35. *Studies in Stereochemical Structure. Part VI. The Isomeric (—)Menthyl α-Naphthylglycollates.*

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THE dispersion of the (—)menthyl mandelates has been described by one of us (Roger, J., 1932, 2168), who also found that the superposition of the slightly complex dispersion of (—)menthyl (—)mandelate on the anomalous dispersion of the (—)menthyl (+)mandelate reproduced the simple dispersion of (—)menthyl *r*-mandelate. The connexion between optical superposition and the fact that (—)menthyl *r*-mandelate could not be resolved by crystallisation was discussed at the time. Meanwhile, McKenzie and Gow (J., 1933, 32) have shown that the diastereoisomeric constituents of (—)menthyl *dl*-α-naphthylglycollate can be separated either by crystallisation or distillation, and an examination of the dispersions of the isomeric (—)menthyl α-naphthylglycollates described by these authors offered a chance of investigating the question already dealt with in the case of the mandelates. Moreover, McKenzie and Gow have shown that there is a definite difference between the derivatives of the optically active α-naphthylglycollic acids and the mandelic acids as regards racemisation and other phenomena.

The following results have now been obtained.

(—)α-Naphthylglycollic Acid.—This acid is much more lævorotatory than (—)mandelic acid in acetone. It exhibits a greater variance with solvent and a similar temperature effect to mandelic acid. The Rupe criteria (see Table I) for the two acids were very similar and the dispersion is very like that of mandelic acid, *i.e.*, normal and slightly complex.

(—)Menthyl (—)α-Naphthylglycollate.—The rotatory power of solutions of this ester varied somewhat with solvent but not with temperature. Concentration had a slight effect in carbon disulphide and in benzene solution. One-term Drude equations expressed the dispersions between λ6563 and λ4358. The Rupe criteria (see Table I) were similar to those of (—)menthyl (—)mandelate except that the values for the alcoholic solutions did not depart markedly from those for the other solutions. The dispersion is normal but slightly complex.

(—)Menthyl (+)α-Naphthylglycollate.—The rotatory powers (always +) varied markedly with solvent and were also affected by temperature and concentration. One-term Drude equations did not express the dispersions, and the Rupe criteria (see Table I) for the (—)menthyl (+)α-naphthylglycollate showed a certain regularity that was entirely lacking in the corresponding mandelate. The dispersion is definitely complex (much more so than that of its diastereoisomeride) but normal, whilst that of (—)menthyl (+)mandelate is anomalous. The " totale intramolekulare Anomalie " of Tschugaev is, therefore, not realised in the visible spectrum in this case (cf. Rupe and Kägi, *Annalen*, 1920, **420**, 33).

(—)Menthyl dl-*α-Naphthylglycollate.*—This compound was obtained by McKenzie and Gow (*loc. cit.*) as a low-melting solid (m. p. 38·5—39·5°) after standing for several weeks. It cannot be purified, however, by distillation or crystallisation, for both these operations cause separation into the constituent diastereoisomerides. With the unpurified ester, the coloured solutions made accurate readings impossible for the blue and violet lines. Samples of the crude ester were therefore dissolved in dry ether, and treated with animal charcoal for 2 minutes, 2 hours, and 2 weeks. The dispersions of each of these samples were determined, and although values for the longer wave-lengths did not alter much, yet those for λ4358 were much improved after 2 weeks, and the dispersion was almost simple and normal, and agreed with the values found by superposition of the rotatory powers of the diastereoisomerides. Whilst the rotatory powers in acetone, chloroform, and alcohol did not vary greatly, that in carbon disulphide showed a depression. This was also shown in the Rupe criteria. The dispersion may be regarded as normal and almost simple, and is similar to that of (—)menthyl *r*-mandelate.

The dispersions of (—)menthyl (+)α-naphthylglycollate and (—)menthyl (+)mandelate also form an interesting contrast with the (—)menthyl esters of benzoyl- and α-naphthoylformic acid. (—)Menthyl α-naphthoylformate showed anomalous dispersion, whilst the

TABLE I.

Dispersion criteria for (—)α-naphthylglycollic acid and (—)menthyl α-naphthylglycollates.

