512. *The Synthesis of 2-Phenyl*iso*phosphindoline.*

By Frederick G. Mann, Ian T. Millar, and H. R. Watson.

The above phosphine, which has hitherto been very difficult to prepare, has now been synthesised readily and in high yield.

The investigation of two other synthetic routes is briefly recorded.

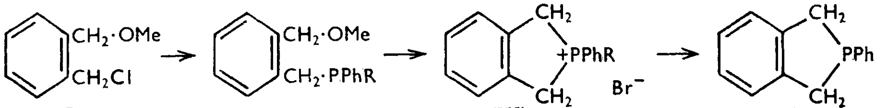
Great interest attaches to 2-phenyl*iso*phosphindoline (IV) because of the nature and variety of its co-ordinated metallic derivatives, but its difficult synthesis has hitherto severely restricted its use. Mann, Millar, and Stewart[1] showed that the interaction of phenylphosphinebis(magnesium bromide), $Ph\cdot P(MgBr)_2$, and *o*-xylylene dibromide gave chiefly an amorphous insoluble powder, which when heated decomposed, producing the crude *iso*phosphindoline in *ca.* 4% yield. Alternatively diphenylphosphine was converted in liquid ammonia into its sodio-derivative, Ph_2PNa, which with *o*-methoxymethylbenzyl chloride (I) gave *o*-methoxymethylbenzyldiphenylphosphine (II; R = Ph); hydrogen bromide converted this phosphine to the *o*-bromomethyl derivative, which rapidly underwent cyclisation by quaternisation to give the bromide (III; R = Ph).

This salt, having two phenyl groups joined to the phosphorus atom, was useless for the preparation of the *iso*phosphindoline (IV) by thermal decomposition. We have now modified this synthesis, in that phenylphosphine in liquid ammonia was treated in turn with 1 equivalent of sodium, ethyl bromide, and again with sodium to promote the sequence, $Ph\cdot PH_2 \longrightarrow Ph\cdot PHNa \longrightarrow Ph\cdot PEtH \longrightarrow Ph\cdot PEtNa$. The last compound

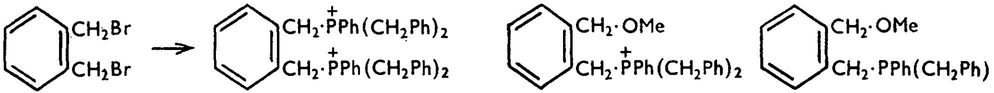
---

[1] Mann, Millar, and Stewart, *J.*, 1954, 2832.

when treated in the ammonia with the chloride (I) gave ethyl-*o*-methoxymethylbenzylphenylphosphine (II; R = Et) in 72% yield: it was characterised by the preparation of the yellow crystalline dibromobis(phosphine)palladium, $[(C_{17}H_{21}OP)_2PdBr_2]$. A boiling solution of the phosphine (II; R = Et) in acetic acid, when treated with hydrogen bromide, similarly gave 2-ethyl-2-phenyl*iso*phosphindolinium bromide (III; R = Et) in 80% yield. Heating this bromide in nitrogen at 15 mm. gave ethylene, hydrogen bromide, and a distillate consisting of 2-phenyl*iso*phosphindoline (IV) and its hydrobromide, from which the pure phosphine (IV) was isolated in 67% yield.



(I) (II) (III) (IV)



(V) (VI) (VII) (VIII)

Two syntheses attempted earlier may be briefly recorded. *o*-Xylylene dibromide (V) readily combined with dibenzylphenylphosphine (2 equivalents) to form *o*-xylylenebis-(dibenzylphenylphosphonium) dibromide (VI; X = Br). This salt was also formed when one equivalent of the phosphine was employed, half the dibromide (V) remaining unchanged: this strong tendency for *o*-xylylene dibromide to form the diquaternary salts with tertiary phosphines and arsines, to the apparently complete exclusion of the monoquaternary salts, has been noted before.[1,2] The dibromide (VI; X = Br) was heated in nitrogen at 0·5 mm. in a flask connected to a receiver and a trap cooled in liquid air. After the thermal decomposition was complete, the trap contained hydrogen bromide, benzene, and toluene. The distillate in the receiver gave, on fractionation, 2-phenyl*iso*phosphindoline (IV) in $<10\%$ yield and much dibenzylphenylphosphine and its oxide: the yield of the phosphindoline was variable, and never exceeded this value.

