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# ROTATORY POWERS OF VARIOUS DIALKYL-SUBSTITUTED

## ESTERS OF $l$-MENTHOL

By

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Examiner. Prof. Read

Thesis for the Degree of Ph.D.

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# CONTENTS.

# INTRODUCTION.

## Optical Activity and the Polarity
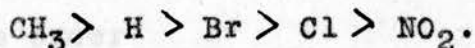## of Substituent Groups.

The chemical enquiry into the nature of optical
activity has in the main been approached by selecting
a particular molecular model, to which one or   more
asymmetric groups are attached, and determining  the
effect upon the rotatory power of introducing  one or
more substituents.

Tschugaeff (Compt. Rend., 1895, 120, 152)
examined the rotatory powers of a homologous series of
esters, and discovered that the removal of the   active
group further and further from the asymmetric centre
had the result of reducing its effect on the rotation
to an almost constant value.   Similar conditions
according to Cohen (Organ. Chem.II, 1924, 241) deter-
mine the large variation in the rotation of $\ell$-menthyl
benzoate when different substituents are present in
the benzene nucleus:  that is to say, the substituent
nearest to the asymmetric centre usually produces the
greatest change.

A great number of investigations have   been
carried out in order to ascertain whether the influence
of active groups or substituents on the rotatory

power of a compound bears any relation to their influence on other properties of the compound.

Flurscheim (J.C.S.,1909, 718) pointed out that substituents could be placed in a more or less well-defined series according to their influence on the dissociation constants of acids and bases; and Olivier (Rec. Trav. Chim., 1914, $\underline{33}$, 244) showed that the influence of radicals on the rate of formation of sulphones from p-bromobenzene sulphonyl chloride and a substituted benzene in a Friedel-Crafts synthesis (the benzene substituents all being present in the para position) was in the order

$$CH_3 > H > Br > Cl > NO_2.$$

A further study by the same investigator of the influence of substituents in the benzene ring on the ease of hydrolysis of the chlorine atom in benzyl chloride gave the following sequence of radicals for the para derivatives:-

$$CH_3 > H > I > Br > Cl > COOH > NO_2.$$

The work of Betti (1907-1923) showed a similar relationship between the influence of substituents on the rotatory power of a certain Schiff's base, and their influence on other properties of compounds.

He prepared the optically active compound by condensing the base d-$\beta$-naphthol benzylamine with benzaldehyde and substituted benzaldehydes, and found

that these bases on being arranged in decreasing order of rotatory power gave a series agreeing closely with that representing the dissociation constants of the benzoic acids corresponding to the aldehydes employed. (The results are summarised in Trans. Faraday Soc., 1930, 26, 337).

Rule and Paterson (J.C.S., 1924, 125, 1121) have pointed out that a series of radicals similar to that obtained by Olivier and others could be constructed from the values of the dielectric constants of compounds of the type $C_6H_5X$ where X is the variable substituent. The influence of substituents in this case is in the order

$$NO_2 > CN > COOH > CHO > Cl > Br > C_2H_5 > CH_3 > H.$$
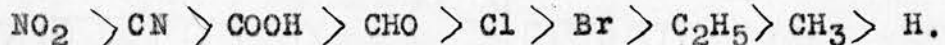
Considerations such as these have led to the conclusion that the similarity of substituent effect in all these cases is to be traced to a fundamental electrical change in the molecule due to the presence of substituent group. In the majority of cases the relative influence of a number of common substituents approximates to the following series:-

$$NO_2, CN, COOH, halogens, OCH_3, H, CH_3, N(CH_3)_2.$$
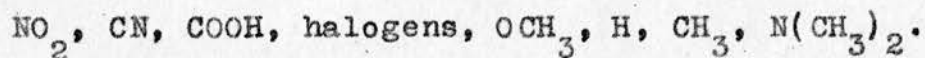
This type of substituent effect has been called the "general polar effect", (Robinson, Ann. Rep.Chem. Soc., 1922, 98); and the substituents arranged in that order are referred to as the "general polar

series".

An important contribution to this problem of
polarity was made by Sir J.J.Thomson (Phil. Mag.,1923,
<u>46</u>, 497). The introduction of a polar group into a
hydrocarbon molecule was compared to the insertion of
an electrostatic doublet. It was suggested that the
substituents were divisible into two classes (i) those
which require an electron to form a complete octet (OH,
$NH_2$, $CH_3$ and halogens) and (ii) those which have one
electron over after completion of the octet ($NO_2$,COOH,
CHO and CN). The relative magnitude of these electro-
static doublets could be determined irrespective of
sign by comparing the molecular inductive capacities
for long wave lengths of the organic compounds RX
where R is a hydrocarbon radical and X the variable
substituent. The hypothesis was advanced that the
magnitude in question is a vector property, and that
for disubstituted benzenes containing two substituents
of similar type the doublets will reinforce one another
in the ortho position, and tend to neutralise one
another in the para position: the reverse holding
true for doublets of dissimilar type. These suggest-
ions were only partly confirmed by R.N. Kerr, (Phil.
Mag., 1927, 331).

A great number of recent investigations have
been directed towards the determination of the "dipole

moments" of compounds. The electrical centre of the
electrons in a molecule does not in general coincide
with the electrical centre of the nuclei;  and  the
distance between these poles multiplied by the charge
on one of them is defined as the dipole moment, which
can be calculated from data referring to the dielectric
constant and refractivity of the compound.   Recent
researches by C.P. Smyth, J.W. Williams, K. Hojendahl,
J. Errera and others indicate that the dipole moment
is a characteristic of the substituent group and large-
ly independent of the hydrocarbon radical to which it
is attached.   It has been concluded from investiga-
tions by these authors that substituents may be divided
into two classes in agreement with the older ideas of
electronegative (1) and electropositive radicals (2),
e.g. (i) $NO_2$, OH, COOH, Cl, Br, I and $OCH_3$ and (ii)
$CH_3$, $NH_2$, $N(CH_3)_2$.   This classification therefore
replaces that formerly given by Sir J. J. Thomson.
From the dipole moments found for different substituents
it is possible to construct a series in which we pass
from a strongly electronegative group through hydrogen
towards groups of increasingly electropositive character:-

$NO_2$, OH, halogens, $OCH_3$, H, CH , $N(CH_3)_2$, $NH_2$.

The great similarity between this series  and
that representing the influence of substituents  on
the dissociation of carboxylic acids, chemical  re-

activity and the optical rotatory powers of the sube
stituted series of compounds prepared by Betti will
at once be apparent.

During recent years Rule and his co-workers
have supplied much evidence to show the validity of
the general polar series in predicting the effect of
substituents on the optical rotatory power of certain
types of compound. This is illustrated by the
following table compiled by Rule, Thompson and
Robertson (J.C.S., 1930, 1889) in which a number of
$l$-menthyl esters of mono-substituted acetic acids,
$X.CH_2COOH$, are arranged in order of increasing magni-
tude of rotatory power in the homogeneous state. The
dipole moments, $\mu$, corresponding to the substituent
groups, the dissociation constants of the parent acids
Ka, and figures recorded by Tasman (Rec. Trav. Chim.,
1927, 46, 653) for the speed with which the phthalide
ring in 5-substituted phthalides is opened by alkalis,
being added for comparison.

TABLE I/

## TABLE I.

| X | $[M]_D^{20}$ | $Ka \ 10^5$ | $\mu \times 10^{18}$ e.s.u. | phthalide opening |
|---|---|---|---|---|
| N(Et)$_2$ | -154.6° | small | - | - |
| N(Me)$_2$ | -156.9 | | +1.4 | 0.31 (NH$_2$) |
| H | -157.3 | 1.8 | - | 1.00 |
| CH$_3$ | -160.2 | 1.4 | +0.4 | - |
| COOH | -160.2 | 160 | -0.9 | - |
| OEt | -160.6 | 23 | - | - |
| OMe | -165 | 33 | -1.2 | - |
| OH | -165 (at 94°) | 15 | -1.7 | - |
| Br | -169 | 138 | -1.5 | 1.53 |
| Cl | -171 | 155 | -1.5 | 1.32 |
| CN | -174 | 370 | -3.8 | 5.71 |

The mode of propagation of the general polar influence has provided material for much discussion. In all probability it is transmitted by two methods (i) directly through space and (ii) by displacement or shift of the valency electrons along the chain of atoms attached to the substituent, the shift being towards electronegative groups such as NO$_2$ and COOH, or away from electropositive groups such as CH$_3$ or NH$_2$. Electronegative groups are generally assumed to be groups having the positive end of the dipole situated

nearest to the attached hydrocarbon chain, and electro-
positive groups to have the reverse arrangement.   This
explanation is thought to be the most probable, although
no method for determining the absolute orientation of
a dipole in space has yet been evolved.   Also, it is
a well-known fact that the dissociation constant of
acetic acid is increased when hydrogen is replaced by
chlorine and depressed when replaced by $CH_3$ or $NH_2$.
The explanation on the basis of chlorine and methyl
representing oppositely orientated dipoles is thus
clearly demonstrated:-

$$\overset{-}{Cl}.\overset{+}{CH_2}.COO \qquad H \qquad\qquad \overset{+}{CH_3}.\overset{-}{CH_2}.COO \qquad H$$

Electron attracted by Cl          Electron repelled by $CH_3$
  facilitating ionisation            repressing ionisation.
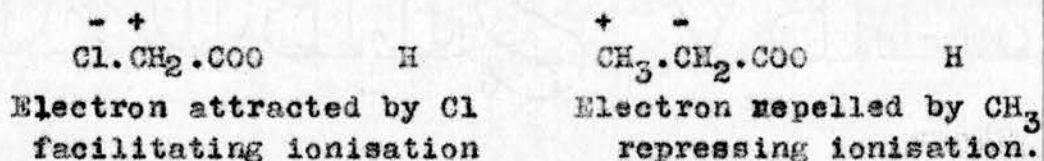
    When we examine the rotatory powers of $l$-menthyl
esters, in particular substituted aromatic esters, we
find in addition to the general polar type of influence
already discussed a second type of substituent effect
in operation.   From considerations of polarity an
abnormal influence is exerted in the ortho position in
the benzene ring by certain electronegative substituents
(e.g. Cl, Br, $OCH_3$).   These substituents lower  the
rotation in the ortho position although they raise the
rotatory power of acetic esters.   The following table
shows values of the rotatory powers of various $l$-menthyl
esters of ortho-substituted and para-substituted

benzoic acids.

TABLE II/.

## TABLE II.

| Ortho series $[M]_D^{20°}$ | Substituent | Para series $[M]_D^{20°}$ | Substituent |
|---|---|---|---|
| -381° | $NO_2$ | -237.5° | $NO_2$ |
| -332 | COOH | -239 (100°) | -O.$CH_3$ |
| -239 | H | -237 | Cl |
| -231 | $CH_3$ | -237 (100°) | $CH_3$ |
| -205 | Br | -239 | H |
| -195 | Cl | -233 (100°) | H |
| -148 | O.$CH_3$ | | |

Rule (J.C.S., 1924, 125, 1121) has pointed out that amongst the ortho-substituted benzoic esters of $l$-menthol, in general, a substituent which is meta directive in benzene substitution raises the rotatory power, and one of ortho-para directive type lowers the value.   The following table is extracted from a paper by Rule, Hay, Numbers and Paterson (J.C.S., 1928, 180) and shows the values of $[M]_D^{20°}$ for $l$-menthyl and $l$-octyl ortho-substituted benzoic esters;   also the percentage of meta and para products obtained on nitration of the corresponding substituted benzenes:-

### TABLE III/

## TABLE III.

| Substituent X | $l$-octyl $[M]_D^{20°}$ | $l$-menthyl $[M]_D^{20°}$ | Nitration of $C_6H_5X$ %m | %p |
|---|---|---|---|---|
| $NO_2$ | -122° | -381° | 93 | 0.4 |
| COOH | -90 to -117 | -332 | 76 | 1.2 |
| H | -77.8 | -239 | - | - |
| $CH_3$ | -68.1 | -231 | 3.1 | 41 |
| I | -44.3 | -237 | - | 66 |
| Br | -49.2 | -205 | 0.3 | 62 |
| Cl | -47.1 | -195 | - | 70 |
| $O.CH_3$ | -33.0 | -148 | chiefly o and p. | |

The magnitude of the change produced by the above substituents in the ortho position is thus found to agree closely with the orientating power of the groups as deduced from the proportion of meta and ortho-para derivatives formed on nitration. The approximate influence of ortho substituents has been summarised by Rule and co-workers (J.C.S., 1928, 178) as follows:-

$(\overset{+}{NH_3})$, $NO_2$, COOH, $CH_3CO$, H, $CH_3$, I, Br, Cl, $OCH_3$, $(\overset{-}{COO})$.

where those to the right of hydrogen lower the rotation and those to left raise it. The exact positions of the ionised complexes are indefinite. With reference to these charged groupings Rule (J.C.S., 1927, 54) has

already drawn attention to the changes observed  in the optical activity of certain acids and bases  on ionisation, pointing out that the characteristic influence of COOH and $NH_2$ often tends to be reversed when these are present as ionic complexes in the form of salts.

Similar changes produced by ionisation have also been traced among optically active aliphatic esters, but the lower rotatory powers caused by the introduction of halogens and menthoxyl appear to be a characteristic of o-substituted aromatic esters and are not found in the corresponding meta or para derivatives, or in the esters of mono-substituted acetic acids.

From the occurrence of a different type of influence in ortho derivatives it has been suggested that the method of transmission of a polar influence may be directly through space as well as along the chain of intervening carbon atoms.  The fact that the optical effect of the substituent on the rotatory power seems related to the directive power of the group  in benzene substitution is of great interest in the light of suggestions made by Ingold (Ann. Rep. Chem. Soc., 1928, 140) concerning the transmission of orientating effects in the benzene ring.  Ingold advances the theory that a given electrochemical group may influence benzene substitution by a direct action through  space

as well as by causing a shift throughout the chain of atoms.

The **investigation** of the rotatory powers of $l$-menthyl naphthoic esters by Bretscher, Rule and Spence (J.C.S., 1928, 1493) revealed further evidence in favour of this spatial influence as the following table shows:-

## TABLE IV.

| $l$-Menthyl Naphthoates $[M]_{5461}^{20°}$ in benzene. | | | | | |
|---|---|---|---|---|---|
| 1-naphthoates | | 2-naphthoates | | Peri-derivatives | |
| unsubstit. | -319° | unsubstit. | -288° | 8 - NO$_2$ | -841° |
| 2 - CH$_3$ | -99.6 | 1 - O.CH$_3$ | -268 | | |
| 2 - O.CH$_3$ | +45.3 | 3 - Cl | -275 | 8 - Cl | -172 |
| | | 3 - O.CH$_3$ | -206 | 8 - OCH$_3$ | -157 |
| Value of $[M]_D^{20°}$ | | | | | |

The abnormal depressive effect of the ortho-para directive substituents is exhibited in the several ortho derivatives of the $\alpha$- and $\beta$-naphthoic esters, and also when the groups are in the peri position. The similarity of the effect produced in the peri position to that obtained in the ortho substituted benzoic esters is noteworthy. Probably the most obvious explanation of this behaviour lies in the spatial proximity of the ortho and peri substituents to the ester grouping. A reasonable hypothesis is

that the anomalous behaviour of these groups with
respect to the general polar series is due to  the
direct propagation of an influence through space,
this influence (owing to the peculiar arrangement of
the o-substituents to each other) acting in an opposite
sense to that transmitted through the chain.
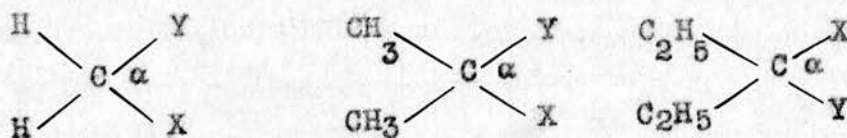
## Homologous Series.

Another important type of influence was dis-
covered by Frankland (J.C.S., 1899, 75, 368) in
examining the molecular rotatory powers of a homologous
series.   Frankland studied the rotation phenomena
exhibited more particularly in the ascent of a homolo-
gous series and found that in certain cases there was
a slight rise in rotation to a maximum followed by a
fall;   in others a fall to a minimum followed by  a
rise, the final fall or rise becoming more or  less
asymptotic.   Frankland observed that this periodic
rise or fall in the rotation occurred when the carbon
chain contained five or a multiple of five carbon
atoms.   This "growing chain" effect, which was later
again examined by Pickard and Kenyon (J.C.S., 1911, 99,
46), was explained by Frankland as being due to  the
chain returning upon itself, in accordance with
Baeyer's Strain Theory and the commonly accepted views
of stereochemistry.

Similar conclusions have been arrived at  by

numerous other investigators from considerations not
only of optical activity but of a large number  of
other properties such as static friction, adhesion,
cohesion, surface tension, surface pressure and
electrical properties of monomolecular films on water,
viscosity, dissociation constants, magnetic rotation,
toxicity, etc. [summarised by Lee,(Trans. Faraday Soc.,
1927, 634)].

A **very interesting investigation** of the growing
chain effect has been carried out by Rule, Hay  and
Paul (J.C.S., 1928, 1347) in the case of a number of
homologous $l$-menthyl alkyloxylic acetic esters and
$l$-menthyl hydrogen dicarboxylic esters.   The results
were interpreted as showing that the growing chain
effect due to the return of the carboxyl group is in
the opposite sense to that due to the return of the
alkoxyl group.   This conclusion is in agreement with
the behaviour of the groups in the ortho-substituted
benzoic esters.

By making use of the valency deflexion theory
advanced by Thorpe and Ingold (J.C.S., 1921, 305),
Rule and Harrower (J.C.S., 1930, 2319) sought to
obtain further evidence bearing on a space effect.
In a series such as:-

$$\begin{array}{ccc}
\begin{array}{c} H \\ \phantom{x} \\ H \end{array}\!\!\searrow\!\!\begin{array}{c} Y \\ C_\alpha \\ X \end{array}\!\!\swarrow &
\begin{array}{c} CH_3 \\ \phantom{x} \\ CH_3 \end{array}\!\!\searrow\!\!\begin{array}{c} Y \\ C_\alpha \\ X \end{array}\!\!\swarrow &
\begin{array}{c} C_2H_5 \\ \phantom{x} \\ C_2H_5 \end{array}\!\!\searrow\!\!\begin{array}{c} X \\ C_\alpha \\ Y \end{array}\!\!\swarrow
\end{array}$$

the replacement of the relatively compact methylene
group by gem-dialkyl groups of increasing bulk leads
to the substituents X and Y being forced into closer
contact, thus bringing about definite and predictable
changes in chemical and physical properties. [Ingold
(J.C.S., 1921, 119, 308;  1928, 1598;        and
Ingold (J.C.S., 1926, 10;  1929, 1692)].   The actual
change in the angle $\alpha$ is assumed to be a matter of a
few degrees only (Ingold, loc.cit) e.g. from 115° to
109°.   By suitably substituting for X and Y these
structural modifications were shown by Rule and Harrower
(loc.cit.) to become evident in the optical properties
of the compounds.   These authors prepared a series of
optically active menthyl esters of the type:-

$$R_2C \diagup \mathrel{\mathop{\diagdown}} \begin{matrix} COOC_{10}H_{19} \\ X \end{matrix}$$
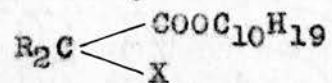
where X is either $COOH$, $OCH_3$, $(\overline{COO})$ or $COOC_{10}H_{19}$ and
R = H, $CH_3$ or $C_2H_5$.   The results are tabulated below:-

TABLE V./

Rotatory Powers, $[M]_{5461}^{20°}$, for $l$-Menthyl Esters, $CR_2\diagup^{COOC_{10}H_{19}}_{\diagdown X}$

## TABLE V.

| Substit. X | State | R = H | R = Me | R = Et |
|---|---|---|---|---|
| $CO_2C_{10}H_{19}$ | Homog. | −311° | −271.9° | −279.1° |
| $CO_2H$ | " | 189.9 | 205.0 | 224.7 |
| OMe | " | 195.3 | 197.9 | − |
| $CO_2C_{10}H_{19}$ | Benzene (C=5) | 324 | 293 | 259 |
| $CO_2H$ | " | 188 | 199 | 213 |
| OMe | " | 184 | 190 | 201 |
| $CO_2C_{10}H_{19}$ | Alcohol (C=5) | − | 321 | 315 |
| $CO_2H$ | " | 193 | 203 | 215 |
| $CO_2Na$ | " | 185 | 164 | 166 |
| OMe | " | 196 | 214 | − |

The increasing proximity of X and $COOC_{10}H_{19}$ resulting from the changes $CH_2 \longrightarrow C(Me)_2 \longrightarrow C(Et)_2$ leads to a marked fall in the rotation of the dimenthyl malonates ($X = CO_2C_{10}H_{19}$); to a rise in the values of the hydrogen malonates ($X = COOH$); and to a fall in those of the corresponding sodium salts ($X = COONa$).

