

solution. This method of preparation is to be preferred over that of condensation of RX with pyrrolidine as the yields are often low by the latter method due to formation of the quaternary derivative.

*p*-Toluidine condenses smoothly with tetramethylene chloride to give *N-p*-tolylpyrrolidine.

The compounds *N-p*-tolylpyrrolidine, *N-n*-butylpyrrole- $\alpha$ -carboxylic acid and *N-n*-butylpyrrole- $\alpha$ -acid amide are reported for the first time. The properties of *N-n*-butylpyrrolidine, *N-n*-butylpyrrole and *N-n*-butylpyrrole- $\alpha$ -carboxy-*N*-butyl amide are given.

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[CONTRIBUTION NO. 36 OF THE CHEMICAL LABORATORY OF THE UNIVERSITY OF UTAH]

## THE CATALYTIC EFFECT OF MAGNESIUM ALCOHOLATES ON THE REACTION OF GRIGNARD REAGENTS WITH CARBON DIOXIDE<sup>1</sup>

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Although many substances have been shown to have deleterious effects in Grignard reactions, nothing appears to be known about the effect of alcohols, which are often present in the organo halides from which the reagents are made. The catalytic behavior of alcohols or their magnesium derivatives was first brought to our attention by the variable yield of triphenylacetic acid obtained from triphenylmethylmagnesium chloride and carbon dioxide. A study of the reaction showed definitely that the presence of small amounts of triphenylcarbinol in the triphenylchloromethane used to make the reagent very materially lowered the yield of triphenylacetic acid.

The systematic addition of increasing quantities of triphenylcarbinol gave a yield curve shown in Fig. 1 as the lower curve, in which an addition of 15.3 mols per cent. of triphenylcarbinol caused the yield of triphenylacetic acid to drop from 75%<sup>2</sup> to 0%. The upper straight line in Fig. 1 represents the yield of acid to be expected based on the yield of acid without addition of the carbinol and subtracting an amount corresponding to the diminution in yield caused by the reaction of a part of the reagent with the carbinol.

The lowering in yield of acid was not caused by an interference in the reaction of the triphenylchloromethane with the magnesium to form the Grignard reagent, since the same amount of triphenylcarbinol (15.3 mole per cent.) when added *after the reagent had been prepared* prevented the reaction

<sup>1</sup> Parts of this paper have been presented at the Berkeley and Eugene meetings of the Pacific Division of the American Association for the Advancement of Science and at the Minneapolis meeting of the American Chemical Society.

<sup>2</sup> The maximum yield obtained was 87.5%, but the method used was not adaptable to the study at hand.

with carbon dioxide from taking place. The same result was observed when the mixture was *stirred* and *refluxed* continuously for twenty-four hours. However, in another experiment a similar solution of triphenylmethylmagnesium chloride, containing 15.3 mole per cent. of carbinol was allowed to *stand* in contact with carbon dioxide, at room temperature, for

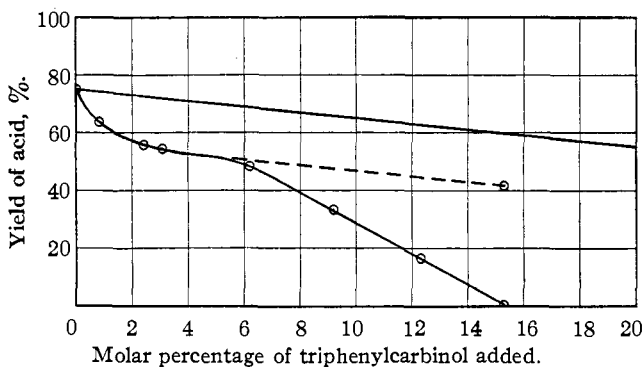


Fig. 1.—The effect of triphenylcarbinol on the yield of triphenylacetic acid obtained by the reaction of triphenylmethylmagnesium chloride with carbon dioxide.

sixty hours. A moderate yield of acid was obtained and is shown in Fig. 1 midway between the two curves mentioned above and is connected with the lower or experimental curve by a dotted line.

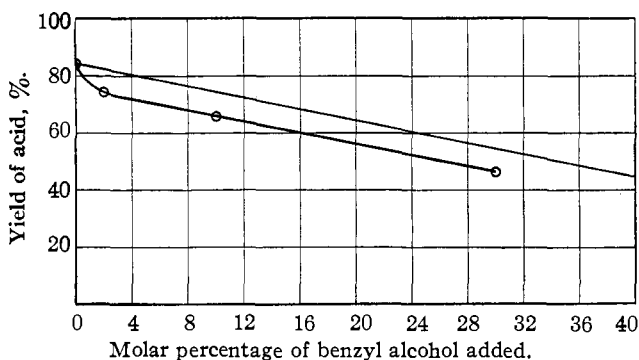


Fig. 2.—The effect of benzyl alcohol on the yield of phenylacetic acid obtained by the reaction of benzylmagnesium chloride with carbon dioxide.

