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From: Chief, Naval Technical Mission to Japan.  
To : Chief of Naval Operations.  
Subject: Target Report - Japanese Fuels and Lubricants, Article 9 -  
Fundamental Hydrocarbon Research.  
Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering miscellaneous Japanese data on the physical properties of some pure hydrocarbons outlined by Targets X-09, X-10, and X-38(N) of Fascicle X-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Comdr. G. L. Neely, USNR, Lt. Comdr. C. S. Goddin, USNR, and Lieut. W. H. Millet, USNR, assisted by Ensign E. R. Dalkey, USNR, as interpreter and translator.



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**X-38(N)-9**

# **JAPANESE FUELS AND LUBRICANTS - ARTICLE 9 FUNDAMENTAL HYDROCARBON RESEARCH**

**"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945  
FASCICLE X-1, TARGETS X-09, X-10, AND X-38(N)**

**FEBRUARY 1946**

**U.S. NAVAL TECHNICAL MISSION TO JAPAN**

# SUMMARY

## MISCELLANEOUS TARGETS

### JAPANESE FUELS AND LUBRICANTS - ARTICLE 9 FUNDAMENTAL HYDROCARBON RESEARCH

This report summarizes data relative to the properties of pure hydrocarbons compiled for the Petroleum Section of the U.S. Naval Technical Mission to Japan by Dr. S. KOMATSU of the First Naval Fuel Depot, OFUNA. These data have been obtained by Dr. KOMATSU and his associates at the Imperial Universities and Institutes throughout Japan. It is Dr. KOMATSU's contention that the chemical behavior of organic compounds can frequently be anticipated by a consideration of the physical properties. In the report which he has submitted, he discusses the application of the physical characteristics of hydrocarbons to the selection of proper treating methods in preparing hydrocarbon fuels. Fuel research programs at OFUNA utilizing these fundamental studies as theoretical background are described in reports of the U.S. Naval Technical Mission to Japan relative to the pine root oil program in Japan and to the aviation gasoline research conducted by the Japanese Navy.

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# REFERENCES

## Location of Target:

First Naval Fuel Depot, OFUNA, Kanagawa Prefecture.

Tokyo Imperial University, TOKYO.

Kyoto Imperial University, KYOTO.

## Japanese Personnel Interviewed:

S. KOMATSU, Ph. D., Civilian Advisor to the Department of Fuel Research, First Naval Fuel Depot, OFUNA, (formerly Professor of Biochemistry at Kyoto Imperial University, foremost chemist of First Naval Fuel Depot).

A. IBUKI, Ph. D., Professor of Biochemistry at Kyoto Imperial University.

# INTRODUCTION

For the past fifteen years Dr. S. KOMATSU has been interested in the relationship between the chemical structure and the physical properties of pure hydrocarbons. During most of this period he was Head of the Department of Biochemistry at Kyoto Imperial University, but in 1943 he came to the First Naval Fuel Depot, OFUNA, as Civilian Advisor to the Department of Fuel Research. While in OFUNA, he applied many of his theories to the research being conducted at the Depot, and related research projects which he had assigned to his co-workers at Kyoto Imperial University and Tokyo Imperial University were continued.

Enclosure A of this report was prepared at the request of the Petroleum Section of the U.S. Naval Technical Mission to Japan with the thought that it might include some new data or might serve as supporting material for that obtained by others interested in this phase of hydrocarbon research, such as the Hydrocarbon Research Committee of the American Petroleum Institute. A review of the information thus obtained shows that it includes a compilation of the data obtained by Dr. KOMATSU and his associates relative to the physical properties and cracking temperatures of some pure hydrocarbons, as well as a study of the decomposition products of these hydrocarbons by ultra-violet ray absorption spectra and Raman spectra.

While it is realized that most of this information was published in Japanese journals before the beginning of the war, and that similar studies have been duplicated in American laboratories, it was felt worthwhile to collect and present the material available at this time without attempting its appraisal.



# THE REPORT

## A. SCOPE OF STUDIES

The report entitled "On the Physical Properties of Some Pure Hydrocarbons," written by Dr. KOMATSU and submitted, herewith, as Enclosure (A), is made up of five parts. In Parts I and II the author discusses the use of such properties as boiling point and density or molecular volume in predicting the chemical behavior of various types of hydrocarbons. Correlations are drawn between the molecular volume and cracking temperatures of related compounds. These temperatures have been determined, and the products of decomposition have been studied by means of ultraviolet absorption spectra. Raman spectra were utilized in examining isomeric hydrocarbon mixtures and also as a means of studying the composition of gasoline distillation fractions.

Part III of Dr. KOMATSU's report is a tabulation of the properties of pure hydrocarbons as determined in Japanese research laboratories. This section includes assembled data pertaining to the boiling points, densities, refractive indices, decomposition temperatures, and decomposition products of approximately one hundred different hydrocarbons. Ninety per cent of these compounds are from the six to eighteen carbon atom range, and octane numbers of twelve of them have been determined. Of particular interest are the conjugated hydroaromatic compounds synthesized by Dr. I. KAGEHIRA of the First Naval Fuel Depot in connection with fundamental lubrication studies and discussed in detail in Enclosures (A), (B)1, and (B)2 of NavTechJap Report, "Japanese Fuels and Lubricants, Article 8 - Naval Research on Lubricants," Index No. X-38(N)-8.

Parts IV and V of the enclosed report tabulate ultraviolet absorption data for twenty-five hydrocarbons and Raman spectra data for thirty-eight hydrocarbons.

## B. APPLICATION TO REFINING TECHNOLOGY

Dr. KOMATSU has indicated that the information presented in Enclosure A is of value in selecting the proper treating methods for the preparation of fuels from various types of hydrocarbons. The following comments are made relative to those portions of the paper which have application to refining techniques.

### 1. Boiling Point and Molecular Volume

Boiling point changes within different homologous series are discussed and correlations between these boiling points and the tendency of organic compounds to form stable groups of five or six carbon atoms are indicated. Based on this assumption, the author points out that, when normal paraffines are subjected to thermal cracking, it can be anticipated that molecules of five, six, nine, or ten carbon atoms will predominate in the distillate.

The author discusses the relationship between thermal stability and close-packing as indicated by the molecular volume. He maintains that compounds of higher density will be more stable than those of lower density with the same number of carbon atoms. In support of this assumption, the molecular volumes and decomposition temperatures are compared for two series of hydrocarbons; n-hexane, cyclo-hexane, and benzene; and ortho-, meta-, and para-xylene.

This hypothesis is also applied to catalytic rearrangements of unsaturated compounds such as the catalytic transformation of octalin to

tetralin and decalin. These reactions were discussed in detail by the author in describing the catalytic rearrangement of terpenes to naphthenes and aromatics in Enclosure (A) of NavTechJap Report, "Japanese Fuels and Lubricants, Article 4 - Pine Root Oil Program," Index No. X-38(N)-4.

## 2. Cracking Temperatures

The cracking or decomposition temperature of hydrocarbons has been studied by Dr. KOMATSU and his associates at Kyoto Imperial University. The method used was to heat 0.2-0.3 grams of sample in a silica reaction vessel, initially evacuated to a pressure of 0.001mm of mercury. Pressure and temperature changes were recorded as heating progressed. Cracking was indicated by sudden changes in pressure and the decomposition products were determined by gas analysis. Enclosure (B) tabulates typical data obtained with this apparatus.

These experiments have indicated, in general, that the cracking temperatures of paraffinic hydrocarbons are below 500°C, those of naphthenic hydrocarbons are usually between 500°C and 600°C, and those of aromatic hydrocarbons are above 700°C. Alkyl-aromatic hydrocarbons have two cracking temperatures--that of the side chain and that of the ring. This is also true of aromatic-naphthenic hydrocarbons, such as tetralin.

## 3. Ultraviolet Absorption Spectra

Dr. KATO of Tokyo Imperial University has utilized ultraviolet absorption spectra to observe the decomposition products of thermally cracked hydrocarbons. In Enclosure (A) data are presented relative to the products of thermal cracking and oxidation at different temperatures for benzene, toluene, ethyl benzene, isopropyl benzene, and tertiary butyl benzene. From data of this type the nature of the thermally cracked products of paraffines, naphthenes, and aromatics was obtained.

## 4. Raman Spectra

Raman spectra have been used as a means of studying the effect of heat on organic compounds. Enclosure (A) presents data obtained by using Raman spectra in examining the polymerization products of n-butene, the dehydration products of n-butanol, and the hydrocarbon constituents of gasoline. A sample of SANGA SANGA straight run gasoline was separated into 23 fractions, and the composition of each fraction was examined.

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**ENCLOSURE (A)**

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**ENCLOSURE (A)**

ON THE PHYSICAL PROPERTIES  
OF SOME PURE HYDROCARBONS  
(In Five Parts)

by

DR. S. KOMATSU

Prepared for and Reviewed with Author by  
the U. S. Naval Technical Mission to Japan

December 1945

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## ENCLOSURE (A)

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## ENCLOSURE (A)

Part I  
RELATION BETWEEN MOLECULAR STRUCTURE  
AND PHYSICAL PROPERTIES

I. INTRODUCTION

The relation between the chemical constitution of organic compounds and their physical properties has been studied by many investigators. Important results of the investigations are discussed in the following books:

- S. Smiles: The Relation Between Chemical Constitution and Some Physical Properties (1910).
- H. Kauffmann: Bezeichungen zur physikalische Eigenschaften u. Chemische Konstitution.
- S. KOMATSU: General Organic Chemistry (1931)
- W. A. Waters: Physical Aspects of Organic Chemistry (1935)
- R. Kremann: Physikalische Eigenschaften u. Chem. Konstitution. (1937).
- V. Henri: Strukture des Molecules (1925)
- N. V. Sidgwick: The Covalent Link in Chemistry (1938)

The conclusion of these researches mentioned in these books is that the boiling point, density, or molecular volume and refractive index of the organic substances are, as a rule, partly additive and partly constitutive. The author maintains that the chemical reactions of organic compounds can be anticipated from their physical properties. For many years the author has been endeavoring to verify this belief at the Biochemical Laboratory, Kyoto Imperial University.

\* \* \* \* \*

- S. KOMATSU & R. NODZU: J. Chem. Soc. Japan 45 (1923) 153
- S. KOMATSU & R. AMATATSU: Mem. Coll. Sci. Kyoto Imp. Uni. A. 13, (1930) 329
- S. KIMURA: Ibid., A, 14, (1931) 173
- S. TANAKA: Ibid., A, 22, (1939) 97
- S. KOMATSU & NAKAYAMA: J. Chem. Soc. Japan 54 (1933), 558.
- S. ARAKI: J. Chem. Soc. Japan 51 (1930), 560, 52 (1931) 818
- S. KOMATSU & HAGIWARA: Ibid, 51 (1930) 552.
- M. HAGIWARA: Ibid, 56 (1935) 269.
- T. OGAWA & T YOKOTA: Bull. Chem. Soc. Japan 5 (1930) 266
- R. NAKAI: Ibid., 5 (1930) 136.
- Y. KAGEHIRA: Ibid., 6 (1931) 241.
- S. FUJITA: J. Chem. Soc. Japan 60 (1941) 296.

\* \* \* \* \*

The present volume is a short summary of the data of the physical properties such as the boiling point, density or molecular volume, refractive index, cracking temperature, absorption spectra of ultra violet rays and the Raman spectra. These data are taken from the researches on pure hydrocarbons, carried out in the chemical laboratories of the Imperial Universities and the Institutes in Japan, and also deal with the significance of physical properties to organic chemistry.

## ENCLOSURE (A)

III. BOILING POINT

The boiling point of hydrocarbons of paraffin series  $C_nH_{2n+2}$ , increases with the number of carbon atoms in the molecule.  $CH_2$  in the homologous series shows constancy in some intervals of carbon number, but this mean value decreases in ascending the series. (S. KOMATSU; General Organic Chemistry, P. 27)

No. of intervals of carbon	Mean value for $CH_2$ (°C)
$C_1 - C_5$	40
$C_6 - C_{10}$	25
$C_{11} - C_{15}$	20
$C_{16} - C_{20}$	15

That is, the boiling point of the hydrocarbons depends both on the mass and structure of the molecule.

Similar relations occur in homologous series of organic acids,  $C_nH_{2n}O_2$ , and amines,  $C_nH_{2n+3}N$ :

No. of intervals of carbons	Organic Acids	Mean value (°C)
$C_1 - C_4$		20
$C_6 - C_{10}$		15
$C_{11} - C_{15}$		10
<u>Amines</u>		
$C_1 - C_4$		30
$C_6 - C_{10}$		25
$C_{11} - C_{15}$		15

From these facts, we have learned that in organic compounds, carbon atoms are closely packed to form a stable group of 5 or 6 atoms; the tendency for carbon atoms to form a group will appear in cyclic compounds and also in a long carbon chain molecules.

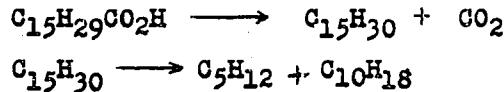
The packing force will evidently be accompanied by the diminution of space occupied by the atomic groups. The diminution of the volume occupied by the atoms themselves with 5 or 6 carbon atomic groups which they undergo by mutual compression (in other words, the energy distribution of long chain hydrocarbons for the  $CH_2$  group in the molecule) is approximately the same within some number of intervals of carbon.

These views were advanced from the occurrence of semiterpenes ( $C_5H_8$ ), terpenes ( $C_{10}H_{16}$ ), and sesquiterpenes ( $C_{15}H_{24}$ ) in nature, and benzene ( $C_6H_6$ ), naphthalene ( $C_{10}H_8$ ), and anthracene or phenanthrene, ( $C_{14}H_{10}$ ) in coal tars.

When the normal paraffins of high molecular weight or long carbon chain compounds are subjected to thermal cracking it will be anticipated that fractions of  $C_5$ ,  $C_6$ ,  $C_9$ , and  $C_{10}$  atomic groups occur mostly in the distillate.

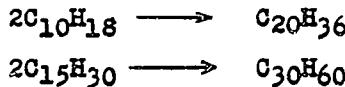
## ENCLOSURE (A)

As a matter of fact, the saturated paraffin hydrocarbons of the carbon atom number C<sub>8</sub>, C<sub>9</sub>, C<sub>10</sub>, C<sub>11</sub>, and also those of the carbon atom number C<sub>15</sub>, C<sub>19</sub>, C<sub>20</sub>, and C<sub>30</sub> of unsaturated character are found in tars as a main reaction product from the dry distillation of palmitic acid in a retort. The thermal reaction which occurs on the fatty acid molecule can be interpreted as follows:



The hydrocarbon residue derived from the splitting off of the CO<sub>2</sub> from palmitic acid, decomposes into C<sub>5</sub> and C<sub>10</sub> atomic groups, since the thermal stability of the atomic groups varies as proposed by G. Egloff and R. I. Moore (Met. Chem. Eng., 16 (1917) 47); that is, C<sub>12</sub>H<sub>26</sub> & C<sub>15</sub>H<sub>32</sub> are most stable and those of less and of more carbon atoms less stable.

The unsaturated groups or free radicals formed by cracking tend to polymerize.



(S. KOMATSU: Biochemical Studies on Pityryrol, Mem. Coll. S. K., I, U, A, 11, (1928) 481; S. ARAKI; Thermal Cracking of Palmitic Acid, Cetyl Alcohol and Hexadecane, J. Chem. Soc. Japan 52 (1931) 818.)

It is worthy of note that the abnormally high boiling points of the compounds are often associated with some of the hydrogen bonds which exist in the molecule. (L. Pauling: The Nature of the Chemical Bond, 1939, P. 270). (Refer H. INOURI; On the Relation Between Boiling Point and Chemical Constitution of Liquid Organic Compounds; J. C. S. Japan, 47 (1925) 153.)

In this connection, hydrogen peroxide and hydrazine which are used for rocket fuel, should be mentioned as one of the most interesting examples in regard to the hydrogen bonds.

### III. DENSITY OR MOLECULAR VOLUME

Density of organic liquids or the volume occupied by their molecules under corresponding states depends not only on the mass but on the nature of their chemical structures as will be illustrated with a few examples which are composed of the same number of carbon atoms--n-hexane, cyclohexane, and benzene.

It is understood from these typical examples that the ring formation is attended by a considerable contraction within the molecule, and the packing force of the molecule is greater in benzene, the aromatic compound, and smaller in n-hexane, the paraffin compound. (Based on their molecular refraction and relative density, they are classified as aliphatic monocyclic, dicyclic and tricyclic sesquiterpenes.)

These results were compatible with the distance between the centers of two singly linked carbon atoms, measured by the X-ray method, and also the heat of rupture of the links (H.R) obtained from extrapolation of the infrared band spectra.

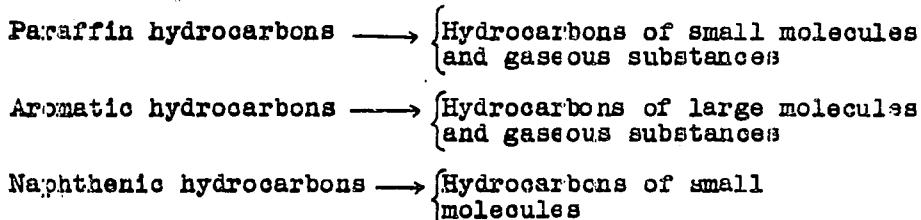
Hydrocarbons of higher density, therefore, should be more thermally stable than the lower density ones, and the idea is emphasized on the heats of formation of links (in Kgm-Cals) calculated from thermochemical data as shown in Table III(A).

## ENCLOSURE (A)

As a matter of fact, approximate values of the decomposition temperatures of the pure compounds obtained (1) from pressure change which was measured under constant volume by S. KOMATSU and his co-workers, (2) from the observation of ultra violet absorption spectra of the decomposed substances by S. KATO and her co-workers.

It was supposed from the heat of rupture of the links that in the thermal cracking of n-paraffins, the rupture of C-C link will take place at first, and then the rupture of C-H link, follows, while aromatic hydrocarbons behave in a different manner. The side chain and hydrogen are removed first and the disruption of the benzene nucleus follows. Cyclohexane and its alkyl derivatives when heated, must decompose entirely into the fragments of similar sizes of molecules judging from the fact that the energy contents of C-C and C-H, links have almost the same value.

The behaviour of paraffin, naphthene and aromatic hydrocarbons towards heat. is illustrated as follows:



These characteristic thermal behaviours of the hydrocarbons are due to the distribution of energy in the molecules; in paraffin and aromatic hydrocarbons, chemical energy is distributed unequally on C-C and C-H links, but the energy in the naphthenic hydrocarbons is equally distributed. (Refer. R. NAKAI, Rep. Nav. F. R. 4, No. 5, OGAWA & TAKAHASHI Ibid., No. 55, FUJIMOTO Ibid., No. 101.).

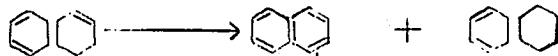
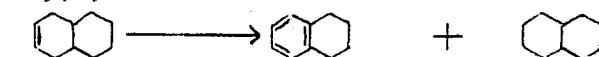
The result of the study was that hydrogenation cracking of gas oil or kerosene to obtain gasoline was a more rational treatment than thermal cracking.

When, however, pine root oil was subjected to catalytic cracking, the reaction product consisted mostly of aromatic hydrocarbons. Such a phenomenon was hardly met with in petroleum cracking, due to the chemical behaviour of terpenes, the hydro-p-cymene derivatives, which occur abundantly in the pine root oil.

A further study of force constant of links and of density is required to solve this abnormal behaviour of terpenes. Another, chemical significance of density, has been studied in the study of hydrogen transformation.

Cyclohexene when heated at 300°C in the presence of Pd-asbestos, was converted into benzene and cyclohexane. (N. Zelinsky & G. Pawlow; Ber. 57 (1924) 1066) Such a chemical reaction (so-called catalytic oxidation-reduction of the unsaturated compounds) was noticed on hydronaphthalene and its derivatives; dihydronaphthalene was passed over Pd-asbestos heated to 250-300°C in an atmosphere of CO<sub>2</sub>, and naphthalene and tetrahydronaphthalene were found to occur in the reaction product by means of the density determination, and cis-octalin under the same reaction conditions was converted into tetralin and trans-decalin:

## ENCLOSURE (A)

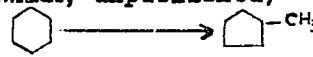
			
B.P.	206.5°	Product	{ 0.974 1.552
d <sub>4</sub> <sup>25</sup>	0.9931		
n <sub>D</sub> <sup>25</sup>	1.5789		
			
B.P.	191°	198-203°	186-188°
d <sub>4</sub> <sup>25</sup>	0.9011	0.954	0.8723
n <sub>D</sub> <sup>25</sup>	1.4912	1.514	1.4719
Product	d <sub>4</sub> <sup>25</sup> 0.905;	n <sub>D</sub> <sup>25</sup> 1.495	

(S. KIMURA: Mem. Coll. Sci. R. I. U. A. 14 (1931) 173)

Thus unsaturated hydrocarbons by the catalytic hydrogen transformation change to stabler hydrocarbons. The catalytic hydrogen transformation was applied to cracked gasolines from petroleum or coal tars to improve the fuel quality, by which unsaturated compounds in the gasoline were removed by converting to stabler forms.

The unsaturated compounds in gasolines, tars or pine root oil, contain C=C link in the molecule, which is a chemically reactive group, but more stable toward heat than the C-C link. The C=C link, therefore, can be removed from the molecule by addition of hydrogen but not by thermocracking.

One important feature in thermochemistry is that cyclohexene by heating is converted to its stable isomer methyl cyclopentane, and tetralin in the same manner, to hydrindene. (M. HAGIWARA; unpublished)

		
B.P.(°C)	81	73
d <sub>4</sub> <sup>25</sup>	0.779	0.750
Cyclohexene	Methyl-cyclopentane.	

These experimental facts harmonize with the occurrence of cyclopentane and its homologue in petroleum and indene in coal tars. The occurrence of these pentamethylene derivatives in nature is explained by assuming the thermochemical reaction occurs on hexamethylene derivatives. However, the conversion of hydrocarbons of higher density into low density isomers, seemed to contradict the hypothesis above mentioned and is hardly explained by the strain theory of Baeyer.

The investigations of the Raman spectra of these compounds gave us a more satisfactory explanation with regard to the isomerization.

## ENCLOSURE (A)

IV. CRACKING TEMPERATURE

Pure hydrocarbons which were heated externally in a quartz vessel, decomposed at a definite temperature. The cracking temperature was observed by the pressure change, and, also, by the formation of new cracked substance by means of the absorption spectra of ultra violet rays. The former experiments were carried out at the Biochemical Laboratory of Kyoto Imperial University and the latter by S. KATO at the Institute of Physical and Chemical Research, TOKYO.\*

The experimental results are shown in Table VI(A). The cracking temperature of paraffines was below 500°; that of polymethylene hydrocarbons or naphthalene about 500°; and that of aromatic hydrocarbons above 700°. These results can be expected from the energy contents of various links such as C-H, C-C, C=C, as shown in Table III(A).

The energy contents of links indicate that alkyl benzenes showed two or more cracking temperatures. As a matter of fact, toluene cracked at 600° and 725°, indicating that the energy of the substance was distributed unequally in the molecule. Tetralin, being a benzeneocyclohexane condensed ring compound, shows evidently two cracking temperatures 556° and 742°.

From these results, the cracking temperature of hydrocarbons seems to be the additive of those of the constituent links.

When the experimental results shown in the appendices were carefully examined, the cracking temperature of hydrocarbons was found to be partly additive and partly constitutive as in the case of other physical properties.

V. ABSORPTION SPECTRA OF THE ULTRA VIOLET RAYS

The heat of formation of the double link C=C is about 123 kg-cal, or 19 kg-cal less than that of two single links ( $2 \times 71.1 = 142.3$ ). Hence if we take the strain in a molecule to be measured by its excess energy content it would appear that the strain in cyclopentane, a 5-carbon ring, is smaller than that in amylene or the latter is more chemically reactive than the cyclopentane.

