

*The Stereochemistry of Organic Derivatives of Phosphorus. Part III.\*  
The Synthesis and Optical Resolution of a Spirocyclic Phosphonium  
Salt possessing Molecular Dissymmetry.*

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Hitherto no spirocyclic phosphonium salt, in which the ring system consists solely of carbon atoms and the phosphorus atom common to both rings, has been synthesised. The considerable difficulties of such synthesis, compared with those of the synthesis of comparable arsonium salts, are briefly indicated. The synthesis of *P*-spiro-bis-1:2:3:4-tetrahydro-phosphinolinium iodide, and its resolution into the (+)- and the (-)-iodide, having  $[M]_D +66^\circ$  and  $-65^\circ$  respectively in chloroform solution, are described. These salts have high optical stability, the rotations of the chloroform solutions at  $15^\circ$  being constant during 4 days.

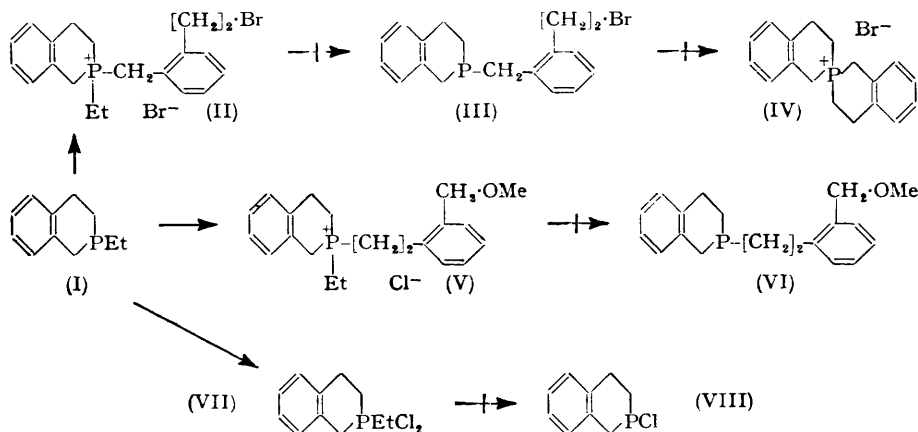
THE tetrahedral disposition of the Group VB elements when 4-covalent can give rise to four main classes of organic derivatives which theoretically should be resolvable into optically active forms. If the element is represented by X, these classes are: (a) the oxide of the tertiary derivative, abcXO; (b) the corresponding sulphide, abcXS; (c) the quaternary salt having the cation  $[abcdX]^+$ ; (d) a suitable spirocyclic quaternary salt. The sulphides in class (b) (to which should be added the selenides) are separated from the oxides because their chemical and stereochemical properties show significant differences from those of the oxides. It is noteworthy that in compounds of nitrogen, phosphorus, and arsenic this activity in each case has hitherto been experimentally realised in only three of the above classes, although the missing class is different in derivatives of each of the three elements. Thus a tertiary amine oxide, abcNO, was resolved into optically active forms by Meisenheimer (*Ber.*, 1908, **41**, 3966), a quaternary salt,  $[abcdN]I$ , by Pope and Peachey (*J.*, 1899, **75**, 1127), and a spirocyclic salt by Mills and Warren (*J.*, 1925, 2507), but tertiary amine sulphides are apparently unknown. A tertiary phosphine oxide was resolved by Meisenheimer *et al.* (*Ber.*, 1911, **44**, 356; *Annalen*, 1926, **449**, 224), a tertiary phosphine sulphide by Davies and Mann (*J.*, 1944, 276), and a quaternary phosphonium salt by Holliman and Mann (*J.*, 1947, 1634), but spirocyclic phosphonium salts, in which the ring system consists solely of carbon atoms and the phosphorus atom which is common to both rings, have not hitherto been synthesised. A tertiary arsine sulphide has been resolved by Mills and Raper (*J.*, 1925, **127**, 2479) and a quaternary and a spirocyclic arsonium salt into optically stable forms by Holliman and Mann (*J.*, 1943, 550; 1945, 45), but attempts to resolve a tertiary arsine oxide, abcAsO, have uniformly failed: this failure, in which the chemistry of arsenic is apparently so different from that of nitrogen and phosphorus, may possibly be due to the conversion  $[abcAsOH]X \longrightarrow abcAsO$  through the (usually transient) dihydroxide,  $abcAs(OH)_2$ , which may itself possess a plane of symmetry (cf. Mann, *J.*, 1945, 71).

We have now synthesised and resolved a spirocyclic phosphonium salt, and the stereochemistry of optically active derivatives of 4-covalent phosphorus has consequently attained a wider basis than that of analogous derivatives of nitrogen or arsenic.

