The Action of Magnesium and of Grignard Reagents on Certain Benzyl Ethers. Part I. The Action of Magnesium on o-, m-, *and* p-*Alkoxy- and -Phenoxy-methylbenzyl Chlorides.*

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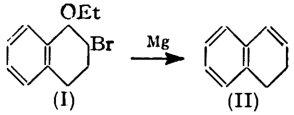
It is shown that although magnesium reacts with the above *meta*-compounds to give normal Grignard reagents, it reacts with the *ortho*- and *para*-compounds to give amorphous polymers of approximate composition $(C_8H_8)_x$. The mechanism of these reactions is discussed, and correlated with that of the interaction of magnesium with other kindred systems.

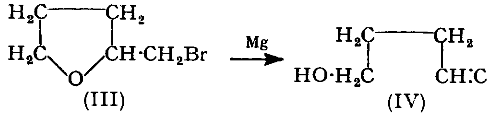
IT has long been known that sodium and magnesium give an apparently anomalous reaction with 2-alkoxy- and 2-aryloxy-ethyl halides, whereby an olefin and the metallic alkoxide or aryloxide are formed: $RO{\cdot}CH_2{\cdot}CH_2X + 2Na \longrightarrow CH_2{:}CH_2 + NaOR + NaX$. Grignard (*Compt. rend.*, 1904, **138**, 1048) showed that magnesium and 2-phenoxyethyl bromide give ethylene and sodium reacts similarly with the chloride (Wohl and Berthold, *Ber.*, 1910, **43**, 2177). Moreover, the presence of certain substituents in the 1- and 2-positions of the ethane residue does not inhibit this reaction. Thus Wislicenus (*Annalen*, 1878, **192**, 106) showed that 2-chloroacetal, $(EtO)_2CH{\cdot}CH_2Cl$, reacted with sodium to give ethyl vinyl ether and sodium ethoxide and chloride: similarly the ortho-esters of α-halogeno-acids give keten acetals:

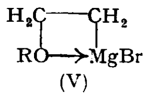
$$(EtO)_3C{\cdot}CHBrR + Na \longrightarrow (EtO)_2C{:}CHR + NaOEt + NaBr$$

(Walters and McElvain, *J. Amer. Chem. Soc.*, 1940, **62**, 1482). A particularly interesting example is 2-bromo-1-ethoxytetralin (I), which with magnesium furnishes 1 : 2-dihydronaphthalene (II) (von Braun and Kirschbaum, *Ber.*, 1921, **54**, 597): it is clear that in this reaction the compound (I) is acting as a 1 : 2-disubstituted derivative of 2-ethoxyethyl bromide. Paul (*Bull. Soc. chim.*, 1933, **53**, 421) extended the reaction to heterocyclic systems, showing that 2-bromomethyltetrahydrofuran (III) on reaction with magnesium followed by hydrolysis gave pent-4-en-1-ol (IV), and it was subsequently found that (IV) is also produced by the action of sodium on the 2-chloro-derivative (as III) (Gambert, Linstead, and Rydon, *J.*, 1937, 1972). Grignard, Paul, and also Swallen and

Boord (*J. Amer. Chem. Soc.*, 1930, **52**, 651) suggested that the reaction with magnesium involved the formation of a normal but unstable Grignard reagent, which rapidly decomposed: on the other hand, a chelation mechanism, involving intermediates of

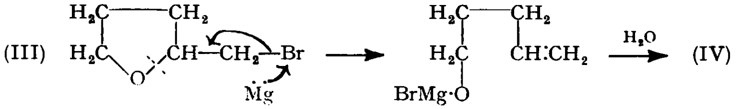

(I) (II)


(III) (IV)

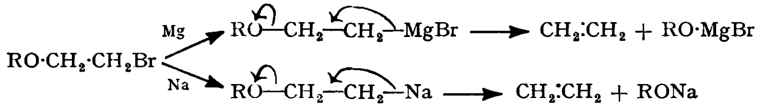

(V)

type (V), was put forward by Tallman (*ibid.*, 1934, **56**, 126), who was unable to detect the formation of a Grignard reagent when magnesium reacted with eight 2-alkoxyethyl bromides, in each case with the liberation of ethylene.

