

XXXIII.—*Position Isomerism and Optical Activity ; the Methylic and Ethylic Salts of Benzoyl and of Ortho-, Meta-, and Para-malic Acid.*

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THE present investigation forms a continuation of the work on the same subject which we have already published in the pages of the Journal of the Chemical Society (Trans., 1896, **69**, 1309—1321; 1583—1592; also P. Frankland and McCrae, Trans., 1898, **73**, 307—329) and which has for its object the determination of the influence respectively exerted by position-isomeric groups attached to the asymmetric carbon atom.

Reasons have been adduced by us for anticipating that, in the case of isomeric di-substituted benzene rings, the para-isomeride should exert the greatest, the ortho- the least, and the meta- an intermediate

influence on the rotation, and experiment shows that this sequence is so far, with two doubtful exceptions (Trans., 1898, 73, 308 and 309), uniformly maintained. We have also given reasons for anticipating that the unsubstituted phenyl group should exert a rotatory influence inferior to that of the para- or meta-groups, but according to circumstances either greater or less than that of the ortho-groups. Experience shows, however, that the rotatory influence of the unsubstituted phenyl group is apparently much more erratic, occupying every possible position as regards the magnitude of the rotatory influences of the three isomeric di-substituted benzene rings.

Preparation of Ethylic and Methylic Malates.

The difficulties attending the preparation of the ethereal salts of malic acid have been pointed out by Anschütz and Reitter (*Zeit. physikal. Chem.*, 1895, 16, 493), who have shown that if the ordinary hydrochloric acid method is employed, a considerable proportion of the malic acid is converted into fumaric acid unless a very low temperature is preserved during the saturation of the alcoholic solution of malic acid with hydrogen chloride. It has also been shown by Purdie, Williamson and Lander (Trans., 69, 829; Purdie and Lander, Trans., 73, 287) that if the method of acting on silver malate with an alkyl iodide is employed, the alkyl malate is mixed with the ethereal salt of the corresponding alkoxy succinic acid which entirely vitiates the optical activity of the product.

In choosing between these two evils, we have resorted to the hydrochloric acid method as the less objectionable of the two, and we have carefully observed the precautions indicated by Anschütz so as to secure the maximum purity of the product.

Ethylic Malate.—Fifty grams of finely powdered malic acid (Kahlbaum), dried in a vacuum desiccator for 3 days, were mixed with 100 grams of absolute ethylic alcohol in which the acid nearly all dissolved; a slow stream of carefully dried hydrogen chloride was then passed through the liquid, which was kept at -18° by means of a freezing mixture. When completely saturated, the liquid was left for 24 hours, a current of dry air was then drawn through for 48 hours, after which it was placed in a vacuum desiccator containing slaked lime, until the smell of hydrochloric acid had nearly disappeared. The excess of alcohol was then distilled off under reduced pressure and at as low a temperature as possible, the ethereal salt being subsequently distilled on an oil-bath. Fifty-one grams of the crude ethereal salt were obtained between 128° and 140° (11 mm. pressure). This exhibited the rotation

$$\alpha_D = -10.30^{\circ}; \quad l = 1, \quad t = 21^{\circ}.$$

This was redistilled, the portion passing over at 129—134° (12 mm. press.) having a rotation

$$\alpha_D = -11.55^\circ; l = 1, t = 17.5^\circ.$$

After treatment in ethereal solution with fused potassium carbonate and redistillation until the rotation was constant, it finally distilled at 129—132° (11 mm. pressure), and exhibited the specific rotation

$$[\alpha]_D^{20} = \frac{-11.84}{1.0 \times 1.1340} = -10.44^\circ \quad (d \ 20^\circ/4^\circ = 1.1340),$$

a value agreeing closely with that obtained by Purdie and Williamson, namely, -10.30° , from Kahlbaum's malic acid by use of the hydrochloric acid method.

0.2302 gave 0.4229 CO₂, 0.1510 H₂O. C = 50.10; H = 7.29.