The very ready synthesis of a spirocyclic arsonium salt (Holliman and Mann, *loc. cit.*), dependent upon the smooth thermal decomposition of a quaternary salt, failed signally for analogous phosphonium salts, owing undoubtedly to the different mechanism and more severe conditions of such decompositions. Thus 2-ethyl-1:2:3:4-tetrahydroisophosphinoline (I) (Beeby and Mann, *J.*, 1951, 411) united readily with *o*-2-bromoethylbenzyl bromide,  $Br[CH_2]_2C_6H_4CH_2Br$ , to give the quaternary salt (II), which when heated under various conditions gave no indication of elimination of ethylene and hydrogen bromide with the formation of the phosphine (III), which would have cyclised spontaneously to the required salt (IV). This result may have been due to the benzyl group's

\* Part II, *J.*, 1947, 1634.

being more readily eliminated from (II) than the ethyl group. Consequently the phosphine (I) was next combined with *o*-2-chloroethylbenzyl methyl ether,  $\text{Cl}\cdot[\text{CH}_2]_2\cdot\text{C}_6\text{H}_4\cdot\text{CH}_2\cdot\text{OMe}$ , to give the salt (V), in the hope that the ethyl group in this would be eliminated before the substituted ethyl group, but again decomposition to the required phosphine (VI) was not achieved. Finally the phosphine (I) was converted into the crystalline dichloride (VII), which, however, unlike its arsenic analogue, on heating dissociated considerably into its original components and did not furnish the monochloro-compound (VIII), from which the phosphine (VI) could undoubtedly have been obtained by the Grignard reaction.

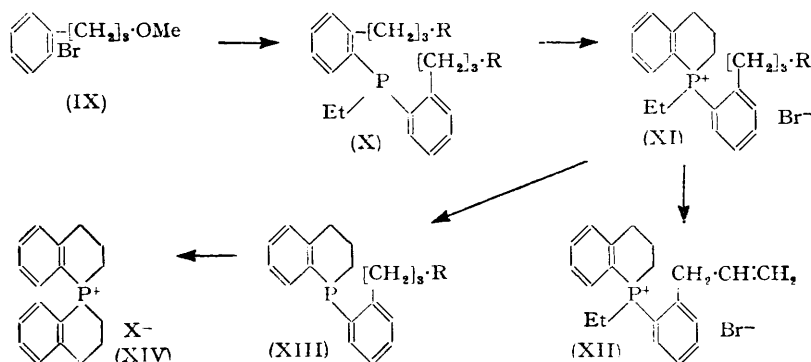


In view of these difficulties, a different synthetic route was adopted, involving thermal decomposition of a quarternary salt having only one alkyl group attached to the phosphorus atom. 3-*o*-Bromophenylpropyl methyl ether (IX) (Beeby and Mann, *loc. cit.*) was converted into the *o*-lithio-derivative, which reacted with ethyldichlorophosphine to give ethyldi-(*o*-3-methoxypropylphenyl)phosphine (X; R = OMe), which was further characterised by conversion into the crystalline orange dibromobis[ethyldi-(*o*-3-methoxypropylphenyl)phosphine]palladium,  $[(\text{C}_{22}\text{H}_{31}\text{O}_2\text{P})_2\text{PdBr}_2]$ . The phosphine (X; R = OMe) when heated with hydrobromic acid gave the 3-bromopropyl derivative (X; R = Br) which readily cyclised in hot chloroform solution to give the crystalline 1-*o*-3-bromopropylphenyl-1-ethyl-1 : 2 : 3 : 4-tetrahydrophosphinolinium bromide (XI; R = Br), which also gave a crystalline picrate.

The attempted elimination of the ethyl group in the phosphonium bromide (XI; R = Br) by thermal decomposition failed, owing to the ready loss of hydrogen bromide and formation of 1-ethyl-1 : 2 : 3 : 4-tetrahydro-1-*o*-allylphenylphosphinolinium bromide (XII), a process which could apparently be reversed by the action of hot hydrobromic acid. To avoid this type of decomposition, the bromide (XI; R = Br) was converted by sodium methoxide in methanol into the 1-*o*-3-methoxypropylphenyl analogue (XI; R = OMe), which, when heated under nitrogen at 250—320°/1 mm., lost ethylene and hydrogen bromide and gave a viscous distillate of 1 : 2 : 3 : 4-tetrahydro-1-*o*-3-methoxypropylphenylphosphinoline (XIII; R = OMe) and its hydrobromide. A mixture of this crude product and 48% hydrobromic acid, when boiled under reflux, furnished the water-soluble hydrobromide of the 1-*o*-3-bromopropylphenyl analogue (XIII; R = Br): basification precipitated the oily free phosphine, which when extracted with chloroform underwent rapid cyclisation in the boiling extract to ( $\pm$ )-*P*-spirobis-1 : 2 : 3 : 4-tetrahydrophosphinolinium bromide (XIV; X = Br); this was converted into the less soluble iodide (XIV; X = I). The phosphorus atom in these salts is not asymmetric, but its tetrahedral disposition produces a dissymmetric cation, and the salts should therefore be susceptible to optical resolution. It is noteworthy that simple salts of this cation, such as the iodide and picrate, very readily separate in well-formed crystals, and thus resemble those of the ( $\pm$ )-*As*-spirobis-1 : 2 : 3 : 4-tetrahydroisoarsinolinium cation

(Holliman and Mann, *loc. cit.*) and the *As-spirobisisoarsindolinium* cation (Lyon and Mann, *J.*, 1945, 30).