Robinson and Smith (*J.*, 1936, 195) confirmed Paul's results and suggested the following mechanism:



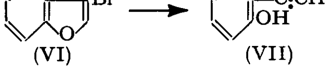
In this scheme the fission of the O–C bond is considered to occur simultaneously with a nucleophilic attack on the bromine by the metal. Since formation of any Grignard reagent presumably involves a similar attack on a halogen atom, it follows that the actual fission of the O–C bond may occur at any time during the attack by the metal or after an actual Grignard reagent has been formed, the ease of the fission being determined by several factors, *e.g.*, the stability of the alkoxide anion which is produced. The mechanism in the simpler ethyl halides may therefore conveniently be indicated:



The fact that sodium usually gives the same ethylene derivative indicates a similar tendency to form a 2-substituted sodium alkyl which then decomposes by the same electronic mechanism: here again, however, the fission of the O–C link may occur almost simultaneously with the reaction of the sodium with the halogen (Crombie and Harper, *J.*, 1950, 1707, 1715).

The general subject has been discussed by Amstutz (*J. Org. Chem.*, 1944, **9**, 30), who also used lithium for this type of reaction, and by Crombie and Harper (*loc. cit.*).

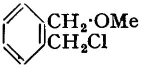
Two extensions follow from the mechanism suggested above. 2-Alkoxy(or 2-aryloxy)-vinyl halides should give acetylenes, whilst vinylogues of the 2-alkoxy(or 2-aryloxy)ethyl halides should give dienes. The first extension has been established by Jacobs, Cramer, and Weiss (*J. Amer. Chem. Soc.*, 1940, **62**, 1849) who showed that 2-phenoxyvinyl bromide and sodium form acetylene and sodium phenoxide, and by Reichstein and Baud (*Helv. Chim. Acta*, 1937, **20**, 892), who showed that 3-bromobenzofuran (VI) on reaction with magnesium, followed by treatment with carbon dioxide and subsequent hydrolysis, gives *o*-hydroxyphenylacetylene (VII) as the main product, and only a very small yield of benzofuran-3-carboxylic acid. Luttringhaus, Saar, and Hauschild (*Ber.*, 1938, **71**, 1673) established the second extension, by showing that 1-bromo-4-phenoxybut-2-ene (VIII)


(VI) (VII)

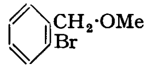
$$PhO\cdot CH_2\cdot CH{:}CH\cdot CH_2Br \xrightarrow{Mg} CH_2{:}CH\cdot CH{:}CH_2$$
(VIII)

and magnesium afford butadiene: for other examples see Schubert, Lanka, and Liddicoet (*Science*, 1952, **116**, 124).

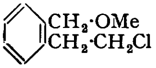
It is clear, however, that on the basis of the above mechanism a similar type of reaction should be given by compounds analogous to the vinylogues (VIII) but in which the •CH:CH• unit of (VIII) has been replaced by a similarly "electron-conducting" *o*- or *p*-phenylene group. This we find to be the case. *o*-Methoxymethylbenzyl chloride (IX) (see preceding paper) reacts readily with magnesium, but the only definite product obtained on hydrolysis is a white, ether-insoluble polymer of composition $(C_8H_8)_x$, which is closely similar to that which Baker, Banks, Lyon, and Mann (*J.*, 1945, 27) obtained by the action of sodium on *o*-xylylene dibromide in ether. This behaviour in the *ortho*-series is shown only by such benzyl halides, for the homologous *o*-bromobenzyl methyl ether (X) and 2-*o*-methoxymethylphenylethyl chloride (XI) form normal Grignard reagents in high yield (Holliman and Mann, *J.*, 1947, 1634), and we now find that *o*-2-methoxyethylbenzyl chloride (XII) also does so.



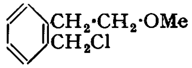
(IX)



(X)



(XI)

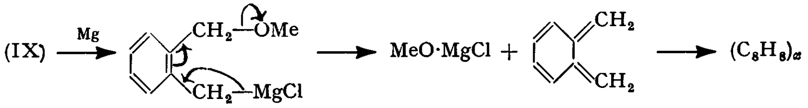


(XII)

We suggest that the behaviour of the chloride (IX) may be regarded as due to the initial formation of a Grignard reagent (XIII) in which an electronic drift similar to that discussed above occurs, and causes decomposition to magnesium methoxychloride and *o*-quinodimethane (XIV), which then rapidly polymerises. However, since, as stated above, in this and similar reactions discussed below, rupture of the ether linkage may be almost simultaneous with the initial action of the magnesium, compounds such as (XIII) may have, at the most, a transient existence.

