Tetrahedron. Vol. 30, pp. 321 to 325. Pergamon Press 1974. Printed in Great Britain

THE FORMATION AND STRUCTURE OF PHENYLCAMPHORIC ACID AND RELATED COMPOUNDS

C. W. BIRD* and Y. C. YEONG
Department of Chemistry, Queen Elizabeth College, London W8 7AH

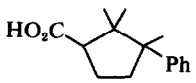
(*Received in the UK* 21 *September* 1973; *Accepted for publication* 8 *October* 1973)

Abstract—The complete structure and stereochemistry of (+)-phenylcamphoric acid has been determined. The acid obtained from the Friedel–Crafts reaction of benzene with isolauronolic acid is identified as (±)-phenylcamphoric acid. α-Campholytic acid is shown to be a likely precursor of phenylcamphoric acid in these reactions. The Friedel–Crafts reaction of 3-cyano-1,2,2-trimethylcyclopentanecarbonyl chloride or 3-cyano-2,2-dimethyl-1-methylenecyclopentane with benzene provides a mixture of phenylcamphornitrile and an isomer. Isofenchocamphoric anhydride similarly provides a mixture of the epimeric 4-phenyl-2,2,4-trimethylcyclopentanecarboxylic acids.

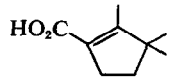
The Friedel–Crafts reaction of (−)-camphoric anhydride with benzene provides a compound m.p. 142° named phenylcamphoric acid to which structure **1** was originally assigned.[1] A similar reaction with isolauronolic acid **2** provided an isomeric acid m.p. 119° assumed to be **3**.[2] The ready formation[3] of isolauronolic acid and lactones of 4-hydroxy-2,4-dimethylcyclohexanecarboxylic acid from camphoric anhydride on treatment with aluminium chloride in chloroform introduces further potential structural ambiguities. Subsequently it was reported[4] that the nitrile **4** provided a phenylcamphornitrile, which gave phenylcamphoric acid on hydrolysis. Despite earlier indications[1] that phenylcamphoric acid was optically active recent publications[5,6] have denied this. The latest paper,[6] which appeared while our own studies were in progress, assigned the gross structure **5** to phenylcamphoric acid and concluded that the acid m.p. 119° was its epimer. This paper records our own findings which correct some of these conclusions and provide additional information on these reactions.

In our hands phenylcamphoric acid as prepared from (−)-camphoric anhydride has a rotation of + 5·5° and all of the derived compounds encountered in the sequel were also optically active. Its 60 MHz NMR spectrum showed *inter alia* the presence of two Me groups attached to quaternary C atoms (δ 0·85 and 1·21) and a Me group attached to a C atom bearing an H atom (δ 0·76, J = 12 Hz), which excludes structure **1** from further consideration. Curtius degradation of phenylcamphoric acid to the primary amine (**6**), exhaustive methylation, quaternisation and Hofmann elimination of the quaternary ammonium hydroxide provided two olefins (**7** and **8**) which were separated by preparative GLC. The structures of these two olefins are established by their 100 MHz NMR spectra whose complete analyses were aided by appropriate decoupling experiments. Thus **8** has singlets at 0·92 and 1·09 δ ascribable to the gem-dimethyl group and a doublet centred at δ 0·93 (J = 6·5 Hz) due to the remaining Me group. The quartet due to the olefinic protons (H_a δ 5·6, H_b δ 5·77, J_{ab} = 5·5 Hz) showed additional splitting due to coupling with H_c (J_{bc} = 2·5 Hz, J_{ac} ~ 1 Hz). Decoupling of H_b revealed H_c δ 3·39 as a quartet (J_{cd} = 9·5 Hz), and decoupling of H_c converted the complex signal due to H_d to a quartet centred at δ 1·69. In olefin **8** the geminal Me groups resonate at δ 1·07 and 1·09 and the remaining one at δ 0·97 (J = 7 Hz). The olefinic proton H_c is observed as an ill-defined triplet at δ 5·96 (J_{ac} = 2·8 Hz) which on irradiation enables the H_aH_b quartet to be clearly discerned with chemical shifts of δ 2·15 for H_a and δ 2·39 for H_b (J_{ab} = 16 Hz). Homoallylic coupling of H_b with H_d is just discernible (J_{bd} ≈ 2 Hz). Proton H_d is observed as a broadened quadruplet at δ 2·67. The complexity of the NMR spectrum in the δ 7·1–7·5 region indicates the conjugated nature of the phenyl group, which is confirmed by the UV spectrum, λ_{max} 255 nm, ε 9, 740. The size of the coupling constant J_{cd} in **7** indicates a *cis* relationship of H_c and H_d. It was subsequently found that decarbonylation of phenylcamphoryl chloride by heating with tris(triphenylphosphine)rhodium chloride provided only the olefin **7**, which was isomerised to **8** by treatment with potassium t-butoxide in dimethylsulphoxide.

