowed to pass through for 8.25 hours. The usual procedure was adhered to in the purification. The amount of crude margaric obtained was 11 grams, while the quantity of by-product (dicetyl) amounted to 12 grams. The margaric acid was dissolved in alcohol, an aqueous alcoholic solution of 2.0 grams of NaOH added and the whole boiled under reflux for four hours. On this occasion there were no drops of oil on the surface of the solution such as had been observed in previous experiments. The solution was very dark grey in colour. On evaporation to dryness, there was obtained a grey mass of substance, which was thoroughly dried and extracted for six hours with dry chloroform. The soap was converted to the acid, forming a brownish mass. The molten acid was boiled for some time in the wash waters, which extracted most of the colouring matter. The solution was then filtered. The filter paper on long standing assumed a brownish coloration, due to the separation of free iodine. The acid was recrystallized to a constant melting point. The dicetyl, amounting to 12 grams, was refluxed with alcoholic sodium hydroxide for three hours and extracted with ether. In this way, a further quantity of margaric acid was obtained.

Experiment No. 4.

Reacting Constituents	Quantity Employed
Cetyl Iodide	35.2 grams
Magnesium	2.7 "
Ether	400 cc.

On this occasion reaction was fairly vigorous over a period of one hour, but had entirely ceased at the expiration of an additional twenty minutes. The solution was refluxed for three hours, and the stream of carbon dioxide allowed to pass through for 8.25 hours. After suitably cooling the mixture, 18 cc. of a solution of 15 cc. of concentrated hydrochloric acid in 15 cc. of water were added. The crude acid was saponified for three and a half hours with an alcoholic solution of three grams of sodium hydroxide. The solution was evaporated to dryness and the residue extracted with ether for seven hours. The ether was distilled off and the acid repeatedly recrystallized from alcohol.

As in the previous experiment, an additional quantity of margaric acid was obtained by suitably treating the dicetyl.

Experiment No.5.

The proportions of reacting constituents employed were the same as in the preceding experiment. The other details were as follows:-

Duration of Initial Reaction	-	1.25 hrs.
Length of Refluxing Period	-	3.5 "
Period of Carbon Dioxide Introduction	-	6.0 "

The quantity of hydrochloric acid (1:1) added was 15 cc. . On allowing to stand the solution became quite brown. It was cooled, filtered and evaporated to dryness, leaving a very brown residue. After some time this changed over to a dark grey. The crude margaric acid, amounting to 22.0 grams, was saponified for five hours and the dicetyl treated with alcoholic sodium hydroxide solution for three hours. The subsequent treatment was identical with that adopted for the purification of the acid in the preceding experiments.

A large number of other experiments of a similar nature were performed and margaric acid thus prepared in quantity.

The experimental details of the synthetical preparation of margaric acid by means of the Grignard reaction involving subsequent oxidation, are as follows:-

In a large flask equipped with a thermometer-well and stirrer, are placed 14.6 grams of brightly polished magnesium turnings; 94.2 grams of brombenzene are mixed with 120 cc. of anhydrous ether, and a few cc. of this mixture, together with a small crystal of iodine to act as a catalyst, are added through a dropping funnel. Should the reaction not start readily, a few cc. more of the brombenzene-ether mixture are added and it may be necessary to warm slightly. When the reaction has started the flask is surrounded by cold water and a hundred cc. of anhydrous ether are added. The remainder of the brombenzene-ether mixture is then added slowly through the dropping funnel, maintaining the contents of the flask in gentle ebullition. When all has been added, the contents are refluxed for three hours.

The flask is then surrounded by ice,and 60 grams of pure methyl stearate dissolved in 150 cc. of anhydrous ether are added with stirring, keeping the temperature about 10-15° C. The contents of the flask are refluxed for one day, after which the ether is distilled off. Ice is added to the residue, with shaking, and enough hydrochloric acid to render distinctly acid not allowing the temperature to rise. The two layers are separated and the water layer extracted with a little ether. This ether is combined with the other layer and the solvent distilled off. The residue is distilled in vacuo under a pressure of 8 mm. of Hg. The material coming over, up to 200°C, is neglected and that distilling over between 200 and 265°C is taken as hexadecydiphenylethylene.

The product is placed in a large flask with a mixture of 60 grams of concentrated sulphuric acid, 1500 cc. of acetic acid and 150 cc. of water. The flask is fitted with a stirrer, dropping funnel and reflux condenser. The contents of the flask are heated to boiling and a concentrated solution of 72 grams of sodium dichromate added, drop by drop, stirring the mixture at boiling temperature for about four hours. When cold, the waters are siphoned off, extracted once with benzene and then discarded. The crude acid is submitted to steam distillation to remove all of the benzophenone. The margaric acid is recrystallized from petrolic ether, chilled thoroughly, filtered and washed. There is a small amount of residue from the petroleum ether. On drying, the white product, melting at 58-59°C, is obtained. The pure acid may be isolated by saponifying the mixture, extracting the dry soap for some time with petrolic ether or dry chloroform, decomposing the alkali salt with hydrochloric acid, and recrystallizing the margaric acid several times from alcohol.

Purification of the Chlorhydrins.

Samples of pure α dichlorhydrin and α monochlorhydrin were obtained by the practical application of the theoretical considerations already described, namely - by the conversion of the commercial α dichlorhydrin into epichlorhydrin and the subsequent treatment of this compound so as to produce α dichlorhydrin and α monochlorhydrin. This method gave rise to the formation of compounds, the purity and structure of which were beyond reasonable doubt.

Preparation of Epichlorhydrin.

A solution of 200 grams of caustic potash in 400 cc of water was well cooled and allowed to drop slowly from a dropping funnel, with constant stirring, into 240 grams of α dichlorhydrin. Rise of temperature was carefully avoided. After the addition of caustic alkali was complete, the epichlorhydrin was removed from the reaction product by repeated extractions with ether. The ether layer was separated, washed several times with water and dried over calcium chloride.

It was filtered from the latter and the ether removed by gently warming on the water bath. The residue was then fractionally distilled, and the portion boiling at 116-118° C collected.

Dichlorhydrin from Epichlorhydrin.

To 70 cc. of fuming hydrochloric acid was added very slowly an equal volume of pure, freshly distilled epichlorhydrin contained in a thin walled separating funnel. The addition was accompanied by a vigorous reaction and the evolution of considerable heat. On cooling, the reaction product separated into two layers. The upper layer was siphoned off and the lower washed in a separating funnel with a 5% solution of sodium carbonate, to remove traces of hydrochloric acid. The lower layer was again separated and allowed to stand for eight hours over calcium chloride. The liquid was then decanted and distilled, the fraction boiling at 176-177° C being collected and the percentage of chlorine determined by alkaline hydrolysis.

			Chlorine Content
Calculated for	-	$C_3H_6OCl_2$	54.96%
Found	-		55.08%

Monochlorhydrin from Epichlorhydrin.

Fifty grams of epichlorhydrin were boiled for fourteen hours with 50 cc. of water under a reflux condenser. At the commencement of the reaction the contents of the flask consisted of two layers. At the end of four hours the liquid was homogeneous. After completion of the reaction the clear, yellowish liquid was fractionally distilled under reduced pressure, the chlorhydrin distilling over at a constant temperature of 113°C under a pressure of 10 mm.

			Chlorine Content
Calculated for	-	$C_3H_7O_2Cl$	32.08%
Found	-		32.12%

Preparation of Silver Margarate

Twenty grams of margaric acid were dissolved in 1000 cc. of 95% alcohol and then there were added successively, 5.1 cc. of aqueous ammonia containing 25.18 grams NH_3 per 100 cc. and a solution of silver nitrate - prepared by dissolving 12.6 grams of silver nitrate in 12.6 cc. of warm water and diluting with 60 cc. of alcohol. The temperature of the margaric acid solution was maintained at 50°C. It was found that the silver salt came down in a readily filterable form when a slightly elevated temperature was employed. The liquid was allowed to stand for four hours in the dark and was then filtered through a large

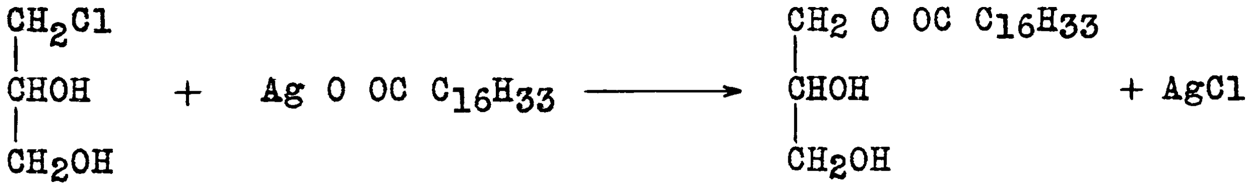
Buchner funnel. The silver salt was dried on a porous plate, powdered and finally dried for several hours in an oven at 50°C. The product was a dry white powder.

Analysis

0.4106 grams gave 0.1174 grams of silver on ignition. Silver content 28.67%. $C_{16}H_{33}COOAg$ requires 28.65 percent Ag.

Synthesis of α Monomargarine using Silver Margarate

Reaction -



$$\begin{array}{l} CH_2Cl \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + Ag\ O\ OC\ C_{16}H_{33} \longrightarrow \begin{array}{l} CH_2\ O\ OC\ C_{16}H_{33} \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + AgCl$$

The reaction vessel consisted of a cylindrical glass tube 100 mm. long and 40 mm. wide. Into this vessel were poured 2.4 grams of α monochlorhydrin, the tube being rotated continually so as to distribute the liquid uniformly over the lower interior surface of the vessel. There were then added to this, in small portions and with thorough mixing, 6.82 grams of silver margarate. The reaction tube was connected to an air reflux condenser and heated slowly in the oil bath to 135° C. The contents of the tube rapidly assumed a liquid consistency and at the end of three hours the liquid was very dark brown in colour. The mixture was thoroughly stirred at regular intervals.

After cooling, the solid fat was removed, and digested with 100 cc. of ether, forming a dark brown suspension. It was then attempted to filter the solution by means of a hot-water funnel. This was not a complete success, however, owing to the fact that a small quantity of the substance, consisting of very fine particles, passed through the filter paper even after several repetitions of the process. Other methods of separation were tried in attempts to effect complete separation. On allowing the suspension to stand in narrow cylindrical vessels for some time, a certain proportion of the particles settled to the bottom under the influence of gravity. This method, however, was not satisfactory, either in the quantity separated or in the time factor. Centrifuging was then resorted to. This method proved fairly successful, but final and complete separation was accomplished by extracting the whole mass with ether in a Soxhlet apparatus provided with an extraction thimble possessing walls of considerable thickness.

This extraction was continued for two hours and the ether distilled off. The residue consisted of a dark solid mass. This was analyzed for free margaric acid due to the decomposition of the silver margarate.

The margaric acid in the product obtained above amounted to 56.2 percent of the whole. The product was fused in a porcelain evaporating dish with the theoretical quantity of sodium bicarbonate necessary to convert the acid completely into the sodium soap, and heated on the water bath for 0.5 hours. It was then allowed to cool and extracted with ether in a Soxhlet. On evaporation of the ethereal solution, it was found that the product possessed an acid reaction. The mixture of fat and free acid, weighing 4.61 grams and containing 44 percent free margaric acid, was fused on the boiling water bath for one hour with the theoretical quantity of $Ca(OH)_2$ required to convert the free acid to the calcium salt. The mass was extracted with three fifty cubic centimetre portions of boiling ether and filtered by means of a hot-water funnel. After evaporation of the ether, it was shown by tests that the mixture was still acid. It was, accordingly, fused with one gram of calcium hydroxide at 100°C for 0.25 hours, according to the method of Berthelot, and treated subsequently as already described. The fat was still acid to litmus. It was then treated with $NaHCO_3$ in the same way, but as before, this method of procedure yielded a fat that was still acid. The mixture was finally dissolved in alcohol (95 percent) and the theoretical amount of sodium hydroxide added. The sodium soap was precipitated; the alcohol evaporated off at a low temperature so as to avoid possible saponification of the glyceride; the dry material extracted in a Soxhlet for one hour, and the solid residue pulverized and extracted again for twenty minutes longer. The residue of sodium margarate weighed 0.9838 grams corresponding to 0.9086 grams of margaric acid which was present in the mixture after the treatment with $Ca(OH)_2$ and $NaHCO_3$. The molten residue from the ether extraction was perfectly neutral as verified by tests. It weighed 2.11 grams and melted at 52-54°C. As this quantity was small and contained a large amount of by-products (as shown by the low melting point), further experiments were carried out in order to obtain the glyceride in sufficient quantity for purposes of further purification.

Experiment No.2

On this occasion the silver margarate employed was dried in the electric oven at 110°C for 1.25 hours, and then at 80°C under a pressure of 47 mm. for one hour. All the apparatus was thoroughly dry. 10.4 grams of silver margarate were mixed as thoroughly as possible with 3.44 grams of α monochlorhydrin and heated at 135°C. In one hour's time the contents of the tube had swelled up almost completely filling the flask, and on stirring, this mass subsided to a mobile liquid, very pungent fumes being evolved. The flask was heated at the temperature indicated for 3.25 hours. On being allowed to cool, the liquid solidified to form a dark gray compact mass. The latter was removed from the flask and extracted with ether, the usual difficulty being encountered regarding the passage of small particles of inorganic matter through the filter.

