

168. *Alkyl-Oxygen Fission in Carboxylic Esters. Part III.*

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Optically active esters of 1-naphthylmethylcarbinol react with carboxylic acids with racemisation, do not react with anhydrous alcohols, but react with alcohols in the presence of water. Optically active esters of phenylmethylcarbinol react similarly with anhydrous formic acid, react with acetic acid only in the presence of water, and do not react with methyl and ethyl alcohols even in the presence of water. Thus, these derivatives react by alkyl-oxygen fission less readily than do the esters of substituted allyl alcohols (Part I, *J.*, 1942, 556) or of *p*-methoxybenzhydrol (Part II, *J.*, 1942, 605). In accordance with this, the tendency to racemisation during the hydrolysis of the hydrogen phthalates with weak alkali is less marked in the examples now discussed than in those given in Parts I and II.

The significance of these observations is briefly discussed and attention is drawn to some other recorded examples of alkyl-oxygen fission in reactions of esters and alcohols.

Certain reactions described in Parts I and II, in particular the formation of neutral phthalic esters and of *p*-tolyl sulphones from hydrogen phthalic esters, have been applied to derivatives of certain substituted benzhydrols and related carbinols. Sulphones have also been prepared from certain of the benzhydrols and from anisyl alcohol by interaction with sodium *p*-toluenesulphinate.

THE (+)hydrogen phthalate, (–)benzoate, and (–)acetate of 1-naphthylmethylcarbinol react with anhydrous formic acid to give *dl*-formate; the (+)hydrogen phthalate and (–)benzoate give *dl*-acetate on reaction with glacial acetic acid. The hydrogen phthalate does not react with anhydrous methyl or ethyl alcohol, but, when the alcohol contains some 30% of water, yields a racemic methyl ether, and an ethyl ether of very low rotatory power.

The (+)hydrogen phthalate, acetate, and monochloroacetate of phenylmethylcarbinol react with anhydrous formic acid, yielding *dl*-formate. The hydrogen phthalate, benzoate, and formate of phenylmethylcarbinol do not react with glacial acetic acid, but, in acetic acid containing some 30% of water, the hydrogen phthalate yields an acetate of low rotatory power, the benzoate yields a racemic acetate, and the solution of the formate undergoes some racemisation. The (+)hydrogen phthalate reacts with monochloroacetic acid (in chloroform solution) with extensive racemisation, but does not react with methyl or ethyl alcohol, either anhydrous or with the addition of some 30% of water.

In a number of the experiments in which reaction occurred, part of the reacting ester was removed before the reaction was complete (see experimental section) and was found to have undergone some racemisation analogous to that which occurs in the reactions of esters of substituted allyl alcohols (Part I, *loc. cit.*).

In the experiments so far reported, the tendency to alkyl–oxygen fission is most marked in the esters of *p*-methoxybenzhydrol (Part II, *loc. cit.*), followed by the substituted allyl esters (Part I, *loc. cit.*). In both these cases the esters react with anhydrous carboxylic acids and alcohols with racemisation. Esters of 1-naphthylmethylcarbinol are somewhat less reactive in this sense: they react with carboxylic acids, but not with anhydrous methyl or ethyl alcohol, though they react with the alcohols when water is added to the medium (*i.e.*, when its ionising power is increased).

Still less reactive are the esters of phenylmethylcarbinol, which react with formic acid but not with acetic acid, and do not react with methyl or ethyl alcohol even in presence of water. This order of reactivity is parallel to the electron-releasing powers of the substituents in the alkyl groups, and is followed by the tendency to alkyl–oxygen fission during alkaline hydrolysis of the hydrogen phthalates. If, in the hydrolysis of the esters described in Parts I and II, weakly alkaline solutions are used, complete racemisation occurs. When the hydrogen phthalate of 1-naphthylmethylcarbinol is hydrolysed by weak alkali (sodium carbonate), some 50% of the product is racemic; hydrolysis of phenylmethylcarbinyl hydrogen phthalate with sodium carbonate gives an alcohol with rotatory power only a little lower than that obtained by hydrolysis with 10*N*-sodium hydroxide solution.

A number of reactions of types described in Parts I and II and above have been applied to derivatives of various of the following alcohols: Anisylethylcarbinol (I), *o*-chlorobenzhydrol (II), *p*-dimethylaminobenzhydrol (III), *p*-methoxy-*p*'-methylbenzhydrol (IV), *p*-methoxy-*p*'-isopropylbenzhydrol (V), *o*-methoxyphenyl-1-naphthylcarbinol (VI), phenyl-3:4-methylenedioxyphenylcarbinol (VII), 3:4-methylenedioxyphenylmethylcarbinol (VIII), *m*-methoxybenzhydrol (IX). (I), (II), (IV), and (VII) have been obtained in optically active forms, and the optically active hydrogen phthalates of (I) and (II) undergo slight racemisation on hydrolysis with 5*N*-sodium hydroxide: on hydrolysis with sodium carbonate of the hydrogen phthalate of (I), some 80% racemisation occurs, and of the hydrogen phthalate of (II), 50% racemisation. The corresponding di-ethers are formed, on heating, from (I), (IV), (V), and (VI), but not from (II) or (III). The hydrogen phthalate of (II) does not react with methyl or ethyl alcohol even when the alcohol contains 30% of water; the hydrogen phthalate of (III) reacts with methyl alcohol to give the methyl ether of (III). The hydrogen phthalates of (I), (IV), (V), and (VI), dissolved in a slight excess of aqueous sodium hydroxide, yield the neutral phthalate; the hydrogen phthalate of (II), and the hydrogen succinates of (II), (IV), and (VI), under the same conditions, undergo hydrolysis; the hydrogen succinate of (I) yields an oil which probably contains neutral succinate, but it could not be purified. By interaction of the hydrogen phthalates, dissolved in an equivalent amount of aqueous sodium hydroxide, with sodium *p*-toluenesulphinate, *p*-tolyl sulphones of (I), (II), (IV), (V), (VI), and (VIII) are obtained in approximately quantitative yield; anisyl *p*-tolyl sulphone is formed from anisyl hydrogen phthalate in 30% yield; the hydrogen phthalate (and hydrogen succinate) of (II) and the hydrogen phthalate of (IX) undergo partial hydrolysis. The hydrogen phthalates of (II) and of anisyl alcohol react with sodium *p*-toluenesulphinate in formic acid solution to give the *p*-tolyl sulphones in good yield. The *p*-tolyl sulphones of (I) and (VI) are also formed under similar conditions from their hydrogen succinates. *p*-Tolyl sulphones are also formed, by interaction with sodium *p*-toluenesulphinate, from the acetate of (I) (70% yield) and anisyl acetate (10% yield) in aqueous ethyl alcohol; the acetate of (II) does not react in this solvent, but gives a quantitative yield of sulphone on reaction in formic acid solution, as does also anisyl acetate.