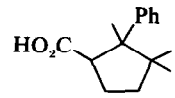
The point of attachment of the carboxyl group of phenylcamphoric acid to the cyclopentane ring was established as follows. The acid was converted to the N,N-dimethylamide, reduced with LAH to the tertiary amine **9**, quaternised and subjected to Hofmann elimination. The resulting olefin **10** showed the anticipated absorptions at δ 0·75(J = 10 Hz), 0·92 and 1·11 for the protons of the three Me groups



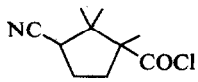
1



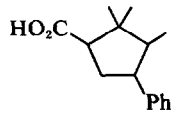
2



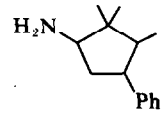
3



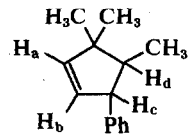
4



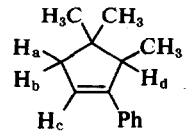
5



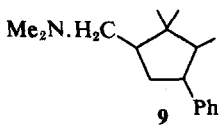
6



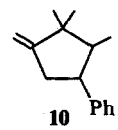
7



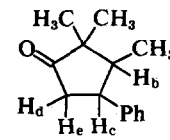
8



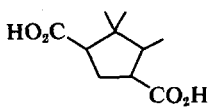
9



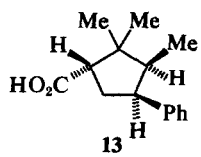
10



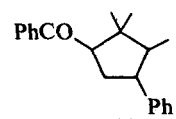
11



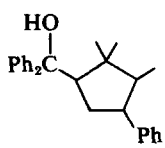
12



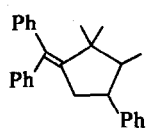
13



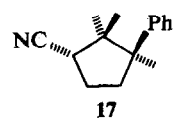
14



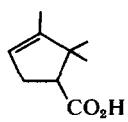
15



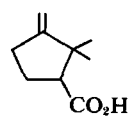
16



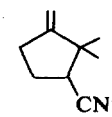
17



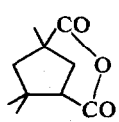
18



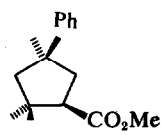
19



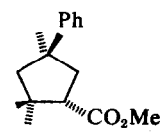
20



21



22



23

and δ 7·2 for those of the phenyl group, in the 60 MHz NMR spectrum. The vinyl protons were observed as a poorly resolved triplet at δ 4·8, the allylic and benzylic protons gave a complex absorption at δ 2·3–3 and the remaining tertiary proton a complex absorption centred at δ 1·7. Ozonolysis of X provided the ketone **11** whose absorptions at δ 7·25, δ 1·1, δ 0·95 and δ 0·87 ($J = 6$ Hz) are readily assigned to the phenyl group and three Me groups. The remainder of the spectrum was analysed by computer fitting the data from both 100 MHz and 220 MHz spectra leading to V_{Hb} δ 1·98, V_{Hc} δ 2·90 ($J = 11{\cdot}2$ Hz), V_{Hd} δ 2·38 (J_{cd} 11·6 Hz) and V_{He} δ 2·77 (J_{ce} 8·0 Hz, J_{de} − 19·0 Hz).

Thus the correct structure of phenylcamphoric acid is **5**. The formation of both olefins **7** and **8** by Hofmann elimination of **6** has precedent[7] in the formation of 1-phenylpropene from 3-phenylpropyltrimethylammonium hydroxide, due to base-catalysed rearrangement of the first formed 3-phenylpropene. The stereochemical disposition of the carboxyl group was established by the ruthenium catalysed hypochlorite oxidation of (±)-phenylcamphoric acid to the dicarboxylic acid **12**. (The reaction was carried out on the (±)-acid, *vide infra*, to permit comparison with the known[8] racemic *cis*-isomers of **12**). The failure of the dicarboxylic acid to form an internal anhydride on treatment with acetyl chloride, under conditions which convert camphoric and isofenchocamphoric acids to their anhydrides, indicates that the carboxyl groups in **12** have a *trans* relationship. Thus the complete relative stereochemistry of phenylcamphoric acid is as depicted in **13**. That this is also the absolute configuration follows from correlation with that established[9] for (+)-camphor.