Extrapolated from values at 70°, 90°, etc., recorded by Hall (J.C.S., 1923, 123, 110).

Rule, Hay and Paul (J.C.S., 1928, 1348).

Rule and Smith (J.C.S., 1925, 127, 2188).

The depressions following the conversion of the acids
into their sodium salts increase continuously in
magnitude from the malonate to the diethyl malonate.
All these observations are in agreement with the
influence of the substituents X in the para and ortho
substituted benzoic esters, on the assumption that the
characteristic ortho effects depend upon the proximity
of X to the ester grouping.   The methoxy esters how-
ever were found to exhibit a continuous rise from the
unsubstituted to the gem-diethyl compound and  thus
presented no parallel to the characteristic depression
brought about by the methoxyl group in $l$-menthyl o-methoxy-
benzoate.

In regard to the modifications of the rotatory
power brought about by the introduction of gem-dialkyl
groups in the case of the di-$l$-menthyl esters, the above
remarks apply only to observations of the rotatory
power in alcohol and benzene solutions.   In the gem-
diethyl compound in the homogeneous state, instead of
a further fall there is a very slight rise in the
rotation.

The object of this thesis was to extend the
series of gem-dialkyl malonic esters further for the
purpose of investigating the above anomaly;  and also
to prepare the corresponding hydrogen malonates and

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d-amino-monocarboxylic esters, in order to ascertain
the influence of salt formation upon the rotatory
power.

The esters described in the following pages are
thus of three main types, in which (a) X = $NH_2$ (or
$NHCl$) and R = H or $CH_3$    (b) X = COOH (or COONa) and
R = $C_3H_7$ or $C_4H_9$  (c) X = $COOC_{10}H_{19}$  and R = $C_3H_7$ or
$C_4H_9$.

Attempts to prepare the optically pure di-$l$-
menthyl esters of dichloro malonic acid and gem-dibenzyl
malonic acid were unsuccessful.

## Influence of Polar Solvents.

Until very recently there was very little
indication of any relationship between the molecular
structure of a solvent, and its effect upon the
rotation of a dissolved optically active substance.

Following up the experiments of Rule and Mitchell
(J.C.S., 1926, 3302), it was suggested in a  later
paper (Rule, J.C.S., 1927) "that polar groups whether
present in the asymmetric compound or in the solvent,
exert an influence on the neighbouring molecules
leading to corresponding changes in rotatory power."
Rule and Mitchell (loc.cit.) examined a series  of
substituted sec-$\beta$-octyl acetates, $CH_2 X.COOC_6H_{17}$, and

found that the increase in rotation due to X was given by

$$I > Br > Cl > OMe > Me > H$$
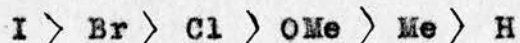
and provided the same solvent was used throughout, the order of substituents was practically independent of the nature of the solvent.  When the solvent was changed by introducing a polar substituent into  the molecule as in $C_6H_5X$ (giving toluene, chlorobenzene etc.) the lowering of rotation caused by the substituent in the solvent in the case of any individual ester was in the order:-

$$Me > H > OEt > Cl > Br > I \quad.$$

The changes produced by substitution in the solvent are thus almost exactly the reverse of those produced  by substitution in the optically active molecule.

Rule, Spence and Bretscher (J.C.S., 1928, 1493) pointed out that among the peri-substituted $l$-menthyl naphthoates the characteristic influence of a substituent was greatest in hydrocarbon solvents, highly polar solvents appearing to diminish the effect of the peri-substituent.

Recently Rule and McLean (J.C.S., 1931, 674) have examined the influence of solvents on the rotatory power of $l$-menthyl methyl naphthalate.  The solvents selected fell into four main types, namely simple derivatives of the four hydrocarbons methane, ethane, benzene and

naphthalene.     The value of $[M]_{5461}^{20°}$, (C = 4) varied

from -219° in nitromethane to -788° in decalin.     In

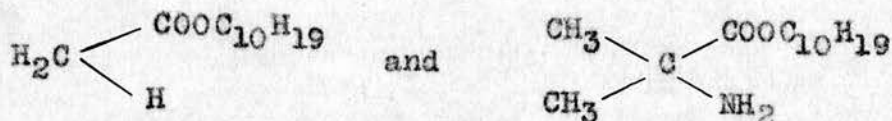the majority of cases they found the fall in rotation

to vary with the polarity of the solvent, as determined

by its dipole moment, and for a given polar substituent

the influence becomes less pronounced as the molecular

volume of the hydrocarbon radical increases.     The polar

influence of solvents was therefore best illustrated by

employing solvents derived from the same hydrocarbon,

and for these a rough approximation to a smooth curve

was obtained when rotatory powers were plotted  against

dipole moments.     The authors concluded that the

sensitivity of the diester towards solvents is intimately

connected with disturbances in the mutual relationship

of the peri groups probably caused by electrical

deformation or dipole association.

In the present thesis a study is made of the

effect of polar solvents derived from benzene  on the

homologous series of di-$l$-menthyl esters of the type:-

$$R_2C \Big\langle \begin{array}{l} CO_2C_{10}H_{19} \\ CO_2C_{10}H_{19} \end{array}$$
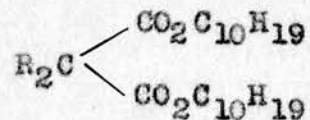
where R = H, $CH_3$, $C_2H_5$, $C_3H_7$ or $C_4H_9$ and also in the

case of $l$-menthyl acetate and $l$-menthyl $\alpha$ amino isobutyrate:-

$$H_2C \Big\langle \begin{array}{l} COOC_{10}H_{19} \\ H \end{array} \qquad and \qquad \begin{array}{c} CH_3 \\ \phantom{x} \\ CH_3 \end{array} \Big\rangle C \Big\langle \begin{array}{l} COOC_{10}H_{19} \\ NH_2 \end{array}$$

## EXPERIMENTAL.

### Preparative and Determinations of Rotatory Power.

#### $l$-Menthyl Acetate.

For comparative purposes the rotatory powers of $l$-menthyl acetate were determined in the homogeneous state, and in the solvents benzene and alcohol for the wave lengths 6708, 5893, 5461 and 4358 A.U.  Further rotations were made in simple solvents derived from benzene for the wave length 5461 A.U. only.  The observed and molecular rotations, together with the graph of the reciprocal of the observed rotation plotted against the square of the wave length of the light used, are given in the following pages.

A sample of $l$-menthyl acetate (B.D.H., 15 gms.) was redistilled under reduced pressure, the first and last fractions being rejected.  The main bulk of the ester distilled at 108°C under 15 mm. pressure,  and gave $[\alpha]_D^{19.4°} = -79.45°$.  Tschugaeff (Ber., 31, 364) found $[\alpha]_D^{19.4°} = -79.42°$.

#### $l$-Menthyl Acetate. M.W.188.2.

##### Observed Rotations.

Length of tube = 2 dcm.

| State | $\frac{C}{g./100 \text{ c.c}}$ | $\alpha_{6708}^{18.2°}$ | $\alpha_{5893}^{18.2°}$ | $\alpha_{5461}^{20°}$ | $\alpha_{4358}^{18.2°}$ |
|---|---|---|---|---|---|
| Homog. | - | -56.11 | -73.48 | -86.75 | -143.8 |
| Alcohol | 5.188 | 6.68 | 8.73 | 10.40 | 17.55 |
| Benzene | 5.068 | 6.38 | 8.20 | 9.78 | 15.70 |

## Molecular Rotations.

| State | C g./100 c.c. | $[M]_{6708}^{18.2°}$ | $[M]_{5893}^{18.2°}$ | $[M]_{5461}^{20°}$ | $[M]_{4358}^{18.2°}$ |
|---|---|---|---|---|---|
| Homog. | - | -120.3 | -157.5 | -185.9 | -308.1 |
| Alcohol | 5.188 | 128 | 167 | 199 | 336 |
| Benzene | 5.068 | 125 | 160 | 191 | 307 |

## Rotatory Powers of $\ell$-Menthyl Acetate in Simple Solvents derived from Benzene.

Length of tube = 2 dcm.  Temperature 20°C.

| Solvent | C g./100 c.c. | α obs. | $[M]_{5461}^{20°}$ |
|---|---|---|---|
| $C_6H_5NO_2$ | 5.010 | 8.84 | -175° |
| $C_6H_5CN$ | 5.240 | 9.48 | 179 |
| $C_6H_5CHO$ | 5.066 | 9.36 | 183 |
| $C_6H_5NH_2$ | 5.042 | 10.57 | 208 |
| $C_6H_5Br$ | 5.256 | 9.78 | 184 |
| $C_6H_5Cl$ | 5.060 | 9.38 | 184 |
| $C_6H_5OCH_3$ | 5.114 | 9.57 | 185 |
| $C_6H_5CH_3$ | 5.116 | 9.56 | 185 |
| $C_6H_3(CH_3)_3$ | 5.160 | 9.64 | 185 |
| $C_6H_{12}$ | 5.170 | 9.86 | 189 |
| $C_6H_6$ | 5.068 | 9.78 | 191 |

# FIGURE 6

SUMMARY OF HOMOLOGOUS SERIES OF DIALKYL-
SUBSTITUTED MALONIC ESTERS IN SOLVENTS
OF THE BENZENE SERIES.

$[M]^{20°}_{5461}$

HOMOLOGOUS SERIES →

| Solvent | $\mu \times 10^{0}$ |
|---|---|
| [ETHYL ALCOHOL] | |
| 1 CYCLO HEXANE | 0 |
| 2 MESITYLENE | 0 |
| 3 BENZENE | 0 |
| 4 TOLUENE | 0 |
| 5 ANISOLE | 1·25 |
| CHLOROBENZENE | 1·55 |
| BROMOBENZENE | 1·55 |
| 6 IODOBENZENE | 1·50 |
| BENZALDEHYDE | 2·75 |
| 7 NITROBENZENE | 3·89 |
| 8 BENZONITRILE | 3·85 |

UNSUBS.    DIMETHYL    DIETHYL    DIPROPYL    DIBUTYL

340

300

250

200

160
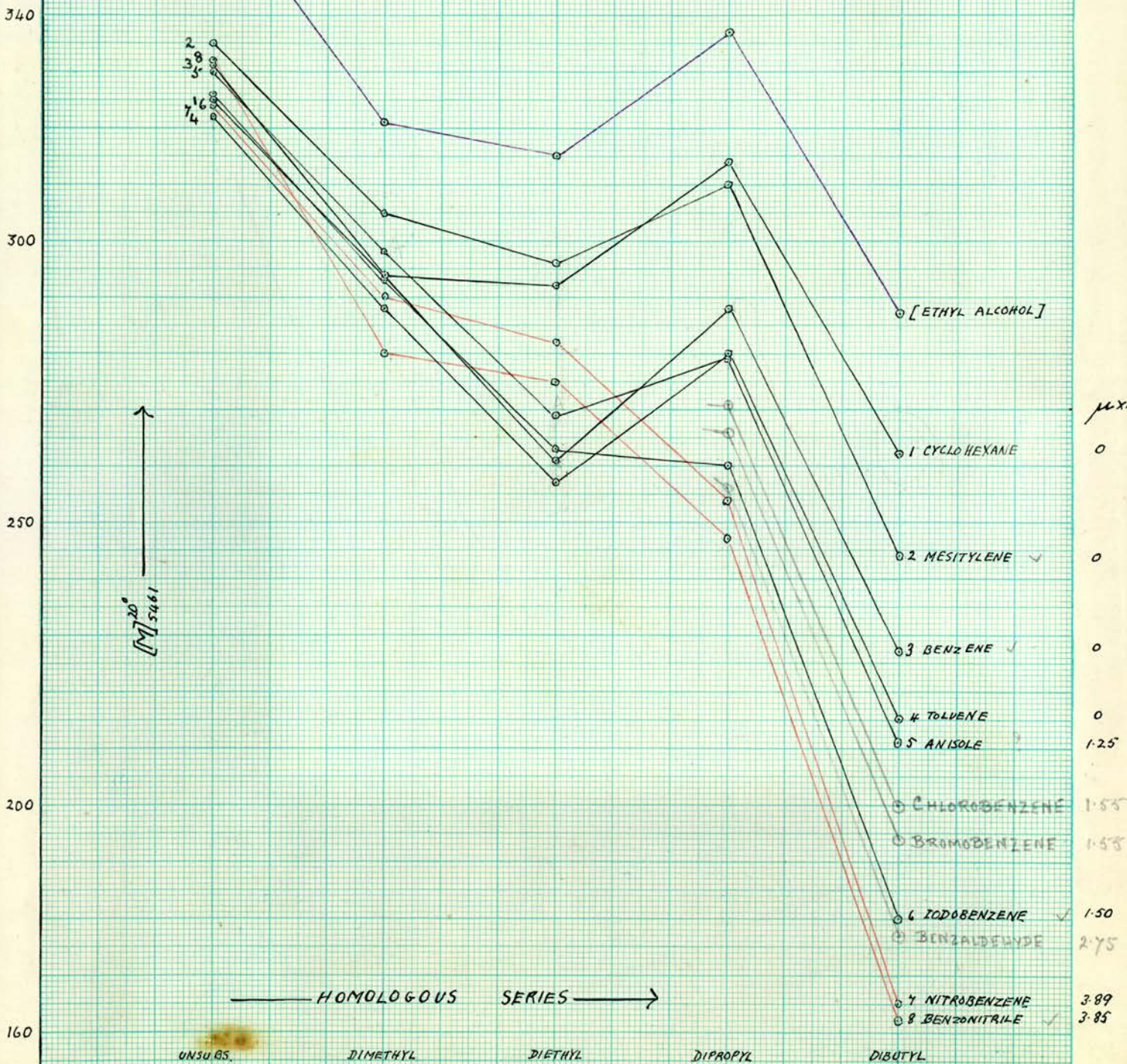
## di-*l*-Menthyl Malonate  M.W.380.3.

The rotatory powers of the above ester previously investigated by Rule and Harrower (J.C.S., 1930, 2324) were observed in simple solvents of the benzene series and also in alcohol.   A sample after recrystallising from methyl alcohol gave $[M]_{5461}^{20.5°}$ = -325° (in benzene) (Rule and Harrower (loc.cit.)   quote $[M]_{5461}^{18°}$ = -324°.

Length of tube = 1 dcm.

### Rotatory Power.

| State | C g./100 c.c. | $\alpha_{5461}^{18°}$ | $[M]_{5461}^{18°}$ |
|---|---|---|---|
| Alcohol | 4.934 | -4.50 | -362 |

### Rotatory Powers of di-*l*-Menthyl Malonate in Simple Solvents derived from Benzene.

Length of tube = 2dcm.          Temperature 20°C.

| Solvent | C g./100 c.c. | α obs. | $[M]_{5461}^{20°}$ |
|---|---|---|---|
| $C_6H_5CN$ | 4.987 | 8.72 | -332° |
| $C_6H_5NO_2$ | 4.987 | 8.50 | 324 |
| $C_6H_5I$ | 4.997 | 8.55 | 326 |
| $C_6H_3OCH_3$ | 4.987 | 8.66 | 330 |
| $C_6H_5CH_3$ | 4.990 | 8.44 | 322 |
| $C_6H_6$ | 5.003 | 8.54 | 335 |
| $C_6H_3(CH_3)_3$ | 4.990 | 8.80 | 335 |
| $C_6H_{12}$ | 5.000 | 8.70 | 331 |

For crude sample of this ester and of the succeeding two compounds I am indebted to J. Harrower.

## Addition of One Atomic Proportion of
## Sodium to di-*l*-Methyl Malonate.

The rotatory power of di-*l*-menthyl malonate was
determined in calcium dried alcohol containing one
atomic proportion of sodium.   The sodium was added in
the form of sodium ethoxide prepared by dropping  the
required amount of sodium into ethyl alcohol which was
filtered through a glass wool filter into a burette and
titrated against standard ($.9105^N$) HCl using phenol
phthalin as indicator.   Two titrations using standard
HCl were made, the mean taken, and the calculated
volume of sodium ethoxide thereupon run into a weighed
amount of di-*l*-menthyl malonate (about .25 gms.) which
had already been dissolved in a small amount of ethyl
alcohol.   This was carried out in a 5 c.c. standard
flask and the time of mixing was taken.   The rotation
was taken as speedily as possible, the time noted, and
rotations were then read at intervals.   By means of
a graph the value of the rotation at zero time was
deduced.

### Rotatory Power.

Length of tube = 1 dcm.                    Temperature 20°C.

| C g./100 c.c. | α extrapol. | $[M]_{5461}^{20°}$ |
|---|---|---|
| 5.028 | -5.0 | -378° |

DI-l-MENTHYL PHTHALATE

1 NITRO BENZENE
2 BENZONITRILE
3 BENZALDEHYDE
4 CHLORO BENZENE
5 BROMO BENZENE
6 IODO BENZENE
7 ANISOLE
8 TOLUENE
9 MESITYLENE
10 cyclo HEXANE
11 BENZENE

ROTATION  $[M]^{26°}_{5461}$   1945

DIPOLE MOMENT  $M \times 10^{18}$
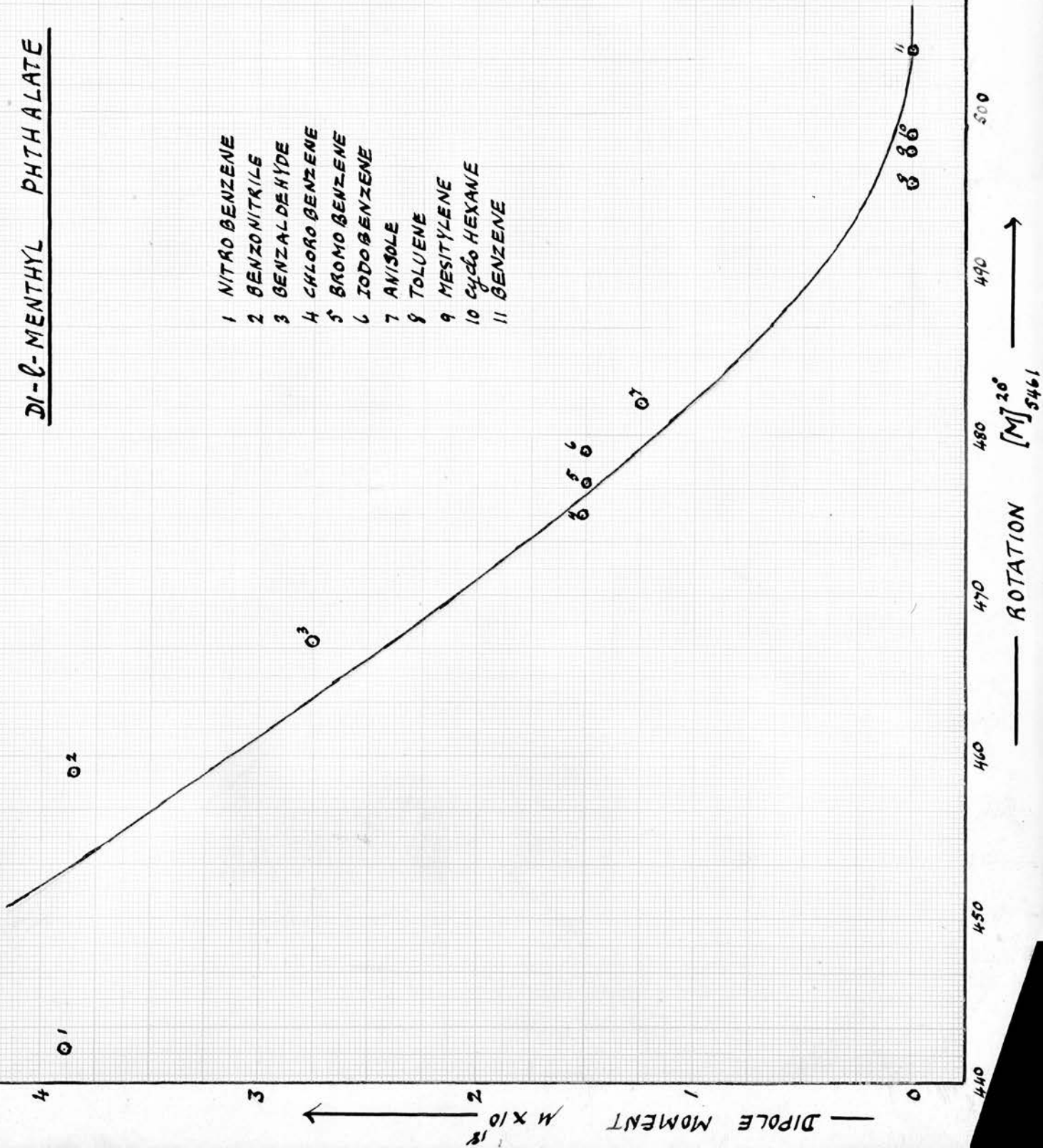
# FIGURE I



HOMOLOGOUS   SERIES   OF   l-MENTHYL   DIALKYL   Hydrogen Esters of

HYDROGEN   MALONATES   (AND   THEIR   SODIUM   SALTS).