Certain sulphones have also been obtained by interaction of the alcohols with sodium *p*-toluenesulphinate, the solutions becoming alkaline from the concomitant production of sodium hydroxide. In aqueous methyl or ethyl alcohol, sulphones have thus been obtained from *p*-methoxybenzhydrol (20% yield), (III) (100%), and anisyl alcohol (10%); in formic acid solution, anisyl alcohol gives a quantitative yield of the sulphone.

(II), dissolved in a slight excess of dilute hydrochloric acid, reacts with *p*-toluenesulphinic acid to give a quantitative yield of sulphone. This method was used by Hinsberg (*Ber.*, 1917, 50, 468) to give the phenyl

sulphone of *pp'*-tetramethyldiaminobenzhydrol (Michler's hydrol); in both reactions the primary function of the hydrochloric acid is presumably as solvent for the aminobenzhydrol, but it will also promote ionic fission of the hydrol by removing the liberated hydroxyl ion as water. The two *p*-dimethylamino substituents in Michler's hydrol result in very easy separation of the hydroxyl group, and the hydrol is known to react with a large number of compounds containing keto-methylene systems, or other groups from which the resulting carbonium kation can displace a proton (Noelting, *Ber.*, 1891, **24**, 3133; 1902, **35**, 318; Weil, *ibid.*, 1894, **27**, 1403; Möhlau and Heinge, *ibid.*, 1902, **35**, 361; O. Fischer and Weiss, *Z. Farben u. Text. Chem.*, 1902, **1**, 1; Fosse, *Ann. Chim. Phys.*, 1909, **18**, 400; Bogert and Rudermann, *J. Amer. Chem. Soc.*, 1922, **44**, 2612; Humphries, *J.*, 1926, 374).

It is convenient here to draw attention to some other cases of alkyl-oxygen fission. The (–)hydrogen phthalate of 2-naphthylmethylcarbinol reacts with formic acid with racemisation (Collyer and Kenyon, *J.*, 1940, 676). The (–)hydrogen phthalate of 1-furylmethylcarbinol reacts with acetic acid with racemisation and yields a racemic alcohol when hydrolysed with sodium carbonate, whereas optical purity is retained on hydrolysis with 10*N*-sodium hydroxide (Duveen and Kenyon, *J.*, 1936, 621).

Norris and Rigby (*J. Amer. Chem. Soc.*, 1932, **54**, 2088) have shown that the interaction of *tert*-butyl alcohol and acetyl chloride yields *tert*-butyl acetate in the presence of dimethylaniline, and the chloride in the absence of base (see the discussion of analogous reactions of *p*-methoxybenzhydrol with acetyl chloride in Part II).

Cohen and Schneider (*J. Amer. Chem. Soc.*, 1941, **63**, 3382) describe the formation of methyl *tert*-butyl ether by the reaction of *tert*-butyl benzoate or 2 : 4 : 6-trimethylbenzoate with methyl alcohol. Burwell (*J. Amer. Chem. Soc.*, 1942, **64**, 1025) describes the acid-catalysed racemisation of (+)-2-butanol; this may be analogous to the acid catalysed racemisation of esters of this alcohol and of (+)-2-octanol which we have under investigation (*Nature*, 1941, **148**, 196). With regard to the footnote to Part II (*loc. cit.*) it should be observed that the reaction of 3 : 3 : 3-trichloro-1-nitro-2-acetoxypropane with ammonia may involve intermediate formation of a nitro-olefin (Irving, *J.*, 1936, 797); both this mechanism and the bimolecular replacement mechanism would involve alkyl-oxygen fission.

EXPERIMENTAL.

dl-1-Naphthylmethylcarbinol (Grignard's method, yield 62%, m. p. 67°) was converted into its hydrogen phthalate (m. p. 132°) and this into the brucine salt (m. p. 155°) by the usual method. The less soluble fraction of the salt, recrystallised four times from acetone and decomposed (acetone + hydrochloric acid), yielded the (+)hydrogen phthalate (see Table), and this on hydrolysis and steam distillation gave the (–)carbinol (see Table), m. p. 48°. A crystalline alkaloidal salt of the (–)hydrogen phthalate could not be prepared; the hydrogen phthalate from the mother liquor from the above recrystallisations was purified *via* the ammonium salt and dissolved in carbon disulphide. Repeated inoculation with *dl*-hydrogen phthalate, followed by filtration, removed the *dl*-ester; the (–)ester was obtained as a gum from the residual solution, and converted into the (+)carbinol, m. p. 46° after recrystallisation from ether-light petroleum. The rotatory powers given in the Table are slightly higher than those recorded by Pickard and Kenyon (*J.*, 1914, **105**, 1130).

Rotatory Powers of (+) and (–)1-Naphthylmethylcarbinol and the (+)Hydrogen Phthalate in Ethyl Alcohol (l, 2) at 20°.

	<i>c.</i>	$[\alpha]_{5893}$.	$[\alpha]_{5780}$.	$[\alpha]_{5461}$.	$[\alpha]_{4358}$.
(+)Carbinol	4.81	+76.4°	+80.7°	+91.9°	+167°
(–)Carbinol	4.94	–78.9	–80.8	–97.8	–150
(+)Hydrogen phthalate.....	5.10	+73.0	—	+81.7	—

Esters of 1-Naphthylmethylcarbinol.—*Acetates* (from the carbinol, using pyridine and acetic anhydride). The *dl*-acetate had b. p. 132°/2 mm., 160°/10 mm.; n_D^{20} 1.5805 (Found : C, 78.4; H, 7.0. $C_{14}H_{14}O_2$ requires C, 78.5; H, 6.6%). The (–)acetate, from the (–)carbinol, had b. p. 173°/15 mm.; α_{6438}^{22} –8.20°; α_{5893}^{22} –11.17°; α_{5780}^{22} –11.71°; α_{5461}^{22} –13.27°; α_{4358}^{22} –23.0 (*l*, 0.25).