A careful spectroscopic comparison of the compound derived from isolauronolic acid with (+)-phenylcamphoric acid indicated that they were structurally identical and that the acid, m.p. 119°, is in fact (±)-phenylcamphoric acid. This was confirmed by showing that the same acid was obtained from the Friedel–Crafts reaction of (±)-camphoric anhydride with benzene. In order to establish the origin of the disparity between our own conclusions and those reported[6] the original Barbier–Wieland degradation of both acids was repeated. The series of compounds **14**, **15** and **16** from both acids had the reported physical properties except that those derived from (+)-phenylcamphoric acid had rotations of +63·5°, −123° and −156° respectively. In particular the olefins **14** derived from (+)- and (±)-phenylcamphoric acids had m.ps of 145° and 141°, which were not depressed on admixture. It was this misleading criterion that led to the conclusion[6] that the two acids, m.p. 142° and 119°, were epimers.

Reexamination of the Friedel–Crafts reaction of the acid chloride **4** with benzene showed that two isomeric nitriles were formed, not just one as hitherto supposed.[4] The major component was identical with phenyl-camphornitrile prepared by dehydration of (−)-phenylcamphoramide with thionyl chloride. The 60 MHz NMR spectrum of the other isomer, subsequently referred to as isophenylcamphornitrile, showed the presence of three Me singlets at δ 0·71, 1·21 and 1·4 in addition to a phenyl group at δ 7·45 and a broad absorption at δ 2–3 due to the remaining 5 hydrogens, which suggests that the compound has the gross structure **17**. The nitrile was hydrolysed to the acid, which failed to crystallise even after purification through its S-benzylisothiouronium salt, and the acid in turn converted to the methyl ester. Examination by GLC of the esterified products of the camphoric anhydride–benzene reaction failed to provide any evidence for the formation of methyl isophenylcamphorate in that case. The stability of methyl isophenylcamphorate towards attempted epimerisation with methanolic sodium methoxide suggests a *trans* relationship between the phenyl and carbomethoxy groups, and hence the indicated stereochemistry of **17**.

The most likely precursor of phenylcamphoric acid is α-campholytic acid **18**, which by *trans* electrophilic addition to the double bond would give phenylcamphoric acid with the observed stereochemistry. One face of the intermediary cyclopentyl carbonium ion would be shielded from approach by benzene due to the bulk of the carboxyl group, which will probably be coordinated to the aluminium chloride. The requisite rearrangement of isolauronolic acid **2** to α-campholytic acid **18** necessary for formation of (±)-phenylcamphoric acid has been encountered in the reaction of **2** with hydrogen bromide.[10] Although the converse acid catalysed rearrangement of α-campholytic acid to isolauronolic acid is known[11] it seemed likely that the former acid might react faster than it rearranged. It is noteworthy that the formation of phenylcamphoric acid is very much faster from camphoric anhydride, 72% in 2 h, than from isolauronolic acid, 38% after 10 days. In practice (−)-α-campholytic acid gave a 67% yield of (+)-phenylcamphoric acid under the same conditions as used for camphoric anhydride. The foregoing α-campholytic acid had been prepared by nitrous acid treatment of aminodihydrocampholytic acid.[12] When obtained by electrolysis of sodium ortho-ethyl camphorate[10,13] the resulting 'campholytic acid' had a very different optical rotation, +7°, to that of the foregoing material, −61·5°. This point had been the subject of earlier literature comment but the discrepancy was not resolved. The NMR spectrum of this second preparation revealed that it was approximately a 2:1 mixture of α-campholytic acid **18** and infra-campholenic acid **19**, although we were unable to resolve the ethyl esters by GLC. The most characteristic spectroscopic features were the broad absorption at δ 5·2 characteristic of the olefinic proton of **18** and a poorly resolved

doublet at δ 4·8 ($J \approx 2$ Hz) attributable to **19**. This mixture of acids also gave an excellent yield, 82%, of (+)-phenylcamphoric acid showing that **19** must undergo double bond migration to **18** under the reaction conditions. Not surprisingly infracampholenonitrile **20** gave a similar mixture of phenylcamphornitrile and isophenylcamphornitrile to that obtained from **4**.