Dialkylmalonic Acids $(C_{10}H_{19}OOC.R_2COOH)$

SOLVENTS

— BENZENE
— ALCOHOL
--- SODIUM SALTS IN ALCOHOL

$[M]_{5461}^{20°}$

← HOMOLOGOUS   SERIES →

UNSUBS.   DIMETHYL   DIETHYL   DIPROPYL   DIBUTYL

220
210
200
190
180
170
160
150
140
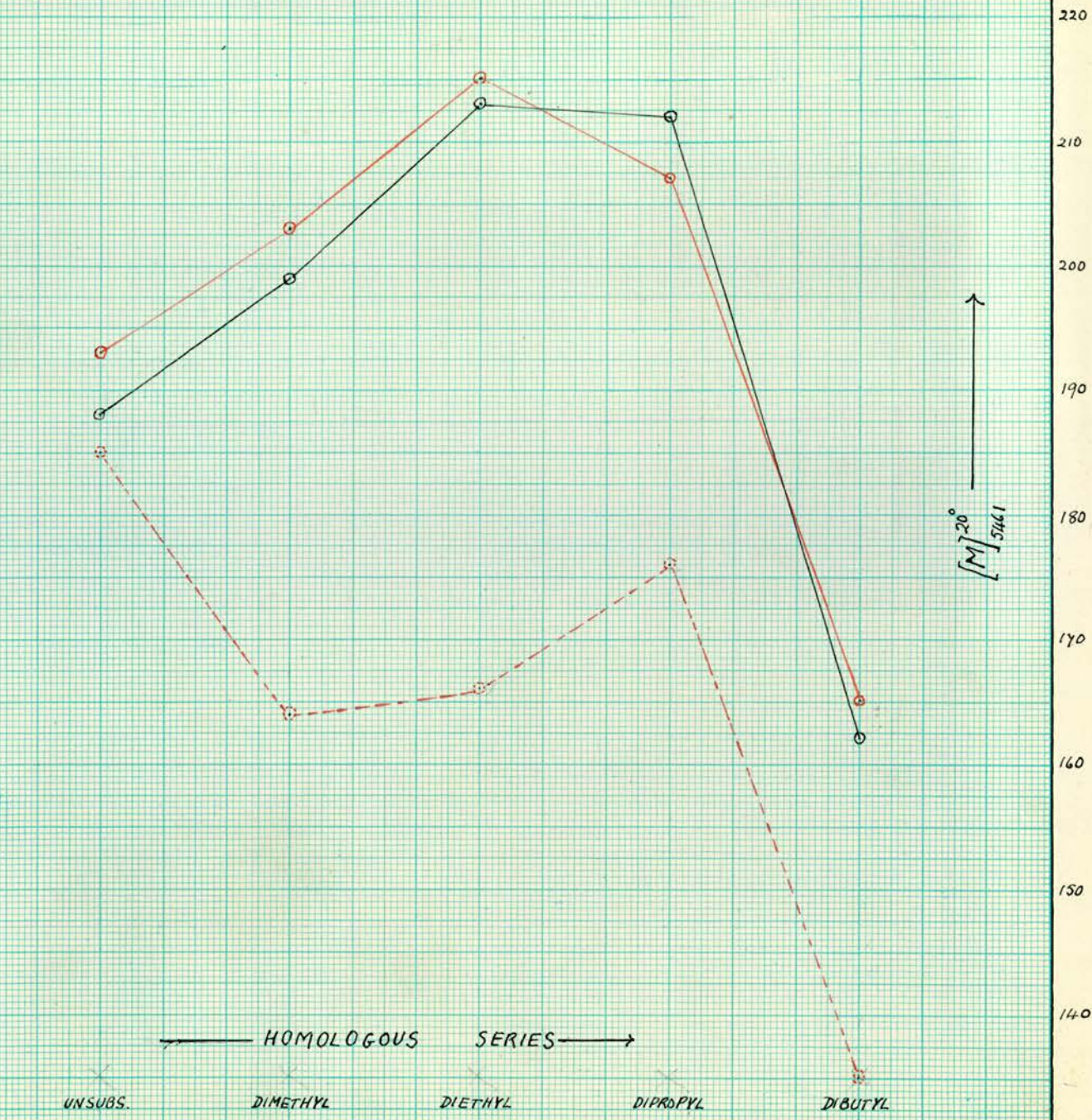
## di-*l*-Menthyl Dimethylmalonate M.W.408.2.

Similar observations of the rotatory powers of this ester were made in simple solvents of the benzene series. $[M]_{5461}^{20^\circ} = -294^\circ$ (in benzene); Rule and Harrower (J.C.S., 1930, 2321) find $[M]_{5461}^{20^\circ} = -293^\circ$.

Length of tube = 2dcm.          Temperature 20°C.

| Solvent | C g./100 c.c. | α obs. | $[M]_{5461}^{20^\circ}$ |
|---|---|---|---|
| $C_6H_5CN$ | 5.018 | 6.88 | -280° |
| $C_6H_5NO_2$ | 4.984 | 7.08 | 290 |
| $C_6H_5I$ | 4.980 | 3.57 | 293 |
| $C_6H_5Br$ | 5.014 | 7.02 | 287 |
| $C_6H_5OCH_3$ | 4.904 | 7.16 | 298 |
| $C_6H_5CH_3$ | 5.032 | 7.09 | 288 |
| $C_6H_6$ | 5.038 | 7.26 | 294 |
| $C_6H_3(CH_3)_3$ | 5.032 | 7.52 | 305 |
| $C_6H_{12}$ | 5.010 | 7.22 | 294 |

In this case a 1 dcm. tube was employed.

### di-*l*-Menthyl Diethylmalonate M.W.436.4.

This ester gave $[M]_{5461}^{20°} = -261°$.   Rule and Harrower (J.C.S., 1930, 2321) found $[M]_{5461}^{20°} = -259°$.

### Rotatory Powers of di-*l*-Menthyl Diethylmalonate in Simple Solvents derived from Benzene.

Length of tube = 2 dcm.                    Temperature 20°C.

| Solvent | C g./100 c.c. | α obs. | $[M]_{5461}^{20°}$ |
|---|---|---|---|
| $C_6H_5CN$ | 5.000 | -6.30 | -275° |
| $C_6H_5NO_2$ | 5.000 | 6.46 | 282 |
| $C_6H_5I$ | 5.040 | 6.07 | 263 |
| $C_6H_5OCH_3$ | 5.000 | 6.15 | 269 |
| $C_6H_5CH_3$ | 5.010 | 5.90 | 257 |
| $C_6H_6$ | 5.023 | 6.00 | 261 |
| $C_6H_3(CH_3)_3$ | 5.023 | 6.82 | 296 |
| $C_6H_{12}$ | 4.988 | 6.67 | 292 |

## di-*l*-Menthyl Dipropylmalonate.

This ester was prepared in three stages from
malonic ester using the following method, the dimethyl
ester of dipropylmalonic acid being an intermediate
compound.

### Dimethyl Propylmalonate.

175 gms. of methyl alcohol were introduced into
a flask fitted with an upright condenser, and 16.1 gms.
of sodium added over a short period. When the first
reaction was over the flask and its contents were
heated on the water-bath until the sodium completely
dissolved.    While the sodium methoxide was still warm
92,4 gms. of methyl malonate were run in from a tap-
funnel;  the solution remained clear at first but
eventually sodium dimethyl malonate was precipitated
as a creamy white mass.

110.6 gms. of propyl bromide (redistilled,b.p.
69°-5-71°) were added.   The reaction set in when the
flask and its contents were placed on the water-bath;
heat was evolved and vigorous shaking was applied during
this period which extended to about thirty minutes.
The white cake of sodium dimethyl malonate gradually
disappeared, and the solution became turbid owing to
separation of sodium bromide.

To complete the reaction, the flask and contents

were left on the water-bath for three hours, after which the excess methyl alcohol was distilled off from a brine bath.    The resulting product was cooled, about an equal volume of water added and the ester extracted with ether.    The extract was dried over calcium chloride overnight and the ether distilled off. The main bulk of the ester distilled at 195°-205°C. Yield 68 gms.

### Dimethyl Dipropylmalonate.

The procedure was the same as in the previous preparation.    The ester was distilled twice under reduced pressure.    The boiling point at ordinary atmospheric pressure was 222° C (by the capillary tube method).    It was found that on standing the dimethyl dipropylmalonate solidified to a crystalline solid. The crystalline mass was then filtered in a Hirsch funnel at the pump. Melting point = 25.2° C.

### di-$l$-Methyl Dipropylmalonate.

The method used was the direct replacement of the methyl groups in the methyl ester by methyl radicals through the agency of metallic sodium.    This type of reaction was discovered by Purdie and later studied by Verley (Bull.Soc.Chim., 1927, **41**, 802). Recently it has been frequently employed by Rule and co-workers in the preparation of menthyl esters.

33 gms. of purified methyl ester (1 mol.) were
mixed with .53 gms. of metallic sodium (.05 atomic
proportion) dissolved in 71.5 gms. of menthol (3 mols.)
in a distilling flask attached to condenser and
receiver.   The flask was kept immersed in an oil bath
up to at least half-way up the neck for a period of
three hours.   During that time a slow current of dry
air was maintained through the whole apparatus to
remove the methyl alcohol formed, and so allow the
balance of the reaction to proceed in favour of the
formation of the menthyl derivative.   After three
hours heating a small quantity of methyl alcohol had
collected in the receiver, and the residue in the
distilling flask had turned a brownish colour, and
become viscid.   Ether was added to the cooled product
and the extract purified by washing with dilute acid
followed by dilute sodium carbonate solution.   Finally
it was washed twice with water.   When the water was
added an emulsion formed which took many hours to
settle.   Eventually the ether extract was dried over-
night with calcium chloride.   When the ether had been
removed the pressure was reduced to 12 mm. and excess
menthol driven off:   the oil-bath was allowed to attain
190°C.   By means of a mercury pump a pressure of .35 mm.
was obtained and the ester distilled.   Two fractions
were collected.   The first fraction distilled at 135°-

175° (20 gms.): the second fraction distilled at 175°-
207° (15 gms.). The first fraction was assumed to
be mainly the mixed methyl menthyl ester and it was
retained for the preparation of $l$-menthyl hydrogen
dipropylmalonate.

The second fraction (yield 30% of the theoretical
at this stage) was shaken up with an equal volume of
methyl alcohol and allowed to settle at a temperature
approximating to -15°C. The thick oil was separated,
and after the addition of ether washed three times
with distilled water, dried rapidly over calcium chloride,
and the ether taken off in a hot desiccator.

The rotatory power of the ester (which was a
clear viscous liquid) was then observed in the homo-
geneous state, $\alpha_{5461}$ = -63.31° at 19.7°C (1 dcm. tube).
On removing the ester from the polarimeter tube, how-
ever, small crystals were noticed and on cooling a
sticky crystalline mass was obtained. The ester was
therefore purified by recrystallisation from absolute
ethyl alcohol. Yield 6 gms. (yield 10%) m.p. 78°-85°.
The crystals when powdered were not so sticky as before
and after a second recrystallisation melted at 85°-93°C.
The ester was eventually recrystallised five times in
all when it melted at 94°C and gave a constant rotation,
$[M]_{5461}^{20°}$ = -288 (in benzene). The ester crystallised
in fine monoclinic crystals.

The rotatory powers of the ester in benzene and alcohol solution were observed for the wave lengths 6708, 5893, 5461 and 4358 A.U.  It was found possible to obtain only a 2 per cent. solution in alcohol. Further rotations using solvents of the benzene series were determined for the mercury green line (5461 A.U.). The observed and calculated rotations together with the graph of the reciprocal of the rotation plotted against the square of the wave length of the light used, are given in the following pages.

Analysis:- 0.1586 gms. of the ester gave 0.4340 gms.
of $CO_2$ and 0.1596 gms. $H_2O$ representing C = 74.6, and H = 11.1.

$C_{29}H_{52}O_4$ requires C = 74.9 and H = 11.3.

### di-$l$-Menthyl Dipropylmalonate M.W.464.4.

#### Observed Rotations.

Length of tube = 2 dcm.                    Temperature 20°(approx.)

| State | C g./100 c.c. | $\alpha_{6708}$ | $\alpha_{5893}$ | $\alpha_{5461}$ | $\alpha_{4358}$ |
|---|---|---|---|---|---|
| Alcohol | 2.068 | -1.83 | -2.47 | -3.00 | -4.80 |
| Benzene | 3.996 | -3.25 | -4.43 | -4.96 | -8.40. |

#### Molecular Rotations./

## Molecular Rotations.

| State | C g./100 cc. | $[M]_{6708}$ | $[M]_{5893}$ | $[M]_{5461}$ | $[M]_{4358}$ |
|---|---|---|---|---|---|
| Alcohol | 2.068 | −207° | −279° | −337° | −539° |
| Benzene | 3.996 | −189 | −258 | −287 | −488 |

## Rotatory Powers of di-*l*-Menthyl Dipropylmalonate in Simple Solvents derived from Benzene.

Length of tube = 2 dcm.          Temperature 20°C.

| Solvent | C g./100 c.c. | α obs. | $[M]^{20°}_{5461}$ |
|---|---|---|---|
| $C_6H_5CN$ | 4.023 | 4.27 | −247° |
| $C_6H_5NO_2$ | 4.008 | 4.38 | 254 |
| $C_6H_5CHO$ | 4.060 | 4.47 | 256 |
| $C_6H_5I$ | 4.066 | 2.28 * | 260 |
| $C_6H_5Br$ | 4.050 | 4.64 | 266 |
| $C_6H_5Cl$ | 4.017 | 4.68 | 271 |
| $C_6H_5OCH_3$ | 4.040 | 4.86 | 279 |
| $C_6H_5CH_3$ | 4.017 | 4.83 | 280 |
| $C_6H_6$ | 3.996 | 4.96 | 287 |
| $C_6H_3(CH_3)_3$ | 4.010 | 5.35 | 310 |
| $C_6H_{12}$ | 3.997 | 5.39 | 314 |

* 1 dcm tube.

## *l*-Menthyl Hydrogen Dipropylmalonate.

It was found by Rule and Harrower (J.C.S.,1930, 2320) that the production of *l*-menthyl hydrogen diethylmalonate by the half-hydrolysis of the di- - menthyl ester was difficult, and gave a poor yield, probably owing to the steric hindrance offered by the two alkyl groups.

The method adopted for the preparation of *l*-menthyl hydrogen dipropylmalonate was exactly similar to theirs, namely, the half-hydrolysis of the lower boiling fraction obtained in the preparation of the corresponding dimenthyl ester.   This fraction (b.p. 135°-175°, under .35 mm.) was assumed to be the menthyl methyl ester, and was found to be more easily hydrolysed.

The proportions taken were as follows:-

20 gms. of ester

1.35 gms. of sodium dissolved in 1200 ccs.

of alcohol (R.S.).

The mixture was refluxed for forty-eight hours until the titre (against $N/250$ HCl) for 2 ccs. of hydrolysis mixture was reduced to 4 ccs.   The small precipitate of disodium salt was filtered off, and the alcohol distilled off under diminished pressure. The residue was then dissolved by shaking with an ether-water mixture, and after repeated extractions

with ether to remove menthol and any unchanged diester,
it was acidified and extracted with ether.   The ether
extract was washed with several changes of water, and
dried over calcium chloride.   Ether was finally
removed in a desiccator kept at 55° C in order to dry
the ester thoroughly.   At this stage the ester was a
yellow viscous liquid and gave $[M]_{5461}^{16°}$ = -200° (in
alcohol).

The acid ester was purified further by dissolving
in a slight excess of dilute sodium carbonate solution,
thus forming the sodium salt, which was extracted with
ether five or six times to remove any traces of diester.
The purified solution of sodium salt was then acidified
with acid, and the precipitated menthyl hydrogen ester
taken up in ether.   This ethereal extract was shaken
up ten or twelve times with water, and finally dried
over calcium chloride.   Ether was then removed in a
heated vacuum desiccator, in which the ester was dried
for twelve hours;   $[M]_{5461}^{18°}$ = -208° (in alcohol).

It was noticed on filtering the ethereal extract
that crystals slowly formed;   and in about a week's
time, the entire ester crystallised out, eventually
forming a slightly sticky powder.   No suitable solvent
could be found for recrystallisation and so the process
of purification was repeated.   This time the product
gave $[M]_{5461}^{18°}$ = -207° (in alcohol), which was taken to

show that the ester was in an optically pure condition.
Yield, 2 gms. (4 per cent. of the theory). M.p.41-42°C.

The rotation of the acid ester was observed for
the wavelengths 6708, 5893, 5461 and 4358 A.U. in
alcohol and benzene, and also in the form of its
sodium salt in alcohol solution.  The last determination
was made by dissolving a known weight of the hydrogen
ester in a standard flask, adding the requisite amount
of freshly-prepared sodium ethoxide to neutralise the
acid taken, and then making up to the mark with alcohol.
Owing to slight opaqueness of the solution the rotation
for the wavelength 5461 A.U. alone was determined.
The graph showing the reciprocal of the rotation
plotted against the square of the wavelength of the
light used is also given.

Analysis:-  0.1134 gms. of the ester gave 0.2920 gms.
of $CO_2$ and 0.1086 gms. $H_2O$ representing
C = 70.2 and H = 10.7.

$C_{19}H_{34}O_4$ requires C = 69.9 and H = 10.5 per cent.

## $\ell$-Menthyl Hydrogen Dipropylmalonate. M.W.326.3.

### Observed Rotations.

Length of tube = 2 dcm.          Temperature 18°C.

| State | C g./100 c.c. | $\alpha_{6708}$ | $\alpha_{5893}$ | $\alpha_{5461}$ | $\alpha_{4358}$ |
|---|---|---|---|---|---|
| Alcohol | 5.052 | -4.24 | -5.56 | -6.42 | -9.46 |
| Benzene | 4.994 | -4.14 | -5.63 | -6.48 | -10.13 |
| Na.salt | 4.018 | - | - | -4.32 | - |

### Molecular Rotations.

| State | C g./100 c.c. | $[M]_{6708}$ | $[M]_{5893}$ | $[M]_{5461}$ | $[M]_{4358}$ |
|---|---|---|---|---|---|
| Alcohol | 5.052 | -137° | -170° | -207° | -306° |
| Benzene | 4.994 | -135 | -184 | -212 | -331 |
| Na.salt | 4.018 | - | - | -176 | - |

## di-*l*-Menthyl Dibutylmalonate.

The preparation of this ester was exactly similar
to that of the dipropylmalonate.

### Dimethyl butylmalonate.

The quantities used were:-

92.4 gms. of methyl malonate

16.1 gms. of Na dissolved in 175 gms. $CH_3OH$

123.6 gms. of n-butyl bromide.

The n-butyl bromide used was prepared from butyl
alcohol, using the sodium bromide and sulphuric acid
method.    It was dried over calcium chloride for
several hours and distilled (B.p. 101°-103°).

The main bulk of the monobutyl derivative
distilled at 109°-110°C under 13 mm. pressure.  Lower
and higher boiling fractions were also obtained.  The
compound did not solidify or show any signs of crystalli-
sation on being maintained at 0°C.   Yield, 75 gms.

### Dimethyl dibutylmalonate.

The proportions taken were as follows:-

95 gms. of monobutyl compound

11.6 gms. of Na dissolved in 126 gms. of $CH_3OH$

100 gms. of n-butyl bromide.

The entire yield of the previous ester was used as
it was decided that purification could be left to the
later stage.    The product distilled mainly at 140°C

under 24 mm. pressure, and was collected from 136°-145°.
It crystallised out in long colourless needles, m.p.
38°, which were powdered and dried in a vacuum desiccator
for three days before being converted into the menthyl
ester.   Yield 41 gms.