Benzoates (benzoyl chloride-pyridine). The *dl*-ester, recrystallised from ether-light petroleum, had m. p. 69–70° (Found : C, 82.6; H, 5.8. $C_{19}H_{16}O_2$ requires C, 82.7; H, 5.8%). The (–)ester [from the (+)carbinol] did not crystallise; b. p. 192°/3.5 mm.; $[\alpha]_{5893}^{20}$ –72.4°; $[\alpha]_{5461}^{20}$ –88.9°; $[\alpha]_{4358}^{20}$ –176.0° (*l*, 2; *c*, 5.0 in ethyl alcohol); α_{5893}^{10} –26.86° (homog., *l*, 0.25).

Esters of Phenylmethylcarbinol.—(+) and (–)Phenylmethylcarbinols were prepared as described by Downer and Kenyon (*J.*, 1939, 1156); the formate is described by Arcus, Balfe, and Kenyon (*J.*, 1938, 485). The (+)acetate had b. p. 106°/10 mm.; n_D^{18} 1.4983 (Kenyon, Phillips, and Taylor, *J.*, 1933, 173, give b. p. 109°/18 mm.; n_D^{20} 1.5045; α_{5893}^{19} +30.75°; α_{5780}^{19} +32.40°; α_{5461}^{19} +37.48°; α_{4358}^{19} +67.8° (*l*, 0.25).

The *dl*-benzoate had b. p. 123.6°/2 mm., n_D^{21} 1.5588 (Found : C, 80.2; H, 6.2. $C_{15}H_{14}O_2$ requires C, 79.8; H, 6.2%). The (+)benzoate [from the (+)carbinol] had b. p. 137–141°/6 mm.; n_D^{21} 1.5593; α_{5893}^{20} –4.40°; α_{5780}^{20} –4.89°; α_{5461}^{20} –5.89°; α_{4358}^{20} –13.34° (*l*, 0.25).

The *dl*-monochloroacetate (acid chloride and pyridine in light petroleum) had b. p. 135–140°/16 mm.; n_D^{21} 1.5177 (Found : Cl, 17.3. $C_{10}H_{11}O_2Cl$ requires Cl, 17.9%). The (+)chloroacetate [from (+)carbinol] had b. p. 135–138°/16 mm.; n_D^{21} 1.5141; α_{6438}^{21} +27.21°; α_{5893}^{21} 32.37°; α_{5780}^{21} +34.07°; α_{5461}^{21} +37.08°; α_{4358}^{21} +70.81° (*l*, 0.25).

Reactions of 1-Naphthylmethylcarbinyl Esters.—*Hydrogen phthalate.* (i) With glacial acetic acid. (a) A solution of the (+)ester (2.82 g.) in 25 c.c. of acid, warmed on the steam-bath, had the following rotatory powers: α_{5893} (*l*, 2) initial, +6.86°; after 10 hours, +4.24°; 23 hours, +1.62°; 32 hours, zero. The mixture then yielded phthalic acid (0.5 g.) and *dl*-acetate (1.3 g.), b. p. 174–175°/15 mm. (Found : C, 78.7; H, 6.4%).

(b) A solution of the (+)ester (4.86 g.) in 50 c.c. of acid had α_{5893} (*l*, 2), initial +5.78°; after 9 hours on steam-bath, +2.69°. The mixture then yielded a hydrogen phthalate with $[\alpha]_{5893}$ +52.2°; $[\alpha]_{5461}$ +64.5° in ethyl alcohol (*l*, 2).

(ii) With aqueous acetic acid. (a) A solution of the (+)phthalate (6.2 g.) in acetic acid (60 c.c.) and water (15 c.c.) after being warmed for 1 hour yielded *dl*-acetate, b. p. 174°/15 mm.; n_D^{20} 1.580 (1.00 g. required for hydrolysis 0.047 g. of KOH. Calc. for $C_{14}H_{14}O_2$: 0.0465 g. of KOH).

(b) A solution of (+)phthalate (5 g.) in acetic acid (50 c.c.) and water (13 c.c.) had $\alpha_{5893}^{20^\circ} + 8.0^\circ$ (*l*, 2). After 1½ hours on the steam-bath it had $\alpha_{5893}^{20^\circ} + 2.1^\circ$ (*l*, 2) and then yielded a hydrogen phthalate with $[\alpha]_{5893}^{20^\circ} + 54.3^\circ$ in ethyl alcohol (*c*, 6.4).
 (iii) With formic acid. From the (+)phthalate (2.5 g.), in formic acid (20 c.c.), after 1 hour at 45°, *dl*-formate (1 g.) was obtained, b. p. 166°/18 mm.; $n_D^{18^\circ} 1.5940$ (Found: C, 77.3; H, 6.1. $C_{15}H_{12}O_2$ requires C, 77.8; H, 6.0%). At 37° no reaction occurred, and at 100° there was much decomposition.

(iv) With methyl alcohol. No reaction occurred with anhydrous methyl alcohol. The *dl*-phthalate, after being heated under reflux for 3 days with methyl alcohol (50 c.c.) and water (15 c.c.), gave *dl*-1-(1'-*naphthyl*)ethyl methyl ether, b. p. 140–143°/9 mm.; $n_D^{17^\circ} 1.5928$ (Found: C, 83.9; H, 7.4. $C_{15}H_{14}O$ requires C, 83.9; H, 7.5%). The (+)phthalate (1 g.) in methyl alcohol (20 c.c.) and water (4 c.c.) gave the following values of $\alpha_{5893}^{20^\circ}$ (*l*, 2): initial, +5.9°; refluxed for 40 hours, +1.5°; refluxed for 64 hours, +0.1°; after 64 hours the solution yielded the *dl*-ether, b. p. 132°/7 mm.; $n_D^{19^\circ} 1.5862$.