On evaporation of the dark brown ethereal solution there remained 9.12 grams of a dark greasy solid. The quantity of free margaric acid in this mass, as determined by analysis, amounted to 49.81 percent. After two fusions on the water bath with $NaHCO_3$, the product was neutral and had lost a considerable quantity of its colour. It was dissolved in 50 cc. of 95 percent alcohol, refluxed with 7 grams of animal boneblack for ten minutes and filtered. The colour of the solution had changed from deep brown to a very light straw yellow. The product appeared to darken on standing and when solid melted at 53-55°C. It was dissolved in 10 cc. of alcohol, 45 cc. of ether were added and the solution allowed to stand for some time, and finally frozen out at 17 C. This treatment was unsatisfactory, yielding only a small quantity of a very yellow substance. The fat was then dissolved in a small quantity of C_6H_6 and precipitated with 4-5 times the volume of alcohol. The yellow product so obtained was decolorized in alcoholic solution with animal boneblack, filtered and the solution concentrated. Small black drops of oil separated out as a result of this treatment. The solution was separated from these and evaporated to dryness. The residue was dissolved in 14 cc. hot benzene and 50 cc. of 95 percent of alcohol added and the whole allowed to stand, and then filtered. A small amount of yellowish substance, melting point 56° C, was obtained.

Experiment No. 3.

To a solution of 1.32 grams of α monochlorhydrin in 20 cc. of ether were added 7.54 grams of silver margarate. The suspension was thoroughly stirred while the ether was slowly evaporated. The mass was then heated to a temperature of 145 C. After two hours the contents of the reaction tube were completely liquid. The material obtained by allowing this to cool, extracting with ether and evaporating the latter, contained 50.09 percent margaric acid and weighed 6.15 grams. It was dissolved in 50 cc. of 95 percent alcohol and the calculated quantity of alcoholic caustic potash added, and the solvent removed at 40°C under a pressure of 29 mm. The dry residue was extracted with $CHCl_3$ but the latter apparently extracted some of the potassium margarate. The resulting alkaline fat was extracted with petrolic ether and the latter evaporated. The residue was still alkaline however. It was finally ground up with $CaCl_2$ and extracted with ethyl ether. The resulting fat was neutral, but the amount obtained was small.

Experiment No.4.

10.24 grams of silver margarate were suspended in 150 cc of phenetole and the whole stirred for 0.75 hours at 130° C. At the end of this time a certain amount of the silver salt remained in suspension. To this was added a solution of 3.6 grams of α monochlorhydrin in 30 cc. phenetole and the system heated to 155°C for 2.5 hours with vigorous stirring. The product at the end of this period consisted of a light brown liquid, free from suspended matter. On the bottom of the reaction flask, however, was a layer of viscous material. A layer of this same substance around the walls of the flask prevented observation on the progress of the reaction during the period of heating. The hot liquid was filtered and allowed to stand over night in the cold. There separated out from the phenetole 2.92 grams of a beautiful white substance consisting of shining platelets (A). These crystals were filtered off and the filtrate evaporated under reduced pressure (29 mm.) on the water math. This treatment yielded a small amount of yellowish material (B). These two fractions were analyzed for margaric acid with the following results:-

Fraction	% Margaric Acid
A	97.5
B	92

The white crystals constituting fraction A, melted at 59.6 C. These figures demonstrated very conclusively that complete decomposition of the silver salt had occurred during reaction.

The fact that complete decomposition took place in this instance is peculiar, in view of the fact that the synthesis of glycerides of palmitic and stearic acids can be effected in phenetole solution.

Experiment No. 5.

Thirteen grams of silver margarate were placed in the reaction tube and there was added a solution of 5.00 grams (31.5% excess) of α monochlorhydrin in 40 cc. of anhydrous ethyl ether. The salt was thoroughly agitated in the ethereal solution and the latter slowly evaporated to dryness. After the ether had been removed, the reaction vessel was heated to 135°C. At the expiration of one hour, half the contents of the vessel were liquid. The reaction was continued for another 1.5 hours. After allowing to cool, the solid cake of fat was removed and extracted with ether in a Soxhlet apparatus. The ether was evaporated to dryness, leaving a dark solid residue weighing 13.22 grams. This was analyzed for free margaric acid and the amount found to be 33.61 percent, being considerably lower than in the previous experiments using direct methods of mixing. The mixture of acid and fat was dissolved in 100 cc. of 95 percent alcohol and caustic potash added. The alcohol was evaporated at 40°C under a pressure of 25 mm. and the dry residue extracted with chloroform. Less than two grams of potassium margarate were obtained as a result of this procedure, and on evaporation of the chloroform the molten fat reacted distinctly alkaline to litmus. According to the calculations based on the analysis of the raw product, there should have been obtained at this point 5.3 grams of potassium margarate. Obviously, the chloroform employed in the extraction of the mixture was carrying through a large amount of soap with the fat. This fact could be accounted for if the solvent contained even a very small amount of water, but this contingency had been guarded against by carefully drying the chloroform over calcium chloride for one week previous to its employment as a solvent. A small quantity of the chloroform soluble material was extracted in a Soxhlet with petrolic ether (b.p. 35-53°C). The fat, however, still possessed an alkaline reaction. A series of investigations was then performed in order to ascertain definitely what circumstance was responsible for the fact that the fat obtained was alkaline. It was discovered after some investigation, that the potassium soap of margaric acid was soluble in α monochlorhydrin. In this experiment a relatively large excess of the chlorhydrin had been employed and hence the fact that the fat obtained was alkaline, was due, no doubt, to the α chlorhydrin exerting a solvation effect on the potassium margarate, carrying a certain proportion of the latter with it in chloroform solution and thence into the fat which, as a consequence of the presence of potassium margarate possessed an alkaline reaction. The following method was tried in an attempt to obtain this ester in a neutral condition, - a portion of the alkaline fat was ground up with sodium chloride and sodium carbonate and the entire mass extracted in a Soxhlet apparatus. The fat obtained on evaporation of the ether was neutral. This result can be explained by the circumstance that the α monochlorhydrin and potassium margarate were dispersed throughout the mass of sodium carbonate and sodium chloride, and as a consequence the chlorhydrin was prevented from exerting any solvent action on the potassium margarate. The fact that small amounts of this salt were not dissolved by the ether (due to presence in the latter of traces of moisture) as would ordinarily be expected, was due to the fact that the sodium chloride acted as a dehydrating agent, and hence, any soap that might have been temporarily dissolved in the ether would be precipitated from solution. Therefore, the sodium chloride could not be replaced by sand or paper.

In addition, this method of separation afforded a complete extraction of the fat, as the sodium chloride acted in such a manner as to prevent the formation of emulsions which are apt to occlude ether soluble material.

The fat obtained on the evaporation of the ether was recrystallized from 50 cc. alcohol and then from 25 cc. ether. The crystals melted at 67.2-68.8°C. It was attempted to recover some product from the mother liquor but the substances obtained on purification melted at 51.53°C.

The products obtained in experiments Nos. 1 and 3, were subjected to recrystallization in the following manner and with the results shown:-

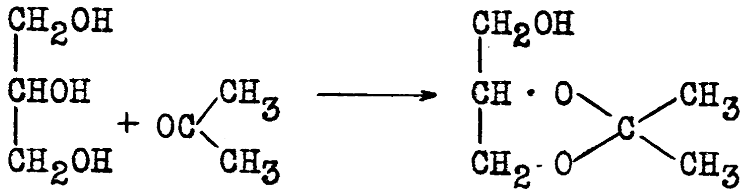
Recrystallization	Solvent	Quantity	M.P.of Crystals °C.	M.P.of Mother Liquor Residue °C.
1	Ether	25 cc.	68.2-69.5	60-64
2	"	20 "	69.3-70.3	62-67
3	"	20 "	69.5-71.2	66-70.5
4	"	20 "	71.5-72	70.2-71.8
5	"	60 "	71.6-72.7	-
6	"	50 "	72.6-73.6	-
7	"	50 "	73	-

The purest product obtained by this method melted at 73° C.

Preparation of α Monomargarine by means of Isopropylidene Glycerol.

Method - Condensation of glycerol and acetone at room temperature in the presence of a catalyst.

Reaction



To 50 grams of freshly distilled anhydrous glycerol were added 325 ccm. of dry acetone containing one percent of hydrochloric acid. The acetone had previously been allowed to stand three days over granular calcium chloride and subsequently distilled over a fresh quantity of the same substance. To the acetone and glycerol contained in a stout-walled bottle, were added 20 grams of strongly heated and powdered sodium sulphate, the flask attached to the fly wheel of a hot-air motor, and rotated for twelve hours at room temperature. This procedure brought about very thorough mixing of the constituents. At the conclusion of the twelve hour period, the greater part of the hydrochloric acid was removed by the addition of lead carbonate and vigorous shaking. The solid matter was filtered off with suction, silver oxide added to the filtrate, and the latter fractionated. The addition of silver oxide prevented any hydrochloric acid arising from the decomposition of organic chlorine compounds, causing partial decomposition of the acetone-glycerol at the somewhat higher temperature. After removal of the acetone, the acetone-glycerol distilled over at 99°C under 29 mm. pressure. The yield amounted to 37 grams. Acetone-glycerol is a colorless liquid possessing practically no odor.

Synthesis of Margaryl-Acetone-Glycerol

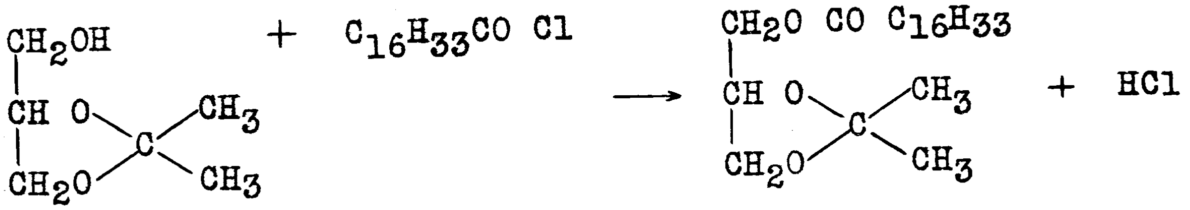
$$C_{16}H_{33} \cdot CO \cdot C_3 H_5 O_3 \cdot C_3 H_6$$

Method - Interaction between margaryl chloride and acetone-glycerol at room temperature.

Reactions

(1) $C_{16}H_{33}COOH + PCl_5 \longrightarrow C_{16}H_{33}\,CO\,Cl + POCl_3 + HCl$

(2)



Margaryl chloride was prepared in the customary manner employed for the preparation of the chlorides of the higher fatty acids.

Fifteen grams of pure margaric acid were placed in a dry fractionating flask provided with a tightly fitting cork and a calcium chloride tube attached to the side tube. There were added 11.6 grams of good quality, finely pulverized phosphorus pentachloride and the flask gently warmed on the water bath for 1.25 hours. The phosphorus oxychloride formed in the reaction as a by-product, was removed by heating the flask on the water bath under a pressure of 29 mm. Hg, the phosphorus oxychloride distilling over and the margaryl chloride remaining behind.

The margaryl chloride could be distilled over at a much higher degree of vacuum, but considerable decomposition occurs at even 10 mm. and the yield of acid chloride is small. Consequently, the margaryl chloride was used in this condition, which was found to be very satisfactory.

To a transparent mixture of 6 grams of acetone-glycerol and 6.38 grams of quinoline, were added 12 grams of margaryl chloride in several portions and with thorough shaking. Reaction took place with the evolution of heat. The reaction mixture was, accordingly, cooled thoroughly after each addition of margaryl chloride and a low reaction temperature was thus maintained. During the addition of the acid chloride, the clear liquid became turbid and in the course of a few minutes, the entire mass assumed the consistency of a paste, and finally the whole mass solidified. The system was allowed to stand for three days at room temperature. It was then taken up with a mixture of 100 ccm. of ether and 100 ccm. of half-normal sulphuric acid, the ether layer siphoned off, washed thoroughly with two successive portions of 60 cc. of N/2 H_2SO_4 and finally shaken vigorously with 20 ccm. of a 10 percent potassium bicarbonate solution. This procedure caused the formation of an emulsion and in order to destroy it, 4 grams of sodium chloride were added to flocculate the soap formed. The solid matter was then filtered off. The ether layer was separated, washed well with distilled water, dried over sodium sulphate and evaporated. The crystalline residue of 11 grams (69 percent of the theoretical) was recrystallized rapidly from 90 cc. of 95 percent ethyl alcohol. The pure product melted at 34.8 C. It possessed a slightly yellowish colour. The entire mass was dissolved in 160 cc. of 95 percent alcohol and allowed to crystallize slowly. The first small crop of crystals separating out was yellow in colour. This was filtered off and the remaining crystals separated in long white needles which melted at 35.5°C.

Margaryl-acetone-glycerol is easily soluble in ether, chloroform, acetone, benzene, petrolic ether, ethyl and methyl alcohols.

Saponification Value.

Calculated for	-	$C_{23}H_{44}O_4$	146.2
Found	-		147.0

Refractive Index

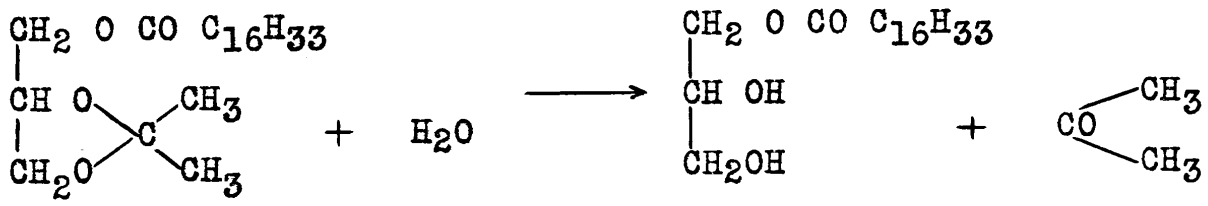
n_D^{45}	1.4403	n_D^{60}	1.4342
n_D^{50}	1.4383	n_D^{65}	1.4323
n_D^{55}	1.4362	n_D^{70}	1.4304
n_D^{75}	1.4286		

Synthesis of α Monomargarine

$C_{16}H_{33}$ CO O CH_2 CH(OH) CH_2 OH

Method - Hydrolysis of margaryl-acetone-glycerol by means of hydrochloric acid at room temperature. This reaction involves cleavage of a portion of the molecule, acetone being eliminated.