### di-$l$-Menthyl Dibutylmalonate.

Quantities:-

41 gms. of methyl dibutylmalonate

.58 gms. of sodium

78 gms. of menthol.

The crude ester mixture resulting from the
reaction (see dipropylmalonate) was taken up in ether,
and the extract washed and dried as in previous
preparation, save that dilute acid was used in place
of the dilure sodium carbonate.   After removal of the
ether the excess of menthol was distilled at 90°-115° C
under 16 mm. pressure.   On redistilling under a high
vacuum the first fraction came over at 120°-190° under
.42 mm. pressure.   It was assumed that this was the
methyl menthyl derivative;   the remainder consisted
largely of the dimenthyl ester.   After standing for
several days the latter crystallised out.   It was
purified by recrystallising several times (about 10
in all) from absolute ethyl alcohol and eventually
gave a constant melting point 58° C, and a constant
rotation, $[M]^{20°}$ = -227° (in benzene).   Yield 26

5461

gms, representing 40 per cent. of the theory. The ester crystallised from alcohol in fine monoclinic crystals.

The required quantity of the solid was melted and poured into a clean polarimeter tube which was then placed in position in the polarimeter and allowed to cool slowly, dust particles beingcarefully excluded. The rotatory power of the ester in the supercooled state was observed for the wavelength 5461 A.U.

The observed and calculated rotations using alcohol and benzene as solvents together with the graph of the reciprocal of these observed rotations plotted against the square of the wavelength of the light used are given in the following pages, as well as the rotatory powers in solvents of the benzene series using the mercury green line.

Density:- It was not found possible to determine the density in the supercooled state at 20°C. A series of densities were therefore determined at 59.4° C, 79° C, and 89.8° C: and the density at 20°C found by extrapolation.
$D_4^{59.4°} = .9256;$   $D_4^{79°} = .9143;$   $D_4^{89.8°} = .9063.$
$D_4^{20°} = .954.$

Analysis:-/

**Analysis:-** 0.1405 gms. of ester gave .3906 gms. of $CO_2$ and .1446 gms. $H_2O$ representing C, 75.8; H, 11.5.

$C_{31}H_{56}O_4$ requires C, 75.5 and H, 11.5 per cent.

## di-*l*-Menthyl Dibutylmalonate. M.W.492.5.

### Observed Rotations.

Length of tube = 2 dcm.                 Temperature 20 °C approx.

| State | C g./100 c.c. | $\alpha_{6708}$ | $\alpha_{5893}$ | $\alpha_{5461}$ | $\alpha_{4358}$ |
|---|---|---|---|---|---|
| Homog. | - | - | - | -20.59 | - |
| Alcohol | 4.954 | -3.75 | -4.83 | -5.78 | -9.47 |
| Benzene | 5.012 | -2.95 | -3.80 | -4.61 | -7.28 |

### Molecular Rotations.

| State | C g./100 c.c. | $[M]_{6708}$ | $[M]_{5893}$ | $[M]_{5461}$ | $[M]_{4358}$ |
|---|---|---|---|---|---|
| Homog. | - | - | - | -213 | - |
| Alcohol | 4.954 | -187 | -241 | -287 | -476 |
| Benzene | 5.012 | -145 | -187 | -227 | -358 |

½ dcm. tube.

41.

## Rotatory Powers of di-*l*-Menthyl Dibutylmalonate in
## Simple Solvents derived from Benzene.

Length of tube = 2 dcm.                    Temperature 20° C.

| Solvent | C g./100 c.c. | α obs. | $[M]_{5461}^{20°}$ |
|---|---|---|---|
| $C_6H_5CN$ | 4.926 | 3.24 | -162° |
| $C_6H_5NO_2$ | 4.932 | 3.29 | 165 |
| $C_6H_5CHO$ | 4.938 | 3.54 | 177 |
| $C_6H_5NH_2$ | 4.926 | 4.30 | 215 |
| $C_6H_5I$ * | 4.905 | 1.79 | 180 |
| $C_6H_5Br$ | 4.934 | 3.88 | 194 |
| $C_6H_5Cl$ | 4.930 | 3.99 | 200 |
| $C_6H_5OCH_3$ | 4.926 | 4.22 | 211 |
| $C_6H_5CH_3$ | 4.932 | 4.30 | 215 |
| $C_6H_6$ | 5.012 | 4.61 | 227 |
| $C_6H_3(CH_3)_3$ | 4.924 | 4.88 | 244 |
| $C_6H_{12}$ | 4.948 | 5.25 | 262 |

* 1 dcm. tube used here.

It was also attempted to obtain a series of results for this compound in solvents derived from ethane; but in so far as very polar solvents were concerned it was only possible to obtain 1 per cent. solution with difficulty. The experimental error in these solutions is in consequence very large; and the series was therefore not completed.

Length of tube = 2 dcm.                    Temperature 20°C.

| Solvent | C g./100 c.c. | $\alpha$ obs. | $[M]_{5461}^{20°}$ |
|---------|---------------|---------------|--------------------|
| $C_2H_5CN$ | 1.018 | -1.14 | -276 |
| $C_2H_5NO_2$ | 1.012 | 1.18 | 287 |
| $C_2H_5OH$ | 4.954 | 5.78 | 287 |
| n-$C_6H_{12}$ | 4.920 | 5.56 | 278 |

## *l*-Menthyl Hydrogen Dibutylmalonate.

This ester was prepared in exactly the same manner as the previously described acid esters, starting from the fraction of the methyl menthyl dibutylmalonate boiling at 120°-190°. After removing the excess menthol in the usual way, and then acidifying, the ether extract was washed twelve times with water, dried over calcium chloride, and the ether removed. The ester was obtained as a pale yellow syrup and was dried for a short time in a heated desiccator.

The rotatory power was observed in alcohol and benzene solutions; the value for $\lambda_{5461}$ being also determined for the sodium salt in pure alcohol.

Analysis:- 0.1246 gms. of the ester gave 0.3235 gms. of $CO_2$ and 0.1184 gms. $H_2O$ representing C = 70.8 and H = 10.6.

$C_{21}H_{38}O_4$ requires C = 71.1 and H = 10.8 per cent.

44.

<u>l-Menthyl Hydrogen Dibutylmalonate.M.W.354.3.</u>

<u>Observed Rotations.</u>

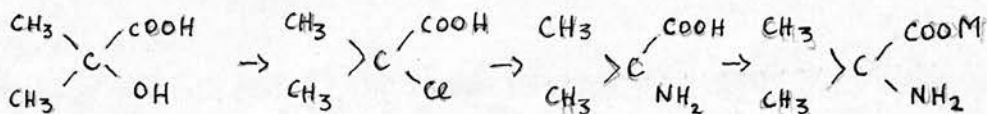Length of tube = 2 dcm.                    Temperature 20°C.

| State | C<br>g./100 c.c. | $\alpha_{5769}$ | $\alpha_{5461}$ |
|-------|------|------|------|
| Benzene | 5.200 | -4.28 | -4.84 |
| Alcohol | 4.947 | 4.04 | 4.57 |
| Na Salt | 4.184 | 1.43 | 1.60 |

<u>Molecular Rotations.</u>

| State | C<br>g./100 c.c. | $[M]_{5769}$ | $[M]_{5461}$ |
|-------|------|------|------|
| Benzene | 5.200 | -143 | -162 |
| Alcohol | 4.947 | 145 | 165 |
| Na Salt | 4.184 | 121 | 135 |

## *l*-Menthyl α-Amino-isobutyrate.

It was originally intended to prepare this compound from α-hydroxy-isobutyric acid thus

$$\begin{array}{c}CH_3 \\ \\ CH_3\end{array}\!\!>\!\!C\!\!<\!\!\begin{array}{c}COOH \\ \\ OH\end{array} \rightarrow \begin{array}{c}CH_3 \\ \\ CH_3\end{array}\!\!>\!\!C\!\!<\!\!\begin{array}{c}COOH \\ \\ Cl\end{array} \rightarrow \begin{array}{c}CH_3 \\ \\ CH_3\end{array}\!\!>\!\!C\!\!<\!\!\begin{array}{c}COOH \\ \\ NH_2\end{array} \rightarrow \begin{array}{c}CH_3 \\ \\ CH_3\end{array}\!\!>\!\!C\!\!<\!\!\begin{array}{c}COOM \\ \\ NH_2\end{array}$$

but this was not possible as there is a tendency for the chloro-acid to decompose to form $CH_2 = C(CH_3)COOH$, methyl acrylic acid.   Hence another method outlined by Zelinsky and Stadnikoff (Ber. 39,1726) and Franchimont and Friedmann (Rec.Trav.Pay.Bas., 27, 197) was resorted to.

## α-Amino-isobutyric Acid.

13 gms. of finely powdered potassium cyanide and 10.6 gms. of ammonium chloride were dissolved in a little water in a pressure bottle, and 11.6 gms of acetone were added.   The mixture was heated in a water-bath for five hours from 50°-60°C.   As  the amino nitrile in question is very soluble in water, it was not extracted by means of ether, but the reaction mixture was treated directly with an equal volume of fuming hydrochloric acid, and then saturated with hydrogen chloride with cooling in a freezing mixture. The mixture was left to itself overnight and next day, after dilution with an equal volume of water, it was refluxed for two hours on the oil-bath in order to

complete the hydrolysis of the nitrile. Water and
hydrogen chloride were then expelled on the water-bath,
and the dry powdered residue extracted several times
with absolute alcohol. The hydrochloride of the
amino acid was recrystallised twice from water, and
very fine hexagonal crystals were obtained.

### Methyl α-Amino-isobutyrate Hydrochloride.

The hydrochloride was converted into its
methyl ester. The difficulty experienced in methylat-
ing a carboxyl group attached to a tertiary carbon atom
is well known, and the preparation carried out as
described in the above transactions yielded scarcely any
free methyl ester. A yield of 35-40% (theor.) of the
pure methyl ester was obtained eventually in the
following manner.

The hydrochloride was dissolved in a quantity
of specially-dried methyl alcohol sufficient to
dissolve it at 40°-50°C. The solution was saturated
with dry HCl, and then refluxed. With hydrogen
chloride gas still being passed in, it was allowed to
cool and the process was repeated. The solution was
finally saturated in the cold; and evaporated almost
to dryness in a desiccator. The moist mass was
finally pressed on a porous plate, and dried by
gentle heat. M.p. 158°-166°C.

## Methyl α-Amino-isobutyrate.

It was next necessary to prepare the free
methyl ester.    For this purpose the hydrochloride was
dissolved in half its weight of cold water (it formed
a thin paste) and the mixture cooled in a freezing
bath, after having added a volume of ether five times
that of the water.    Into this mixture was passed drop
by drop (with mechanical stirring) the calculated amount
of 33% aqueous caustic soda, taking care that the
temperature did not rise above zero.    This done,
enough potassium carbonate was added to reduce the
mixture to a stiff paste difficult to stir.    The
paste was extracted four times with dry ether, the
extract dried for ten minutes with anhydrous potassium
carbonate, and for. two days with anhydrous sodium
sulphate.    The authors (Rec. Trav. Pay Bas., 27, 197)
state that the ester comes over to some extent when
distilling off the excess of ether.    This was  not
noticed particularly until the water-bath was in the
region of 100°C, and almost all excess ether had been
driven off.    The ester smelt of ammonia on being
removed from the water-bath.    It is recorded as dis-
tilling at 136°C under 749 mm. pressure without
decomposition, but when this was tried out on a
small scale, white fumes were evolved, and it was
therefore deemed advisable to distil at a lower pressure.

The bulk came over at 40°-40.5°C under 15 mm. pressure.
(45°C under 20 mm. pressure Rec. Trav. Bay Bas, 27,
197). Yield 26 gms. representing 35-40% of the
theoretical.

### $l$-Menthyl α-Amino-isobutyrate.

The quantities taken were as follows:-

22.5 gms. of methyl α-amino-isobutyrate

58.5 gms. of menthol

.86 gms. of sodium.

The sodium was dissolved in the menthol in
the usual way. Keeping the oil-bath at 125°-130°C
almost the calculated amount of $CH_3OH$ distilled over
in a current of air, the maximum temperature to which
oil-bath was raised being 138°C.    The mixture in
the flask was cooled somewhat, taken up in petrol ether,
and the whole acidified by means of dilute sulphuric
acid after the addition of some water.    Menthol was
removed from the aqueous mixture by repeated extraction
with petrol ether, and the aqueous liquor was then
made alkaline with sodium hydroxide.    The liberated
amino compound was taken up in petrol ether, washed
with water and then dried over anhydrous sodium
sulphate.    Some difficulty was experienced during
the above acidification, owing to the formation of
three layers of liquid. The greater part of the

ether was taken off on the oil-bath, and the solution
was poured into a crystallising dish, and taken down
in a vacuum desiccator.   Afterwards, it was transferred
to a distilling flask, and the pressure reduced to
9 mm., but no unchanged methyl ester distilled over
on raising the temperature.  The menthyl ester was
distilled twice using a high vacuum pump, the rotatory
power being observed before and after each distillation.

| Pressure | B.P. | $\alpha_{5461}$ in 1 dcm. tube. |
|----------|------|--------------------------------|
| .036 mm. | 90°C | -74.65 at 20.3°C |
| .015 mm. | 82°C | -74.69 at 20°C |

The ester before distillation gave $\alpha_{5461}$ = -74.30 at
20°C which  shows that it was obtained in a comparatively
pure state.

Density:- $D_{4°}^{20°}$ = .9366

Analysis:- 0.1198 gms. ester gave ammonia which
                required 8.88 ccs. of .056N HCl represent-
                ing 5.81% Nitrogen.

                $C_{15}H_{27}O_2N$ requires 5.81% Nitrogen.


        The rotatory powers were observed for the wave-
lengths 6708, 5893, 5461 and 4358 A.U., using the
ester in the homogeneous state, and also in alcohol
and benzene solutions.   These values together with

the graph of the reciprocal of the observed rotations plotted against the square of the wavelength of the light used, appear in the succeeding pages.   The rotatory powers for the same lines were observed for the hydrochloride of the ester in alcohol solution. The latter was prepared by adding the calculated amount of alcoholic hydrogen chloride to a weighed quantity of the ester dissolved in a little alcohol in a standard flask, and then making up to the mark with alcohol.

The rotatory powers of $l$-menthyl $\alpha$-amino-isobutyrate were also determined in some simple solvents derived from benzene.

### $l$-Menthyl $\alpha$-Amino-isobutyrate. M.W.241.2.

#### Observed Rotations.

Length of tube = 2 dcm.                    Temperature 20°C approx.

| State | C g./100 c.c. | $\alpha_{6708}$ | $\alpha_{5893}$ | $\alpha_{5461}$ | $\alpha_{4358}$ |
|---|---|---|---|---|---|
| Homog. | - | -48.55 | -63.70 | -74.65 | -123.5 |
| Benzene | 5.280 | 5.37 | 6.92 | 8.36 | 13.49 |
| Alcohol | 5.098 | 5.66 | 7.43 | 8.69 | 14.39 |
| HCl salt | 4.700 | 5.34 | 7.16 | 8.44 | 14.11 |

Molecular Rotations./

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## Molecular Rotations.

| State | C g./100 c.c. | $[M]_{6708}$ | $[M]_{5893}$ | $[M]_{5461}$ | $[M]_{4358}$ |
|---|---|---|---|---|---|
| Homog. | - | -124.8 | -163.7 | -192.4 | -317.2 |
| Benzene | 5.280 | 123 | 158 | 191 | 309 |
| Alcohol | 5.098 | 134 | 176 | 206 | 341 |
| HCl salt | 4.770 | 137 | 184 | 217 | 362 |

## Rotatory Powers of $l$-Menthyl α-Amino-isobutyrate in Simple Solvents derived from Benzene.

Length of tube = 2 dcm.          Temperature 20°C approx.

| Solvent | C g./100 c.c. | α obs. | $[M]_{5461}^{20°}$ |
|---|---|---|---|
| $C_6H_5CN$ | 5.126 | 8.08 | -189° |
| $C_6H_5NO_2$ | 5.016 | 7.84 | 188 |
| $C_6H_5CHO$ | 5.012 | 6.86 | [165] |
| $C_6H_5NH_2$ | 5.072 | 8.38 | 199 |
| $C_6H_5Br$ | 5.720 | 9.83 | [208] |
| $C_6H_5OCH_3$ | 4.820 | 7.31 | 183 |
| $C_6H_5CH_3$ | 5.166 | 8.01 | 187 |
| $C_6H_6$ | 5.280 | 8.36 | 191 |

[ ] Possible interaction.
Note: Curtius Ber.(J.pr[2] 37, 187) points out that methyl amino acetate absorbs $CO_2$ from the air. This was suspected in the case of  -menthyl α-amino-isobutyrate: it was kept therefore in a small burette which had a calcium chloride-sodalime  tube attached.

## *l*-Menthyl Aminoacetate.

The production of this ester required the preparation of glycocoll ester hydrochloride.

### Glycocoll Ester Hydrochloride.

This was obtained by condensing formaldehyde with ammonium cyanide to form methylene amino aceto-nitrile, which was hydrolysed in the presence of cold ethyl alcohol saturated with HCl to form the glycocoll ester hydrochloride, m.p. 138°. Klages (Ber. 36,1506) records m.p. 144°.

### Glycocoll Ester.

50 gms. of glycocoll ester hydrochloride (Fischer, Ber. 34, 433) were mixed with 25 c.c. of water (whereby a partial solution took place); 100 c.c. of ether were introduced, and the mixture treated with cooling with 40 c.c. of 33 per cent sodium hydroxide solution. Then as much dry granular potassium carbonate was added as was sufficient to convert the watery mixture into a thick paste. After vigorous stirring the ethereal mixture was poured off, the paste being extracted two or three times with a little ether, and the united ethereal solutions, after filtration, dried for ten minutes with anhydrous potassium carbonate, followed by several hours with anhydrous sodium sulphate. The ether was removed, and the ester then distilled at

43°-44°C under 11 mm. pressure.    Yield 52 per cent of theoretical.

### *l*-Menthyl Aminoacetate.

Quantities taken:-

7 gms. glycocoll ester

21.2 gms. menthol

.312 gms. sodium.

A trial preparation was carried out in the same manner as the previous ester.    On adding the glycocoll ester to the sodium menthoxide, however, it was observed that the mixture, after shaking, became solid.    It was therefore almost impossible to maintain a current of dry air throughout the apparatus to facilitate the removal of ethyl alcohol.    The calculated amount of ethyl alcohol was, however, distilled over by main- taining the flask and its contents at 110°-120°C for three hours.    Ether and dilute acid were added to the cold mixture as in the previous preparation, but it was found that a considerable quantity of green-coloured solid refused to dissolve.    Filtration was therefore resorted to, and the product worked up in the usual way.    About 3 c.c. of the menthyl ester (3 per cent. of theoretical yield) were obtained eventually:    this includes the yield obtained when the preparation was repeated with somewhat larger quantities.

The green solid was examined;    it was found to

contain nitrogen;   and possessed the properties of a
diketo piperazine.   This is apparently the main
product of the reaction.

The ester was distilled twice under high
vacuum.   Although, by the slight trace of menthol in
the neck of the distilling flask, it appeared to decom-
pose slightly, the rotatory power, $\alpha_{5461}^{20^\circ}$ = -85.79°,
was unchanged by distillation within the limits of
experimental error.

Determinations of the rotatory power were made
as before, using the ester in the homogeneous state
and in benzene solution.   The rotatory powers of the
ester and its hydrochloride in ethyl alcohol were also
determined.

After these determinations of rotatory power
the ester was purified through the hydrochloride.   The
rotation of the regenerated ester was unchanged.

<u>Density</u>:-   $D_{4^\circ}^{20^\circ}$ = .9760.

<u>Analysis</u>:-   .0333 gms. of ester gave ammonia which
required 2.85 c.c. of .056N HCl representing
6.71 per cent Nitrogen.

$C_{12}H_{23}O_2N$ requires 6.57 per cent Nitrogen.