(v) With ethyl alcohol. No reaction occurred with the anhydrous alcohol. The *dl*-phthalate (5 g.) refluxed for 3 days in ethyl alcohol (50 c.c.) and water (16 c.c.) gave *dl*-1-(1'-*naphthyl*)ethyl ethyl ether, b. p. 144°/7 mm.; $n_D^{19^\circ} 1.5870$ (Found: C, 84.2; H, 8.0. $C_{14}H_{16}O$ requires C, 84.0; H, 8.0%). A solution of the (+)phthalate (3.9 g.) in ethyl alcohol (40 c.c.) and water (10 c.c.) gave the following values of $\alpha_{5893}^{20^\circ}$ (*l*, 2) (duration of refluxing in brackets): (0 hour) +10.6°; (60 hours) +1.3°; (72 hours) +1.2°. After 72 hours the solution yielded an ethyl ether (1.9 g.), b. p. 149°/7 mm., $n_D^{20^\circ} 1.5839$, $[\alpha]_{5893}^{20^\circ} + 2.20^\circ$ in ethyl alcohol (*l*, 2.36; *c*, 5.00), and a hydrogen phthalate (1.4 g.), $[\alpha]_{5893}^{20^\circ} + 8.9^\circ$ in ethyl alcohol.

(vi) Hydrolysis of the hydrogen phthalate. The phthalate (8 g., 1 mol., $[\alpha]_{5893}^{20^\circ} + 18.66^\circ$ in ethyl alcohol, *l*, 2; *c*, 2.04), dissolved in a little ethyl alcohol, was heated with 6 c.c. of 10*N*-sodium hydroxide (2.5 mols.) first on the steam-bath, then in a current of steam. From an ethereal extract of the residual liquid, 3.1 g. of crude alcohol were obtained, m. p. 50–57°; $[\alpha]_{5893}^{20^\circ} - 21.35^\circ$ in ethyl alcohol (*l*, 2; *c*, 2.58). This alcohol was converted into its hydrogen phthalate which was purified by precipitation from ammoniacal solution; yield 3.5 g., $[\alpha]_{5893}^{20^\circ} + 18.3^\circ$ (*l*, 2; *c*, 2.68) in ethyl alcohol.

In a similar experiment with 8 g. of the same phthalate, using 6.7 g. (2.5 mols.) of sodium carbonate instead of sodium hydroxide for the hydrolysis, 1.2 g. of crude alcohol were obtained. The hydrogen phthalate, purified by precipitation from solution in sodium carbonate, had $[\alpha]_{5893}^{20^\circ} + 7.53^\circ$ (*l*, 2; *c*, 2.1) in ethyl alcohol.

Benzoate. (i) With glacial acetic acid. The (–)benzoate (5 g.) did not react at room temperature with acetic acid (50 c.c.); at 80°, the solution racemised in 3 days and then yielded *dl*-acetate, b. p. 173°/15 mm.; $n_D^{20^\circ} 1.580$. The initial solution had $\alpha_{5893}^{20^\circ} - 14.8^\circ$ (*l*, 2); when this had fallen to -6.7° (37 hours) the benzoate was recovered from a portion; it had m. p. 117°, $[\alpha]_{5893}^{20^\circ} - 28.9^\circ$ in ethyl alcohol (*l*, 2; *c*, 3.6).

(ii) With formic acid. From a solution of (–)benzoate (1 g.) in formic acid (20 c.c.) after 4 hours at room temperature, *dl*-formate (0.6 g.) was obtained, b. p. 168°/18 mm.; $n_D^{21^\circ} 1.5911$.

Acetate. With formic acid. (i) (–)Acetate (0.505 g.), made up to 10 c.c. with formic acid, gave the following mutarotation data of $\alpha_{5893}^{15^\circ}$ (*l*, 1): initial, -1.21° ; 3 mins. after solution, -0.86° ; 4.5 mins., -0.67° ; 6.0 mins., -0.65° ; 7.6 mins., -0.52° ; 8.9 mins., 0.46° ; 10.2 mins., -0.40° ; 11.8 mins., -0.34° ; 13.25 mins., -0.28° ; 16.25 mins., -0.20° ; 19.25 mins., -0.11° .

(ii) (–)Acetate (0.542 g.), made up to 10 c.c. with formic acid, gave the following $\alpha_{5893}^{21^\circ}$ (*l*, 1): initial, -1.1° ; 0.15 min., -1.0° ; 7.5 mins., -0.03° . The two solutions, when mixed, yielded *dl*-formate, b. p. 161°/10 mm.; $n_D^{19^\circ} 1.5932$ (1.000 g. required for saponification 47.9 mg. of KOH).

Reactions of Phenylmethylcarbonyl Esters.—Hydrogen phthalate. (i) With acetic acid. No reaction occurred with glacial acetic acid at 100°. 5.2 G. of (+)phthalate in 40 c.c. of acetic acid and 15 c.c. of water, kept at 100°, had $\alpha_{5893}^{20^\circ}$ (*l*, 2): initial, +1.54°; 40 mins., +0.98°; 90 mins., +0.53°. The solution then yielded *dextro*-acetate* (1.2 g.), b. p. 104°/11 mm., $\alpha_{5893}^{18^\circ} + 0.97^\circ$ (*l*, 0.25), and *laevo*-phthalate, 1.7 g., $[\alpha]_{5893}^{20^\circ} - 27.5^\circ$ in ethyl alcohol.

(ii) With formic acid. (+)Phthalate (1 g.) in formic acid (10 c.c.) after 1 hour at 37° yielded *dl*-formate, b. p. 89–90°/15 mm.; $n_D^{20^\circ} 1.5055$.

(iii) With chloroacetic acid. 4 G. in chloroform (10 c.c.) after 7 hours on the steam-bath yielded *dextro*-chloroacetate (5 g.), b. p. 138°/17 mm.; $n_D^{21^\circ} 1.5129$; $\alpha_{5861}^{20^\circ} + 0.28^\circ$ (*l*, 0.25).

