

that the salts are alkaline does not seem to decrease the amount of protein extracted as in the case of acid salts. The uniformity of the results obtained leads one to believe that a definite globulin is being extracted.

As stated before, this set of extractions shows no lyotropic series, indicating that the various anions are alike in their solvent effect upon the globulin. This evidence does not agree with that obtained by Gortner<sup>6</sup> in his studies on wheat and other seed proteins. However, in most cases he was probably working with a mixture of substances and might easily be extracting other substances with the globulin. This would account for the conflicting results. On the basis of these results he has raised an objection to the present definitions of globulins, which is justified by his experiments. Different salts may show a difference in their "peptizing" ability toward certain protein systems. In the case of orange seeds, however, uniformity seems to be the rule. Further studies along these lines are in progress.

### Conclusions

1. Normal solutions of the salts used in this study extract the same amount of nitrogen from the orange seed meal and there is no evidence for the existence of a lyotropic series in this particular system.
2. Pomelin is soluble equally as well in normal solutions of salts of strong bases and weak acids as in solutions of neutral salts.
3. The presence of acid during the extraction apparently decreases the amount of nitrogen extracted.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF IOWA STATE COLLEGE]

## SOME REARRANGEMENT REACTIONS OF BENZYL MAGNESIUM CHLORIDE

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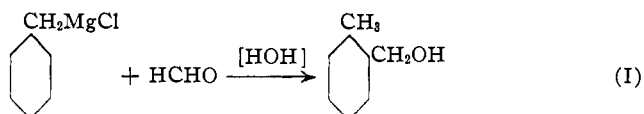
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### Introduction

Organomagnesium halides are very widely used in studies of the mechanisms of organic reactions and in the proof of structure of compounds. Such utility would be markedly circumscribed by uncertainties concerning rearrangements of the Grignard reagents. The present study is a continuation of earlier work<sup>1</sup> on the mechanism of such rearrangements and a classification of reactants which induce such transformations, primarily with a view to learning which simple compounds might be used with confidence in studies of Grignard reagents.

<sup>1</sup> (a) Gilman and Harris, *THIS JOURNAL*, **49**, 1825 (1927), and (b) Gilman and Kirby, *ibid.*, **51**, 3475 (1929).

The first reported rearrangement of this kind was in the reaction between benzylmagnesium chloride and formaldehyde as a consequence of which *o*-tolylcarbinol was formed.<sup>2</sup>



A second anomalous behavior of benzylmagnesium chloride was subsequently observed in its reaction with benzaldehyde,<sup>3</sup> and the course of this reaction is still not definitely known.<sup>4</sup> The related triphenylmethylmagnesium chloride,  $(\text{C}_6\text{H}_5)_3\text{CMgCl}$ , was also shown to react abnormally with benzaldehyde.<sup>5</sup> Such rearrangements, with a limited group of reactants, appear to be general with  $\text{RMgX}$  compounds having the grouping  $-\text{C}(\text{C}_6\text{H}_5)_2-\text{CH}_2\text{MgX}$ , if one may generalize from the behavior of  $\alpha$ -naphthylmethylmagnesium chloride,<sup>1b</sup>  $\alpha$ - $\text{C}_{10}\text{H}_7\text{CH}_2\text{MgCl}$ ; benzohydrilmagnesium chloride,<sup>6</sup>  $(\text{C}_6\text{H}_5)_2\text{CHMgCl}$ ; and cinnamylmagnesium chloride,<sup>1a,7</sup>  $\text{C}_6\text{H}_5-\text{CH}=\text{CHCH}_2\text{MgCl}$ .

The reactants which have been reported as undergoing abnormal transformations with this type of Grignard reagent are very few in number. Confining attention to benzylmagnesium chloride, anomalous behavior has been observed not only with formaldehyde and benzaldehyde and derivatives, but also with ethyl chlorocarbonate<sup>8</sup> and chloromethyl methyl ether.<sup>9</sup> From the present study it appears that the rearrangements with benzylmagnesium chloride are more general than has been suspected and include such compounds as ethylene oxide, ethyl formate, chloromethyl ethyl ether and acetyl chloride.

Of equal importance is the observation that the rearrangement does not involve exclusively the *ortho* position. For example, the reaction

<sup>2</sup> Tiffeneau and Delange, *Compt. rend.*, **137**, 573 (1903); Grignard, *Bull. soc. chim.*, **29**, 953 (1903).  $\beta$ -Phenylethyl alcohol is not obtained in this reaction. (See p. 3542 of Ref. 7 of this paper.)

<sup>3</sup> Chichibabin, *Ber.*, **42**, 3474 (1909).