o-Methoxymethylbenzyl chloride combined readily with dibenzylphenylphosphine to give the phosphonium chloride (VII), which on being heated as before afforded benzyl-*o*-methoxymethylbenzylphenylphosphine (VIII). This phosphine with hydrogen bromide in acetic acid gave ultimately a water-insoluble syrup which was not further investigated. The failure of these two routes emphasises further the greater value of the sodium–liquid ammonia method than of the thermal decomposition of phosphonium salts for the preparation of many tertiary phosphines which do not have three identical substituents.[3]

The greater supplies of the *iso*phosphindoline (IV) now available have enabled us to make a detailed investigation (to be reported later) of its co-ordinated derivatives with palladium dihalides in particular, and also with other metallic salts.

EXPERIMENTAL

o-Methoxymethylbenzyl chloride (I) and phenylphosphine were prepared as described by Mann and Stewart,[4] and Mann and Millar [5] respectively.

*Ethyl-*o*-methoxymethylbenzylphenylphosphine* (II; R = Et).—A solution of phenylphosphine (31·8 g.) in ether (20 c.c.) was added under nitrogen to liquid ammonia (150 c.c.) in a 3-necked flask equipped with an efficient condenser and a potassium hydroxide guard-tube, and immersed in acetone–carbon dioxide. The vigorously stirred suspension was treated with sodium (6·5 g., 1 equiv.) in small pellets. After 20 min. the intense blue colour was replaced by a deep orange one, and ethyl bromide (31·8 g., 1 mol.) was slowly added. After 30 min. the mixture was treated with sodium (6·4 g.) as before, and finally dropwise with the chloride (I)

[2] Lyon, Mann, and G. H. Cookson, *J.*, 1947, 662.
[3] Hitchcock and Mann, *J.*, 1958, 2081.
[4] Mann and Stewart, *J.*, 1954, 2819.
[5] Mann and Millar, *J.*, 1952, 3039.

(44·0 g., 0·92 mol.) dissolved in ether (30 c.c.). The solution, on being stirred for 1 hr., became almost colourless. The ammonia was allowed to distil off and the residual sludge treated cautiously with cold boiled water (150 c.c.), followed by ether (50 c.c.). The ethereal layer was separated, the aqueous layer was extracted with ether (30 c.c.), and the combined extracts were washed with water, dried (K_2CO_3), and distilled, the phosphine (II; R = Et) being obtained as a colourless malodorous oil, b. p. 202—206°/13 mm. [51·1 g., 72%, calc. on the chloride (I)].

The oxide and the metho-bromide, -picrate, -perchlorate, and -chloroplatinate of the phosphine all formed uncrystallisable gums. The phosphine reacted with potassium bromopalladite also to form a gum: when, however, air was passed through a solution of this gum in cold light petroleum (b. p. 60—80°), *dibromobis(ethyl-*o*-methoxymethylbenzylphenylphosphine)-palladium* was deposited, forming yellow crystals, m. p. 129·5—130°, after two recrystallisations from ethanol (Found: C, 50·05; H, 5·1. $C_{34}H_{42}O_2Br_2P_2Pd$ requires C, 50·4; H, 5·2%).

*2-Ethyl-2-phenyl*iso*phosphindolinium Bromide* (III; R = Et).—A vigorous stream of hydrogen bromide was passed through a boiling solution of the phosphine (II; R = Et) (25 g.) in acetic acid (450 c.c.) for 5½ hr. The solvent was removed at 20 mm., and the residual lachrymatory oil shaken with cold boiled water (400 c.c.) and chloroform (250 c.c.) under nitrogen. The chloroform layer was extracted with water (3 × 100 c.c.), but before each extraction it was boiled under reflux for 30 min. to promote quaternisation. The combined aqueous extracts were evaporated at 20 mm., and the residual oily bromide was then dissolved in a minimum of methanol to promote crystallisation, and the solution evaporated to dryness. The colourless residue (23·7 g., 80%), when recrystallised from acetone containing a trace of methanol, afforded the *monohydrated bromide* (III; R = Et), m. p. 273° (decomp., in an evacuated tube): the hydrate was unaffected at 105°/0·5 mm. for 14 hr. (Found: C, 56·0; H, 6·2. $C_{16}H_{18}BrP,H_2O$ requires C, 56·7; H, 5·9%). It gave a yellow *picrate*, m. p. 102—102·5° (from methanol) (Found: C, 56·4; H, 4·4; N, 9·2. $C_{22}H_{20}O_7N_3P$ requires C, 56·3; H, 4·3; N, 9·0%).