Solvent.	λ_0^2.	λ_α.	P.R.D.	λ_0^2.	λ_α.	P.R.D.
		(—)Acid.			(—)Ester.	
$COMe_2$	0·06096	628	155	0·05200	642	146
C_6H_6	—	—	—	0·05666	633	151
$CHCl_3$	0·05792	633	152	0·05720	633	151
CS_2	—	—	—	0·06099	629	155
EtOH	0·06005	630	154	0·05551	636	150
H_2O	0·05332	637	147	—	—	—
		(+)Ester.			*dl*-Ester.	
$COMe_2$	0·1285	550	197	0·03038	676	118
C_6H_6	0·1360	541	199	0·02230	687	103
$CHCl_3$	0·1141	563	190	0·02581	682	110
CS_2	0·1064	575	188	* 0·01924	690	96
EtOH	0·1106	566	188	0·02978	679	117

* The ester used in the carbon disulphide solution was decolorised for 2 weeks, that used in the other solvents for 2 hours.

benzoylformate had only a normal and complex dispersion (Roger and Ritchie, *Biochem. Z.*, 1932, **253**, 240), *i.e.*, the relative effects of the phenyl and the α-naphthyl group are reversed in the two sets of compounds.

The rotatory power of (—)menthyl *dl*-α-naphthylglycollate can be calculated from the values of the diastereoisomerides, and agrees with that determined experimentally for the ester itself. The values from an equimolar solution of the diastereoisomerides also agreed, as did those when separate equimolar solutions were superimposed in the polarimeter, *e.g.*, in carbon disulphide (see Table II). It will be seen, therefore, that the Rupe criteria obtained by superposition agree remarkably well with those obtained from the *dl*-ester.

TABLE II (all rotations negative).

	λ 6563.	λ 6162.	λ 5893.	λ 5461.	λ 5106.	λ 4861.	λ 4358.
I	35·5°	40·3°	44·4°	52·3°	60·3°	66·7°	84·6°
II	35·4	40·3	44·4	52·3	60·5	66·9	83·5
III	35·3	40·2	44·1	52·0	60·1	66·9	83·8
IV	35·3	40·2	44·2	52·0	60·0	67·0	83·9

I. Values calculated from the superposition of the diastereoisomerides.
II. Superposition of equimolar solutions of the diastereoisomerides.
III. One solution composed of equal amounts of the diastereoisomerides.
IV. Observed values for (—)menthyl *dl*-α-naphthylglycollate.

TABLE III.

Dispersion criteria calculated from II *in Table* II.

Solvent.	λ_0^2.	λ_α.	P.R.D.	Solvent.	λ_0^2.	λ_α.	P.R.D.
$COMe_2$	0·02966	676	117	CS_2	0·02005	692	99
C_6H_6	0·02794	681	114	EtOH	0·03146	675	120
$CHCl_3$	0·02735	676	112				

This same superimposability was found with the (—)menthyl mandelates, but there is one important difference between the two sets of esters, inasmuch as (—)menthyl *dl*-α-naphthylglycollate can be resolved into its diastereoisomerides by recrystallisation or by distillation (McKenzie and Gow, *loc. cit.*), whilst (—)menthyl *r*-mandelate is partially racemic. This definitely shows that there is no connexion between the optical superposition exhibited by these esters and the question whether they are partially racemic compounds or not. Rupe and Kägi (*loc. cit.*) obtained perfect superposition with an equimolar mixture of their diastereoisomerides, and it was found that the rotatory powers of this mixture obeyed a one-term Drude equation. Tschugaev and Glebko (*Ber.*, 1913, **46**, 2752) found the principle to hold in the (—)menthylurethanes of *d*- and *l*-tartaric acids and *meso*-tartaric acid, and we find that the rotatory powers of the *meso*-derivative obey approximately a one-term Drude equation. Patterson and Buchanan (J., 1924, **125,** 2579) have examined the di(—)*sec.*-octyl dimethoxysuccinates, and find superposition in the homogeneous state, but not in *o*-nitrotoluene. In both circumstances, however, we find that one-term Drude equations approximately express the calculated values for the *i*-ester; for instance (in *o*-nitrotoluene):