(iv) Hydrolysis of the hydrogen phthalate. The phthalate (7 g., $[\alpha]_{5893}^{20^\circ} - 12.73^\circ$, *l*, 2; *c*, 2.28 in ethyl alcohol), dissolved in a little ethyl alcohol, was heated with 6 c.c. of 10*N*-sodium hydroxide (2.5 mols.) first on the steam-bath, then in a current of steam. From the distillate, by extraction with ether, the alcohol was obtained, $\alpha_{5893}^{18^\circ} + 4.28^\circ$ (*l*, 0.25). The hydrogen phthalate from this alcohol was purified by precipitation from ammonia solution. Yield 4.0 g., $[\alpha]_{5893}^{20^\circ} - 11.73^\circ$ in ethyl alcohol (*l*, 2; *c*, 2.5).

In a similar experiment, 7 g. of the same phthalate were hydrolysed with 12 g. (2.5 mols.) of sodium carbonate. The purified phthalate (3 g.), into which the liberated alcohol was reconverted, had $[\alpha]_{5893}^{20^\circ} - 10.51^\circ$ (*l*, 2; *c*, 3.1) in ethyl alcohol.

(v) Methyl and ethyl alcohols, dry or in presence of water, did not react with the phthalate when heated under reflux for 72 hours.

Acetate with formic acid. *dextro*-Acetate (0.5 g.) in formic acid (10 c.c.) gave the following values of $\alpha_{5893}^{21^\circ}$ (*l*, 2): initial, +5.35°; 3.75 mins., +4.35°; 9 mins., +3.68°; 13.5 mins., +3.12°; 20.5 mins., +2.36°; 28 mins., +1.85°; 32.2 mins., +1.46°; 43.2 mins., +1.11°; 55 mins., +0.69°; 70.5 mins., +0.24°. A solution of the same concentration gave $\alpha_{5893}^{19^\circ}$ (*l*, 2): initial, +13.15°; 15 mins., +9.2°; 24 mins., +9.0°; 35 mins., +8.0°; 53 mins., +6.6°; 66 mins., +5.7°; 80 mins., +4.9°; 98 mins., +4.12°; 116 mins., +3.55°; 140 mins., +2.75°; 159 mins., +2.08°; 192 mins., +1.22°; 252 mins., +0.15°. The two solutions were finally mixed and yielded *dl*-formate (0.6 g.), b. p. 91°/15 mm.; $n_D^{20^\circ} 1.506$.

Benzoate with acetic acid. No reaction occurred with dry acetic acid. (–)Benzoate (1 g.) in acetic acid (20 c.c.) and water (4 c.c.), after 15 hours on the steam-bath, yielded *dl*-acetate, b. p. 98°/10 mm.; $n_D^{20^\circ} 1.5047$.

Monochloroacetate with formic acid. A solution of the (+)chloroacetate (1 g.) in anhydrous formic acid (20 c.c.) became optically inactive after 7 days at room temperature, and then yielded the *dl*-formate (0.6 g.), b. p. 90°/15 mm.; $n_D^{20^\circ} 1.5045$.

Formate. (i) With acetic acid. No reaction occurred with glacial acetic acid. The rotatory power of a solution of (–)formate (0.6 g.) in acetic acid (12 c.c.) and water (2 c.c.) fell from $\alpha_{5893}^{20^\circ} - 2.08^\circ$ (*l*, 1) to -1.02° after 4 weeks at room temperature.

(ii) With formic acid. A solution of the (–)formate (0.9 g.) in formic acid (16 c.c.) became inactive after 25 hours at room temperature and then yielded the *dl*-formate, b. p. 90°/15 mm.; $n_D^{20^\circ} 1.505$.

Preparation of Carbinols (I)–(IX).—All Grignard complexes were decomposed with ice and ammonium chloride. *Anisylethylcarbinol (I).* Grignard reaction with anisaldehyde (Hell and Hoffmann, *Ber.*, 1904, **37**, 4190; 1905, **38**, 1678). 80% Yield, b. p. 143°/17 mm.

o-Chlorobenzhydrol (II). Grignard reaction with *o*-chlorobenzaldehyde (Tschitchibabin and Schlesler, *J. Russ. Phys. Chem. Soc.*, 1925, **56**, 149). 70% Yield, m. p. 65–66°.

* In this and the following papers the prefixes *dextro* and *laevo* denote optically impure substances.

p-Dimethylaminobenzhydrol (III). From the ketone (Hurd and Webb, *Org. Synth.*, Coll. Vol. I, p. 213) reduced in alcohol by sodium amalgam (Albrecht, *Ber.*, 1888, **21**, 3293) or preferably by zinc powder and sodium hydroxide (1 g. each per g. of ketone) in alcohol (20 c.c. per g. of carbinol). 90% Yield, m. p. 69—70°.

p-Methoxy-*p*'-methylbenzhydrol (IV). Grignard reaction with anisaldehyde. 80% Yield of the compound, m. p. 61—62° from ethyl ether—light petroleum (Found: C, 78.8, H, 7.0. $C_{15}H_{16}O_2$ requires C, 78.9; H, 7.0%).

p-Methoxy-*p*'-isopropylbenzhydrol (V). Grignard reagent (from *p*-bromocumene, Jacobsen, *Ber.*, 1879, **12**, 430) reacted with anisaldehyde. 55% Yield, m. p. 63—64° from ether—light petroleum.

o-Methoxyphenyl-1-naphthylcarbinol (VI). Grignard reaction with *o*-methoxybenzaldehyde. After preparation of the naphthylmagnesium bromide, it is desirable to add 500 c.c. of benzene per g.-mol. to prevent the reagent separating as a hard, slowly reactive mass. 60% Yield of the compound, m. p. 102—103° from ether—light petroleum (Found: C, 82.1; H, 5.9. $C_{18}H_{16}O_2$ requires C, 81.8; H, 6.1%).