*2-Phenyl*iso*phosphindoline* (IV).—The bromide (III; R = Et) (25·0 g.) was placed under nitrogen in a 250 c.c. flask fitted with an air-condenser and a receiver. It was heated at 15 mm. with a brush flame until only a slight carbonaceous residue remained, and a mixture of the phosphine and its hydrobromide had collected in the receiver and the condenser. This product was extracted with a mixture of ether and saturated aqueous sodium carbonate (30 c.c.). The ethereal layer was separated, the aqueous layer extracted with ether, and the combined ethereal extracts, when dried and distilled, gave the phosphine (IV) (11·0 g., 67%), b. p. 182—186°/15 mm., 110—113°/0·2 mm. (lit.,[1] 110—112°/0·2 mm.) (Found: *M*, cryoscopic in benzene, 210. Calc. for $C_{14}H_{13}P$: *M*, 212). It gave a methiodide, m. p. 208—210° (decomp.), after crystallisation from ethanol [lit.,[1] 207—209° (decomp.)].

For experiments requiring small quantities (0·1—0·5 g.) of the phosphine, it was conveniently stored in, and dispensed from, a graduated all-glass syringe of 5 c.c. capacity, fitted with a Polythene cap, and stored under nitrogen.

o*-Xylylenebis(dibenzylphenylphosphonium) Dibromide* (VI; X = Br).—*o*-Xylylene dibromide (27·7 g.) was added to a solution of dibenzylphenylphosphine [1] (61 g., 2 mol.) in benzene (50 c.c.) under nitrogen. The mixture, which when warmed deposited the syrupy diquaternary salt, was heated under reflux for 30 min., and the solvent decanted: the residual dibromide was washed with benzene and confined in a vacuum over paraffin wax, then forming an almost colourless, hygroscopic, hard glass (88·7 g.), very soluble in the ordinary solvents.

An ethanolic solution, when treated with ethanolic sodium picrate, deposited *o*-xylylenebis-dibenzylphenylphosphonium) dipicrate (VI; X = $O{\cdot}C_6H_2O_6N_3$), which gave the yellow *mono-ethanolate*, m. p. 122—124°, on recrystallisation from ethanolic acetone (Found: C, 62·3; H, 4·5; N, 7·2. $C_{60}H_{50}O_{14}N_6P_2,C_2H_6O$ requires C, 62·7; H, 4·75; N, 7·1%).

The dibromide (VI; X = Br) (88 g.) was placed in a flask connected to an air-condenser and receiver, the latter in turn being connected to a trap cooled in liquid air. The salt, under nitrogen at 0·5 mm., when carefully heated with a free flame, fused and then decomposed smoothly at a moderate temperature, giving first a nearly colourless mobile distillate and finally a more viscous amber distillate. A friable black solid residue (4·0 g.) remained.

The trap contained much hydrogen bromide; after removal of this, the colourless liquid residue on fractionation gave benzene (4·6 g.) and toluene (6·7 g.). No benzyl bromide or other product was detected.

The main distillate was shaken under nitrogen with chloroform (50 c.c.) and saturated aqueous sodium carbonate (100 c.c.) for 1 hr., and the organic layer then separated, washed with water, dried (Na_2SO_4), and distilled in nitrogen, giving the fractions: (A) b. p. 116—130°/0·7 mm. (5·8 g.); (B) b. p. 160—210°/0·5 mm. (5·6 g.); (C) b. p. 210—300°/0·5 mm. (20·5 g.).

Fraction (B), which partly solidified, consisted mainly of dibenzylphenylphosphine; it gave dibenzylmethylphenylphosphonium iodide, m. p. and mixed m. p. 204—206° (from ethanol) (lit.,[1] 206—208°) and yellow dibromobis(dibenzylphenylphosphine)palladium crystals (insoluble in ethanol), m. p. and mixed m. p. 236—238° (lit.,[1] 240—242°).

The solid fraction (C) on redistillation gave dibenzylphenylphosphine oxide (from aqueous ethanol), m. p. and mixed m. p. 171° (lit.,[1] 174°).