0.2083 „ 0.3834 CO₂, 0.1368 H₂O. C = 50.20; H = 7.30.

C₈H₁₄O₅ requires C = 50.53; H = 7.37 per cent.

Methylic Malate.—This was prepared in exactly the same way as the ethylic compound. Forty-eight grams of crude ethereal salt, boiling at 128—142° under 12 mm. pressure, were obtained from 50 grams of dry malic acid and 100 grams of methylic alcohol. This product had a rotation

$$\alpha_D = -6.70^\circ; l = 1, t = 18.5^\circ.$$

The product was fractionated under diminished pressure until of practically constant rotation; the final product boiled at 129° (11 mm.), and exhibited the following rotations.

$$\alpha_D = -8.36^\circ; l = 1, t = 16.6^\circ.$$

$$\alpha_D = -8.41^\circ; l = 1, t = 20$$

$$\alpha_D = -8.46^\circ; l = 1, t = 40$$

$$[\alpha]_D^{20} = \frac{-8.41}{1 \times 1.2301} = -6.84^\circ.$$

Purdie and Williamson give as the observed rotation $\alpha_D = -8.17^\circ$.

Anschütz and Reitter $[\alpha]_D = -6.88^\circ$. Walden $[\alpha]_D = -6.85^\circ$.

0.2300 gave 0.3735 CO₂ and 0.1285 H₂O. C = 44.29; H = 6.21.

0.2191 „ 0.3551 CO₂ „ 0.1212 H₂O. C = 44.20; H = 6.15.

C₆H₁₀O₅ requires C = 44.44; H = 6.17 per cent.

Ethylic Benzoylmalate.

Ethylic malate was slowly added to an excess of benzoic chloride heated in an oil-bath at 140°, the temperature being subsequently raised to 170°, at which it was maintained for 40 minutes. The excess of benzoic chloride was distilled off first under reduced pressure and

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then, on raising the temperature, the crude ethylic benzoylmalate passed over at 210—220° (12 mm.); the latter was refractionated under diminished pressure until the rotation was constant. It was a thick, colourless liquid which we were unable to obtain in the solid state.

0·2210 gave 0·4941 CO₂ and 0·1222 H₂O. C = 60·97; H = 6·14.

0·2153 „ 0·4818 CO₂ „ 0·1203 H₂O. C = 61·03; H = 6·21.

C₁₅H₁₈O₆ requires C = 61·22; H = 6·12 per cent.

$d_{40^{\circ}/4^{\circ}} = 1·1361$; $d_{50^{\circ}/4^{\circ}} = 1·1253$; $d_{60^{\circ}/4^{\circ}} = 1·1158$.

With this product, the following polarimetric determinations were made.

Rotation of ethylic benzoylmalate.

Temperature.	Observed rotation α_D in 99·9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
21°	- 4·47°	1·1561	- 3·87°
35	- 6·02	1·1414	- 5·28
46	- 7·00	1·1298	- 6·20
66	- 8·59	1·1095	- 7·75
73	- 9·02	1·1021	- 8·19
78	- 9·31	1·0969	- 8·50
98	- 10·57	1·0759	- 9·84
137	- 12·48	1·0349	- 12·08

Methylic Benzoylmalate.

The mode of preparation was similar to that described above for the ethylic compound. The crude product was dissolved in chloroform, well shaken with a solution of sodium carbonate, and, after separation, the chloroform solution was dried with fused potassium carbonate. After removing the chloroform, the liquid was fractionated under reduced pressure until the rotation was constant, it passed over at 210—223 (12 mm.); it could not be induced to solidify.

0·2346 gave 0·4991 CO₂ and 0·1147 H₂O. C = 58·02; H = 5·43.

0·2312 „ 0·4951 CO₂ „ 0·1105 H₂O. C = 58·40; H = 5·31.

0·2242 „ 0·4798 CO₂ „ 0·1082 H₂O. C = 58·37; H = 5·36.