Phenyl-3:4-methylenedioxyphenylcarbinol (VII). Grignard reagent with piperonal. Yield 70%, b. p. 235—236°/23 mm. 3:4-Methylenedioxyphenylmethylcarbinol (VIII). Grignard reagent with piperonal. 80% Yield of the compound, b. p. 146—148°/17 mm., n_D^{25} 1.5594 (Found: C, 65.1; H, 5.9. $C_9H_{10}O_3$ requires C, 65.1; H, 6.0%).

m-Methoxybenzhydrol (IX). Grignard reagent with *m*-methoxybenzaldehyde. B. p. 195—197°/8 mm. *Hydrogen phthalates*. From the carbinol (1 mol.), phthalic anhydride (1 mol.), and pyridine (1.1 mols.). For (I), (II), (VII), (VIII), (IX), and anisyl alcohol, the reagents were kept at 60° for 1—5 hours; and hydrogen phthalate then precipitated, by addition of acetone and slight excess of hydrochloric acid, as an oil which slowly solidified in ice-water. For (IV), (V), and (VI), benzene (1 c.c. per g. of carbinol) was added to the reagents, and reaction conducted at 20° for 3 days. On dilution with acetone and extraction of the pyridine with dilute hydrochloric acid, the hydrogen phthalate crystallised from the benzene (this method is advantageous). *M* determined by rapid titration (cold) with 0.1*N*-sodium hydroxide.

Hydrogen Phthalates.

Carbinol.	Crystallised from :	M. p.	Formula.	<i>M</i> (found).	<i>M</i> (calc.).
(I)	Ether—ligroin	72—74°	$C_{18}H_{16}O_5$	319	314
(II)	Ligroin	177—178	$C_{21}H_{15}O_4Cl$	362	366
(IV)	Benzene—ligroin	128	$C_{23}H_{20}O_5$	377	376
(V)	"	110	$C_{25}H_{24}O_5$	398	404
(VI)	Benzene	174—175	$C_{26}H_{20}O_5$	413	412
(VII)	Ether—ligroin	121	$C_{22}H_{16}O_6$	378	376
(VIII)	"	94	$C_{17}H_{14}O_6$	314	314
(IX)	"	120—122	$C_{22}H_{15}O_5$	365	362
Anisyl alcohol	Methylene chloride—ligroin	68			

Hydrogen Succinates. These were prepared in the same way as the corresponding hydrogen phthalates.

(I)	Ether—ligroin	36—37°	$C_{14}H_{16}O_5$	266	267
(II)	Ligroin	109—110	$C_{17}H_{15}O_4Cl$	318	318
(IV)	Ether—ligroin	59—60	$C_{19}H_{20}O_5$	306	308
(VI)	Benzene—ligroin	126	$C_{22}H_{20}O_5$	366	364

Optically Active Hydrogen Phthalates and Succinates.—Prepared by the usual method (see, *e.g.*, Part II), the solvent being acetone, except for (II), for which equal parts of acetone and methyl alcohol were used.

Phthalates of (I) from cinchonidine salt. The less soluble, twice recrystallised, had m. p. 162—163° and gave a *dextro*-hydrogen phthalate, m. p. 76—78°; $[\alpha]_D^{18}$ +7.8° in benzene (*l*, 2; *c*, 4.8). From the first mother liquor, a *laevo*-phthalate was obtained, m. p. 73—76°; $[\alpha]_D^{20}$ -10.5° in benzene (*l*, 2; *c*, 6.5).

Hydrogen succinates, similarly showed $[\alpha]_D^{20}$ -32.5° and +22.5° respectively in ethyl alcohol (*l*, 2; *c*, 2.0).

Hydrogen phthalates of (II) from brucine salt. The less soluble, 4 times recrystallised, had m. p. 217° and gave a phthalate with $[\alpha]_D^{20}$ +11.2° in ethyl alcohol. When this phthalate was recrystallised from carbon disulphide, the more *dextro*-salt remained in solution and had m. p. 66—68°; $[\alpha]_D^{20}$ in ethyl alcohol (*l*, 2; *c*, 1.0); λ_{6438} +13.0°; λ_{5893} +14.4°; λ_{5461} +16.6°; λ_{4358} +25.9°; and $[\alpha]_D^{20}$ in benzene (*l*, 2; *c*, 1.6); λ_{5893} +13.5°; λ_{5780} +15.2°; λ_{5461} +15.4°; λ_{4358} +20.9°. The mother liquor from the first brucine salt gave a hydrogen phthalate, which was dissolved in methylene chloride; the less *laevo*-salt crystallised out, and the more soluble fraction was hydrogen phthalate, m. p. 69—71°, with $[\alpha]_D^{20}$ -15.6° in ethyl alcohol (*l*, 2; *c*, 2.6).

The phthalate of (IV) from the quinidine salt, several times recrystallised, had $[\alpha]_D^{20}$ (*l*, 2; *c*, 1.5): in acetone, -11.7°; in ethyl alcohol, -9.7°; in nitromethane, -3.6°; in chloroform, -11.0°. In all these solvents racemisation occurred, the approximate half-life periods (hours) being: in acetone, 25; in ethyl alcohol, 18; in chloroform, 3; in nitromethane, 1½.

The quinidine salt of (VII), three times recrystallised, gave phthalate, m. p. 114°. The first mother liquor gave a *dextro*-phthalate, m. p. 115—116° (after recrystallisation from ether—ligroin), $[\alpha]_D^{20}$ +20.0° (*l*, 2; *c*, 1.5) in benzene.

Optically active forms of (II). From the hydrogen phthalates (5 g. in ethyl alcohol (25 c.c.) with sodium hydroxide (1.5 g.; 2.5 mols.) heated under reflux for 1 hour. On dilution with water, the carbinol was precipitated (2.4 g.) and was then recrystallised from ligroin.

The *dextro*-hydrogen phthalate gives *laevo*-carbinol, m. p. 65° with $[\alpha]_D^{19}$ (*l*, 2) in ethyl alcohol (*c*, 2.1): λ_{5893} -4.5°; λ_{5780} -7.5°; λ_{5461} -7.7°; λ_{4358} -18.0°. In carbon disulphide (*c*, 2.5): λ_{5893} -3.2°; λ_{5780} -6.5°; λ_{5461} -6.6°; λ_{4358} -17.1°. In benzene (*c*, 3.2): λ_{5893} -6.6°; λ_{5780} -8.0°; λ_{5461} -8.0°; λ_{4358} -14.5°. In ether (*c*, 1.9): λ_{5893} -7.1°; λ_{5780} -11.7°; λ_{5461} -11.7°. λ_{4358} -30.4°. The *dextro*-carbinol had $[\alpha]_D^{20}$ +4.7° (*l*, 2; *c*, 2.3) in ethyl alcohol.