Fraction (A) on redistillation in nitrogen gave the colourless fractions: (*a*) b. p. 90—100°/0·5 mm. (0·8 g.), a liquid, not identified; (*b*) b. p. 104—108°/0·5 mm. (1·9 g.); and (*c*) b. p. 110—120°/0·5 mm. (1·8 g.). Fraction (*b*) consisted largely of 2-phenyl*iso*phosphindoline; with methyl iodide, it readily gave the crystalline methiodide, m. p. and mixed m. p. 210—211° (Found: C, 50·5; H, 4·5. Calc. for $C_{15}H_{16}IP$: C, 50·85; H, 4·55%). However, it appeared to contain an impurity not readily removable by distillation, since other derivatives were obtained crystalline only with difficulty. Thermal decomposition of the methiodide gives the phosphine only in poor yield,[1] and purification of the ethobromide or ethiodide was difficult; convenient isolation of the pure phosphine by conversion into a quaternary salt and pyrolysis of the latter was thus precluded. Fraction (*c*) also contained the *iso*phosphindoline, identified as above, together with some 2-phenyl*iso*phosphindoline oxide, which separated when set aside and when recrystallised from ethanolic light petroleum (b. p. 40—60°) gave the *monohydrate*, m. p. 98—100° (after drying over P_2O_5 at 60°/0·1 mm.) (Found: C, 68·2; H, 6·2. $C_{14}H_{13}OP,H_2O$ requires C, 68·25; H, 6·2%).

Pyrolysis of an equimolecular mixture of the dibromide (VI; X = Br) with *o*-xylylene dibromide gave only a very small yield of mixed phosphines, together with much unchanged *o*-xylylene dibromide; pyrolysis of mixtures of the salt with smaller proportions of *o*-xylylene dibromide gave results very similar to those noted in detail above.

Dibenzyl-(o*-methoxymethylbenzyl*)*phenylphosphonium Chloride* (VII).—*o*-Methoxymethylbenzyl chloride (I) (5·1 g.) in benzene (10 c.c.) was added to dibenzylphenylphosphine (8·5 g., 1 mol.) in benzene (10 c.c.) under nitrogen. No deposition of quaternary salt occurred on boiling the mixture under reflux: the solvent was therefore distilled off, and the residue gently heated for 15 min. before cooling and washing it with light petroleum (b. p. 60—80°). The resulting chloride (VII) formed a hard deliquescent glass, too soluble in all the common solvents for recrystallisation. The corresponding picrate, iodide, nitrate, oxalate, and aurichloride were also too soluble for recrystallisation. The chloride (13·0 g.), when heated under nitrogen at 0·5 mm., fused and decomposed at rather a high temperature, giving first a colourless oily distillate (2·0 g.) and, on stronger heating, a viscous distillate (5 g.). A dark residue, not volatile at a low red heat, remained (3·5 g.).

The viscous distillate was shaken mechanically under nitrogen with chloroform (10 c.c.) and saturated aqueous sodium carbonate (10 c.c.) for 2 hr., and the organic layer then separated, washed with water, dried (Na_2SO_4), and fractionally distilled under nitrogen, giving an oil, b. p. 210—225°/0·5 mm. (0·5 g.), and then benzyl-(*o*-methoxymethylbenzyl)phenylphosphine (VIII), b. p. 275—295°/0·5 mm. (1·4 g., 14%), which crystallised at once in the receiver. No suitable solvent for recrystallisation could be found. A small residue (1 g.) remained.

The phosphine gave a very soluble colourless *methiodide*, m. p. 193—195° (from ethanol-ether) (Found: C, 58·0; H, 5·5. $C_{23}H_{26}OIP$ requires C, 58·0; H, 5·5%), and with aqueous-ethanolic potassium palladobromide it gave orange *dibromobis*[*benzyl-*(o*-methoxymethylbenzylphenyl*)*phosphine*]*palladium*, m. p. 132—133° (from ethanol) (Found: C, 57·0; H, 4·75. $C_{44}H_{46}O_2Br_2P_2Pd$ requires C, 56·5; H, 4·95%).

Passage of dry hydrogen bromide for 3 hr. through a solution of the phosphine in glacial acetic acid at 100°, followed by removal of the solvents and treatment of the residue with chloroform and aqueous sodium hydrogen carbonate, gave a water-insoluble syrup which failed to give a picrate.

We are greatly indebted to Messrs. Albright and Wilson, Ltd., for a grant (to H. R. W.).

UNIVERSITY CHEMICAL LABORATORY, CAMBRIDGE. [*Received, February 26th,* 1958.]