that these films are not homogeneous but consist of many little aggregates of metal. As the film builds up, these aggregates gradually come together, thus forming a conducting film. With time, the aggregates of any particular film gradually coalesce, hence causing a continuous decrease in the resistance. The resistance is, therefore, due in part to the gaps between aggregates. An accidental jar may suddenly break a number of the contacts, thereby causing a sudden increase in the resistance. Heating causes the molecules to accelerate in motion, and hence increases the number of contacts, and causes a decrease in resistance instead of the usual increase.

It is a curious fact that all of the impacts of metal on the glass are not inelastic in spite of the fact that the temperature of the wall is far below the condensation temperature of the metal. The number of inelastic impacts decreases as the temperature increases; hence it is easier to obtain a film at very low temperatures.

The difficulty in obtaining any degree of constancy in the resistance of the films seemed to indicate that it was inadvisable to attempt any further experiments along this line.

These experiments were made while the author was a National Research Fellow in Chemistry.

CONTRIBUTION FROM THE
CHEMICAL LABORATORY OF THE
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA
A. W. GAUGER

RECEIVED APRIL 1, 1925
PUBLISHED SEPTEMBER 5, 1925

---

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF STANFORD UNIVERSITY]

# A CHEMICAL INVESTIGATION OF CHAULMOOGRA OIL. I

BY TADAICHI HASHIMOTO

RECEIVED DECEMBER 15, 1924 PUBLISHED SEPTEMBER 5, 1925

## Introduction

In recent years chaulmoogra oil has assumed considerable importance in connection with the treatment of leprosy, as it seems to be the only known effective remedy for this disease. The experimental treatment of leprosy with the oil or with its derivatives has been carried out in various places and has definitely established the value of the oil for this purpose.[1]

[1] Hollmann and Dean, *J. Cut. Dis.*, **37**, 367 (1919). Heiser, *Public Health Rept.*, **29**, No. 42, 2763 (1914). McCoy and Hollmann, *Public Health Service Bull.*, **75** (1916). Rogers, *Indian Med. Gaz.*, **51**, 195, 437 (1916); **54**, 165 (1919); **55**, 125 (1920); *Indian J. Med. Res.*, **5**, 277 (1917); *Brit. Med. J.*, **2**, 559 (1916); *Lancet*, **200**, 1178 (1921). Carthews, *Indian Med. Gaz.*, **1918.** MacDonald and Dean, *Public Health Ped.*, **35**, No. 34, 1959 (1920). MacDonald, *J. Am. Med. Assoc.*, **75**, No. 27, 1483 (1920). Sweeney and Walker, *J. Infectious Diseases*, **26**, 238 (1920). Schöbl, *Philippine J. Sci.*, **23**, No. 6 (Dec., 1923).

The oil is obtained from the seeds of trees belonging to the order of *Fla ourtiaceae*,[2] of which a number of species are known, so that considerable differences are to be found in samples from different sources.

Extensive investigations have already been made with the object of isolating and identifying the individual chemical components of the oil. Thus Power and his collaborators[2] have used the method of fractional crystallization of large quantities of the free fatty acids and succeeded in the isolation of chaulmoogric and hydnocarpic acids, but it was practically impossible to separate the components whose quantities were very small.

Dean and Wrenshall[3] have studied the mixed free fatty acids by means of fractional distillation in a vacuum, but they covered only the first 85–90% of the distillate which contained only chaulmoogric and hydnocarpic acids.

As it is practically impossible to distil the last fraction under pressures of 1–3 mm., since it undergoes decomposition as the temperature rises higher and the time of heating is prolonged, the present investigation was undertaken with the view to so far improving the method of vacuum distillation that it might be possible to study the substances contained in the high-boiling residue. The important result to be accomplished was an improvement of the method of producing the vacuum and the following apparatus was designed for this purpose.

## Apparatus

Fig. 1 shows a sketch of the vacuum-distillation apparatus used.

The distilling flask was a modification of the Claisen flask with a fractionating bulb D and a separating funnel A attached to the neck to permit the introduction of a liquid without making any rearrangement in the system. The flask was made of Pyrex glass and had a capacity of 2 liters. For each distillation a liter of the liquid was used.