In view of the unexpected course of the Friedel–Crafts reaction between camphoric anhydride and benzene, the behaviour of the isomeric isofenchocamphoric anhydride **21** was examined. A mixture of two acids was obtained. Small samples of the derived methyl esters were obtained by preparative GLC. The 220 MHz NMR spectra indicate that they are the epimeric esters **22** and **23** which are formed in the ratio 2:3. Thus compound **22** has singlets due to Me groups at δ 0·98, δ 1·01 and δ 1·38 and doublets assignable to the isolated methylene group centred at δ 1·74 and δ 2·24 (J = 3 Hz). The Me singlets for the other compound **23** are observed at δ 0·84, δ 1·29 and δ 1·31 with the methylene doublets at δ 1·9 and δ 2·07 (J = 3 Hz). The assigned stereochemistries are indicated by the epimerisation of **22** to the less sterically hindered **23** on treatment with sodium methoxide in methanol.

EXPERIMENTAL

NMR spectra at 220 and 100 MHz together with the computer simulation were recorded by the P.C.M.U., Harwell and those at 60 MHz on a Perkin–Elmer R12B spectrometer for $CDCl_3$ solns with internal TMS. Analytical GLC was performed on a Pye 104 instrument using a 5 foot column packed with celite coated with 5% of SE30. The GLC/MS measurements were carried out on an MS30 by the U. of L. Mass Spectrometry Service. Optical rotations were measured for $CHCl_3$ solns (c 1·0) on a 141 Perkin–Elmer Polarimeter.

(+)-Phenylcamphoric acid and derivatives. (+)-Phenylcamphoric acid prepared from (−)-camphoric anhydride by the method of Rothstein and Saville[14] had m.p. 139° $[\alpha]_D^{25}$ + 5·5° (lit[14] m.p. 139°). The methyl ester had m.p. 94° $[\alpha]_D^{25}$ + 10·6° (lit[1] m.p. 93–94°). The *amide* was prepared from the acid chloride[5] and ammonia, m.p. 134° from aqueousmethanol $[\alpha]_D^{25}$ − 24·6° (Found: C, 78·1; H, 8·9; N, 6·2. $C_{15}H_{21}NO$ requires: C, 78·0; H, 9·0; N, 6·0%). Similarly was prepared the N,N-*dimethylamide*, m.p. 136° from MeOH $[\alpha]_D^{25}$ + 16·7° (Found: C, 78·9; H, 9·4; N, 5·5. $C_{17}H_{25}NO$ required: C, 78·7; H, 9·6; N, 5·4%).

(±)-Phenylcamphoric acid. This compound was prepared from (±)-camphoric anhydride following the method used for the (+)-acid and had m.p. 117°. It was identical with a sample prepared[5] from isolauronolic acid. (Lit[5] m.p. 117–119°). The methyl ester had b.p.$_{0.1}$ 101°, m.p. 74° (Lit[6] m.p. 74°).

(−)-2,2,3-Trimethyl-4-phenylcyclopentylamine **6**. (−)-Phenylcamphoryl chloride (20 g) was boiled with sodium azide (30 g) in xylene (40 ml) with stirring for 3 hr. The cooled mixture was filtered, and the combined benzene washings and filtrate evaporated *in vacuo*. The crude isocyanate was added dropwise to conc HCl (100 ml) and the mixture heated under reflux for 2 h. After the soln had been cooled and made alkaline with NaOH the amine was extracted with ether. Distillation gave the *amine* (8·7 g, 54%) b.p.$_{0.6}$ 120°, n_D^{23} 1·5275, $[\alpha]_D^{25}$ − 13·7° (Found: C, 82·7; H, 10·5; N, 6·7. $C_{14}H_{21}N$ requires: C, 82·8; H, 10·3; N, 6·9%).

(+)-N,N,2,2,3-Pentamethyl-4-phenylcyclopentylamine. The amine **7** (8 g) was added slowly to a mixture of 99% formic acid (10 ml) and 40% aqueous formaldehyde (15 ml) cooled in ice. The mixture was heated on a steam-bath for 7 h, cooled, acidified to pH 2 and extracted several times with ether. The aqueous layer was then made alkaline with NaOH and the dimethylamine extracted with ether. The dimethylamino compound (7·6 g, 84%) had b.p.$_{0.3}$ 116° n_D^{21} 1·5203, $[\alpha]_D^{25}$ + 5·9° (Found: C, 83·4; H, 10·6; N, 5·9. $C_{16}H_{25}N$ requires: C, 83·3; H, 10·7; N, 6·0%).