C₁₃H₁₄O₆ requires C = 58·65; H = 5·26 per cent.

The following density determinations were made.

$d_{40^{\circ}/4^{\circ}} = 1·1944$; $d_{60^{\circ}/4^{\circ}} = 1·1759$; $d_{70^{\circ}/4^{\circ}} = 1·1665$,

and the following polarimetric observations.

Rotation of methylic benzoylmalate.

Temperature.	Observed rotation α_D in 99.9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
21°	-6.81°	1.2121	-5.62°
33	-8.27	1.2009	-6.89
44	-9.36	1.1907	-7.87
64	-10.93	1.1721	-9.33
99	-13.16	1.1395	-11.56
137.5	-15.04	1.1037	-13.64

Ethylic Orthotoluylmalate.

This was prepared in the usual manner by adding ethylic malate to twice the theoretical quantity of orthotoluic chloride heated at 140° and ultimately to 170°. The excess of acid chloride was distilled off under reduced pressure, the residue being then dissolved in chloroform and shaken for 24 hours with a solution of sodium carbonate to remove any remaining acid chloride. After washing repeatedly with water, the chloroform solution was dried with potassium carbonate, and the chloroform distilled off. The rotation of the crude product thus obtained was

$$\alpha_D = -5.75^\circ; \quad l = 1, \quad t = 20^\circ.$$

It was purified by repeated fractionation under reduced pressure until the rotation was constant; it distils at 215—225° (12 mm.).

0.2170 gave 0.4895 CO₂ and 0.1277 H₂O. C = 61.52; H = 6.54.

0.2072 „ 0.4719 CO₂ „ 0.1227 H₂O. C = 62.11; H = 6.58.

0.2088 „ 0.4759 CO₂ „ 0.1231 H₂O. C = 62.16; H = 6.55.

C₁₆H₂₀O₆ requires C = 62.34; H = 6.49 per cent.

The following density determinations were made,

$$d_{40^\circ/4^\circ} = 1.1228; \quad d_{60^\circ/4^\circ} = 1.1057; \quad d_{70^\circ/4^\circ} = 1.0968,$$

and the following polarimetric observations.

Rotation of ethylic orthotoluylmalate.

Temperature.	Observed rotation α_D in 92.36 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
21°	-6.58°	1.1391	-6.25°
43	-7.74	1.1202	-7.48
71	-9.04	1.0960	-8.93
100	-10.27	1.0713	-10.38
136	-11.54	1.0403	-12.01

Methylic Orthotoluylmalate.

This was prepared in a similar manner to the ethylic salt. The crude compound, after washing with sodium carbonate solution, exhibited the following rotations.

$$\alpha_D = -8.56^\circ; (l=1, t=9.5^\circ)$$

$$\alpha_D = -13.08^\circ; (l=1, t=100^\circ)$$

As solidification could not be induced, the purification was effected by fractionation under reduced pressure until the rotation was constant; the liquid passed over at 214—225° (12 mm.).

0.2174 gave 0.4759 CO₂ and 0.1123 H₂O. C=59.70; H=5.74.

0.2216 „ 0.4841 CO₂ „ 0.1131 H₂O. C=59.58; H=5.67.

0.2307 „ 0.5054 CO₂ „ 0.1196 H₂O. C=59.75; H=5.76.

C₁₄H₁₆O₆ requires C=60.00; H=5.71 per cent.

The following density determinations were made,

$$d_{40^\circ/4^\circ} = 1.1744; d_{50^\circ/4^\circ} = 1.1647; d_{60^\circ/4^\circ} = 1.1550,$$

and the following polarimetric observations.

Rotation of methylic orthotoluylmalate.

Temperature.	Observed rotation α_D in 99.9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
23°	-10.61°	1.1909	-8.94°
35.5	-11.17	1.1788	-9.49
48	-11.72	1.1666	-10.06
64	-12.45	1.1511	-10.83
98	-13.85	1.1181	-12.40
135	-15.23	1.0822	-14.09

Ethylic Metatoluylmalate.