The flask was placed in the tall, cylindrical oil-bath and heated by the resistance wire F immersed in the oil which was constantly stirred by passing air through the tube E. The great advantage of using such a tall bath lay in the fact that the fractionating column was protected from air drafts, and that its length could be regulated easily by changing the level of the oil. For a liquid mixture that boils at a comparatively low temperature, or that is in no danger of being decomposed at high temperature, it is always desirable to use a long fractionating column to effect a more efficient separation.

---

[2] For the distribution and character of chaulmoogra trees see: Holmes, *Pharm. J.*, **64**, 522 (1900); **66**, 595 (1901). Power and Gornall, *J. Chem. Soc.*, **85**, 838, 851 (1904). Power and Barrowcliff, *ibid.*, **87**, 884 (1905); **91**, 557 (1907). Brill, *Philippine J. Sci.*, Sect. A, **11**, 75 (1916); **12**, 37 (1917). Brill and Williams, *ibid.*, **12**, 207 (1917). S. Ghosh, *Indian J. Med. Res.*, **4**, 691 (1916); **8**, 211 (1920). Goulding and Akers, *Proc. Chem. Soc.*, **24**, 197 (1913).

For the older literature see: Moss, *Year Book Pharm.*, 523, **1879**. Hooper, *Agricultural Ledger*, No. 5 (1905). Holmes, *Pharm. J.*, **64**, 522 (1900); **66**, 595 (1901). Petit, *J. pharm. chim.*, **26**, 445 (1892). Schindelmeiser, *Ber. deut. pharm. Ges.*, **14**, 164 (1904); *Z. angew. Chem.*, **37**, No. 1, 4 (1924).

[3] Dean and Wrenshall, This Journal, **42**, 2626 (1920).

In such cases a big difference in the temperatures of the bath and the vapor can be maintained. But when the mixture has a very high boiling point or undergoes decomposition at the higher temperature even under very low pressure, it is advisable to maintain the difference in temperature between the oil-bath and the vapor as small as possible. By raising the level of the oil in the bath, the liquid could be distilled when the temperature of the oil-bath was less than 10° above the boiling point of the former. This was very important in the distillation of the last fraction.

For the production of vacuum, two types of pumps were used; the automatic Sprengel and the mercury-vapor condensation pump, with a Nelson oil-sealed pump as auxiliary. Two condensation pumps were used in series to increase the efficiency. These were so arranged that when Stopcocks 2, 6 and 8 were closed, they took care of the upper and lower receiver separately.

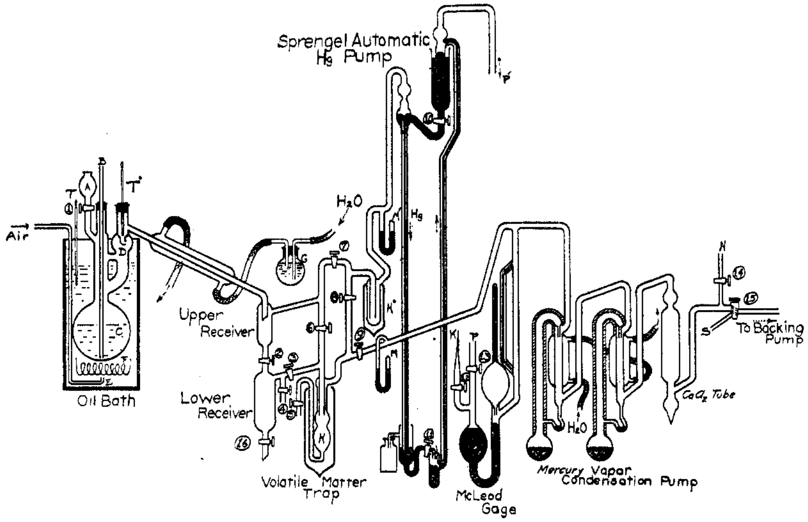


Fig. 1.