It is noteworthy that the resonance energy of *o*-quinodimethane (XIV) has been calculated by quantum-mechanical means to be of the same order of magnitude as that of a benzene nucleus (Pullman, Berthier, and Pullman, *Bull. Soc. chim.*, 1948, 450; Namiot, Dyatkina, and Syrkin, *Compt. rend. Acad. Sci. U.R.S.S.*, 1945, **48**, 267) and that the reactivity of the methylene groups in (XIV) should be similarly comparable to that of simple aromatic free radicals; consequently, *o*-quinodimethane (XIV) bears approximately the same "energetic" relation to the benzyl chloride (IX) as ethylene bears to, for example, 2-methoxyethyl chloride. The reaction mechanism we propose by analogy is therefore supported also on these grounds.

The poly-*o*-xylylene formed from *o*-quinodimethane (XIV) softens at *ca.* 60° to a plastic mass which can be drawn out into long threads.



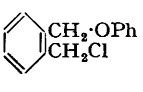
(XIII) (XIV)

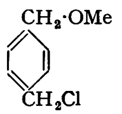
o-Phenoxymethylbenzyl chloride (XV) reacts similarly with magnesium, with the formation of the polymer $(C_8H_8)_x$ and (on the addition of water) the liberation of phenol, in confirmation of the suggested mechanism.

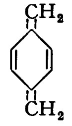
Incidentally, it is known that benzyl ethers are attacked by organo-lithium and -sodium compounds (cf. Wittig and Löhmann, *Annalen*, 1942, **550**, 260) but, with the exception of those types now under investigation, are usually stable to magnesium and Grignard reagents under normal conditions (see preceding paper for examples). In view of this potential complication, we have limited our study to the action of magnesium on the chloride (IX) and its analogues.

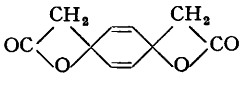
The action of magnesium on *o*-*tert.*-butoxymethylbenzyl chloride is of particular interest, because in this compound the strong inductive effect of the *tert.*-butyl group towards the oxygen might have reversed the electron drift described above, and thus allowed the chloride to form a Grignard reagent of normal stability. We find, however, that this chloride reacts slowly, but also gives the polymeric *o*-xylylene, and it is clear therefore that this inductive effect is insufficient.

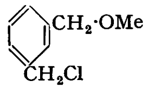
The reaction of *p*-methoxymethylbenzyl chloride (XVI) with magnesium is, as expected, analogous to that of the *o*-isomer (IX). Though sluggish, it affords a white polymer of approximate composition $(C_8H_8)_x$ which, however, unlike its *o*-isomer, does not soften appreciably below 200° and cannot be drawn into threads. This is probably identical with the *lin.*-poly-*p*-xylylene described by Brown and Farthing (*J.*, 1953, 3270). There is little doubt that a similar mechanism applies in this case also, involving intermediate formation of *p*-quinodimethane (XVII). Szwarc (*J. Chem. Phys.*, 1948, **16**, 128; *J. Polymer Sci.*, 1951, **6**, 319) has found that the intermediate (XVII), which he prepared by the pyrolysis of *p*-xylene, is reasonably stable as a gas but rapidly polymerises on cooling; he also prepared a number of analogues, of comparable reactivity (see also Szwarc, *Discuss. Faraday Soc.*, 1947, **2**, 46; Coulson, Craig, Maccoll, and Pullman, *ibid.*, p. 36). Hagemeyer (U.S.P. 2,4871,742/1949) claimed to have prepared (XVII) by the thermal decomposition of the compound (XVIII) obtained by the addition of keten to *p*-benzoquinone.


(XV)


(XVI)


(XVII)

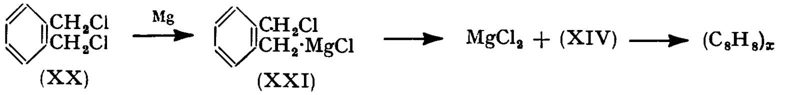

(XVIII)


(XIX)

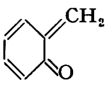
A further corollary to the above mechanism is that *m*-methoxymethylbenzyl chloride (XIX) should be unable to show this type of reaction. We find that, although the chloride (XIX) reacts only slowly with magnesium, so that the "entrainment method" has to be employed, a normal Grignard reagent results and when treated with water gives methyl *m*-methylbenzyl ether. *m*-Phenoxymethylbenzyl chloride, however, reacts readily with magnesium alone, and hydrolysis of the Grignard reagent similarly gives *m*-methylbenzyl phenyl ether in high yield. In neither case was any polymer formed.