<sup>4</sup> Schmidlin and Banùs, *ibid.*, **45**, 3193 (1912); Marshall, *J. Chem. Soc.*, **105**, 527 (1914); **107**, 509 (1915); Banùs and Vila, *Anales. soc. españ. fís. quím.*, **19**, 326 (1921); [*Chem. Abstracts*, **16**, 3479 (1922)]; Banùs, *ibid.*, **26**, 372 (1928); [*Chem. Abstracts*, **23**, 2178 (1929)]; Banùs and Calvet, *ibid.*, **27**, 49 (1929); [*Chem. Abstracts*, **23**, 3205 (1929)].

<sup>5</sup> Schmidlin, *Ber.*, **39**, 4183 (1906); **41**, 426 (1908); Chichibabin, *ibid.*, **40**, 3965 (1907); Schmidlin and Hodgson, *ibid.*, **41**, 430 (1908). See, also, Gilman and Jones, *THIS JOURNAL*, **51**, 2840 (1929).

<sup>6</sup> Unpublished observations.

<sup>7</sup> Gilman and Harris, *THIS JOURNAL*, **53**, 3541 (1931).

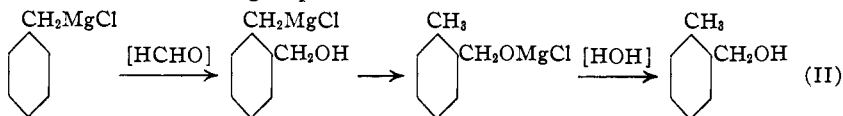
<sup>8</sup> See p. 1826 of Ref. 1a.

<sup>9</sup> Baeyer, German patent 154,658 [*Chem. Zentr.*, II, 1355 (1904)]. Bottomley, Lapworth and Walton, *J. Chem. Soc.*, 2215 (1930).

with ethylene oxide is the first clearly defined case of a *para* rearrangement, to the apparent exclusion of any *ortho* compound.<sup>10</sup> Chloromethyl ethyl ether and chloromethyl methyl ether<sup>9</sup> give both *ortho* and *para* rearrangement products. Ethyl formate likewise gives both types of rearrangement product, but the extent of *para* rearrangement is comparatively small. In brief, then, the rearrangements with benzylmagnesium chloride can be exclusively *ortho* or exclusively *para* or mixtures of the two in varying proportions depending on the reactants and the experimental conditions.

Not all reactants give rise to rearrangement products. It has been definitely shown that carbon dioxide gives exclusively the normal and expected phenylacetic acid,  $C_6H_5CH_2COOH$ . This is fortunate, in a sense, because the carbonation of Grignard reagents has been extensively employed for the characterization of such reagents. However, even this orthodox reagent is not reliable with *all*  $RMgX$  compounds inasmuch as it has been shown recently<sup>1a,7</sup> to react abnormally with the Grignard reagent prepared from cinnamyl chloride to give phenylvinylacetic acid,  $C_6H_5C(COOH)HCH=CH_2$ , and not phenylisocrotonic acid,  $C_6H_5CH=CHCH_2COOH$ . At present, therefore, it is impossible to select any reagent with definite assurance that it will undergo a so-called normal transformation with *all* types of Grignard reagents. There may or may not be such a reactant and only future experiments by a group of workers will answer the need. Not much is now known concerning  $RMgX$  compounds having the general grouping  $\begin{array}{c} | \\ -C=C-C-MgX \\ | \end{array}$  because many of them, like  $\alpha$ -naphthylmethylmagnesium chloride,<sup>1b</sup> cinnamylmagnesium chloride,<sup>11</sup> allylmagnesium bromide<sup>12</sup> and *p*-methoxybenzylmagnesium bromide<sup>13</sup> have only recently become available, either at all or in satisfactory yields.

Several mechanisms have been proposed for the rearrangements of benzylmagnesium chloride. The first of these by Tiffeneau and Delange<sup>2</sup> involves the following sequence of reactions:



Then Schmidlin and Banùs<sup>4</sup> suggested that benzylmagnesium chloride might be an equilibrium mixture of benzenoid and quinonoid forms, in

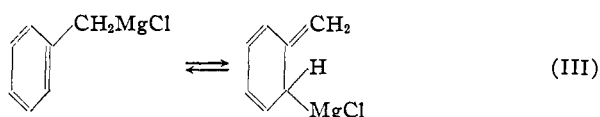
<sup>10</sup> Chichibabin<sup>3</sup> reported *p*-benzoylbenzoic acid among the oxidation products of the reaction between benzylmagnesium chloride and benzaldehyde. However, Schmidlin and Banùs, *Ber.*, **45**, 3193 (1912), failed to obtain that compound. A *para* rearrangement has been reported with triphenylmethylmagnesium chloride.