Before starting the operation, Stopcocks 1, 4, 5, 7 and 16 were closed. All the gases passed through the volatile-substance trap H, cooled with liquid air or liquid ammonia, a small portion being discharged through the Sprengel pump, and the larger portion through the mercury-vapor condensation pumps to the air. When sufficiently low pressure was obtained, the oil-bath was slowly heated. The first fraction collected in the lower receiver was withdrawn through 16 after Stopcocks 2 and 3 had been closed and air admitted through 4. Then Stopcocks 16, 4, 6 and 8 were closed and 7 was opened. This separated the system into two sections. Stopcock 3 was opened gradually and the lower receiver was evacuated, while the distillation was continued undisturbed by the aid of the Sprengel pump. As soon as the pressure in the lower system was brought down to the minimum, Stopcocks 2, 6 and 8 were opened and 7 was closed, thus bringing the apparatus to the previous condition. The same operation was repeated for each fraction. The whole distillation was thus carried out without disturbing the vacuum system and without causing any appreciable fluctuation in the temperature of the vapor. The pressure was measured with a McLeod gage.

The volatile substance collected during the distillation was taken out through 5 by applying air pressure through 4, closing 16, 2, 6, 8 and 9. The receivers were washed with alcohol and ether by the application of suction. The great advantage in using the mercury-vapor condensation pumps was their great capacity and ease of operation. Any desirable low pressure could be obtained by admitting the air through a long, small capillary. By means of this apparatus, the distillations could be carried out at very low pressures, which were often as low as 0.01 mm. and never higher than 0.05 mm. It should be pointed out that because of the very low pressures (concentrations) the distillations must necessarily be very slow, since enormous volumes of these dilute vapors must pass over in order to form a small amount of liquid. When a small quantity of water remained in the liquid, troublesome bumping was often experienced at the start of the distillation. This could be completely eliminated by passing a small stream of air or carbon dioxide through the small glass tubing B, which reached a position to within 5 or 6 mm. of the bottom of the flask. Instead of having, as in the usual form, a capillary at the lower end of the tube, which was liable to be broken or clogged, the upper end of B was drawn into a long, fine capillary. The amount of the gas passing through the liquid was regulated by changing the length of the capillary by breaking it off until the desired flow was obtained. As soon as the liquid became free from water, no bumping or frothing was experienced with this type of flask.

## Material

The oil used was specially prepared for this investigation from the seeds of *Taraktogenus Kurzii*, King, by the Smith-Amstreet Company of Calcutta, India. It was slightly yellow and possessed the odor characteristic of the oil; m. p., 22–23°; $d_{25}^{25}$, 0.9503; $[\alpha]_D$, +50.7°; sap. no., 211.2; acid no., 26.5; iodine no., 104.8.

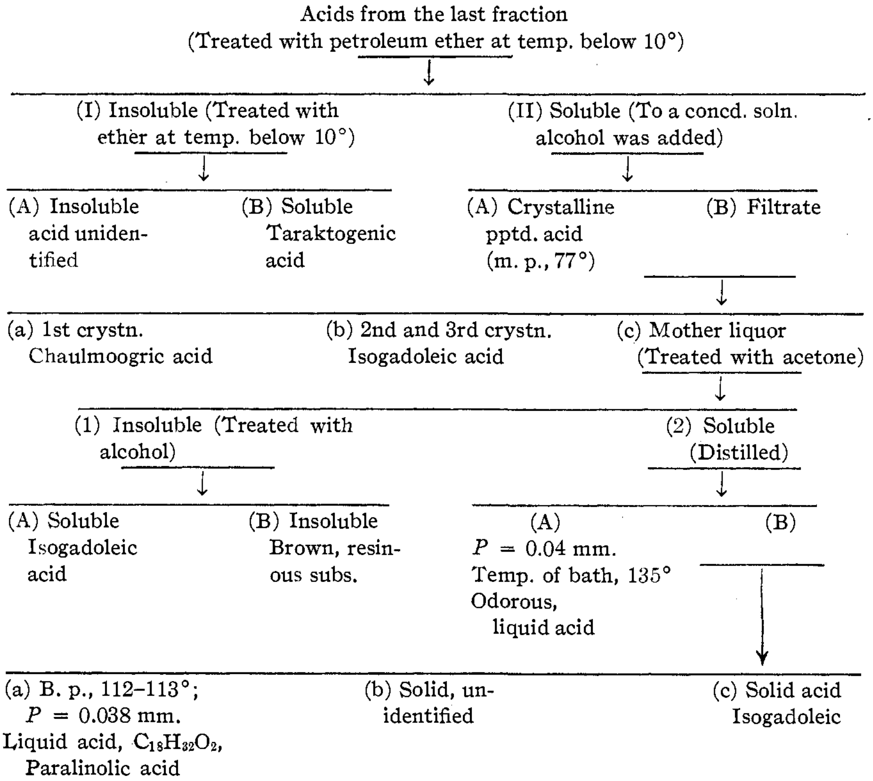
On saponification it yielded white, solid fatty acids; m. p., 43–45°; iodine no., 110.12; $[\alpha]_D$, +52.1°; neutralization value, 205.0 (by titrating the alcoholic solution with 0.1 *N* potassium hydroxide solution) and 257.5 (by boiling the alcoholic solution with an excess of potassium hydroxide solution for one-half hour in a water-bath and titrating back the excess with standard hydrochloric acid). As will be shown later, these two neutralization values are apparently due to the existence of a peculiar, new, liquid lactone which cannot be titrated in the ordinary way, probably on account of the slowness of the reaction velocity between it and the alkali in the cold solution.