Now the mechanism proposed involves a potential carbanion such as (XIII), since only then can the methoxyl group be eliminated as the stable methoxide ion. In contrast, therefore, any reagent which when applied to (IX) causes the benzyl group to act as a potential cation must also cause it to show "normal" behaviour. Thus the chloride (IX) when treated with potassium cyanide gives the benzyl cyanide, with sodium iodide gives the benzyl iodide (p. 2820) and with sodiodiphenylphosphine forms *o*-methoxymethylbenzyldiphenylphosphine (see following paper).

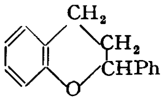
A further example of the formation of the *o*-quinodimethane (XIV) is afforded by *o*-xylylene dichloride (XX), which, unlike the corresponding dibromide (cf. Baker *et al.*, *loc. cit.*), reacts very readily with magnesium with the formation of a white ether-insoluble polymer, apparently identical with that obtained from the chloride (IX). This polymer is the main product under widely varied conditions and, since the mildest conditions used undoubtedly precluded extensive Wurtz-type coupling, it is probable that the dichloride (XX) first forms the mono-Grignard reagent (XXI), which rapidly loses magnesium chloride to form *o*-quinodimethane (XIV), and the usual polymerisation then immediately follows. We failed to confirm Hersch's claim (U.S.P. 2,615,033/1952), based on inadequate evidence, that the dichloride (XX) gives a normal di-Grignard reagent with magnesium.



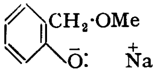
There is considerable evidence (Hultzsch, *Ber.*, 1941, **74**, 898; Hultzsch, "Chemie der Phenolharze," Springer, Berlin, 1st Edn., 1950, p. 63) that the highly reactive and readily polymerised *o*-quinomonomethane (XXII) and its derivatives are intermediates in the formation of phenol–formaldehyde resins, and in the self-condensations of *o*-phenolic alcohols generally. Hultzsch (*J. prakt. Chem.*, 1941, **158**, 275) also claims that the synthesis of many chromans and chromens by the condensation of saligenins with ethylenes and acetylenes—for example, condensation of saligenin with styrene to 2-phenylchroman (XXIII)—proceeds by "diene" addition of the ethylene or acetylene to the intermediate (XXII) derived from the saligenin. Further, *o*-methoxymethylphenol readily decomposes (Thiele and Dimroth, *Annalen*, 1899, **305**, 110), particularly in the presence of bases, to form a resinous polymer with liberation of methanol. This can be explained by a mechanism analogous to that suggested for (IX) but involving the intermediate (XXII); the sodium salt (XXIV) of the phenol can eliminate a methoxide ion, leaving (XXII) which immediately polymerises; the sodium methoxide formed repeats the decomposition, which when once started proceeds to completion.



(XXII)



(XXIII)



(XXIV)

We are now investigating the application of the considerations discussed above to systems containing *o*-quinomonomethane-imines, *i.e.*, the nitrogen analogues of (XXII).

EXPERIMENTAL

The magnesium used throughout had been activated by Holliman and Mann's method (*J.*, 1942, 739), metallic turnings being used instead of powder.

o-*Methoxymethylbenzyl Chloride* (IX) *and Magnesium.*—A solution of the chloride (7 g.) in ether (35 c.c.) was added dropwise to magnesium (1·1 g.) under ether (5 c.c.). A gentle reaction proceeded smoothly, with deposition of an amorphous white solid. The mixture was then boiled under reflux for 3 hr., cooled, and then stirred while hydrolysed by the addition of aqueous ammonium chloride. Filtration gave the crude ether-insoluble polymer (2·4 g.).

The ether solution, when dried and distilled, gave fractions, (*a*) b. p. $<$130°/0·1 mm. (1 g.), mainly unchanged chloride (IX), (*b*) b. p. 130—170°/0·1 mm., a pale yellow ethanol-soluble oil (0·6 g.), and (*c*) b. p. 170—245°/0·1 mm., a viscous brown syrup (0·5 g.) sparingly soluble in ethanol.

The polymer was partially purified by dissolution in benzene followed by precipitation with ethanol, but traces of magnesium derivatives and of organic solvents were difficult to remove in this and in all other samples of amorphous polymeric material [Found: C, 91·3; H, 7·7. Calc. for $(C_8H_8)_x$: C, 92·3; H, 7·7%]: it softened at *ca.* 60° to form a plastic mass.

When set aside, fraction (*b*) remained as a mobile oil: (*c*) formed a gum which could not be obtained crystalline and appeared also to be polymeric.