<sup>11</sup> Gilman and Harris, *Rec. trav. chim.*, **50** (1931).

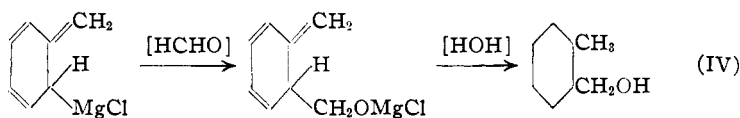
<sup>12</sup> Gilman and McGlumphy, *Bull. soc. chim.*, **43**, 1322 (1928).

<sup>13</sup> Gilman and Zoellner, *ibid.*, **49**, 7 (1931).

accordance with the two corresponding forms suggested for the related triphenylmethylmagnesium chloride:

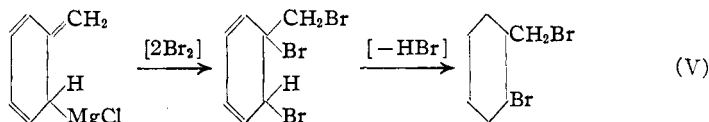


With this mechanism, the equilibrium is shifted completely to the left with carbon dioxide, to the right with formaldehyde, and with benzaldehyde the displacement of the equilibrium depends on the concentration of reactants and the mode or order of addition of the Grignard solution. At that time there was no observed para rearrangement with benzylmagnesium chloride. However, our present para rearrangement (with ethylene oxide, for example) can be fitted in with such a scheme of things by merely introducing a para-quinonoid form; and, where both ortho and para rearrangements are observed, it only becomes necessary to extend equilibrium (III) to include the para-quinonoid form. Using formaldehyde as a type, the quinonoid form is believed to react as follows<sup>4</sup>



Banùs and Vila<sup>4</sup> are inclined to discard the quinonoid form (III) because one molecule of it should react with one molecule of a di-carbonyl compound like benzil and because *o*-tolylmagnesium halides react normally with benzaldehyde.<sup>14</sup>

The quinonoid form might be expected to react with bromine to some extent at low temperatures to give *o*-bromobenzyl bromide, as follows

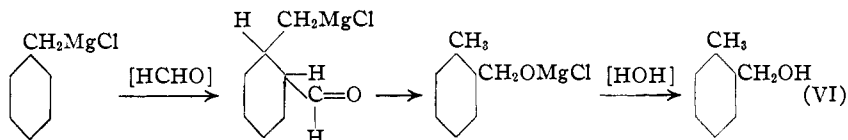


The only product isolated from this reaction was benzyl bromide of high purity. This experiment is hardly of unequivocal importance, because the equilibrium (III) might have been shifted under the experimental conditions. The presence of a quinonoid form might be definitely ascertained by chemical means were it possible to reduce catalytically benzylmagnesium chloride, which so far is not the case. Catalytic reduction followed by carbonation and hydrolysis would be expected to give among the products 2-methylcyclohexanecarboxylic acid. Ozonization, likewise, is of little

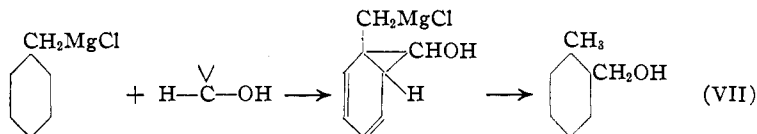
<sup>14</sup> Banùs and Medrano, *Anales soc. españ. fis. quim.*, **21**, 436 (1923); [*Chem. Abstracts*, **18**, 2144 (1924)]. They point out that the normal reaction with *o*-tolylmagnesium halides implies that it is not in equilibrium with the quinonoid form of benzylmagnesium chloride, (III).

present promise, but for another reason: namely, the highly explosive reaction between phenylmagnesium bromide and ozone.<sup>15</sup> Absorption spectra studies now in progress with triphenylmethylmagnesium halides may be of assistance.