[α].	λ 6716.	λ 5790.	λ 5461.	λ 4960.
Calc. from $\frac{1}{2}(d + l)$	3·76°	4·67°	5·68°	8·46°
Calc. from $[\alpha] = 1{\cdot}252/(\lambda^2 - 0{\cdot}08984)$	3·47	5·09	6·0	8·02
Obs. for *i*-ester	2·46	3·08	3·37	4·26

It may so happen, however, that in the homogeneous state the rotatory powers of the *meso*- and *r*-esters are by chance identical, but it does not follow that they should be identical in solution. This question has been examined by Walden (*Z. physikal. Chem.*, 1896, **20**, 377; cf. Patterson and Patterson, J., 1915, **107**, 142) with the amyl tartrates. He found no agreement between the *meso*- and the *r*-ester, but his experiment is not conclusive. He distilled the *r*-ester repeatedly, and may have partially separated his product; moreover, the amyl alcohol was not pure. The first of these points is important, since the resolution of racemic acid has been effected by borneol and menthol (Wren, Williams, and Myddleton, J., 1920, **117**, 191; cf. Wren and Still, J., 1917, **111**, 513; Wren and Hughes, J., 1924, **125**, 1739).

Wood, Such, and Scarf (J., 1926, 1928) also found no superposition with the *sec.*-butyl lactates, but once again we find that a one-term Drude equation approximately fits the dispersion of the values calculated from the diastereoisomeric esters, as shown below:

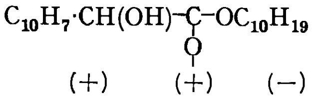
[α].	λ 6708.	λ 5893.	λ 5461.	λ 4861.	λ 4358.
Calc. from $\frac{1}{2}(d + l)$	7·79°	10·06°	11·85°	15·33°	18·91°
Calc. from $[\alpha] = 3{\cdot}317/(\lambda^2 - 0{\cdot}1929)$	7·71	10·13	11·89	15·29	19·3
Obs.	6·79	8·47	9·60	11·34	12·9

Here the *dl-sec.*-butyl *l*-lactate might have undergone a partial separation during distillation, but the authors showed that this was not so by saponifying their ester, thus obtaining an optically inactive alcohol. Hydrolysis of the *d-sec.*-butyl *l*-lactate gave a pure *d-sec.*-butyl alcohol. In this case, however, there are no complications arising from the existence of a *meso*- and a racemic form of the acid. The " Entfernungsatz " (Freudenberg, *Ber.*, 1933, **66**, 190) offers an explanation, since in the lactates the asymmetric centre of the *sec.*-butyl alcohol is directly linked to the carboxyl group and is thus comparable with the *sec.*-octyl tartrates where superposition does not hold, although it occurs with the amyl tartrates. The (—)menthyl esters of mandelic and α-naphthylglycollic acid do not apparently fall in with the " Entfernungsatz " as here the asymmetric carbinol centre is directly united to the carboxyl group (cf. Roger and Ritchie, *loc. cit.*).

The exceptions to the superposition rule are capable of other interpretations. In the few cases where data are available we have shown that the dispersion calculated from superposition values should be simple or almost simple, a prediction not always fulfilled in practice. In cases such as that of the homogeneous *dl-sec.*-butyl *l*-lactate the physical state is that of the solution of one compound in another, and solvent effect may have to be considered. The dispersion of one diastereoisomeride in solution in the other may be so altered by the act of solution that the dispersions of both may no longer be superimposed to give a simple dispersion. With the *dl*-α-naphthylglycollate in solvents, this solution effect apparently is not marked.

On the basis of asymmetric induction, the following configurations are possible for

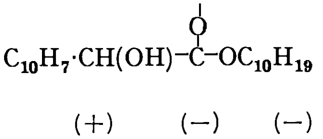
(I.)



$$C_{10}H_7\cdot CH(OH)-\underset{O}{C}-OC_{10}H_{19}$$

(+) (+) (−)

(II.)



$$C_{10}H_7\cdot CH(OH)-\overset{O}{C}-OC_{10}H_{19}$$

(+) (−) (−)