-Menthyl Aminoacetate. M.W.213.2./

## *l*-Menthyl Aminoacetate. M.W.213.2.

### Observed Rotations.

Length of tube = 2 dcm.          Temperature 20°C approx.

| State | C g./100 c.c. | $\alpha_{6708}$ | $\alpha_{5893}$ | $\alpha_{5461}$ | $\alpha_{4358}$ |
|---|---|---|---|---|---|
| Homog. | - | -55.99 | -74.42 | -85.79 | -142.79 |
| Benzene | 5.014 | 5.90 | 8.04 | 9.18 | 16.75 |
| Alcohol | 4.972 | - | - | 9.20 | - |
| HCl salt | 4.952 | - | - | 9.20 | - |

### Molecular Rotations.

| State | C g./100 c.c. | $[M]_{6708}$ | $[M]_{5893}$ | $[M]_{5461}$ | $[M]_{4358}$ |
|---|---|---|---|---|---|
| Homog. | - | -122.3 | -158.2 | -187.5 | -312 |
| Benzene | 5.014 | 126 | 171 | 195 | 323 |
| Alcohol | 4.972 | - | - | 198 | - |
| HCl salt | 4.952 | - | - | 198 | - |

## Attempted Preparation of *l*-Menthyl α-Amino diethylacetate: $(C_2H_5)_2 C(NH_2) . COOC_{10}H_{19}$.

This first required the preparation of the hydrochloride of α-amino-diethylacetic acid and the corresponding methyl ester.

### Hydrochloride of α-amino-diethylacetic acid.

Quantities:-

13 gms. KCN

10.6 gms. $NH_4Cl$

17.7 gms. of diethyl ketone.

This compound was prepared in exactly the same manner as the previous dimethyl amino compound. Yield (using four times the above amounts) 20 gms. The compound did not melt; but sublimed at high temperatures.

### Methyl ester.

The above hydrochloride was not so soluble in methyl alcohol as the corresponding dimethyl derivative. The esterification was repeated four times, but the yield (6 gms.) was still too small to proceed with, since the free methyl ester had first to be prepared before introducing the methyl radical. The amino acid melted at 187°-192° and was not further examined.

## Attempted Preparation of di-*l*-Menthyl Dichloromalonate.

The preparation of this menthyl ester was attempted, using the method outlined by Reinbach for the preparation of the ethyl ester (Ber. 35, 1815).

### Dichloromalonic Acid.

10.4 gms. of finely divided and well-dried malonic acid were taken, covered with 100 c.c. of dry ether, and then 25 gms. of sulphuryl chloride dropped slowly in. After all the malonic acid had been brought into solution by gently warming on the water-bath, the gaseous products of the reaction were driven off, and the ether removed. The ethereal residue was allowed to stand in the vacuum desiccator for several days.

### di-*l*-Menthyl Dichloromalonate.

Reinbach (loc.cit.) esterified the ethereal residue by mixing it with 12 c.c. of ethyl alcohol, and passing through dry gaseous HCl. Using menthol instead of alcohol, HCl was passed in for eight hours, excess menthol taken off at the pump, and the residual liquid distilled using the high vacuum pump. It was subjected to three distillations, each time rejecting the first and last fractions until the rotation was constant. It was noticed, however, that the boiling point fell with each distillation (from 124° to 93°C under almost the same pressure) which suggested that

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decomposition was taking place.

$$\alpha_{5461}^{15°} = -83.85° \text{ (using 1 dcm. tube)}.$$

Analysis:- The compound was analysed by Carius' method; and
it was found not to conform to the expected
formula.   In fact as much AgCl was formed as
there was $AgNO_3$ present.   The constancy of
the optical rotation, however, suggested a
stable compound, and a further analysis gave
26.2 per cent Cl.   di-$l$-Menthyl dichloro-
malonate should contain 15.8 per cent Cl.
The compound may be the  -menthyl ester of
dichloroacetic acid which contains 26.6 per
cent Cl.

## Attempted Preparation of di-$l$-Menthyl
## Dibenzylmalonate.

The preparation of this ester was attempted in order to obtain further evidence of the space effect of bulky gem-groupings in substituted malonates.

### Diethyl benzylmalonate.

Quantities:-

120 gms. ethyl malonate

11 gms. sodium

60 gms. benzyl chloride.

Using the usual method of preparation (Ber., 35, 1821) an ester was obtained which distilled at 203°-205° C under 7 mm. pressure.   Yield 77 gms.

### Diethyl dibenzylmalonate.

The procedure was the same as in the previous preparation.   The main bulk of the ester distilled at 250°-252° C under 40 mm. pressure.   Yield 67 gms.

### di-$l$-Menthyl Dibenzylmalonate (see previous preparation)

Quantities:-

67 gms. of dibenzyl methyl malonate

98 gms. of menthol

72 gms. of sodium.

The difficulty with this syrupy ester was its purification. Distillation even with the use of the

high vacuum pump would have inevitably resulted in decomposition. Purification was attempted in the following manner.

The ester was shaken up with an equal volume of methyl alcohol (containing 4 per cent $H_2O$) in a separating funnel which was placed in luke-warm water until ester and solvent formed one liquid phase. The separating funnel and contents were then placed in a freezing mixture: the ester was thus thrown out and was separated, taken up in ether and washed ten times with water. The alcohol-free extract was then dried with calcium chloride and the ether taken off in a cold desiccator. Eventually the ester was dried in a heated desiccator for three days.

The syrupy ester was purified four times in all, but the rotation did not remain constant.

| | | | | |
|---|---|---|---|---|
| 1 | $\alpha = -20.20$ | | | ( 14.3°C |
| 2 | $\alpha = -22.14$ | | | ( 18.7°C |
| | | ) in 1 dcm. tube | | |
| 3 | $\alpha = -22.31$ | | | ( 14.5°C |
| 4 | $\alpha = -27.16$ | | | ( 20.5°C |

Owing to the heavy loss of ester by the above treatment the purification was abandoned.

Purification of Solvents./

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## Purification of Solvents.

(1) Ethyl Alcohol.   "Absolute" ethyl alcohol was
   refluxed over freshly prepared lime and then
   fractionated.   B.p. 77.85°/749 mm.

(2) Benzene. B.D.H. "extra pure" benzene was partially
   frozen out, dried and fractionated;   f.p. 55°, b.
   p. 80°-80.1°.

(3) Benzonitrile.   B.D.H. benzonitrile was dried and
   partially frozen out;   the crystalline portion was
   fractionated under reduced pressure.   It was
   obtained as a colourless liquid of f.p. -12.9° and
   b.p. 82.5°/15 mm.

(4) Nitrobenzene.   B.D.H. nitrobenzene was fractionated
   and the portion boiling over 190°-190.4° was
   partially frozen out.   The crystalline portion was
   melted, dried and fractionated under reduced pressure;
   f.p. 5.6°-5.7°;   b.p. 90°-91°/15 mm.

(5) Benzaldehyde.   B.D.H. benzaldehyde was washed with
   $Na_2CO_3$ solution, dried and fractionated, care being
   taken to expose to the air as little as possible;
   b.p. 179°-179.2°.

(6) Aniline.   Kahlbaum's aniline "from sulphate" was
   dried and fractionated, giving an almost colourless
   liquid;   b.p. 182.9°-183°.

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(7) <u>Iodobenzene.</u> B.D.H. iodobenzene was well washed
with sodium carbonate solution and water, dried
over calcium chloride and fractionated;  b.p. 187.8°-
188.1°.

(8) <u>Bromobenzene.</u> Treated in the same way as the iodo-
compound.  It was obtained almost colourless;
b.p. 154.8°-155.2°.

(9) <u>Chlorobenzene.</u> Treated in the same way as the bromo-
compound;  b.p. 131.6°-132°.

(10) <u>Anisole.</u> B.D.H. anisole was dried and fractionated.
It was colourless and gave no phenol reaction;  b.p.
153.8°.

(11) <u>Toluene.</u> Aytoun, Scott and Co.'s "pure" toluene
was dried with metallic sodium wire and fractionated;
b.p. 109.7°-109.8°.

(12) <u>Mesitylene.</u> B.D.H. mesitylene was dried over
calcium chloride and fractionated.

(13) <u>Cyclohexane.</u> B.D.H. cyclohexane was dried, partially
frozen out, and finally re-dried and fractionated;
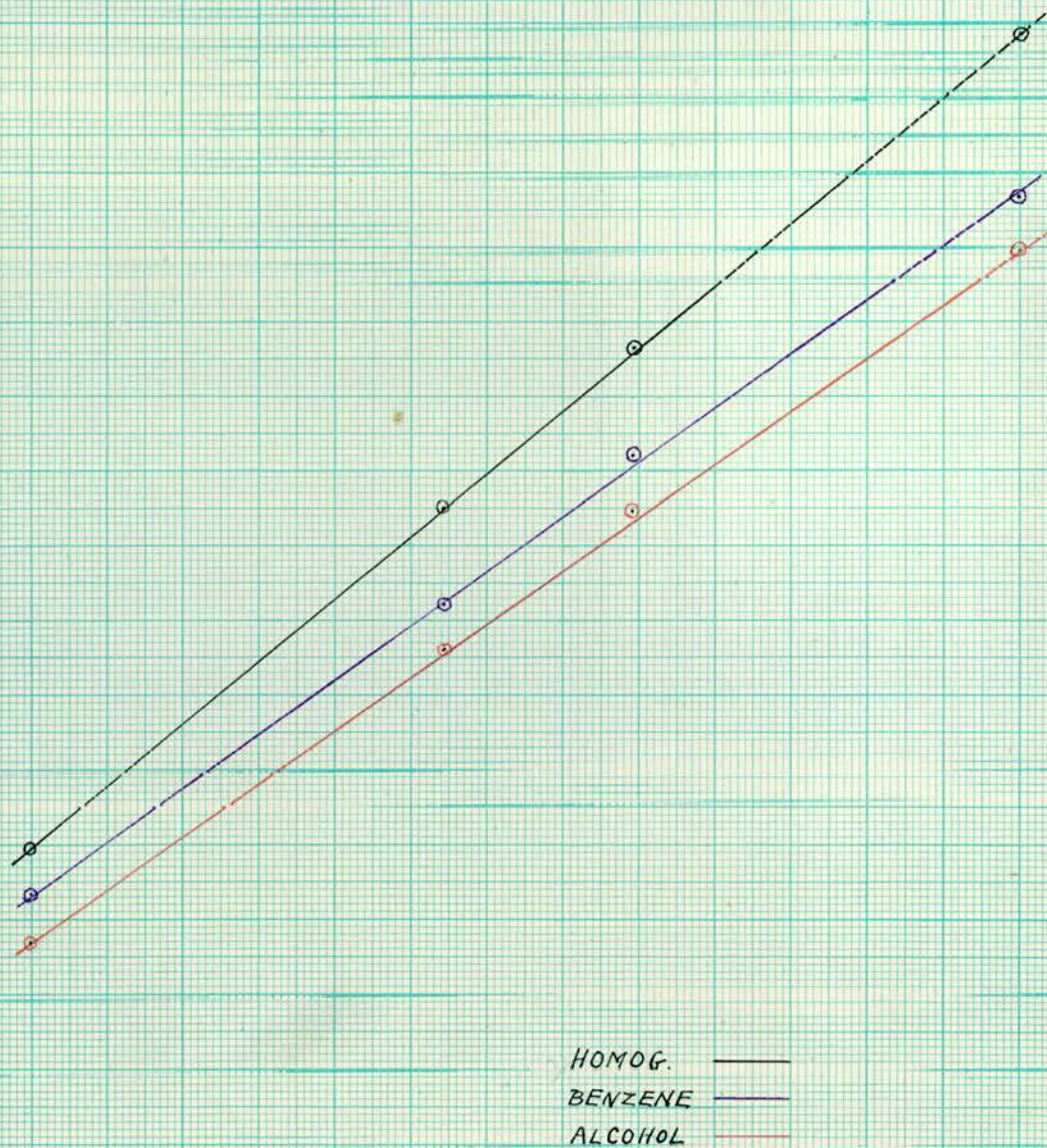b.p. 80.1°-80.3°.

## Dispersion Ratios.

On plotting the reciprocal of the rotation against the square of the wavelength a straight line graph, within the limits of experimental error, is obtained for the esters examined. The following table shows the values of the dispersion ration $\alpha_{4358}/\alpha_{5893}$.

| Ester. | $\dfrac{\alpha_{4358}}{\alpha_{5893}}$ | | |
|---|---|---|---|
| | Homog. | Benzene | Alcohol |
| $l$-menthyl acetate | 1.96 | 2.01 | 1.92 |
| di-$l$-menthyl dipropyl-malonate | - | 1.94 | 1.90 |
| di-$l$-menthyl dibutyl-malonate | - | 1.96 | 1.92 |
| $l$-menthyl hydrogen dipropylmalonate | - | 1.70 | 1.80 |
| $l$-menthyl $\alpha$-amino-isobutyrate | 1.93 | 1.94 | 1.95 |
| $l$-menthyl aminoacetate | 1.92 | - | 2.04 |

*l-MENTHYL ACETATE*

GRAPH SHOWING $\frac{1}{\alpha}$ AGAINST $\lambda^2$

| | | |
|---|---|---|
| HOMOG. | | |
| BENZENE | | |
| ALCOHOL | | |

200

1·00

·10

20    25    30    35    40    45

*l*-MENTHYL AMINOACETATE

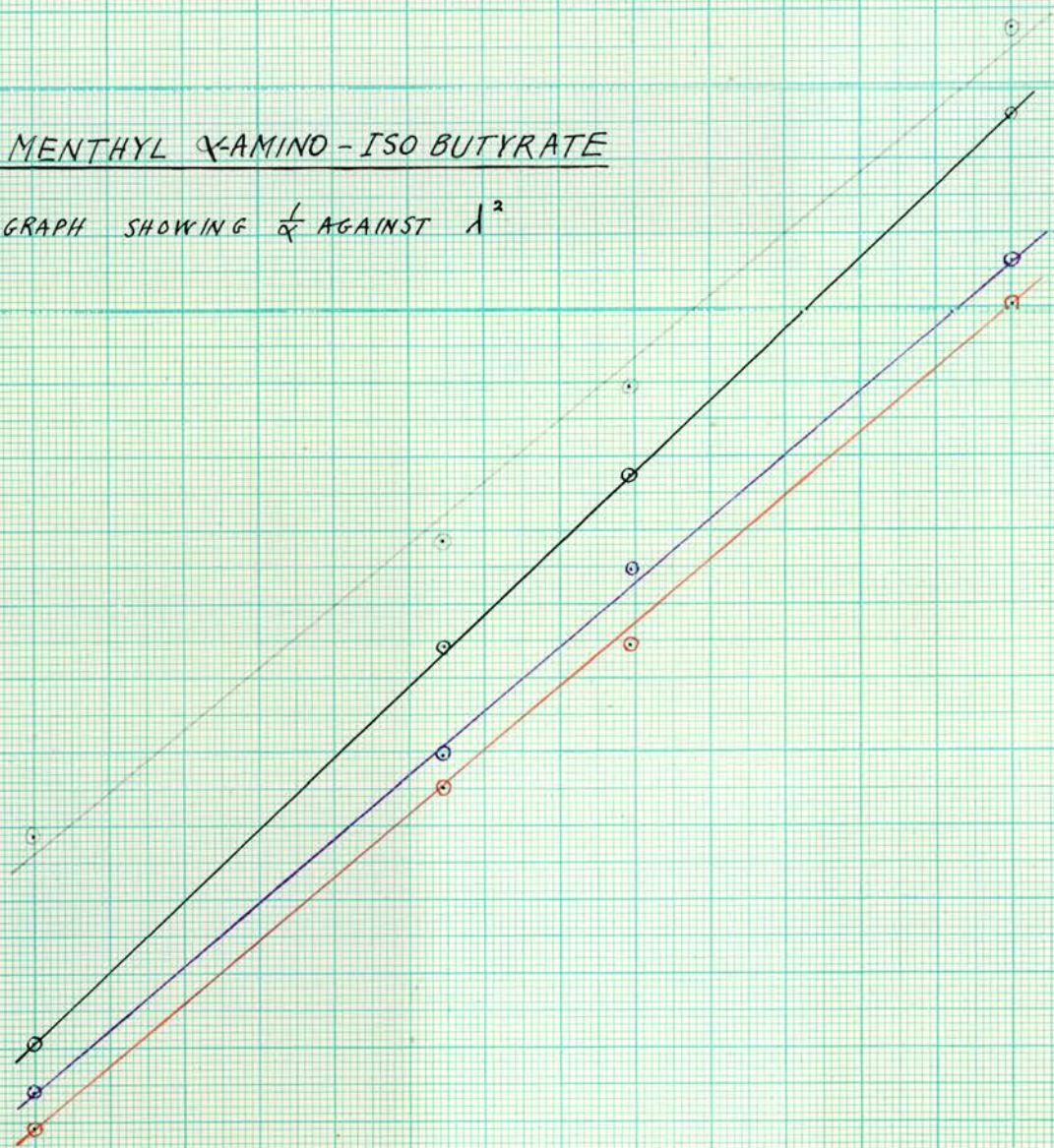GRAPH SHOWING $\frac{1}{\alpha}$ AGAINST $\lambda^2$

HOMOG. ———
ALCOHOL ———

*l*- MENTHYL ɣ-AMINO - ISO BUTYRATE

GRAPH SHOWING $\frac{1}{\alpha}$ AGAINST $\lambda^2$

HOMOG ----
BENZENE ——
ALCOHOL ——
Na salt in alcohol ----
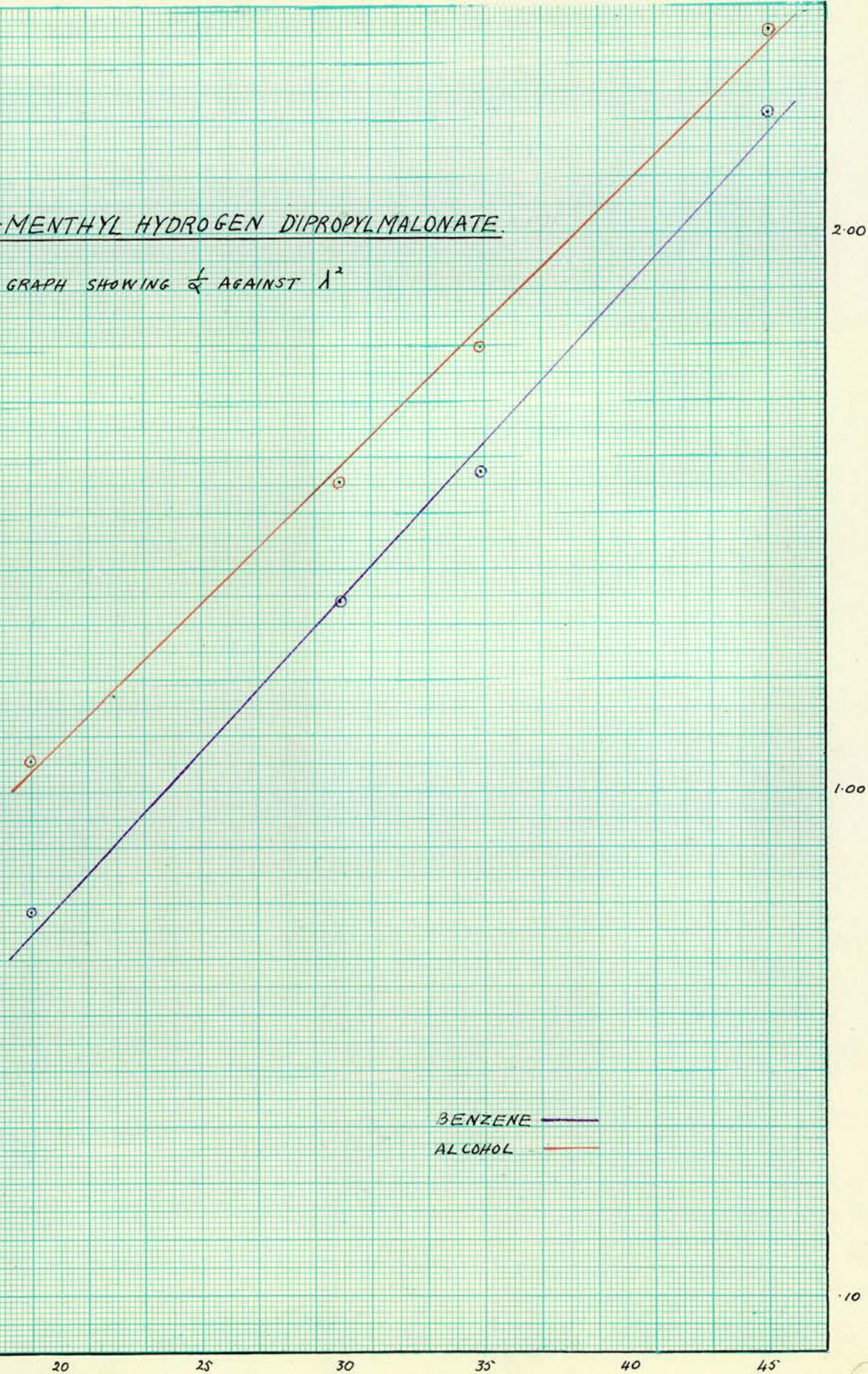
2.00

1.00

·10

20    25    30    35    40    45

③

*l*-MENTHYL HYDROGEN DIPROPYLMALONATE.