		Heat of formation (kg-cal)
Cyclopentane	C <sub>5</sub> H <sub>10</sub>	1288.7
Amylene	C <sub>5</sub> H <sub>10</sub>	1269.6
Calc. for	C <sub>5</sub> H <sub>10</sub>	1291.8

The characteristic properties of the olefinic linkage are its capacity for a direct addition of reagents such as halogens and hydrogen and its susceptibility to the attack of oxygen or oxidizing agents. It must be the C=C link in the molecule, from which electrons dissociate themselves from one of the carbon atoms and become unshared electrons, by means of absorption effect on the ultra violet rays.

\* The experimental results on o-xylene and cyclopentane by KATO are illustrated in Figures 1(A) and 2(A).

## ENCLOSURE (A)

Some organic compounds which contain the atomic groups  $C=C$ ,  $C\equiv C$ ,  $C=O$ ,  $\rightarrow CH$ ,  $>CH_2$  in the molecule show, on the absorption spectra of the ultra violet rays, the characteristic feature even in a dilution of mol/10,000. Therefore, a compound of these atomic groups was identified and confirmed even in a solution or in such a state of mixture as KATO worked in her studies on thermal cracking and oxidation. Among her experiments, the thermal cracking of benzene, toluene, ethyl benzene, isopropyl benzene and tertiary butyl benzene and their chemical reactions with oxygen are very interesting.

Table V(A) shows the experiment by which the physical properties of these hydrocarbons were measured in the Biochemical laboratory.

Table VI(A) shows the cracked products and the reaction products when equal number of molecules of hydrocarbon and oxygen are reacted at various temperatures.

The reactivity of hydrocarbons with oxygen increased in the following order:

Benzene  
Toluene  
Ethyl benzene  
Isopropyl benzene

It may be explained by the conception of the co-ordinate link that the hydrogen in the methyl group, the acceptor of electrons, which has two shared valence electrons, will carry four; the tendency of the hydrogen to act as acceptor increases gradually by replacing hydrogen atoms in the methyl group by the methyl group.

In the same way, the double links in unsaturated hydrocarbons may play a part in the coordination link.

This conception will be harmonized with the experimental results of the absorption spectra of the ultra violet rays of these compounds.

Substances forming strong intra-molecular hydrogen bonds show the absorption spectrum in the neighborhood of  $3500 \text{ cm}^{-1}$ , its first overtone being at about  $7,000 \text{ cm}^{-1}$  (L. Pauling: The Nature of the Chemical Bond, 1939, p. 264).

In Table VII(A) the  $v_0(\text{cm}^{-1})$  denotes the minimum energy for excitation of non-bonding electron, molecular vibration due to the excitation  $a_1, a_2, a_3, a_4$ . (in wave number  $\text{cm}^{-1}$ ).

The excitation energy of the non-bonding electron of benzene nucleus is the maximum for benzene and the minimum for toluene.

Excited energy calculated in Kg-Cal/mol from  $v_0$

Kg-Cal/mol

Benzene.....	110.0
Toluene.....	106.76
Ethyl Benzene.....	106.92
Isopropyl Benzene.....	107.14
Tert. Butyl Benzene.....	107.23

When hydrogen of the  $CH_3$  group in toluene is replaced by  $CH_3$  group, more energy is required for the excitation of the electron than that for toluene. This fact indicates that the negative character of the carbon atom in a  $CH_3$ -group decreases gradually, and in consequence the absorption spectra of isopropyl

## ENCLOSURE (A)

benzene and tertiary butyl benzene appeared in the region of long wave length and diffused while benzene and toluene showed a sharp band as can be seen in Figure 3(A).

The significance of the physical properties of organic compounds can be illustrated by the addition of oxygen to the double bonds, experimented by S. TANAKA (Mem. Ccll. Sci. Kyoto Imp. Uni., A. 22 (1939) 98) on p-menthene and benzaldehyde.

When menthene,  $C_{10}H_{18}$  was oxidized by peracetic acid, persulphuric acid or  $H_2O_2$ , the product  $C_{10}H_{18}O$  was identified to be menthene oxide by the physical constants, in comparing with those of  $\gamma$ -menthone:

The product,  $C_{10}H_{18}O$ , B.P. (74-5)<sub>14</sub>,  $d_4^{25}$  0.8946,  $n_A^{25}$  1.44369,  $n_B^{25}$  1.44595,  $n_B^{25}$  1.45148,  $n_V^{25}$  1.45502,  $(\alpha)_D^{25}$  53,17°.

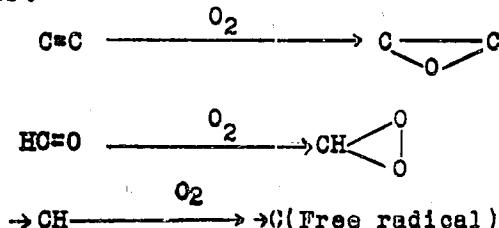
	Mol. Heat of Combustion	Parachor	
	(Kg. Cal.)	$\frac{M}{D-d} \gamma^{1/4}$	$\sum(P)$
Product, $C_{10}H_{18}O$	1302.8	396.1	381.9
$\gamma$ -menthone $C_{10}H_{18}O$	1278.7	400.9	405.1

In general, ethylene oxide compounds have been produced by the oxidation of the ethylenic compounds.

Menthene oxide when heated to 100° for 20 minutes with a drop of acetic acid was converted 25% into a brown coloured polymer.

It is well known that in physical properties, especially in the ultraviolet ray absorption, there is a close resemblance between the ethylenic and carbonyl linkages as shown in Table VIII(A), and that in chemical properties they resemble each other in the tendency to auto-oxidation, addition reactions with oxygen and halogen, and polymerization.

The tendency to gum formation in gasolines and to autoxidation of pine root oil should be attributed to the link  $C=C$ ,  $C=O$  or the more positive character of carbon atom in the molecule, and to the probable formation of ethylene oxide ring in the following manner:



In this connection, the study on styrene ozonide by F. KAWAMURA (Bull. Chem. Soc. Japan, 16 (1941) 382.) should be noted. It has been found that the styrene ozonide possessed no oxidizing action upon styrene but accelerates its polymerization.

The author has prepared the peroxides of various ketones and aldehydes by the action of hydrogen peroxide as antidentalons for diesel fuel; acetone, methyl ethyl ketone and cyclohexanone derivatives were found to give good results for

## ENCLOSURE (A)

this purpose (unpublished).

The molecular structure of naphthalene was ascertained by S. KIMURA ultra-violet absorption spectra. (Stereo chemical studies on hydronaphthalenes. Mem. Chem. Coll. Sci. Kyoto Imp. Univ., A, 14 (1931) 303).

According to his investigation, the absorption spectra of naphthalene in an alcohol solution gives two series of absorption bands, one series composed of 9 sharp and intensive bands in the region  $\lambda = 3400\text{A} - 2900\text{A}$ , which are divided into 2 groups according to the frequency interval (A)  $\Delta \lambda = 14800 \text{ cm}^{-1}$  and (B)  $\Delta \lambda = 540 \text{ cm}^{-1}$ , and the other series composed of 5 broad and diffused bands in  $\lambda = 2900\text{A} - 2500\text{A}$ , as can be seen in Figures 4(A), 5(A), and 6(A).

The absorption spectra of dihydro- and tetrahydro-compounds, are also composed of two series of absorption bands which are similar in frequency intervals:

	$\Delta \lambda \text{ cm}^{-1}$
	(A)                   (B)
Naphthalene	1480       540
$\Delta$ -Dihydro-	1630       475
Tetrahydro-	1563       497

The absorption of light by benzene shows 7 sharp absorption bands in the ultra-violet region due to the benzene nucleus, not appearing in the alcohol solutions of di- and tetrahydrobenzenes, (see Figures 3(A), 4(A), 5(A), and 6(A)). The relationship shown in the absorption spectra of these two series of compounds of naphthalene and benzene, leads to the idea that the chemical structure of benzene is different from that of its hydrogenated compounds, while di- and tetrahydronaphthalenes have the same chemical structure as naphthalene. However, the absorption spectra of octa- and decahydro-naphthalenes in the ultra-violet region were observed to be entirely different in nature from those of the other hydrocompounds studied above, and to be composed only of broad, diffused bands in  $\lambda = 2750\text{A} - 2400\text{A}$  of the frequency intervals  $\Delta \lambda = 1500 \text{ cm}^{-1}$ , which correspond to the second series of the absorption bands of naphthalene and the first series of the absorption bands were absent in these hydro compounds. These facts are in favour of the view that the molecular structure of naphthalene is partly changed in the octahydro- and decahydro-compounds, such a difference in the absorption spectra between the compounds of the naphthalene series and those of the benzene series may be explained by assuming a bicyclic structure for the naphthalene molecule; in the dihydro- and tetrahydronaphthalene, the hydrogen atoms combined to one of the rings in the naphthalene molecule, but in octahydro- and decahydro-naphthalenes they are added to both rings.

Accordingly, in the former, the addition of hydrogen atoms to naphthalene did not effect its absorption spectra, while in the latter, only the second series of absorption bands would appear in the ultra violet region owing to the partial change in the chemical structure of naphthalene. The absorption bands of the second series, which were situated in the neighbourhood of from  $\lambda = 35000 \text{ cm}^{-1}$  to the more ultra violet region were observed to appear throughout all the compounds of the naphthalene series. The origin of these bands was attributed to some vibration of a bicyclic carbon linking.

Dr. HAGIWARA's observation, made in the course of his study of terpenes, that pinane, the saturated bicyclic compounds, exhibited a selective absorption band in the ultra-violet region but that a saturated monocyclic hydrocarbon such as methane showed no selective absorption band, supported the above view that there was an absorption caused by the bicyclic ring.

## ENCLOSURE (A)

This idea of the bicyclic nature of the naphthalene molecule was also confirmed by the study of the catalytic reduction of naphthalene.

By reduction, benzene yielded cyclohexane as a sole reaction product, while naphthalene absorbed hydrogen in a two or more step reaction, forming tetrahydro-, octahydro-, and decahydro-naphthalenes. These results indicated that the distribution of energy in the naphthalene molecule differed from that of the benzene molecule in not being uniform, and this view of the distribution of energy in the naphthalene molecule was supposed from the fact that the absorption spectra of naphthalene were composed of two groups of bands of different frequency interval. The structure formula (1) of naphthalene, which advocated by Willstetter, was thus supported to be a reasonable one from the study of absorption spectra of ultra violet rays.



By applying T. YOKOTA and H. FUJIMOTO's research on the absorption spectra of anthracene and its hydrogenated compounds, I. WATANABE, I. KOIKE, and S. IKASAKI have investigated the chemical reaction of the catalytic reduction of anthracene in presence of nickel oxide under high temperature and high pressure of hydrogen. (Rep. the Naval Fuel Research No. 143 (1941) Figures 7(A), 8(A), 9(A), 10(A), 11(A), and 12(A).

Table I(A)  
EXAMPLES ILLUSTRATING THE RELATION BETWEEN MOLECULAR VOLUME  
AND MOLECULAR STRUCTURE

Substance Formula		M.W.	B.P.	$d_4^{25}$	$V_m^{**}$	D. Temp. *
n-Hexane	$C_6H_{14}$	84	69	0.6558	127.7	410°
Cyclohexane	$C_6H_{12}$	82	81	0.7736	105.8	550°
Benzene	$C_6H_6$	76	80	0.8715	87.2	745°
o-Xylene	$C_8H_{10}$	104	141.9	0.8509	121.7	600°
p-Xylene	$C_8H_{10}$	104	136.3	0.8566	120.7	650°
m-Xylene	$C_8H_{10}$	104	138	0.8600	120.0	650°

\* D. Temp. Decomposition Temperature

\*\*  $V_m$ . Molecular Volume. (G. Le Bas; The mol. volumes of liquid chem. compounds (1915)).

## ENCLOSURE (A)

Table II(A)  
RELATIVE FORCES AND DIMENSIONS OF CERTAIN HYDROCARBON LINKAGES

Link	H. Rup. (kg-cal)	Substance	Method	Distance (Å)
C <sub>al</sub> -C <sub>al</sub>	88	Acetone	Pre-dissociation	1.54
C <sub>ar</sub> -C <sub>ar</sub>				1.45
C = C				1.44
C <sub>al</sub> -H	97	Hexane	Infra-red	
C <sub>al</sub> -H	94	Cyclohexane	Infra-red	
C <sub>ar</sub> -H	117	Benzene	Infra-red	

(N. V. Sidgwick: The covalent link in chemistry, 110, 119)

Table III(A)  
HEATS OF FORMATION OF HYDROCARBON  
LINKAGES

Link	Heat of formation (kg-cal)
C <sub>al</sub> -C <sub>al</sub>	71
C <sub>ar</sub> -C <sub>ar</sub>	97.2
C <sub>ar</sub> -C <sub>al</sub>	79.4
C = C	123
C <sub>al</sub> -H	93.6
C <sub>ar</sub> -H	101.7

(N. V. Sidgwick: The covalent link  
in chemistry, 110, 119)

## ENCLOSURE (A)

TABLE IV(A)  
THERMAL DECOMPOSITION PRODUCTS

Substance Formula	n-hexane $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$	cyclohexane $\text{CH}_2-\text{CH}_2-\text{CH}_2$ $\text{CH}_2-\text{CH}_2-\text{CH}_2$	benzene $\text{CH}_2-\text{CH}-\text{CH}$ $\text{CH}-\text{CH}-\text{CH}$	$\alpha$ -Xylene $\text{CH}_3-\text{CH}=\text{CH}_2$	p-Xylene $\text{CH}_3-\text{C}_6\text{H}_4-\text{CH}_3$	n-Xylene $\text{CH}_3-\text{C}_6\text{H}_3(\text{CH}_3)_2$
Decomposition temp. (°C)	550°	580°	745°	590° 680°	650° 744°	660° 710°
Reaction products (Confirmed)	$\text{CH}_3\text{CH}_2-\text{OH}:\text{CH}_2$ $\text{CH}_3\text{CH}_2-\text{CH}_2$	$\text{CH}_2:\text{CH} \cdot \text{CH}:\text{CH}_2$ $\text{CH}_2:\text{CH}_2$	$\text{CH}_3-\text{CH}:\text{CH}_2$ , 610-650°C, $\text{CH}_2-\text{OH}=\text{CH}$ $\text{CH}=\text{CH}-\text{CH}$ $\text{CH}=\text{CH}-\text{CH}_3$ ,	$\text{C}_6\text{H}_5\text{CH}_3$	$\text{C}_6\text{H}_5\text{CH}_6$	$\text{C}_6\text{H}_6$
				600° $\text{CH}_2:\text{CH} \cdot \text{CH}_2$	650° $\text{CH}_2:\text{CH} \cdot \text{CH}_2$	650° $\text{C}_6\text{H}_6$

## ENCLOSURE (A)

Table V(A)  
SOME PHYSICAL PROPERTIES

I	II	III	IV	V	VI
Substance	Benzene	Toluene	Ethyl benzene	Isopropyl benzene	Tert. butylbenzene
	C <sub>6</sub> H <sub>6</sub>	C <sub>6</sub> H <sub>5</sub> .CH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub> .CH <sub>2</sub> CH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	C <sub>6</sub> H <sub>5</sub> .C(CH <sub>3</sub> ) <sub>3</sub>
M. W.	78	92	106	120	134
B. P. (°C)	80.2 80.6	109.8 109.9	134.5 135	150 ~ 152	165 ~ 166
d <sub>4</sub> <sup>25</sup>	0.8715	0.8611	0.8630	0.8596	0.8667
n <sub>D</sub> <sup>25</sup>	1.4960	1.4912	1.4913	1.4914	1.4962
Ab. sp. (I)	38450(3)	37305(5)	37460(5)	37580(8)	37650(7)
(V)	38612(8)	37425(5)	37490(7)	37620(9)	3770(5)
	39445(4)	37485(10)	37528(10)	38058(5)	37980(5)
	39543(10)	38020(7)	37558(6)	38103(7)	38180(10)
	40370(3)	38400(7)	37597(7)	38150(6)	38228(5)
	40460(7)	38422(9)	38423(4)	38540(10)	38608(7)
	41286(2)	38455(8)	38453(9)	38580(7)	38855(6)
	41378(7)	38668(8)	38485(9)	38812(6)	38930(5)
	41884(1)	38732(5)	38523(7)	39058(9)	39116(9)
	42300(5)	38765(5)	38763(6)	39490(4)	39546(3)
	43010(2)	38945(6)	38840(6)	39741(4)	
	43215(2)	39395(6)	38935(6)		
		39600(6)	38980(8)		
(III)	49100(7)	39367(4)	39012(7)		
	49980(10)	39850(3)	39045(7)		
	50900(10)	39880(3)	39414(6)		
	51750(8)	40248(2.5)	39445(3)	40682(2)	40082(4.5)
	52610(5)	41310(1.5)	41520(2)	41625(1)	40710(3)
					41643(1)

(S. KOMATSU &amp; S. KATO, unpublished)

## ENCLOSURE (4)

Table VI(A)  
THERMAL REACTION PRODUCTS

Temp (°C)	I	II	III	IV	V
600°C	--	--	C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , C <sub>6</sub> H <sub>5</sub> CH=CHC <sub>6</sub> H <sub>5</sub> , CH <sub>2</sub> =CH <sub>2</sub> , C <sub>6</sub> H <sub>6</sub>	C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , C <sub>6</sub> H <sub>5</sub> CH=CHC <sub>6</sub> H <sub>5</sub> , (CH <sub>3</sub> -CH <sub>3</sub> , CH <sub>4</sub> , C <sub>6</sub> H <sub>6</sub> , CH <sub>3</sub> CH=CH <sub>2</sub> CH <sub>2</sub> =CH, CH=CH <sub>2</sub>	C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , C <sub>6</sub> H <sub>6</sub> , CH <sub>3</sub> .CH <sub>3</sub> , (CH <sub>3</sub> ) <sub>2</sub> C=CH <sub>2</sub> CH <sub>2</sub> =CHCH=CH <sub>2</sub>
650°C		C <sub>6</sub> H <sub>5</sub> .CH=CHC <sub>6</sub> H <sub>5</sub> H <sub>2</sub>			

## REACTION PRODUCTS WITH OXYGEN

100°C	C <sub>6</sub> H <sub>5</sub> .CHOHCH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub> .CH(CH <sub>3</sub> )OH	--	--
150°C	--	--	C <sub>6</sub> H <sub>5</sub> (CH <sub>3</sub> ) <sub>2</sub> OH	C <sub>6</sub> H <sub>5</sub> C <sub>3</sub> H <sub>6</sub> CH <sub>2</sub> OH
200°C	C <sub>6</sub> H <sub>5</sub> .CHO	--	--	--
450°C	--	C <sub>6</sub> H <sub>5</sub> .CH=CH <sub>2</sub>	--	--
500°C	--	--	C <sub>6</sub> H <sub>5</sub> OH, C <sub>6</sub> H <sub>5</sub> .C(CH <sub>3</sub> )=CH <sub>2</sub>	C <sub>6</sub> H <sub>5</sub> OH (CH <sub>3</sub> COCH <sub>3</sub> )
550°C	C <sub>6</sub> H <sub>5</sub> OH	C <sub>6</sub> H <sub>5</sub> CHO, HCHO	--	C <sub>6</sub> H <sub>5</sub> (CH <sub>3</sub> ).CH <sub>2</sub> HCHO, C <sub>6</sub> H <sub>5</sub> COCH <sub>3</sub>
600°C ~ 650°C	--	C <sub>6</sub> H <sub>5</sub> OH	C <sub>6</sub> H <sub>5</sub> COCH <sub>3</sub> , HCHO, C <sub>6</sub> H <sub>5</sub> OH, CO	C <sub>6</sub> H <sub>5</sub> CHO, HCHO, CO

KOMATSU (pure hydrocarbon part I)

## ENCLOSURE (A)

Table VII(A)  
EXCITATION ENERGIES OF COMPOUNDS  
CONTAINING THE BENZENE NUCLEUS

Substance	$\nu_0$ (cm <sup>-1</sup> )	$\epsilon_1$	$\epsilon_2$	$\epsilon_3$	$\epsilon_4$
Benzene	38624	922	922	465	
Toluene	37485	937	960	535	455
Ethyl benzene	37528	925	957	522	412
Isopropyl benzene	37620	920	960	483	310
Ter. butyl benzene	37650	diffuse	977	530	330

Table VIII(A)  
X-RAY COMPARISON OF ETHYLENIC AND  
CARBONYL LINKAGES

Physical properties	Links	
	C=C	C=O
Parachor	23.2	23.0
N <sub>D</sub>	1.7	2.2
Raman effect	1630 Å	1722 Å
Ultra-violet absorption band	2700 Å	2700-800 Å

X-38(N)-9

## ENCLOSURE (A)

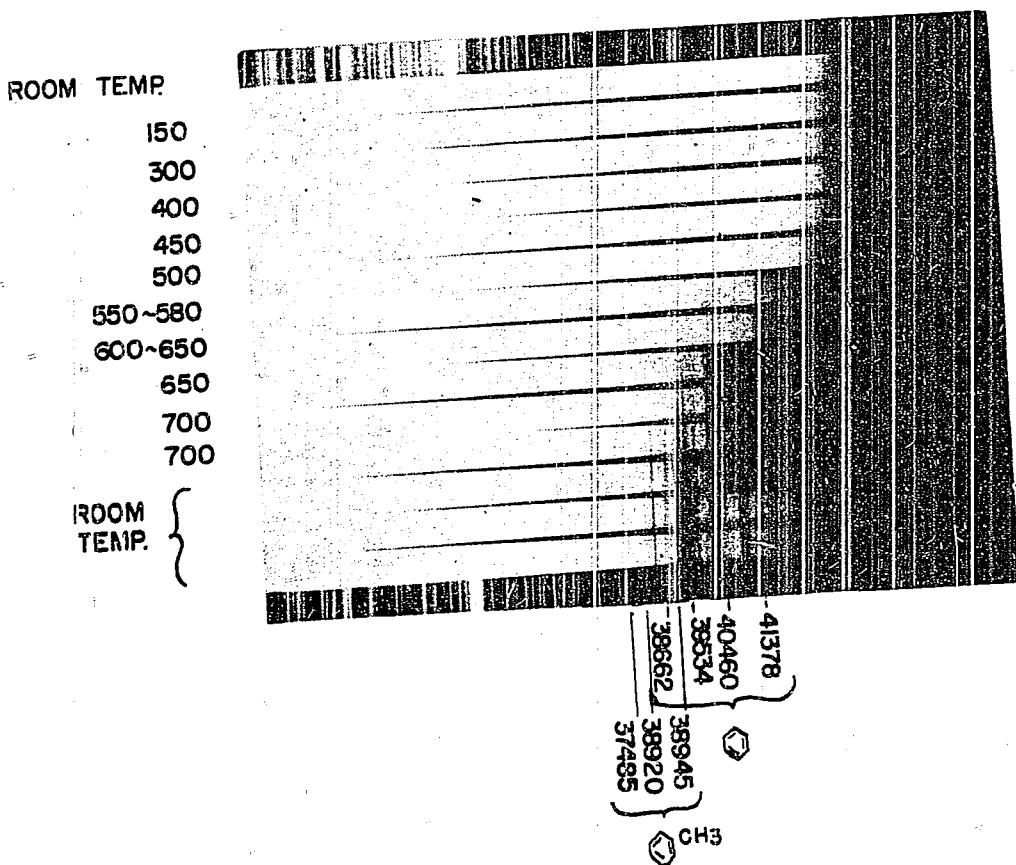


Figure 1(A)  
ABSORPTION SPECTRA OF O-XYLENE AND CYCLOPENTANE  
AND THEIR THERMAL DECOMPOSITION PRODUCTS

1 m.mol o-xylene was heated gradually in a 170cc quartz tube, and absorption spectra were taken at 150°, 300°, 400°, 450°, 500°, 550-580°, 600-650° and 700° respectively, the results shown in Figure 1(A) indicate that benzene and toluene were formed at about 600°.