Reaction



To a solution of three grams of margaryl-acetone-glycerol in 15 cc. of anhydrous ether, was added 15 cc. of concentrated aqueous hydrochloric acid (Sp.gr. 1.19). On shaking, the temperature of the mixture increased somewhat and a clear solution resulted. It soon separated, however, into two layers. During the process the temperature of the reacting constituents was kept between 22 and 25°C by suitable cooling. After the hydrochloric acid had been added, the system was maintained at a temperature of 20°C for 0.5 hours; 60 cc. of water were then added and the mass allowed to stand 0.5 hours in a cold mixture. The α monomargarine separated out as a voluminous lustrous mass on the surface of the liquid. It was then filtered with suction, thoroughly washed with water and dried over sodium sulphate, and finally phosphorus pentoxide. It was recrystallized twice from 75 cc. of warm ether, and melted at 74.5 to 76° C. After two further recrystallizations from the same volume of ether, it melted at 76.4° C.

α Monomargarine crystallizes in thin elongated plates tapering to a point at either end. It is easily soluble in benzene, chloroform, alcohol, ethyl acetate and butyl alcohol, but difficultly soluble in cold ether.

Saponification Value

Calculated for	-	$C_{20}H_{40}O_4$	163.0
Found	-		161.1

Solubilities

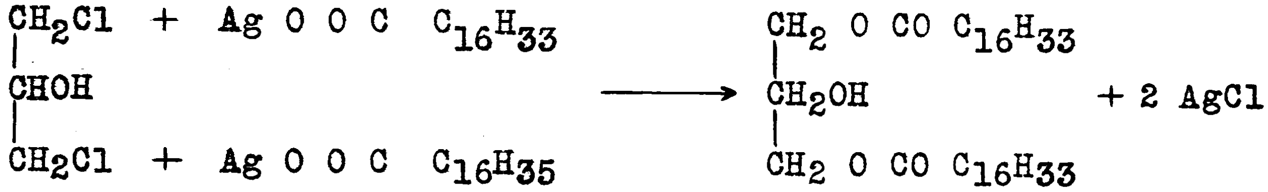
Temperature °C.	Absolute Alcohol (in 100 cc.)	Ether (in 100 cc.)
0	0.3015 grams	0.1945 grams
15	1,0545 "	0.7810 "

Refractive Index

n_D^{80} 1.4412

Synthesis of α Dimargarine

Reaction



$$\begin{array}{l} CH_2Cl + Ag\ O\ O\ C\ \ C_{16}H_{33} \\ | \\ CHOH \\ | \\ CH_2Cl + Ag\ O\ O\ C\ \ C_{16}H_{35} \end{array} \longrightarrow \begin{array}{l} CH_2\ O\ CO\ C_{16}H_{33} \\ | \\ CH_2OH \\ | \\ CH_2\ O\ CO\ C_{16}H_{33} \end{array} + 2\ AgCl$$

The reaction was carried out on a small scale at first to determine the optimum conditions.

In the reaction vessel were placed 1.17 grams of α dichlorhydrin and to this were added 5.85 grams of silver margarate, and the two substances continuously mixed. The mixture was then subjected to a temperature of 140-150 C for three hours. In a short time a certain amount of condensation was observed on the sides of the tube at a temperature of 105 C. At certain intervals approximately 0.25 hour apart, the oil bath was removed, the tube disconnected from the air condenser and the molten mass thoroughly mixed. The apparatus was then reconnected, the oil bath replaced and the heating continued. The mixture gradually changed in colour from a light gray to almost black.

At no time did the condensate in the reflux rise to more than about two inches above the top of the cork in the tube. At the expiration of three hours the mixture was allowed to cool. The solid residue was boiled up with 100 cc. of ether and filtered through a hot funnel. The filtrate was very dark brown in colour. This process was repeated several times. Upon filtering the final washings through an ordinary funnel, a considerable amount of pure white substance crystallized out on the sides of the filter paper. This material melted at 52-54° C.

On evaporation of the ethereal solution, there were obtained 2.9 grams of a dark brown residue melting at 52-54° C, thus exhibiting the same melting point as the white substance mentioned above. Free margaric formed 55.6% of the mixture, as determined by analysis. The free acid was neutralized and separated from the fat in the usual manner. The quantity of the latter obtained, however, was too small to purify further.

Experiment No. 2

In this experiment, 11.68 grams of silver margarate were added to a solution of 2.40 grams of α-dichlorhydrin in 40 cc. of anhydrous ether, and the two thoroughly mixed. The ether was evaporated by inserting the reaction tube in the electric oven at a temperature of 50° C, at the same time drawing a stream of air through the oven. As the mass became viscous, due to the loss of ether, it was stirred vigorously and finally it settled to a hard dry cake. The latter was powdered in the tube and heated on an oil bath under a reflux. Apparently, there was no reaction after the contents had been maintained at 130°C for one hour. The temperature was increased to 140°C and kept at this point for another hour without any visible evidence of the occurrence of a reaction. The temperature was finally raised to 155°C and maintained there for an additional 2.5 hours and reaction ultimately took place. On cooling, the fat set to a hard dark mass, which was removed from the tube, divided into small portions, transferred to a Soxhlet apparatus and extracted with ether for three hours. The ether apparently did not extract the entire amount of fat and accordingly benzene was also employed. The solvent was evaporated, leaving 6.74 grams of a dark brown residue, of which 44.87% consisted of free margaric acid.

The mixture was dissolved in 75 cc. of 95 percent alcohol, the margaric acid, amounting to 2.98 grams, was converted to the potassium soap by the addition of an alcoholic solution of 0.6191 grams of potassium hydroxide. The soap separated out and the alcohol was evaporated under a pressure of 26 mm. of mercury at a temperature of 40°C. The dry soap was extracted with pure dry chloroform. On evaporation of the solvent, it was found that the fat possessed an acid reaction. It was dissolved in neutral alcohol and a dilute potassium hydroxide solution added until it was neutral to phenolphthalein. The solution was warmed on the water bath at 40°C. In a few minutes the solution had an acid reaction; a few more drops of alcohol potassium hydroxide were added to neutralize the solution, and again after a few minutes standing the solution was acid.

It would thus appear that a continual process of hydrolysis was in operation. The alcohol was finally removed under reduced pressure at room temperature, the glyceride ground up with sodium chloride and extracted with ethyl ether. After distilling off the ether, the fat was dissolved in alcohol, decolorized for some minutes with 1.0 gram of animal boneblack and recrystallized. The crystals were united with those obtained in the preceding experiments and recrystallized, with the following results:-

Recrystallization	Solvent	Quantity cc.	M.P. of Crystals °C.
1	Alcohol	75	55.5-58
2	"	50	60.5-61.8
3	"	50	60.7-63.5

The combined product was then fractionally recrystallized from 75 cc. of ether.

Fractions	Melting Point °C
1	63.3-64
2	61.5-65
3	56.5-58
4	55.3-56

Experiment No. 4

Parthiel's modification was then employed for the preparation of the fat. 7.89 grams of silver margarate were mixed in a mortar with 1.36 grams of α dichlorhydrin and sufficient dry xylene added to form a thick paste. The product was heated slowly to 155° C, and after two hours was almost completely liquid. After solidifying, it was extracted with ether, the latter evaporated and the product analyzed for free margaric acid.

The quantity of acid in this experiment amounted to 47.5 percent of the total weight of the raw product. The substance was dark brown in colour. The free acid was neutralized in the usual manner, the product dissolved in 60 cc. of hot alcohol, filtered and allowed to stand some time in the cold. There separated out a small quantity of intensely yellow crystals melting indefinitely between 53° and 61° C.

Experiment No. 5

In this experiment potassium margarate was substituted for the silver salt.

Five grams of margaric acid were dissolved in 350 cc. of 95% alcohol and exactly neutralized with alcoholic potassium hydroxide, using phenolphthalein as indicator. The alcohol was distilled off and the potassium margarate dried for one hour at a temperature of 125°C under a pressure of 40 mm. mercury.

6.37 grams of potassium margarate were then ground up thoroughly with 1.52 grams of α dichlorhydrin and heated to a temperature of 160-170° C for three hours. The reaction mixture was of a dark yellow tint as compared with the almost black products that were obtained at the parallel stage in the preceding experiments, in which silver margarate was used. Extraction with benzene dissolved the whole mass; the solvent was then evaporated and the residue extracted with dry chloroform. This procedure separated the fat from the potassium chloride formed in the reaction. After evaporation of the chloroform, the product was found to contain 8.6 percent of free margaric acid. The decomposition was thus very much less than in the preceding experiments. After removal of the acid, the fat was recrystallized from 90 cc. alcohol, the resulting crystals melted at 60.5-67°C. The yellow crystals were extracted with 100 cc. boiling alcohol and separated from a small amount of tarry material. The crystals were then subjected to systematic recrystallization as follows:-

Recrystallization	Solvent	Volume of Ether -cc.	Melting Point Crystals	Melting Point Residue
1	Ether	25	66 -69.5	48 -55
2	"	25	67.6-70.7	50 -63
3	"	25	68.4-71	56 -66
4	"	50	68.8-71.2	68 -69
5	"	50	69.5	68.5-69

The final product consisted of a small amount of crystals, yellowish in colour.

Conditions now having been established for the preparation of the glyceride by means of α dichlorhydrin and potassium margarate, the experiment was performed on a larger scale.

Experiment No. 6

17.84 grams of potassium margarate, dried for two hours at 120°C under a pressure of 18 mm. of mercury, were mixed as thoroughly as possible in a large evaporating dish, with 4.5 grams of α dichlorhydrin. There were added to this and thoroughly admixed with it, about 20 cc. of xylene, dried for a long time over metallic sodium. The resulting mass was of a thick pasty consistency. It was then introduced into the reaction vessel and heated slowly to 160-170° C for 3.5 hours with frequent stirring. The contents of the flask separated into two layers, the upper consisting of a light coloured liquid, and the lower a white solid. The solid material obtained on allowing the reaction mixture to cool was removed from the flask and extracted with chloroform. The residue, insoluble in this solvent, consisted solely of potassium chloride, no unchanged potassium margarate being present. This was demonstrated by digesting the chloroform insoluble material with boiling dilute hydrochloric acid, upon which treatment there was no separation of margaric acid. The fact that the potassium margarate was completely decomposed during the reaction, shows a distinct difference in behaviour, as observed by Bomer and Limprich.

On evaporation of the chloroform, there were obtained 11.2 grams of a slightly yellowish material, This was analyzed for free acid in the usual manner and in this case it amounted to 3.24 percent. The product was dissolved in 100 cc. of alcohol, the calculated quantity of alcoholic potassium hydroxide added, the solution introduced into a distillation flask, the latter immersed in a water-bath at 40° C and the alcohol evaporated under a pressure of 18 mm. mercury. The dry residue so obtained was dissolved in 50 cc. chloroform. To this solution were added 2.0 grams of animal boneblack and the mixture boiled for seven minutes. The chloroform solution was evaporated to dryness and the perfectly white product repeatedly recrystallized from ether, with the following results-

Recrystallization	Volume of Ether - cc.	Melting Point of Crystals °C.
1	90	67
2	80	67 -68.5
3	75	69 -71
4	75	70 -71.5
5	70	70.8-71.8

The material obtained after the fifth recrystallization was subjected to fractional recrystallization from a mixture of chloroform and alcohol. It was suspended in 75 cc. of 95%

alcohol and completely dissolved by the addition of 25 cc. of chloroform. The beaker was then set aside and as the crystals separated out, four fractions were obtained with melting points as follows:-

Fraction	Melting Points °C
1	71.8 - 72.4
2	68.5 - 71
3	68.5 - 71
4	68.5 - 71

One recrystallization of fraction No. 1 - from 90 cc. of ether - gave a perfectly white product melting at 71.8° C.

Saponification Value

Calculated for	- $C_{37}H_{22}O_5$	188.1
Found	-	188.2

Solubilities

Temperature °C	Absolute Alcohol (in 100 cc.)	Ether (in 100 cc.)
0	0.0010 grams	0.0565 grams
15	0.0210 "	0.5150 "

Refractive Index

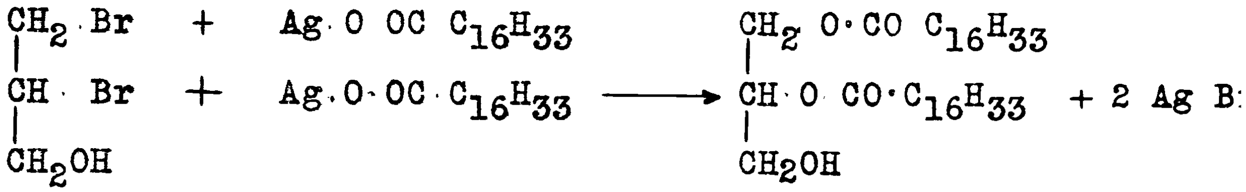
n_D^{75} 1.4407

Dimargarine crystallizes from chloroform in thin branched needles melting at 71.8° C. It is easily soluble in carbon tetrachloride, ethyl acetate, petrolic ether, acetone and butyl alcohol.