In order to obtain a sufficient supply of the high-boiling acids, 5 liters of the oil was saponified, the acids were precipitated with hydrochloric acid, washed and converted into the ethyl esters by treatment with absolute alcohol and dry hydrogen chloride. After these esters had been washed and dried they were submitted to distillation in the apparatus described above. The distillation was carried out in 1-liter portions, being continued in each case until 80 to 85% had distilled. The combined high-boiling residues constituted the material for the present investigation. Before proceeding to the study of this material, however, a careful study of the lighter fraction which had distilled was made. The esters were first submitted to repeated high-vacuum fractional distillation, after which they were saponified, the free acids precipitated with hydrochloric acid and recrystallized repeatedly from various solvents to constant melting points.

Both chaulmoogric and hydnocarpic acids were obtained, and no other products, thus confirming the work of Power and of Dean with their collaborators.

The point at which the distillation of the chaulmoogric and hydnocarpic fractions had been completed was announced by a drop in the temperature in the still-head, and by virtual cessation of the delivery of distillate. The level of the oil in the bath was then raised and the temperature brought up to 190°. A slightly yellow, viscous liquid distilled very slowly, partly solidified at the room temperature and had a faint, characteristic odor. It took about 15 hours to obtain 50–60 cc., the pressure being 0.05 mm. The rate of distillation, however, was greatly increased by passing a small quantity of water vapor into the liquid. The highest temperature of the bath ever used was 190°. The solid was filtered off and separated into two parts by fractional crystallization. The final two compounds obtained melted at 68° and 65.5°, respectively. The solid was a mixture of chaulmoogric acid and one of the new acids which will be described later.

A Chart Showing the Methods of Separation of the Constituents of the Last Fraction of the Ethyl Esters of Chaulmoogra Oil



The slightly yellow liquid from the last fraction was saponified in the usual manner. The acids set free by acidifying the soap were extracted with ether and washed with water until free from hydrochloric acid. The ether was then distilled and the fatty acids were allowed to cool. The solid mass of the fatty acids thus obtained was slightly yellow. It was treated with petroleum ether (b. p., 40–60°) at a temperature not higher than 10° (when the solution is warmed or boiled, all dissolves) and filtered with suction, the receiver being kept in an ice-bath. This was repeated thrice. The insoluble residue (1)[4] comprised approximately 10% of the last fraction. This was then treated with ether in the same way, yielding a dark brown oily residue which was soluble in alcohols, but from which no pure substances were isolated. The ether solution (1) (B) was concentrated and left in the refrigerator overnight. Faintly yellow crystals separated. The dry substance melted at 100–103°. The alcoholic solution was boiled with animal charcoal for a few hours and filtered. The filtrate was practically colorless and, when allowed to crystallize, an almost colorless product was obtained. The dry material melted at 112–113°. It was recrystallized a few times more from 85% alcohol and the final product was snow-white, in the form of thin platelets. The dry crystals melted at 113.5° (uncorr.). The melting point did not change, when the substance was recrystallized from benzene and acetone.