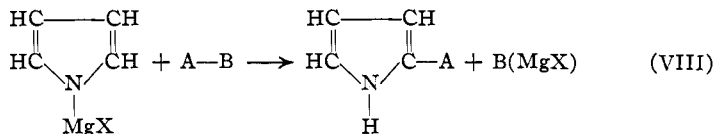
Other mechanisms, using formaldehyde as the reactant, are the following<sup>16</sup>



and that involving a methylenic modification of formaldehyde



Admittedly, none of the several proposed interpretations has any convincing experimental support. If the latter interpretations and that of Tiffeneau and Delange<sup>2</sup> have any merit, it lies in the emphasis they direct to the fact that no migration of the  $-\text{MgX}$  has necessarily occurred and the apparent rearrangement is one that ensues when the  $\text{RMgX}$  compound reacts with particular compounds. This is well illustrated with pyrrolmagnesium halides where the  $-\text{MgX}$  group is almost certainly attached to nitrogen and yet in many reactions the substituent finds itself generally on the  $\alpha$ -carbon atom.<sup>17</sup>



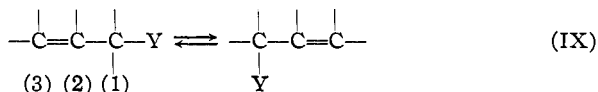
Whatever explanation may be correct, it appears to be definitely established that the rearrangement reactions of benzylmagnesium chloride types are general with  $\text{RMgX}$  compounds having the grouping:  $-\text{C}=\text{C}-\text{C}-\text{MgX}$ . It apparently does not occur with cyclohexylmethylmagnesium halides,  $\text{C}_6\text{H}_{11}\text{CH}_2\text{MgX}$ ; and our experiments have shown that there is no nuclear rearrangement with formaldehyde and  $\beta$ -phenylethylmagnesium bromide,  $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{MgBr}$ ,  $\beta$ -styrylmagnesium bromide,  $\text{C}_6\text{H}_5\text{CH}=\text{CHMgBr}$ , and phenylacetylmagnesium bromide,  $\text{C}_6\text{H}_5\text{C}\equiv\text{CMgBr}$ . It would be interesting to ascertain whether *o,o,p*-trisubstituted benzylmagnesium halides undergo rearrangement.

<sup>15</sup> Private communication from Professor L. I. Smith.

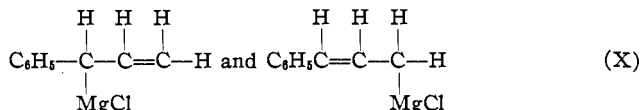
<sup>16</sup> J. E. Kirby, Doctoral Thesis, Iowa State College, 1929.

<sup>17</sup> Gilman and Heck, *THIS JOURNAL*, **52**, 4949 (1930).

Inasmuch as the rearrangement is common to compounds having the  $-\text{C}=\text{C}-\text{C}-\text{MgX}$  group, it appears altogether reasonable to consider them as allylic rearrangements



of a three-carbon system where the element or group (Y) shifts from carbon (1) to carbon (3) with the accompanying displacement of a double bond. Such an interpretation has very recently<sup>7</sup> been proposed for cinnamylmagnesium chloride reactions. Despite the fact that there is no general agreement on the mechanism or mechanisms underlying allylic rearrangements, the case for cinnamylmagnesium chloride finds support with related types. With cinnamylmagnesium chloride we have the following



and all reactions so far studied are best explained on the basis of the first formula. The second formula is not excluded because, as with pyrrolmagnesium halides, the position of the  $-\text{MgX}$  group need not be that assumed by the group which replaces it. The two formulas illustrated in (X) may be merged and represented by the internally symmetrical formula given (with the  $\text{MgX}$  ion or ions held electrostatically) and from an electronic viewpoint the difference in electron attraction between a phenyl group and the hydrogen displaces the electrons in the brackets from right to left and so determines whether the entering group or element attaches itself to carbon (1) or carbon (3). Such a scheme adapts itself to some of the cinnamyl derivatives. For example, carbon (3) being relatively negative would attract and hold the  $-\text{MgX}$  group, and carbon (1) being relatively positive would attract a halogen.

In the case of benzylmagnesium chloride and related aryl- $\text{CH}_2\text{MgX}$  types, the double bond necessary for an allylic system is contained in the benzene nucleus. This, however, need not affect seriously such a system because it has been definitely shown that such nuclear unsaturation gives normal conjugated system reactions with  $\text{RMgX}$  compounds when the nuclear olefinic linkage is conjugated with lateral unsaturation as in benzophenone-anil,<sup>18</sup>  $(\text{C}_6\text{H}_5)_2\text{C}=\text{NC}_6\text{H}_5$ , and highly phenylated ketones.<sup>19</sup> If we admit an allylic system for the rearrangements of benzylmagnesium

<sup>18</sup> Gilman, Kirby and Kinney, *THIS JOURNAL*, **51**, 2252 (1929).