GRAPH SHOWING $\frac{1}{\alpha}$ AGAINST $\lambda^2$

2·00

1·00

·10

BENZENE ————
ALCOHOL ————

20    25    30    35    40    45

④

DI-l-MENTHYL DIPROPYLMALONATE

GRAPH SHOWING $\frac{1}{\alpha}$ AGAINST $\lambda^2$

BENZENE ————
ALCOHOL ————
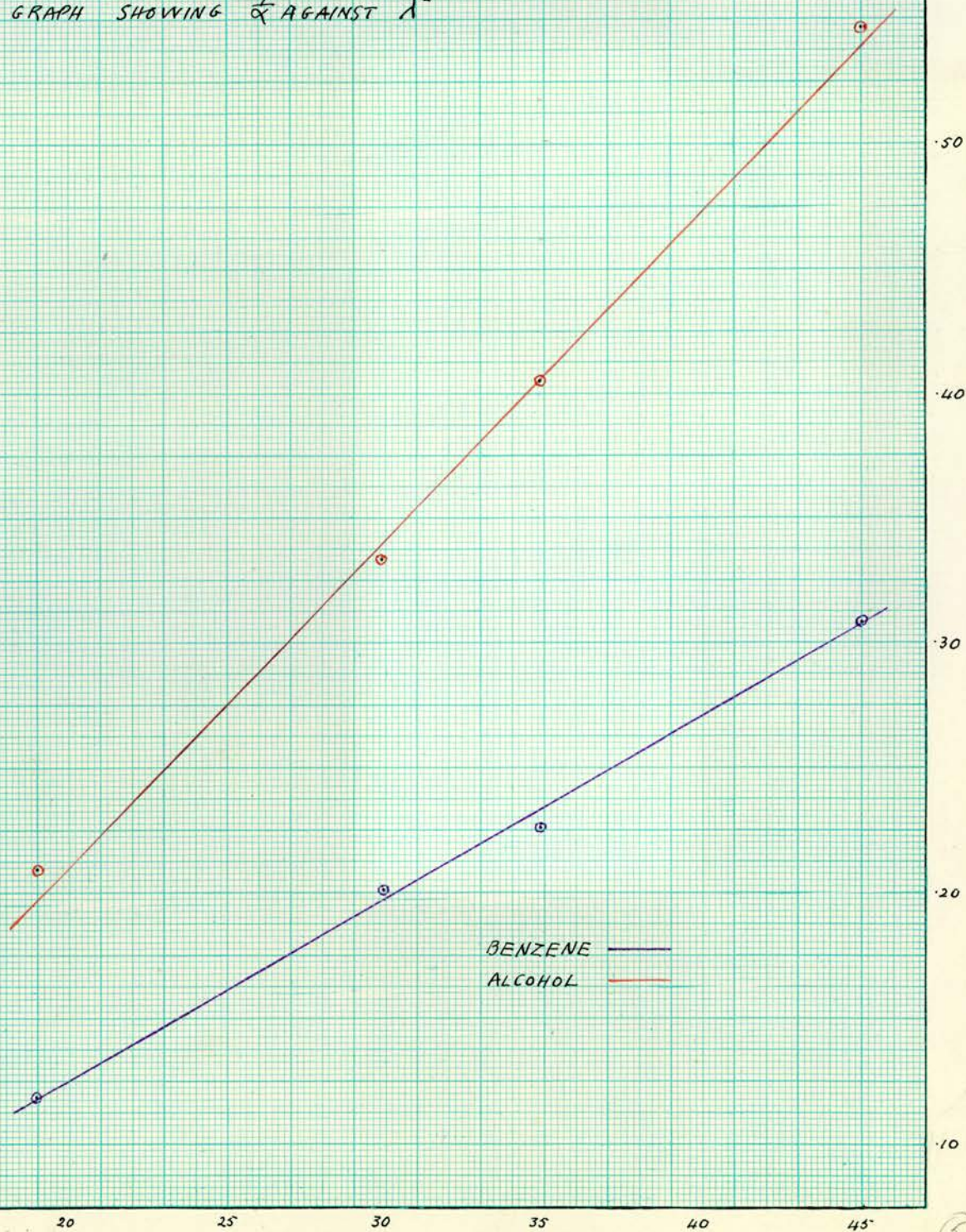
DI-*l*-MENTHYL DIBUTYL MALONATE.

GRAPH SHOWING $\frac{l}{q}$ AGAINST $\lambda^2$

BENZENE ————
ALCOHOL ————

64.
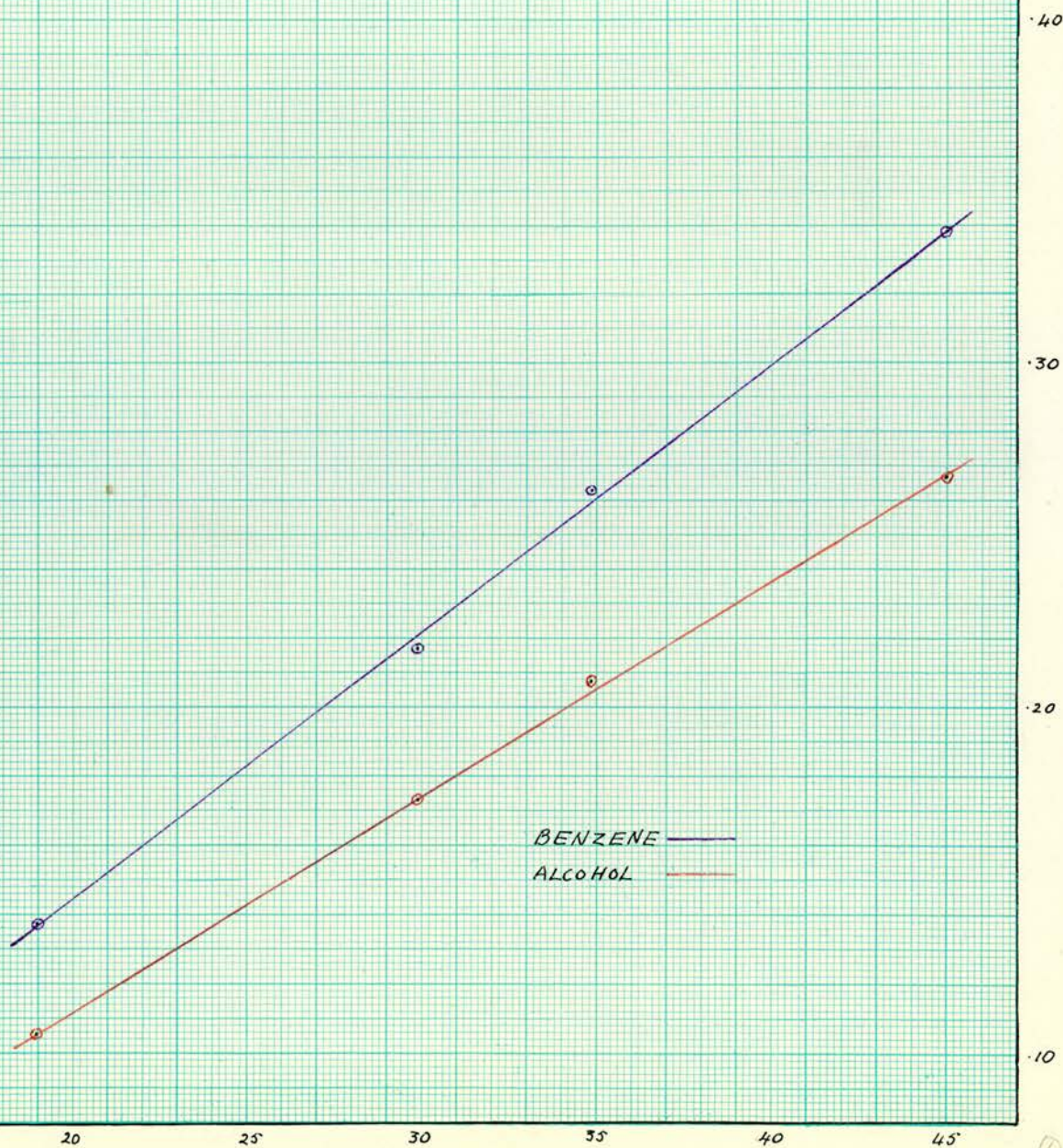
## DISCUSSION OF RESULTS.

For the purposes of comparison the values of the rotatory power $[M]_{5461}^{20°}$ for the esters of the general type, $CR_2 \diagdown \begin{smallmatrix} COOC_{10}H_{19} \\ X \end{smallmatrix}$ are reproduced in the following table. Several additional values have been included from other sources, as indicated in the footnotes.

| Substit. X | State | R=H | R=Me | R=Et | R=Pr | R=Bu |
|---|---|---|---|---|---|---|
| $CO_2C_{10}H_{19}$ | Homog. | -311.0[1] | -271.9[4] | -279.1[4] | - | -213 |
| $CO_2H$ | " | 189.9[2] | 205.0[4] | 225.0[4] | - | - |
| OMe | " | 195.3[3] | 198.0[4] | - | - | - |
| H | " | 185.9 | - | - | - | - |
| $NH_2$ | " | 187.3 | 192.4 | - | - | - |
| $CO_2C_{10}H_{19}$ | Benzene (C=5) | 324[4] | 293[4] | 259[4] | 288 | 227 |
| $CO_2H$ | " | 188[4] | 199[4] | 213[4] | 212 | 162 |
| OMe | " | 184[4] | 190[4] | 201[4] | - | - |
| H | " | 191 | - | - | - | - |
| $NH_2$ | " | 195 | 191 | - | - | - |
| $CO_2C_{10}H_{19}$ | Alcohol (C=5) | 362 | 321[4] | 315[4] | 337 | 287 |
| $CO_2H$ | " | 193 | 203[4] | 215[4] | 207 | 165 |
| $CO_2Na$ | " | 185[4] | 164[4] | 166[4] | 176 | 135 |
| OMe | " | 196[4] | 214[4] | - | - | - |
| H | " | 199 | - | - | - | - |
| $NH_2$ | " | 198 | 206 | - | - | - |
| $NH_2HCl$ | " | 198 | 217 | - | - | - |

1. Extrapolated from values at 70°,90° etc. recorded by Hall,(J.C.S.,1923,123,110).
2. Rule, Hay and Paul, (J.C.S., 1928, 1348).
3. Rule and Smith, (J.C.S., 1925, 127, 2188).
4. Results for these homogeneous esters and their corresponding values in alcohol and benzene solutionswere determined by Rule and Harrower, (J.C.S., 1930, 2321).

Amino Esters and their Hydrochlorides of the type

$$CR_2 \begin{cases} COOC_{10}H_{19} \\ X \end{cases} \quad ; \quad \text{Rotatory Powers, } [M]_{5461}^{20°}$$
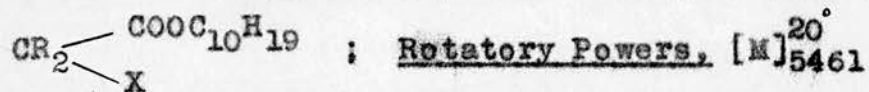
TABLE I.

| Substit. X | State | R = H | R = Me |
|---|---|---|---|
| $NH_2$ | Homog. | -187.3° | -192.4° |
| $NH_2$ | Benzene | 195 | 191 |
| $NH_2$ | Alcohol | 198 | 206 |
| $NH_2 HCl$ | Alcohol | 198 | 217 |

Since the gem-diethyl amino compound was not obtained it is difficult to say very much about the influence of the gem-dimethyl group in increasing the proximity of the amino substituent to the carbomenthoxy complex. As will be seen from the above table there is a rise in the value of the rotation as we pass from the unsubstituted to the dimethyl derivative in the homogeneous state and in alcohol solution; but in benzene the value falls. Probably the most reliable index of the rotation is that given in benzene which is a non-polar solvent. In alcoholic solution the conditions are complicated by the power of the hydroxylic solvent to associate with the amino group, and a similar state of association must be attributed to the homogeneous amino ester. It is not possible to discuss the influence of such changes upon the rotatory power

until more is known as to the nature of the electronic
rearrangement involved.    In dilute benzene solution
the tendency will be for the associated molecules to
become separated.    Since the electronegative carboxyl
group leads to a rise in rotation in the malonate, a
rise which is further increased in the dimethyl
derivative, it is probably to be expected that the
electropositive amino group should produce a change of
the reverse type as is actually observed in benzene
solution.

It is to be noticed that the conversion of the
amino-acetate into its hydrochloride produces no per-
ceptible difference in the value of the rotation (i.e.
any rise in the rotation is so small that it falls
within the limit of experimental error).    On the other
hand, in the case of the gem-dimethyl compound, salt
formation causes a rise of 12°.    The behaviour of the
corresponding acid esters when converted into their
sodium salts (Rule and Harrower's figures) is very
similar, although the change is here in a downward
direction.    As similar results have been observed
among the ortho-substituted amino- and carboxy- benzoates,
it may be assumed that the greater magnitude of the
variations in the gem-dimethyl amino ester is due to
the amino group being forced into closer proximity to
the ester group containing the active radical.

It is interesting to compare the molecular
rotations of $l$-menthyl amino-acetate with those of the
alkylamino-acetates prepared by Rule, Thompson and
Robertson (J.C.S., 1930, 1888).

### TABLE II.

Rotatory Powers, $[M]^{20°}_{5461}$ for $l$-menthyl esters of
the type, $H_2C\diagdown{}^{COOC_{10}H_{19}}_{X}$

| Substit. X | $[M]^{20°}_{5461}$ (homog.) | $[M]^{20°}_{5461}$ (in alcohol) | $[M]^{20°}_{5461}$ (hydrochloride in alcohol.) |
|---|---|---|---|
| $N(C_2H_5)_2$ | -182.7° | -203° | -208° |
| $N(CH_3)_2$ | 185.5 | 201 | 207 |
| $NH_2$ | 187.5 | 198 | 198 |

The higher value obtained for the unsubstituted
amino compound suggests that it may occur to some
extent in chelate type. In the chelate compound the
co-ordinate bond between the ketonic oxygen and the
hydrogen atoms is supposed to produce an electron trans-
fer away from the asymmetric atom, which would be
expected to lead to an increase in the rotatory power
e.g.

$$H\diagdown N\diagup{}^{H}\nearrow O$$
$$CH_2 . \overset{\parallel}{C} . O C_{10}H_{19}$$

68.

Substitution of the amino substituent prevents co-ordination as the diminishing values $NH_2 \rightarrow N(CH_3)_2 \rightarrow$ $N(C_2H_5)_2$ in the homogeneous state appear to show. These changes, however, are of very small magnitude. The opposite trend of the values for the amino-compounds in alcohol and their hydrochlorides in the same solvent is in agreement with an increasingly stronger positive field exerted at the asymmetric atom by the respective substituents as a result of increased ionisation.

Co-ordination of the unsubstituted amino-compound is thus one factor which may cause anomalies in a series such as that of the $l$-menthyl esters of monosubstituted acetic acids. Nevertheless, the general tendency of the electropositive groups ($NEt_2$, $NMe_2$, $NH_2$, H, $CH_3$) to give low rotations is readily seen from the following table.

TABLE III./

## TABLE III.

Rotatory Powers of Homogeneous *l*-Menthyl Esters of

Monosubstituted Acetic Acids:   $XCH_2COOH$.

| Substit. X | $\mu \times 10^{18}$ | $K_a \times 10^5$ | $[M]_D^{20°}$ |
|---|---|---|---|
| $N(Et)_2$ | - | } Small | -154.6° |
| $N(Me)_2$ | +1.4 | | 156.9 |
| $NH_2$ | - | | 158.2 |
| H | +0.4 | 1.8 | 157.3 |
| $CH_3$ | -0.9 | 1.4 | 160.2 |
| COOH | - | 160 | 160.2 |
| $OC_2H_5$ | -1.2 | 23 | 160.6 |
| $OCH_3$ | -1.7 | 33 | 165 |
| OH | -1.5 | 15 | 165 |
| Br | -1.5 | 138 | 169 |
| Cl | -1.5 | 155 | 171 |
| CN | -3.8 | 370 | 174 |

Acid Esters and their Sodium Salts of the type

$$R_2C < \begin{matrix} CO_2C_{10}H_{19} \\ X \end{matrix} \quad ; \quad \text{Rotatory Powers}, [M]_{5461}^{20°}$$
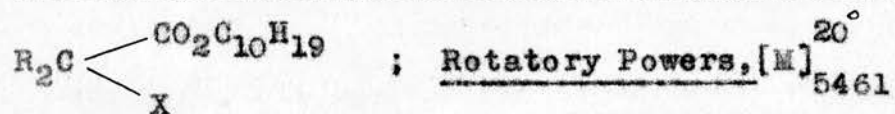
### TABLE IV.

| Substit.X | State | R=H | R=Me | R=Et | R=Pr | R=Bu |
|---|---|---|---|---|---|---|
| COOH | Benzene | -188° | -199° | -213° | -212° | -162° |
| COOH | Alcohol | 193 | 203 | 215 | 207 | 165 |
| COONa | Alcohol | 185 | 164 | 166 | 176 | 135 |

Rule and Harrower observed a continuous rise
in the optical rotations of the dialkyl-substituted
$l$-menthyl hydrogen malonates containing the groups,
$CH_2 \longrightarrow C(CH_3)_2 \longrightarrow C(C_2H_5)_2$. The experimental
results recorded in this thesis, however, shew that at
the gem-dipropyl hydrogen malonate there is a slight
fall, and at the gem-dibutyl compound a decided fall
in the optical rotation, as observed in alcohol and
benzene solutions (see curves in figure 1).

The observed rise in the rotation for the first
three members of the gem-dialkyl hydrogen malonate
series was apparently, as pointed out by Rule and Harrower
(loc.cit.), in accordance with the deductions drawn for
ortho-substituted benzoic esters. The continuous rise,
however, for the corresponding methoxyl derivatives was
not analgous to the characteristic depression brought
about by the methoxyl group in $l$-menthyl o-methoxyl
benzoate. It was, therefore, suggested by these authors
that the continuous rise in the rotatory powers of the
methoxyl and carboxyl esters for the first three members
of the series might be due in part to the normal
specific influence of the alkyl groups.

The following values of $[M]_D$ observed by Rupe
(Trans. Faraday Soc., 1914, 10, 46) for methyl substituted
acetic acids indicate that the primary influence of
the substituent is to raise the rotation;

and this effect is ultimately masked by a second
(possibly spatial) effect which depresses the rotation
in the tertiary compound.   The fall in the case of
the tertiary compound is even better demonstrated
when phenyl groups are substituted:-

$[M]_D$

$CH_3CO_2C_{10}H_{19}$     -158°                          $[M]_D$

$CH_3CH_2CO_2C_{10}H_{19}$   160.2      $C_6H_5CH_2CO_2C_{10}H_{19}$  -185.1°

$(CH_3)_2CHCO_2C_{10}H_{19}$163.5      $(C_6H_5)_2CHCO_2C_{10}H_{19}$  226.8

$(CH_3)_3CCO_2C_{10}H_{19}$ 161.5      $(C_6H_5)_3CCO_2C_{10}H_{19}$   14.6 (in toluene)

The values of the optical rotation of the gem-dialkyl
hydrogen malonates rise and fall in a very similar
manner, and probably from the same cause.