When the reaction with magnesium was carried out as above, and the cooled product treated with a large excess of solid carbon dioxide, subsequent hydrolysis furnished only the ether-insoluble polymer with a smaller quantity of the ether-soluble gum.

o-*Phenoxymethylbenzyl Chloride* (XV) *and Magnesium.*—A solution of the chloride (1 g.) in ether (5 c.c.) was similarly added to magnesium (0·12 g.) under ether (0·5 c.c.), a white solid separating as before. The mixture was then boiled under reflux for 3 hr., cooled and hydrolysed as before. The white ether-insoluble polymer (0·5 g.) softened at *ca.* 60°, and was apparently identical with that similarly obtained from (IX). The aqueous layer was repeatedly extracted with ether, and the extracts were combined and then extracted with 10% aqueous sodium hydroxide. The alkaline extract, when acidified and extracted with ether, gave phenol, identified by (*a*) a purple coloration with ferric chloride and (*b*) conversion by bromine water into *s*-tribromophenol, m. p. 92—93° alone and mixed [0·65 g., indicating 50% yield of phenol from (XV)]. The chloride (XV) was unaffected by bromine water under similar conditions.

o-tert.-*Butoxymethylbenzyl Chloride and Magnesium.*—An experiment with these reagents carried out as that with (IX), gave a rather slow reaction with deposition of an insoluble product. Heating and hydrolysis gave ultimately a colourless polymer (Found: C, 89·9; H, 7·7%), softening at *ca.* 60°, almost certainly identical with that obtained from (IX). No indication of the formation of a normal Grignard reagent could be obtained.

o-2-*Methoxyethylbenzyl Chloride* (XII) *and Magnesium.*—When a solution of the chloride (4·4 g.) and ethyl bromide (1·3 g.) in ether (35 c.c.) was added to magnesium (0·9 g.) under ether (5 c.c.), a reaction ensued with the formation of a white precipitate which subsequently redissolved. The dark solution was heated, then cooled, and hydrolysed with dilute hydrochloric acid, no insoluble products being obtained. Distillation of the ether layer gave (*a*) *methyl* 2-o-*methylphenylethyl ether*, b. p. 112—118°/32 mm., 204—206°/760 mm., a liquid having a pleasant odour (Found: C, 79·1; H, 9·4. $C_{10}H_{14}O$ requires C, 80·0; H, 9·3%), and (*b*) a fraction, b. p. 220—230°/20 mm., too small for purification, which was almost certainly *oo*′-di-(2-methoxyethyl)dibenzyl [cf. reaction of (XIX) with magnesium].

p-*Methoxymethylbenzyl Chloride* (XVI) *and Magnesium*.—This chloride reacted with magnesium much less readily than did (IX), and it was therefore mixed with ethyl bromide to accelerate the reaction. A solution of the chloride (XVI) (6·7 g.) and ethyl bromide (2 g.) in ether (50 c.c.) was added dropwise to activated magnesium (1·5 g.) under ether (2 c.c.). Reaction occurred slowly with deposition of a white amorphous solid. The mixture was then heated, hydrolysed, and filtered as described for (IX). The amorphous solid (3·3 g.), after thorough washing and drying, had no definite m. p. and did not soften below 250° : it was insoluble in ethanol and almost so in benzene, and consequently all samples after various attempted purifications retained a magnesium residue (Found : C, 86·6; H, 7·9%).

m-*Methoxymethylbenzyl Chloride* (XIX) *and Magnesium*.—When a solution of the chloride (6·7 g.) and ethyl bromide (2·1 g.) in ether (50 c.c.) was added to magnesium (1·5 g.) under ether (2 c.c.), a very sluggish reaction ensued with deposition of a gum. The mixture was boiled for 3 hr., then cooled and hydrolysed with dilute sulphuric acid, the gum redissolving. Fractionation of the dried ether layer gave the fractions (*a*), b. p. 108—120°/42 mm., a colourless liquid of very pleasant odour, and (*b*) b. p. 226—230°/18 mm., a colourless oil Fraction (*a*) could not be purified by fractional distillation and was identified as methyl *m*-methylbenzyl ether, by selective oxidation with cold dilute aqueous potassium permanganate to *m*-toluic acid, m. p. 106—107° (alone and mixed). Fraction (*b*) was crude 3 : 3′-di(methoxymethyl)dibenzyl: since distillation on this small scale did not give a pure sample (Found : C, 78·3; H, 8·6. Calc. for $C_{18}H_{22}O_2$: C, 80·0; H, 8·1%), it was identified by heating with a mixture (1 : 1 by vol.) of 48% aqueous hydrobromic acid and acetic acid, whereby it furnished 3 : 3′-*di*(*bromomethyl*)*dibenzyl*, colourless crystals, m. p. 80—81°, from ethanol (Found : C, 52·4; H, 4·6. $C_{16}H_{16}Br_2$ requires C, 52·2; H, 4·3%). The formation of this dibenzyl derivative was not unexpected, as benzyl halides when treated with magnesium under vigorous conditions frequently give such derivatives.