(—)menthyl (+)α-naphthylglycollate and a solution would probably consist of an equilibrium mixture of the two forms. This equilibrium would readily be displaced by alteration of physical conditions. Now, if the (+)α-naphthylglycollyl complex has a greater dextro-inducing influence than the (+)mandelyl complex, then there should be a definite preponderance of one of the forms under all conditions. It would appear that in chloroform solutions of (—)menthyl (+)mandelate the contributions of the separate centres (real and induced) to the optical activity of the molecule balance one another under certain conditions of wave-length and temperature. On the other hand, solutions of esters of the type under consideration may be homogeneous, and the phenomena described may depend on the extent to which induction of the carbonyl groups takes place. This group in any of these compounds may be capable of exhibiting a " maximum " induction, but under conditions of examination it may seldom be able to attain this " maximum " and therefore is only " partially " induced. The extent of the contribution of this induced centre to the optical activity of such esters will, therefore, vary and be influenced by physical conditions and by the variation of R in the R·CH(OH) complex (cf. work of W. Kuhn on the " Vizinalregel," *Hand- und Jahrbuch der chemischen Physik*, 1932, **8**, III, 121).

EXPERIMENTAL.

(—)α-*Naphthylglycollic Acid.* (All rotations are negative.)

(1) In acetone ($c = 3{\cdot}2375$, $l = 2$, $t = 20°$); $[\alpha] = 53{\cdot}77/(\lambda^2 - 0{\cdot}06096)$.

	λ 6563.	λ 6162.	λ 5893.	λ 5461.	λ 5106.	λ 4861.	λ 4358.
[α] obs. …………	145·8°	168·7°	187·4°	226·4°	269·6°	306·8°	416·2°
[α] calc. …………	145·5	168·8	187·8	226·8	269·3	306·8	416·9

(2) In chloroform * ($c = 0{\cdot}9805$, $l = 2$, $t = 3{\cdot}5°$).

[α] obs. …………	166·7	190·7	212·6	254·0	303·4	349·3	—

Same solution, $t = 20°$; $[\alpha] = 59{\cdot}43/(\lambda^2 - 0{\cdot}05792)$.

[α] obs. …………	161·2	183·5	204·5	246·8	292·7	334·5	452·3
[α] calc. …………	159·4	184·8	205·3	247·4	293·1	333·2	450·0

Same solution, $t = 35°$.

[α] obs. …………	149·4	171·3	191·7	231·5	272·9	313·0	—

(3) In ethyl alcohol ($c = 2{\cdot}779$, $l = 2$, $t = 0°$).

[α] obs. …………	154·5	177·6	197·9	239·6	283·9	323·2	—

Same solution, $t = 20°$; $[\alpha] = 53{\cdot}41/(\lambda^2 - 0{\cdot}06005)$.

[α] obs. …………	144·0	166·6	186·7	224·4	266·7	302·6	411·8
[α] calc. …………	144·1	167·1	186·0	224·3	266·3	303·1	411·1

Same solution, $t = 38°$.

[α] obs. …………	137·1	160·5	177·4	211·9	253·5	287·2	—

(4) In water * ($c = 1{\cdot}195$, $l = 2$, $t = 20°$); $[\alpha] = 45{\cdot}66/(\lambda^2 - 0{\cdot}05332)$.

[α] obs. …………	120·9	138·9	156·5	185·8	220·1	250·6	336·4
[α] calc. …………	121·0	139·9	155·3	186·5	220·2	249·6	334·4

(+)α-*Naphthylglycollic Acid.* (All rotations are positive.)

(1) In ethyl alcohol ($c = 2{\cdot}804$, $l = 2$, $t = 20°$); $[\alpha] = 52{\cdot}91/(\lambda^2 - 0{\cdot}06302)$.

[α] obs. …………	144·2	166·5	186·3	225·4	268·0	304·5	414·8
[α] calc. …………	143·9	167·0	186·1	225·0	267·7	305·4	417·0

* The optically active forms of this acid are not readily soluble in chloroform or water.

(–)*Menthyl* (–)*α-Naphthylglycollate.* (All rotations are negative.)

(1) In acetone ($c = 2{\cdot}525,\ l = 2,\ t = 1^\circ$).

