XVII.—*The Influence of Solvents on the Rotation of Optically Active Compounds. Part VII. Solution-volume and Rotation of Menthol and Menthyl Tartrates.*

By THOMAS STEWART PATTERSON and FRANCIS TAYLOR, B.Sc.

IN a recent paper (this vol., p. 33) we have described the preparation of *l*-menthyl *d*-tartrate and its diacetyl derivative, and have given an account of the optical behaviour of these substances as well as of menthol. It seemed worth while to examine them in solution also in order to ascertain whether a relationship between solution-volume and rotation similar to that which has been shown to exist in the case of ethyl tartrate (Patterson, Trans., 1901, **79**, 191, 484; 1902, **81**, 1107; 1904, **85**, 1153) could be traced. The present communication records the results obtained for ethyl alcohol, benzene, and nitrobenzene.

Two or three solutions were made up in each case and their rotations and densities determined at several temperatures.

The influence of temperature-change on the rotation of the dissolved substance is given directly by the experimental figures, which are collected at the end of the paper, whilst by interpolation: (1) the molecular rotation at 20°, (2) the molecular-solution-volume at 20° of the dissolved substance for each concentration examined may be deduced, and from these in turn (3) an approximate value of the molecular rotation at 20° at infinite dilution, and (4) an analogous value for the molecular-solution-volume may be obtained.

These interpolated data are reproduced below, the constants for the respective homogeneous substances being given in the tables, so that the influence of concentration-change may be examined in each case.

The figures for the percentage composition of the solutions have been rounded off in the text.

Menthol.—The molecular rotation of fused menthol, which has a value of about -77.22° at 20°, increases slightly with rise of temperature to reach a maximum of -77.94° at 58.5° , and then diminishes again to -77.24° at 100° .

Menthol in Ethyl Alcohol.

<i>p.</i>	$[M]_D^{20^\circ}$.	Volume $^{20^\circ}$
0.0	-77.70°	172.3 c.c.
1.6	77.69	172.3 "
8.3	77.69	172.6 "
100.0	77.22	173.26 "

Solution in alcohol has little effect on the rotation of menthol, but a slight increase is produced. In agreement with this, there is only a small change in volume; a contraction of 0.96 c.c. corresponds with an increase of 0.48° in molecular rotation.

The figures on p. 130 show that in both the solutions examined there is, with rise of temperature from 10° to 50° , a slight but distinct increase of rotation amounting to about 0.3° . The behaviour is therefore in this respect similar to that of the homogeneous substance.

Menthol in Benzene.

p .	$[M]_D^{20^\circ}$.	Volume $^{20^\circ}$.
0.0	-70.4°	179.84 c.c.
1.46	70.6	179.8 "
7.50	71.8	178.0 "
100.0	77.22	173.26 "

From these data, it appears that whilst the rotation of solutions of menthol in benzene diminishes with increasing dilution, the volume of the dissolved substance increases. The behaviour is thus the opposite in both respects to that found for alcoholic solutions. A diminution in rotation of 6.82° corresponds with an increase of volume of 6.58 c.c.

In both solutions examined, the rotation is practically insensitive to temperature-change.

Menthol in Nitrobenzene.

p .	$[M]_D^{20^\circ}$.	Volume $^{20^\circ}$.
0.0	-73.60°	176.5 c.c.
1.5	73.60	176.5 "
2.1	73.40	176.0 "
6.7	73.35	175.7 "
30.5	73.70	174.6 "
100.0	77.22	173.26 "

Nitrobenzene as a solvent has, like benzene, the general effect of lowering the rotation of menthol. The depression, however, is not directly proportional to the concentration, since a minimum rotation of -73.28° apparently occurs about $p=10$. Further dilution below this concentration brings about a slight increase in rotation to the value -73.6° at infinite dilution. The total change in rotation in passing from the homogeneous substance to infinite dilution is thus 3.62° and is accompanied, again as in benzene, by an increase in volume of 3.24 c.c.

Whereas, however, the rotations of alcoholic solutions increase with rise of temperature and those of benzene solutions are constant, the rotations of nitrobenzene solutions diminish fairly rapidly, a behaviour which is thus opposed also to that of fused menthol.

So far, therefore, as volume-change and rotation-change due to solution are concerned, the behaviour of menthol in these three solvents is consistent and tends strongly to support the suggestion that the two phenomena are closely related to each other. In the following table, the values of these changes are contrasted.