## ENCLOSURE (A)

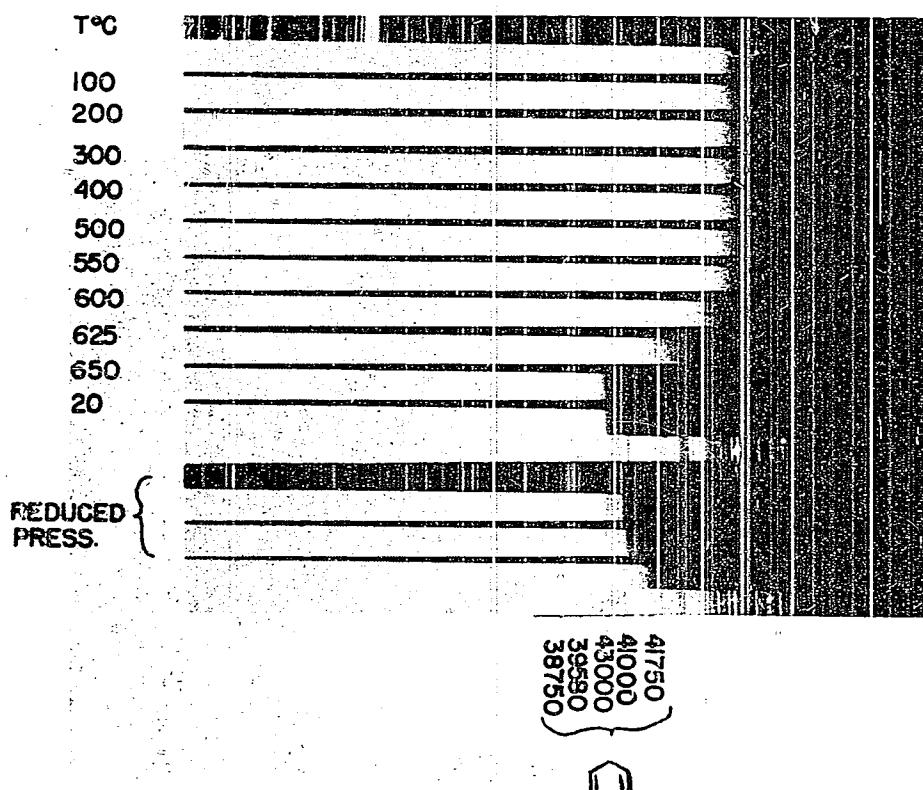


Figure 1(A) cont.

30 mg of cyclopentane were heated to 650°, the formation of ethylene and propylene at 500-550°C and of cyclopentadiene at 625°C was confirmed from the absorption spectra shown in this plate.

## ENCLOSURE (A)

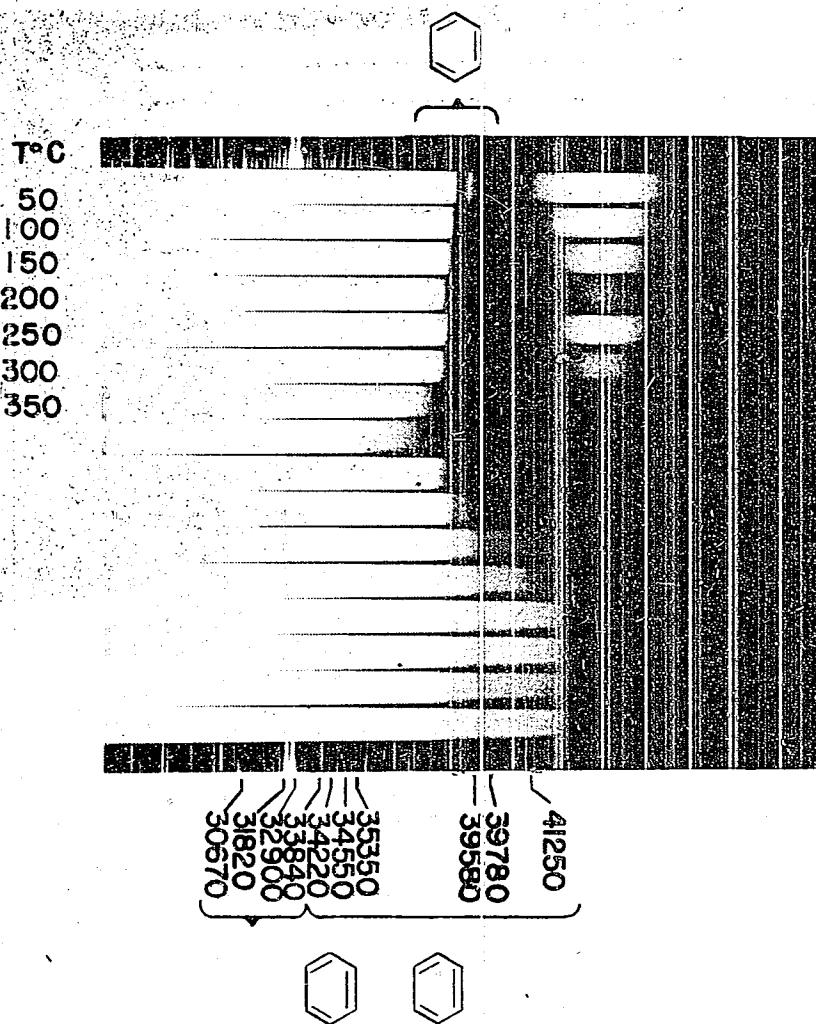


Figure 2(A)  
ABSORPTION SPECTRA OF THE OXIDATION PRODUCTS OF  
O-XYLENE AND CYCLOPENTANE

0.1 m. mol o-xylene was heated with 0.5 m. mol oxygen o-Tolyl carbinol at 150°C, formaline, o-toluic aldehyde and o-oxybenzaldehyde at 300°C were formed. Figure 2(A).

## ENCLOSURE (A)

T C  
20  
200  
300  
350  
400  
20

38750  
39580  
40300  
40750  
41750  
42500  
43250



Figure 2(A) cont.

20 mg of cyclopentane was heated to 400°C with 10cc O<sub>2</sub>, and the formation of cyclopentadiene was confirmed by the absorption spectra. Figure 2(A) cont.

## ENCLOSURE (A)

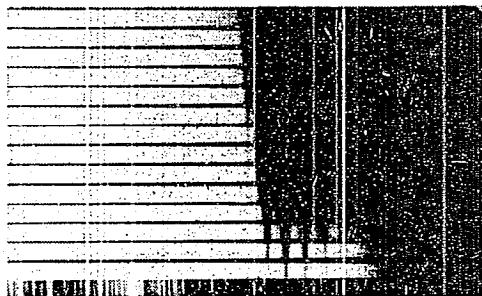
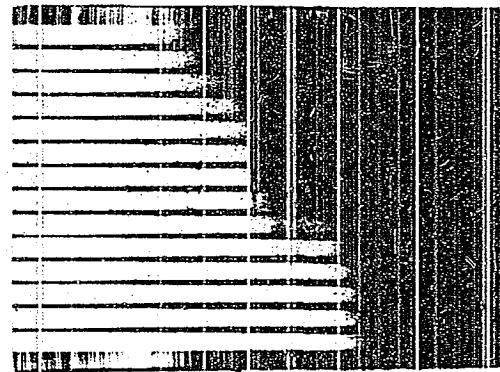
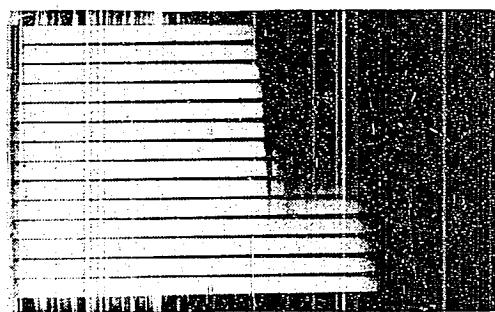
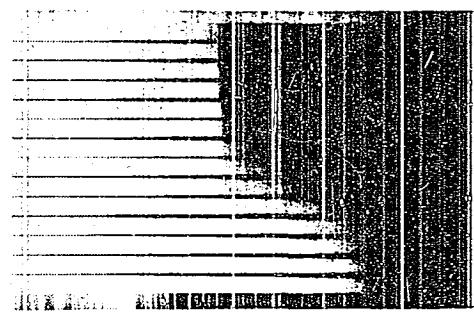
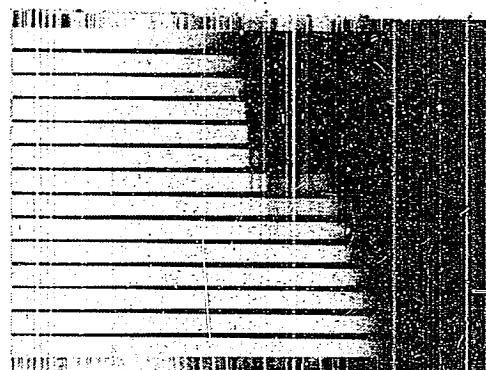
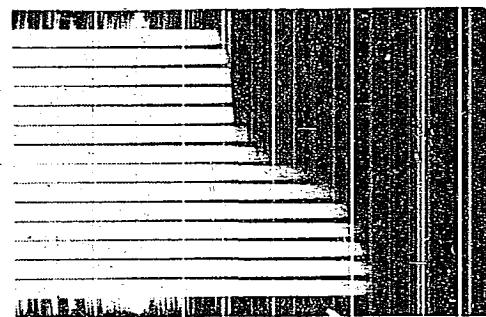
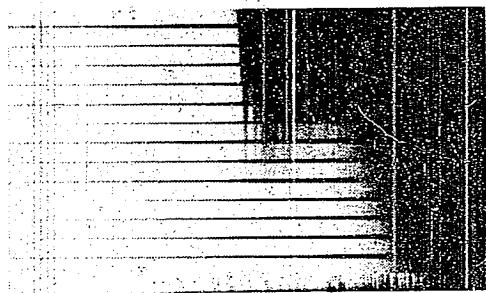
Benzene 1/100<sup>m</sup>T-Butylbenzene 1/1000<sup>m</sup>Toluene 1/500<sup>m</sup>O-Xylene 1/1000<sup>m</sup>

Figure 3(A)  
ABSORPTION SPECTRA OF BENZENE AND ITS DERIVATIVES

**ENCLOSURE (A)**



*Cumene 1/1000<sup>m</sup>*

*P-Xylene 1/1000<sup>m</sup>*

*Figure 3(A)cont:*

ENCLOSURE (A)

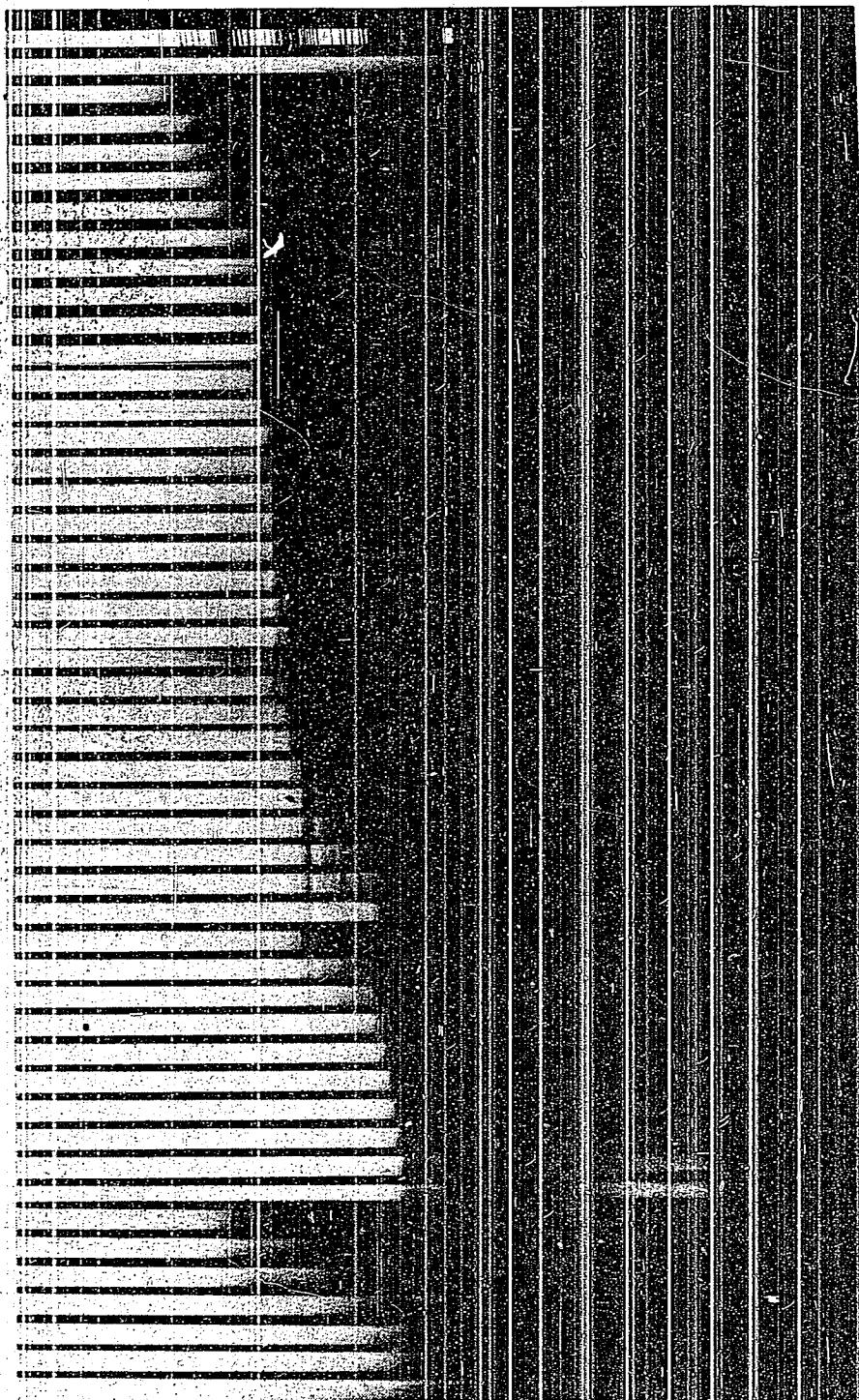
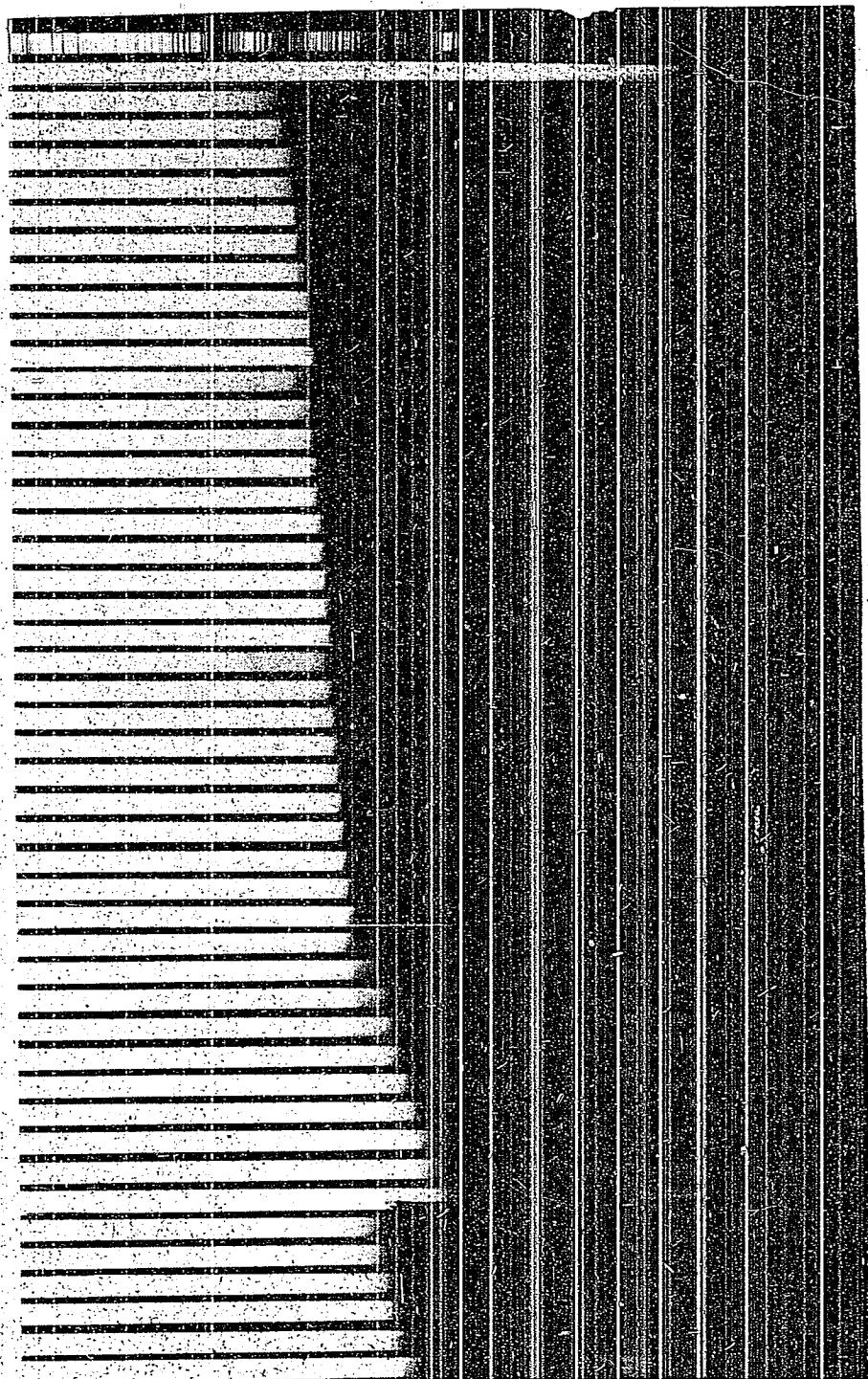


Figure 4(A)  
ABSORPTION SPECTRA OF NAPHTHALENE  
IN 1/1000 MOLAR ALCOHOL SOLUTION

**ENCLOSURE (A)**



**Figure 5(A)**  
**ABSORPTION SPECTRA OF DIHYDRONAPHTHALENE**  
**IN 1/1000 MOLAR ALCOHOL SOLUTION**

## ENCLOSURE (A)

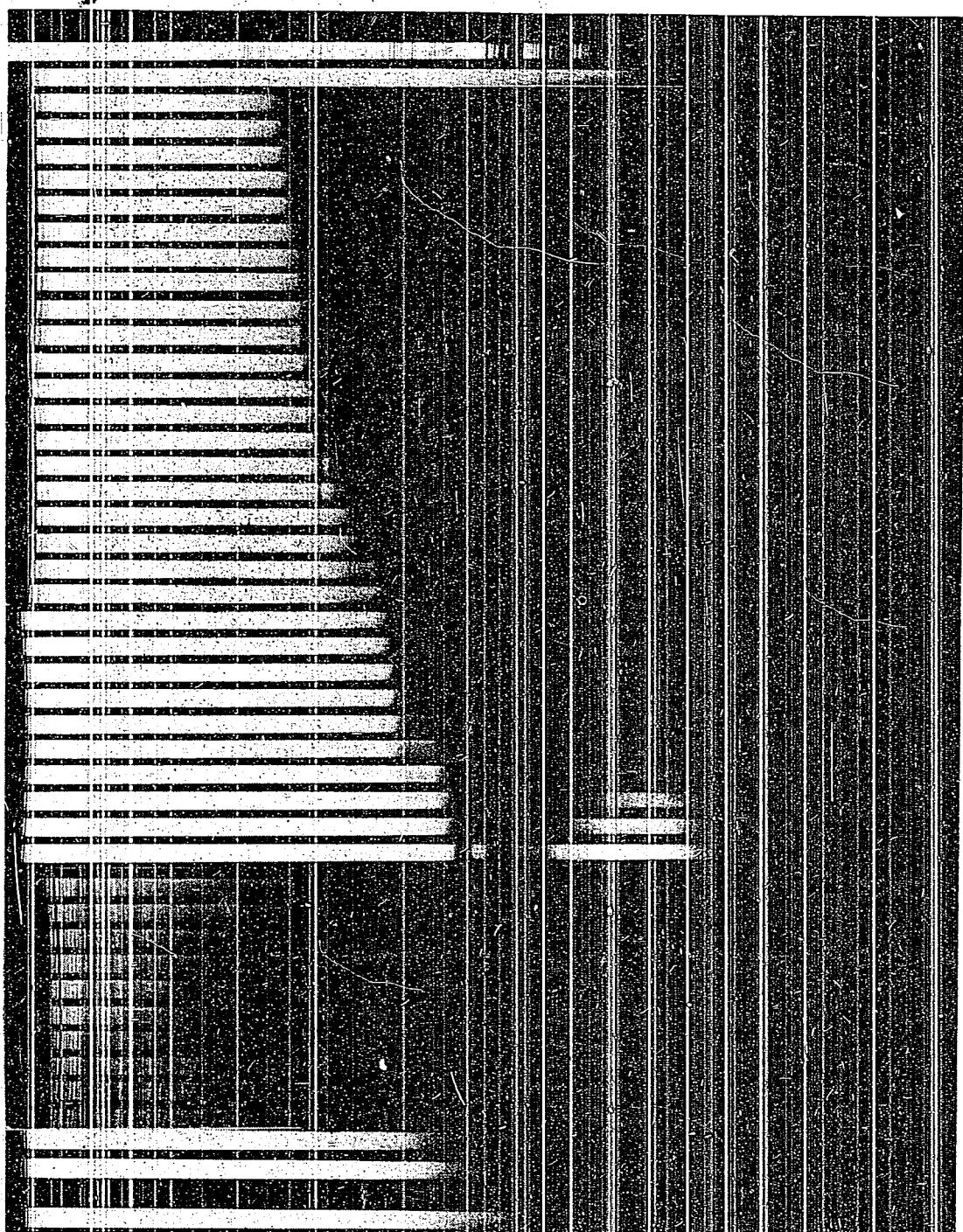


Figure 6(A)  
ABSORPTION SPECTRA OF TETRAHYDRONAPHTHALENE  
IN 1/1000 MOLAR ALCOHOL SOLUTION

## ENCLOSURE (A)

Pure anthracene (M.P. 216-216.5°C) was reduced at 175°, 200°, 225°, 250° and 300°, in the presence of 1% nickel oxide under 100 atmosphere's pressure of H<sub>2</sub>. The product was studied by the absorption spectrum of its cyclohexane (<sup>25</sup>n<sub>D</sub> 1.42330) solution.

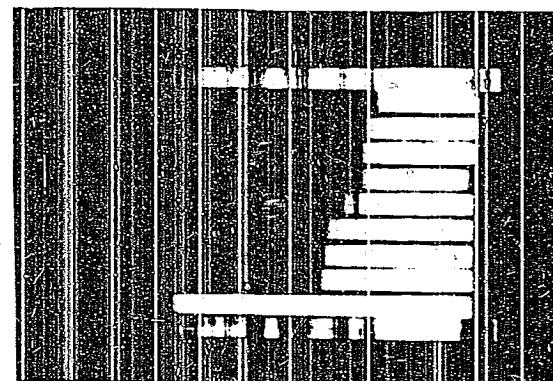
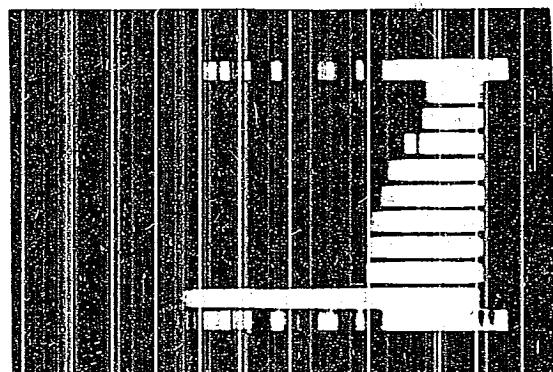
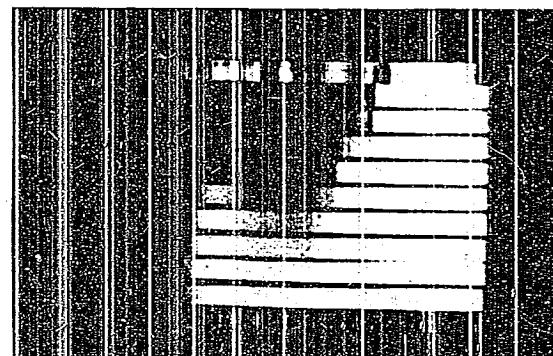


Figure 7(A)  
ANTHRACENE REDUCED AT 175°C

The reaction product at 175°C consisted of 90% tetrahydroanthracene and 10% octahydroanthracene.