In the case of the conversion of the gem-dipropyl
and gem-dibutyl compounds into their respective sodium
salts the consequent fall in rotation is fairly large
in both cases, and this is in agreement with the fact
that these are relatively strong acids as compared with
the unsubstituted derivative.   The following figures
for the primary dissociation constants ($K_1$) recorded
by Gane and Ingold extend only as far as the dipropyl
derivative:-

| Acid | $K_1$ |
|------|-------|
| $CH_2(COOH)_2$ | .00141 |
| $(CH_3)_2C(COOH)_2$ | .00066 |
| $(C_2H_5)_2C(COOH)_2$ | .00639 |
| $(C_3H_3)_2C(COOH)_2$ | .009 |

As we ascend the series (see curve in figure 1) there is a general decrease in the rotatory power of the sodium salts; a result apparently of the increased proximity of the $COO'$ and $COOC_{10}H_{19}$ complexes. For the corresponding free acids up to the dipropyl derivative there is a general increase, both in alcohol and benzene solutions, due in all probability to the carboxyl group being forced into closer relationship with the carbomenthoxy complex. This behaviour is similar to that of d-sec-$\beta$ octyl hydrogen phthalate and terephthalate, and their sodium salts as observed by Rule and MacGillivray (J.C.S., 1929, 2275). Superimposed upon these changes is a tendency for a maximum rotation to occur at the dipropyl derivative, the significance of which is discussed later.

| Solvent | $[M]_{5461}$ | (d-sec-octyl hydrogen terephthalate.) | $[M]_{5461}$ | (d-sec-$\beta$ octyl hydrogen phthalate.) |
|---|---|---|---|---|
| Alcohol | +145° | | +162° | |
| Sodium salt in alcohol | +148.3 | | +83.35 | |

The behaviour of the unsubstituted hydrogen malonate on ionisation resembles that of the acid terephthate, whereas that of the higher homologues is more comparable to the acid phthalate. The negative pole formed on ionisation, the result of complete

separation of the two components of the OH dipole,
may be regarded as having a more powerful and extensive
electric field, than would, in ordinary circumstances,
belong to a simple dipole.    As the distance between
the negative pole, and the asymmetric atom decreases,
when we pass from the unsubstituted to the higher gem-
dialkyl compounds, the difference between the molecular
rotations of the free acids and their ionised forms,
although it does not increase with any regularity,
nevertheless, maintains the high magnitude set by the
gem-dimethyl derivative.    The real difference between
the COOH group and COO residue for the higher homologues
is probably diminished somewhat by the ionisation of
the acid esters in alcohol.

The sudden fall at the dibutyl compound (see
figure 1) may be either a periodic depression in the
curve, or due to some radical change in the relation
between the carboxyl and carbomenthoxy complexes with
greatly reduced distance.  In the peri-derivative,
$l$-menthyl hydrogen naphthalate, Rule and McLean
observed that the rotation of the acid is highly
positive in benzene and of a low negative value in
alcohol.    In this case, also, it appears that when
the carboxyl group is brought into very close proximity
to the ester complex the rotation is strongly diminished
as compared with the corresponding ester in which no
free carboxyl is present.

The final conclusions drawn from the curves in figure 1 are summarised with those of the dimenthyl esters at the end of the next section.

Rotatory Powers of di-$l$-Menthyl gem-Dialkyl Malonates of the type $R_2C \diagup \overset{CO_2C_{10}H_{19}}{\diagdown CO_2C_{10}H_{19}}$ .

### TABLE V.

| State | R=H | R=Me | R=Et | R=Pr | R=Bu |
|-------|------|--------|--------|------|------|
| Homog. | -311° | -271.9° | -271.9° | - | -213° |
| Benzene | 324 | 293 | 259 | 288 | 227 |
| Alcohol | 362 | 321 | 315 | 337 | 287 |

It was observed by Rule and Harrower (loc.cit.) that the molecular rotations in benzene and alcohol solutions exhibit on the whole a regular decrease, as we pass from the malonate to the gem-diethyl derivative. At the gem-dipropyl compound there is a moderate rise followed at the gem-dibutyl compound by a very marked fall in rotation. The general decrease can be explained as being due to the packing of the carbomenthoxy complexes together as a result of the decreased angle between the corresponding valency bonds as we pass from the unsubstituted malonate to the gem-dibutyl compound.

A similar effect has been observed by Cohen (J.C.S., 1916, 225) in the rotatory powers of dimenthyl phthalate and terephthalate.
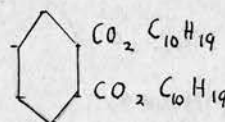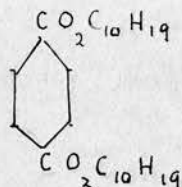
$$[M]^{20°}_{5893} = -526° \text{ (terephthalate)} \qquad [M]^{20°}_{5893} = -444° \text{ (phthalate)}$$

It has already been pointed out that the behaviour of the gem-dialkyl hydrogen malonates was comparable to that of the acid phthalates: the resemblance between the corresponding dimenthyl esters is even more striking.

Walden (Zeit.Phy. Chem., 1896, 20, 377), in an examination of the diamyl esters of fumaric and maleic acids, found that the molecular rotation $[M]_D$ of the fumaric compound (+15.7°) was greater than that of the maleate (+11.8°), a case similar to that discussed above.

It is interesting at this point to summarise the three principal homologous series of $l$-menthyl esters of aliphatic acids, namely:-

1. Homologous Series of the type, $C_x H_{2x+1} \ CO_2 C_{10} H_{19}$
2. Homologous Series of the type, $(C_x H_{2x})_n (CO_2 C_{10} H_{19})_2$
3. Homologous Series of the type, $(C_x H_{2x+1})_2 C.(CO_2 C_{10} H_{19})_2$

In the first type ( $l$-menthyl esters of the normal fatty acids, studied by Tschugaeff) neither the molecular rotations nor the dissociation constants vary to any great extent. The usual effect ascribed to the return of the growing chain is first apparent in the valerate, leading to a slight rise in this and the two succeeding members.

## TABLE VI.

| Ester | K | $[M]_D$ (homog) |
|---|---|---|
| H.COOM | -0214 | -146.3° |
| $CH_3$.COOM | .00130 | 157.3 |
| $C_2H_5COOM$ | .00145 | 160.2 |
| $C_3H_7COOM$ | .00175 | 156.9 |
| $C_4H_9COOM$ | .00159 | 157.3 |
| $C_5H_{11}COOM$ | .00156 | 157.7 |
| $C_6H_{13}COOM$ | .00147 | 157.7 |
| $C_7H_{15}COOM$ | .00146 | 155.8 |

Both the menthyl and octyl esters of the second
type have been investigated by Hall (J.C.S.,1923, 105:
1923, 32), and here any chain effect is apparently
subordinated to and almost obliterated by an alternating
effect supposed to be due to the alternate cis and trans
structure of the saturated dicarboxylic acids and their
derivatives. (See note on page 80).

Now, in the third type (menthyl esters of the
gem-dialkyl malonates examined in this thesis) the
only exception to the general decrease in rotatory
power as we ascend the series, as observed in alcohol
and benzene solutions, occurs at the dipropyl compound.
This abnormality, therefore, resembles that of the
acetic acid series, except that it is more pronounced.

FIGURE 2

HOMOLOGOUS SERIES OF DIALKYL-SUBSTITUTED MALONIC ESTERS OF *l*-MENTHOL IN BENZENE AS SOLVENT.

## TABLE VII.

| Ester. | $K_1$ | $K_2$ | $[M]^{20°}_{5461}$ (homog.) | $[M]^{20°}_D$ (C=5 in benzene.) |
|---|---|---|---|---|
| $(COOM)_2$ | 10? | - | - | -371° |
| $CH_2(COOM)_2$ | .00141 | 43.7 | -311° | 278 |
| $(CH_3)_2C(COOM)_2$ | .00066 | 15.3 | 271.9 | 246 |
| $(C_2H_5)_2C(COOM)_2$ | .00639 | .590 | 279.1 | 222 |
| $(C_3H_7)_2C(COOM)_2$ | .009 | .342 | - | 259 |
| $(C_4H_9)_2C(COOM)_2$ | - | - | 213 | 187 |

In the malonic series there appears to be little
or no connection between the abnormal variations in dis-
sociation constant and rotatory power.    This is only
to be expected since the molecules of the menthyl ester
can only in a general way be compared to those of the
simpler acid;   the considerable bulk of the menthyl com-
plex will exert a great influence on the spatial dis-
position of the carboxylic groups.    The values in the
last column of Table VII are plotted in figure 2 and
clearly show the deviation at the dipropyl compound
from the otherwise steady fall in rotation with increas-
ing length of the gem-dialkyl group.    As has already
been stated the general fall in rotation is interpreted
as being due to the increased packing of the ester groups.

   This anomalous behaviour of the dipropyl compound
is illustrated not only by its optical rotation   but

also by its melting point, and the solubility of the
ester in ethyl alcohol.   Five per cent. solutions in
alcohol were made for every ester of the series with
the exception of the dipropyl derivative for which it
was only possible to prepare a two per cent. solution.

M.p. of unsubstituted ester      =      57-27.5°C.

B.p. of gem-dimethyl ester      =      208-215° under 2 mm.
                                                      pressure.

M.p. of gem-diethyl ester      =      52-53°C.

M.p. of gem-dipropyl ester      =      94°C.

M.p. of gem-dibutyl ester      =      58°C.

In the homogeneous esters (see molecular rotations
in Table V) this maximum in the rotatory power was
already becoming apparent in the diethyl derivative.
The dipropyl ester was not examined in the homogeneous
state owing to the small amount of material available,
but judging from its behaviour in solvents, it is
probable that the maximum effect is exhibited in the
homogeneous state in the dipropyl compound.

General Conclusions for Homologous Series of Esters
of the type, $R_2C \overset{CO_2C_{10}H_{19}}{\underset{X}{\diagdown}}$ , where X = COOH,

COONa or $CO_2C_{10}H_{19}$.

I.  All these esters (as indicated by the curves in
figures 1 and 2) exhibit relatively high values at
the gem-dipropyl and low values at the gem-dibutyl
derivative.

II.  The curves for X = COOH and X = COO$^|$ trend in
opposite directions between the unsubstituted and
dipropyl compounds, and this has been interpreted
as being due to the increased proximity of the group
X to the carbomenthoxy complex.  Owing to insufficient
data it is not possible to pursue the comparison
further, the trend of the curves above the dibutyl
derivative being unknown.

III.  The curves for X = $CO_2C_{10}H_{19}$ and COO$^|$ both tend to
fall with increasing molecular weight of the ester.
They show in addition a maximum at the dipropyl
derivative.

    The fact that all compounds show a maximum at
the dipropyl compound argues a common cause.  At this
point the growing alkyl chains have completed the
first spirals of 5 carbon atoms (including the common
atom marked X and the carbon of the carboxyl group).
In reality there are two growing chains present which
are identical with one another:-

$$CH_3 \cdots\cdots CH_2CH_2 \diagdown \quad X \diagup CO_2C_{10}H_{19}$$
$$CH_3 \cdots\cdots CH_2CH_2 \diagup C \diagdown CO_2X$$
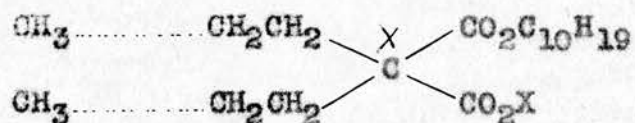
    It may be noted that the spiral is not the only
form a chain can assume, nor considered solely on
mathematical grounds is it the most probable (Pickard
Kenyon and Hunter, J.C.S., 1931, 1).  Nevertheless, the

accumulative evidence, as supplied by over thirty
different physical properties (Lee, Trans. Faraday
Soc., 1927, 634) points to a spiral formation.    It
would therefore appear that polarity is a factor
which must be taken into account in connection with
these returning chain effects.    Rule, Hay and Paul's
results (J.C.S., 1928, 1347) for cases in which
alkyloxyl and carboxyl radicals respectively were
situated at the termini of growing chains have already
been mentioned in the introduction to this thesis.

In the two homologous series under discussion we
have positively charged hydrogen atoms at the end of
each growing chain, and it is very probable that each
of these radicals, on the return of the chain in the
dipropyl compound, is strongly attracted by the corres-
ponding negatively-charged ketonic oxygen, e.g.
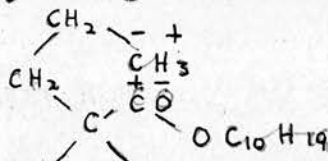


The greater stability of the ring formation in
such a case may well account for the higher rotation.
The rise would be further increased in the malonates
owing to the double action of the second propyl and
COOR groups.

Until the values for higher homologues are avail-
able it is not possible to draw any more definite con-
clusions from the experimental results under discussion.

Note/

<u>Note</u>:- The low rotatory power of the di-$l$-menthyl malonate is explained by Hall (J.C.S.,1923, 105) on the cis configuration

$$CH_2 \begin{matrix} CO & \diagdown \, OH \\ & \diagup \, OH \\ CO \end{matrix}$$
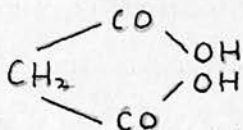
already assigned to malonic acid by Price and Brazier (J.C.S.,1915, <u>107</u>, 1719.).

The effect of adding one atomic proportion of sodium to di-$l$-menthyl malonate in alcoholic solution is recorded in the experimental section of this thesis. The rotation speedily falls on adding the sodium (in the form of sodium ethoxide) owing to hydrolysis of the ester, but by extrapolation by means of a time-graph, it was found that for the sodium compound $[M]_{5461}^{20°} = -378°$. The molecular rotation of the ester itself in alcohol is $[M]_{5461}^{20°} = -362°$. The rise in rotation is possibly due to the production of the enolic form e.g.

$$H.C \begin{matrix} C \diagup \!\!\!= O \\ \diagdown OM \\ C \diagup ONa \\ \diagdown OM \end{matrix}$$
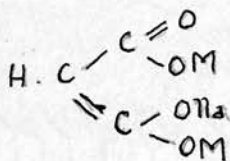
The presence of the double bond might well be sufficient to cause an increase in the rotatory power.

## Influence of Polar Solvents.

In the following table are summarized the rotatory powers of $l$-menthyl esters of the type, $R_2C{<}{\overset{CO_2C_{10}H_{19}}{X}}$ in simple solvents derived from benzene. The solvent effect is first examined in detail for each ester, and then the significance of the effect is discussed for the series as a whole.

The di-$l$-menthyl gem-dialkyl malonates are particularly suitable for examination in solvents, as these esters contain two asymmetric groups and two alkyl chains, and the resulting effects are in consequence almost doubled.

Rotatory Powers $[M]^{20°}_{5461}$ of $l$-menthyl Esters of the type $R_2C{<}{\overset{CO_2C_{10}H_{19}}{X}}$ in Simple Solvents derived from Benzene./

82.

Rotatory Powers $[M]^{20°}_{5461}$ of *l*-Menthyl Esters of

the type $R_2C \big\langle \begin{smallmatrix} CO_2C_{10}H_{19} \\ X \end{smallmatrix}$     in Simple Solvents

derived from Benzene.

| Solvent * | R=H X=H | R=H X=CO₂M | R=Me X=CO₂M | R=Et X=CO₂M | R=Pr X=CO₂M | R=Bu X=CO₂M | R=Me X=NH₂ |
|---|---|---|---|---|---|---|---|
| $C_6H_5CN$ | -179° | -332° | -280° | -275° | -247° | -162° | -189° |
| $C_6H_5NO_2$ | 175 | 324 | 290 | 282 | 254 | 165 | 188 |
| $C_6H_5CHO$ | 183 | - | - | - | 256 | 177 | [165] |
| $C_6H_5NH_2$ | 208 | - | - | - | - | 215 | 192 |
| $C_6H_5I$ | - | 326 | 293 | 263 | 260 | 180 | - |
| $C_6H_5Br$ | 184 | - | 287 | - | 266 | 194 | [208] |
| $C_6H_5Cl$ | 184 | - | - | - | 271 | 200 | - |
| $C_6H_5OCH_3$ | 185 | 330 | 298 | 269 | 279 | 211 | 183 |
| $C_6H_5CH_3$ | 185 | 322 | 288 | 257 | 280 | 215 | 187 |
| $C_6H_6$ | 191 | 325 | 294 | 261 | 288 | 227 | 191 |
| $C_6H_3(CH_3)_3$ | 185 | 335 | 305 | 296 | 310 | 244 | - |
| $C_6H_{12}$ (Cyclo-bexane) | 189 | 331 | 294 | 292 | 314 | 262 | - |
| Max. range | 33° | 11° | 25° | 35° | 67° | 100° | |

[ ]  Probable chemical interation with solvent.

*    The solvents are arranged in order of diminishing

dipole moments.

TABLE VIII./

FIGURE 3

ROTATORY POWERS OF ℓ'-MENTHYL ACETATE
IN BENZENE DERIVATIVES.

1 BENZENE
2 cyclo-HEXANE
3 MESITYLENE
4 TOLUENE
5 ANISOLE
6 CHLOROBENZENE
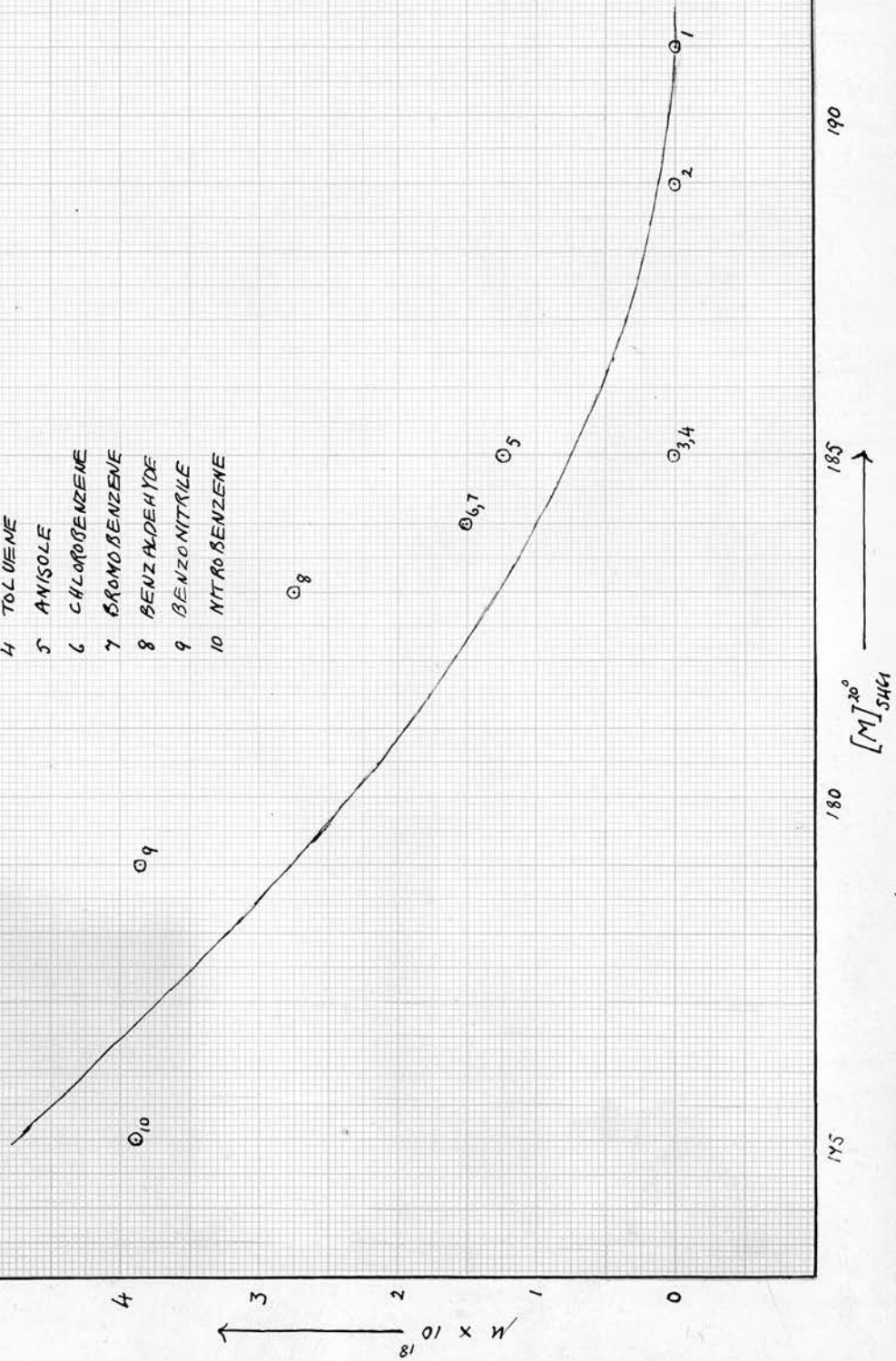7 BROMOBENZENE
8 BENZALDEHYDE
9 BENZONITRILE
10 NITROBENZENE

## TABLE VIII.

Rotatory Powers of $l$-Menthyl Acetate in Simple Solvents derived from Benzene.

| Solvent | $\mu \times 10^{18}$ | $[M]^{20°}_{5461}$ |
|---------|---------------------|---------------------|
| $C_6H_5NO_2$ | 3.89 | -175° |
| $C_6H_5CN$ | 3.85 | 179 |
| $C_6H_5CHO$ | 2.75 | 183 |
| $C_6H_5NH_2$ | 1.60 | 208 |
| $C_6H_5Br$ | 1.50 | 184 |
| $C_6H_5Cl$ | 1.52 | 184 |
| $C_6H_5OCH_3$ | 1.25 | 185 |
| $C_6H_5CH_3$ | 0.4 | 185 |
| $C_6H_3(CH_3)_2$ | 0 | 189 |
| $C_6H_{12}$ | 0 | 191 |
| $C_6H_6$ | 0 | 191 |

The ester did not show a great variation in rotatory power between polar and non-polar solvents, the maximum difference being 12°. With the exception of the value in aniline, in which association is probably responsible for the abnormally high figure, the rotations are approximately in the order of the dipole moments of the solvents used. When the rotatory powers of the ester are plotted against the dipole moments of the solvents a rough approximation to a smooth curve is obtained (see Figure 3).