m-*Phenoxymethylbenzyl Chloride and Magnesium*.—A solution of the chloride (5 g.) in ether (15 c.c.) was added dropwise to magnesium (0·6 g.) under ether (5 c.c.) : reaction proceeded readily with formation of a brown solution which was then boiled for 0·5 hr., cooled, and hydrolysed with aqueous ammonium chloride. The aqueous layer was extracted repeatedly with ether, and the united ether extracts were extracted with dilute aqueous sodium hydroxide. The ether on distillation gave m-*methylbenzyl phenyl ether*, b. p. 168—170°/17 mm. (Found : C, 85·0; H, 7·1. $C_{14}H_{14}O$ requires C, 84·9; H, 7·0%) (2·65 g., 62%).

The alkaline extract, when acidified and extracted with ether, furnished phenol, identified and estimated as *s*-tribromophenol, m. p. 88—90° (alone and mixed) (0·2 g., corresponding to *ca*. 2% yield from the chloride).

o-*Xylylene Dichloride* (XX) *and Magnesium*.—(i) A solution of the dichloride (0·25 g.) in ether (5 c.c.) was added dropwise to magnesium (0·1 g.) under ether (2 c.c.), a reaction occurring steadily with deposition of a white solid. Hydrolysis with aqueous ammonium chloride followed by filtration gave an amorphous white polymer, which softened at *ca*. 60° (Found : C, 88·9; H, 7·7%). Evaporation of the ethereal layer gave a gum which was very soluble in benzene, from which it was precipitated as a gum by addition of ethanol, in which it was very sparingly soluble.

(ii) The above experiment was repeated on a larger scale with unactivated magnesium, the deposition of the white solid again occurring. The mixture was then added to an excess of solid carbon dioxide and allowed slowly to evaporate. No acid could be detected in the residue, which contained the above two polymers.

(iii) In order to detect the presence of even a smaller proportion of a true di-Grignard reagent, the addition of phenyldichlorophosphine, which would have formed phenyl*iso*phosphindoline (see following paper), was employed. A solution of the dichloride (XX) (5 g.) in ether (30 c.c.) was therefore slowly added to magnesium (1·5 g.) under ether (10 c.c.) with the usual deposition of white solid as in (i), and the complete mixture then boiled under reflux for 2 hr., cooled, treated with a solution of phenyldichlorophosphine (5 g.) in benzene (10 c.c.), and again boiled for 2 hr. After cooling and hydrolysis, the ether-insoluble polymer, as in (i), was collected. Distillation of the ethereal layer gave only unchanged dichlorophosphine (0·1 g.), and a polymeric residue which on cooling formed a stone-hard mass.

(iv) Experiment (iii) was repeated, with the mixture however cooled in ice-water throughout, the dichlorophosphine being added in ether (35 c.c.) instead of benzene. Again only polymeric products were obtained, without even the odour of a tertiary phosphine.

(v) The dichloride (XX) and the dichlorophosphine were added simultaneously to the cold magnesium, in the hope that the mono-Grignard reagent (XXI) on formation would now immediately react with the chlorophosphine and thus decomposition to (XIV) would be arrested: further reaction with magnesium, with subsequent cyclisation, might then ensue. However formation of the polymer was still the dominant reaction. A solution of the dichloride (XX) (8·75 g.) and phenyl dichlorophosphine (8·95 g., 1 mol.) in ether (30 c.c.) was added dropwise to magnesium (2·7 g., 2·2 atoms) in ether (5 c.c.) under nitrogen, and the mixture then stirred for 5 hr. After hydrolysis with aqueous ammonium chloride, and drying, the ethereal layer yielded only unchanged dichloride (XX), m. p. 54—55° (alone and mixed). Filtration gave a considerable yield of the polymer, soluble in benzene but reprecipitated by ether, and indistinguishable from that obtained in (i)—(iv) above. We are indebted to Dr. I. T. Millar for this experiment.

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