<sup>19</sup> Kohler and Nygaard, *ibid.*, **52**, 4128 (1930).

chloride, we are thrown back to the quinonoid form (III) of Schmidlin and Banùs<sup>4</sup> as one of several explanations of allylic rearrangements. However, not only is there no present agreement on the mechanism of allylic rearrangements in general, but there are explanations which interpret the "rearrangement" without recourse to the migration of elements or groups.<sup>7</sup> Furthermore, an extension of allylic systems is desirable to include para rearrangements. It is interesting to recall that with cinnamylmagnesium chloride<sup>7</sup> the rearrangement is apparently halted in the lateral allylic system and that no so-called double-allylic rearrangement occurs to give an ortho or para nuclear substituted product. This need not be interpreted to mean that there is no allylic system in the benzylmagnesium chloride type which results, namely,

$$\begin{array}{c} \text{C}_6\text{H}_5\text{C}-\text{CH}=\text{CH}_2 \\ | \\ \text{MgCl} \end{array}$$

Instead, there is the possibility that the  $\text{C}_6\text{H}_5\text{CH}=\text{CHCH}_2\text{MgCl}$  underwent one allylic rearrangement with a given reactant, and that the formation of the product (with carbon dioxide,  $\text{C}_6\text{H}_5\text{CH}(\text{COOH})-\text{CH}=\text{CH}_2$ ) destroyed the  $-\text{MgX}$  group and so rendered impossible a second allylic rearrangement to the nucleus. Because of a similarity between cinnamylmagnesium and benzylmagnesium halides, it is reasonable to assume that the rearrangements of benzylmagnesium halide types also involve free radicals<sup>7</sup> and the electronic interpretations which have been proposed for general allylic rearrangements.<sup>7</sup>

### Experimental Part

**Oxidation Procedure for Nuclear Substitution Products.**—Because of the difficulty in isolating small quantities of reaction products, the residual oils and in some cases all of the product, were oxidized to the corresponding acids and any benzoic, phthalic and terephthalic acids identified by customary methods. In general, an excess of permanganate was employed, usually in concentrations of about 5% and containing about 10% of sodium or potassium hydroxide. At the conclusion of the oxidation, which required from thirty minutes to several hours, depending on the nature of the material, the excess permanganate was destroyed by adding a little alcohol, and the heavy manganese dioxide precipitate filtered off with suction. After washing the sludge of manganese dioxide with a little dilute alkali, the filtrate and washings were combined and acidified with hydrochloric acid.

The separation depends on the varying solubilities of benzoic, phthalic and terephthalic acids in water and chloroform. Benzoic acid is soluble in water<sup>20</sup> to the extent of 0.34 g. in 100 g. at 25°, and soluble in chloroform; phthalic acid is soluble in water<sup>21</sup> to the extent of 0.54 g. in 100 g. at 14°, and insoluble in chloroform;<sup>22</sup> and terephthalic acid is only soluble in water<sup>23</sup> to the extent of one part in 67,000, and insoluble in chloroform.<sup>21</sup>

On acidification, all of the terephthalic acid precipitates along with part of the benzoic acid, which is usually present in the largest quantity. The phthalic acid stays in solution along with the remainder of the benzoic acid. The precipitated acids are

<sup>20</sup> Hoffmann and Langbeck, *Z. physik. Chem.*, 51, 394 (1905).

<sup>21</sup> Graebe, *Ann.*, 238, 321 (1887).

<sup>22</sup> Zincke and Breuer, *ibid.*, 226, 53 (1884).

<sup>23</sup> Baeyer, *ibid.*, 251, 284 (1889).

separated by simply extracting the benzoic acid from the terephthalic acid with chloroform. The water solution is extracted two or three times with ether, the ether dried over sodium sulfate and evaporated to dryness. The residual benzoic acid and phthalic acids are separated by a chloroform extraction of the benzoic acid. Had isophthalic acid formed during any of the oxidations it would have escaped detection in the above procedure. The solubility of isophthalic acid in water is low (1 part in 7800) and it probably would have appeared along with the terephthalic acid.

**Carbon Dioxide.**—An ether solution of 0.25 mole of benzylmagnesium chloride was sprayed upon the vanes of a stirrer contained in a flask, cooled by an ice-salt mixture, through which carbon dioxide circulated. Despite the apparent purity of the resulting phenylacetic acid, it was fractionally crystallized in an unsuccessful effort to isolate any toluic acids which might be present. Hot water was used as the solvent because *o*- and *p*-toluic acids are less soluble than phenylacetic acid in water. Oxidation of the yellow residual oil gave only benzoic acid.