Synthesis of β Dimargarine

$C_{16}H_{33} \cdot CO \cdot O \cdot CH_2 \cdot CH \cdot O \cdot CO \cdot C_{16}H_{33} \cdot CH_2 \cdot OH$

Reaction



$$\begin{array}{l} CH_2 \cdot Br \\ | \\ CH \cdot Br \\ | \\ CH_2OH \end{array} \begin{array}{l} + \; Ag \cdot O\,OC\,C_{16}H_{33} \\ \\ + \; Ag \cdot O \cdot OC \cdot C_{16}H_{33} \\ \\ \\ \end{array} \longrightarrow \begin{array}{l} CH_2\,O \cdot CO\,C_{16}H_{33} \\ | \\ CH \cdot O\,CO \cdot C_{16}H_{33} \\ | \\ CH_2OH \end{array} + 2\,Ag\,B$$

α-β Dibrom-propylic alcohol

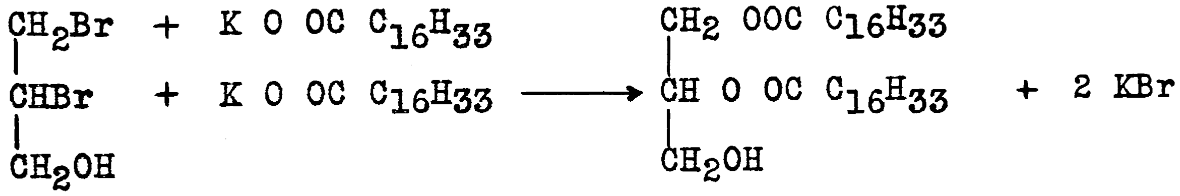
β Dimargarine

The αβ dibrom propylic alcohol employed was Schuhardt's product. It was purified by distillation in vacuo, and a determination of its saponification value showed it to be pure.

19.3 grams of silver margarate were intimately mixed with 12 grams of the dibrom propylic alcohol, forming a thick paste. This was introduced into the reaction flask and heated slowly in an oil bath. In the course of 1.75 hours, when the temperature had reached 110°C, the entire contents of the flask became liquid. The temperature was raised to 150°C and maintained at that point for 0.75 hours. An automatic stirring device, operated by a hot-air motor, kept the contents thoroughly mixed during the process. As the reaction proceeded, there was a considerable evolution of very pungent fumes. The final product, on cooling, consisted of two layers, a black upper layer, whereas the lower was a yellow crystalline substance. The solid fat was removed and extracted in a Soxhlet with ethyl ether. After distillation of the latter, there were obtained 18.9 grams of a brownish black substance of a greasy consistency. Analysis of this material showed a margaric acid content of 41.8 percent. It was recrystallized from 90 cc. of 95 percent alcohol and then melted at 57-58.5°C. The product thus obtained was dissolved in 75 cc. of benzene, 2 grams of animal boneblack added and the solution boiled for some time. This treatment effected no diminution in the intensity of the colour. An additional 3 grams of boneblack were added and the solution boiled for thirty minutes. The colour, however, remained unaltered. The liquid was filtered from the charcoal and evaporated to dryness. The solid residue contained 82.3 percent of margaric acid as determined by analysis. The fact that the percentage of free margaric acid increased so enormously from 41.8 percent to 82.3 percent during the course of one recrystallization, showed that the original reaction mixture consisted mostly of margaric acid, $\alpha\beta$ dibrom propyl alcohol and by-products. The substance was dissolved in 75 cc. alcohol, the acid converted to the potassium soap, the alcohol removed in the usual manner, the dry residue extracted with chloroform, and on evaporation of this there was obtained a very small quantity of low melting substances.

Synthesis of β Dimargarine by means of the Potassium Salt

Reaction



$$\begin{array}{l} CH_2Br \\ | \\ CHBr \\ | \\ CH_2OH \end{array} \begin{array}{l} + \; K\,O\,OC\,C_{16}H_{33} \\ \\ + \; K\,O\,OC\,C_{16}H_{33} \\ \\ \\ \end{array} \longrightarrow \begin{array}{l} CH_2\,OOC\,C_{16}H_{33} \\ | \\ CH\,O\,OC\,C_{16}H_{33} \\ | \\ CH_2OH \end{array} + 2\,KBr$$

16.47 grams of potassium margarate were dried under a pressure of 25 mm. at 125°C for one hour, ground up with 7 grams of αβ dibrom propylic alcohol, heated slowly to 160-170°C and maintained at that temperature for 3.25 hours, continual stirring being maintained during the process. The solid fat obtained on cooling was extracted with dry chloroform, which when evaporated left as a residue a brown oil, which gradually solidified. The chloroform insoluble material amounted to 5.2 grams. The fat was recrystallized from 50 cc. of 95 percent alcohol and weighed 11.51 grams. Analysis showed an acid content of 19.6 percent. This was removed in the usual manner. The resulting product was recrystallized from 30 cc. alcohol and formed a thick greasy residue. It was dissolved in 40 cc. of chloroform, decolorized with boneblack, filtered, the solution evaporated to dryness, and the product recrystallized from ether. The details follow;-

Recrystallization	Volume of Ether - cc.	Melting Point of Crystals °C
1	35	61 -64.5
2	30	62 -65
3	25	62.5-66
4	25	64 -66.5
5	25	65 -68.8

The material obtained from recrystallization No.5, was dissolved in a mixture of 80 cc. alcohol and 30 cc. of chloroform and fractionally recrystallized from this solution.

Fractions	Melting Point °C
1	62.0-66
2	69.7
3	69.7

Fractions 2 and 3 were combined and recrystallized, the melting point remaining unchanged.

Saponification Value.

Calculated for	- $C_{37}H_{72}O_5$	-	188.1
Found	-	-	186.0

Solubilities

Temperature °C	Absolute Alcohol (100 cc.)	Ether (100 cc.)
15	0.0445 grams	0.7430 grams
0	0.0075 "	0.0745 "

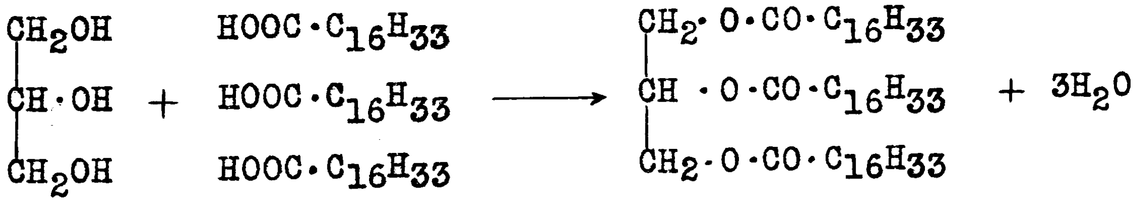
Refractive Index

n_D^{75} 1.4404

β-dimargarine melts at 69.7°C, and is soluble in petrolic ether, acetone, butyl alcohol, carbon tetrachloride and ethyl acetate. It crystallizes from chloroform in narrow plates.

Synthesis of Trimargarine

Reaction



$$\begin{array}{l} CH_2OH \\ | \\ CH\cdot OH \\ | \\ CH_2OH \end{array} + \begin{array}{l} HOOC\cdot C_{16}H_{33} \\ HOOC\cdot C_{16}H_{33} \\ HOOC\cdot C_{16}H_{33} \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \end{array} + 3H_2O$$

Glycerol Margaric Acid Trimargarine

The glycerol was carefully dehydrated by heating it slowly in an evaporating dish to 175°C, on a sand bath. Two grams of anhydrous glycerol were added to 20 grams of margaric acid and the mixture heated slowly to 185°C. This procedure occupied

1.5 hours. The temperature was maintained between 190 and 200°C for an additional 5.0 hours. During the reaction the melt was stirred very rapidly, the glycerol being thus divided into small particles which were continually kept dispersed throughout the molten acid. During the reaction, water distilled over, accompanied by a small amount of white substance. The solid fat obtained on cooling was recrystallized from a solution of 80 cc. of alcohol and 30 cc. of benzene. When washed and dried, it melted at 53.5-56.6°C. After extraction with two 150 cc. portions of hot alcohol, it melted at 57-58°C. As this apparently did not tend towards a pure product, all the fractions were combined and analyzed for margaric acid. The material weighed 19.15 grams and contained 28.48 percent of free acid. The theoretical quantity of alcoholic potassium hydroxide was added to an alcoholic solution of the glyceride, the solvent evaporated under reduced pressure, the dried residue extracted with chloroform, the latter distilled off and the residue recrystallized from ether.

Recrystallization	Value of Ether -cc.	Melting Point of Crystals °C
1	50	57.5-59.0
2	50	60.0-60.8
3	60	60.2-60.9
4	50	60.7-61.2
5	25	61.0-61.6
6	50	61.2-62.0
7	50	61.2-62.1

The product obtained from recrystallization No.7, was recrystallized from alcohol and benzene with the following result:-

Recrystallization	Benzene -cc	Alcohol -cc	Melting Point°C.
9	30	30	61.7-62.3
10	30	20	61.9-62.4
11	30	20	62.2-62.5
12	30	20	62.5-62.8
13	30	20	62.7

The residue from the last recrystallization melted at 62.4°C, showing that the product was pure.

Saponification Value

Calculated for	$C_{54}H_{104}O_6$	198.4
Found		199.4

Solubilities

Temperature °C	Absolute Alcohol (100 cc.)	Ether (100 cc.)
15	0.0100 grams	0.2770 grams
0		0.0261 "

Refractive Index

n_D^{70}	1.4421
n_D^{75}	1.4401

Trimargarine is soluble in cold chloroform and carbon tetrachloride, in warm acetone, ethyl acetate, butyl alcohol and ether.

MIXED TRIGLYCERIDES

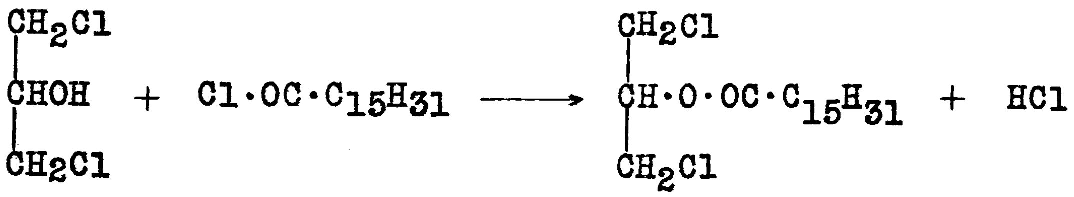
β-Palmito-α-γ-dimargarine

The first stage in the synthesis of this compound involved the preparation of β-palmito-α-γ-dichlorhydrin.

β-Palmito-α-γ-dichlorhydrin

$CH_2Cl.\ CH(O\cdot CO\cdot C_{15}H_{31})\cdot CH_2Cl.$

Reaction



$$\begin{array}{l} CH_2Cl \\ | \\ CHOH \\ | \\ CH_2Cl \end{array} + Cl\cdot OC\cdot C_{15}H_{31} \longrightarrow \begin{array}{l} CH_2Cl \\ | \\ CH\cdot O\cdot OC\cdot C_{15}H_{31} \\ | \\ CH_2Cl \end{array} + HCl$$

Palmityl chloride was prepared in the usual manner, i.e.; by the addition of 9.75 grams of good quality phosphorus pentachloride to 12 grams of pure palmitic acid, in a dry distilling flask. The flask was heated on the water-bath for forty-five minutes and the phosphorus oxychloride then removed under a pressure of 28 mm. mercury. To the acid chloride contained in the flask were added 7.24 grams of α-dichlorhydrin and the flask warmed on the water-bath for 1.75 hours during which time a large quantity of hydrochloric acid fumes was evolved. On cooling overnight, the liquid set to a white solid. It was recrystallized from alcohol. The substance had a tendency to separate out as an oil. Accordingly, it was recrystallized very slowly from a large volume of alcohol. After three recrystallizations from 150 cc. of solvent, it melted sharply at 34.4° C.

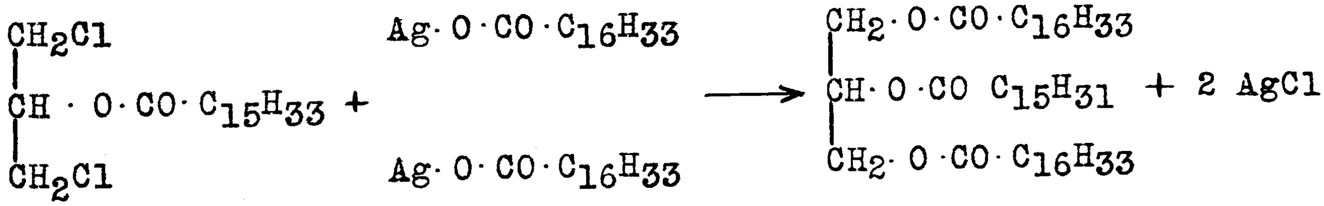
Saponification Value

Calculated for	-	$C_{19}H_{36}O_2Cl_2$	458.7
Found	-		457.2

Synthesis of β-Palmito-α-γ-dimargarine.

$CH_2(O\cdot CO\cdot C_{16}H_{33})CH\ (O\cdot CO\cdot C_{15}H_{33})\cdot CH_2\cdot (O\cdot CO\cdot C_{16}H_{33})$

Reaction



$$\begin{array}{l} CH_2Cl \\ | \\ CH\cdot O\cdot CO\cdot C_{15}H_{33} \\ | \\ CH_2Cl \end{array} + \begin{array}{l} Ag\cdot O\cdot CO\cdot C_{16}H_{33} \\ \\ \\ \\ Ag\cdot O\cdot CO\cdot C_{16}H_{33} \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH\cdot O\cdot CO\ C_{15}H_{31} \\ | \\ CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \end{array} + 2\ AgCl$$

5.26 grams of β-palmito-dichlorhydrin and 12.5 grams of silver margarate were thoroughly mixed and heated to a temperature of 155° C for four hours. On this occasion there was no division into two layers as had been observed in previous experiments, but the thin liquid was interspersed with brown solid particles. The product was allowed to cool, the solid fat broke up and extracted with ether. The solution was filtered from silver chloride and the filtrate evaporated to dryness. There were obtained 10.42 grams of solid material. Analysis of the product showed a margaric acid content of 21.51 percent. The substance was dissolved in 90 cc. of alcohol, the calculated quantity of alcoholic potassium hydroxide added, the solvent removed under diminished pressure and the residue extracted with petrolic ether.