## ENCLOSURE (A)

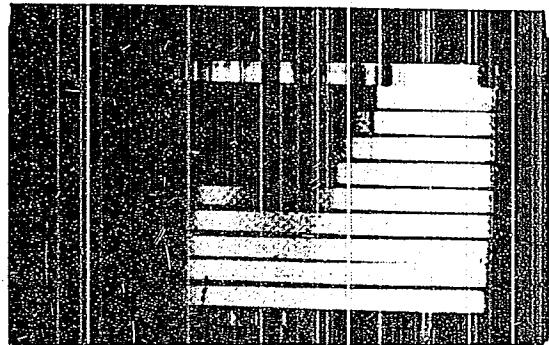
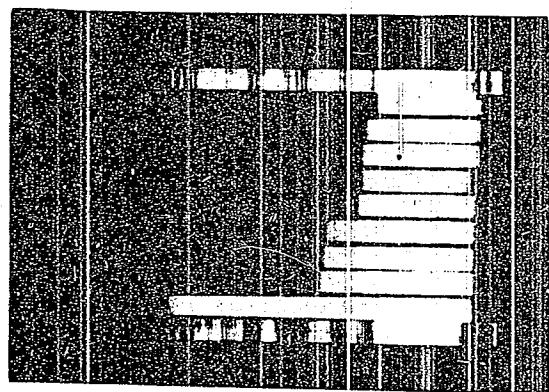
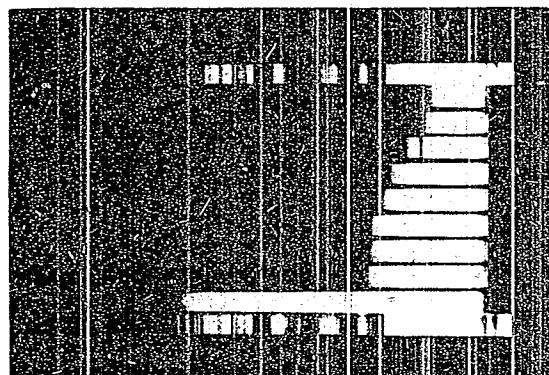


Figure 8(A)  
ANTHRACENE REDUCED AT 200°C

The reaction product at 200°C consisted of 100% tetrahydroanthracene, and trace of dihydroanthracene.

## ENCLOSURE (A)

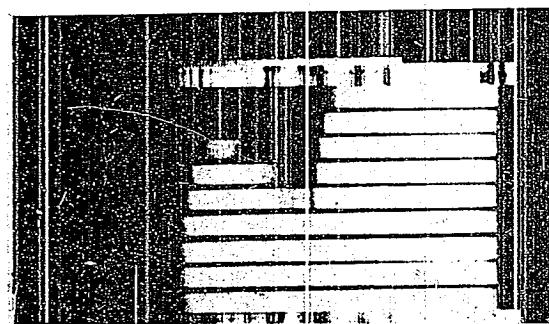
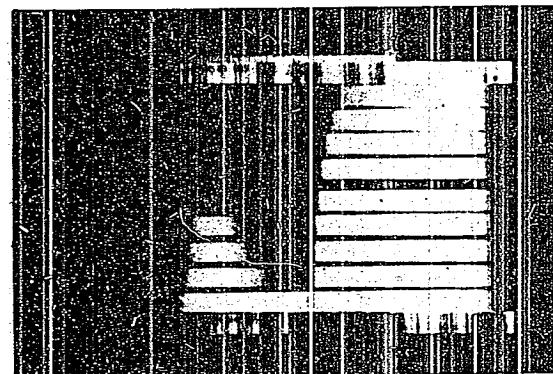
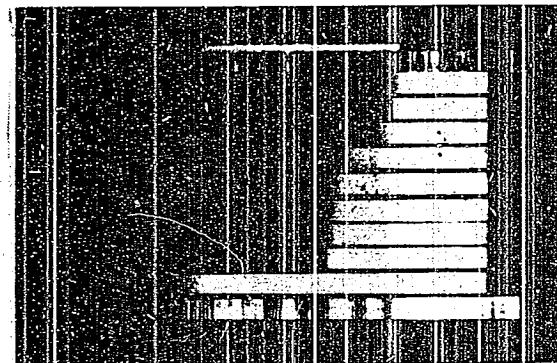


Figure 9(A)  
ANTHRACENE REDUCED AT 225°C

The reaction product at 225°C consisted of mostly octahydroanthracene and a small amount of tetra and perhydro compounds.

## ENCLOSURE (A)

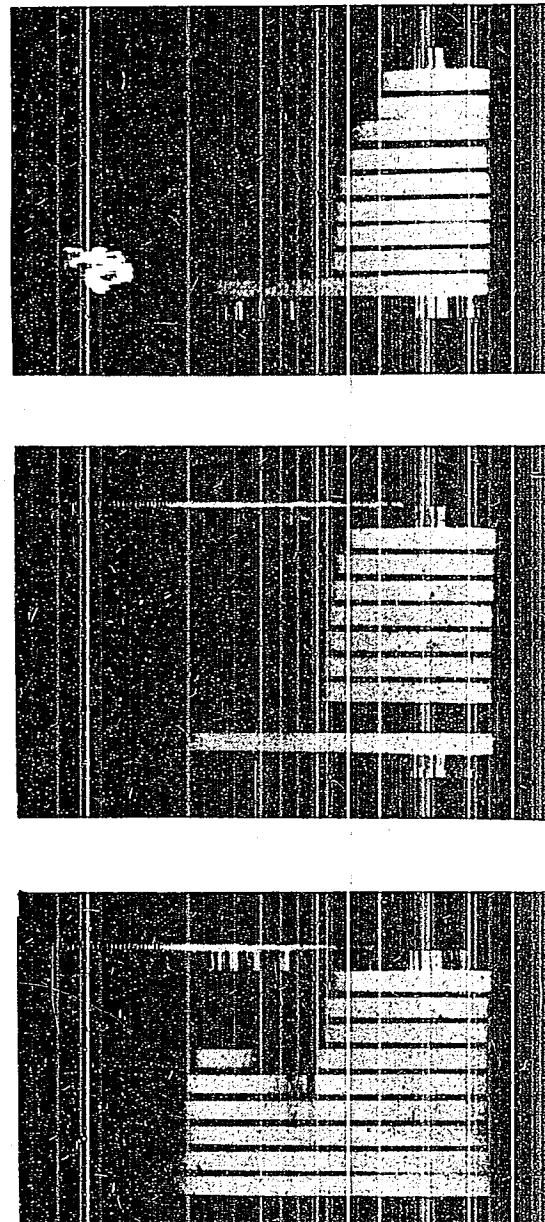


Figure 10(A)  
ANTHRACENE REDUCED AT 250°C

The reaction product at 250°C consisted of octahydro, tetrahydro and perhydro-anthracenes.

## ENCLOSURE (A)

The reaction product at 300°C, consisted of the solid (M.P. 71-72°C) (Plate V) and the liquid ( $d_4^{25}$  0.9710,  $n_D^{25}$  1.5280). (Plate VI).

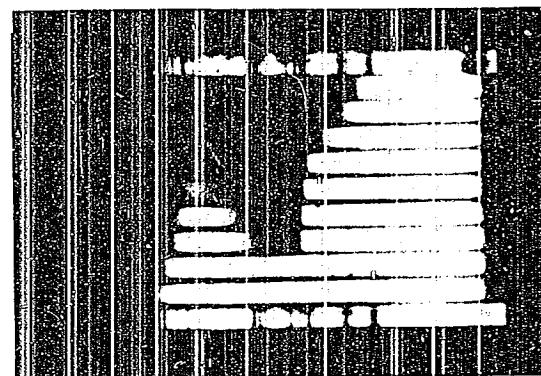
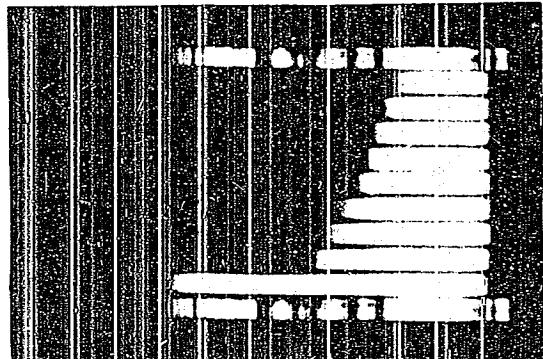
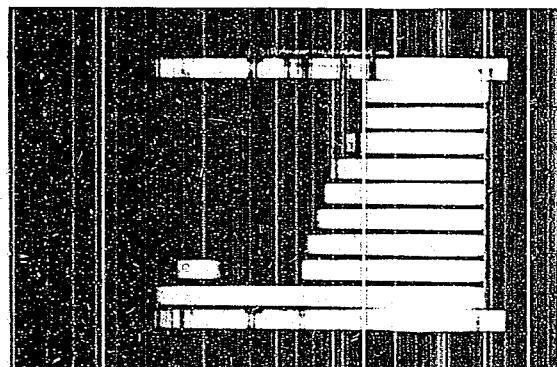


Figure 11(A)  
ANTHRACENE REDUCED AT 300°C SOLID PRODUCT

The solid product consisted of mostly octahydroanthracene and with 3% tetrahydro compounds.



## ENCLOSURE (A)



## ENCLOSURE (A)

## Part. II

## THE IDENTIFICATION OF HYDROCARBONS BY THE USE OF RAMAN SPECTRA

The study of the Raman spectra of organic compounds, as pointed out by Dadieu & Kohlrausch (Ber., 63 (1930) 251. 1675), enables one to identify the substances in a mixture or in the pure state, by means of particular lines in the spectra of organic compounds with particular atomic groups. Various investigators in Japan have employed the Raman spectra for the identification of various hydrocarbons in gasolines and also to detect isomeric substances which were formed in the course of the chemical reaction of alcohols and hydrocarbons (as in the dehydration of n-butanol by the catalytic action with alumina).

The values of the force constant, f, calculated from the data of the Raman spectra for single, double and triple links are roughly proportional to the heat of the rupture of the links. Thus the Raman spectra have enabled the author to observe the behavior of organic compounds under the influence of heat. n-butanol from the market, B.P. 116-7°C,  $d_4^{20}$  0.8098,  $n_D^{20}$  1.3980 was converted, by the dehydration with alumina at 400°C, into n-butene, (of purity 94.7%) which passed over the phosphoric acid catalyst heated at 150°C, with space velocity 300 kg/l-hr and the product shows the physical constants  $d_4^{20}$  0.7116,  $n_D^{20}$  1.4013, M.W. 115, O.N. 90.8 & the Raman spectra. (Table IX(A)).

These Raman spectra of the reaction product were compared with those of 2, 3, 4 trimethyl pentane (T. TORIYAMA, J. Chem. Soc. Japan 64 (1943) 1423), 2, 2, 3 trimethyl pentane and also 2,2,4 trimethyl pentane (S. MIZUSHIMA, S. MORINO and OKAZAKI'S results). And it was assumed to be composed of:

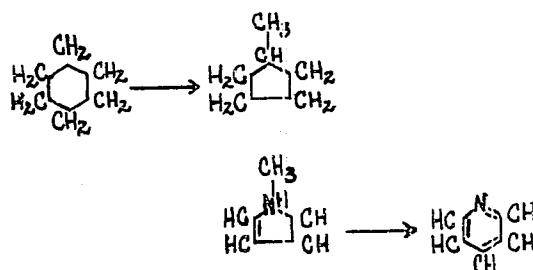
35 - 40% 2,3,4 trimethyl pentane  
35 - 40% 2,2,3 trimethyl pentane  
and 20 - 25% 2,2,4 trimethyl pentane

When n-butanol was dehydrated by TAKEDA with alumina at 350°C the product, after water cooling passed the receiver cooled with solid CO<sub>2</sub>. The products distilled and their Raman spectra are shown in Table X(A).

These results were compared with those observed by Bourguet and Fiaux (Bull. Soc. Chem. 2 (1935) 1958) of butene-1 and also of butene-2 by Gerschinowitz & Wilson (J. Chem. Phy., 6 (1930) 247). This comparison indicates that the product consists mostly of butene-1. (S. MIZUSHIMA, Y. MORINO, R. FUJISHIRO, K. OKAZAKI and Y. KAKIUCHI (1943), unpublished).

The direct-run gasoline from Sanga Sanga oil (O.N. 91.2 with 0.1% Pb.) was fractionated by SONODA, into 23 fractions (Table XI(A)). (Table XI(A)).

According to the author's opinion, the occurrence of cyclopentane derivatives, indene, 5-membered carbon ring, pyridine, quinoline, 6 membered carbon and nitrogen ring, in petroleum and coal tars, is due to the isomerization of cyclohexane derivatives and hydronaphthalenes, 6 carbon membered ring, and pyrrole derivatives, 5 carbon and nitrogen ring, under the influence of high temperature and high pressure.



## ENCLOSURE (A)

Based on this hypothesis, M. HAGIWARA, one of the author's co-workers, studied this problem. He has succeeded in converting cyclohexane and cyclohexene into methyl cyclopentane, and dehydronaphthalene into methyl indene respectively by subjecting them to high temperature and pressure in an autoclave.

He also reported the Raman spectra of these compounds used as an evidence for this chemical change (Tables XIII(A), XIV(A)).

(Refer also T. HAYASHI: Sci. P. Inst. Phy. Chem. Res. 23 (1934) 274.)  
The Raman shifts of indene appears to be smaller than that of 1,2-dihydronaphthalene.

It was noteworthy that a new base has been isolated by T. EGUCHI from Fushun shale tar (Bull. Soc. Chem. Japan 2 (1927) 176; 3 (1928) 227), which, on analysis and examination of its physical (Bp. 199.8°,  $d_4^{25}$  1.029,  $n_D^{25}$  1.541.  $n_D^0$  1.536; M. R 36.34) and chemical properties was concluded to probably have the structure of a "cyclopentano-pyridine" and was called pyrindane. The molecular structure of this base was later confirmed by synthesis by American chemists.

## ENCLOSURE (A)

Table IX(A)  
RAMAN SPECTRA OF THE ISOMERIZED PRODUCT OF n-BUTENE  
( $\nu_0$  cm $^{-1}$ )

220 (o.d)	1075	(3)
300~330 (4)	1100	(0)
347 (1)	1119	(2)
393 (1)	1159	(4b)
418 (0)	1183	(3b)
442 (16)	1205	(1)
470 (5)	1212	(1)
526 (3b)	1245	(3)
570 (4)	1265	(0)
610 (0)	1295	(3)
669 (26)	1319	(4)
688 (1)	1350	(4)
714 (6)	1435	
752(10b)	1470	(10)
745 (4b)		
810 (4)		
824 (4)		
890 (6)		
700 (2)		
926 (6b)		
953 (6)		
976 (2)		
994 (6)		
1010 (2b)		
1029~1047 (2)		

In table, b = broad line, d = diffused line.

## ENCLOSURE (A)

Table X(A)  
 RAMAN SPECTRA OF THE DEHYDRATED PRODUCT OF n-BUTANOL  
 $(\nu \text{ cm}^{-1})$

214	(0)	1293	(6)
387	(1)	1375	(3)
438	(3)	1417	(5)
500	(3)	1456	(4)
585	(0)	1640	(10)
633	(3)	1658	(2)
741	(0b)	1678	(2)
791	(1)	2729	(3)
832	(2)	2854	(4)
850	(4)	2875	(3)
868	(2)	2908	(6b)
910	(3)	2937	(?)
988	(2)	2970	(5)
1017	(3)	3001	(7b)
1065	(3)	3079	(5)
1258	(4)		

## ENCLOSURE (A)

Table XI(A)  
RAMAN SPECTRA OF EACH FRACTION

	Fraction (°C)	Yield (wt %)	
1.	19~30	3.88	It was confirmed to include 2 methyl butane 2% (wt.)
2.	30~35	2.38	It was confirmed to include 2 methyl butane 2% (wt.)
3.	35~40	0.55	n-pentane 2% (wt.)
4.	40~45	0.16	Cyclopentane 2% (wt.)
5.	45~50	0.21	2,2.-dimethyl butane 1% (wt.)
6.	50~55	0.40	2,3.-dimethyl butane 1% (wt.)
7.	55~60	0.68	2.-methyl pentane 3% (wt.)
8.	60~65	2.77	3.-methyl pentane 1% (wt.)
9.	65~70	5.30	n-hexane 3% (wt.)
10.	70~75	4.80	methyl cyclopentane 2% (wt.)
11.	75~80	3.69	2,2.-dimethyl pentane 1% (wt.)
12.	80~85	2.22	benzene 7% (wt.)
13.	85~90	1.69	Cyclohexane 6% (wt.)
14.	90~95	5.27	2,4.-dimethyl pentane 2% (wt.)
15.	95~100	8.88	2,3.-dimethyl pentane 1% (wt.)
16.	100~105	8.94	2.-methyl hexane 1% (wt.)
17.	105~110	8.75	trans-1,2.-dimethyl cyclopentane 2% (wt.)
18.	110~115	5.13	n-heptane 2% (wt.)
19.	115~120	2.08	methyl cyclohexane 11% (wt.)
20.	120~125	3.41	toluene 14% (wt.)
21.	125~130	4.66	1,3.-dimethyl cyclohexane 1,4.-dimethyl cyclohexane 4% (wt.) 2% (wt.)
22.	130~135	3.97	n-octane 3% (wt.)
23.	135~140	5.38	ethyl benzene 2% (wt.) p-xylene 2% (wt.) m-xylene 6% (wt.) o-xylene 1% (wt.)

## ENCLOSURE (A)

Table XIII(A)  
RAMAN SPECTRA OF CYCLOHEXANE, CYCLOHEXENE  
AND METHYLCYCLOPENTANE

<u>Cyclohexane</u>	<u>Cyclohexene</u>	<u>Methylcyclopentane</u>
	176 (1)	
	273 (3b)	281 (1)
375 (1)	395 (5)	292 (5)
425 (2)	451 (2)	428 (2)
	494 (2)	530 (4)
	641 (1)	
	703 (2b)	
800 (8)	825 (8)	780 (3b)
	873 (2)	842 (5)
	905 (3)	886 (8)
	968 (3)	978 (4)
	1038 (2)	1017 (4)
1026 (5)	1066 (6)	1079 (4)
1155 (1)	1139 (10)	
1264 (6)	1220 (5)	1204 (2b)
	1247 ( $\frac{1}{2}$ )	1274 (2)
	1269 (3)	1310 (2b)
1344 (1)	1342 (2b)	1348 (1)
1437 (5)	1433 (8b)	
	1664 (6)	1452 (6b)
2659 (2)	2836 (6b)	2722 (4)
2691 (1)	2869 (3)	2865 (12b)
2885 (2)	2912 (6)	2921 (10b)
2938 (10)	2931 (6)	2956 (15b)

## ENCLOSURE (A)

Table XIII(A)  
RAMAN SPECTRA OF DIHYDRONAPHTHALENE AND INDENE

1,2.-dihydronaphthalene(  $\nu$  cm<sup>-1</sup> )

3026	3038
2760	2765
1618	1589
1554	1534
1472	1443
1375	1379
1332	1343
1280	1276
1202	1190
1143	1140
1091	1099
1020	1049
933	1003
865	924
726	821
	710

indene

## ENCLOSURE (A)

Table XIV(A)  
RAMAN SPECTRA OF EACH FRACTION OF SANGA SANGA GASOLINE (NO. 1)

	30°C~35°C	35°C~40°C	45°C~50°C	50°C~55°C	55°C~60°C	60°C~65°C
	219 (00)			216 (00)	222 (0)	225 (00)
275 (00)	275 (06)	271 (1)	275 (006)	275 (006)	260 (1)	
336 (1)	336 (2)	337 (0)	332 (16)	326 (26)	324 (26)	
369 (0)	365 (1)		363 (0)		366 (1)	
401 (5)	401 (7)	402 (5)	401 (3)	401 (1)	404 (1)	
463 (36)	464 (36)	464 (16)	445 (2)	445 (4)	445 (4)	
			467 (00)			
			478 (00)	478 (0)	478 (0)	
			503 (00)	504 (0)	506 (00)	
			530 (00)		528 (00)	
			548 (00)	548 (00)		
	662 (00)			607 (0)	607 (2)	
		692 (00)			674 (00)	
	709 (2)					
	732 (00)	712 (4)	712 (4)	711 (3)	712 (1)	
		732 (1)	730 (2)	730 (3)	728 (2)	
761 (2)	762 (2)			749 (1)	749 (1)	
766 (8)	760 (7)	766 (4)	766 (2)	767 (1)		
796 (6)	795 (4)	779 (00)	797 (1)	799 (00)		
		794 (1)				
843 (6)	841 (6)	817 (1)	814 (3)	815 (5)	815 (5)	
		843 (4)	842 (3)	840 (1)		
868 (5)	868 (5)	869 (2)	871 (2)	871 (0)	847 (1)	
		888 (6)	889 (7)		871 (1)	
910 (3)	909 (36)	908 (1)	890 (76)	891 (6)	891 (46)	
	926 (00)		928 (00)	928 (0)		
954 (4)	954 (3)	954 (1)	957 (2)	940 (0)	941 (1)	
987 (1)	988 (2)			957 (3)	957 (3)	
		993 (1)	994 (1)	993 (5)	991 (10)	
			1013 (1)	1015 (00)	1017 (1)	
1028 (1)	1028 (5)	1028 (3)				
1039 (4)	1039 (5)	1037 (3)	1041 (3)	1039 (4)	1038 (5)	
1072 (36)	1073 (5)	1073 (2)	1073 (36)	1094 (26)	1076 (36)	
1146 (5)	1145 (5)	1146 (2)	1147 (3)	1148 (4)	1147 (4)	
1175 (16)	1179 (2)	1220 (1)		1175 (3)		
		1254 (1)				
	1282 (16)	1220 (1)	1221 (06)	1221 (006)	1180 (46)	
		1254 (1)	1255 (08)	1253 (008)		
1267 (16)	1265 (1)				1270 (0)	
1304 (56)	1303 (56)	1302 (4)	1302 (36)	1302 (46)	1301 (3)	
1334 (1)	1335 (1)	1334 (1)	1338 (16)	1339 (36)	1338 (2)	
1425	1426	1426	1438 (66)	1442 (66)	1384 (0)	
(7)	(6)	(6)	1461 (66)	1462 (66)	1431 (6)	
1469	1470	1469			1469	
					1587 (1)	
					1607 (1)	
2365 (06)	2623 (00)		2629 (00)	2629 (0)		
	2669 (28)		2671 (00)			
2720 (2)	2720 (3)		2719 (2)	2717 (3)	2712 (3)	
2737 (2)	2737 (3)	2729 (26)	2738 (2)	2737 (2)	2740 (3)	
2839 -(8)	2840 (9)	2843 (5)	2842 (6)	2838 (6)	2754 (10)	
2875 (108)	2874 (10)	2872 (108)	2871 (10)	2871 (0)	2837 (8)	
2906	2907 (8)	2906 (7)	2908 (7)	2902 (7)	2869 (108)	
2939 (7)	2937 (9)	2937 (7)	2928 (7)	2931 (7)	(7)	
2970 (86)	2971 (9)	2964 (86)	2968 (96)	2968 (86)	2966 (98)	
			3066 (2)	3045 (1)	3045 (5)	
				3066 (4)	3067 (8)	
					3167 (0)	
					3188 (1)	

## ENCLOSURE (A)

Table XV(A)  
RAMAN SPECTRA OF EACH FRACTION OF SANGA SANGA GASOLINE (NO. 2)