**Bromine.**—A cold solution of 0.25 mole of benzylmagnesium chloride was added over a one-half hour period to a 0.5 mole solution of bromine in ether cooled by carbon dioxide snow and ether. The cold mixture was immediately hydrolyzed by pouring upon cracked ice. Practically all of the product distilled at 73–74° (10 mm.) to give a 63% yield of benzyl bromide, which was characterized as benzyl phthalimide.

**Benzonitrile.**—The yield of phenyl benzyl ketone from a 0.3 mole run was 53.4%. The ketone was identified by a mixed melting point determination with an authentic specimen, and by its oxime. Because of difficulty with the nitric acid oxidation<sup>24</sup> of phenylbenzylcarbinol,  $C_6H_5CHOHCH_2C_6H_5$ , to the ketone, 10 g. of the carbinol was oxidized by stirring for one hour at 50–60° with a solution containing 4.5 g. of sodium dichromate and 6 cc. of concentrated sulfuric acid in 100 cc. of water.

Exhaustive permanganate oxidation of the oily residue from the Grignard reaction gave only benzoic acid.

**Chloroacetophenone,  $C_6H_5COCH_2Cl$ .**—Oxidation of the mixture from a low temperature (–18°) reaction between 0.1 mole of chloroacetophenone and 0.7 mole of benzylmagnesium chloride gave only benzoic acid.

**Diphenylcarbamine Chloride,  $(C_6H_5)_2NCOCl$ .**—The acid amide mixture from a 0.1-mole run of diphenylcarbamine chloride and benzylmagnesium chloride was hydrolyzed by alcoholic potash to give phenylacetic acid but no toluic acids.

**Acetyl Chloride.**—*o*-Methylacetophenone and related products are formed to a limited extent, because oxidation of the reaction mixture from acetyl chloride and benzylmagnesium chloride gave not only benzoic acid but also a very small quantity of phthalic acid.

**Ethylene Oxide.**—Ethylene oxide was distilled into a 0.5 mole solution of benzylmagnesium chloride until a negative color test<sup>25</sup> showed that the Grignard reagent had been used up. The thick mixture was broken up, toluene added, most of the ether distilled off, and the mixture then refluxed with stirring for one hour. After hydrolysis, the mixture was steam distilled. An ether extraction of the steam distillate gave 32.5 g. or 47.8% of a colorless oil with fragrant odor, distilling at 113–115° (10 mm.).

The non-volatile residue from the steam distillation yielded a small amount of terephthalic acid on oxidation.

Oxidation of a 4-g. sample of the oil obtained as a major reaction product gave 1 g. of benzoic acid and nearly 1 g. of terephthalic acid. No phthalic acid was isolated. The oil, which liberates gas with sodium, appears to be a mixture of  $\gamma$ -phenylpropanol and one or more of its isomers.

<sup>24</sup> Limpricht and Schwanert, *Ann.*, 155, 64 (1870).

<sup>25</sup> Gilman and Schulze, *THIS JOURNAL*, 47, 2002 (1925).



**Chloromethyl Ethyl Ether**,  $\text{ClCH}_2\text{OC}_2\text{H}_5$ .—Several experiments were carried out with the chloro ether prepared in accordance with the directions of Wedekind.<sup>26</sup> Oxidation of the products from one run gave benzoic, phthalic and terephthalic acids in quantities which showed that approximately 53% of the reaction was normal, 16% ortho rearrangement and 31% para rearrangement.

From another experiment in which 0.3 mole of the chloro ether was added to an equivalent quantity of the cooled benzylmagnesium chloride, there was obtained 21.9 g. of an oil distilling at 93–97° (7 mm.) and an indefinite oil collected over 170–220° (7 mm.). Permanganate oxidation of a 5.01-g. sample of the low boiling oil gave 1.133 g. of benzoic acid, 0.655 g. of terephthalic acid and 0.092 g. of phthalic acid. The high boiling oil was redistilled and a middle fraction of 1.9 g. was taken between 165–180° (6 mm.), most of it coming over at 175°. Oxidation of this fraction gave 0.2 g. of benzoic acid, 0.1 g. of phthalic acid and 0.2 g. of terephthalic acid.

In a third experiment, carried out like the first by adding the Grignard reagent to the chloro ether, 28 g. of oil distilling at 93–97° (7 mm.) and 5.4 g. distilling between 130–220° (7 mm.) were obtained. Oxidation of 10.68 g. of the low boiling oil gave 3.934 g. of benzoic acid, 0.465 g. of phthalic acid and 1.75 g. of terephthalic acid. Zeisel analyses gave considerable difficulty in the way of obtaining satisfactory check values from aliquots of a selected batch of oil. Because of this difficulty, some ethyl  $\beta$ -phenylethyl ether,  $\text{C}_2\text{H}_5\text{OCH}_2\text{CH}_2\text{C}_6\text{H}_5$ , was synthesized in order to ascertain whether the trouble was inherent in an ether of this type, which is the normal reaction product of benzylmagnesium chloride and chloromethyl ethyl ether. The ethyl  $\beta$ -phenylethyl ether was finally synthesized as follows.