Various methods of purification, such as fractional solution, precipitation from mixed solvents, fractional recrystallization, and repeated recrystallization from ether were essayed.

(a) A small quantity was dissolved in 5 cc. of ether and precipitated with 15 cc. of alcohol. White crystals melting at 52-54°C were obtained. The ether soluble material consisted of a greasy brown substance.

(b) A portion of the glyceride was agitated in ether at 0°C for some time. The ether insoluble material melted at 53.5-55°C.

(c) Another portion was recrystallized from 15 cc. of ether, the crystals melting at 57-58°C. The residue melted at 48-51°C.

The entire mass was then dissolved in alcohol and benzene. It was difficultly soluble in alcohol alone, but the addition of a small quantity of benzene rapidly effected solution. As the solution cooled, a brown oil separated out from which the solution was decanted and recrystallization induced by allowing it to stand at a low temperature for some time.

The oil obtained was dissolved in benzene, filtered, evaporated to dryness, taken up in 30 cc. of alcohol, the solution decanted from a little oil and on cooling a small quantity of crystals melting at 54.2°C to 55°C were obtained.

(d) About one-third of the total product was dissolved in 70 cc. of ether and four fractions collected as the crystals separated out.

Fraction	Melting Point °C
1	57.6 - 58.6
2	57.2 - 57.8
3	57.8 - 58.2
4	55.8 - 61.5

It will be observed from the preceding data that the most consistent results were obtained by recrystallization from ether. Accordingly, the various fractions, melting above 55 °C, were combined and subjected to systematic recrystallization from ether. The details follow:-

Recrystallization	Volume of Ether -cc	Melting Point of Crystals °C	Melting Point Residue °C.
1	60	56.3 - 57.3	55 - 60.5
2	60	56.5 - 57.5	56 - 57
3	50	57.2 - 57.6	56.2- 57
4	50	57.4 - 58.2	57 - 57.4
5	40	58.1 - 58.6	57.8- 58.0
6	40	58.1 -	-

Saponification Value

Calculated for	- $C_{53}H_{102}O_6$ -	201.8
Found		203.2

Solubilities

Temperature °C	Absolute Alcohol (100 cc.)	Ether (in 100 cc.)
22	0.0179 grams	-
0		0.0805 grams
15	0.0135 "	1.097 "

Refractive Index

n_D^{75}	1.4428
n_D^{70}	1.4406
n_D^{65}	1.4385

β-palmito-α-γ-dimargarine melts at 58.3°C and crystallizes from ether in needles radiating from a common centre. It is easily soluble in chloroform, acetone, petrolic ether and butyl alcohol.

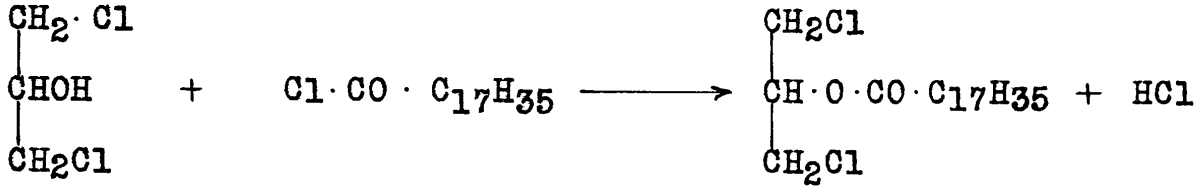
β-Stearo-α-γ-dimargarine

The preparation of this mixed triglyceride required the synthesis of β-stearo-α-γ-dichlorhydrin as an intermediate compound.

β-Stearo-α-γ-dichlorhydrin

$CH_2 \cdot Cl \cdot CH \cdot (O \cdot CO\ C_{17}H_{35}) \cdot CH_2 \cdot Cl$

Reaction



$$\begin{array}{l} CH_2 \cdot Cl \\ | \\ CHOH \\ | \\ CH_2Cl \end{array} \quad + \quad Cl \cdot CO \cdot C_{17}H_{35} \longrightarrow \begin{array}{l} CH_2Cl \\ | \\ CH \cdot O \cdot CO \cdot C_{17}H_{35} \\ | \\ CH_2Cl \end{array} + HCl$$

Stearyl chloride was prepared in the manner described in the cases of margaric and palmitic acids. 12 grams of stearic acid were treated with 8.8 grams of phosphorus pentachloride in a dry distilling flask, the latter being warmed on the water-bath for thirty-five minutes. After removal of the phosphorus oxychloride under diminished pressure, 6.5 grams of α-dichlorhydrin were added and the reaction mixture heated for 1.0 hour on the boiling water-bath. On cooling, the product formed a white solid. It was recrystallized several times from alcohol.

Rexrystalliza-tion	Volume of Alcohol- cc.	Melting Point of Crystals °C
1	250	37.8 - 39
2	125	39.5
3	150	39.5

The melting point of β-stearo-α-γ-dichlorhydrin is 39.5 °C.

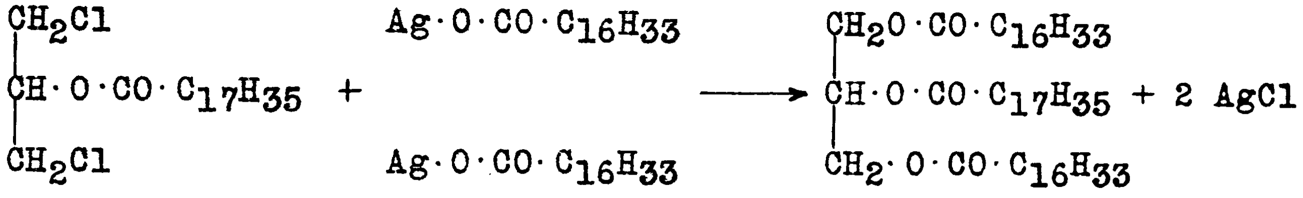
Saponification Value

Calculated for -	$C_{55}H_{106}O_6$	426.0
Found		427.3

β-Stearo-α-γ-dimargarine

$$CH_2(O\cdot CO\cdot C_{16}H_{33})\cdot CH\cdot(O\cdot CO\cdot C_{17}H_{35})\cdot CH_2\cdot(O\cdot CO\cdot C_{16}H_{33})$$

Reaction



$$\begin{array}{l} CH_2Cl \\ | \\ CH\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ CH_2Cl \end{array} + \begin{array}{l} Ag\cdot O\cdot CO\cdot C_{16}H_{33} \\ \\ Ag\cdot O\cdot CO\cdot C_{16}H_{33} \end{array} \longrightarrow \begin{array}{l} CH_2O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \end{array} + 2\ AgCl$$

To 6.88 grams of β-stearo-α-γ-dichlorhydrin were added 13 grams of silver margarate. After thorough mixing they were heated for three hours at 150-155 °C. The reaction progressed fairly rapidly, differing in this respect from the preceding reaction. After heating for one hour the contents of the flask were of a thin liquid consistency. On cooling, the product separated into two layers, the top layer consisting of a small amount of light brown substance and the lower, a dark brown material. The ether soluble material weighed 14.2 grams and on analysis showed a margaric acid content of 25.3% (3.6 grams).

The product was dissolved in 300 cc. of alcohol (95%)

and the requisite quantity of alcoholic sodium hydroxide added. In this experiment, during evaporation the soap produced by the addition of the alkali coagulated, forming a very large volume of mixed soap and fat. This behaviour was quite different from that observed in previous experiments in which the soap separated more or less in a finely divided state. There was not the customary violent bumping during evaporation at reduced pressure. This facilitated the process which was accomplished fairly rapidly in this case. The dry residue of admixed soap and fat was extracted with petrolic ether. The solution obtained was dark in colour and on evaporation left an almost black residue, which was dissolved in 80 cc. of benzene and refluxed for fifteen minutes with 2 grams of boneblack, the colour changing from black to brown. After filtration, the solution was evaporated to half volume, allowed to cool and then 130 cc. of alcohol were added. The fat was, in this manner, precipitated as a gray amorphous mass. When dry, it was somewhat lighter in colour, and melted at 57.5-59°C. It was recrystallized from a mixture of alcohol and benzene, but the colour of the product, apparently, did not improve in the least as a result of this treatment. Recrystallization from a solvent consisting of equal parts of alcohol and ether, yielded a product somewhat lighter in colour. Finally, a perfectly white product was obtained by fractional solution of the fat in boiling alcohol. It was found that in adding alcohol to the gray precipitate in a beaker and warming, that when the temperature of the alcohol had risen above the melting point of the fat, the latter formed an oil which settled to the bottom. The solution was then boiled and the oil thoroughly stirred up in the solvent. The beaker was removed from the heater and the solvent allowed to cool. The supernatant liquid was decanted and set aside. After standing for some time, crystals separated out. These were filtered, washed and dried. More alcohol was added to the residue in the beaker and the process repeated. In this manner, four fractions were obtained, the colour of each successive solution being more intense than the preceding. The final insoluble residue consisted of a black hard tar. The details of this fractional solution follow:-

Fraction	Volume of Alcohol cc.	Melting Point of Crystals °C
1	95	60-60.5
2	45	59-59.5
3	60	60.3-61.3
4	25	58.5-59.5

Fractions 1, 2 and 3 separated out in a flocculent condition, whereas No.4 consisted of very fine particles. The first three portions were united and fractionally recrystallized from ether.

Fraction	Melting Point of Crystals 0°C
a	60.5-61
b	59.3-60
c	57 -58

Fraction "c" was neglected; "a" and "b" were united and again recrystallized.

Recrystallization	Volume of Ether cc.	Melting Point of Crystals °C	Melting Point of Residue °C
1	50	60.7-61.0	58.5-59.5
2	35	61.4-62.4	60.9-61.6

Fraction 2 was again recrystallized from ether, the crystals finally melting at 62.8 °C.

Saponification Value

Calculated for	-	$C_{55}H_{106}O_6$	-	195.1
Found				193.5

Solubilities

Temperature °C	Absolute Alcohol (in 100 cc)	Ether (in 100 cc)
0		0.0475 grams
15	0.0048 grams	0.4270

Refractive Index

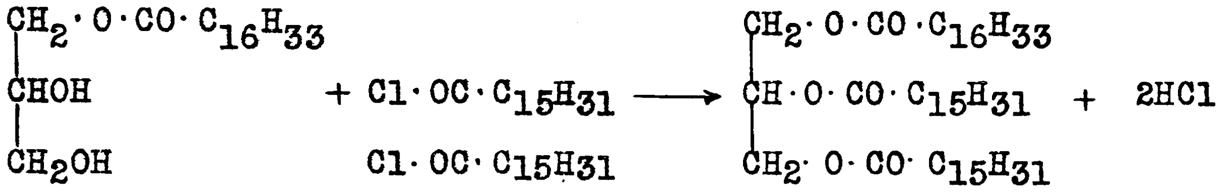
n_D^{75}	1.4410
n_D^{70}	1.4430
n_D^{65}	1.4450

β-stearo-dimargarine melts at 62.8° C. It is soluble in carbon tetrachloride, butyl alcohol, ethyl acetate, acetone and petrolic ether. It crystallizes from chloroform in thin needle clusters.

α Margaro-β-γ-dipalmitin

$$CH_2 \cdot (OCO \cdot C_{16}H_{33}) \cdot CH \cdot (O \cdot CO \cdot C_{15}H_{31}) \cdot CH_2(O \cdot CO \cdot C_{15}H_{31})$$

Reaction



$$\begin{array}{l} CH_2 \cdot O \cdot CO \cdot C_{16}H_{33} \\ | \\ CHOH \\ | \\ CH_2OH \end{array} \quad \begin{array}{l} + \ Cl \cdot OC \cdot C_{15}H_{31} \\ \ \ \ Cl \cdot OC \cdot C_{15}H_{31} \end{array} \longrightarrow \begin{array}{l} CH_2 \cdot O \cdot CO \cdot C_{16}H_{33} \\ | \\ CH \cdot O \cdot CO \cdot C_{15}H_{31} \\ | \\ CH_2 \cdot O \cdot CO \cdot C_{15}H_{31} \end{array} + 2HCl$$

Monomargarine

α-Margaro-β-γ-dipalmitin

The α-monomargarine employed in this synthesis was that prepared by the method already described. 1.5 grams of this substance were dissolved with very gentle warming in 8 cc. of dry chloroform, contained in a small flask, and 1.5 grams of pyridin added. After cooling, 3 grams of palmityl chloride were slowly added, the flask being corked and shaken thoroughly after each addition of acid chloride. As the palmityl chloride was added the solution became turbid. It was reconverted to a homogeneous solution by the addition of chloroform. In this way, an additional 12.0 cc. of chloroform were added. The flask was tightly stoppered and allowed to remain at room temperature for 48 hours. It was then treated with a cold mixture of 100 cc. of half-normal sulphuric acid and the same volume of ether, and thoroughly agitated. The ethereal solution was washed with two 60 cc. portions of sulphuric acid of the same strength, then with two volumes of 20 cc. of 2 percent potassium bicarbonate solution and finally with three successive portions of 20 cc. of distilled water. To the ether layer were added five grams of sodium sulphate and the solution allowed to remain over the dehydrating agent for twelve hours. The sodium sulphate was filtered off, the solvent evaporated and the glyceride recrystallized from 180 cc. of alcohol. The crystals melted at 54-57°C. After recrystallization from 10 cc. of ether, the substance melted at 57-62.5°C. The crystals were then dissolved in 4 cc. of chloroform and 10 cc. of alcohol added. The product, separating out on cooling, melted at 57-61° C. Owing to the fact that the melting point of this product was not sharp, the fat was dissolved in 100 cc. of ether and the treatment with potassium bicarbonate, distilled water and sodium sulphate repeated. After three recrystallizations from 25 cc. of ether the glyceride melted at 57.8°C.