	6500 ~ 7000	7000 ~ 7500	7500 ~ 8000	8000 ~ 8500	8500 ~ 9000	9000 ~ 9500
225 {00}	215 (00)	210 (00)	215 (1)	215 (1)	217 (1)	
230 {00}	235 (0)	231 {0}	231 {0}	233 {0}	231 {0}	
304 ] (0)	316 (06)	308 {0}	307 (0)	305 {1}	305 {1}	
334 ] (0)		350 (00)	347 (00)	353 (00)	347 (00)	
370 (1)	368 (0)	381 (08)	399 (10)	383 (0)	386 (00)	
385 (00)	404 (00)			403 (1)		
405 {0}	422 (0)	427 (1)	426 (1)	432 (1)	427 (00)	
427 {00}				443 (00)	445 (1)	
444 (8)	445 (0)			495 (00)	495 (0)	
				521 (0)	519 [1]	
530 (0)	527 (0)	531 (0)	542 (00)	543 (0)	545 (1)	
607 (3)	605 (3)	607 (3)	608 (2)	607 (1)	607 (1)	
	691 (00)	693 (0)	689 (0)	693 (0)	697 (00)	
726 {00}					729 {00}	
747 {00}	742 (0)	771 (00)	771 (0)	769 (2)	769 (4)	
779 (00)					784 (3)	
800 {2}	800 (4)	807 (7)	808 (7)	802 (6)	801 (6)	
815 {26}	814 (08)	825 (00)	822 (00)	823 (0)	826 (00)	
849 {1}	846 (1)	848 {2}	848 (0)	846 (0)	844 (0)	
870 {0}				869 (00)	880 (00)	
891 (38)	889 (26)	889 (2)	895 (0)	895 (1)	896 (1)	
957 (1)	957 (0)	958 (00)	958 (0)	956 (0)	919 (00)	
991 (12)	991 (12)	991 (13)	992 (10)	992 (9)	992 (1)	
994 {1}	994 {3}	995 {3}	986 (1)		992 {5}	
1028 {08}	1028 (36)	1028 (56)	1004 (0)	1004 (3)	1003 (5)	
1037 {3}			1028 (56)	1029 (56)	1031 (6)	
1064 {0}	1060 {00}	1079 {16}			1042 (00)	
1077 (2)	1081 {28}	1113 {00}	1080 (1)	1080 (16)	1063 (0)	
1141 (26)	1138 (1)	1142 (0)	1148 (11)	1141 (1)	1144 (16)	
1183 (5)	1159 (1)	1160 (2)	1160 (2)	1183 (2)	1182 (0)	
	1182 (4)	1183 (06)	1185 (3)		1191 (0)	
				1212 (1)	1210 (2)	
	1221 (006)				1250 (0)	
1267 (1)	1285 (5)	1266 (5)	1266 (4)	1265 (4)	1247 (1)	
1301 {2}	1301 (2)	1303 (16)	1305 (16)	1302 (1)	1266 (3)	
1330 ] (1)	1342 (2)	1347 (10)	1343 (2)	1348 (2)	1341 (26)	
1350 ] (1)			1379 (0)	1379 (0)	1380 (1)	
1431 ] (5)	1438 ] (4)	1443 (15)	1442 (6)	1443 (66)	1443 (56)	
1462 {2}	1468 {36}	1459 (46)	1459 (46)	1462 (46)	1463 (56)	
1588 {2}	1587 {3}	1589 {3}	1589 {2}	1589 {1}	1588 (0)	
1608 {1}	1607 {2}	1608 {2}	1608 {2}	1607 {1}	1607 (1)	
	2633 {00}					
2661 {1}	2621 {0}	2627 {00}	2627 {1}	2630 {0}	2630 (00)	
	2661 {0}	2665 {2}	2665 {2}	2666 {2}	2665 {1}	
					2678 (00)	
2728 {26}	2699 {0}	2698 {0}	2698 {1}	2700 {1}		
2841 {9}	2728 {1}	2729 {1}	2729 {2}	2724 {2}	2726 (2)	
2871 {10}	2852 {0}	2851 {00}	2853 (10)	2850 {96}	2853 (10)	
	2868 {10}	2867 {8}	2867 {5}	2867 {5}	2871 {97}	
	2910 {6}	2917 {5}				
				2932 (98)	2922 {96}	
					2938 (96)	
2941 {7}	2996 {6}	2941 {66}	2963 {7}	2963 {96}	2964 {9}	
2966 {9}	2961 {10} {6}	2963 {66}				
3045 {5}	3044 {8}	3047 {66}	3045 {5}	3042 {36}	3047 {3}	
3065 {9}	3064 {10}	3065 {10}	3065 {8}	3064 {5}	3064 {4}	
3171 {0}	3171 {0}	3172 {1}				
3188 {1}	3188 {8}	3187 {3}				

## ENCLOSURE (A)

Table XVI(A)  
RAMAN SPECTRA OF EACH FRACTION OF SANGA SANGA GASOLINE (NO. 3)

95~100°C	100~105°C	105~110°C	110~115°C	115~120°C	120~125°C
216 (3)	215 (3)	214 (36)	218 (36)	217 (26)	154 (0)
261 (1)	260 (0)	216 (0)	258 (00)	257 (00)	214 (08)
281 (00)			278 (00)	278 (00)	224 (1)
308 (2)	311 (0)	309 (0)	309 (00)	312 (00)	257 (00)
348 (0)	346 (0)	345 (1)	345 (0)	340 (00)	279 (1)
			371 (00)	373 (00)	310 (00)
385 (00)					374 (00)
405 (3)	405 (1)	403 (1)	407 (00)	409 (0)	410 (06)
			418 (00)	420 (1)	418 (4)
445 (2)	445 (1)	446 (1)			
464 (0)		462 (1)		457 (06)	453 (16)
496 (0)	494 (00)	495 (00)	495 (00)	495 (0)	474 (00)
520 (3)	520 (2)	520 (4)	521 (4)	520 (2)	496 (3)
					518 (1)
544 (2)	544 (1)	545 (1)	545 (0)	544 (1)	535 (2)
622 (1)	624 (1)	622 (26)	623 (3)	621 (16)	543 (4)
			701 (00)	702 (1)	703 (1)
728 (0)	731 (0)	728 (1)	728 (1)	725 (1)	725 (4)
752 (0)				748 (1)	748 (3)
			762 (1)	760 (2)	759 (3)
768 (5)	767 (4)	767 (2)	768 (1)	769 (2)	769 (4)
784 (5)	785 (5)	785 (6)	785 (8)	784 (5)	784 (3)
800 (1)					
	809 (00)	809 (1)	811 (1)	808 (00)	
844 (3)	842 (2)	843 (2)	843 (1)	846 (00)	828 (0)
					849 (00)
				875 (00)	857 (00)
				895 (00)	876 (00)
895 (16)	896 (00)	896 (1)	895 (1)	895 (00)	894 (0)
				934 (00)	
957 (1)	958 (00)	958 (00)		951 (00)	956 (06)
974 (2)	975 (1)	974 (2)	975 (2)	975 (0)	980 (00)
981 (1)	992 (00)	991 (00)	992 (00)		
1003 (8)	1003 (10)	1002 (10)	1003 (10)	1002 (10)	1002 (7)
1030 (8)	1031 (5)	1029 (6)	1029 (?)	1029 (4)	1028 (3)
1058 (1)	1058 (0)	1058 (0)	1058 (2)	1059 (2)	1057 (5)
				1075 (06)	1074 (16)
1081 (26)	1082 (06)	1086 (06)	1083 (06)		
1136 (16)				1138 (06)	1139 (16)
1157 (16)				1154 (1)	
1160 (2)	1164 (16)		1154 (3)		1167 (2)
1179 (0)	1179 (0)	1180 (1)	1178 (2)	1179 (1)	
1192 (2)					
1211 (3)	1203 (3)	1208 (5)	1208 (6)	1208 (3)	1207 (1)
				1219 (1)	1215 (1)
1248 (2)	1245 (1)	1246 (2)		1245 (2)	
1265 (2)	1265 (1)	1264 (1)			1245 (3)
1303 (2)	1303 (16)	1304 (16)	1265 (00)	1264 (1)	1264 (2)
1344 (2)	1346 (1)	1347 (16)	1303 (16)	1302 (26)	1302 (36)
1363 (1)			1342 (06)	1345 (26)	1344 (36)
1375 (2)	1378 (1)	1378 (3)	1378 (4)	1378 (2)	1378 (3)
1403 (0)		1402 (1)	1399 (1)		
1432 (5)	1441 (36)	1440 (36)	1440 (26)	1439 (46)	1426 (6)
	1460 (36)	1460 (36)	1459 (36)	1459 (56)	1455 (14)
1467 (1)					1461 (7)
1586 (1)	1585 (1)	1587 (2)	1585 (2)	1587 (1)	
1607 (2)	1607 (3)	1608 (3)	1605 (3)	1604 (2)	1606 (1)
2629 (0)					
2662 (1)	2662 (0)	2661 (0)	2661 (1)	2667 (0)	2667 (1)
2725 (16)	2726 (06)	2722 (0)	2723 (1)	2727 (06)	2727 (16)
		2740 (0)	2746 (1)		
		2838	2840	2836	2840
		(8)	(4)	(5)	(10)
2871(106)	2874 (8)	2874 (8)	2871 (5)	2870 (8)	2879 (6)
(5)	2911 (8)	2909 (8)			
		(8)	(4)	(7)	(9)
2931(106)			2921 (5)	2923 (7)	2929 (9)
					(6)
2961 (96)	2962 (6)	2961 (3)	2958 (4)	2957 (7)	2961 (8)
3043 (36)	3042 (36)	3042 (26)	3039 (26)	3040 (26)	
3081 (56)	3062 (56)	3062 (46)	3057 (46)	3060 (4)	3056 (36)

## ENCLOSURE (A)

Table XVII(A)  
RAMAN SPECTRA OF EACH FRACTION OF SANGA SANGA GASOLINE (NO. 4)

125°C ~ 130°C	130°C ~ 135°C	135°C ~ 140°C
151 (08)	152 (2)	151 (00)
200 (0)	201 (2)	199 (2)
225 (2)	226 (4)	228 (36)
256 (00)	258 (00)	
279 (2)	276 (3)	278 (36)
310 (0)	309 (3)	309 (2)
	362 (0)	358 (00)
375 (0)		398 (00)
407 (00)	402 (00)	
418 (2)	423 (00)	
	443 (00)	
454 (1)	455 (4)	455 (3)
	482 (00)	491 (00)
496 (1)	497 (1)	
512 (1)	516 (4)	515 (3)
534 (0)	536 (4)	535 (5)
543 (1)	543 (1)	
	556 (0)	557 (0)
	581 (0)	530 (1)
623 (00)	622 (1)	621 (0)
845 (0)	846 (2)	845 (2)
708 (0)	708 (1)	704 (0)
723 (6)	725 (8)	724 (10)
	735 (1)	735 (2)
748 (3)	748 (28)	
761 (2)		
770 (4)	769 (3)	770 (3)
	795 (0)	
	809 (1)	812 (2)
828 (4)	828 (5)	828 (4)
846 (00)	842 (1)	
857 (0)	856 (00)	860 (00)
878 (00)	878 (00)	877 (00)
895 (0)	895 (00)	894 (00)
	939 (00)	940 (00)
956 (008)	954 (00)	
985 (00)		
1001 (8)	1000 (10)	1000 (10)
1031 (3)	1030 (50)	1031 (3)
1059 (5)	1053 (16)	1051 (2)
		1062 (00)
1076 (1)	1081 (1)	1083 (00)
1096 (08)	1095 (1)	1095 (2)
1138 (06)	1140 (006)	
1165 (2)	1164 (16)	1157 (00)
1205 (3)	1204 (5)	1204 (5)
1219 (1)	1220 (06)	1219 (0)
1247 (4)	1248 (6)	1247 (4)
1264 (28)	1266 (4)	1265 (2)
1303 (36)	1300 (0)	
		1310 (1)
1344 (26)	1347 (16)	
1378 (4)	1377 (6)	1378 (4)
		1432 (3)
1443 (76)	1441 (56)	
1451 (8)	1452 (56)	1465 (3)
	159C (3)	1557 (1)
1596 (0)		1591 (2)
1613 (26)	1608 (3)	1608 (2)
	1620 (4)	1619 (3)
2862 (00)		
2621 (0)		
2666 (1)	2663 (2)	2663 (0)
2728 (6)	2732 (2)	2731 (1)
2839 (10)	2848 (76)	2841 (2)
	2866 (7)	2866 (4)
2875 (7)	(5)	2819 (46)
2927 (008)	2925 (70)	
2950 (8)		2957 (26)
	2965 (60)	
	3014 (25)	3018 (1)
3032 (1)	3030 (2)	3033 (1)
3048 (36)	3055 (60)	3053 (3)

## ENCLOSURE (A)

	Distillation Temperature °C																								
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	Comp. % in Ref. 1		
2 methyl butane	A	B	B	B	C	D																		2	
n-pentane	A	B	B	B	C	C																		2	
Cyclo-pentane	B	B	A	A	B	B	C																	1	
2,2. Dimethyl butane	C	B	B	B	B	C																		<1	
2,3. Dimethyl butane	D	C	C	C	B	B	C																	1	
2 - methyl pentane		C	E	B	A	B	C																	3	
3 - methyl pentane			G <sup>a</sup>	G <sup>a</sup>																				1	
n - Hexane			C	B	B	C																		3	
methyl cyclo pentane				B	B	C																		2	
2,2. Dimethyl pentane					G <sup>a</sup>																			<1	
Decane	D	C	B	B	A	B	B	C	D															7	
Cyclo-hexane	D	D	C	B	B	B	B	B	C															6	
2,4. Dimethyl pentane						O	C	C	C															2	
3,3. Dimethyl pentane						C	O	C	C															1	
2 - methyl hexane						C	C	C	C															1	
Trans 1, 2. Dimethyl cyclo pentane						O	O	C	C															2	
Methyl cyclo hexane	D	D	C	B	B	B	B	B	O	O														11	
Toluene	D	C	B	B	B	A	A	A	A	B	O													14	
1,3 Dimethyl cyclohexane							O	S	A	S	S													4	
1,4 Dimethyl cyclohexane								O	B	B	O													2	
n-octane								O	O	B	B	C												3	
ethyl - Decane								O	O	B	B	B												1	
P-xylene									O	B	B	B	A											2	
m-xylene									O	B	B	B	A											6	
o - xylene									O	O	B	B	O											1	
yield %	2.38	0.55	0.16	0.21	0.40	0.68	2.77	5.30	4.60	3.69	2.22	1.69	5.27	8.84	8.75	5.13	2.08	2.42	4.66	3.97	5.38				
	A = 40 ~ 60%																								
	B = 20 ~ 30%																								
	C = 10% ±																								
	D = Little																								

## ENCLOSURE (A)

**Part III**  
**SOME TABULATED PHYSICAL PROPERTIES**  
**OF IMPORTANT HYDROCARBONS**

**A. PHYSICAL PROPERTIES OF PURE HYDROCARBONS**

<u>Compound</u>	<u>Formula</u>	<u>B.P. (°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	<u>O.N.</u>
n-hexane	C <sub>6</sub> H <sub>14</sub>	69.1-69.3	0.6558	1.3730	36 (1)
2-methyl pentane	C <sub>6</sub> H <sub>14</sub>	61 - 63	0.6535		(1)
2-2-dimethyl butane	C <sub>6</sub> H <sub>14</sub>	50 - 51.9	0.6468	1.36252	(1)
2-3-dimethyl butane	C <sub>6</sub> H <sub>14</sub>	57 - 58	0.6569	1.3708	95 (1)
3-ethyl pentane	C <sub>7</sub> H <sub>16</sub>	91.5-93.5	0.6929	1.3900	(1)
2-2-dimethyl pentane	C <sub>7</sub> H <sub>16</sub>	78 - 82	0.6712	1.3815	(1)
3-3-dimethyl pentane	C <sub>7</sub> H <sub>16</sub>	84 - 88	0.6881	1.3892	(1)
2-3-dimethyl pentane	C <sub>7</sub> H <sub>16</sub>	90 - 93	0.689	1.5873	(1)
3-methyl 3-ethyl pentane	C <sub>8</sub> H <sub>18</sub>	115- 120	0.7192	1.4031	(1)
3-3-dimethyl hexane	C <sub>8</sub> H <sub>18</sub>	109 - 115	0.7126	1.3981	(1)
3-4-dimethyl hexane	C <sub>8</sub> H <sub>18</sub>	113 - 118	0.7182	1.4052	(2)
2-2-3-trimethyl butane	C <sub>7</sub> H <sub>16</sub>				104 (2)
2-2-3-trimethyl pentane	C <sub>8</sub> H <sub>18</sub>				101 (2)
2-3-4-trimethyl pentane	C <sub>8</sub> H <sub>18</sub>				97 (2)
			<u>d<sub>4</sub><sup>20</sup></u>	<u>n<sub>D</sub><sup>20</sup></u>	(5)
2-2-4-trimethyl pentane	C <sub>8</sub> H <sub>18</sub>	99.3	0.6921	1.3916	
n-heptane	C <sub>7</sub> H <sub>16</sub>	98.4	0.6836	1.3777	(5)
		<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>		
2-methyl 2-ethyl pentane	C <sub>8</sub> H <sub>18</sub>	114 - 119	0.702	1.400	(3)
2-2-dimethyl hexane	C <sub>8</sub> H <sub>18</sub>		0.07	1.404	(3)

## ENCLOSURE (A)

<u>Compound</u>	<u>Formula</u>	<u>B.P. (°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	<u>O.N.</u>	
3-4-dimethyl hexane	C <sub>8</sub> H <sub>18</sub>	117	0.714	1.407	(3)	
2-5-dimethyl hexane	C <sub>8</sub> H <sub>18</sub>	108 - 110	0.7004	1.3947	(3)	
2-methyl hexane	C <sub>7</sub> H <sub>16</sub>	87 - 91	.6882	1.3862	(3)	
Decane	C <sub>10</sub> H <sub>22</sub>	170 - 172	0.7270	1.4100	(4)	
2-6-dimethyl octene	C <sub>10</sub> H <sub>20</sub>	160 - 161	0.7450	1.4250	(4)	
Hexadecane	C <sub>16</sub> H <sub>34</sub>	140 - 144/11	0.7703	1.4321	(4)	
Benzene	C <sub>6</sub> H <sub>6</sub>	80.2 - 80.6	0.8715	1.4960	103.3	(6)
Methyl Benzene	C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub>	109.8-109.9	0.8611	1.4912	110	(6)
Ethyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>2</sub> H <sub>5</sub>	134.5-135	0.8630	1.4913	(7)	
Propyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>3</sub> H <sub>7</sub>	156 - 157	0.8577	1.4878	102	(7)
Isopropyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>3</sub> H <sub>7</sub>	150.2-150.8	0.8575	1.4874	102	(7)
Butyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>4</sub> H <sub>9</sub>	179 - 179.5	0.8567	1.4857	102	(7)
Isobutyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>4</sub> H <sub>9</sub>	169.5-170.5	0.8570	1.4852	102	(7)
Tert. Butyl Benzene		165 - 166	0.8627	1.4885	102	(7)
c-Xylene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	141.9-142	0.8509	1.4850	(6)	
p-O-Xylene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	136.3	0.8566	1.4920	108	(6)
m-O-Xylene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	138 - 138.3	0.8600	1.4931	108	(6)
p-cymene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> )(C <sub>3</sub> H <sub>7</sub> )	173.9-174.1	0.8528	1.4869	(8)	
p-Di Tert. Butyl	C <sub>6</sub> H <sub>4</sub> (C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	230 - 233			108	(9)
n-Amyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>5</sub> H <sub>11</sub>	204 - 50	0.8694	1.4838	(10)	
n-Nonyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>9</sub> H <sub>19</sub>	280 - 281	0.8572	1.4799	(10)	
n-Octadecyl	C <sub>6</sub> H <sub>5</sub> C <sub>18</sub> H <sub>37</sub>	(235)15	0.8085	1.4469	(10)	
Styrene	C <sub>8</sub> H <sub>8</sub>	143 - 1450	0.8979	1.5378	(10)	
Diphenyl	C <sub>12</sub> H <sub>10</sub>	248 - 90			(11)	
1-4-Diphenyl benzene	C <sub>18</sub> H <sub>14</sub>	211.5-212			(11)	
1-3-Diphenyl benzene	C <sub>18</sub> H <sub>14</sub>	85.5 - 86.5			(11)	
Anthracene	C <sub>14</sub> H <sub>10</sub>	212.5-213.5			(11)	
Phenanthrene	C <sub>14</sub> H <sub>10</sub>	97 - 98			(11)	
Acenaphthene	C <sub>12</sub> H <sub>10</sub>	266.5-267.5			(11)	
Pyrene	C <sub>16</sub> H <sub>10</sub>	148 - 149			(11)	

## ENCLOSURE (A)

<u>Compound</u>	<u>Formula</u>	<u>B.P.(°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	<u>O.N.</u>
Cyclo Pentane	C <sub>5</sub> H <sub>10</sub>	48.9 - 50°	0.7422		(12)
Cyclo Pentene	C <sub>5</sub> H <sub>8</sub>	45 - 60	0.7422	1.4039	76.8 (6)
Cyclo Hexane	C <sub>6</sub> H <sub>12</sub>	80.7 - 81.0	0.7736	1.4218	65 (6)
Cyclo Hexene	C <sub>6</sub> H <sub>10</sub>	83.1 - 83.4	0.8059	1.4430	75 (6)
Methyl Cyclo Hexane	C <sub>6</sub> H <sub>11</sub> CH <sub>3</sub>	100 - 103	0.7619	1.4191	(6)
Ethyl Cyclo Hexane	C <sub>6</sub> H <sub>11</sub> C <sub>2</sub> H <sub>5</sub>	120 - 30	0.8154	1.4568	75 (6)
Methane	C <sub>1</sub> H <sub>2</sub> O				
Δ <sub>3</sub> menthene	C <sub>10</sub> H <sub>18</sub>	168 - 169.5	0.8107	1.4487	(a)D +107.24
		<u>B.P.(°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	<u>M.R.</u> <u>M.V.</u>
Cyclo Hexane	C <sub>6</sub> H <sub>10</sub>	81.5 - 82	0.8064	1.4434	27.03 102.49 (13)
Methylcyclo HexaneΔ1	C <sub>7</sub> H <sub>12</sub>	109 - 110	0.8050	1.4462	31.81 119.25 (13)
Methylcyclo HexaneΔ2	C <sub>7</sub> H <sub>12</sub>	104.5 - 105	0.7970	1.4413	31.83 120.45 (13)
Methylcyclo HexaneΔ3	C <sub>7</sub> H <sub>12</sub>	101.5 - 102	0.7951	1.4385	31.77 120.74 (13)
Phenyl Cyclo Hexane	C <sub>12</sub> H <sub>16</sub>	234 - 60	0.9431	1.5313	52.56 (15)
Di Cyclo Hexyl	C <sub>12</sub> H <sub>22</sub>	231 - 30	0.8836	1.4777	53.20 (15)
Hexahydro-1-3-Diphenyl Benzene	C <sub>18</sub> H <sub>20</sub>	176 - 8/2.6	1.0102	1.5798	77.78 (15)
Dodecahydro-1-3-Diphenyl Benzene	C <sub>18</sub> H <sub>26</sub>	176 - 8/2	0.9742	1.5425	78.31 (15)
Perhydro-1-3-Diphenyl Benzene	C <sub>18</sub> H <sub>32</sub>	182 - 4/5	0.9443	1.5176	79.61 (15)
Hexahydro-1-4-Diphenyl Benzene	C <sub>18</sub> H <sub>20</sub>	178-108/1.5			
Dodecahydro-1-4-Diphenyl Benzene	C <sub>18</sub> H <sub>26</sub>	{178-180/1.8 96 - 97			
Perhydro-1-4-Diphenyl Benzene	C <sub>18</sub> H <sub>32</sub>	{130-134/2.5 48 - 49			
Dihydro Anthracene	C <sub>14</sub> H <sub>12</sub>	108.5	1.1675	1.5776	180.1 (14)
Tetra Hydro Anthracene	C <sub>14</sub> H <sub>14</sub>	79	1.1047	1.5571	182.1 (14)
Tetra Hydro Anthracene	C <sub>14</sub> H <sub>14</sub>	88	1.1176	1.5686	182.1 (14)