*Anal.* Subs., (I) 0.1010, (II) 0.1013, (III) 0.1054: $H_2O$, (I) 0.0941, (III) 0.0989; $CO_2$, (I) 0.2716, (II) 0.2724, (III) 0.2833. Calcd. for $C_6H_{10}O_3$: C, 73.41; H, 10.27. Found: C, (I) 73.34, (II) 73.36, (III) 73.31; H, (I) 10.27, (III) 10.49.

SILVER SALT.—The silver salt was prepared by treating an alcoholic solution of the ammonium salt with a 10% solution of silver nitrate. The white, milky, amorphous precipitate was filtered and washed several times with dil. alcohol and water until free from soluble silver salts. The salt was dried in an air-bath at 110°.

*Anal.* Subs., 0.1240, 0.1040: Ag, 0.0332, 0.0281. Calcd. for $C_{18}H_{29}O_3Ag$: Ag, 26.90. Found: 26.77, 27.01.

*Neutralization Value.*—The alcoholic solution of the acid was titrated with 0.10514 *N* potassium hydroxide solution.

*Anal.* Subs., 0.1333, 0.1285: 4.38, 4.18 cc. of KOH soln. equal to 0.025837, 0.02448 of KOH. Calcd. for $(C_{18}H_{30}O_3)_m$: KOH required, 19.07%. Found: 19.38, 19.19%.

*Iodine No.*—Subs., 0.1519: $I_2$, 0.06039. Calcd. for 1 atom of iodine $(C_{18}H_{30}O_3)_n$: 42.7. Found: 42.51.

Since each double bond absorbs two atoms of iodine, the composition of this acid must be $C_{36}H_{60}O_6$. Its structure is unknown. It is optically inactive and easily oxidized by potassium permanganate. It is readily soluble in chloroform and ether and in warm alcohol and acetone, but is very slightly soluble in cold petroleum ether; it is also soluble in hot benzene, but as soon as the solution is allowed to cool it crystallizes immediately. The compound is designated as "Taraktogenic acid" by the author.

The petroleum ether solution (II) was concentrated and hot alcohol was added. On cooling, minute crystals separated; these were filtered off and recrystallized from alcohol until the melting point became constant. The final product was snow-white and showed a beautiful crystalline form (thin platelets) under the microscope; m. p., 77°. It was not positively identified but may have been arachidic acid, which is known as an important constituent of peanut oil.

The filtrate (II) (B) was left in the refrigerator overnight. The first crystalline product consisted of approximately 55% of the last fraction. It was purified by repeated recrystallization from dil. alcohol. The final product melted at 68°; [α], 58° in chloroform. It was, therefore, chaulmoogric acid.

---

[4] These are notations referring to the accompanying chart.

The second and third crystalline products were combined and recrystallized from alcohol. The first product thus obtained melted at 65–66°. It was recrystallized from petroleum ether, ether and acetone until no further change of the melting point took place. This acid was chaulmoogric acid; m. p., 68°.

The mother liquor was concentrated and again allowed to crystallize in the refrigerator. The crystals separated were soft and yellow. The process of the purification of this substance was tedious, involving many repetitions of the crystallization from ether, alcohol and acetone. The final dry product was snow-white; m. p., 65.5–66° (uncorr.). The melting point was not changed by further crystallization. The sample, dried in a vacuum desiccator, was analyzed.

*Anal.* Subs., 0.1099, 0.1031, 0.1021: $H_2O$, 0.1203, 0.1132, 0.1125; $CO_2$, 0.3121, 0.2839, 0.2899. Calcd. for $C_{20}H_{38}O_2$: C, 77.34; H, 12.34. Found: C, 77.47, 77.15, 77.45; H, 12.25, 12.20, 12.34.

*Neutralization Value.*—0.1551 g. of the acid required 0.02838 g. of KOH to neutralize completely. Calcd. for $C_{20}H_{38}O_2$: neutr. val., 180.8. Found: 182.9.