In preliminary attempts to resolve the cation (XIV), the iodide was converted into the (+)-camphorsulphonate, the (+)-bromocamphorsulphonate, and the (+)-camphornitronate, but these salts after repeated crystallisation gave no evidence of resolution: the (−)-quinate, (−)-*N*-1-phenylethylphthalamate, the (−)-*N*-menthylphthalamate, and the (+)-1-methyl-*n*-hexyl hydrogen phthalate formed intractable oils.



The (−)-menthoxyacetate of the cation (XIV) was also initially obtained as an oil, which however after considerable trouble was obtained crystalline from acetone solution. This material, when repeatedly recrystallised from ethyl acetate, gave the optically pure (−)-phosphonium (−)-menthoxyacetate having ethyl acetate (4 mols.) of crystallisation, m. p. 78—80°,  $[M]_D -140^\circ$  in ethanol, both values unchanged by further crystallisation. This salt gave the solvent-free (−)-phosphonium iodide (XIV; X = I), m. p. 246—248°,  $[M]_D -65^\circ$  in chloroform.

The mother-liquor from the first of the above recrystallisations, when worked up, furnished a small crop of the (±)-phosphonium (−)-menthoxyacetate, also having ethyl acetate (4 mols.) of crystallisation, m. p. 59—60°, which gave the (±)-phosphonium iodide (XIV; X = I), m. p. 294—295°.

The various mother-liquors, which were now rich in the (+)-phosphonium (−)-menthoxyacetate, were united and evaporated to dryness, and the residue in aqueous solution was converted into the iodide. The latter, when crystallised from ethanol, gave first a crop of the (±)-phosphonium iodide, and then yielded the more soluble (+)-phosphonium iodide (XIV; X = I), which after repeated recrystallisation was obtained optically pure, having m. p. 246—248°, and  $[M]_D +66^\circ$  in chloroform.

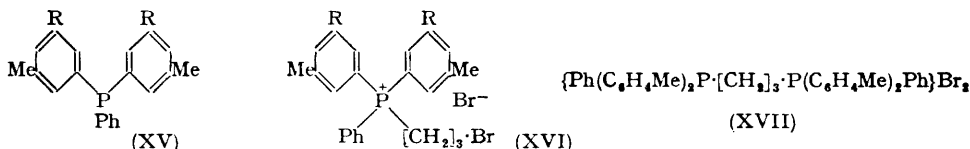
The iodide has high optical stability, and its solution in chloroform at room temperature was unchanged after four days. The calculated values for the rotatory dispersion have

Source of light	Cd	Na	Hg	Cd	Hg
$\lambda$ (Å) .....	6438	5893	5461	5086	4358
$\lambda^2$ (Å <sup>2</sup> ) $\times 10^{-8}$ .....	0.414	0.347	0.298	0.259	0.190
$\alpha$ (obs.) .....	-0.315°	-0.35°	-0.395°	-0.44°	-0.72°
$[M]$ .....	-59.5	-66	-75	-83	-136
$\alpha$ (calc.) .....	-0.287	-0.35	-0.417	-0.49	-0.72
$\alpha$ (obs.) - $\alpha$ (calc.) .....	-0.028	0.00	+0.022	+0.05	0.00

been obtained for a 0.520% solution of the (+)-iodide in chloroform. The calculated rotations are based on the equation  $\alpha = k/(\lambda^2 - \lambda_0^2)$ , where the rotation constant  $k = 0.1070$  and  $\lambda_0^2 = 0.0413 \text{ Å}^2$ . Although the range of wavelengths employed is too short to provide decisive evidence, the differences in the values of  $\alpha$  (obs.) -  $\alpha$  (calc.) indicate that the dispersion is not simple: this receives strong confirmation from the fact that when  $\lambda^2$  is plotted against  $1/\alpha$  (obs.) a pronounced and smooth curve is obtained, whereas a straight line should be obtained for simple dispersion obeying the above equation.