	λ 6563.	λ 6162.	λ 5893.	λ 5461.	λ 5106.	λ 4861.	λ 4358.
[α] obs.	101·0°	—	129·4°	155·0°	—	206·6°	275·0°

Same solution, $t = 21^\circ$; $[\alpha] = 36{\cdot}85/(\lambda^2 - 0{\cdot}05373)$.

[α] obs.	98·0	112·7	125·7	150·5	178·2	202·2	268·3
[α] calc.	97·7	113·1	125·5	150·8	178·0	201·8	270·4

Same solution, $t = 40^\circ$.

[α] obs.	100·6	—	128·7	155·6	—	207·7	—

The concentration effect in this solvent was negligible :

$c = 10{\cdot}123,\ l = 1,\ t = 20^\circ,\ \alpha_{5893} = -12{\cdot}78^\circ,\ [\alpha]_{5893} = -126{\cdot}3^\circ$.

(2) In benzene ($c = 1{\cdot}8065,\ l = 2,\ t = 21^\circ$); $[\alpha] = 33{\cdot}13/(\lambda^2 - 0{\cdot}05588)$.

[α] obs.	88·8	102·1	113·4	137·0	162·4	182·6	245·5
[α] calc.	88·4	102·3	113·7	136·8	161·7	183·7	247·1

The concentration effect was much more evident in this solvent :

$c = 10{\cdot}102,\ l = 1,\ t = 20^\circ,\ [\alpha] = 34{\cdot}46/(\lambda^2 - 0{\cdot}05666)$.

[α] obs.	92·39	106·5	118·5	142·3	168·9	192·4	260·0
[α] calc.	92·12	106·7	118·7	142·8	169·0	191·9	258·5

(3) In chloroform ($c = 2{\cdot}4595,\ l = 2,\ t = 21^\circ$); $[\alpha] = 40{\cdot}23/(\lambda^2 - 0{\cdot}05776)$.

[α] obs.	107·7	125·6	139·8	167·9	199·2	225·6	—
[α] calc.	107·8	124·9	139·1	167·3	198·3	225·4	—

Same solution, $t = 55^\circ$.

[α] obs.	104·0	119·1	135·3	161·0	193·1	221·1	—

There was no temperature effect at -13° and 0° : $[\alpha]_{5893}^{-13^\circ}\ -140{\cdot}2^\circ$, $[\alpha]_{5893}^{0^\circ}\ -140{\cdot}2^\circ$.

Same solvent ($c = 8{\cdot}562,\ l = 1,\ t = 20^\circ$); $[\alpha] = 41{\cdot}21/(\lambda^2 - 0{\cdot}0572)$.

[α] obs.	110·4	127·6	142·0	170·8	202·5	230·4	310·3
[α] calc.	110·4	127·7	142·1	171·0	202·5	230·1	310·6

There is, therefore, a small concentration effect in this solvent.

(4) In carbon disulphide ($c = 1{\cdot}687,\ l = 2,\ t = 0^\circ$).

[α] obs.	121·0	141·1	157·1	190·9	227·4	258·1	—

Same solution, $t = 20^\circ$; $[\alpha] = 45{\cdot}82/(\lambda^2 - 0{\cdot}05388)$.

[α] obs.	121·3	140·5	156·8	188·6	220·9	250·8	338·8
[α] calc.	121·6	140·6	156·2	187·6	221·6	251·2	337·0

Same solvent ($c = 10{\cdot}7,\ l = 1,\ t = 20^\circ$); $[\alpha] = 43{\cdot}64/(\lambda^2 - 0{\cdot}06099)$.

[α] obs.	118·4	136·5	152·5	184·0	218·5	249·0	339·0
[α] calc.	118·0	137·0	152·4	184·0	218·5	249·0	338·6

In this case the temperature does not influence the rotation, whereas increase of concentration causes a noticeable diminution in rotatory power.

(5) In ethyl alcohol ($c = 10{\cdot}675,\ l = 1,\ t = 20^\circ$); $[\alpha] = 42{\cdot}65/(\lambda^2 - 0{\cdot}05551)$.

[α] obs.	114·0	131·1	146·2	175·6	207·8	236·2	316·6
[α] calc.	114·0	131·6	146·2	175·8	207·8	235·9	317·4

(—)*Menthyl* (+)α-*Naphthylglycollate.* (All rotations are positive.)