Rotation- and Volume-change of Menthol.

Solvent.	Total rotation-change due to solution.	Total volume-change due to solution.
Ethyl alcohol	+0.48°	-0.96 c.c.
Nitrobenzene	-3.62	+3.24 „
Benzene	-6.82	+6.58 „

A contraction of 0.96 c.c. in the menthol molecule on solution in alcohol produces an *increase* of rotation of 0.48°; an *expansion* of 3.24 c.c. on solution in nitrobenzene is accompanied by a *diminution* in rotation of 3.62°, whilst the greater expansion of 6.58 c.c. in benzene is accompanied by the greater diminution in rotation of 6.82°, a relationship which is almost linear.

l-Menthyl d-Tartrate.—The molecular rotation of the homogeneous compound varies fairly rapidly with temperature, having the values -288° at 0°, -284° at 20°, and -264.5° at 100°.

l-Menthyl d-Tartrate in Ethyl Alcohol.

<i>p.</i>	$[M]_D^{20}$.	Volume ²⁰ .
0.0	-306.7°	395.0 c.c.
1.22	306.2	395.8 „
6.7	306.1	397.7 „
7.9	304.2	398.3 „
100.0	284.0	402.0 „ *

The relationship between rotation- and solution-volume is in this instance of a similar character to that observed for menthol in alcohol, but the changes are considerably greater. The rotation increases by 22.7°, whilst the volume diminishes by 7 c.c. The influence of temperature-change on the substance in solution is much the same as on the homogeneous ester.

l-Menthyl d-Tartrate in Benzene.

<i>p.</i>	$[M]_D^{20}$.	Volume ²⁰ .
0.0	-296.5°	407.0 c.c.
1.64	296.1	406.6 „
7.42	292.7	409.5 „
100.0	284.0	402.0 „ *

* As this substance is very viscid, its density could not be determined directly at low temperatures, and had therefore to be found by extrapolation through nearly 100°. The value for the molecular volume is therefore liable to some error.

Benzene as a solvent brings about an increase in the rotation of menthyl tartrate, but this increase is accompanied by a slight expansion of the molecule, instead of a contraction as might be expected from the preceding results. The increase of rotation amounts to 12.5° and the expansion to about 5 c.c., but this last number, owing to there being a considerable discrepancy between the two experimental values for molecular-solution-volume (406.6 and 409.5 c.c.), is somewhat uncertain.

The rotation of the ester diminishes with rise of temperature in this solvent also, which is the same as for the homogeneous compound.

l-Menthyl d-Tartrate in Nitrobenzene.

p .	$[M]_D^{20}$.	Volume $^{20^\circ}$.
0.0	-245.0°	408.8 c.c.
1.42	245.3	408.8 „
6.49	246.3	408.2 „
100.0	284.0	402.0 „ *

Solution in nitrobenzene causes a considerable diminution, 39° , in the rotation of menthyl tartrate, whilst at the same time an expansion of about 6.8 c.c. takes place in the molecule.

It is noticeable also that whilst in alcohol and benzene the rotation of menthyl tartrate diminishes with rise of temperature, it increases in nitrobenzene. In a solution of $p = 6.9$, this increase amounts to about 3° between 10° and 60° .

Comparing now these rotation- and volume-changes, the following table is obtained :

Rotation- and Volume-change of l-Menthyl d-Tartrate.

Solvent.	Total rotation-change due to solution.	Total volume-change due to solution.
Ethyl alcohol	+ 22.7°	- 7.0 c.c.
Benzene.....	+ 12.5	+ 5.0 „
Nitrobenzene ..	- 39.0	+ 6.8 „

The numbers for alcohol and nitrobenzene, it will be seen, are consistent ; a contraction of 7 c.c. in the former solvent is attended by an increase in rotation of 22.7° , whilst in the latter an expansion of 6.8 c.c. accompanies a diminution of 39° in rotation. Benzene, however, although in both respects intermediate between the other two solvents, is not in close agreement. Judging by the rotation-change, a contraction of between 3 and 4 c.c. would have been expected instead of the expansion actually found.

l-Menthyl Diacetyl-d-tartrate.—The rotation of the homogeneous

* See note on page 124.

ester diminishes fairly rapidly on heating. It has the value -268.7° at 0° , -256.5° at 20° , and -227.5° at 100° .

l-Menthyl Diacetyl-d-tartrate in Ethyl Alcohol.

p .	$[M]_D^{20^\circ}$.	Volume $^{20^\circ}$.
0.0	-268.5°	478.0 c.c.
1.8	268.8	478.7 „
7.3	267.7	480.0 „
100.0	256.5	486.6 „ *

Solution in alcohol thus causes an increase of 12° in the rotation of menthyl diacetyltartrate, whilst at the same time a contraction of 8.6 c.c. occurs in the molecule.