Some model experiments, conducted to test another synthetic route, are briefly recorded. Phenyldi-*m*-tolylphosphine (XV; R = H) was quaternised with trimethylene dibromide

to give 3-bromopropylphenyldi-*m*-tolylphosphonium bromide (XVI; R = H). The cyclisation by aluminium bromide of the 3-bromopropyl group in this salt on to the *ortho*-position of the tolyl group to give the tetrahydro-5-methylphosphinoline ring was investig-



ated, in the hope that the inactivation of this position by the positive pole on the phosphorus atom would be less than the activation by the methyl group: these attempts failed. To increase the activation of the aromatic ring, di-(3:5-dimethylphenyl)phenylphosphine (XV; R = Me) was similarly converted into the bromide (XVI; R = Me), but this salt also gave no evidence of cyclisation.

It is noteworthy that the salt (XVI; R = H) was obtained by the action of trimethylene dibromide (10 mols.) on the phosphine, but the use of trimethylene bromide chloride (1 mol.) gave trimethylene-1:3-bis(phenyldi-*m*-tolylphosphonium bromide) (XVII) in 30% yield.

#### EXPERIMENTAL

All the following rotations were measured at 15° in a 4-dm. tube, with the Na<sub>D</sub> light (λ, 5893Å). All compounds isolated, unless otherwise stated, were colourless.

*Reactions of 1-Ethyl-1:2:3:4-tetrahydroisosphosphinoline (I).*—The following exemplify briefly the various attempts to synthesise a spirocyclic salt from the phosphine (I).

(1) A solution of the phosphine (I) (0.87 g.) in ether (10 c.c.) was added to one of *o*-2-bromoethylbenzyl bromide (1.36 g., 1 mol.) also in ether (5 c.c.). After 90 min. the crude precipitated oily bromide (II) was separated, dissolved in ethanol, and reprecipitated with ether. The bromide (0.43 g.), which could not be obtained crystalline and gave an oily picrate, effervesced without distillation under nitrogen at 270—350°/0.3 mm., and the brownish-black glassy residue gave no picrate.

(2) A mixture of the phosphine (I) (3.48 g.) and *o*-2-chloroethylbenzyl methyl ether (3.61 g., 1 mol.) was heated under nitrogen at 150—160° for 40 min., forming a hard glass, undoubtedly the chloride (V), which could not be obtained crystalline. This was heated at 360—370°/0.3 mm., undergoing effervescence as a golden oil distilled over. This was shaken with ether and aqueous sodium hydrogen carbonate, and the ethereal extract when distilled gave the phosphine (I), b. p. 70—82°/0.2 mm. (1.15 g.) (b. p. 123—127°/16 mm. on redistillation), and a non-volatile product.

Another portion of the oil was dissolved in a mixture (1:1 by vol.) of acetic acid and hydrobromic acid (constant b. p.), which was heated at 130—140° for 2½ hr. whilst hydrogen bromide was passed through it in order to form the bromomethyl analogue of (VI) and then the salt (IV). The acids were therefore removed at reduced pressure, and the residue shaken with aqueous sodium hydrogen carbonate and with chloroform. The aqueous layer gave no precipitate with sodium picrate. The chloroform extract was evaporated: an aqueous solution of the residue gave an oily picrate, but repeated recrystallisation from water gave only an impure picrate, m. p. 39—45° (Found: C, 54.8; H, 3.9%). Lack of material prevented further investigation.

(3) A solution of chlorine (0.60 g., 1 mol.) in carbon tetrachloride (43 c.c.) was added dropwise to a stirred solution of the phosphine (I) (1.5 g.) in the tetrachloride (5 c.c.), immersed in solid carbon dioxide-acetone under nitrogen. A cloudy suspension was rapidly formed and then deposited colourless very hygroscopic crystals (1.99 g., 95%) of the dichloride (VII). They were collected, dried, and heated under nitrogen at 100°/20 mm. for 45 min., until the initial vigorous effervescence had ceased. The residue, when twice distilled at 0.0005 mm. (with some decomp.), gave a cloudy viscous distillate, b. p. 180—185° (Found: Cl, 6.8%), which was still impure and was not identified.

It is noteworthy that 1-ethyl-1:2:3:4-tetrahydrophosphinoline, when added dropwise to carbon tetrachloride at -70°, caused a series of small explosions with the formation of a charred mass. When chlorine diluted with nitrogen was passed over a solution of the phosphine in light petroleum (b. p. 60—80°), it also gave a white crystalline dichloride, which did not furnish the monochloride when heated.

*Ethyl-di-(o-3-methoxypropylphenyl)phosphine* (X; R = OMe).—This experiment was conducted throughout in an atmosphere of nitrogen. *n*-Butyl-lithium in light petroleum (b. p. 40–60°) (1765 c.c.; 0.989N) was slowly added to a stirred solution of 3-*o*-bromophenylpropyl methyl ether (IX) (400 g., 1 mol.) in the petroleum (1.5 l.) at 10°. After the addition of ether (50 c.c.) the mixture was boiled under reflux for 1½ hr., more ether (850 c.c.) being added to dissolve precipitated material. Ethyldichlorophosphine (114 g., 0.5 mol.) in petroleum (500 c.c.) was then added to the cooled, stirred solution, which was again boiled for 1 hr., cooled, and hydrolysed with water. The organic layer, when dried and distilled, gave the *phosphine* (X; R = OMe), b. p. 215–218°/2 mm. (203 g., 65%) (Found: C, 73.9; H, 8.8. C<sub>22</sub>H<sub>31</sub>O<sub>2</sub>P requires C, 73.7; H, 8.7%).