## ENCLOSURE (A)

<u>Compound</u>	<u>Formula</u>	<u>B.P. (°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	<u>M.R.</u>	
Octa Hydro-Anthracene	C <sub>14</sub> H <sub>20</sub> C <sub>14</sub> H <sub>20</sub>	71	0.9450	1.5671	192.2	(14)
Perhydro Anthracene	C <sub>14</sub> H <sub>24</sub>	(115-125)2.5	1.0338	1.4826	192.2	(14)
Tetra Hydro-phenanthrene	C <sub>14</sub> H <sub>14</sub>	160-162/10.9	1.0706	1.6260	60.12	
Octahydro-phenanthrene	C <sub>14</sub> H <sub>20</sub>	159-160/12	1.0167	1.5620	59.38	
Perhydro-phenanthrene	C <sub>14</sub> H <sub>24</sub>	132-134/10.7	0.9502	1.5020	59.69	
Tetrahydro-Acenaphthene	C <sub>12</sub> H <sub>13</sub>	245 - 247	1.0065	1.5550	50.42	(11)
Dodecahydron-Acenaphthene	C <sub>12</sub> H <sub>19</sub>	235 - 237	0.9462	1.5020	51.20	
Hexahydro-pyrene	C <sub>12</sub> H <sub>16</sub>	131 - 132				
Dodecahydron-pyrene	C <sub>16</sub> H <sub>20</sub>	158 - 160/3	1.0497	1.5742	66.71	
Perhydro-pyrene	C <sub>16</sub> H <sub>20</sub>	144 - 148/4	0.9835	1.5230	67.63	
Diphenyl-methane	C <sub>13</sub> H <sub>12</sub>	170/5	1.0042	1.5763	55.42	(16)
Benzyl-benzene	C <sub>20</sub> H <sub>18</sub>		1.0467	1.6020	84.64	
Dibenzyl Diphenyl C <sub>27</sub> H <sub>20</sub> Methane			1.0683	1.6170	114.04	
Dodecahydron-diphenyl Methane	C <sub>13</sub> H <sub>20</sub>	224-4.5/745	0.8723	1.4747	58.07	
Octadecahydro-dibenzyl Benzene	C <sub>20</sub> H <sub>36</sub>	169-173/2.2	0.9127	1.4940	88.19	
Tetracocahydro-dibenzyl-diphenyl-methane	C <sub>27</sub> H <sub>48</sub>	240-280/5	0.9492	1.5206	119.38	

<u>Compound</u>	<u>Formula</u>	<u>B.P. (°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	
Naphthalene	C <sub>10</sub> H <sub>8</sub>				
Δ <sub>2</sub> Dihydro Naphthalene	C <sub>10</sub> H <sub>10</sub>	206.5-207	0.9926	1.5782	(17)
Tetrahydro Naphthalene	C <sub>10</sub> H <sub>12</sub>	204 -204.3	0.9644	1.5408	(17)
Cis Octa-hydronaphthalene	C <sub>10</sub> H <sub>16</sub>	191 - 191.5	0.9135	1.4918	(17)
Cis Decahydro-naphthalene	C <sub>10</sub> H <sub>18</sub>	189.8-190	0.8905	1.4770	(17)

## ENCLOSURE (A)

<u>Compound</u>	<u>Formula</u>	<u>B.P. (°C)</u>	<u>d<sub>4</sub><sup>25</sup></u>	<u>n<sub>D</sub><sup>25</sup></u>	
Deca Hydro Cadalene	C <sub>15</sub> H <sub>28</sub>	(97 - 100) <sub>4</sub>	0.8730	1.4745	(18)
Tetrahydro Cadalene	C <sub>15</sub> H <sub>22</sub>	(108 - 118) <sub>4</sub>	0.907	1.506	
Dihydro Cadalene	C <sub>15</sub> H <sub>20</sub>	(108 - 114) <sub>4.5</sub>	0.9150	1.5085-224 <sup>(a)D</sup>	
a-methyl Naphthalene	C <sub>10</sub> H <sub>7</sub> CH <sub>3</sub>	(238 - 9.2°)	1.0173	1.6120	(19)
Δ <sup>2</sup> Dihydro Methyl Naphthalene	C <sub>10</sub> H <sub>9</sub> CH <sub>3</sub>	(122 - 125) <sub>29</sub>	0.9898	1.5710	
Longifolene	C <sub>15</sub> H <sub>24</sub>	(114 - 6) <sub>10</sub>	0.9317	1.5041+42.2	(20)
Trans-Decahydro Naphthalene	C <sub>10</sub> H <sub>18</sub>	185 - 9°	0.8748	1.4701	

Notes

- (1) T. NAKAYAMA: Alkylation of acetone, methyl ethyl ketone.
- (2) ISHIDA: Alkylation of ketone.
- (3) S. KOMATSU & T. NAKAYAMA: Alkylation of ketone.
- (4) YAMAOKA: Sc. & Exp. Rep. No. 144(1941) prep. from undecyl alcohol C<sub>11</sub>H<sub>23</sub>OH.
- (5) MIYATA: Ibid., No. 83(1940). From butyrone.
- (6) Y. AKITA: Octane Value (1941). Japanese & refer. T. SUWA: Fuel Research Rep. 30.(1935).49.
- (7) Benzene and Alcohol or Alkylchloride by Friedel-Crafts reaction, Benzene and ketone in presence of AlCl<sub>3</sub>, or SO<sub>4</sub>H<sub>2</sub>. (S.KOMATSU & E. IBUKI)
- (8) Synthesized from menthene.
- (9) Synthesized from benzene and tert-butyl alcohol.
- (10) S. KOMATSU & S.KANEDA: Synthesized from benzene and alcohol.
- (11) I. KAGEHIRA (Rep. Imp. Naval Fuel Depot, No. 128(1938);No. 97(1935).
- (12) Hydrogenation of benzene, dehydration from cyclo hexanol with SO<sub>2</sub>H<sub>2</sub>.3H<sub>2</sub>O.(S.K. & E.I.)
- (13) S.KOMATSU, S.TANAKA & T. WAIDA: J. Ch. Soc. Japan 54(1933)794.
- (14) T.YOKOTA: Exp. & Sc. Rep. 13(1938) 81. 81.
- (15) Y. KAGEHIRA: Loc. cit.
- (16) I. KAGEHIRA: Unpublished.
- (17) S. KIMURA: Hydrogenation of naphthalene.
- (18) S. KIMURA: Hydrogenation of sesquiterpene.
- (19) S. FUJITA: Synthesized from tetalone and methyl iodide.
- (20) KUMAGAI: Isolated from pine resin.

## ENCLOSURE (A)

## B. THERMAL DECOMPOSITION TEMPERATURE OF HYDROCARBONS

<u>Compound</u>	<u>Formula</u>	<u>Decomposition Temp. (°C)</u>	<u>(I)</u>	<u>(II)</u>
Cyclopentane	C <sub>5</sub> H <sub>10</sub>	566	CH <sub>2</sub> =CH <sub>2</sub> , CH <sub>3</sub> CH=CH <sub>2</sub> ,	
Cyclopentene	C <sub>5</sub> H <sub>8</sub>	507		
Cyclohexane	C <sub>6</sub> H <sub>12</sub>	550	(CH <sub>2</sub> =CH) <sub>2</sub> , CH <sub>3</sub> CH=CH <sub>2</sub> , C <sub>2</sub> H <sub>4</sub> , C <sub>6</sub> H <sub>6</sub> , C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub>	
Cyclohexene	C <sub>6</sub> H <sub>10</sub>	500		
n-hexane	C <sub>6</sub> H <sub>14</sub>	550	CH <sub>3</sub> CH <sub>2</sub> CH=CH <sub>2</sub> , CH <sub>3</sub> CH=CH <sub>2</sub>	
2-3-dimethyl butane	C <sub>6</sub> H <sub>14</sub>	535	(CH <sub>3</sub> ) <sub>2</sub> C=C(CH <sub>3</sub> ) <sub>2</sub> , CH <sub>3</sub> CH=CH <sub>2</sub>	
3-Ethyl Pentane	C <sub>7</sub> H <sub>16</sub>	610		
2-methyl Pentane	C <sub>6</sub> H <sub>14</sub>	410		
2-2-dimethyl butane	C <sub>6</sub> H <sub>14</sub>	460		
2-2-4-trimethyl pentane	C <sub>8</sub> H <sub>18</sub>	580	(CH <sub>3</sub> ) <sub>2</sub> C=CH <sub>2</sub> , CH <sub>3</sub> -C(CH <sub>3</sub> ) <sub>2</sub> -CH=CH <sub>3</sub> , C <sub>2</sub> E <sub>6</sub> CH <sub>2</sub>	

(I) S. KOMATSU &amp; E. IBUKI. (unpublished)

(II) S. KATO &amp; F. SOMENO: Sci. P. I. Phy. Chem. Res. 21(1943)256

## ENCLOSURE (A)

<u>Compound</u>	<u>Formula</u>	<u>Decomp. Temp. (°C)</u>		<u>Reaction Product</u>
		(I)	(II)	
Benzene	C <sub>6</sub> H <sub>6</sub>	600	750	
Toluene	C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub>	600 - 725		C <sub>6</sub> H <sub>6</sub> , (C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> , (C <sub>6</sub> H <sub>5</sub> CH) <sub>2</sub>
Ethyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>2</sub> H <sub>5</sub>	535 - 721		C <sub>6</sub> H <sub>5</sub> CH-CH <sub>2</sub> , (C <sub>6</sub> H <sub>5</sub> CH) <sub>2</sub> , C <sub>2</sub> H <sub>4</sub> , CH <sub>3</sub> CH=CH <sub>2</sub>
Isopropyl Ben- zene	C <sub>6</sub> H <sub>5</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	506 - 756		C <sub>6</sub> H <sub>6</sub> , C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , (C <sub>6</sub> H <sub>5</sub> CH) <sub>2</sub> (CH <sub>3</sub> ) <sub>2</sub> CH=CH <sub>2</sub>
Tert. Butyl Benzene	C <sub>6</sub> H <sub>5</sub> C(CH <sub>3</sub> ) <sub>3</sub>	498 - 720		C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , C <sub>6</sub> H <sub>6</sub> , C <sub>2</sub> H <sub>4</sub>
c-xylene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	588 - 703		C <sub>6</sub> H <sub>5</sub> , C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> } above 700° CH <sub>2</sub> =CHCH=CH <sub>2</sub>
m-xylene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	633 - 730		C <sub>6</sub> H <sub>6</sub> } (C <sub>6</sub> H <sub>5</sub> CH) <sub>2</sub>
p-xylene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	740		C <sub>6</sub> H <sub>5</sub> C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> } 
p-methyl Isopropyl Benzene	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> )C <sub>3</sub> H <sub>7</sub>	525 - 692		
p-diisopropyl Propyl Benzene	C <sub>6</sub> H <sub>4</sub> (C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	615 - 730		
n-propyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>3</sub> H <sub>7</sub>	550 - 650		{C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , (C <sub>6</sub> H <sub>5</sub> CH) <sub>2</sub> C <sub>6</sub> H <sub>6</sub> , CH <sub>3</sub> CH=CH <sub>2</sub> }
n-butyl Benzene	C <sub>6</sub> H <sub>5</sub> C <sub>4</sub> H <sub>9</sub>	550 - 700		{C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub> , (C <sub>6</sub> H <sub>5</sub> CH) <sub>2</sub> C <sub>6</sub> H <sub>6</sub> , CH <sub>2</sub> =CH-CH=CH <sub>2</sub> }
Tetralin	C <sub>10</sub> H <sub>12</sub>	556 - 742		
Decalin	C <sub>10</sub> H <sub>18</sub>	539 - 746		

- (I) S. KOMATSU & E. IBUKI (unpublished)  
 (II) S. KATO & S. TONOMURA: Sci. Pap. Inst. Phy. Chem. Res.  
 21(1942)774.



## ENCLOSURE (A)

Part IV  
DATA ON THE ULTRAVIOLET ABSORPTIVE  
PROPERTIES OF SOME HYDROCARBONS

Benzene(1) C<sub>6</sub>H<sub>6</sub> 78I

38450(3)	41286(2)
38612(8)	41378(7)
39445(4)	41884(1)
39534(10)	42300(5)
40370(3)	43010(2)
40460(9)	43215(2)

II

49100(7)	51750(8)
49980(10)	52610(5)
50900(10)	

Toluene(1) C<sub>6</sub>H<sub>5</sub>CH<sub>3</sub> 92

37305(5)	38668(8)
37425(5)	38732(5)
37485(10)	38765(5)
38020(7)	38945(6)
38400(7)	39395(6)
38422(9)	39600(6)
38454(8)	

M-Xylene(1) C<sub>6</sub>H<sub>4</sub>(CH<sub>3</sub>)<sub>2</sub> 106

36735(6)	38100(4)
36900(5)	38215(4)
36980(8)	38330(3)
37430(6)	38420(3)
37870(9)	38684(2)
37930(10)	38890(2)

Naphthalene(1) C<sub>10</sub>H<sub>8</sub> 128

35900(8)	37700(7)
36350(6)	38300(2)
36950(3)	38620(5)
37350(10)	39150(2)

Anthracene(1) CH-C<sub>6</sub>H<sub>4</sub>-CH=C<sub>6</sub>H<sub>4</sub> 178

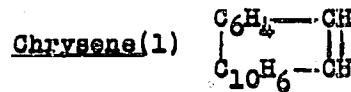
26750	39700
28250	40900
29750	

Phenanthrene(1) C<sub>6</sub>H<sub>4</sub>-CH-C<sub>6</sub>H<sub>4</sub>-CH

34150	39750
35050	41350
36700	

Note: Wave lengths are in cm<sup>-1</sup>.

## ENCLOSURE (A)



31750	34300
33100	37350

\* \* \* \* \*

Naphthalene(2)

I	
3384	3071
3219	3059
3160	3031
3126	2992

II	
2888	2684
2856	2567
2825	

Tetrahydro-naphthalene(2)

I	
3210	3005
3175	2980
3120	2888
3073	2868
3056	2840
3026	

II	
2745	2625
2689	2586
2670	2532

Octahydro-naphthalene(2) (cis)

2727	2550
2673	2463

Decahydro-naphthalene(2)

Diffused  
2780

Note: Wave lengths are in Angstrom units ( $\text{\AA}^0$ ).

\* \* \* \* \*

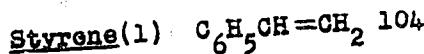
Ethylene (Gas)(1)  $\text{C}_2\text{H}_4$  28

50610(3)	54000(9)
51690(5)	54800(10)
52500(7)	55560(10)
53240(8)	

Note: Wave lengths are in  $\text{cm}^{-1}$ .

RESTRICTED

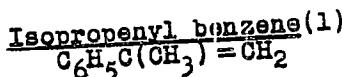
## ENCLOSURE (A)



I	
34750(8)	36950(8)
35750(10)	37200(4)
35900(9)	37300(5)
36710(7)	

II	
39500	42700(strong)
40900	46000

III	
46820(2)	48000(5)
47100(1)	49000(10)
47450(1)	



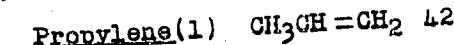
118

I	
34900(2)	35800(1.)
35300(3)	36300(4)

II	
39000	
40200	
42600(strong)	

Stilbene(1)  $C_6H_5\overset{CH}{||}C_6H_5$  118

31000	34000
32320	41800



52730(5)	53450(6)
53070(5)	53870(8)

<u>Isobutylene(1)</u> $(CH_3)_2C=CH_2$	56
49500(3)	52850(10)
50900(4)	54340(8)
51650(6)	

<u>Tetramethyl ethylene(1)</u> $(CH_3)_2C=C(CH_3)_2$	84
43140(2)	50110(6)
44480(3)	50670(8)
45850(3)	52200(9)
48640(6)	53430(10)

Note: Wave lengths are in  $\text{cm}^{-1}$ .

## ENCLOSURE (A)

Styrene(1)  $C_6H_5OH = CH_2$  104

34770(8)	42700
35760(10)	46000
35900(9)	46820(2)
36670(7)	47100(1)
36970(8)	47450(1)
37800(5)	48000(5)
39500	49000(10)
40900	

Butadiene(1)  
 $CH_2 = CH$ .  $CH = CH_2$  54

I	
46300(3)	49000(7)
47770(5)	

II	
50600(8)	52850(5)
51840(5)	53400(5)
52200(5)	53700(10)

Isoprene(1)  $CH_2 = C - CH = CH_2$   
 $\quad \quad \quad \quad \quad |$   
 $\quad \quad \quad \quad \quad CH_3$

I	
44850(5)	47550(6)
46350(8)	

II	
52400(5)	52880(5)

Dimethylbutadiene(1)  
 $CH_2 = C - C(CH_3)_2 = CH_2$  82  
 $\quad \quad \quad \quad \quad |$   
 $\quad \quad \quad \quad \quad CH_3$

43450(4)	45350(7)
43850(5)	46470(4)
45000(6)	46850(3)

Stilbene(1)  $C_6H_5 \cdot CH$   
 $\quad \quad \quad \quad \quad ||$   
 $\quad \quad \quad \quad \quad C_6H_5 \cdot CH$  180.

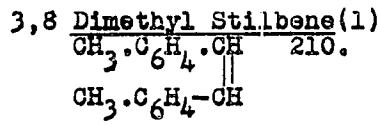
31000	34000
32400	41800

2,7 Dimethyl Stilbene(1)  
 $CH_3 \cdot C_6H_4 \cdot CH$   
 $\quad \quad \quad \quad \quad ||$   
 $\quad \quad \quad \quad \quad CH_3 \cdot C_6H_4 \cdot CH$  210.

30500	32000
-------	-------

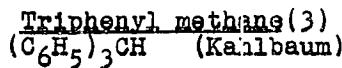
Note: Wave lengths are in  $\text{cm}^{-1}$ .

## ENCLOSURE (A)

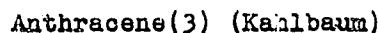


30350	33650
32000	

\* \* \* \* \*



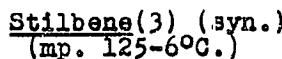
<u>Ether solution</u>	
304 (m)	276 (Weak)
293	270
281	264



<u>Ether solution</u>	
376	335 (Weak)
371 (Weak)	323
357	308
350 (Weak)	295
338	

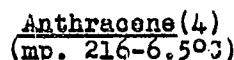


<u>Ether solution</u>	
376	325
371 (Weak)	308
356	271
354 (Weak)	264
334	254
335 (Weak)	



<u>Ether solution</u>	
322	290 (b.)
308	237

\* \* \* \* \*



I	
26670	29600
27230	29980
28140	31030
28460	32410

II	
39480	41680
40600	

Note: Wave lengths are in  $\text{cm}^{-1}$ .

## ENCLOSURE (A)

Dihydro anthracene(4)

I	
26540	29550
27120	29920
28050	30930
28460	32510

II	
37040	38010

Tetrahydro anthracene(4)

I	
26820	28650
27140	29550
28130	30080

II	
30630	31680
31060	32140

III	
33560	36270
34930	37820

IV	
39430	

Octahydro anthracene(4)

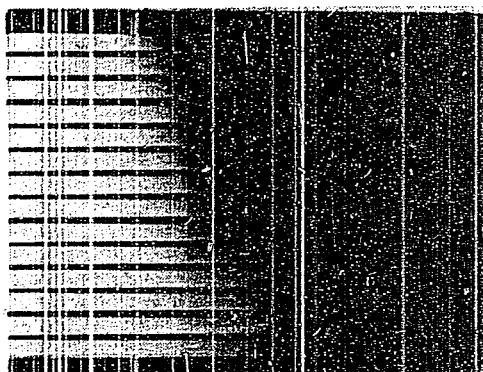
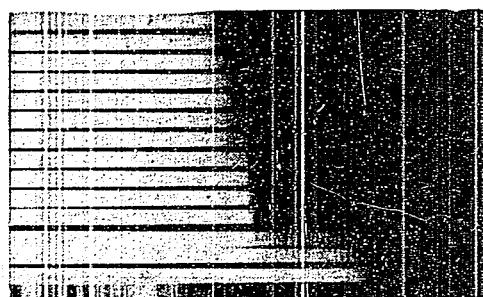
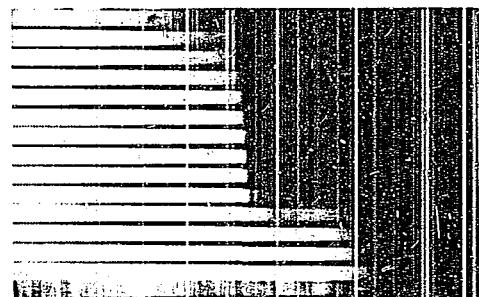
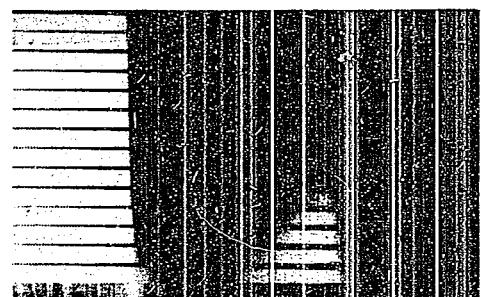
I	
35160	37200
35840	37880
36540	

Note: Wave lengths are in  $\text{cm}^{-1}$ .

Notes

- (1) S. KATO, F. SORIENO & S. TONOMURA, Sc. Rep. I.P.C.R. 21, (1943) 256, 277, 774.
- (2) S. KIMURA; Mem. Col. Sc. KYOTO I. U. A 14 (1931) 173.
- (3) M. TAKAOKA: J. Chem. Soc. Japan, 60 (14) 1090.
- (4) T. YOKOTA & T. FUJIMOTO: Report of the First Naval Fuel Depot. No. 143 (1941).