	λ 6563.	λ 6162.	λ 5893.	λ 5461.	λ 5106.	λ 4861.	λ 4358.
(1) In acetone (c = 3·622, l = 2, t = 20°).							
[α] obs.	14·2°	17·0°	19·9°	25·3°	32·9°	39·8°	61·3°
Same solvent (c = 10·0505, l = 2, t = 21°).							
[α] obs.	15·0	17·7	20·7	26·9	34·3	40·8	60·9
(2) In benzene (c = 10·2885, l = 2, t = 20°).							
[α] obs.	14·8	17·9	20·9	27·5	35·3	42·8	67·2
Same solution, t = 35°.							
[α] obs.	16·5	19·6	22·9	29·6	37·9	45·9	—
(3) In chloroform (c = 10·244, l = 2, t = 1°).							
[α] obs.	24·8	29·4	33·5	42·5	53·2	63·0	—
Same solution, t = 20°.							
[α] obs.	25·4	30·0	34·6	44·0	55·0	65·0	96·7
(4) In carbon disulphide (c = 10·261, l = 2, t = 1°).							
[α] obs.	49·3	58·4	66·8	83·5	103·1	121·2	—
Same solution, t = 20°.							
[α] obs.	47·4	56·0	63·8	79·5	98·0	115·5	169·7
Same solution, t = 31°.							
[α] obs.	46·0	54·5	62·4	77·7	95·7	112·0	—
(5) In ethyl alcohol (c = 10·2865, l = 2, t = 0°).							
[α] obs.	25·4	30·0	34·2	43·2	53·6	63·2	—
Same solution, t = 21°.							
[α] obs.	24·4	28·7	33·2	41·9	52·1	61·5	90·2
Same solution, t = 39°.							
[α] obs.	23·9	27·8	32·3	40·5	50·8	59·3	—

(—)*Menthyl* dl-α-*Naphthylglycollate.* (All rotations are negative.)

After two minutes' decolorisation with animal charcoal (see p. 130); solutions still slightly coloured :

(1) In acetone (c = 3·3685, l = 2, t = 21°); $[\alpha] = 16{\cdot}82/(\lambda^2 - 0{\cdot}0292)$.

[α] obs.	42·0	47·9	52·8	62·7	72·7	80·9	98·7
[α] calc.	41·9	48·0	52·9	62·5	72·7	81·2	104·6

(2) In benzene (c = 3·5135, l = 2), $\alpha_{5893}^{21^\circ}$ −3·34°, $[\alpha]_{5893}^{21^\circ}$ −47·5°.
(3) In chloroform (c = 3·2885, l = 2), $\alpha_{5893}^{20^\circ}$ −3·51°, $[\alpha]_{5893}^{20^\circ}$ −53·4°.
(4) In carbon disulphide (c = 2·93, l = 2), $\alpha_{5893}^{21^\circ}$ −2·66°, $[\alpha]_{5893}^{21^\circ}$ −45·4°.
(5) In ethyl alcohol (c = 3·33, l = 2), $\alpha_{5893}^{21^\circ}$ −3·83°, $[\alpha]_{5893}^{21^\circ}$ −57·5°.

After 2 hours' decolorisation; solutions practically colourless :

(1) In acetone (c = 3·52, l = 2, t = 20°); $[\alpha] = 16{\cdot}75/(\lambda^2 - 0{\cdot}03038)$.

[α] obs.	42·1	48·0	52·6	62·9	72·4	81·3	102·0
[α] calc.	41·8	48·0	52·9	62·6	72·7	81·3	105·0

(2) In benzene (*c* = 4·1415, *l* = 2, *t* = 20°); [α] = 15·83/(λ^2 − 0·0223).

	λ 6563.	λ 6162.	λ 5893.	λ 5461.	λ 5106.	λ 4861.	λ 4358.
[α] obs.	38·8°	44·3°	48·8°	57·5°	66·3°	74·0°	91·6°
[α] calc.	38·8	44·3	48·7	57·4	66·4	74·0	94·5

(3) In chloroform (*c* = 3·6115, *l* = 2, *t* = 20°); [α] = 17·6/(λ^2 − 0·02581).