Shaking with aqueous-ethanolic potassium palladobromide (0.45 mol.), followed by brief boiling, gave *dibromobis[ethyl-di-(o-3-methoxypropylphenyl)phosphine]palladium*, pale orange crystals, m. p. 165.5–166.5° (from ethanol) (Found: C, 53.6; H, 6.6. C<sub>44</sub>H<sub>62</sub>O<sub>4</sub>Br<sub>2</sub>P<sub>2</sub>Pd requires C, 53.7; H, 6.35%).

1-*o*-Bromopropylphenyl-1-ethyl-1:2:3:4-tetrahydrophosphinolinium Bromide. (XI; R = Br).—The phosphine (X; R = OMe) (89 g.) was added under nitrogen to 48% hydrobromic acid (1 l.), which was then reduced to *ca.* 200 c.c. by gentle distillation during 1½ hr., care being taken not to overheat the more concentrated solution, which contained the hydrobromide of the phosphine (X; R = Br). This solution was cooled and treated with sodium carbonate solution until effervescence ceased. The liberated phosphine (X; R = Br) was quickly extracted with chloroform, which was then evaporated on a steam-bath, and the residue was heated for a further 15 min. A solution of this crystalline residue in ethanol (40 c.c.) was diluted with ethyl acetate (60 c.c.) and filtered, and more ethyl acetate added until the solution just remained clear: the *bromide monohydrate* (XI; R = Br) slowly separated in needles (63 g.) and further addition of ethyl acetate to the filtrate gave a second crop (31 g., total yield 81%). The salt was purified by a repetition of the above process, and obtained as needles, m. p. 110–112°, unaffected by further treatment (Found: C, 50.4; H, 5.3; Br, 33.95. C<sub>20</sub>H<sub>25</sub>Br<sub>2</sub>P<sub>2</sub>H<sub>2</sub>O requires C, 50.7; H, 5.7; Br, 33.7%). It gave a *picrate*, yellow needles, m. p. 83–85°, from ethanol (Found: C, 51.95; H, 4.4; N, 7.2. C<sub>26</sub>H<sub>27</sub>O<sub>7</sub>N<sub>3</sub>BrP requires C, 51.7; H, 4.5; N, 6.95%).

*Action of Heat on the Bromide* (XI; R = Br).—The bromide (0.82 g.) was heated under nitrogen at 0.5 mm. in a flask contained in an oil-bath. Effervescence started at *ca.* 130°, and ceased after the flask had been heated at 150° for 30 min. and then at 200° for 30 min. A solution of the glassy product in a minimum of hot ethanol, when diluted with hot ethyl acetate to incipient turbidity and then set aside, deposited crystals (0.35 g.), m. p. 133–137°, increased to 155–158° by repetition of the crystallisation. This crude bromide (XII), on treatment with aqueous sodium picrate, gave 1-ethyl-1:2:3:4-tetrahydro-1-*o*-allylphenylphosphinolinium picrate (as XII), yellow crystals, m. p. 130–131° after crystallisation from ethanol and methanol in turn (Found: C, 59.8; H, 5.2; N, 8.15. C<sub>26</sub>H<sub>26</sub>O<sub>7</sub>N<sub>3</sub>P requires C, 59.7; H, 5.0; N, 8.0%).

The picrate was shaken with 25% hydrobromic acid, and the solution, after thorough extraction with ether and treatment with concentrated aqueous potassium iodide, deposited the *iodide* (as XII), m. p. 168–170° after crystallisation from ethanol (Found: C, 56.6; H, 6.1; C<sub>20</sub>H<sub>24</sub>IP requires C, 56.9; H, 5.7%).

In earlier attempts to prepare the bromide (XI; R = Br), a solution of the phosphine (X; R = OMe) in a mixture of acetic and 48% hydrobromic acid was boiled under reflux whilst hydrogen bromide was passed through it. Evaporation of the solution under reduced pressure then gave a crude product, a portion of which on recrystallisation gave the bromide (XII). This crude product, when boiled with hydrobromic acid, gave the bromide (XI; R = Br) in good yield. The conversion of the bromide (XII) → (XI; R = Br) was not attempted, however, with a pure sample of the former.