The preparation was effected in exactly the same manner as that already described for the orthotoluyyl compound. The product was a colourless liquid distilling at 212—220° (13 mm.).

0.2389 gave 0.5435 CO₂ and 0.1427 H₂O. C=62.05; H=6.64.

0.2328 „ 0.5290 CO₂ „ 0.1383 H₂O. C=61.97; H=6.60.

C₁₆H₂₀O₆ requires C=62.34; H=6.49 per cent.

The following density determinations were made,

$$d_{40^\circ/4^\circ} = 1.1185; d_{50^\circ/4^\circ} = 1.1086; d_{60^\circ/4^\circ} = 1.0989,$$

and the following polarimetric observations.

Rotation of ethylic metatoluylmalate.

Temperature.	Observed rotation α_D in 99.9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
21°	-5.30°	1.1371	-4.67
28	-5.98	1.1303	-5.30
33.5	-6.44	1.1249	-5.73
38.5	-6.84	1.1200	-6.11
41.5	-7.06	1.1170	-6.33
54.5	-7.94	1.1043	-7.20
60	-8.41	1.0989	-7.66
71	-9.04	1.0881	-8.32
99.5	-10.52	1.0603	-9.93
137.5	-11.92	1.0229	-11.66

Methylic Metatoluylmalate.

This was obtained in like manner, as a thick, almost colourless, liquid distilling at 215—225° (12 mm.).

0.2094 gave 0.4599 CO₂ and 0.1098 H₂O. C = 59.90; H = 5.83.

0.2126 „ 0.4665 CO₂ „ 0.1108 H₂O. C = 59.84; H = 5.79.

C₁₄H₁₆O₆ requires C = 60.00; H = 5.71 per cent.

The following density determinations were made,

$d_{40^\circ/4^\circ} = 1.1723$; $d_{50^\circ/14^\circ} = 1.1622$; $d_{60^\circ/4^\circ} = 1.1521$,

and the following polarimetric observations.

Rotation of methylic metatoluylmalate.

Temperature.	Observed rotation α_D in 99.9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$
20°	-7.55°	1.1925	-6.34°
32	-8.68	1.1804	-7.36
46	-9.85	1.1662	-8.45
67.5	-11.31	1.1445	-9.89
99	-13.04	1.1127	-11.73
136	-14.49	1.0753	-13.49

Ethylic Paratoluylmalate.

The preparation was carried out in exactly the same manner as already described for the orthotoluyll compound. The ethylic salt was obtained as a thick, colourless liquid which was purified by fractionation under reduced pressure until the rotation was constant.

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0.2253 gave 0.5111 CO₂ and 0.1320 H₂O. C = 61.87; H = 6.51.

0.2215 „ 0.5021 CO₂ „ 0.1304 H₂O. C = 61.82; H = 6.54.

C₁₆H₂₀O₆ requires C = 62.34; H = 6.49 per cent.

The following density determinations were made,

$d_{40^{\circ}/4^{\circ}} = 1.1162$; $d_{50^{\circ}/4^{\circ}} = 1.1052$; $d_{60^{\circ}/4^{\circ}} = 1.0943$,

and the following polarimetric observations.

Rotation of ethylic paratoluylmalate.

Temperature.	Observed rotation α_D in 99.9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
20°	-0.25°	1.1382	-0.22°
29	-1.06	1.1283	-0.94
35	-1.71	1.1217	-1.53
51	-2.99	1.1041	-2.71
62	-3.71	1.0920	-3.40
99	-5.83	1.0513	-5.55
136	-7.38	1.0106	-7.31

Note.—On the first occasion when we prepared ethylic paratoluylmalate, this substance, before distillation, but after it had been washed in chloroform solution with sodium carbonate, became quite thick through separation of crystals; the latter were recrystallised several times from methylated spirit until of constant melting point (95°), when they presented the appearance of long, shining blades. These crystals dissolved slowly in caustic potash on heating, and on adding hydrochloric acid, paratoluic acid melting at 176° was deposited. On analysis,

0.1549 gave 0.4257 CO₂ and 0.0787 H₂O. C = 74.95; H = 5.65.