1,1,2-Trimethyl-3-phenylcyclopent-3 and 4-enes. The dimethylamine (6·5 g) was added to a soln of MeI (18 g) in dry ether (20 ml). After 24 h the methiodide had crystallised in almost quantitative yield, with m.p. 205°. This salt (9 g) was stirred with freshly prepared Ag_2O (12 g) in 50% aqueous MeOH (50 ml) overnight. The filtrate was then evaporated at 40° *in vacuo* to a syrup, which was decomposed at 40 mm and a bath temp of 140°. The two olefins were collected by ether extraction and distilled b.p.$_{1.6}$ 120–122°. Samples of the two olefins **7** and **8** were isolated by preparative GLC using an Autoprep 705 instrument fitted with a 20 ft column packed with 80–100 mesh Celite which was coated with 10% SE30. The olefins were identical with samples obtained more conveniently in the following experiments.

Decarbonylation of (−)-phenylcamphoryl chloride. The acid chloride (18 g) was heated with tris(triphenylphosphine)rhodium chloride at 220° for 15 h. The cold mixture was poured into water and extracted with cyclohexane. The cyclohexane extract was washed several times with dil NaOH aq, dried and evaporated. Distillation of the residue gave (+)-**7** (9·9 g, 79%) b.p.$_{1.5}$ 120°, n_D^{23} 1·5148, $[\alpha]_D^{25}$ + 128·5 (Found: C, 89·9; H, 10·0. $C_{14}H_{18}$ requires: C, 90·3; H, 9·7%).

Isomerisation of **7**. The olefin **7** (5 g) was heated with a soln of t-BuOK (3 g) in dry DMSO (30 ml) on a water-bath for 10 h. The mixture was cooled and extracted with cyclohexane. Evaporation *in vacuo* of the cyclohexane extract gave **8** (4·8 g, 96%) b.p.$_{1.4}$ 121°, n_D^{23} 1·5372, $[\alpha]_D^{25}$ − 55° (Found: C, 90·1; H, 9·5. $C_{14}H_{18}$ requires: C, 90·3; H, 9·7%).

(+) - N, N - Dimethyl - N - (2, 2, 3 - trimethyl - 4 - phenylcyclopentylmethyl)amine. A soln of (+) - N, N - dimethylphenylcamphoramide (12 g) in dry ether (50 ml) was added slowly to a stirred slurry of LAH (10 g) in ether. The mixture was heated under reflux for 72 h and then EtOAc added cautiously to destroy excess LAH. A soln of 3N NaOH (200 ml) was added subsequently and the product extracted with ether. Pure **9** (9·2 g, 82%) was obtained by distillation b.p.$_{1.0}$ 125°, n_D^{21} 1·5089, $[\alpha]_D^{25}$ + 34·8° (Found: C, 83·4; H, 10·7; N, 5·5. $C_{17}H_{27}N$ requires: C, 83·2; H, 11·0; N, 5·7%).

(+)-1-Methylene-2,2,3-trimethyl-4-phenylcyclopentane. The amine **9** was converted to the methiodide m.p. 295° by reaction with MeI in ether. The methiodide (12·2 g) was stirred with freshly prepared Ag_2O (20 g) in 50% aqueous MeOH (100 ml) for 24 h. The filtered soln was evaporated *in vacuo* below 40° to a syrup which was then decomposed at 150° under reduced pressure of 50 mm. The olefin was subsequently distilled (3·1 g, 50%) b.p.$_{18}$ 160°, n_D^{24} 1·5188, $[\alpha]_D^{25}$ + 26°. (Found: C, 90·1; H, 10·2. $C_{15}H_{20}$ requires: C, 90·0; H, 10·0%).

(+)-2,2,3-Trimethyl-4-phenylcyclopentanone. Ozonised

O_2 was passed for 2 h through a soln of **10** (2·5 g) in chloroform (20 ml) cooled in an ice–salt bath. The chloroform was removed *in vacuo* < 35° and the residue then boiled with water for ½ h. The product was extracted with ether and chromatographed on silica gel. Elution with benzene gave successively unreacted olefin (1·8 g) and **11** (0·4 g), m.p. 94° $[\alpha]_D^{25}$ +77·5°. ν_{max} 1740 cm^{-1} (Lit[6] m.p. 91·5°).