1-Ethyl-1:2:3:4-tetrahydro-1-*o*-3-methoxypropylphenylphosphinolinium Bromide (XI; R = OMe).—A solution of the bromide (XI; R = Br) (50 g.) in methanol (60 c.c.) was added at 15° to a solution obtained by the interaction of sodium (4.83 g., 1 atom equiv.) and methanol (90 c.c.), and the mixture set aside for 18 hr. It was then carefully neutralised with hydrobromic acid, and the solvents were removed at 50° under reduced pressure. The residue was extracted with cold ethanol (25 c.c.), which when filtered to remove sodium bromide, and concentrated under reduced pressure, gave the crude crystalline bromide (XI; R = OMe).

This material could not be satisfactorily recrystallised but was pure enough for the next stage. A sample, purified by repeated dissolution in ethanol and reprecipitation with ethyl acetate, gave the crystalline *bromide monohydrate*, m. p. 144–146° (Found: C, 59.9; H, 7.1.

$C_{21}H_{28}OBrP, H_2O$  requires C, 59.3; H, 7.1%). This gave the yellow *picrate*, m. p. 84—96° (from methanol) (Found: C, 58.7; H, 5.5; N, 7.4.  $C_{27}H_{30}O_8N_3P$  requires C, 58.6; H, 5.1; N, 7.6%).

(±)-P-spiroBis-1:2:3:4-tetrahydrophosphinolinium Bromide (XIV; X = Br).—The bromide (XI; R = OMe) (50 g.) was heated under nitrogen at 2 mm. in a short-necked distilling-flask. Effervescence started when the bath temperature reached *ca.* 250°, and the heating was gradually increased to maintain a slow steady distillation of the product, the process being complete when the temperature reached 320° after *ca.* 1½ hr. The distillate (11.3 g.), the first part of which was a fairly mobile oil and the last part a viscous oil forming a glass when cold, was undoubtedly the phosphine (XIII; R = OMe) increasingly contaminated with its hydrobromide. A mixture of the distillate and 48% hydrobromic acid (100 c.c.) was boiled under reflux for 2 hr., considerably concentrated, cooled, and treated with an excess of aqueous sodium carbonate. The precipitated oily phosphine (XIII; R = Br) was quickly extracted with chloroform, and the latter evaporated on the steam-bath, the residual bromide (XIV; X = Br) finally solidifying. Since crystallisation of this salt proved wasteful, its aqueous solution was treated with an excess of concentrated aqueous potassium iodide, thus precipitating the colourless *iodide* (XIV; X = I) (10.5 g., 24%), m. p. 294—295° after repeated crystallisation from ethanol (Found: C, 55.0; H, 4.8.  $C_{18}H_{20}IP$  requires C, 54.8; H, 5.1%). It gave a *picrate*, yellow needles, m. p. 128—129° from ethanol (Found: C, 58.0; H, 4.5; N, 8.8.  $C_{24}H_{22}O_7N_3P$  requires C, 58.2; H, 4.5; N, 8.5%).

Resolution of the spiro-Iodide (XIV; X = I).—Silver (–)-menthoxyacetate was prepared by Mann and Watson's method (*J.*, 1947, 511). A solution of the iodide (6.43 g.) in hot ethanol (250 c.c.) was added to a suspension of the silver salt (5.24 g., 1 mol.) in boiling water (500 c.c.) containing ethanol (20 c.c.), which was then boiled for 30 min. and filtered. Since, however, a small proportion of the silver menthoxyacetate had decomposed during this process, the filtrate was treated dropwise with a hot saturated aqueous solution of the silver salt until no further turbidity developed, filtered again, concentrated, and ultimately heated at 100° under reduced pressure until only a mobile oil remained.

This oil could not be immediately crystallised. A small sample was stirred vigorously with ether, the latter decanted, and the oil then exposed to the air (for chance inoculation) for long periods: the treatment was repeated with light petroleum, also without success. It was then dissolved in ethyl acetate, and the solution allowed to evaporate spontaneously: this treatment was repeated with acetone and, after many attempts, crystallisation occurred from this solvent, and provided a "seed" for the major quantity.

The latter was dissolved in warm ethyl acetate (20 c.c.), which when cooled and seeded deposited prismatic crystals of the optically impure (–)-phosphonium (–)-menthoxyacetate, m. p. 70—74° (2.9 g.). This crop, when recrystallised from ethyl acetate, gave the salt, m. p. 75—77.5° (1.12 g.); three more recrystallisations gave the solvated (–)-phosphonium (–)-menthoxyacetate as prisms, m. p. 78—80° (0.67 g.) (Found: C, 66.3; H, 8.5.  $C_{30}H_{41}O_3P, 4C_4H_8O_2$  requires C, 66.3; H, 8.8%). These prisms, which were well-formed crystals, when finely crushed gave a faint odour of ethyl acetate. A 0.812% solution in ethanol had  $\alpha -0.545^\circ$ ,  $[M] -140^\circ$ . One more recrystallisation gave the salt of unchanged m. p., and a 0.63% ethanolic solution then had  $\alpha -0.425^\circ$ ,  $[M] -140^\circ$ . Meanwhile, the mother-liquor which had deposited the above crop, m. p. 75—77.5°, on spontaneous partial evaporation deposited a second crop, which on recrystallisation furnished more (–)-phosphonium salt (0.94 g.), identical with the former final product.