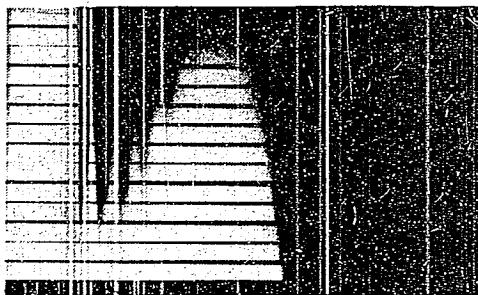
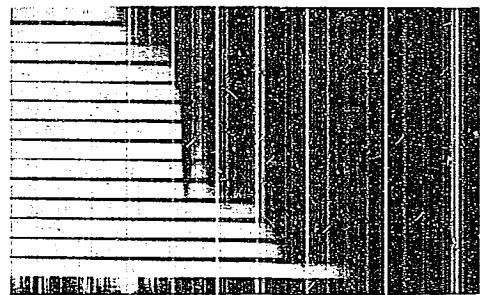
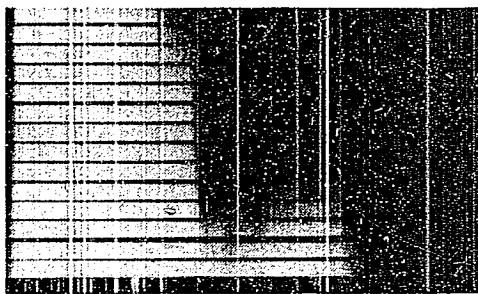
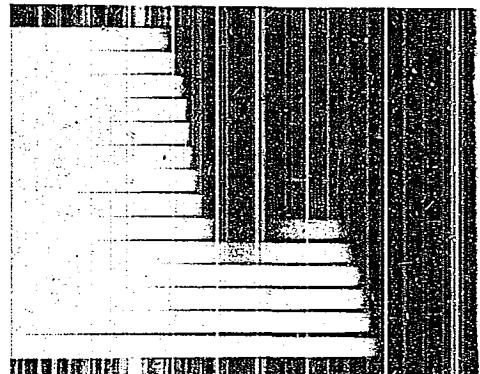
## ENCLOSURE (A)

Vinylbenzene 1/50000<sup>a</sup>1-Phenylbutadiene 1/10000<sup>a</sup>Diphenylmethane 1/1000<sup>a</sup>Sym-Diphenylethane 1/1000<sup>a</sup>

Diphenylethylene

Figure 13(A)  
ABSORPTION SPECTRA

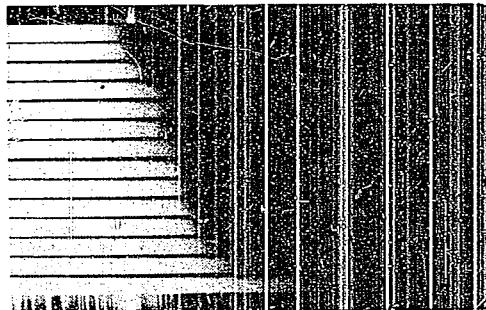
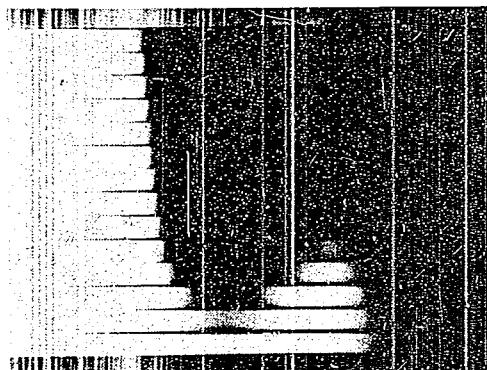
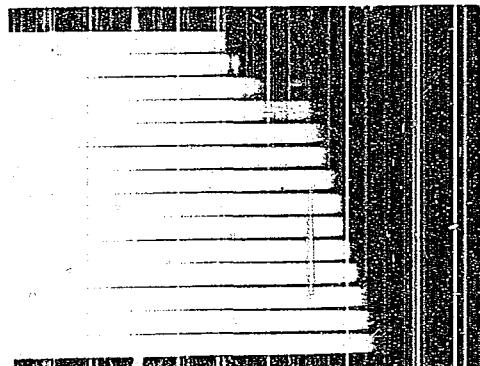
## ENCLOSURE (A)

Anthracene 1/10000<sup>m</sup>Phenanthrene 1/10000<sup>m</sup>Naphthalene 1/10000<sup>m</sup>

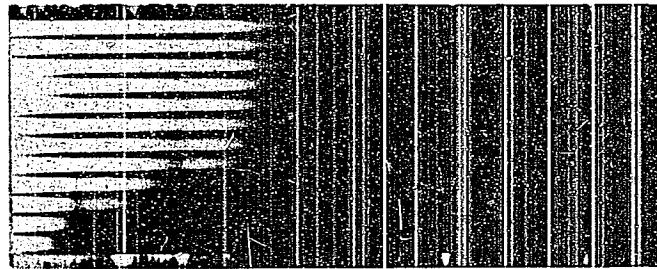
Methyl Naphthalene

Figure 14(A)  
ABSORPTION SPECTRA

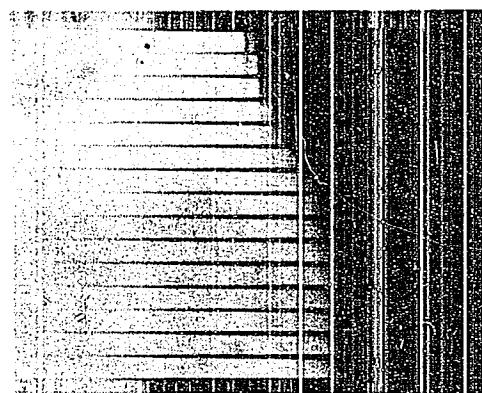
## ENCLOSURE (A)

Diphenyl 1/5000<sup>a</sup>P-Diphenylbenzene 1/10000<sup>a</sup>M-Diphenylbenzene 1/10000<sup>a</sup>Figure 15(A)  
ABSORPTION SPECTRA

## ENCLOSURE (A)



Cyclohexene (gas)



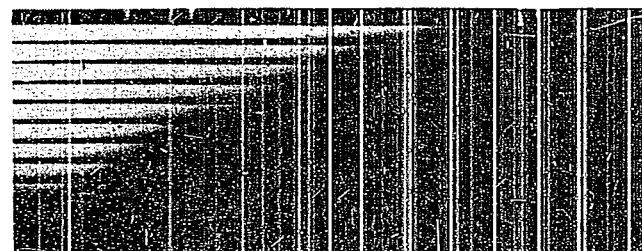
Cyclohexadiene (gas)

Figure 16(A)  
ABSORPTION SPECTRA

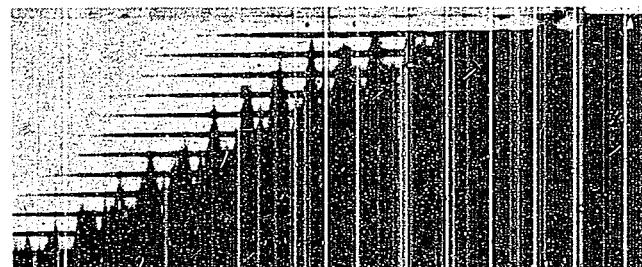
**ENCLOSURE (A)**



*Propylene (gas)*



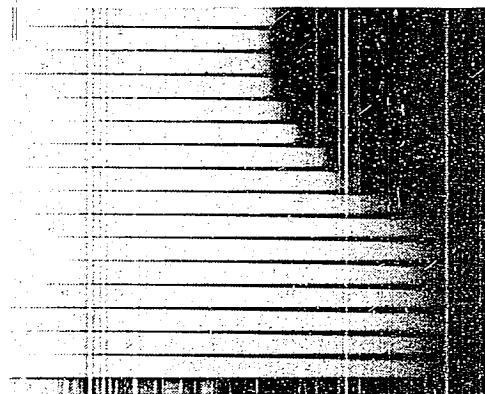
*1-Butylene (gas)*



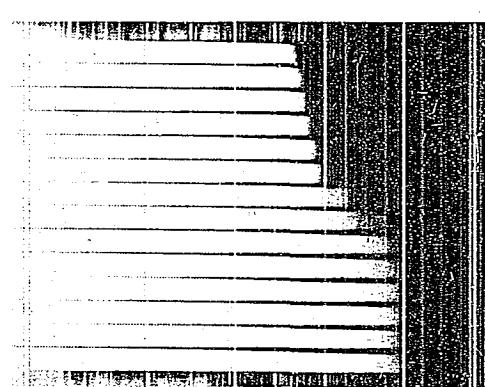
*Acetylene (gas)*

*Figure 17(A)  
ABSORPTION SPECTRA*

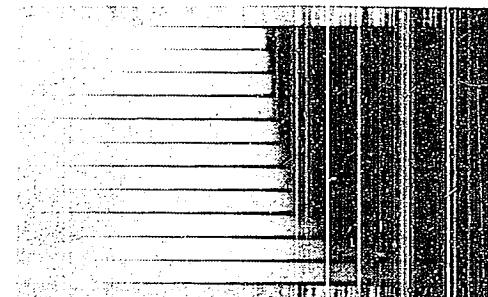
## ENCLOSURE (A).



Isoprene (gas)



Butadiene (gas)



2,3-Dimethylbutadiene (gas)

Figure 17(A) cont.

## ENCLOSURE (A)

Part V  
DATA ON THE RAMAN SPECTRA OF HYDROCARBONSEthane

(From Ethylmagnesium iodide and water)

993	(7)	2883	(10)
1462	(5b)	2914	(4)
2732	(4)	2939	(10)
2863	(3)	2695	(9)

W. NAKAMURA &amp; E. KANDA: J. Chem. Soc. Japan, 60 (1939) 1275.

\* \* \* \* \*

n-Butane(Butylchloride reduced by sodium in liquid ammonia and distilled.)  
(J. C. S. 49 (1927) 750)

223	(0)	1168	(0)
259	(0)	1168	(0)
287	(0)	1281	(0)
320	(1)	1301	(1b)
429	(5)	1444	(5b)
789	(2)	2666	(1)
809	(0)	2702	(1)
827	(6)	2733	(3)
837	(7)	2860	(8)
955	(1b)	2877	(10)
980	(2)	2914	(5)
1057	(4)	2938	(8b)
1077	(1)	2962	(6b)
1150	(2)		

S. MIZUSHIMA, MORINO and OKAZAKI: J. Ch. Soc. Japan, 60 (1939), 289.  
W. NAKAMURA and E. KANDA: Ibid. 60 (1939), 1275.

\* \* \* \* \*

n-Pentane B.P. 36.3,  $n_D^{20}$  1.3577.  
(From Fischer oil purified by distillation)

333	(1)	1264	(1)
400	(7)	1302	(4b)
467	(2)	1437	(5b)
764	(3)	1458	(6b)
838	(5)	2666	(1)
864	(4)	2713	(1)
904	(1b)	2733	(2)
953	(0)	2847	(5)
990	(1)	2861	(5)
1025	(3)	2875	(10)
1035	(3)	2908	(5b)
1072	(3b)	2936	(8b)
1142	(3)	2964	(8b)
1165	(0)		

OKAZAKI: J. Chem. Soc. Japan, 60 (1939) 559.

S. MIZUSHIMA, MORINO & TAKEDA: Sc. Pap.  
Inst. Phy. Chem. Res., (TOKYO) 38 (1941) 437.

## ENCLOSURE (A)

n-Hexane, B.P. 6819,  $n_D^{20}$  1.3748.  
 (Fischer oil distillation)  $d_4^{20}$  0.6615.

310	(2b)	1081	(3)
329	(1)	1140	(3)
370	(4)	1304	(4)
399	(4)	1439	(6)
448	(1b)	1456	(6)
746	(Ob)	2703	(1)
809	(1b)	2731	(2)
820	(3)	2849	(5b)
867	(3)	2861	(5b)
895	(6)	2875	(12)
949	(Ob)	2896	(4b)
970	(0)	2911	(5b)
1004	(1)	2939	(10)
1038	(3)	2964	(10)

OKAZAKI; J. Chem. Soc. Japan, 60(1939) 559,  
 S. MIZUSHIMA, MORINO & TAKEDA: Sc. Pap.  
 Inst. Phy. Chem. Res. (TOKYO) 38 (1941) 437.

\* \* \* \* \*

2-2-Dimethyl butane, (Neohexane)  
 (Phillip's material was fractionated. B.P. 49.5 - 50.5)

97	(1b)	1252	(6)
258	(2)	1304	(3)
336	(3)	1446	(8)
361	(3)	1466	(4b)
408	(1)	2655	(0)
484	(2)	2711	(2)
712	(10)	2851	(3)
868	(5)	2865	(7)
926	(6)	2892	(4)
995	(0)	2903	(12)
1017	(4)	2940	(8b)
1075	(3)	2965	(8b)
1215	(6)		

S. MIZUSHIMA, MORINO & TAKEDA: Loc. cit.

\* \* \* \* \*

## ENCLOSURE (A)

## 2-3, Dimethyl butane

96	(1b)	1159	(3b)
220	(0)	1196	(2)
291	(1)	1263	(0)
346	(1)	1300	(3)
378	(0)	1321	(0)
397	(0)	1344	(3)
432	(0b)	1388	(0)
477	(2)	1440	(5b)
504	(3)	1467	(6b)
629	(00)	2670	(0)
728	(10)	2718	(3)
755	(5)	2735	(0)
815	(0)	2756	(1)
847	(0)	2774	(1)
869	(3)	2855	(7)
929	(3)	2871(10b)	
940	(3)	2903	(5b)
956	(2)	2935	(4b)
1029	(2)	2961(10b)	
1039	(3)	2982	(6)
1150	(1)		

OKAZAKI: J. Chem. Soc. Japan, 60(1939) 559.

\* \* \* \* \*

## 20 n-Heptane

- (I) B.P. 98.4°C d<sub>4</sub> 0.6838; n<sub>D</sub><sup>20</sup> 1.3877 (from Prof. NAGAI)  
 (II) (Sample from standard fuel for octane rating, California  
 Chem. Co. B.P. 98.4 - 98.6°C fractionated.)

## (I)

198	(0)	1031	(1)
225	(0)	1045	(3)
282	(1)	1056	(2)
312	(6)	1069	(2)
356	(2)	1081	(4)
394	(3)	1138	(4)
405	(1)	1161	(2)
454	(1)	1209	(0)
506	(1)	1235	(1)
696	(0)	1262	(0)
722	(0)	1281	(0)
742	(1)	1299	(6b)
777	(2b)	1310	(1)
805	(0)	1342	(1)
826	(3)	1365	(0)
840	(4)	1433	(8b)
852	(3)	1458	(8b)
868	(0)	2670	(0)
888	(2)	2710	(1)
900	(5)	2732	(3)
907	(3)	2844	(10)
929	(1)	2873	(8)
949	(1)	2900	(5b)
961	?	2938	(8)
988	(00)	2964	(10b)
1021	(1)		

## ENCLOSURE (A)

n-Heptane (Continued)

## (II)

282	(0)	1138	(3)
309	(4)	1163	(1)
356	(0)	1207	(0)
394	(2)	1272	(1)
453	(1)	1300	(8)
483	(0)	1343	(0)
505	(0)	1370	(0)
719	(0)	1436	(8b)
743	(0)	1457	(8b)
778	(1)	2670	(1)
838	(3)	2707	(1)
854	(1)	2733	(3)
886	(1)	2850	(7)
904	(4)	2880	(3)
931	(0)	2874	(10)
962	(1)	2906	(8b)
1020	(1)	2938	(10)
1046	(4)	2964	(10)

MIZUSHIMA, MORINO &amp; OKAZAKI: J. Chem. Soc. Japan, 60(1939) 290.

\* \* \* \* \*

2,2,3.Trimethyl butane

219	(0)	1109	(3)
260	(0)	1160	(0)
295	(1)	1204	(2)
358	(4)	1218	(4)
389	(3)	1250	(5)
437	(1)	1326	(3b)
460	(2)	1361	(0)
521	(4)	1435	(2)
561	(0)	1452	(5)
583	(0)	1471	(3)
603	(00)	2711	(4)
687	(10)	2733	(0)
833	(4)	2756	(0)
922	(7b)	2867	(8)
957	(1)	2905	(6)
1054	(00)	2947	(7b)
1080	(3)	2988	(7b)

S. MIZUSHIMA, MORINO &amp; OKAZAKI: J. Chem. Soc. Japan, 60(1939) 289.

\* \* \* \* \*

## ENCLOSURE (A)

n-Octane, B.P. 124°,  $d_4^{20}$  1.3978;  $n_D^{20}$  1.7043

196	(0)	999	(0)
218	(0)	1026	(2)
241	(0)	1045	(2)
279	(5)	1060	(4)
295	(1)	1083	(4b)
347	(0)	1137	(4)
374	(1)	1162	(1)
399	(0)	1199	(0)
427	(1)	1226	(0)
457	(0)	1299	(5b)
505	(0b)	1342	(0)
696	(0)	1366	(0b)
723	(1)	1434	(7b)
735	(1)	1459	(5b)
765	(1)	2668	(1)
815	(2b)	2714	(0)
843	(2)	2732	(3)
861	(3)	2849	(10)
878	(3)	2873	(6)
896	(4)	2904	(6)
953	(1)	2937	(6)
970	(2)	2965	(8b)

MIZUSHIMA, MORINO & OKAZAKI: J. C. S. Japan, 60(1939) 289.

\* \* \* \* \*

2,2,3.Trimethyl pentane

345	(2b)	1201	(2)
373	(0)	1221	(3)
393	(1)	1246	(3)
446	(1)	1303	(1)
469	(0)	1328	(1)
526	(3)	1348	(1)
716	(6)	1444	(6b)
828	(2)	1468	(4b)
894	(3)	2717	(0)
927	(5)	2866	(6b)
975	(3)	2907	(5b)
1088	(2)	2945	(4b)
1081	(1)	2972	(10b)
1118	(0)		

MIZUSHIMA, MORINO & OKAZAKI: J. C. S. Japan, 60(1939) 289.

\* \* \* \* \*

## ENCLOSURE (A)

2,2,4-Trimethyl pentane  
B.P. 98.0 - 98.1°C,  $d_4^{20}$  0.6918;  $n_D^{20}$  1.3916 (America)

191	(1)	1113	(1b)
260	(0)	1167	(2)
292	(3b)	1205	(3b)
310	(1b)	1246	(5)
350	(1)	1283	(2)
370	(0)	1302	(0)
417	(1)	1349	(2)
456	(0)	1364	(0)
510	(3b)	1390	(0b)
714	(0)	1432	(1)
745	(10)	1447	(5)
816	(0)	1461	(2)
828	(2)	1469	(3)
861	(0)	2715	(2)
899	(5)	2759	(0)
926	(6)	2842	(3)
952	(3)	2862	(8b)
978	(0)	2906	(6b)
1014	(0)	2935	(3)
1020	(1)	2956	(10b)
1097	(2)		

TAKEDA: J. C. S. Japan, 62(1941) 896.

\* \* \* \* \*

n-Nonane

196	(0)	926	(0)
221	(0)	970	(1b)
248	(3)	1019	(1)
264	(4)	1046	(0)
283	(1)	1092	(3)
340	(1)	1082	(3b)
375	(1)	1134	(3)
404	(1)	1159	(1)
417	(1)	1192	(0)
453	(1b)	1217	(0)
490	(0)	1299	(4b)
510	(0)	1340	(0)
548	(0)	1433	(8)
697	(0)	1460	(8)
721	(1)	2666	(1)
751	(1)	2706	(1)
781	(1)	2731	(1)
830	(3)	2846	(10)
843	(3)	2873	(2)
871	(3)	2933	(7)
892	(4)	2964	(9)

OKAZAKI: J. C. S. Japan 60(1939) 559.

\* \* \* \* \*

## ENCLOSURE (A)

n-Decane

200	(0)	991	(1)
230	(3)	1008	(1)
250	(5)	1023	(1)
339	(0)	1047	(2)
359	(1)	1062	(4)
404	(2b)	1080	(4)
441	(1)	1092	(3)
465	(1)	1133	(4)
521	(0)	1161	(2)
661	(0)	1189	(0)
692	(1)	1211	(0)
723	(1)	1301	(6b)
744	(1)	1340	(1)
722	(2b)	1366	(1)
810	(2b)	1433	(8b)
844	(3b)	1460	(6b)
870	(1)	2673	(1)
886	(3)	2732	(3)
898	(3)	2850	(10)
921	(1)	2897	(6b)
952	(1)	2936	(7)
971	(1)	2966	(8)

OKAZAKI: J. C. S. Japan, 60(1939) 559.

\* \* \* \* \*

n-Dodecane

195	(1)	964	(1)
218	(1)	1002	(0)
236	(2b)	1032	(1b)
308	(0)	1061	(3)
349	(0)	1078	(3)
397	(1)	1100	(0)
421	(1)	1129	(3)
453	(0)	1159	(1)
487	(0)	1300	(6b)
724	(1)	1341	(1)
749	(0)	1369	(1)
772	(1b)	1433	(7b)
805	(1)	1461	(5b)
817	(1)	2670	(0b)
845	(2b)	2718	(0)
872	(1)	2730	(3b)
893	(3)	2849	(10)
917	(0)	2896	(8b)
931	(0)	2936	(8)
955	(L)	2964	(9b)

OKAZAKI: Loc. cit.

\* \* \* \* \*

## ENCLOSURE (A)

n-Cetane

199	(1)	1063	(4)
215	(2)	1082	(5b)
231	(1)	1108	(0)
278	(0b)	1132	(4)
330	(0)	1165	(0)
356	(0)	1304	(7b)
404	(1)	1314	(2)
450	(0)	1344	(0)
724	(1)	1368	(1)
742	(0)	1435	(8b)
762	(0)	1460	(6b)
784	(0)	2673	(0b)
808	(0)	2713	(2)
839	(2b)	2730	(3)
871	(2)	2748	(10b)
894	(3)	2885	(8b)
962	(1)	2937	(8b)
997	(0)	2965	(6b)
1015	(0)		

OKAZAKI: Loc. cit.

\* \* \* \* \*

2,3-Dimethyl butene-2.  
(From pinacone B.P. 72.5 - 73.5)

131	(2)	1215	(2)
404	(1)	1378	(2)
502	(1)	1447	(2)
602	(0)	1665	(2)
686	(1)	2775	(1)
894	(1)	2853	(4)
1017	(1)	2903	(7)
1145	(7)	2997	(1)

MORI: So. Pap. Inst. Chem. Phy. Res. (TOKYO) 25(1934) 31.

\* \* \* \* \*

Cyclopentane

215	(1)	1484	(1)
284	(2b)	2553	(1)
713	(1)	2626	(1)
887	(10b)	2867	(10b)
1027	(4b)	2899	(4)
1168	(0b)	2941	(7b)
1280	(1b)	2970	(6)
1444	(5b)		

OKAZAKI: J. C. S. Japan, 60(1939) 559.

\* \* \* \* \*

## ENCLOSURE (A)

Cyclohexane $d_4^{20}$  0.7794;  $n_D^{20}$  1.4269B.P. 80.7/760.  $d_4^{20}$  0.7734;  $n_D^{25}$  1.4250 (MATSUNO) (from KAGEHIRA)

202	(1)	1485	(1)
382	(3d)	2347	(1d)
425	(4)	2463	(1)
699	(2b)	2534	(1)
767	(1)	2552	(1)
784	(1)	2600	(1b)
802	(10)	2628	(2)
833	(1d)	2663	(5b)
1026	(8)	2697	(3)
1154	(4)	2762	(0)
1264	(8)	2850	(10)
1342	(3)	2885	(3)
1405	(0)	2898	(2)
1425	(1)	2920	(8)
1444(10d)		2933	(8)
1465	(1)		

K. MATSUNO &amp; K. HAN; Bull. Chem. Soc. Japan, 11(1936) 321; OKAZAKI Loc. cit.

\* \* \* \* \*

Methyl cyclohexane  $d_4^{20}$  0.7710;  $n_D^{20}$  1.4238.

307	(1)	1264	(3)
335	(0)	1305	(2)
405	(3)	1344	(3)
444	(4)	1362	(1)
545	(3)	1398	(0)
751	(0)	1440	(4)
768	(10)	1458	(4)
801	(0)	1495	(0)
844	(4)	2359	(0)
972	(3)	2467	(0b)
1031	(6)	2661	(2b)
1056	(1)	2719	(1)
1087	(26)	2850	(10b)
1162	(3)	2891	(1)
1201	(2)	2926	(8b)
1246	(2)	2957	(1)

OKAZAKI: J. C. S. Japan, 60 (1939) 559.

\* \* \* \* \*

## ENCLOSURE (A)

1,2, Dimethyl cyclohexane  $d_4^{20}$  0.7862;  $n_D^{20}$  1.4320.  
(cis.+trans-mixture)

140	(0b)	1004	(4)
280	(0)	1053	(3)
310	(0)	1104	(3)
330	(1)	1161	(3b)
414	(3)	1220	(3)
440	(0)	1255	(5)
469	(0)	1300	(2)
498	(3)	1317	(2)
536	(2)	1353	(2b)
592	(1)	1374	(0)
729	(1)	1443	(6)
748	(3)	1460	(4)
784	(0)	2662	(1)
799	(0)	2725	(0b)
819	(0)	2850	(10b)
841	(3)	2873	(3b)
852	(0)	2890	(3)
919	(0)	2925	(10b)
943	(3)	2960	(3b)
975	(3)		

OKAZAKI: J. C. S. Japan, 60 (1939) 551.

\* \* \* \* \*

1,3, Dimethyl cyclohexane  $d_4^{20}$  0,7732;  $n_D^{20}$  1.4260.

155	(0b)	1006	(0)
251	(0)	1057	(5)
352	(0)	1077	(0)
370	(0)	1106	(0b)
406	(0)	1165	(0b)
418	(3)	1180	(1)
449	(1b)	1219	(1)
485	(0)	1267	(2b)
543	(3)	1302	(1)
621	(0)	1347	(2b)
750	(3)	1439	(3)
769	(4)	1459	(5)
797	(0)	2666	(0)
828	(0)	2720	(0)
845	(1)	2841	(8)
856	(0)	2865	(8b)
934	(0)	2890	(3)
955	(0)	2926	(10b)
980	(1)	2957	(5b)

OKAZAKI: J. C. S. Japan, 60 (1939) 559.

\* \* \* \* \*

## ENCLOSURE (A)

1,4, Dimethyl cyclohexane  $d_4^{20}$  0.7753;  $n_D^{20}$  1.4269.

125	(1)	1186	(2)
250	(0b)	1205	(2)
374	(4)	1248	(3)
431	(0)	1263	(3)
453	(2)	1305	(2b)
472	(3)	1346	(4b)
635	(2)	1437	(4)
759	(10)	1460	(6)
787	(2)	2667	(1b)
926	(0)	2721	(1)
953	(3)	2745	(0)
974	(1)	2846	(10b)
1002	(1)	2869	(5b)
1060	(5b)	2928	(10b)
1097	(1b)	2955	(5b)
1165	(3)		

OKAZAKI: Loc. cit.

\* \* \* \* \*

Benzene B.P. 80.5/760;  $d_4^{25}$  0.8728;  $n_D^{25}$  1.4992.