Eight grams (0.35 atom) of metallic sodium in thin slices was added to a solution of 36.6 g. (0.3 mole) of phenylethyl alcohol in dry benzene. The mixture was stirred mechanically and refluxed for about seventeen hours to insure as nearly complete conversion of the alcohol to alcoholate as possible. Fifty-five grams (0.36 mole) of ethyl sulfate was then added through the dropping funnel. A pasty mass separated. The mixture was stirred and refluxed for eight hours. The mass was then removed from the stirring flask and the small pieces of unused sodium removed. Strong ammonium hydroxide was then added and the mixture warmed to hydrolyze the excess ethyl sulfate. The whole mixture was then steam distilled. The oil collected was washed three times with water, then with 50% calcium chloride solution, and finally dried over anhydrous calcium chloride. The benzene was then distilled off and the residual oil distilled under reduced pressure. The yield of oil boiling at 77–82° (7 mm.) was 25.8 g., corresponding to 57.3% of the theoretical amount. On redistillation the boiling point was found to be 85–87° (7 mm.);  $d_{25}^{25}$  0.9200;  $n_D^{25}$  1.4708. A Zerewitinoff analysis of this oil showed no active hydrogen. Although one Zeisel analysis gave a correct value, several were about 2% low.

**Ethyl Chlorocarbonate**,  $\text{ClCOOC}_2\text{H}_5$ .—A solution of 0.25 mole of benzylmagnesium chloride was prepared in the usual manner from 32 g. of benzyl chloride and 6.1 g. of magnesium turnings. The Grignard solution was quickly filtered through glass wool into a separatory funnel. A solution of 126 g. (1.0 mole) of ethyl chlorocarbonate in twice its volume of anhydrous ether was placed in a one-liter 3-necked flask and cooled in an ice-salt mixture. The Grignard solution was then slowly added to the solution in the flask. The addition required about forty-five minutes, vigorous stirring being maintained during the addition. After hydrolyzing with iced hydrochloric acid, the whole mixture was steam-distilled. The distillate was extracted with ether, the ether extracts dried over sodium sulfate and the ether then distilled off. The remaining oil was

<sup>26</sup> Wedekind, *Ber.*, **36**, 1383 (1903). From our experiments we recommend that the chloromethyl ethyl ether be fractionated under reduced pressure.

refluxed for three hours with 10% alcoholic potassium hydroxide. The solution was cooled, extracted with ether to remove unhydrolyzed oils, and then acidified with hydrochloric acid. The total volume was then about 800 cc. The solution was milky but contained no crystals. After about two hours a few flaky crystals separated and were filtered off. These weighed 1.0 g. (2.9%) and melted at 103–105°. A mixed melting point with *o*-toluic acid was found to be 103°. The remaining water solution was twice extracted with ether, the ether extracts washed with a little cold water and in turn extracted with 100 cc. of 10% potassium hydroxide. On acidification with hydrochloric acid and cooling, 4.7 g. of slightly impure phenylacetic acid was obtained in the form of shining leaflets melting at 68°. A mixed melting point with phenylacetic acid was 71°. This fractional separation of *o*-toluic and phenylacetic acids was of course not quantitative. Approximately 20% of ortho rearrangement appears to have occurred.

A second experiment was carried out in the hope of showing the presence of ethyl *p*-toluate in the reaction products along with ethyl phenylacetate and ethyl *o*-toluate. Two-tenths mole of benzylmagnesium chloride solution was slowly added to a well-stirred solution of 40 g. (0.37 mole) of ethyl chlorocarbonate in 200 cc. of ether. The temperature was kept at about –13–15° by means of an ice–salt mixture. The addition required about one hour. A color test showed the absence of Grignard reagent. After hydrolyzing with ice and dilute hydrochloric acid, the mixture was steam-distilled until nothing more came over. The residual tar was exhaustively oxidized in the customary manner. A trace of *o*-phthalic acid was found and a cloudiness indicative of terephthalic acid.