The rotation diminishes fairly rapidly with rise of temperature.

l-Menthyl Diacetyl-d-tartrate in Benzene.

p .	$[M]_D^{20^\circ}$.	Volume $^{20^\circ}$.
0.0	-286.5°	481.6 c.c.
1.5	286.0	481.8 „
7.8	284.2	482.5 „
100.0	256.5	486.6 „ *

A considerable increase in rotation, 30° , takes place in this case also. Corresponding with it, however, there is only a small volume-change of 5 c.c.

The rotation diminishes with rise of temperature, much as in the fused ester.

l-Menthyl Diacetyl-d-tartrate in Nitrobenzene.

p .	$[M]_D^{20^\circ}$.	Volume $^{20^\circ}$.
0.0	-239.0°	483.5 c.c.
1.53	238.5	484.0 „
6.27	237.8	483.0 „
100.0	256.5	486.6 „ *

Nitrobenzene as a solvent, unlike benzene and alcohol, causes a considerable diminution, of 17.5° , in the rotation of menthyl diacetyltartrate. There is, however, only a very slight volume change, and the above numbers are scarcely sufficient to enable one to decide definitely whether this change is an expansion or contraction. On the one hand, the value for the molecular volume, 486.6 c.c., is somewhat uncertain, whilst on the other, since the value found for the volume in 1.53 per cent. solution is greater than that in 6.27 per cent. solution,

* This value is also somewhat uncertain, because the density used in its calculation was obtained by extrapolation through a considerable range of temperature.

the value at infinite dilution may perhaps be greater than 483.5 c.c. It is, therefore, only certain that the volume-change is very small.

The rotation in this case also diminishes on heating, much as in the homogeneous ester. It may be noticed, too, that a concentration of minimum rotation possibly exists at about $p = 10$.

On comparing the values of the rotation- and volume-changes for menthyl diacetyltartrate, we obtain the following table :

Rotation- and Volume-change of l-Menthyl Diacetyl-d-tartrate.

Solvent.	Total rotation change due to solution.	Total volume change due to solution.
Alcohol	+ 12.0°	- 8.6 c.c.
Benzene	+ 30.0	- 5.0 „
Nitrobenzene.....	- 17.5	- 3.1 „

In this instance, whilst the rotation changes are fairly large, the volume-changes are small, and the relationship between the variables is not so satisfactory as in the other two cases. Thus, although the molecular contraction in benzene is less than in alcohol, the rotational change is greater, and although the diminution in rotation due to solution in nitrobenzene ought, judging by analogy, to be accompanied by an expansion of the molecule, very little change, and that apparently a contraction, occurs, but, as has already been mentioned, the volume-change in the last case is rather uncertain.

We consider that, on the whole, these results help to confirm the suggestion that rotation in solution and molecular-solution-volume are closely related phenomena. For menthol, the facts are in complete agreement with theory. With menthyl tartrate, the results for alcohol and nitrobenzene are in close agreement, although the relationship between the two variables in benzene is anomalous. Difficulties are met with for menthyl diacetyltartrate also, but here, as has been pointed out, although in alcohol and benzene the relationship is not a quantitative one, it is in agreement with theory, in so far as, in both cases, contraction brings about increased rotation. Thus, out of the nine examples studied, contraction produces increased rotation in four instances, expansion causes diminished rotation in three instances, contraction accompanies diminished rotation in one case, whilst expansion accompanies increased rotation in another. Thus, out of nine observations, seven are in accord with the theory, and of the two exceptions one at least is somewhat doubtful.

Attention may be directed to two further points illustrated by the data obtained in this investigation. In the table below, numbers are given showing the sensitiveness of the rotations of the active compounds examined, to change of volume.