## TABLE IX.

### Rotatory Powers of di- $l$-Menthyl Malonate in Simple Solvents derived from Benzene.

| Solvent. | $\mu \times 10^{18}$ | $[M]^{20°}_{5461}$ |
|---|---|---|
| C H CN<br>6 5 | 3.85 | -332° |
| C H NO<br>6 5 2 | 3.89 | 324 |
| C H I<br>6 5 | 1.50 | 326 |
| C H OCH<br>6 5 3 | 1.25 | 330 |
| C H CH<br>6 5 3 | 0 | 322 |
| C H<br>6 6 | 0 | 325 |
| C H (CH )<br>6 3 3 3 | 0 | 335 |
| C H<br>6 12 | 0 | 331 |

For the malonate, the maximum observed variation amounts only to 9°, the lowest value being in toluene (-322°) and the highest in mesitylene (-335°). These differences are not very much greater than the probable experimental error, which is of the order $\pm$ 2°. No connection whatever can be observed in this case between the molecular rotation, and the polar nature of the solvent.

It is interesting to compare these values with

those obtained for $l$-menthyl acetate inasmuch as the deviation from the law of optical superposition is most obviously explained by the spatial proximity of the

two carbomenthoxy complexes, recalling the similar
changes in the o- and p- dicarboxylic esters derived
from benzene.

## TABLE X.

### Rotatory Powers of di-*l*-Menthyl Dimethyl Malonate in Simple Solvents derived from Benzene.

| Solvent | $\mu \times 10^{18}$ | $[M]^{20°}_{5461}$ |
|---------|------------------|-----------------|
| $C_6H_5CN$ | 3.85 | -280° |
| $C_6H_5NO_2$ | 3.89 | 290 |
| $C_6H_5I$ | 1.50 | 293 |
| $C_6H_5Br$ | 1.50 | 287 |
| $C_6H_5OCH_3$ | 1.25 | 298 |
| $C_6H_5CH_3$ | 0 | 288 |
| $C_6H_6$ | 0 | 294 |
| $C_6H_3(CH_3)_3$ | 0 | 305 |
| $C_6H_{12}$ | 0 | 294 |

The maximum range here is 25°, and, as in the
previous case, little or no agreement can be traced
between the dipole moment of the solvent and the
rotatory power of the dissolved ester.

## TABLE XI.

### Rotatory Powers of di- $l$-Menthyl Diethylmalonate In
### Simple Solvents derived from Benzene.

| Solvent | $\mu \times 10^{18}$ | $[M]^{20°}_{5461}$ |
|---|---|---|
| $C_6H_5CN$ | 3.85 | $-275°$ |
| $C_6H_5NO_2$ | 3.89 | 282 |
| $C_6H_5I$ | 1.50 | 263 |
| $C_6H_5OCH_3$ | 1.25 | 269 |
| $C_6H_5CH_3$ | 0 | 257 |
| $C_6H_6$ | 0 | 261 |
| $C_6H_3(CH_3)_3$ | 0 | 296 |
| $C_6H_{12}$ | 0 | 292 |

In this compound the irregularities amount almost
to a reversal of the effects which might be expected
from the work of Rule and McLean upon $l$-menthyl methyl
naphthalate. The rotations in polar solvents are
higher than in the non-polar solvents benzene and
toluene. Cyclohexane and mesitylene, however, give
still higher values.

# FIGURE 4



ROTATORY POWERS OF DI-l-MENTHYL DIPROPYL MALONATE

IN BENZENE DERIVATIVES.

1 cyclo-HEXANE
2 MESITYLENE
3 BENZENE
4 TOLUENE
5 ANISOLE
6 CHLORO BENZENE
7 BROMO BENZENE
8 IODO BENZENE
9 BENZALDEHYDE
10 NITRO BENZENE
11 BENZO NITRILE

$[M]^{20°}_{5461}$
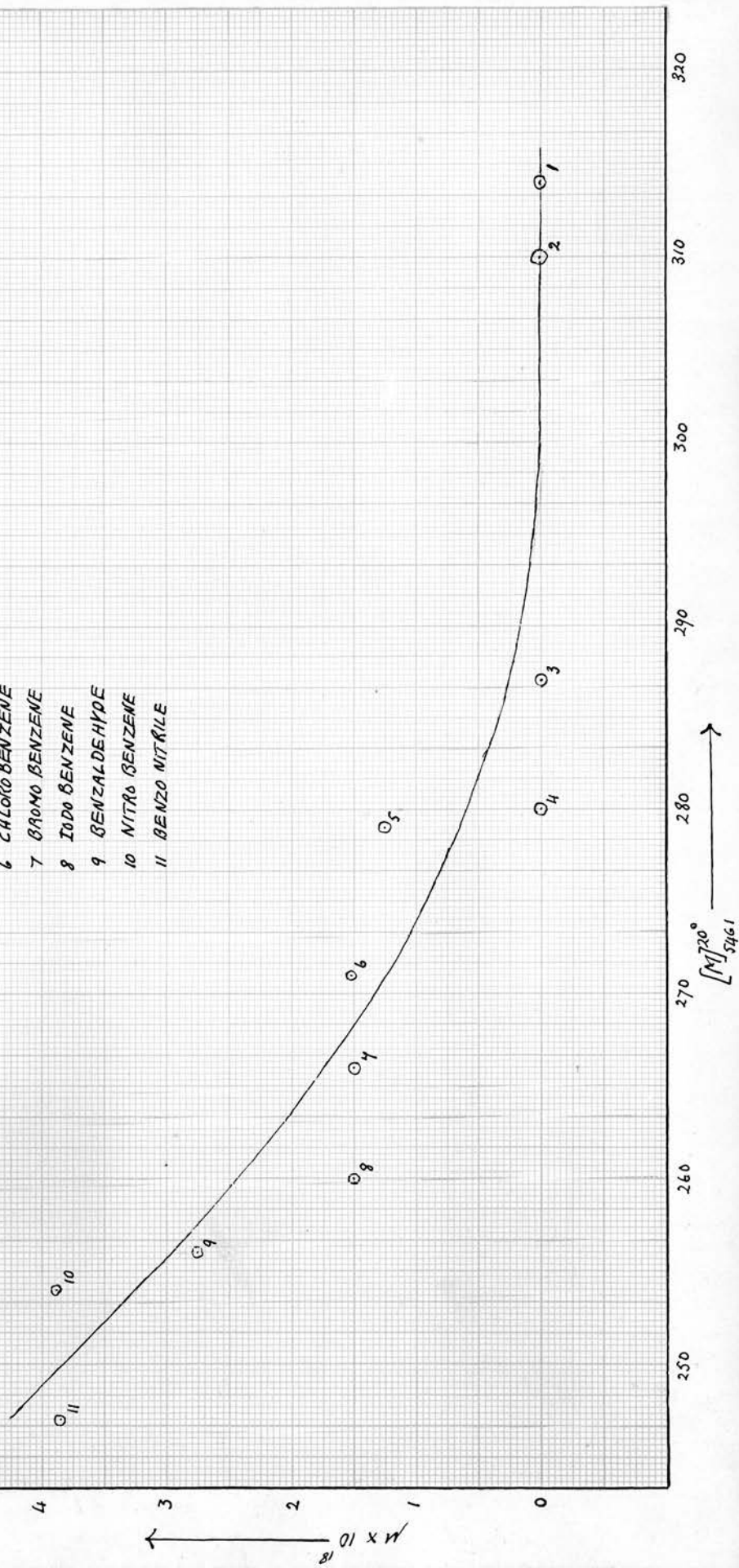
$M \times 10^{18}$

## TABLE XII.

### Rotatory Powers of di- $\ell$ -Menthyl Dipropylmalonate in Simple Solvents derived from Benzene.

| Solvent | $\mu \times 10^{18}$ | $[M]^{20°}_{5461}$ |
|---|---|---|
| $C_6H_5CN$ | 3.85 | -247° |
| $C_6H_5NO_2$ | 3.89 | 254 |
| $C_6H_5CHO$ | 2.75 | 256 |
| $C_6H_5I$ | 1.50 | 260 |
| $C_6H_5Br$ | 1.50 | 266 |
| $C_6H_5C$ | 1.52 | 271 |
| $C_6H_5OCH_3$ | 1.25 | 279 |
| $C_6H_5CH_3$ | 0 | 280 |
| $C_6H_6$ | 0 | 287 |
| $C_6H_3(CH_3)_2$ | 0 | 310 |
| $C_6H_{12}$ | 0 | 314 |

This ester offers a strong contrast to the compounds previously discussed. In this case there is an excellent agreement between the dipole moments of the solvents and the rotatory powers of the dissolved ester. On plotting these two values in the form of a graph (fig. 4) the points lie on a rough approximation to a smooth curve. The maximum variation here amounts to 67° on the molecular rotation. As has already been pointed out by Rule and McLean (loc. cit.), the polar

solvents are themselves associated to varying degrees. Hence, the polar influence of the homogeneous solvent will be less than that anticipated from the magnitude of its dipole moment, which is calculated for extreme dilution in a non-polar medium. In addition, further irregularities will be caused by the varying molecular volumes and structures of the solvents. In no case, therefore, is a close mathematical agreement to be expected between the dipole moment and the value of the rotatory power.

## TABLE XIII.

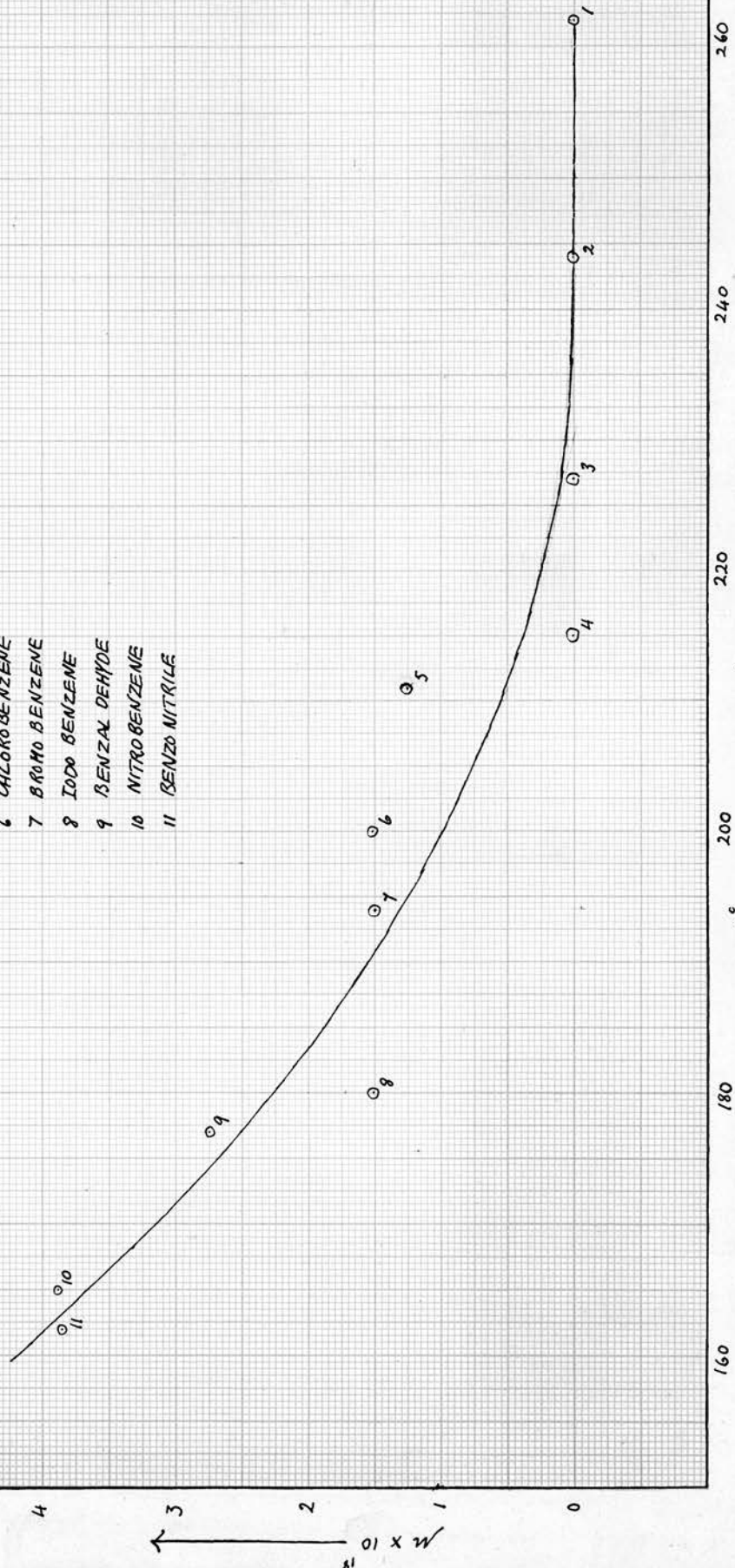## Rotatory Powers of di- $l$ -Menthyl Dibutylmalonate in Simple Solvents derived from Benzene.

| Solvent | $\mu \times 10^{18}$ | $[M]_{5461}^{20°}$ |
|---------|---------------------|-------------------|
| $C_6H_5CN$ | 3.85 | -162° |
| $C_6H_5NO_2$ | 3.89 | 165 |
| $C_6H_5CHO$ | 2.75 | 177 |
| $C_6H_5NH_2$ | 1.60 | 215 |
| $C_6H_5I$ | 1.50 | 180 |
| $C_6H_5Br$ | 1.50 | 194 |
| $C_6H_5Cl$ | 1.52 | 200 |
| $C_6H_3OCH_3$ | 1.25 | 211 |
| $C_6H_5CH_3$ | 0 | 215 |
| $C_6H_6$ | 0 | 227 |
| $C_6H_3(CH_3)_3$ | 0 | 244 |
| $C_6H_{12}$ | 0 | 262 |

FIGURE 5

ROTATORY POWERS OF DI-ℓ-MENTHYL DIBUTYL MALONATE

IN BENZENE DERIVATIVES.

1 cyclo-HEXANE
2 MESITYLENE
3 BENZENE
4 TOLUENE
5 ANISOLE
6 CHLOROBENZENE
7 BROMO BENZENE
8 IODO BENZENE
9 BENZAL DEHYDE
10 NITRO BENZENE
11 BENZO NITRILE

$[M]^{20°}_{5461}$

89.

The rotatory powers of the dibutyl derivative are
also in excellent agreement with the polar properties
of the solvent.   Only one solvent, aniline, is appre-
ciably displaced in the third column.   The highest rota-
tory power is observed in cyclohexane and the lowest in
benzonitrile, a difference of 100°.   This range is
therefore greater than that found for the dipropyl com-
pound.   On plotting the molecular rotations against
dipole moments of solvents, the graph (fig. 5) is found
to be an approximation to a smooth curve.

TABLE XIV.

Rotatory Powers of $l$-Menthyl $\alpha$-Amino-isobutyrate in

Simple Solvents derived from Benzene.

| Solvent | $\mu \times 10^{18}$ | $[M]_{5461}^{20°}$ |
|---------|---------|---------|
| $C_6H_5CN$ | 3.85 | -189° |
| $C_6H_5NO_2$ | 3.89 | 188 |
| $C_6H_5CHO$ | 2.75 | 165 [x] |
| $C_6H_5NH_2$ | 1.60 | 199 |
| $C_6H_5Br$ | 1.50 | 208 [x] |
| $C_6H_5OCH_3$ | 1.25 | 183 |
| $C_6H_5CH_3$ | 0 | 187 |
| $C_6H_6$ | 0 | 191 |

This compound shows no great variation in rotatory
power, save in benzaldehyde and bromobenzene, two sol-
vents which are in a position to react with the solute.
Probably in this case a further factor interfering with
a simple relationship is the high associating power of
the amino group in the basic ester.

## SUMMARY OF SOLVENT EFFECT.

In figure 6 are plotted graphs showing the values
$[M]_{5461}^{20°}$ for the foregoing dimenthyl esters in common
solvents, the horizontal axis indicating the ascending
homologous series.

It is very interesting to follow the variations in
solvent influence as we pass from the malonate to the
dibutylmalonate, i.e. in the series $CH_2$, $(CH_3)_2 C:$,
$(C_2H_5)_2 C:$, $(C_3H_7)_2 C:$, $(C_4H_9)_2 C:$.  Reference to diagram
6 illustrates three separate effects in operation, namely
(a) an increasingly regular influence, due to the polar
nature of the solvent, as the molecular weight of the

ester rises, (b) a more or less continuous fall in the
molecular rotation with increase in molecular weight
of the esters, and (c) a third effect leading to depres-
sions and maxima as the size of the substituent alkyl
increases.   These three influences are discussed

separately in the following paragraphs, in which the
comparison is restricted to curves 1—8 in fig. 6

representing solvents of the benzene series.

The polar effect of the solvent is seen even more clearly from the diagram than from the tables of molecular rotations. The values for the unsubstituted malonate and the gem-diethyl ester show practically no relationship to the dipole moment of the solvent. Those for the gem-dimethyl malonate are in moderately good agreement, while for the dipropyl and dibutyl-malonates the arrangement is almost identical with that of the dipole moments. Among the higher homologues, therefore, the greater the dipole moment of the solvent, the lower is the rotatory power of the dissolved ester. These results strongly resemble those recorded by Rule and McLean (loc. cit.) for $l$-menthyl methyl naphthalate, which were interpreted on the assumption that in the more polar solvents the characteristic influence of the carboxylic dipoles upon the active group was diminished through dipole association with the solvent. This view is also supported by the behaviour of $l$-menthyl acetate which has definitely lower rotations in the strongly polar liquids, nitrobenzene and benzonitrile.

The curious partial inversions found for the malonate and the diethyl compound suggest that the polar character of the solvent may affect the rotation by more than one mechanism. The most probable process in the average case is association or dipole association between solvent and ester. In addition to the polarity

of the solvent as indicated by the dipole moment it is likely that the residual valency of both solvent and solute enters into the problem: This may account, for example, for the differences observed among the non-polar solvents benzene, toluene, mesitylene and cyclo-hexane. Another possibility is that the rotation may be influenced by the increasing length of the alkyl chain in the ester, which may return to the neighbour-hood of the carboxyl group. The most stable arrange-ment of the molecule in this case is almost certain to vary with physical structure as well as the polarity of the solvent.

The more or less continuous fall in rotation, as the length of the gem-dialkyl chains increase, appears to be best interpreted according to the Thorpe-Ingold theory of valency deflexion. As the bulk of the alkyl groups becomes greater, the carboxy-menthyl complexes will be forced closer together. It has already been pointed out that this proximity in the case of the benzene dicarboxylic esters leads to a diminished rotation, hence, on this basis the low molecular rotation of the higher members of the malonic series is to be expected. This point could be dis-cussed with more certainty if the shape of the curve were known for still higher homologues of the series.

The present results, however, go to support the conclusions previously advanced by Rule and Harrower.

The maxima which are observed in solvents for the dipropyl member may be the result of an attraction of an electrostatic nature leading to ring formation of particular stability,
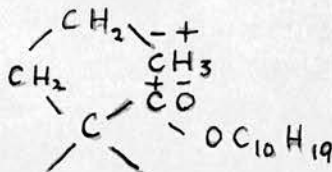


in which the hydrogen atoms at the alkyl chain (+) are held by the oxygen (-) of the ketonic group.   A similar stable structure for the dibutyl member (where the rotations are of a low order) is apparently not possible. It is evident that some fundamental change, some radical alteration in the residual affinity of the molecule has taken place in the dipropyl ester, and that this change is even more persistent in the dibutyl ester since these two esters show large variations in rotatory power, and an increasingly good agreement between their molecular rotations in solvents and the dipole moments of the latter.

At all events the entire results obtained in the solvents of the benzene series, especially when graphed as in figure 6, enable us to follow the chain effect in a homologous series more systematically than otherwise would have been the case, and they are a confirmation of the suggestion made by Frankland (J.C.S.,1912, 101, 660) namely, that some solvents should permit a

more unrestricted development of the rotatory effect
of a homologous group than is the case when the same
compounds are examined in the liquid condition.

In conclusion I wish to thank Dr. H. G. Rule
for much valuable advice and guidance during the
course of this investigation.