*Iodine No.*—Subs., 0.1383: $I_2$, 0.01356. Calcd. for $C_{20}H_{38}O_2$: $I_2$ No., 81.80. Found: 78.13.

SILVER SALT.—The silver salt was prepared by treating an alcoholic solution of the ammonium salt with silver nitrate. The white, amorphous precipitate was filtered off and washed with alcohol and water until it showed no test for silver. It was dried in a vacuum at 100°.

*Anal.* Calcd. for $C_{20}H_{37}O_2Ag$: Ag, 25.86. Found: 26.16.

When the substance was dried in air for some hours at 80°, the results were too low but were exactly what would have been expected if the compound had absorbed one molecule of oxygen.

Apparently the acid belongs to the oleic series ($C_nH_{2n-2}O_2$) and is isomeric with "gadoleic acid," $C_{20}H_{38}O_2$, found by Bull[5] in cod-liver oil and herring and whale oils. Bull's acid had the neutralization value 180.5 and iodine number 80.3. The acid isolated by the author differs from gadoleic in that it melts at 65.5° instead of 24.5°, which is the melting point of gadoleic acid. Further, the iodine number does not agree as well as might be wished.

The acid was readily soluble in chloroform, ether, petroleum ether and hot alcohol, but sparingly soluble in acetone. The potassium salt was an amorphous powder and slightly soluble in alcohol and water. It was easily oxidized by potassium permanganate. The substance is provisionally designated "isogadoleic acid."

When the mother liquor (II) (B) (c) (alcoholic solution) was treated with a large quantity of cold acetone a white solid substance separated which was filtered off, and the filtrate was treated again in the same manner.

The solid (c) (1) thus separated was then dissolved in hot alcohol. The clear solution (c) (1) (A) was separated from the insoluble, brown, resinous residue and allowed to crystallize in the refrigerator. After several recrystallizations the product melted at 65–66°. It was isogadoleic acid.

The acetone solution (c) (2) was a deep brown. The acetone was distilled and 50 cc. of the liquid residue was then distilled. When the temperature of the bath reached 135° and the pressure of the system was 0.04 mm., the first drop of the condensed vapor was formed at the end of the delivery tube, without any appreciable rise in the temperature on the thermometer inserted in the flask. The temperature of the bath was kept at 135° for a few hours. Approximately 5 cc. of the liquid was collected (c) (2) (A). It was a light pale yellow and had a peculiar aromatic odor. This substance is not yet

---

[5] Bull, *Ber.*, **39**, 3574 (1906).

identified. The temperature of the bath was then raised and the distillation was continued under 0.018mm. pressure with the following results.

| Fraction | I | II | III | IV |
|---|---|---|---|---|
| Temp. of vapor, °C. | to 130 | 130–135 | 135–140 | above 140 |
| Approx. vol., cc. | 10 | 15 | 10 | 10 |

The first fraction was a thin, pale liquid and had a strong aromatic odor. The second and third fractions were somewhat more deeply colored liquids, but a small amount of crystals separated when the liquid was placed in the refrigerator. The liquid portions of the second and third fractions were combined with the first fraction and redistilled. Only the portion that distilled at 112–113° under a pressure of 0.038 mm. was collected (c) (2) (B) (a). It amounted to about 18 cc. and was a practically colorless, odorless, thin liquid; f. p., —11.6 (uncorr.); $d^{15}_{15}$, 0.9129; $n^{25}_{D}$, 1.46195.

*Anal.* Subs., 0.1327, 0.1550, 0.1222: $H_2O$, 0.1367, 0.1593, 0.1262; $CO_2$, 0.3733, 0.436, 0.3451. Calcd. for $C_{18}H_{32}O_2$: C, 77.07; H, 11.50. Found: C, 76.89, 76.82, 77.04; H, 11.53, 11.50, 11.56.