0.1812 „ 0.4990 CO₂ „ 0.0919 H₂O. C = 75.11; H = 5.64.

These figures negatived the possibility of this substance being ethylic paratoluylmalate, but, on the other hand, they point unmistakably to its being *paratoluic anhydride*, C₁₆H₁₄O₃, which requires C = 75.60, H = 5.51 per cent. As this compound does not appear to have been prepared before, we had no further means of identifying it with the quantity at our disposal. Benzoic anhydride melts at 42°.

Methylic Paratoluylmalate.

Even this ethereal salt was only obtained as a liquid distilling between 200° and 225° under 13 mm. pressure.

0.2317 gave 0.5074 CO₂ and 0.1213 H₂O. C = 59.72; H = 5.82.

0.2264 „ 0.4955 CO₂ „ 0.1192 H₂O. C = 59.69; H = 5.85.

C₁₄H₁₆O₆ requires C = 60.00; H = 5.71 per cent.

The following density determinations were made,

$$d\ 40^{\circ}/4^{\circ} = 1.1725 ; d\ 50^{\circ}/4^{\circ} = 1.1617 ; d\ 60^{\circ}/4^{\circ} = 1.1509,$$

and the following polarimetric observations.

Rotation of methylic paratoluylmalate.

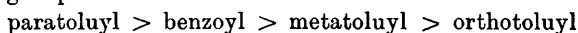
Temperature.	Observed rotation α_D in 99.9 mm. tube.	Density compared with water at 4°.	$[\alpha]_D$.
18.5°	- 3.75°	1.1957	- 3.14°
29.5	- 4.77	1.1838	- 4.03
37.5	- 5.40	1.1752	- 4.60
50	- 6.35	1.1617	- 5.47
66	- 7.40	1.1444	- 6.47
99	- 9.23	1.1088	- 8.33
136	- 10.83	1.0688	- 10.14

The results recorded above may be summarised as follows.

1. The lævorotation of ethylic is greater than that of methylic malate.

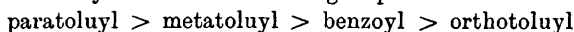
2. The lævorotation of ethylic malate is diminished by the introduction of the benzoyl and three toluy groups. The lævorotation of methylic malate is also diminished by the introduction of the benzoyl, paratoluy, and metatoluy groups, but is increased by the introduction of the orthotoluy group. The exceptional influence of the orthotoluy group on methylic malate will be discussed later, the uniform effect in the other cases of the substitution is to depress the lævorotation, or, in other words, to exert a dextrorotatory, influence.

3. At the ordinary temperature (20°), the dextrorotatory influence of these groups follows in the order

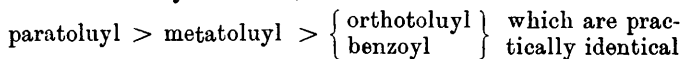


both for methylic and ethylic malate.