This salt in aqueous solution, when treated with aqueous potassium iodide, deposited the (–)-phosphonium iodide (XIV; X = I), needles, m. p. 246—248° after crystallisation from ethanol (Found: C, 55.0; H, 5.3.  $C_{18}H_{20}IP$  requires C, 54.8; H, 5.1%); a 0.668% solution in chloroform had  $\alpha -0.44^\circ$ ,  $[M] -65^\circ$ .

The original mother-liquor, which had deposited the salt of m. p. 70—74°, on spontaneous evaporation furnished a viscous semisolid residue; this was drained and the sticky solid (2.35 g.), when recrystallised from ethyl acetate (5 c.c.), gave a mixture (m. p. 55.5—57°; 0.75 g.) mainly of needles containing the higher-melting prisms. A solution of this mixture in ethyl acetate (5 c.c.), when cooled and seeded with the above (–)-phosphonium (–)-menthoxyacetate, deposited *ca.* 0.1 g. of the latter. This was collected, and the filtrate, when reheated and allowed to cool, deposited uncontaminated needles of the solvated (±)-phosphonium (–)-menthoxyacetate (0.23 g.), m. p. 58—60°, unchanged by further crystallisation (Found: C, 66.4; H, 8.8.  $C_{30}H_{41}O_3P, 4C_4H_8O_2$  requires C, 66.3; H, 8.8%). This gave the (±)-phosphonium iodide, m. p. 294—295°, alone and when mixed with the original salt.

The ethyl acetate mother-liquors from the above work were united [omitting only those used for the final recrystallisations of the (-)-phosphonium salt] and evaporated to dryness under reduced pressure. The residue in aqueous solution, when treated with aqueous potassium iodide, deposited the iodide (2.34 g.), m. p. 240—280°. A solution of this salt in boiling ethanol (75 c.c.) was allowed to cool spontaneously without disturbance: after 4 hr., a crop of the ( $\pm$ )-phosphonium iodide (0.92 g.), m. p. 287—289°, was rapidly collected, the solution being supersaturated with respect to the (+)-phosphonium iodide. The filtrate, when concentrated to 50 c.c. and rapidly cooled, gave the (+)-phosphonium iodide (0.64 g.), m. p. 245—246.5°, which after seven recrystallisations from ethanol gave the optically pure *iodide*, m. p. 246—248° (Found: C, 55.0; H, 4.8%); a 0.520% solution in chloroform had  $\alpha$  +0.35°,  $[M] +66^\circ$  (for rotations at other wave-lengths, see p. 4109).

The following salts of the spirocyclic cation were also prepared: The ( $\pm$ )-*phosphonium (+)-camphorsulphonate* was obtained by mixing hot aqueous solutions of equimolar quantities of the phosphonium iodide and of the silver sulphonate, and evaporating the filtrate to dryness under reduced pressure. The residue, recrystallised six times from ethyl methyl ketone, gave the sulphonate (XIV; X = C<sub>10</sub>H<sub>15</sub>O<sub>4</sub>S), m. p. 170.5—171.5° (Found: C, 67.2; H, 7.2. C<sub>28</sub>H<sub>35</sub>O<sub>4</sub>SP requires C, 67.4; H, 7.1%): it gave an inactive iodide. The (+)-*bromocamphorsulphonate*, similarly prepared, gave an oil which solidified when rubbed with acetone, and when then recrystallised five times from ethyl methyl ketone had m. p. 184.5—185.5°,  $[M] +289^\circ$  (Found: C, 58.4; H, 6.2. C<sub>28</sub>H<sub>34</sub>O<sub>4</sub>BrSP requires C, 58.25; H, 5.9%): it also gave an inactive iodide. The (+)-*camphornitronate*, similarly prepared and recrystallised eight times from the ketone, had m. p. 150—152° (Found: C, 72.6; H, 7.6; N, 3.2. C<sub>28</sub>H<sub>34</sub>O<sub>3</sub>NP requires C, 72.6; H, 7.4; N, 3.0%): it gave an inactive picrate.