The oil and ether from the steam distillation were separated from the water and dried over sodium sulfate. The ether was distilled off and the temperature raised to 110° to remove unused ethyl chlorocarbonate. The residue yielded 9.5 g. of liquid esters boiling at 98° (6 mm.). This corresponds to a yield of 29% of mixed, isomeric esters. The total amount of oil was hydrolyzed by refluxing for six hours with 10% alcoholic potash. Acidification yielded an oily precipitate and attempts to crystallize from water were fruitless. The oil was recovered from the water by ether extraction, and then taken up in 95% alcohol and set aside to crystallize slowly. After about three months a crop of heavy, blunt needles, many over one-half inch long, had formed. These needles were removed from the oil and dried on filter paper; yield, 1.1 g.; m. p. 100–101°. A mixed melting point determination showed them to be *o*-toluic acid. The residual oil weighed 4.0 g. The yield of *o*-toluic acid was 4% based on Grignard reagent used; 14% based on the total ester obtained; and 21.5% on the total acid derived by hydrolysis of the ester.

**Ethyl Formate.**—Oxidation of the reaction mixture obtained by adding 0.3 mole of benzylmagnesium chloride to 0.3 mole of ethyl formate at –18°, yielded 9 g. of benzoic acid, 0.75 g. of phthalic acid and a quantity of terephthalic acid insufficient to isolate.

**Benzyl Chloride.**—A mixture of 0.2 mole of benzylmagnesium chloride and 0.2 mole of benzyl chloride was refluxed for two and one-half hours after stirring for three hours at room temperature. A negative color test showed that the Grignard reagent had been used up. The yield of dibenzyl was 64.8%. Exhaustive oxidation of the oils gave only benzoic acid.

**Cyclohexylmethylmagnesium Bromide (C<sub>6</sub>H<sub>11</sub>CH<sub>2</sub>MgBr) and Formaldehyde.**—Gaseous formaldehyde was added to 0.25 mole of cyclohexylmethylmagnesium bromide<sup>27</sup> until a negative color test was obtained (forty-five minutes). The yield of cyclohexyl-

<sup>27</sup> There was no difficulty in initiating the formation of this Grignard reagent, which, incidentally, was completely free of any color or cloudiness.

ethanol<sup>28</sup> was 14.7 g. or 46%; b. p. 198–202° (742 mm.);  $n_D^{20}$  1.4648. The oil was identified by oxidation to  $\beta$ -cyclohexylacetaldehyde.<sup>28</sup> The semicarbazone of the aldehyde, after recrystallization from alcohol, melted at 147–149°, and the cyclohexylacetamide (m. p., 165–166°) showed no depression in a mixed melting point determination. The identification of by-products has not been completed.

**Formaldehyde with  $\beta$ -Phenylethylmagnesium Bromide ( $C_6H_5CH_2CH_2MgBr$ ),  $\beta$ -Styrylmagnesium Bromide ( $C_6H_5CH=CHMgBr$ ) and Phenylacetylmagnesium Bromide ( $C_6H_5C\equiv CMgBr$ ).**—Formaldehyde was passed into each of these three Grignard reagents until a negative color test was obtained. Oxidation of parts of the main reaction products and of residual oils gave only benzoic acid.

**Sodium Phenate and Ethyl Chlorocarbonate.**—In order to determine whether sodium phenate,  $C_6H_5ONa$ , might undergo nuclear substitution by rearrangement under the moderate conditions used with benzylmagnesium chloride, 0.3 mole of ethyl chlorocarbonate was added slowly with vigorous stirring to 0.3 mole of sodium phenate in toluene at  $-18^\circ$ . The initial heavy paste disappeared, and after allowing the mixture to warm up to room temperature it was hydrolyzed. The yield of ethyl phenylcarbonate was 28.2 g. or 56.6%. No ethyl salicylate (one of the possible rearrangement products) was isolated.

### Summary

Benzylmagnesium chloride undergoes rearrangement reactions with a variety of compounds. The rearrangement may be exclusively ortho, exclusively para or mixtures of ortho and para in varying proportions depending on the reactants and on experimental conditions. Carbon dioxide and some other reagents behave normally. The rearrangements of benzylmagnesium chloride and related types having the group  $-C=C-\overset{|}{\underset{|}{C}}-MgX$  can be correlated with allylic or three-carbon system rearrangements.

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<sup>28</sup> Hiers and Adams, *THIS JOURNAL*, **48**, 1091 (1926).

<sup>29</sup> Wallach, *Ann.*, **359**, 313 (1908), reported that m. p. as 132–134°. Zelinsky, *Ber.*, **41**, 2628 (1908) prepared the ethanol and his constants are in agreement with ours. The melting point of the semicarbazone of the aldehyde was not given in the *Ber.* reference. See, also, Zelinsky, *J. Russ. Phys.-Chem. Soc.*, **38**, 930 (1906).