Saponification Value

Calculated for	-	$C_{52}H_{100}O_6$	-	205.0
Found	-			203.7

Solubilities

Temperature °C	Absolute Alcohol (in 100 cc.)	Ether (in 100 cc.)
15	0.0424 grams	1.3855
0		0.2295

Refractive Index

n_D^{75}	1.4400
n_D^{70}	1.4420
n_D^{65}	1.4440

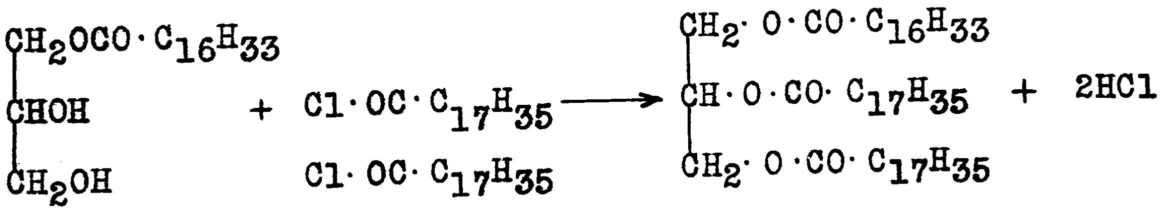
α-Margaro-β-γ-dipalmitin melts at 57.8°C. It dissolves readily in petrolic ether, butyl alcohol, ethyl acetate and acetone. It separates out from chloroform on slow evaporation, in short needles.

α-Margaro-β-γ-distearin

$$CH_2\cdot(O\cdot CO\cdot C_{16}H_{33})\cdot CH\cdot(O\cdot CO\cdot C_{17}H_{35})\cdot CH_2\cdot(O\cdot CO\cdot C_{17}H_{35})$$

This glyceride was prepared by the action of two molecules of stearyl chloride on one of α-monomargarine.

Reaction



$$\begin{array}{l} CH_2OCO\cdot C_{16}H_{33} \\ CHOH \\ CH_2OH \end{array} + \begin{array}{l} Cl\cdot OC\cdot C_{17}H_{35} \\ Cl\cdot OC\cdot C_{17}H_{35} \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \\ CH\cdot O\cdot CO\cdot C_{17}H_{35} \\ CH_2\cdot O\cdot CO\cdot C_{17}H_{35} \end{array} + 2HCl$$

To a solution of 1.4 grams of α monomargarine in 7 cc. of chloroform and 1.5 cc. of pyridin were added 3.08 grams of stearyl chloride in 6 cc. of chloroform. The solution was thoroughly shaken and allowed to stand three days at room temperature. There was then added a mixture of 100 cc. of half-normal sulphuric acid and 110 cc. of ether. After vigorous shaking, an emulsion formed which settled very slowly. The ether layer was siphoned off and on the addition of 50 cc. of half-normal sulphuric acid to this liquid an emulsion again formed at the junction of the two liquids. This was separated, the ethereal solution washed with potassium bicarbonate and distilled water. The ethereal solution was dried over sodium sulphate for ten hours, filtered and evaporated. After recrystallization, once from 10 cc. of ether and twice from a mixture of 4 cc. of chloroform and 30 cc. alcohol, the product melted at 63.8 °C.

Saponification Value

Calculated for -	$C_{56}H_{108}O_6$	192.0
Found		191.6

Solubilities

Temperature °C	Absolute Alcohol (in 100 cc.)	Ether (in 100 cc.)
15	0.0212 grams	0.2980 grams
0		0.0345 "

Refractive Index

n_D^{75}	1.4407
n_D^{70}	1.4426
n_D^{65}	1.4445

α-Margaro-β-γ-distearin melts at 63.6°C, and is soluble in acetone, ether, ethyl acetate, petrolic ether and carbon tetrachloride. By the slow concentration of a solution of the glyceride in chloroform, it is obtained in clusters of needles.

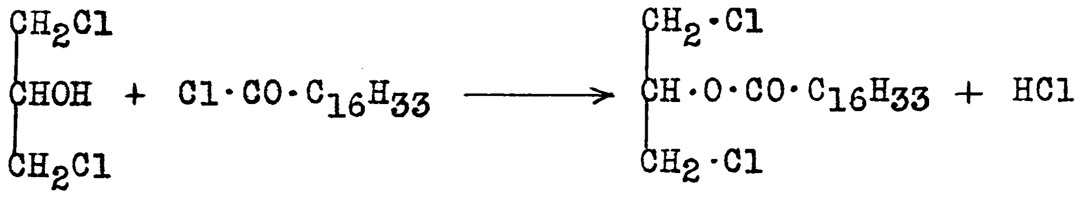
β-Monomargarine.

It was necessary to prepare β-margaryl-dichlorhydrin as a preliminary step in this synthesis.

Preparation of β-Margaryl-α-γ-dichlorhydrin

$$CH_2\cdot Cl\cdot CH\cdot(O\cdot OC\cdot C_{16}H_{33})\cdot CH_2\cdot Cl$$

Reaction



$$\begin{array}{l} CH_2Cl \\ CHOH \\ CH_2Cl \end{array} + Cl\cdot CO\cdot C_{16}H_{33} \longrightarrow \begin{array}{l} CH_2\cdot Cl \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ CH_2\cdot Cl \end{array} + HCl$$

Margaryl chloride was prepared in the usual manner, the proportions used being 16 grams of margaric acid and 12.3 grams of phosphorus pentachloride.

In spite of the fact that the removal of the phosphorus oxychloride was conducted cautiously (warmed on water-bath under pressure of 16 mm.) the margaryl chloride was of a dark colour. To the acid chloride contained in a 500 cc. distilling flask were added 9.18 grams of pure α-dichlorhydrin and the flask heated on the water-bath for 1.5 hours. A copious evolution of hydrochloric acid fumes occurred. On cooling, the material formed a viscous liquid. It was dissolved in 20 cc. of ether, filtered and 170 cc. of alcohol (95 percent) added. On warming, solution occurred. After allowing the solution to cool slowly to room temperature and immersing the liquid in a well cooled mixture of ice and salt, white crystals separated out on long standing. The material was easily soluble in ether, but difficultly so in alcohol and yet it appeared to form a supersaturated solution in the latter solvent. After the dark liquid had been dissolved in ether, and an excess of alcohol added, the solution was concentrated until a drop taken out on a stirring rod solidified on cooling. Obviously, the solution was of such a concentration that crystals would be expected to separate out on cooling. However, on allowing the solution to stand for three and a half hours, no precipitation occurred. Rubbing the sides of the beaker with a glass rod had no effect. Crystals could only be obtained by allowing the liquid to cool very slowly to room temperature by placing it in a bath of hot water and then immersing it in a well cooled salt-ice mixture for a prolonged period. The white material so obtained was filtered rapidly in the cold, washed and dried. The crystals melted at 26.5°C. The substance was recrystallized from 210 cc. of alcohol and the melting point remained unchanged. The yield, however, was small.

Experiment No.2

It was then attempted to prepare the compound, utilizing the method Fischer applied to α-iodhydrin. 6.0 grams of α-dichlorhydrin were dissolved in 4.2 cc. of pyridin and a solution of 13.42 grams of margaryl chloride in 30 cc. chloroform was added slowly. The mixture was cooled after each addition of acid chloride and in a short time it separated into two layers. The addition of 15 cc. of chloroform caused the solution to again become homogeneous. The contents of the flask were allowed to remain at room temperature for three days. There were then added 150 cc. of ether which caused the separation of a small amount of yellowish product. On introducing 100 cc. of half-normal sulphuric acid, the solid re-dissolved. The ether layer was siphoned off and washed with three portions of 20 cc. of potassium bicarbonate solution, the first consisting of 20 cc. and then two portions of 10cc. It was washed three times with 20 cc. of distilled water and dried over sodium sulphate. The yellow product obtained on evaporation of the dry ethereal solution, was dissolved in a mixture of 25 cc. of ether and 60 cc. alcohol, and allowed to crystallize out at 0°C.

The product was filtered off rapidly with suction in the cold, and washed with cold alcohol. The solid was of a greasy consistency and distinctly yellow in colour. It was taken up in 160 cc. of alcohol and cooled to 0 °C. On this occasion it separated out in a gelatinous condition. The substance was allowed to re-dissolve in the alcohol merely by removing the latter from the cold mixture. As the alcohol warmed up to room temperature, the substance gradually dissolved with the exception of a small quantity of a dark brown viscous material. The solution was decanted from this and again cooled to zero. The substance again separated, however, in a gelatinous condition and evidently possessed a very low melting point, and further experimentation with this method of preparation of β-margaryl-dichlorhydrin was abandoned. It was finally prepared in quantity by the method first attempted.

In this experiment, 19.2 grams of margaric acid were converted into the chloride and this was treated with 11 grams of α-dichlorhydrin. As before, the residue obtained after 1.5 hours heating on the water-bath did not solidify on cooling to room temperature. It was dissolved in 50 cc. of ether, filtered and the solution evaporated to dryness. The liquid was taken up in 400 cc. of alcohol, again filtered and allowed to stand for some time. As the solution cooled, a small amount of dark oil separated from which the solution was decanted. The main product was then recrystallized at 0 °C. It was recrystallized again from 400 cc. of alcohol and melted at 26.0 °C. Another recrystallization from the same volume of alcohol yielded the pure white substance melting at 26.5°C.

Saponification Value

Calculated for	-	$C_{20}H_{38}O_2\ Cl_2$	-	441.5
Found				440.1

Refractive Index

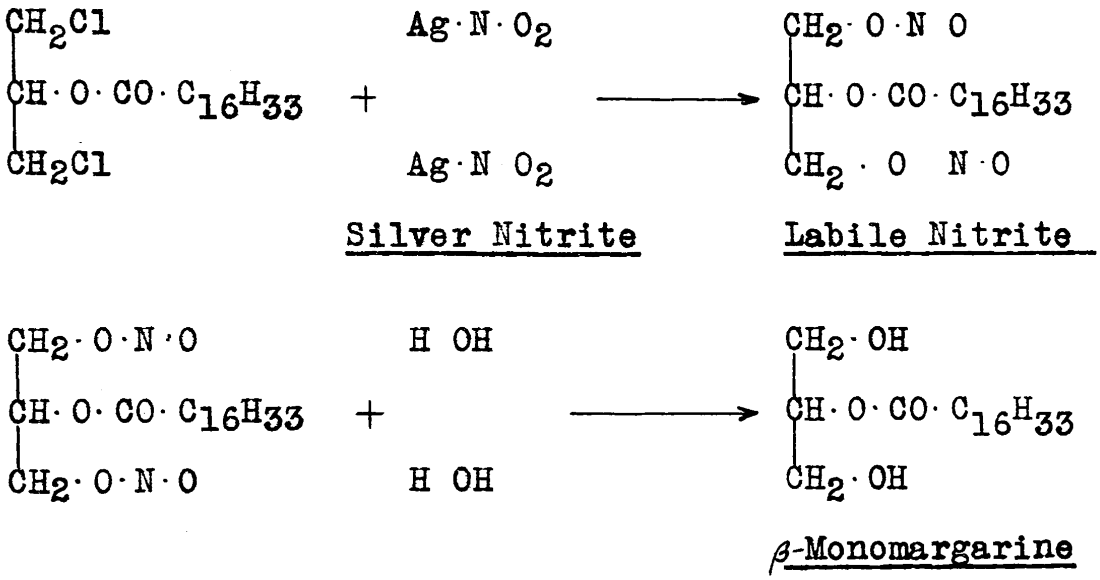
n_D^{75}	1.4405
n_D^{70}	1.4424
n_D^{60}	1.4462
n_D^{50}	1.4500
n_D^{40}	1.4538

β-Margaryl-α-y-dichlorhydrin is soluble in ether, chloroform, carbon tetrachloride, acetone, butyl alcohol, ethyl acetone and petrolic ether. It crystallizes from chloroform, in short thin needles, on slow evaporation.

β-Monomargarine

$CH_2\cdot OH\cdot CH\cdot(O\cdot CO\cdot C_{16}H_{33})\cdot CH_2\cdot OH$

Reaction



$$\begin{array}{l} CH_2Cl \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ CH_2Cl \end{array} + \begin{array}{l} Ag\cdot N\cdot O_2 \\ \\ Ag\cdot N\,O_2 \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot N\,O \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ CH_2\cdot O\;\;N\cdot O \end{array}$$

Silver Nitrite — Labile Nitrite

$$\begin{array}{l} CH_2\cdot O\cdot N\cdot O \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ CH_2\cdot O\cdot N\cdot O \end{array} + \begin{array}{l} H\;OH \\ \\ H\;OH \end{array} \longrightarrow \begin{array}{l} CH_2\cdot OH \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ CH_2\cdot OH \end{array}$$

β-Monomargarine

The two reactions indicated take place in one operation; and the synthesis was performed in an atmosphere of hydrogen. The presence of this gas prevented any possible injurious effect due to the excess of air to the mixture. It reduced the nitrous oxide gases evolved in the process with the formation of water, which at the temperature employed saponified the nitrous ester in "statu nascendi", giving rise to the desired β-monoglyceride.

15.2 grams of pure dry margaryl dichlorhydrin were intimately ground up with 12.3 grams of silver nitrite and a sufficient quantity of strongly heated purified quartz sand added to produce a homogeneous paste. The mass was introduced into the reaction tube, the latter immersed in the oil bath and connected with the hydrogen generating apparatus by means of a triple bored rubber stopper. Two of these served for the introduction and exit of the gas. The other carried a stirring arrangement which permitted the mixture being stirred without affecting the hydrogen pressure in the system.