4. At a high temperature (136°), on the other hand, the sequence of the dextrorotatory influences of these groups is



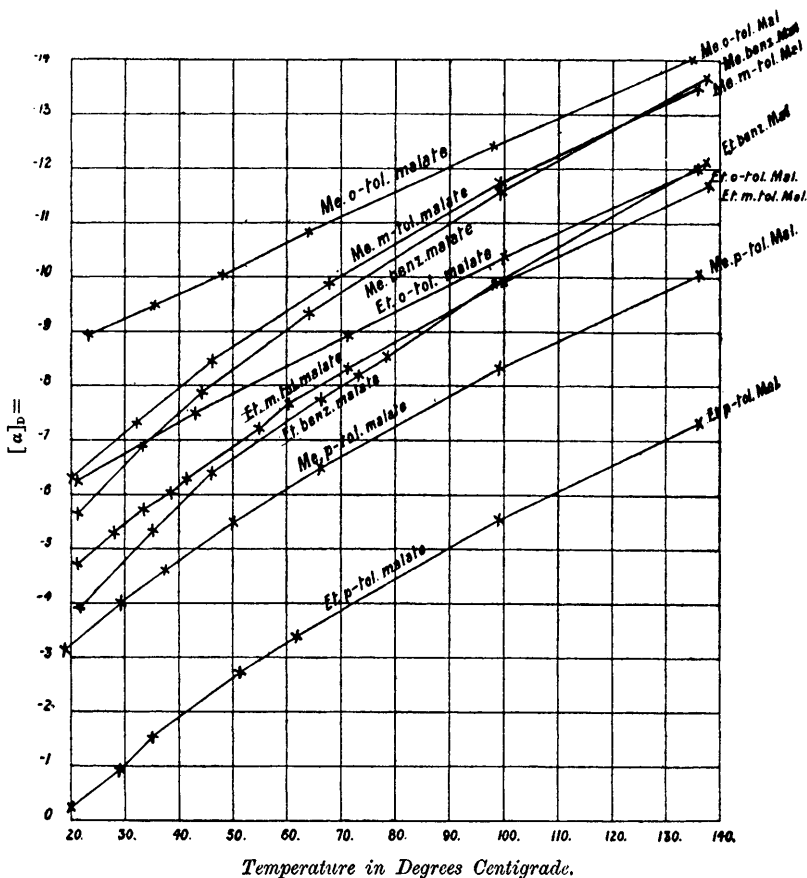
in the case of methylic malate, and



in the case of ethylic malate.

Thus it will be seen from the diagram on p. 346 that the specific rotation curve for methylic benzoylmalate cuts that for methylic metatoluylmalate at a temperature of about 120°, and that the specific rotation curve for ethylic benzoylmalate cuts that for ethylic metatoluylmalate at about 95°, and that for ethylic orthotoluylmalate at about 132°. Again, it will be seen that the influences of the benzoyl, metatoluy, and orthotoluy groups become almost identical at the high

Specific Rotation of Methylic and Ethylic Salts of Benzoyl and Toluyll (o, m, and p) Malic Acid.



temperature (136°), both in the case of ethylic and methylic malate respectively.

5. At the ordinary temperature (20°), the rotatory influences of the several groups are as follows.

Benzoyl	Methylic malate	dextrorotatory
	Ethylic malate	ditto.
Orthotoluyll	Methylic malate	lævorotatory
	Ethylic malate	dextrorotatory.
Metatoluyll	Methylic malate	dextrorotatory
	Ethylic malate	ditto.

Paratoluyyl	{	Methylic malate	dextrorotatory
		Ethylic malate	ditto.

Thus in all cases the dextrorotatory influence of the aromatic group is greater on the ethylic than on the methylic compound, indeed the orthotoluyyl group, whilst exerting a dextrorotatory influence on ethylic malate, exerts a lævorotatory influence on methylic malate.

6. At a high temperature (136°), on the other hand, the rotatory influences of the several groups are as follows.

Benzoyl	{	Methylic malate	lævorotatory
		Ethylic malate	ditto.
Orthotoluyyl	{	Methylic malate	lævorotatory
		Ethylic malate	ditto.
Metatoluyyl	{	Methylic malate	lævorotatory
		Ethylic malate	ditto.
Paratoluyyl	{	Methylic malate	lævorotatory
		Ethylic malate	dextrorotatory.

Thus, again, the dextrorotatory influence of the aromatic group is more pronounced on the ethylic than on the methylic compound; indeed, at the high temperature the influence of all four aromatic groups is actually lævorotatory on methylic malate, whilst the paratoluyyl group at any rate has still a dextrorotatory influence on ethylic malate.

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