Oxidation of (±)-phenylcamphoric acid. (±)-Phenylcamphoric acid (5 g) was dissolved in 0·1 N KOH (15 ml) and then 12% NaOCl soln (370 ml), 2% ruthenium trichloride soln (2 ml) and $CHCl_3$ (40 ml) were added. The mixture was stirred at room temp and small aliquots removed periodically for estimation of remaining hypochlorite. After 36 h when all hypochlorite had been consumed, the mixture was acidified with conc HCl and continuously extracted with ether. Evaporation of the extract and crystallisation of the residue from benzene gave (±)-2,2,3 - trimethylcyclopentane - 1,3 - dicarboxylic acid (2·5 g, 58%) m.p. 185° (Found: C, 59·9; H, 8·1. $C_{10}H_{16}O_4$ requires: C, 60·0; H, 8·0%). ν_{max} 1700, 2400–3300 cm^{-1}.

(−)-Phenylcamphornitrile. (−)-Phenylcamphoramide (16 g) and $SOCl_2$ (20 ml) in dry benzene (40 ml) were heated under reflux for 5 h. The cooled mixture was poured onto ice and the product extracted with benzene. Distillation gave (−)-phenylcamphornitrile (9·5 g 68%) $b.p._{\cdot 0\cdot 1}$ 118°, n_D^{23} 1·5181, $[\alpha]_D^{25}$ −21·7° (Found: C, 83·2; H, 9·5; N, 6·7. $C_{14}H_{19}N$ requires: C, 83·5; H, 9·4; N, 6·9%). ν_{max} 2240 cm^{-1}.

Friedel–Crafts reaction of (+)-3-cyano-1, 2, 2-trimethylcyclopentanecarbonyl chloride with benzene. Aluminium chloride (8 g) was added slowly to a stirred benzene soln (30 ml) of the acid chloride,[4] obtained from $SOCl_2$ treatment of the corresponding acid[15] (6·3 g). After additional stirring for 2 h the mixture was poured onto ice and dil H_2SO_4. The products (4·6 g, 66%) were isolated by ether extraction and distilled, $b.p._{\cdot 0\cdot 1}$ 118–121°. Examination by GLC MS showed the presence of two isomeric nitriles in an approximate 1 : 1 ratio, which were separated by distillation using a spinning band column (Micro column 8100). The separation was monitored by GLC. Early fractions were of pure (−)-phenylcamphornitrile identical with authentic material, *vide supra.* Later fractions comprised (+)-isophenylcamphornitrile $b.p._{\cdot 0\cdot 1}$ 121°, n_D^{23} 1·5272, $[\alpha]_D$ +36·7 (Found: C, 83·6; H, 9·2; N, 6·8. $C_{14}H_{19}N$ requires: C, 83·5; H, 9·4; N, 6·9%), ν_{max} 2240 cm^{-1}.

(+)-Isophenylcamphoric acid. (+)-Isophenylcamphornitrile (1·5 g) was heated in a sealed tube at 130° for 15 h with AcOH (3 ml) and conc HCl (6 ml). The mixture was diluted with water and chloroform extracted. After several washes with water the chloroform soln was extracted with dil NaOH aq. Acidification of this extract provided isophenylcamphoric acid (0·9 g, 52%) as an oil which was characterised as its S-benzylisothiouronium salt m.p. 104–5°, $[\alpha]_D^{25}$ +22·5° (MeOH). (Found: C, 69·3; H, 7·8; N, 7·2; S, 8·4. $C_{23}H_{30}N_2O_2S$ requires: C, 69·4; H, 7·5; N, 7·0; S, 8·0%). The regenerated acid (0·5 g) was dissolved in MeOH and the soln saturated with HCl. After several h the soln was diluted with water and the ester extracted into ether. Evaporation and "distillation" gave methyl (+)-isophenylcamphorate (0·4 g, 77%) $b.p._{\cdot 0\cdot 1}$ *ca* 100°. $[\alpha]_D^{25}$ +122°, n_D^{23} 1·5189 (Found: C, 77·8; H, 8·6. $C_{16}H_{22}O_2$ requires: C, 78·0; H, 8·9%). It was readily distinguished from methyl (+)-phenylcamphorate by a GLC.