The hydrogen was generated in a Kipp apparatus by means of zinc and hydrochloric acid. The gas was thoroughly dried by passing it through two sulphuric acid wash-bottles, one calcium chloride tower and a phosphorus pentoxide tube. It was then led into the reaction flask and finally through a wash-bottle containing water. By regulating the rate at which the gas passed through the latter wash-bottle, it was possible to maintain a pressure of hydrogen in the reaction vessel greater than atmospheric. The flask was heated to a temperature of 125-130°C for 12.5 hours and the introduction of hydrogen maintained during the entire period. During the first hour of heating,the gray mass gradually darkened and there was a considerable evolution of gas and water. The gas evolved caused the mixture to swell up and was prevented from completely filling the flask only by vigorous stirring at this period. The water produced in the reaction collected in the glass tube between the reaction vessel and the water wash-bottle. In about twenty minutes'time, the mixture subsided and remained quiescent during the next 11.0 hours.

After cooling, the solidified mass was extracted in a Soxhlet with chloroform. A considerable amount of silver chloride passed through with the fat. The chloroform was distilled off and the colloidal silver chloride precipitated by the addition of a few drops of alcoholic hydrochloric acid. The alcohol was evaporated to dryness and the product recrystallized twice from ether. It melted indefinitely at 61.5-69.5 °C. The residue from the mother liquor consisted of a large quantity of brown greasy material. The crystals obtained were yellow, but on allowing them to stand overnight the colour changed to black. That this was not due to the presence of silver was demonstrated by the fact that when the solid was dissolved in ether and shaken with dilute hydrochloric acid, there was no precipitate of silver chloride formed. It was attempted to decolorize with superfilchar but no change in the intensity was observed. After recrystallization from 40 cc. of 95% of alcohol, the crystals softened at 67.5° and finally melted at 70.2 °C. It was recrystallized from a solution of 75 cc. of petrolic ether and 20 cc. of ethyl ether and a small quantity of a greyish material was obtained, melting at 72.5-74°C.

Experiment No.2

15.35 grams of β-margaryl-dichlorhydrin and 18.6 grams (50% excess) of silver nitrite were heated together to 120-130 °C for 10 hours in a stream of hydrogen. Constant stirring of the molten mass was maintained by means of a mercury-seal apparatus, which, at the same time, enabled the reaction to be conducted under a slight pressure of hydrogen. During the course of the synthesis, the product changed in colour to a gray, then white, and finally black. The appearance of the white colour was due to the separation of silver chloride, which rapidly darkened. The black solid residue obtained weighed 27.8 grams. It was ground up, extracted with ether and the latter evaporated. After recrystallization from ether, the product melted at 58-63°C. It was recrystallized four times from alcohol and then melted at 59-64°C. Systematic recrystallization was then carried out with the following results:-

Recrystallization	Solvent	Melting Point of Crystals °C
6	petrolic ether	64.0 - 69
7	" "	64.0 - 70
8	" "	64.0 - 71
9	" "	65.0 - 71
10	ethyl ether	66.5 - 70
11	" "	67.5 - 71
12	ether-petrolic ether	67.5 - 71.5
13	" " "	69.5 - 72.5
14	" " "	72.5 - 74

The substance obtained in experiment No.1 was combined with the product of recrystallization No.14, and the whole subjected to further purification.

15	ethyl ether	73.0 - 74.8
16	" "	74.9 - 75.5
17	" "	75.4

Saponification Value

Calculated for	-	$C_{20}H_{40}O_4$	-	163.0
Found				164.6

Solubilities

Temperature °C	Ether (in 100 cc.)	Absolute Alcohol (in 100 cc.)
15	0.2400 grams	0.2450 grams
0	0.0725 "	0.1015 "

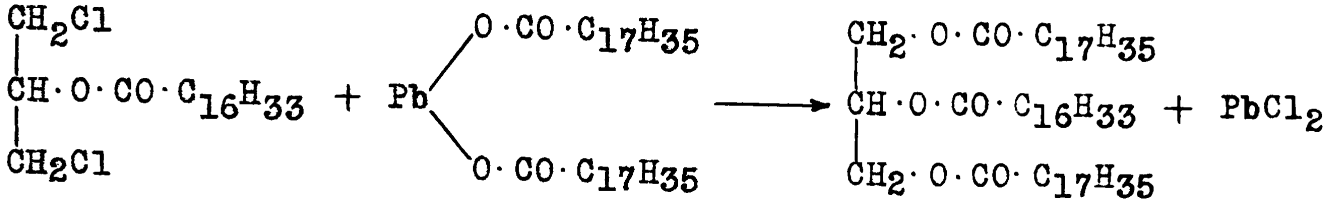
Refractive Index

n_D^{80}	1.4413
n_D^{75}	1.4433

β-Monomargarine melts at 75.7°C (corrected). It is soluble in carbon tetrachloride, acetone, butyl alcohol, ethyl acetate, petrolic ether and chloroform. From the latter solvent it crystallized in rosettes of beautiful, sharp, white needles.

Synthesis of β-Margaro-α-γ-distearin

Reaction



$$\begin{array}{l} CH_2Cl \\ | \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH_2Cl \end{array} + Pb\begin{array}{l} O\cdot CO\cdot C_{17}H_{35} \\ \\ O\cdot CO\cdot C_{17}H_{35} \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{17}H_{35} \\ | \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH_2\cdot O\cdot CO\cdot C_{17}H_{35} \end{array} + PbCl_2$$

β-Margaryl-dichlorhydrin was prepared for this synthesis and the one following, in the manner described in the preparation of β-monomargarine.

Twenty grams of lead stearate and 9.9 grams of β-Margaryl-dichlorhydrin were intimately mixed in the reaction vessel at a temperature of 12 °C. The mixture was heated for 3.5 hours at a temperature of 145 °C. The employment of the lead salt permitted the reaction being carried out at a lower temperature than that necessary for the interaction of β-Margaryl-dichlorhydrin and silver margarate.

The reaction product, after cooling, was extracted with ether for 3.75 hours. On evaporation of the solvent there were obtained 15.9 grams of raw product. It was dissolved in 400 cc. of 95% alcohol and the requisite quantity of alcohol sodium hydroxide added to remove the acid from the mixture. Free acid was present in the crude material to the extent of 5.1 grams (corresponding to 32% of the reaction product). The alcohol was distilled off under reduced pressure at 40 °C and the dry soap extracted with ether. The solvent was evaporated, the residue dissolved in dry chloroform, the solution filtered and the filtrate evaporated to dryness.

The glyceride was subjected to repeated recrystallizations, the details of which follow:-

Recrystallization	Solvent	Volume cc.	Melting Point of Crystals °C.
1	ether-alcohol	60 - 15	60.0 - 63
2	" "	40 - 40	61.0 - 63.9
3	"	40	62.9 - 64
4	"	40	64.0 - 64.6
5	"	40	65.0 - 65.3
6	" "	30 - 25	65.6 - 66.2
7	" "	50 - 15	66.0
8	"	35	66.3

Saponification Value

Calculated for	- $C_{56}H_{108}O_6$ -	192.0
Found		194.1

Solubilities

Temperature °C	Ether (in 100 cc.)	Absolute Alcohol (in 100 cc.)
15	0.1855grams	0.0090 grams
0	0.0240 "	

Refractive Index

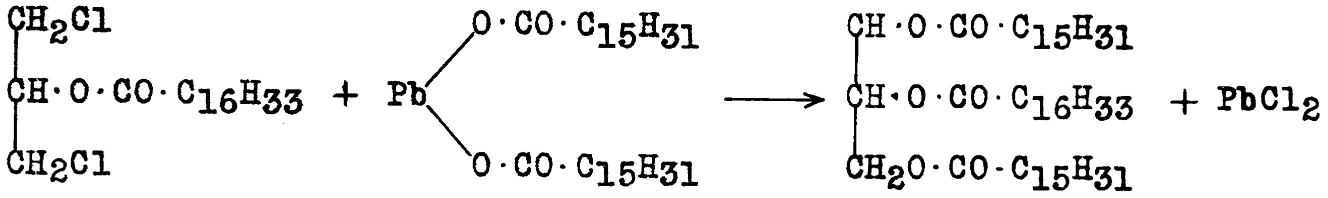
n_D^{70} 1.4425

n_D^{75} 1.4405

β- Margaro -distearin is soluble in cold chloroform and carbon tetrachloride, in warm ether, acetone, butyl alcohol and benzene. It crystallizes from chloroform in long glistening needles, which melt at 66.4° C.

Synthesis of β-Margaro-α-γ-dipalmitin

Reaction



Fourteen grams of lead palmitate were added to 7.45 grams of β-Margaryl-dichlorhydrin in a cylindrical glass vessel. The temperature was maintained at 14 °C during the mixing. The reaction flask was heated at 125 °C for 4 hours. Shortly after applying the heat, the reacting constituents liquefied completely and in the course of thirty minutes lead chloride commenced to separate out. On evaporation of the solution obtained by extracting the solid reaction product with ether, there remained a residue of 10.2 grams. It was ascertained by analysis that 3.2 grams of acid were present. This was removed in the usual manner, and the product recrystallized.

Recrystallization	Solvent	Volume cc.	Melting Point of Crystals °C
1	ether	75	54.5 - 58
2	ether-alcohol	20-100	57.0 - 58.5

The fat was dissolved in 150 cc. of ether and washed three times with 20 cc. of distilled water. The solution was dried over Na_2SO_4, filtered and evaporated. The residue was recrystallized, with the following results:-

Recrystallization	Solvent	Volume cc.	Melting Point of Crystals °C
1	alcohol	100	57.5 - 59
2	ether	50	58.0 - 59.1
3	"	50	58.9 - 59.5
4	"	40	59.3 -
5	"	40	59.3 -

Saponification Value

Calculated for -	$C_{52}H_{100}O_6$ -	205.0
Found		205.8

Solubilities

Temperature °C	Ether (in 100 cc.)	Absolute Alcohol (in 100 cc.)
15	1.1420 grams	0.0392 grams
0	0.2805	

Refractive Index

n_D^{65}	1.4432
n_D^{70}	1.4412
n_D^{75}	1.4392

β-Margaro-α-γ-dipalmitin crystallizes from chloroform in long glistening needles, which melt at 59.5°C (corrected). It is soluble in cold chloroform, carbon tetrachloride and in warm ether, acetone, ethyl acetate and petroleum ether. It is less soluble in alcohol.

Synthesis of α-Stearo-β-γ-dimargarine

To obtain this glyceride it was necessary to prepare Stearyl-acetone-glycerol and α-Monostearin.

Stearyl-acetone-glycerol

To a mixture of 7.1 grams of acetone-glycerol and 6.4 grams of quinoline in a thick walled flask, were added 13.5 grams of stearyl chloride in several portions and with continual shaking. In order to prevent the temperature rising, due to the heat of reaction, the flask was well cooled. During the addition of the acid chloride, the solution became turbid, and in the course of a few minutes the contents of the reaction vessel solidified completely. After standing for two days the product was dissolved in a mixture of 125 cc. of N/2 sulphuric acid and 125 cc. of ether. The ether layer was washed twice with 60 cc. portions of N/2 H_2SO_4, and finally with 25 cc. of a 10% potassium bicarbonate solution. This caused the formation of an emulsion, and in order to destroy it, five grams of sodium chloride were added. The solution was filtered, washed thoroughly with successive small quantities of distilled water; dried over sodium sulphate and evaporated. The residue was recrystallized from hot alcohol. It separated from this solvent in the form of long, colorless needles, melting at 40.4 °C.

α-Monostearin

Five grams of stearyl-acetone-glycerol were dissolved in 25 cc. of ether and to this solution were added 25 cc. of concentrated hydrochloric acid. On shaking, a heating effect occurred and the clear solution finally separated into two layers. During the reaction the temperature was maintained between 20° and 25 °C. The reaction flask was immersed in a bath at 20°C for thirty minutes, 100 cc. of distilled water were then added and the system allowed to remain at 0 °C for forty-five minutes. The α-Monostearin separated as a voluminous mass floating on the surface of the liquid. It was filtered off, washed thoroughly with water and recrystallized twice from 75 cc. of ether. After drying, the crystals melted at 81° C.

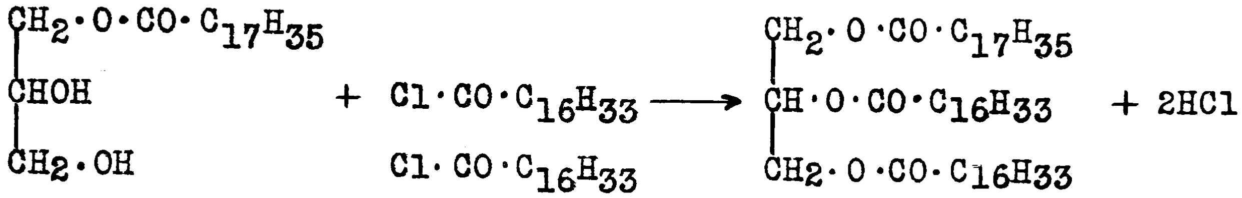
Saponification Value

Calculated for	-	$C_{21}H_{42}O_4$	-	156.6
Found				154.8

α-Stearo-β-γ-dimargarine

$CH_2 \cdot O \cdot CO \cdot C_{17}H_{35} \cdot CH \cdot O \cdot CO \cdot C_{16}H_{33} \cdot CH_2 \cdot O \cdot CO \cdot C_{16}H_{33}$

Reaction



$$\begin{array}{l} CH_2 \cdot O \cdot CO \cdot C_{17}H_{35} \\ CHOH \\ CH_2 \cdot OH \end{array} + \begin{array}{l} Cl \cdot CO \cdot C_{16}H_{33} \\ Cl \cdot CO \cdot C_{16}H_{33} \end{array} \longrightarrow \begin{array}{l} CH_2 \cdot O \cdot CO \cdot C_{17}H_{35} \\ CH \cdot O \cdot CO \cdot C_{16}H_{33} \\ CH_2 \cdot O \cdot CO \cdot C_{16}H_{33} \end{array} + 2HCl$$

To a solution of 1.5 grams of α-Monostearin and 1.4 grams of quinoline in 10 cc. of dry chloroform were added slowly 2.7 grams of margaryl chloride. The temperature of the solution was kept below 30° C by suitable cooling. The contents of the flask were shaken vigorously for one hour. The flask was then attached to a hot-air engine and rotated for twelve hours. After the elapse of 12 hours the liquid separated into two layers. The addition of 14 cc. of chloroform caused the solution to again become homogeneous. The system was allowed to stand an additional twenty-four hours. It was taken up in 75 cc. of ether and 75 cc. of $N/_2$ H_2SO_4. This caused the formation of a voluminous mass which was contained in the sulphuric acid layer. The ether layer was siphoned off, washed twice with sulphuric acid and with 30 cc. of 10% $KHCO_3$ solution. The soap so formed was removed and the solution washed repeatedly with water. After drying over sodium sulphate, the ether was evaporated and the residue recrystallized four times from ether.