[α] obs.	43·3	50·0	54·7	64·8	75·0	83·3	102·6
[α] calc.	43·5	49·7	54·8	64·6	74·9	83·6	107·3

(4) In carbon disulphide (*c* = 3·3195, *l* = 2, *t* = 20°); [α] = 14·15/(λ^2 − 0·03265).

[α] obs.	35·3	41·1	45·0	53·8	61·9	69·1	83·3
[α] calc.	35·6	40·8	45·0	53·3	62·1	69·5	90·0

(5) In ethyl alcohol (*c* = 3·1395, *l* = 2, *t* = 20°); [α] = 18·34/(λ^2 − 0·02978).

[α] obs.	45·9	52·4	57·7	68·5	79·6	88·4	110·5
[α] calc.	45·7	52·6	57·8	68·3	79·4	88·8	114·5

After two weeks' decolorisation :

(1) In benzene (*c* = 5·6025, *l* = 2, *t* = 20°); [α] = 15·71/(λ^2 − 0·01923).

[α] obs.	37·8	43·8	48·0	56·3	65·0	72·4	92·5
[α] calc.	38·2	43·6	47·9	56·3	65·1	72·4	92·0

(2) In carbon disulphide (*c* = 6·2435, *l* = 2, *t* = 20°); [α] = 14·51/(λ^2 − 0·01924).

[α] obs.	35·3	40·0	44·2	52·0	60·0	67·0	83·9
[α] calc.	35·3	40·2	44·2	52·0	60·0	66·8	85·0

The dispersion of the ester was determined by the superposition of separate equimolecular solutions of the two diastereoisomeric esters.

(1) In acetone (*c* = 10·123, *l* = 1, *t* = 20°)*; [α] = 16·75/(λ^2 − 0·02966).

[α] obs.	41·8	47·7	52·8	62·4	72·5	81·0	102·3
[α] calc.	41·8	47·9	52·7	62·4	72·5	81·1	104·5

(2) In benzene (*c* = 10·103, *l* = 1, *t* = 20°)*; [α] = 15·52/(λ^2 − 0·02794).

[α] obs.	38·7	43·9	48·6	57·4	66·8	74·3	94·8
[α] calc.	38·5	44·1	48·6	57·4	66·7	74·5	95·8

(3) In chloroform (*c* = 8·562, *l* = 1, *t* = 20°)*; [α] = 17·24/(λ^2 − 0·02735).

[α] obs.	42·6	49·0	54·0	63·4	74·0	82·8	105·6
[α] calc.	42·7	48·9	53·9	63·6	73·9	82·5	106·0

(4) In carbon disulphide (*c* = 10·698, *l* = 1, *t* = 20°)*; [α] = 14·51/(λ^2 − 0·02005).

[α] obs.	35·4	40·3	44·4	52·3	60·5	67·1	83·5
[α] calc.	35·4	40·4	44·4	52·3	60·4	67·3	85·7

(5) In ethyl alcohol (*c* = 10·675, *l* = 1, *t* = 20°)*; [α] = 17·73/(λ^2 − 0·03146).

[α] obs.	44·4	50·8	56·4	66·6	77·6	86·2	110·8
[α] calc.	44·4	50·9	56·1	66·5	77·4	86·6	111·9

The dispersion of the ester was also determined by making one solution composed of equal amounts of the two diastereoisomerides.

(1) In carbon disulphide (*c* = 10·014, *l* = 2, *t* = 20°); [α] = 14·45/(λ^2 − 0·02037).

[α] obs.	35·3	40·2	44·1	52·0	60·1	66·9	83·8
[α] calc.	35·2	40·2	44·2	52·0	60·1	66·9	85·2

* These factors apply to each tube in each case.

(2) In ethyl alcohol ($c = 8{\cdot}512$, $l = 2$, $t = 20°$); $[\alpha] = 17{\cdot}77/(\lambda^2 - 0{\cdot}03011)$.

	λ 6563.	λ 6162.	λ 5893.	λ 5461.	λ 5106.	λ 4861.	λ 4358.
[α] obs.	44·6°	50·8°	56·4°	66·4°	77·4°	86·8°	111·2°
[α] calc.	44·4	50·8	56·0	66·3	77·0	86·2	111·2

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