Experiments on hydrolysis of laevo-phthalates of (I) and (II). (i) Hydrolysis of *laevo*-phthalate of (I) (all $[\alpha]_D^{20}$ in benzene, *l*, 2), using in each experiment 6.3 g. of hydrogen phthalate of $[\alpha]_D^{20}$ -10.5°, with 2.5 mols. of alkali, 20 minutes at 70°, followed by dilution with water and conversion of the precipitated carbinol into hydrogen phthalate, which (to avoid separation of stereoisomerides) was taken without recrystallisation for $[\alpha]$ observation.

(a) With sodium hydroxide (from 1.1 g. of sodium) in 96% ethyl alcohol (30 c.c.). The re-formed phthalate had $[\alpha]_D^{20}$ -9.7° (*c*, 2.3).

(b) With 10 c.c. of 5*N*-sodium hydroxide. The re-formed phthalate had $[\alpha]_D^{20}$ -7.7°.

(c) With 5 g. of sodium carbonate in 30 c.c. of water. The re-formed phthalate had $[\alpha]_D^{20}$ -2.3° (*c*, 2.2).

(ii) Hydrolysis of *laevo*-phthalate of (II) (all $[\alpha]_D^{20}$ in ethyl alcohol, *l*, 2). In each experiment, 7 g. of hydrogen phthalate ($[\alpha]_D^{20}$ -6.34°), with 2.5 mols. of alkali, 30 minutes at 70°, procedure as above.

(a) With sodium hydroxide (from 1.1 g. of sodium) in 96% ethyl alcohol (20 c.c.). The carbinol obtained had $[\alpha] +1.9^\circ$ (c, 1.9), and its phthalate had $[\alpha] -6.1^\circ$ (c, 1.8).

(b) With 11 c.c. of 5N-sodium hydroxide, gave carbinol, $[\alpha] +1.7^\circ$ (c, 1.8), and phthalate, $[\alpha] -5.4^\circ$ (c, 2.4).

(c) With 6 g. of sodium carbonate in 50 c.c. of water, gave carbinol, $[\alpha] +1.0^\circ$ (c, 1.9) and phthalate, $[\alpha] -1.9^\circ$ (c, 2.2). Chlorides of (II), (III), and (VI).—(M by hydrolysis with N-sodium hydroxide).

(II) The carbinol (2.8 g.), thionyl chloride (1.5 g.), and pyridine (2.5 g.) after several hours at 20° , gave the chloride (1.5 g.) which, extracted with ligroin, had b. p. $148-149/9$ mm. (Found: *M*, 237. Calc. for $C_{13}H_{10}Cl_2$: *M*, 237). The chloride from carbinol of $[\alpha]_{589}^{20} -6.6^\circ$ in benzene, on hydrolysis with 0.3N-sodium hydroxide, gave carbinol of $[\alpha]_{589}^{20} -5.2^\circ$ in benzene. The chloride did not react with water.

(III) The carbinol on trituration with concentrated hydrochloric acid (excess removed over lime) gave chloride which separated as an oil from ligroin (Found: *M*, 250. Calc. for $C_{15}H_{15}OCl$: *M*, 247).

(VI) From the carbinol, by the same method as for the chloride of (III). *M*. p. 142° (from ligroin) (Found: *M*, 281. Calc. for $C_{18}H_{16}OCl$: *M*, 283). The chloride (m. p. and mixed m. p. 142°) was also obtained, and isolated as above, on heating the hydrogen phthalate of (VI) for several hours with concentrated hydrochloric acid.

Di-ethers of (I), (IV), (V), and (VI).—That of (I) remained as a residue on distillation thereof, and had b. p. $209/12$ mm., $190/9$ mm., $179/7$ mm. The others were obtained in about 80% yield on heating the carbinols till no more water was evolved [(IV), 10 mins. at 140° ; (V), 25 mins. at 140° ; (VI), 10 mins. at 195°]. Ethers were not obtained on heating (II) at 165° or (III) at 210° .

<i>Di-ethers</i> of:	Crystallised from:	M. p.	Formula.	Found (%)		Required (%)	
				C.	H.	C.	H.
(I)	Liquid (see b. p. above)	—	$C_{20}H_{26}O_3$	76.7	8.3	76.4	8.3
(IV)	Ether-methyl alcohol	103—104	$C_{30}H_{30}O_2$	82.4	6.8	82.1	6.9
(V)	" "	101—102	$C_{34}H_{39}O_3$	82.9	7.7	82.6	7.7
(VI)	Benzene or methylene chloride-ligroin	261—262	$C_{36}H_{30}O_3$	84.9	5.6	84.7	5.9

The methyl ether of (III) separated on cooling a methyl-alcoholic solution of (III) which had been heated under reflux for a few minutes, and was recrystallised from methyl alcohol; m. p. $47-48^\circ$ (Found: *N*, 5.5. $C_{16}H_{18}ON$ requires *N*, 5.5%). Anisyl acetate, from the alcohol and acetic anhydride, has b. p. $139-140/16$ mm., $258-261/758$ mm., $n_D^{15} 1.515$ (Tiffeneau, *Bull. Soc. chim.*, 1911, 9, 827; Vavon, *Ann. Chim.*, 1914, 1, 158).

Neutral Phthalic Esters.—Prepared as in Part II, the hydrogen phthalate being dissolved in a slight excess of aqueous sodium hydroxide (10—20 c.c. of 0.3N per g. of phthalate). The hydrogen phthalate of (II) did not yield a neutral ester, but underwent some hydrolysis; that of (I) gave an impure neutral ester which would not crystallise and was contaminated with a little carbinol, 0.96 g. yielding, on hydrolysis, 0.38 g. of carbinol (Calc.: 0.34 g.) and 0.28 g. of phthalic acid (Calc.: 0.35 g.). That of (V) gave impure neutral ester as an uncrystallisable oil, 3 g. giving 1.9 g. carbinol on hydrolysis (Calc.: 2.2 g.). The hydrogen phthalates of (IV) and (VI) gave crystalline neutral esters, as below:

Neutral phthalate of:	Deposition complete after:	Yield (%)	Crystallised from:	M. p.	Formula.	Found (%)		Required (%)	
						C.	H.	C.	H.
(IV)	30 mins.	80	Ether-ligroin	116—117	$C_{38}H_{34}O_6$	81.8	5.9	82.1	6.1
(VI)	7 days	40	Benzene-ligroin	222—223	$C_{24}H_{34}O_6$	80.2	5.2	80.2	5.2