If the curve in Fig. 1 is compared with those of the other reagents investigated (Figs. 2, 3, 4) it will be noted that the curve for triphenylmethylmagnesium chloride differs from all of the others in that there is a downward change in direction of the curve beyond about 6 mole per cent. addition of carbinol, but that the dotted line makes a curve that compares very nicely

with all of the others. There seems to be at least two possible explanations of this unique behavior of triphenylmethylmagnesium chloride. In the first place this reagent, as well as many of its reaction products, differs from the other reagents in being much less soluble in ether. The reaction

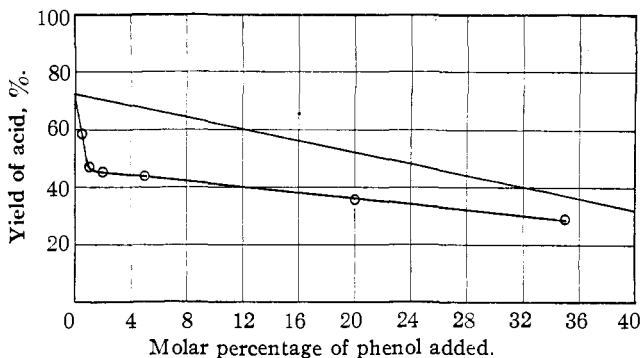


Fig. 3.—The effect of phenol on the yield of benzoic acid obtained by the reaction of phenylmagnesium bromide with carbon dioxide.

of the reagent with carbon dioxide is accompanied by the solution of the yellowish precipitate of the reagent with the formation of a clear deep blood-red solution which more or less quickly, depending upon the rate of addition of the carbon dioxide, precipitates a yellowish-white substance which

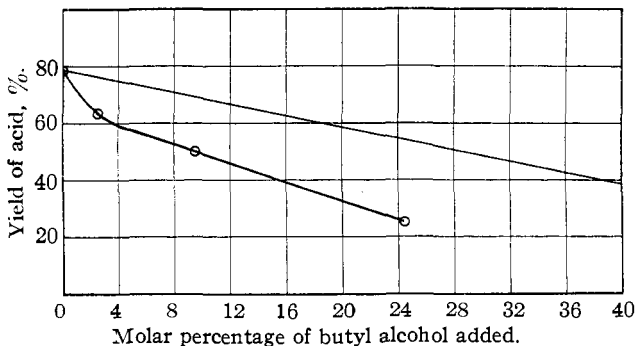
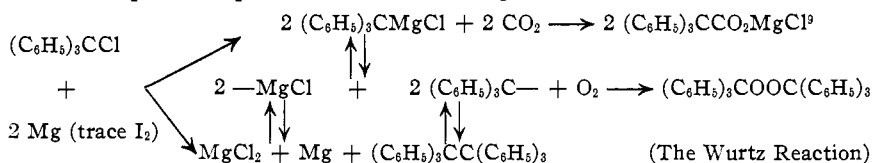


Fig. 4.—The effect of butyl alcohol on the yield of valeric acid obtained by the reaction of butylmagnesium bromide with carbon dioxide.

is probably the magnesium salt of triphenylacetic acid. When triphenylcarbinol was added, however, in amounts corresponding to the downward drop in the curve (6 mole per cent. or more) the reagent did not dissolve nor was a red solution produced, indicating that in the heterogeneous mixture a new factor influencing the course of the reaction was present. This

point on the curve might well correspond to the formation of a precipitate of the magnesium derivative of triphenylcarbinol.

Gilman and McGlumphy<sup>3</sup> and Gomberg and Bachmann<sup>4</sup> have shown recently that triphenylmethylmagnesium iodide may be prepared from triphenylmethyl and magnesium iodide, a reaction which explains the high yields of triarylmethylmagnesium halides from the tertiary halides of the type of triphenylchloromethane. This reaction is incorporated in the combined reactions given below. The reverse process, the dissociation of triphenylmethylmagnesium chloride into triphenylmethyl, seems probable in view of the fact that oxygen<sup>5</sup> reacts smoothly with the solution to give an almost quantitative yield of triphenylmethyl peroxide,<sup>6</sup> a reaction more characteristic of triphenylmethyl than of Grignard reagents.<sup>7</sup> Thus, the reactions of triphenylmethylmagnesium chloride are complicated by the possible presence of triphenylmethyl,<sup>8</sup> which may in part be responsible for the greater effect of triphenylcarbinol on this reagent. These inter-relationships are expressed in the following reactions.