Substance.	Total variation of rotation.	Total variation of volume.	Molecular volume.	Variation of rotation due to 1 per cent. volume- change.
Menthol.....	7.3°	7.54 c.c.	173.3 c.c.	1.7°
<i>l</i> -Menthyl <i>d</i> -tartrate	61.7	13.8 „	402.0 „	18.0
<i>l</i> -Menthyl diacetyl- <i>d</i> -tartrate	47.5	5.5 „	486.6 „	42.0

An example will show how these numbers are obtained. Solution in alcohol increases the rotation of menthyl tartrate by 22.7°, whilst benzene diminishes the rotation by 39°. The total range is therefore 61.7°. Similarly, the total range of volume is 13.8 c.c., the molecular volume being 402 c.c. A contraction of 1 per cent., that is, of 4.02 c.c., occasions a rotation change of 18°. From the last column in the table, it will be seen that the sensitiveness increases greatly with increase in the size of the molecule. The larger the molecule, the greater is the effect produced on its rotation by a given percentage volume change.

In conclusion, the following table gives a survey of the rotation values obtained :

	[M] _D ^{20°} .			
	At infinite dilution in			
	Homogeneous.	Alcohol.	Benzene.	Nitrobenzene
Menthol.....	-77.22°	-77.7°	-70.4°	-73.6°
<i>l</i> -Menthyl <i>d</i> -tartrate	284.0	306.7	296.5	245.0
<i>l</i> -Menthyl diacetyl- <i>d</i> -tartrate	256.5	268.5	286.5	239.0

The numbers show that the relationship amongst the rotation values for a given set of related active compounds is not constant, even when all are subjected to what one might expect to be similar conditions. Thus, the ratio of the above numbers for alcohol is different from that for the homogeneous condition, whilst both in turn differ from the ratios obtained in benzene and nitrobenzene.

It is thus clear that any comparison of rotation data which have been determined in different solvents is apt to be very misleading, and that even data determined under the same conditions, as in the present investigation, have only a special, and but little general, value. The results hitherto obtained, however, seem to indicate that for any given active substance it may be possible to obtain an expression connecting the rotation in solution with that in the homogeneous condition by taking the volume-change into account.

Thus we have for menthol, from some of the results described in this paper (p. 124), the expression :

$$[M]_D^{20^\circ}(\text{soln.}) = [M]_D^{20^\circ}(\text{homog.}) + 0.97^\circ dv,$$

where dv is the change of volume for a particular solvent and 0.97° * is the average increase in rotation for unit alteration in volume. From this formula, we obtain the following numbers :

Solvent.	dv .	$[M]_D^{20^{\circ}}$ solution	
		Calculated.	Found.
Alcohol	-0.96 c.c.	-78.1°	-77.7°
Benzene	+6.58 ,,	70.8	70.4
Nitrobenzene	+3.24 ,,	74.1	73.6

The calculated and experimental values are thus in fair agreement, and, although expressions giving equally good results cannot be established for the other compounds examined, we hope that future investigation will result in the explanation of existing anomalies and the discovery of further regularities.

EXPERIMENTAL DATA.

Menthol in Benzene.

$p = 1.45555$. Density of benzene = 0.878918 at $20^{\circ}/4^{\circ}$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
9.1°	-2.343°	0.8914	-45.15°	-70.43°
17.0	2.301	0.8819	44.83	69.93
23.0	2.323	0.8755	45.57	71.09
32.6	2.287	0.8653	45.39	70.81

Densities Determined :

Temperature	17.96°	20°	25.07°	30.5°
Density	0.88092	0.878752 *	0.87336	0.8676

* The values marked thus have been obtained by interpolation from the other data given.

$p = 7.49708$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
7.1°	-12.339°	0.8916	-46.15°	-71.99°
17.6	12.124	0.8811	45.89	71.59
28.0	11.931	0.8709	45.69	71.28
34.2	11.926	0.8646	45.99	71.73

Densities Determined :

Temperature	17.45°	20°	25.7°	32.05°
Density	0.88130	0.878719 *	0.87295	0.86632

* This value is obtained by dividing the total range of rotation (7.3°) by the total change of volume (7.54 c.c.).

Menthol in Ethyl Alcohol.