The hydrogen succinates of (II), (IV), and (VI) underwent extensive hydrolysis under the above conditions. That of (I) deposited an oil (50% yield) which, from the amount of alkali needed for its hydrolysis and recovery of carbinol therefrom, apparently contained 70% of neutral ester and 30% of carbinol.

p-Tolyl Sulphones from Hydrogen Phthalates.—(See Table.) Prepared as in Part II (*loc. cit.*), using equimolecular amounts of phthalate and sodium *p*-toluenesulphinate, in a slight excess of aqueous sodium hydroxide, e.g., 3.8 g. phthalate of (IV), 34 c.c. of 0.3N-sodium hydroxide, added to 2.2 g. of sodium *p*-toluenesulphinate in 50 c.c. of water. In the same way, sulphones were obtained from the hydrogen succinates of (I) (30%) and (VI) (90%). The phthalate and succinate of (II) gave no sulphone, but underwent partial hydrolysis under these conditions. The phthalate (4 g.) of (II) and sodium *p*-toluenesulphinate (3.5 g.) in formic acid (30 c.c.) at 70° for 10 hours, yielded the sulphone, precipitated by addition of water (90% yield). Anisyl hydrogen phthalate (1.1 g.) and sodium *p*-toluenesulphinate (0.8 g.) in formic acid at 20° (for 3 hours) yielded the sulphone (90%), precipitated by addition of water after removal of phthalic acid precipitate.

<i>p</i> -Tolyl sulphone of:	Pptn. from aq. solution ceased after:	Yield (%)	Crystallised from:	M. p.	Formula.	Found: S, %	Required: S, %
(I)	1 day, 20°	100	Aqueous alcohol	124	$C_{17}H_{20}O_3S$	10.4	10.5
(II)	—	—	Alcohol	114	$C_{20}H_{17}O_2ClS$	9.1	9.0
(III)	—	—	Benzene	186	$C_{23}H_{23}O_2NS$	8.5	8.8
(IV)	30 mins., "	95	Alcohol	93—94	$C_{22}H_{22}O_3S$	8.8	8.8
(V)	2 hours, "	90	"	123—124	$C_{24}H_{24}O_3S$	8.0	8.1
(VI)	4 days, "	95	"	188—189	$C_{25}H_{25}O_3S$	7.7	8.0
(VII)	3 days, "	50	Acetic acid	146	$C_{21}H_{18}O_4S$	8.8	8.8
(VIII)	1 day, "	45	Alcohol	150	$C_{16}H_{16}O_4S$	10.2	10.5
Anisyl alcohol	3 hours, 80°	30	"	120—121	$C_{15}H_{16}O_3S$	11.9	11.6

p-Tolyl sulphone from p-methoxybenzhydryl acetate. Preparation of the acetate is given in Part II (*loc. cit.*). The sulphone was identified by mixed m. p. with an authentic specimen (Part II). The acetate (2.1 g.) was heated at 80° in 50 c.c. of 50% aqueous ethyl alcohol, with proportions of sodium hydroxide and *p*-toluenesulphinate as given below, until precipitation ceased (time, see below).

Mols. per mol. of acetate	Sodium hydroxide	1.5	0.07	0.07	0.07	0
	Sodium <i>p</i> -toluenesulphinate	1	4	2	1	2
Time		2 hours	2 hours	40 mins.	10 mins.	1 hour
Yield of sulphone (%)		nil	92	88	84	70

93% hydrolysis

Anisyl p-Tolyl Sulphone from Anisyl Acetate.—The acetate (0.9 g.), sodium *p*-toluenesulphinate (1.1 g.), and 0.3 c.c. of 0.3N-sodium hydroxide in 30 c.c. of 30% aqueous ethyl alcohol, after 6 hours at 70°, on dilution with water yielded the sulphone (0.2 g.; 14%), m. p. and mixed m. p. 119–120°. The acetate (1.5 g.) and sodium *p*-toluenesulphinate (1.8 g.) in 40 c.c. of formic acid, after 8 hours at 130°, on dilution with water yielded the sulphone (2.1 g.; 90%), m. p. 119–120°.

The *p*-tolyl sulphones of (IV) and (VI) were also prepared by reaction of the respective chlorides with sodium *p*-toluenesulphinate in aqueous acetone.

Preparation of p-Tolyl Sulphones from Carbinols.—(i) From *p*-methoxybenzhydrol (2 g.) and sodium *p*-toluenesulphinate (2 g.) in 60 c.c. of 60% aqueous alcohol, during 4 hours at 80°, the hydrol (1.5 g.), m. p. and mixed m. p. 65°, separated. On cooling the now alkaline solution, the sulphone (0.7 g.; 20%) separated, m. p. and mixed m. p. 159°.

(ii) From (III) (0.7 g.) and sodium *p*-toluenesulphinate (0.7 g.), in 30 c.c. of 60% aqueous methyl alcohol, during 5 days at 20°, the sulphone (1 g.) separated, m. p. and mixed m. p. 185–186°.

(iii) From anisyl alcohol (4.5 g.) and sodium *p*-toluenesulphinate (10 g.) in 100 c.c. of 50% aqueous ethyl alcohol, after 5 hours at 80°, the sulphone (0.8 g., 10%) separated on addition of water; recrystallised from ethyl alcohol it had m. p. and mixed m. p. 120–121° (Found: S, 11.9. Calc: S, 11.6%). Also, from anisyl alcohol (2.5 g.) and sodium *p*-toluenesulphinate (3.9 g.) in 100 c.c. of formic acid, after 6 hours at 80°, the sulphone crystallised on addition of water (3.8 g.; quantitative), m. p. and mixed m. p. 120°.

Reaction of (II) with p-toluenesulphinic acid. *p*-Dimethylaminobenzhydrol (1 g.) in 10 c.c. of dilute hydrochloric acid (1.1 mols.) was added to *p*-toluenesulphinic acid (0.9 g.) in water (60 c.c.). After 2 hours at 20° the sulphone had crystallised in quantitative yield (for m. p. and analysis, see Table).

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