Gilman and St. John<sup>9a</sup> have recently shown that bromomagnesium triphenylcarbinolate when heated in ether solution was transformed slowly into triphenylmethane, and that in the presence of ethylmagnesium bromide the transformation did not take place. This reaction suggests the possibility that triphenylmethane was responsible for the decreased yield of triphenylacetic acid. However, the addition of triphenylmethane to a solution of triphenylmethylmagnesium chloride had little effect on the yield of acid obtained therefrom.

The reagent most closely related to triphenylmethylmagnesium chloride

<sup>3</sup> Reference 12 of a paper by Gilman and Fothergill, *THIS JOURNAL*, 51, 3152 (1929).

<sup>4</sup> Gomberg and Bachmann, *ibid.*, 52, 2455 (1930).

<sup>5</sup> Gilman and Fothergill, Ref. 3, p. 3151, have presented other evidence for the dissociation of triphenylmethylmagnesium chloride.

<sup>6</sup> This reaction has been observed by Schmidlin, *Ber.*, 39, 4183 (1906); 41, 423 (1908).

<sup>7</sup> Several studies of the reaction of Grignard reagents with oxygen have been recorded but peroxides have not been isolated excepting from the triarylmagnesium halides although the assumption has been made by a number of authors that peroxides are formed as intermediates.

<sup>8</sup> Gomberg and Bachmann, Ref. 4, p. 2456, have suggested that the presence of triphenylmethyl in the reaction of triphenylchloromethane with magnesium has been the cause of certain misunderstandings in connection with this reagent.

<sup>9</sup> This reaction is affected very greatly by the presence of triphenyl carbinol.

<sup>9a</sup> Gilman and St. John, *Rec. trav. chim.*, November, 1930.

that was studied was diphenylmethylmagnesium chloride. Only small yields of this reagent were obtainable,<sup>10</sup> the major product being tetraphenylethane. The yield, furthermore, was very dependent on the history of the diphenylchloromethane from which the reagent was made, as, for example, a yield of 23% obtained with freshly distilled chloride dropped to 4% by merely allowing the chloride to stand in a brown, glass-stoppered bottle for three weeks.

Many attempts were made by Mr. Langlois in this Laboratory to overcome these difficulties and to dissociate tetraphenylethane in the presence of magnesious iodide, endeavoring to produce diphenylmethylmagnesium chloride in a way similar to the formation of triphenylmethylmagnesium chloride from triphenylmethyl and magnesious iodide and to effect the cleavage of tetraphenylethane with magnesious iodide similar to the cleavage observed with the alkali metals.<sup>11</sup> The reaction, unfortunately, was not realized even working to temperatures as high as 300° in an atmosphere of carbon dioxide.

The effect of diphenylcarbinol on the reaction of diphenylmethylmagnesium chloride with carbon dioxide could not be determined accurately because of the experimental difficulties with the reagent. One comparable result is given in the experimental part which shows only a slight diminution of the yield. This small effect may be masked by the presence of diphenylcarbinol in the chloride used to make the reagent.

The results obtained for phenylmethyl or benzylmagnesium chloride, phenylmagnesium chloride and butylmagnesium bromide were more conclusive (Curves 2, 3, 4). In the reaction of all of these reagents with carbon dioxide the presence of a small quantity of the alcohol or phenol corresponding to the reagent produced a marked drop in the yield of acid beyond that caused by the expected reaction of the carbinol with a part of the reagent. The latter is shown by the upper line in each diagram. Further additions caused further diminutions in the yields of the acids, but the lowering of the yield was much less precipitous.

The results shown in the diagrams (1, 2, 3, 4) above were all obtained by adding the carbinol along with the organo halide from which the reagents were made. The effects of adding the carbinol after the reagents had been made are shown in Table I, in which it is to be noted that in all cases, except the action of phenol on phenylmagnesium bromide, about the same lowering in yield was obtained. With the exception mentioned the loss in yield was considerable while not nearly as great as that caused by adding the phenol with the phenyl bromide when making the reagent.

The effect of adding phenol to triphenylmethylmagnesium chloride and

<sup>10</sup> Gilman and Zoellner, *THIS JOURNAL*, **52**, 3984 (1930), have succeeded recently in materially increasing the yield of this reagent and the acid obtained from it.