Toward potassium hydroxide solution, the substance acted more like a lactone than an acid. Boiling for a half hour with excess of alkali was necessary in order to obtain a maximum constant value. The value finally found was 206.5. The calculated value for $C_{18}H_{32}O_2$ is 200.4. The difference between the two neutralization values of the original mixed fatty acids (see above) obtained by the two different methods was probably due to the presence of this substance. Power obtained 215 as the neutralization value of the mixed fatty acids, while the saponification value of the oil was 213. His comparatively low neutralization value may possibly also be explained by the presence of such a substance as this.

*Iodine No.*—The most peculiar characteristic of this substance was that it did not absorb a normal amount of iodine. It was, however, found that the prolongation of the time of the absorption increased the iodine absorbed to a great extent, as follows (by Wijs' soln.): 21 hours, 116.02 g.; 72 hours, 136.53 g.; 262 hours, 163.64 g.

The solid (c) (2) (B) (b) separated from Fractions II and III was recrystallized from acetone in a freezing mixture. It was snow-white after a second crystallization; m. p., 52° (not quite constant). Since the quantity obtained was very small, further investigation was impossible. The last fraction (4) yielded a crystalline product (c) (2) (B) (c) which proved to be "isogadoleic" acid. Further work on both these substances is under way and the results will be published later.

## Acknowledgment

The author takes great pleasure in acknowledging his deep appreciation of the kind support given to him by the Faculty of the Chemistry Department of this University. He desires to make special mention of the constant assistance rendered by Dr. E. C. Franklin and Professor S. W. Young of the Department, without which the work could not have been brought to the present stage. The investigation is being continued as rapidly as circumstances permit.

## Summary

1. An improved vacuum-distillation apparatus for high vacua and great capacity is described. With this apparatus distillation can be carried out under pressures as low as 0.01 mm. without difficulty.

2. By means of this apparatus the last 10–15% of the ethyl esters of the fatty acids of chaulmoogra oil were distilled without any appreciable decomposition. From the distillation products the following new substances were isolated: (*a*) taraktogenic acid, $C_{36}H_{60}O_6$; m. p., 113.5° (uncorr.); iodine no., 42.51; (*b*) isogadoleic acid, $C_{20}H_{38}O_2$; m. p., 65.5–66° (uncorr.); (*c*) a lactone-like substance, $C_{18}H_{32}O_2$; m. p., —11.6 (uncorr.); (*d*) an acid, new in the oil, possibly arachidic acid; (*e*) a brown, resinous material which is insoluble in organic solvents; (*f*) two unidentified solids, probably acids.

3. The presence of chaulmoogric and hydnocarpic acids, and these only, in the lighter fractions of the esters of the non-volatile acids is confirmed.

STANFORD UNIVERSITY, CALIFORNIA

---

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY]

# SOME NEW DERIVATIVES OF CYCLOHEXANONE[1]

BY CLARENCE E. GARLAND[2] AND E. EMMET REID

RECEIVED MARCH 18, 1925 PUBLISHED SEPTEMBER 5, 1925

## Introduction

The present investigation had a double object: to obtain more information about the condensation products of cyclohexanone and to prepare alkyl substitution products of cyclohexane. These hydrocarbons belong to the class of naphthenes that occur in petroleum in large amounts and great variety, but about which little is known. Every member of this class that is prepared adds that much to the foundation which is needed for a study of the naphthenes.

## Historical

Vorländer and Hobohm[3] condensed benzaldehyde with cyclohexanone in alcoholic solution, using sodium hydroxide as a condensing agent. Later, Wallach[4] prepared a series of condensation products of cyclohexanone using a number of aldehydes. All of these gave yellow derivatives except the salicylaldehyde, which was considered to have formed an anhydride between the two hydroxyls.

Borsche, using the method of Paal,[5] hydrogenated a series of unsaturated ketones.

---

[1] This paper was presented before the Organic Division at the 67th Meeting of the American Chemical Society, Washington, D. C., April 23, 1924.

[2] From the Doctor's dissertation of Clarence E. Garland, Johns Hopkins University, 1924.

[3] Vorländer and Hobohm, *Ber.*, **29**, 1840 (1896).

[4] Wallach, *Ber.*, **40**, 71 (1907); *Göttingen Nachrichten*, **404** (1907); "Terpene und Campher," **1914**, p. 405.

[5] Borsche, *Ber.*, **45**, 46 (1912).