$p = 1.5749$. Density of alcohol = 0.790801 at 20°/4°.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
12.0°	-2.500°	0.7992	-49.66°	77.47°
19.0	2.490	0.7932	49.83	77.74
27.9	2.470	0.7856	49.91	77.86

Densities Determined:

Temperature	18.15°	20°	23.87°	29.06°
Density	0.79397	0.792386 *	0.78908	0.78460

$p = 8.26794$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
12.0°	-13.243°	0.8058	-49.69°	-77.51°
17.6	13.167	0.8011	49.70	77.53
18.1	13.173	0.8006	49.78	77.66
29.7	13.065	0.7909	49.95	77.92
41.6	12.985	0.7807	50.29	78.46
46.9	12.888	0.7762	50.21	78.33

Densities Determined:

Temperature ...	18.32°	20°	23.71°	29.47°	35.17°
Density	0.80049	0.799072 *	0.79595	0.79104	0.78617

Menthol in Nitrobenzene.

$p = 1.4539$. Density of nitrobenzene = 1.20353 at 20°/4°.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
22.5°	-3.272°	1.1947	-47.09°	-73.46°
32.9	3.223	1.1839	46.80	73.00

Densities Determined:

Temperature	19.25°	20°	28.93°	43.2°
Density	1.19796	1.19723 *	1.1885	1.1745

$p = 2.05718$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
8.5°	-4.728°	1.2063	-47.63°	-74.30°
24.0	4.595	1.1909	46.89	73.14
39.0	4.472	1.1760	46.21	72.08

Densities Determined:

Temperature	19.6°	20°	31.7°	41.7°
Density	1.19152	1.19474 *	1.18324	1.17352

$$p = 6.6542.$$

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
9.8°	-14.950°	1.1855	-47.37°	-73.89°
25.3	14.532	1.1706	46.63	72.74
46.4	14.180	1.1503	46.29	72.21
67.2	13.790	1.1301	45.84	71.51
78.7	13.607	1.1198	45.65	71.22

Densities Determined:

Temperature	17.05°	20°	24.42°	47.15°
Density	1.17858	1.17573 *	1.17142	1.1495

$$p = 30.4894.$$

t .	α_D^{20} (100 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
19.1°	-15.715°	1.0892	-47.30°	-73.78°
22.7	15.60	1.0859	47.10	73.47
25.3	15.52	1.0834	46.98	73.28
29.7	15.42	1.0795	46.84	73.06

Densities Determined:

Temperature	19.6°	20°	31.6°	41.2°	54.1°
Density	1.0888	1.08848 *	1.0777	1.0690	1.0571

l-Menthyl d-Tartrate in Ethyl Alcohol.

$$p = 1.2119. \text{ Density of alcohol} = 0.790801 \text{ at } 20^\circ/4^\circ.$$

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
12.0°	-2.835°	0.8001	-73.10°	-311.4°
22.5	2.741	0.7911	71.48	304.5

Densities Determined:

Temperature ..	17.74°	20°	26.33°
Density	0.795300	0.793348 *	0.787913

$$p = 6.69547.$$

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
12.8°	-15.730°	0.8110	-72.42°	-308.5°
14.9	15.682	0.8094	72.34	308.2
25.5	15.285	0.8002	71.34	303.9
28.1	15.210	0.7980	71.18	303.2
34.1	15.030	0.7927	70.80	301.6
36.4	14.962	0.7907	70.65	301.0
62.7	14.150	0.7679	68.80	293.1

Densities Determined:

Temperature	17.64°	20°	26.46°	42.24°
Density	0.806938	0.804914 *	0.799372	0.785674

$p = 7.92984$. Density of alcohol = 0.792198 at 20°/4°

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
9.7°	-18.743°	0.8176	-72.26°	-307.8°
19.1	18.367	0.8098	71.50	304.5
26.0	18.097	0.8037	70.98	302.3
33.9	17.77	0.7969	70.30	299.5

Densities Determined:

Temperature	19.75°	20°	30.38°	41.6°
Density	0.80904	0.808828 *	0.79992	0.79008

l-Menthyl d-Tartrate in Benzene.

$p = 1.63747$. Density of benzene = 0.87869 at 20°/4°.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
10.5°	-4.085°	0.8910	-70.00°	-298.2°
14.0	4.055	0.8873	69.79	297.3
16.1	4.039	0.8850	69.71	297.0
27.5	3.952	0.8733	69.10	294.4
29.0	3.938	0.8715	69.01	294.0

Densities Determined:

Temperature	19.82°	20°	27.7°	39.75°
Density	0.88121	0.881017 *	0.87285	0.86004

$p = 7.41659$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
9.4°	-18.552°	0.8992	-69.53°	-296.2°
17.3	18.227	0.8915	68.92	293.6
25.8	17.858	0.8828	68.17	290.4
33.3	17.637	0.8753	67.90	289.2
37.2	17.425	0.8713	67.41	287.2

Densities Determined:

Temperature	18.1°	20°	26.05°	30.4°
Density	0.89087	0.88893 *	0.88242	0.87831

l-Menthyl d-Tartrate in Nitrobenzene.