405	(1b)	1215	(0)
527	(0)	1405	(1)
606	(4)	1586	(3)
680	(0)	1605	(2)
800	(0)	2458	(1)
850	(3)	2512	(0)
907	(0)	2548	(1)
980	(2)	2925	(1)
992	(10)	2948	(4)
1007	(1)	3041	(5)
1036	(0)	3063	(8)
1148	(0)	3164	(2)
1176	(4)	3186	(3)

MIZUSHIMA, MORINO & OKAZAKI: J. C. S. Japan, 60 (1939) 289.

NISHIO: Jap. Jour. Phy. 4 (1930) 1.

MATSUNO & HAN: Bull. Chem. Soc. Japan, 11 (1936) 321.

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## ENCLOSURE (A)

Phenyl cyclonexane B.P. 92/5mm  $d_4^{25}$  0.9339;  $n_D^{25}$  1.5225. (from KAGEHIRA.)

106	(2b)	1048	(4)
141	(1d) ?	1082	(3b)
157	(1d) ?	1121	(3b)
238	(1d)	1155	(6d)
277	(6)	1175	(4)
360	(1d) ?	1198	(5)
380	(1)	1229	(4)
411	(1)	1262	(4)
437	(2)	1281	(6)
460	(2)	1297	(1)
621	(6)	1328	(1d)
741	(1d)	1349	(1d)
773	(5)	1440	(5)
827	(5)	1574	(1b)
839	(1d)	1597	(6)
862	(3)	1608	(5)
894	(2d)	2692	(1) ?
925	(1) ?	2852	(4)
995	(10)	2932	(4)
1002	(10)	3062	(3)
1030	(6)		

K. MATSUNO & K. HAN: B. C. S. Japan, 11 (1936) 321.

\* \* \* \* \*

Dicyclohexyl B.P. 94/10mm  $d_4^{25}$  0.8853;  $n_D^{25}$  1.4820 (from KAGEHIRA.)

102	(1d) ?	1038	(5b)
246	(1)	1083	(5)
318	(3b)	1118	(3d)
364	(1d)	1160	(3d)
435	(1)	1199	(2b)
480	(2)	1240	(2)
485	(2)	1267	(6d)
512	(1)	1351	(4)
766	(4)	1444	(8d)
787	(3)	1493	(1d)
801	(1)	2663	(1)
846	(5)	2853	(5)
958	(1)	2890	(2)
1002	(2)	2921	(8b)

K. MATSUNO & K. HAN: B. C. S. Japan 11 (1936) 321.

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## ENCLOSURE (A)

Naphthalene

(in Alcohol)

513	(5)
762	(5)
1027	(3)
1381	(10)
1463	(5d)
1581	(3)
3070	(5d)

(in Benzene)

514	(6)
764	(6)
778	(1) ?
1028	(4)
1382	(8)
1464	(4)
1577	(4)
3064	(8)

K. MATSUNO &amp; K. HAN: B. C. S. Japan, 11(1936) 321.

\* \* \* \* \*

Tetrahydro-naphthaleneB.P. 71-72/6mm  $d_4^{25}$  0.966;  $n_d^{25}$  1.5410 (from KAGEHIRA)

117	(5d)
164	(6b)
267	(4d)
318	(1d)
436	(6)
457	(4)
511	(4b)
585	(6)
704	(3)
728	(8)
746	(1)
766	(3)
808	(3)
822	(4d)
872	(3)
907	(2b)
941	(2d)
1040	(10)
1071	(4)
1117	(1d)
1164	(6b)

1205	(6)
1235	(3)
1284	(3)
1301	(3)
1345	(4)
1360	(4)
1385	(5)
1435	(6)
1452	(3)
1463	(3)
1496	(1b)
1583	(4)
1602	(6)
2674	(2b)
2713	(2d)
2866	(6)
2885	(6)
2914	(3d)
2994	(6b)
3029	(3d)
3044	(5)

K. MATSUNO &amp; K. HAN: B. C. S. Japan, 11. (1936) 321.

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## ENCLOSURE (A)

Indene

B.P. 62/10mm  $d_4^{25}$  0.9813;  $n_D^{25}$  1.5755 (TAKEDA)  
 T. HAYASHI: Sc. Pap. Inst. Ph. Ch. Res. 23 (1933) 274.  
 Purified Kahlbaum Substance; (182-2.5) 768;  $d_4^{12}$  1.0001  $n_D^{10}$  1.580.

204	(3d)	1609	(10)
379	(2)	2890	(4)
391	(2)	3036	(2b)
532	(8)	3066	(3b)
591	(6d)	3113	(2d)
730	(10)	206	(6)
762	(3d)	351	(0)
830	(5d)	380	(5)
841	(2)	515	(5)
860	(5)	577	(5)
912	(11)	710	(5)
923	(1d)	737	(4b)
944	(5b)	821	(5)
1018	(10)	924	(5)
1067	(6)	1003	(6)
1110	(6b)	1049	(5)
1152	(3d)	1099	(7b)
1204	(10)	1144	(3)
1225	(6d)	1190	(7)
1285	(5)	1276	(7b)
1310	(5b)	1343	(6)
1359	(10)	1379	(6)
1394	(8d)	1443	(6)
1457	(10)	1534	(8)
1490	(2)	1589	(10)
1550	(10)	2766	(3)
1587	(5)	3035	(4b)

K. MATSUNO & K. HAN: B. C. S. Japan, 11 (1936) 321.

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## ENCLOSURE (A)

1,2, Dihydro-naphthalene

B.P. 74.0-74.5 (6mm)

Hilger's constant deviation type dispersion 20 Å per mm near 4358 Å.  
Plates: Ilford Hypersensitive Panchromatic Plate.

148	(5)	1143	(5)
199	(5)	1202	(5)
264	(5)	1259	(5b)
397	(4)	1280	(4)
468	(4)	1332	(4)
530	(4)	1375	(4)
567	(4)	1472	(4)
665	(4)	1554	(5b)
726	(4b)	1618	(6b)
787	(4)	2759	(2)
865	(4)	2814	(3)
933	(4)	2919	(3)
1020	(4b)	3026	(3b)
1091	(4)		

HAYASHI: Sc. Pap. Inst. Phy. Ch. Res. 23 (1933) 274.

\* \* \* \* \*

Decahydro-naphthalene  
B.P. 63/9 d<sub>4</sub><sup>25</sup> 0.8847; n<sub>D</sub><sup>25</sup> 1.4770 (from KAGEHIRA)

152	(1b)	1020	(3)
297	(0)	1047	(4)
329	(2d)	1060	(3b)
356	(2)	1150	(1)
381	(2)	1170	(2)
408	(5)	1236	(1)
442	(1d)	1249	(4)
491	(4)	1260	(4)
601	(4)	1275	(4)
751	(6)	1353	(4d)
759	(5d)	1369	(4d)
802	(3)	1452	(6b)
856	(5)	2661	(3d)
876	(3)	2857	(8b)
932	(1d)	2896	(4)
990	(3b)	2916	(8b)

K. MATSUNO &amp; K. HAN: B. C. S. Japan, 11 (1936) 321.

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## ENCLOSURE (A)

Tetrahydro-acenaphthene

B.P. 98/5mm  $d_4^{25}$  1.0115;  $n_D^{25}$  1.5582 (from KAGEHIRA)

130	(3)	1095	(4)
161	(6b)	1116	(3)
220	(6)	1128	(3)
250	(4d)	1157	(3)
381	(4)	1185	(3)
402	(2)	1222	(6d)
456	(7)	1250	(3)
507	(4d)	1278	(5d)
568	(8)	1338	(5d)
591	(5)	1432	(8)
607	(1) ?	1452	(6)
650	(10)	1609	(7d)
723	(1d)	2490	(1d) ?
764	(2)	2593	(1) ?
799	(3)	2639	(1) ?
826	(1)	2666	(3b)
858	(2)	2840	(7b)
872	(1)	2856	(2)
939	(1)	2940	(5b)
953	(3)	3043	(5d)
1030	(5)	3069	(1d) ?
1061	(6)		

K. MATSUNO & K. HAN. Bull. Ch. Soc. Japan, 11 (1936) 321.

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Decahydro-acenaphthene

B.P. 80/5  $d_4^{25}$  0.9456;  $n_D^{25}$  1.5016 (from KAGEHIRA)

177	(2d)	1096	(6b)
326	(1)	1161	(0)
356	(1)	1212	(1) ?
372	(2d)	1236	(2)
432	(2)	1289	(5b)
498	(3d)	1371	(5b)
515	(1d)	1448	(8d)
547	(4)	1481	(4d)
595	(1)	2600	(1)
620	(3)	2663	(3d)
722	(6)	2677	(2) ?
754	(4)	2697	(2)
804	(1)	2748	(2d)
854	(3d)	2761	(2d) ?
910	(2)	2851	(4b)
950	(4)	2893	(4)
1025	(4)	2925	(6b)
1068	(8b)	2942	(6b)

K. MATSUNO & K. HAN: Bull. Ch. S. Japan, 11 (1936) 321.

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## ENCLOSURE (A)

Decahydro-pyrene

B.P. 160/5  $d_4^{25}$  1.0553.  $n_D^{25}$  1.5782 (from KAGEHIRA)

158	(2b)	1221	(5)
318	(1d)	1281	(10)
389	(2b)	1315	(2)
412	(0d)	1339	(1)
525	(2)	1361	(3d)
557	(1)	1435	(6b)
587	(2b)	1579	(1d)
614	(1)	1604	(3d)
642	(0d)	2826	(4)
810	(0)	2861	(2b)
891	(4)	2934	(5b)
1061	(6b)	3085	(3)
1097	(6b)		

K. MATSUNO & K. HAN: Bull. Chem. Soc. Japan, 11 (1936) 321.

\* \* \* \* \*

Perhydropyrene

B.P. 164/10  $d_4^{25}$  0.9875;  $n_D^{25}$  1.5225 (from KAGEHIRA)

261	(1d)	1009	(1)
294	(1)	1032	(1)
322	(2)	1056	(4)
351	(3)	1092	(3)
372	(2d)	1148	(4b)
420	(4b)	1159	(3b)
426	(4b)	1217	(1)
464	(4b)	1229	(4d)
490	(1)	1248	(3d)
532	(1)	1291	(1b)
563	(3)	1327	(0)
634	(1b)	1348	(1)
678	(1d)	1357	(4b)
743	(4)	1444	(4d)
790	(2)	2820	(3)
833	(2)	2853	(3)
862	(2)	2912	(4b)
969	(1)	2938	(4b)
	?		

K. MATSUNO & K. HAN: Bull. Chem. Soc. Japan, 11 (1936) 321.

\* \* \* \* \*

## ENCLOSURE (A)

Cedrene B.P. 116-7/10mm  $n_D^{30}$  1.4943.  
 Dehydration of Cedrol.  
 (see Bull. Sc. 9 (1934) 327)

87 (2b)		938 (6b)
124 (Od)	?	965 (5b)
144 (4b)		986 (3d) ?
189 (3b)		1001 (5d)
237 ( $\frac{1}{2}$ d)		1024 (2)
260 (4b)		1038 (3)
(288) (0)		1066 (6)
308 (4)		(1087) (2)
317 (3)		1105 (2d)
340 (1)		1127 (5b)
(364) (2)		1143 (6b)
389 (3b)		1167 (6b)
410 (3)		1201 (6b)
437 (2d)		1219 (2)
454 (2d)		1237 (3b)
491 (3)		1275 (5)
532 (5)		1297 (5)
571 (8)		1325 (2d)
587 (4)		1350 (5)
611 (4)		1375 (5)
630 (2)		1434 (8)
656 (3)		1452 (8)
698 (3)		1475 (6b)
733 (8b)		(1646) ( $\frac{1}{2}$ ) ?
780 (8)		1666 (10)
802 (2)		2830 (2b)
819 (6)		2875 (2)
(833) ( $\frac{1}{2}$ )		2915 (6b)
850 (4b)		2937 (6b)
(873) ( $\frac{1}{2}$ d)		2967 (6b)
915 (5b)		3030 (2d)

K. MATSUNO: Bull. Chem. Soc. Japan, 10 (1935) 220.

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## ENCLOSURE (A)

B.P. 120-3/12mm  $d_4^{34}$  0.92386:  $n_D^{34}$  1.4883  $a_D$  D-86.31°  
*Sesquichamenea*  
Leaves Arisan Hinoki Chamaecyparis obtusa, Siebe. Zucc. of  
Formosana Hayata (K. KAFUKU & T. NOZOE, B. C. S. Japan 6(1931) 111.

91 (3b)	1022 (1d)
132 (3b)	1042 (2)
254 (3d)	1058 (2)
280 (3)	1100 (3b)
302 (2d)	1119 (3b)
336 (2d)	1155 (6b)
360 (5d)	1186 (1)
386 (5d)	1192 (4)
407 (1)	1208 (1)
434 (4)	1263 (4)
496 (3)	1296 (4)
539 (3)	1322 (2b)
572 (3)	1346 (2)
590 (8)	1375 (4)
604 (4)	1398 (4)
684 (1)	1434 (5)
770 (6)	1453 (4d)
814 (5)	1471 (4)
843 (1d)	1647 (1)
882 (4b)	1680 (10)
907 (4d)	2844 (4b)
926 (1d)	2869 (3b)
934 (2)	2908 (6b)
954 (4)	2966 (2b)
964 (4)	3006 (5b)
988 (1d)	3084 (1)
1006 (4)	3167 (4)

K. MATSUNO & K. HAN. B. C. S. Japan 11 (1936) 576.

\* \* \* \* \*

B.P. 162°,  $d_4^{17.5}$  0.8442:  $n_D^{20}$  1.4681  $a_D$  + 72  
*d, Sabinene*  
Leaves Arisanhinoki (K. KAFUKU. T. NOZOE & C. HATA, B. C. S. 6 (1931) 40.

120 (5b)	1031 (5)
169 (2b)	1067 (4)
214 (1)	1109 (6b)
306 (3)	1145 (4d)
333 (1)	1170 (3d)
362 (3d)	1197 (6)
373 (1)	1214 (1d)
441 (3)	1270 (4b)
491 (1d)	1308 (4b)
509 (3)	1379 (5d)
566 (2)	1415 (8)
634 (3d)	1438 (4d)
655 (5)	1447 (5d)
785 (5)	1468 (4d)
808 (4d)	1656 (10b)
866 (4b)	2830 (4)
882 (2d)	2913 (2)
915 (6d)	2940 (2)
930 (1)	2964 (6)
954 (6b)	2996 (4b)
989 (3)	3070 (4b)

K. MATSUNO & K. HAN. B. C. S. Japan 11 (1936) 576.

## ENCLOSURE (A)

a-d<sub>2</sub> Pinene   
 B.P. 155-6 d<sub>4</sub><sup>20</sup> 0.8585; n<sub>D</sub><sup>20</sup> 1.4671; [α]<sub>D</sub><sup>+45.25</sup>  
 Root-oil, CHAMAECYPARIS OBTUSA SIEBE. Zucc. of Formosana Hayata (HINOKI)

134	(3b)	1042	(3d)
208	(2b)	1085	(3)
261	(3d)	1125	(2)
306	(2d)	1163	(4)
333	(0)	1183	(3b)
388	(3b)	1223	(3b)
426	(2)	1264	(4b)
465	(2)	1308	(2)
488	(3)	1328	(3b)
564	(4)	1374	(3d)
620	(3)	1433	(5d)
667	(6)	1444	(3b)
774	(4)	1468	(2)
822	(2)	1660	(6)
844	(5)	2833	(4d)
885	(1)	2874	(4b)
905	(3)	2912	(5b)
930	(1)	2951	(3b)
953	(3b)	2988	(5d)
998	(0)	3051	(4b)
1015	(1d)		

K. MATSUNO & K. HAN. Bull. Ch. Soc. Japan, 11 (1936) 576.

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**RESTRICTED**

**ENCLOSURE (B)**

**ENCLOSURE (B)**

**DATA ON THE THERMAL CRACKING  
OF PURE HYDROCARBONS**

obtained from  
**Professor A. IBUKI**

## ENCLOSURE (B)

Sample	De-compo-sition temp. (°C)	Percent of gaseous products	Reac-tion time (min)	Pressure of vessel** (mm Hg)	Composition of gaseous products (vol%)			
					C <sub>2</sub> H <sub>2</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>n</sub> H <sub>n</sub>	C <sub>n</sub> H <sub>2n+2</sub>
Cyclohexane	550	41.9	10	92	4.3	27.5	8.1	13.5
	550	43.3	60	110	5.7	15.8	4.2	11.1
2,3 dimethyl butane	502	15.6	10	174	1.2	16.4	11.9	4.9
	497	41.0	60	162	1.2	25.6	7.2	5.3
2,2 dimethyl butane	485	5.1	10	210	0.6	18.1	6.3	8.3
	484	27.0	60	210	1.4	29.7	4.8	6.7
n-hexane	44.3	2.5	10	120	1.9	30.5	12.9	1.4
	44.5	16.7	60	120	2.6	43.2	7.0	2.0
2 methyl pentane	460	13.5	60	140	1.5	32.1	9.2	3
	462	4.9	10	54	1.0	23.9	10.4	7.6
2 ethyl pentane	468	18.7	60	50	0.4	31.2	5.0	5.2
								58.2

\* n = Average number of carbon atoms in saturated hydrocarbons.

\*\* Just before decomposition.

## ENCLOSURE (B)

Sample	De-composition temp. (°C)	Percent of gaseous products	Reac-tion time (min)	Pressure of vessel** (mm Hg)	Composition of gaseous products ( vol %)						
					C <sub>2</sub> H <sub>2</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>n</sub> H <sub>m</sub>	CO	H <sub>2</sub>	C <sub>n</sub> H <sub>2n+2</sub>	n*
Cyclopentane	566	18.5	10	204	5.2	51.5	12.2	14.0	17.1	2.3	2.3
	560	45.6	30	225	2.8	42.8	2.3	15.6	36.5	2.0	2.0
	565	24	60	215	1.7	33.3	8.3	15.4	41.4	1.9	1.9
Cyclopentene	500	7.5	10	205	15.2	32.7	1.6	41.3	9.2	1.7	1.7
	506	11.5	30	203	10.1	27.8	3.3	13.6	15.2	1.5	1.5
	507	12.0	60	235	5.0	24.1	3.5	43.6	23.8	1.4	1.4
Cyclopentanol	482	1.3	10	21	8.9	36.6	4.5	3.1	39.7	7.2	1.8
	490	6.9	30	20	15.7	35.7	5.6	6.4	28.4	8.5	1.7
	507	12.0	60	20	10.7	30.2	5.1	8.0	25.5	19.0	1.3
Cyclopentone	530	11.9	10	19	6.4	41.6	8.5	25.1	9.4	9.0	1.9
	530	41.2	30	19	1.6	26.4	5.5	37.1	10.5	18.9	1.7
	540	47.0	60	20	2.0	19.3	4.3	35.3	14.8	24.6	1.8
Cyclohexane	550	41.9	10	92	4.3	27.5	8.1	13.5	46.5	2.0	2.0
	550	43.3	60	110	5.7	15.8	4.2	11.1	63.2	1.7	1.7
	496	5.9	10	55	16.4	61.4	0	7.7	14.5	1.4	1.4
Cyclohexene	499	13.6	60	54	8.4	39.0	7.5	14.7	30.4	1.4	1.4

\* n - Average number of carbon atoms in saturated hydrocarbons.

\*\* Just before decomposition.

## ENCLOSURE (B)

Sample	De-composition temp. (°C)	Percent of gaseous products	Reaction time (min)	Pressure of vessel: (mm Hg)	Composition of gaseous products (vol %)						
					C <sub>2</sub> H <sub>2</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>n</sub> H <sub>m</sub>	CO	H <sub>2</sub>	C <sub>n</sub> H <sub>2n+2</sub>	n*
Cyclohexanol	501	4.0	16	3	0.8	41.6	5.4	9.7	26.5	16.5	1.6
	503	30.0	60	3	4.0	37.2	4.7	15.3	13.6	25.2	1.4
Cyclohexone	560	32.2	10	13	1.4	57.0	1.0	26.0	7.1	7.5	1.4
	556	52.0	60	15	1.6	24.2	2.3	29.4	6.3	36.2	1.4
Tertiary Butyl Benzene	498	2.8	10	8	1.4	27.6	6.4	17.0	47.6	1.0	
	497	10.0	60	9	0.9	20.5	4.6	11.9	62.1	1.2	
	500	23 (790°)		9	0.9	6.7	6.7	27.7	64.7	1.0	
Isopropyl Benzene	506	2.3	10	11	1.5	11.7	3.4	38.7	44.7	1.0	
	507	6.4	60	15	2.3	11.3	3.8	26.7	55.9	1.0	
Ethyl Benzene	535	1	10	20	2.1	18.8	5.5	43.7	29.9	1.0	
	535	3	60	14	1.1	11.2	5.0	38.2	44.5	1.0	
Toluene	600	6	10	31	1.5	3.0	2.6	31.2	61.7	1.0	
	720	12 (740°)		33	2.7	2.6	2.0	38.7	54.0	1.0	
	600	1 (635°)		37	2.3	17.6	5.9	31.4	42.8	1.0	
	720										
Benzene	750	1	60	90	2.7	1.0		96.3			

\* n = Average number of carbon atoms in saturated hydrocarbons.

\*\* Just before decomposition.

**RESTRICTED**

**ENCLOSURE (C)**

## ENCLOSURE (C)

LIST OF JAPANESE DOCUMENTS PERTAINING TO HYDROCARBON RESEARCH  
OBTAINED FROM THE FIRST NAVAL FUEL DEPOT, OFUNA

(Forwarded to the Washington Document Center via ATIS. ATIS No. 4584)

<u>NavTechJap No.</u>	<u>Title</u>	<u>Author</u>	<u>Year</u>
ND26-0013.1	Cracking by Heat. (Thermal)	S. KOMATSU	Jan. 1929.
13.2	Gas Analysis for Acetylene, Ethylene, Benzene Mixtures.	T. FUJIO A. SHIRAI	Sept. 1929.
13.3	Combustion.	N. ISOGAI	Aug. 1930.
13.4	Hydrocarbons.	M. AKITA	Dec. 1932.
13.5	Influence of non-Combustible Gas on the Combustion of Hydrocarbons.	E. ISOGAI	Mar. 1933.
13.6	Heat of Vaporization.	M. AKITA	Aug. 1933.
13.7	Quantitative Analysis of Hydro- carbons.	M. AKITA	Dec. 1933.
13.8	Studies on the Combustion of Hydro- carbons under Constant Volume. Part II. Combustion of Aromatic Hydrocarbons.	M. AKITA S. IGASAKI	June 1934.
13.9	Relation between the Residual Gas of Flame and Explosive Limits of Gas.	M. AKITA N. ISOGAI	Apr. 1935.
13.10	Physical Properties of Pure Hydro- carbon Mixtures.	S. YAMAGUCHI K. MITSUI	July 1937.
13.11	Studies on the Catalytic Action of Metallic Oxide on Decane and Dealine.	A. YAMAOKA	Dec. 1941.
13.12	On the Synthesis of Decane.	A. YAMAOKA	Dec. 1941.
13.13	On the Chemical Analysis of Gaseous Olefines by Means of Sulphuric Acid.	Y. YAMALIA	Dec. 1941.
13.14	The Explosion Limit of Hydrocarbons under High Pressure and the Mechanism of Combustion.	H. HONDA	Mar. 1942.
13.15	Separation of Gaseous Hydrocarbons by Liquefaction.	T. TANAKA	Feb. 1943.
13.16	On the Molecular Volume of Hydro- carbons.	H. ASADA	Oct. 1943.

## ENCLOSURE (C)

<u>NavTechJap No.</u>		<u>Author</u>	<u>Year</u>
ND26-0013.17	On the Measurement of the Mean Molecular Weight of Gasoline	H. ASADA	Oct. 1943.
13.18	On the Chemical Analysis of Gas Oil.	K. KOBAYASHI	Sept. 1943.
13.19	On the Raman Spectra Analysis of the Bahrein Gasoline.	S. MIZUSHIMA T. WADA	Nov. 1943.
13.20	The Raman Effect and Its Application.	R. TOKUHIRO	Nov. 1943.
13.21	On the Raman Spectra-Analysis of the Sanga Sanga Gasoline.	S. MIZUSHIMA T. TOBIYAMA	Jan. 1944.
13.22	On the Combustion of Butane and Isobutane.	M. HAGIHARA H. HONDA	Jan. 1944.