The epimerisation of methyl isophenylcamphorate was attempted by heating it under reflux for 36 h in MeOH in which a small piece of Na had been previously dissolved. The ester was recovered unchanged as indicated by GLC and IR spectrum.

Reaction of (−)-α-campholytic acid with benzene. (−)-α-Campholytic acid[12] (1·2 g) was reacted with benzene (20 ml) in the presence of $AlCl_3$ (1·8 g) under precisely the same conditions as employed for (−)-camphoric anhydride. The product was (+)-phenylcamphoric acid (1·2 g, 67%).

Under the same conditions the 'low rotating' campholytic acid,[10,13] a 1:2 mixture of 1 - methylene - 2, 2 - dimethylcyclopentane - 3 - carboxylic acid and 2,2,3 - trimethylcyclopent - 3 - enecarboxylic acid, gave an 82% yield of (+)-phenylcamphoric acid.

Reaction of (±)-3-cyano-1-methylene-2,2-dimethylcyclopentane with benzene. Under the same conditions used for the Friedel-Crafts reaction of 3 - cyano - 1, 2, 2 - trimethylcyclopentanecarbonyl chloride with benzene, **20**[16] gave a 61% yield of phenylcamphornitrile and isophenylcamphornitrile which were identified by GLC/MS.

Friedel–Crafts reaction with isofenchocamphoric anhydride. The reaction was carried out in the same way as for camphoric anhydride using isofenchocamphoric anhydride obtained from oxidation[17] of (±)-isofenchone.[18] The acid fraction was esterified by saturating its MeOH soln with dry HCl. Examination of the resulting methyl esters by GLC/MS showed the presence of two isomeric esters (M^+ 246. Calc for $C_{16}H_{22}O_2$ M^+ 246). Small samples for NMR examination were obtained by preparative GLC (*vide supra*).

Both esters were separately heated under reflux for 24 h in MeOH to which a small piece of Na had been added previously. Ester **23** was recovered unchanged, while subsequent GLC examination showed that **22** had been epimerised to **23**.

Acknowledgements—We are indebted to the British Council for the award of a scholarship (Y.C.Y.), and to Farbwerke Hoechst AG for providing a source of isofenchone.

REFERENCES

[1]E. Burcker, *C. R. Acad Sci. Paris* **119**, 426 (1894); *Bull. Soc. Chim. Fr.* **13**, 901 (1895)
[2]J. F. Eijkman, *Chemisch Weekblad* **4**, 727 (1907); *Chem. Zent.* II 2046 (1907)
[3]F. H. Lees and W. H. Perkin, *J. Chem. Soc.* **79**, 356 (1901); W. H. Perkin and J. Yates, *Ibid.* **79**, 1373 (1901)
[4]F. Salmon-Legagneur, *Ann. Chim.* **8**, 29 (1927); *C. R. Acad. Sci. Paris* **182**, 791 (1926)
[5]W. Bleazard and E. Rothstein, *J. Chem. Soc.* 68 (1961)
[6]J. R. Bantick and E. Rothstein, *Ibid.* C 2512 (1971)
[7]J. Weinstock, *J. Org. Chem.* **21**, 540 (1956)
[8]S. Beckmann and B. Geiger, *Chem. Ber.* **94**, 1910 (1961)
[9]F. H. Allen and D. Rogers, *Chem. Commun.* 837 (1966); A. J. Birch, *Ann. Rep. Prog. Chem.* **47**, 191 (1950)
[10]J. Walker and W. Cormack, *J. Chem. Soc.* **77**, 378 (1900)
[11]W. A. Noyes, *Amer. Chem. J.* **17**, 421 (1895)
[12]W. A. Noyes, *Ibid.* **16**, 500 (1894)
[13]J. Walker, *J. Chem. Soc.* **63**, 495 (1893)
[14]E. Rothstein and R. W. Saville, *Ibid.* 1961 (1949)
[15]H. Rupe and J. Splittgerber, *Ber. Ges. Dtsch. Chem.* **40**, 4313 (1907)
[16]E. E. Van Tamelen and J. E. Brenner, *J. Am. Chem. Soc.* **79**, 3839 (1957)
[17]D. Mukherji and J. C. Bardhan, *J. Chem. Soc.* 197 (1949)
[18]W. Hückel and H. J. Kern, *Liebigs Ann.* **687**, 40 (1965)