*Phenyldi-m-tolylphosphine* (XV; R = H).—A solution of phenyldichlorophosphine (20.5 g.) in benzene (100 c.c.) was slowly added under nitrogen to a stirred Grignard reagent prepared from *m*-bromotoluene (49.3 g., 2.5 mols.) in ether (150 c.c.) and magnesium (7.0 g.). The mixture was boiled under reflux for 1½ hr., cooled, and hydrolysed with aqueous ammonium chloride. The organic layer, when separated, dried, and distilled, gave the *phosphine*, b. p. 210—220°/0.5 mm. (26 g., 75%), which readily solidified and gave crystals, m. p. 53—53.5°, from methanol (Found: C, 82.8; H, 6.7. C<sub>20</sub>H<sub>19</sub>P requires C, 82.7; H, 6.6%). The phosphine was characterised by treatment of a portion in chloroform with bromine (1 mol.), and hydrolysis of the dibromide by shaking its solution with dilute aqueous ammonia. The chloroform layer on evaporation gave the colourless *phosphine oxide*, m. p. 108.5—109° from light petroleum (b. p. 60—80°) (Found: C, 78.4; H, 6.5. C<sub>20</sub>H<sub>19</sub>OP requires C, 78.4; H, 6.25%).

*Di-(3:5-dimethylphenyl)phenylphosphine* (XV; R = Me) was similarly prepared from 1-bromo-3:5-dimethylbenzene; the crude product, b. p. 150—195°/1 mm., solidified, and when thrice recrystallised from methanol gave the phosphine, m. p. 98° (Found: C, 83.1; H, 7.2. C<sub>22</sub>H<sub>23</sub>P requires C, 83.0; H, 7.3%).

*3-Bromopropylphenyldi-m-tolylphosphonium Bromide* (XVI; R = H).—A mixture of the phosphine (XV; R = H) (5 g.) and trimethylene dibromide (34.8 g., 10 mols.) was heated under nitrogen at 100° for 3 hr. Addition of ether to the cold product yielded the *salt* (8.3 g., 98%) which on repeated recrystallisation from ethanol-ethyl acetate (1:10 by vol.) had m. p. 190.5—191.5° (Found: C, 56.4; H, 4.95. C<sub>23</sub>H<sub>25</sub>Br<sub>2</sub>P requires C, 56.1; H, 5.1%).

*Trimethylene-1:3-bis(phenyl-m-tolylphosphonium Bromide)* (XVII).—A mixture of the phosphine (XV; R = H) (3 g.) and trimethylene chlorobromide (1.63 g., 1 mol.) was heated at 150° for 40 min. The solid product (3.72 g.; m. p. 173—250°) was triturated with ether, and when recrystallised once from ethanol and twice from water gave the *bromide* (0.96 g., 30%), m. p. 314—315° (Found: C, 65.9; H, 5.8. C<sub>45</sub>H<sub>44</sub>Br<sub>2</sub>P<sub>2</sub> requires C, 66.0; H, 5.7%).

*3-Bromopropyl-di-(3:5-dimethylphenyl)phenylphosphonium Bromide* (XVI; R = Me).—This *bromide*, prepared as (XVI; R = H), formed crystals, m. p. 203—205°, when slowly precipitated from ethanolic solution by the addition of ethyl acetate (Found: C, 57.4; H, 5.3; Br, 30.6. C<sub>25</sub>H<sub>29</sub>Br<sub>2</sub>P requires C, 57.7; H, 5.6; Br, 30.7%).

*Di- $\alpha$ -naphthylphenylphosphine*.—Prepared by the action of  $\alpha$ -naphthylmagnesium bromide on phenyldichlorophosphine, this *phosphine* formed crystals, m. p. 207.5—208.5°, from ethyl methyl ketone (Found: C, 86.15; H, 5.4. C<sub>26</sub>H<sub>19</sub>P requires C, 86.2; H, 5.3%). In view of the failure to cyclise the bromides (XVI; R = H and Me), the interaction of this phosphine and trimethylene dibromide was not investigated.

The following compounds were prepared as reagents for attempted resolutions. (-)-*N-Menthylphthalamic Acid*.—(-)-Menthylamine (8.1 g.) in ether (150 c.c.) was added to a boiling solution of phthalic anhydride (7.75 g., 1 mol.) in ether (300 c.c.), which was heated under reflux for

1 hr., and then concentrated to *ca.* 50 c.c. Careful addition of light petroleum (b. p. 40—60°) (400 c.c.) precipitated the white *acid* (15.1 g., 95%), m. p. 154.5—155.5° after recrystallisation from di-*n*-butyl ether (Found: C, 71.6; H, 8.1; N, 4.3.  $C_{18}H_{25}O_3N$  requires C, 71.3; H, 8.3; N, 4.6%). The addition of silver nitrate (1 mol.) to the sodium salt, each in aqueous solution, precipitated the *silver salt monohydrate*, m. p. 222° (decomp.) (Found: Ag, 25.2.  $C_{18}H_{24}O_3NAg, H_2O$  requires Ag, 25.2%).

(+)-1-Methyl-*n*-hexyl hydrogen phthalate similarly gave a *silver salt monohydrate*, m. p. 130—133° (preliminary softening) (Found: Ag, 27.9.  $C_{15}H_{19}O_4Ag, H_2O$  requires Ag, 27.8%).

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