$p = 1.42535$. Density of nitrobenzene = 1.20353 at 20°/4°.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
16.7°	-3.945°	1.2040	-57.46°	-244.8°
28.4	3.932	1.1927	57.82	246.3
36.2	3.923	1.1850	58.05	247.3

Densities Determined:

Temperature	18.51°	20°	27.6°	43.3°
Density	1.20234	1.20088 *	1.19345	1.17809

$$p = 6.48726.$$

<i>t.</i>	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
10.1°	-17.970°	1.2014	-57.65°	-245.6°
18.4	17.905	1.1935	57.81	246.2
21.1	17.875	1.1908	57.84	246.4
51.9	17.567	1.1609	58.28	248.3
56.9	17.532	1.1560	58.41	248.8

Densities Determined:

Temperature	19.3°	20°	30.25°	50.25°
Density	1.19236	1.19168 *	1.18176	1.16248

l-Menthyl Diacetyl-d-tartrate in Ethyl Alcohol.

$$p = 1.7888. \quad \text{Density of alcohol} = 0.790801 \text{ at } 20^\circ/4^\circ.$$

<i>t.</i>	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
18.7°	-3.007°	0.7955	-52.83°	-269.4°
21.6	2.983	0.7930	52.57	268.1
29.6	2.920	0.7862	51.91	264.7
41.3	2.840	0.7759	51.16	260.9

Densities Determined:

Temperature	17.72°	20°	24.78°	40.66°
Density	0.79642	0.794465 *	0.79037	0.77647

$$p = 7.26494.$$

<i>t.</i>	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
13.0°	-12.487°	0.8117	-52.94°	-270.0°
17.4	12.369	0.8080	52.68	268.7
23.9	12.175	0.8024	52.22	266.3
40.2	11.684	0.7883	51.01	260.1

Densities Determined:

Temperature	16.63°	20°	30.69°
Density	0.808676	0.805775 *	0.796572

l-Menthyl Diacetyl-d-tartrate in Benzene.

$p = 1.49569$. Density of benzene = 0.878822 at $20^{\circ}/4^{\circ}$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
7.5°	-3.148°	0.8947	-58.80°	-299.9°
16.0	3.013	0.8854	56.87	290.0
26.0	2.875	0.8747	54.94	280.2
41.2	2.687	0.8582	52.31	266.8

Densities Determined:

Temperature	22.6°	20°	33.46°	40.8°
Density	0.87827	0.881057 *	0.86676	0.8588

$p = 7.80199$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
8.0°	-16.385°	0.9032	-58.12°	-296.4°
17.9	15.640	0.8930	56.10	286.1
35.0	14.522	0.8749	53.20	271.3

Densities Determined:

Temperature	20°	20.23°	29.05°	43°
Density	0.8.0537 *	0.890276	0.881188	0.86651

l-Menthyl Diacetyl-d-tartrate in Nitrobenzene.

$p = 1.52859$. Density of nitrobenzene = 1.20353 at $20^{\circ}/4^{\circ}$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
9.9°	-3.487°	1.2106	-47.12°	-240.3°
17.0	3.447	1.2038	46.85	238.9
27.5	3.390	1.1935	46.46	236.9
49.9	3.270	1.1721	45.62	232.6

Densities Determined:

Temperature	19.28°	20°	30.45°	39.2°
Density	1.20163	1.20092 *	1.19074	1.18202

$p = 6.26591$.

t .	α_D^{20} (400 mm.).	Density.	$[\alpha]_D^{20}$.	$[M]_D^{20}$.
17.0°	-14.000°	1.1960	-46.69°	-238.1°
32.7	13.733	1.1809	46.39	236.6
44.7	13.490	1.1693	46.02	234.7
61.0	13.140	1.1535	45.44	231.7

Densities Determined:

Temperature	20°	20.5°	32.12°	45.77°
Density	1.19307 *	1.19259	1.18134	1.16815

The thanks of the authors are due to the Research Fund Committees of the Royal Society and the Chemical Society for grants which defrayed the expenses of this investigation.

THE UNIVERSITY,
GLASGOW.

THE UNIVERSITY,
LEEDS.