The product melted at 62.1°C.

Saponification Value

Calculated for	- $C_{55}H_{106}O_6$	-	195.1
Found		-	197.4

Solubilities

Temperature °C	Ether (in 100 cc.)	Absolute Alcohol (in 100 cc.)
15	0.8490	0.0328
0	0.1565	-

Refractive Index

n_D^{65}	1.4435
n_D^{70}	1.4415
n_D^{75}	1.4395

α-Stearo-dimargarine crystallizes from ether in long, thin, pointed, transparent plates which melt at 62.1°C. It is soluble in chloroform, carbon tetrachloride, petrolic ether, acetone, and butyl alcohol.

Synthesis of α-Palmito-β-γ-dimargarine

It was necessary, as a preliminary step, to prepare palmityl-acetone-glycerol and α-Monopalmitin.

Palmityl-acetone-glycerol

Palmityl chloride (11.25 grams) prepared in the usual manner, was added to a solution of 6.4 grams of quinoline in 6.0 grams of acetone-glycerol. When all the acid chloride had been added, the contents of the flask became solid. After two days' standing at room temperature, the product was purified in the manner described in the case of stearyl-acetone-glycerol. The compound crystallized from ether in leaflets, melting at 34.4° C.

α-Monopalmitin

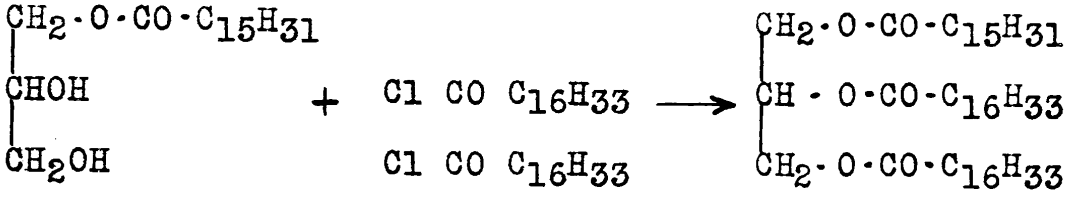
3.8 grams of palmityl-acetone-glycerol were dissolved in 19 cc. of ether. To this solution were added gradually, 19 cc. of concentrated hydrochloric acid. The temperature was maintained at 22° C. The clear liquid separated into two layers and α-monopalmitin began to precipitate out from solution. The flask was immersed in a bath at 25-30° C for forty minutes; 75 cc. of water were then added and the system kept at 0° C for thirty minutes, with frequent shaking. The glyceride was filtered off, repeatedly washed with cold water and dried. After three recrystallizations from large volumes of ether, it melted at 77.6°C.

Saponification Value

Calculated for - $C_{19}H_{38}O_4$ - 169.8

Found - 171.7

α- Palmito-β-γ-dimargarine



$$\begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{15}H_{31} \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + \begin{array}{l} Cl\ CO\ C_{16}H_{33} \\ Cl\ CO\ C_{16}H_{33} \end{array} \longrightarrow \begin{array}{l} CH_2\cdot O\cdot CO\cdot C_{15}H_{31} \\ | \\ CH\cdot O\cdot CO\cdot C_{16}H_{33} \\ | \\ CH_2\cdot O\cdot CO\cdot C_{16}H_{33} \end{array}$$

Two grams of α-Monopalmitin and 2.2 grams of quinoline were dissolved in 10 cc. of dry chloroform. 3.8 grams of margaryl chloride were added with constant shaking. In the course of a few minutes the reacting constituents solidified. The addition of 14 cc. of chloroform caused the mass to redissolve. The flask containing the solution was shaken for two days by means of a hot-air engine.

The chloroform solution was concentrated by spontaneous evaporation and taken up in a mixture of ether and half normal H_2SO_4. The ether layer was washed again with sulphuric acid, $KHCO_3$, distilled water, and evaporated. After five recrystallizations from ether the glyceride melted at 57.3°C.

Saponification Value

Calculated for - $C_{53}H_{102}O_6$ - 201.8

Found - 199.7

Refractive Index

n_D^{65} 1.4424

Solubilities

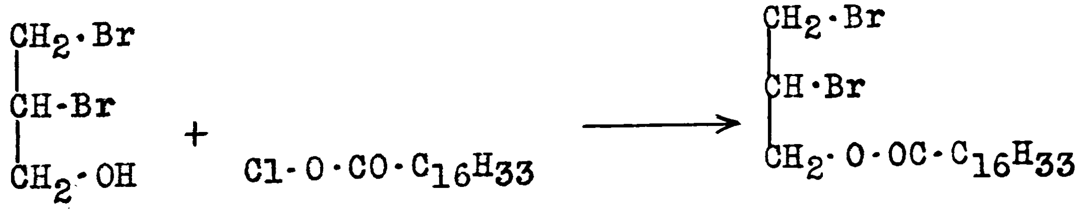
Temperature °C.	Ether (in 100 cc.)
0	0.2250 grams.
15	1.4240 "

α- Palmito-β-γ-dimargarine melts at 57.3° C. It is soluble in chloroform, carbon tetrachloride, acetone, ethyl acetate, butyl alcohol and petrolic ether. From the latter solvent it crystallizes in long needles in sheaf formation.

γ-Margaro-α-β-dibromhydrin

$CH_2\cdot Br \cdot CH \cdot Br \cdot CH_2\cdot(O\cdot OC\cdot C_{16}H_{33})$

Reaction



$$\begin{array}{l} CH_2\cdot Br \\ | \\ CH\text{-}Br \\ | \\ CH_2\cdot OH \end{array} + Cl\cdot O\cdot CO\cdot C_{16}H_{33} \longrightarrow \begin{array}{l} CH_2\cdot Br \\ | \\ CH\cdot Br \\ | \\ CH_2\cdot O\cdot OC\cdot C_{16}H_{33} \end{array}$$

Five grams of margaric acid were converted into the chloride in the usual manner, and there were added to the product in a well dried flask, 4.85 grams of α-β-dibrompropyl alcohol. The bromhydrin was introduced in small portions in the cold. On warming slightly, reaction occurred. The heat was then removed until the ebullition had subsided somewhat. This procedure of alternate heating and cooling was repeated several times. Finally, the flask was warmed on the water-bath for one hour. On allowing to cool, the contents solidified. The product was recrystallized three times from 250 cc. of 95 percent alcohol, and when pure melted at 35.5° C.

Saponification Value

Calculated for	-	$C_{20}H_{38}O_2 Br_2$	-	358.0
Found			-	356.1

Refractive Index

n_D^{40}	1.4712
n_D^{50}	1.4692
n_D^{60}	1.4652
n_D^{70}	1.4612

This compound is easily soluble in chloroform, ethyl acetate, butyl alcohol, phenetole, acetone and ether. It is difficultly soluble in cold, but fairly readily in hot alcohol, and crystallizes from this solvent in beautiful glistening needles.

DISCUSSION

It is evident, from a consideration of the preceding experimental results, that the silver salts of margaric acid are not suitable for the synthesis of "simple margarines" by interaction with the appropriate chlor- or bromhydrins. They can be employed successfully, however, in the preparation of "mixed" glycerides containing margaric, palmitic and stearic acids. In the latter cases the final phase of the synthesis involves reaction between two substances which, under ordinary temperature conditions, are solids, and hence may be intimately mixed before the initiation of the reaction. In the case of the "simple" margarines, due to the fact that thorough mixing of the reacting constituents is impossible, the silver salt is decomposed at the elevated temperature before the silver salt has an opportunity of reacting in the desired manner.

Owing to the greater stability of the potassium salt of margaric acid it is preferable to the silver salt for syntheses of this type.

The lead salts of the fatty acids are very suitable for the preparation of mixed triglycerides. Due to their relatively low melting point, reactions in which they are involved may be carried out at lower temperatures than when other salts are used. Accordingly, there is less chance for the occurrence of side reactions and purification of the resulting glyceride is facilitated.

It will be readily observed, however, that the preparation of pure glycerides, employing any of the methods described, is a matter of considerable difficulty.

Consideration of the table attached hereto leads to some interesting and important observations. In it are tabulated the compounds synthesized in this investigation, as well as their solubilities, melting points and refractive indices. The figures appearing in brackets after the latter, represent the temperature at which the observation was made.

In the case of the mixed triglycerides, for the sake of clearness, the compounds are represented in an abbreviated form. The acid residues in these compounds are shown in their relative positions and are designated by the first letter of the name of the acid. Thus -

M - margaric acid residue
P - palmitic " "
S - stearic " "

"Simple Margarines"

It will be seen that of the simple margarines the two monoglycerides are more soluble in alcohol than in ether, whereas with the two diglycerides and triglyceride, the reverse is the case.

Again, it will be seen that the β-monomargarine is less soluble than α-monomargarine and α-dimargarine than β-dimargarine. These phenomena agree with the structure of the compounds in view of the fact that the symmetrical compounds have the lower solubility.

A comparison of the refractive indices is very interesting. It will be seen that there is very little difference in the values of this property in the isomeric compounds considered. It is slightly higher in the case of the symmetrical compound.

Mixed Triglycerides

Consider the isomeric compounds, M.P.M. and P.M.M., which are respectively β-Palmito-α-γ-dimargarine and α-Palmito-β-γ-dimargarine. It will be observed that the former has a lower solubility in both solvents and a higher melting point, which would be expected from its symmetrical structure.

Again, the compound S.M.M. might be expected to melt lower than the compound M.S.S., owing to the fact that the former possesses a preponderance of the lower melting acid. Its solubility would also be expected to be greater, as margaric acid is more soluble than stearic. Apropos of these considerations, it will be seen from a consultation of the table that the compound S.M.M. has a lower melting point and a greater solubility than the compound M.S.S.

The solubility figures in the table represent the number of grams of glyceride dissolved in 100 cc. of solvent at the temperature specified.

Solubilities

	Ether		Alcohol		Refractive Index	Melting Point °C.
	0°C	15°C	0°C	15°C		
onomargarine	0.1945	0.7810	0.3015	1.0545	1.4412 (80)	76.4
onomargarine	0.0725	0.2400	0.1015	0.2450	1.4433 (95) 1.4413 (80)	75.7
imargarine	0.0565	0.5150	0.0010	0.0210	1.4407 (75)	71.8
imargarine	0.0745	0.7430	0.0075	0.0445	1.4404 (75)	69.7
rimargarine	0.0261	0.2770	-	0.0100	1.4421 (70) 1.4401 (75)	62.7
·β·γ .P.M.	0.0805	1.0970	-	0.0135	1.4428 (65) 1.4406 (70) 1.4385 (75)	58.3
.M.M.	0.2250	1.4240	-	-	1.4424 (65)	57.3
.M.P.	0.2805	1.1420	-	0.0392	1.4432 (65) 1.4412 (70) 1.4392 (75)	59.5
.P.P.	0.2295	1.3855	-	0.0424	1.4440 (65) 1.4420 (70) 1.4400 (75)	57.8
.S.M.	0.0475	0.4270	-	0.0048	1.4450 (65) 1.4430 (70) 1.4410 (75)	62.8
.M.M.	0.1565	0.8490	-	0.0328	1.4435 (65) 1.4415 (70) 1.4395 (75)	62.1
.M.S.	0.0240	0.1855	-	0.0090	1.4405 (70) 1.4425 (75)	66.4
.S.S.	0.0345	0.2980	-	0.0212	1.4445 (65) 1.4426 (70) 1.4407 (75)	63.8

	Solubilities					
	Ether		Alcohol		Refractive Index	Melting Point°C.
	0°C	15°C	0°C	15°C		
Margaryl-acetone-glycerol					1.4403 (45)	35.5
					1.4383 (50)	
					1.4362 (55)	
					1.4342 (60)	
					1.4323 (65)	
					1.4304 (70)	
					1.4286 (75)	
Margaryl-dichlor-hydrin					1.4538 (40)	26.5
					1.4500 (50)	
					1.4462 (60)	
					1.4424 (70)	
					1.4405 (75)	
Margaryl-α-β-dibromhydrin					1.4712 (40)	35.5
					1.4692 (50)	
					1.4652 (60)	
					1.4612 (70)	

SUMMARY

The "simple margarines" and the complete series of mixed triglycerides containing margaric, palmitic and stearic acids have been synthesized and their properties investigated.

A comparison has been made of the applicability of the potassium, lead and silver salts of margaric, palmitic and stearic acids to syntheses of the type described in the present investigation.

Some interesting relationships between the structure and properties of the margarines have been indicated and have been shown to hold in a general way for this series of compounds and also for the mixed triglycerides prepared in this work.

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