<sup>11</sup> Ziegler and Thielmann, *Ber.*, **56B**, 1740 (1923).

TABLE I  
 RESULTS OF EXPERIMENTS

Reagent	Mole per cent. of carbinol added	Yield to be expected, %	Yield adding carbinol before, %	Yield adding carbinol after, %
Triphenylmethylmagnesium chloride	15.3	59.7	0	0
Benzylmagnesium chloride	10	74.5	65.8	62.5
Phenylmagnesium bromide	1	71.1	47	61.4
Butylmagnesium bromide	9.5	68.9	50	48

triphenylcarbinol to phenylmagnesium bromide was determined in attempting to find some explanation for the catalysis. In these two determinations the yields of the acids were about the expected amount based on the maximum yields and subtracting for the amount of carbinol added. Thus the effect appears to be concerned with the carbinol corresponding to the Grignard reagent. However, the reaction of triphenylmethylmagnesium chloride with carbon dioxide was very materially affected by the addition of small quantities of benzaldehyde, the addition of 28.4 mole per cent. of benzaldehyde being sufficient entirely to prevent the formation of the acid with carbon dioxide. These results are shown in Fig. 5, the depression curve being the lower straight line.

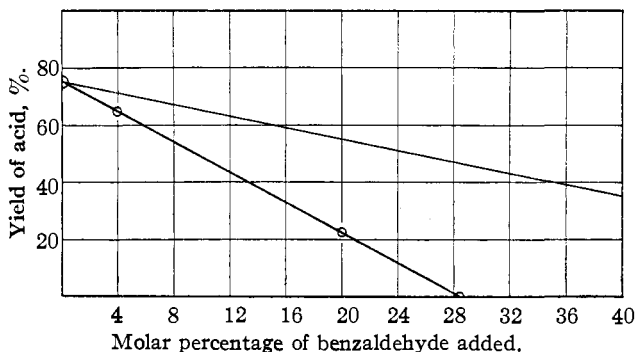
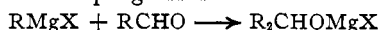


Fig. 5.—The effect of benzaldehyde on the yield of triphenylacetic acid obtained by the reaction of triphenylmethylmagnesium chloride with carbon dioxide.

The explanation offered for the depressing effect of benzaldehyde is that the reagent reacted with the aldehyde, forming the magnesium derivative of  $\alpha,\beta,\beta,\beta$ -tetraphenylethyl alcohol, which appears to be about half as effective as triphenylcarbinol.

The addition of alcohols to the reaction of Grignard reagents with carbonyl compounds other than carbon dioxide would be expected to cause very little lowering of the yield because of the fact that high yields are obtainable from the reaction in spite of the fact that magnesium alcoholates are produced as the reaction progresses.



This view was tested in one experiment only in which 2.43 mole per cent. of butyl alcohol was added to butylmagnesium bromide and then the reagent allowed to react in the usual way with benzaldehyde. The lowering in yield was 2.5% as compared with the addition of 2.43%.

The mechanism of the catalytic effect of the presence of magnesium alcoholates on the reaction of Grignard reagents with carbon dioxide is not clear at this time. The curves seem to have a characteristic shape and the percentage depression is much greater for smaller additions of the alcohol. Some further studies under way may help to clear this up.

### Experimental Part

**Reactions Involving Triphenylmethylmagnesium Chloride.**—The triphenylmethylmagnesium chloride was prepared in essentially the way that Gilman and Zoellner<sup>12</sup> recommend, except that we did not carry out the reaction under an inert atmosphere. This probably is quite advantageous as we obtained an increase of 12.5% in the yield of triphenylacetic acid by carrying out the entire reaction in an atmosphere of dry carbon dioxide (compare Expt. 4 with 3).

Especial care was taken to free the triphenylchloromethane from impurities by dissolving the crude product of the Friedel and Crafts reaction in a minimum of boiling chloroform followed by dilution with three volumes of ether as the solution cooled. The chloride crystallized well, the recovery was good and the color was practically removed. The material was then recrystallized from boiling gasoline as it was found that the trace of chloroform present interfered with the reaction. The melting point was 115°. Moisture should be excluded from the chloride as the hydrogen chloride produced as well as the carbinol was found to be an active negative catalyst.

Crude triphenylchloromethane direct from the Friedel and Crafts synthesis was quite reactive. Several preparations were found to react smoothly with magnesium to form the Grignard reagent, while the more purified material described above did not. This led to an investigation of the effect of anhydrous aluminum chloride, which may have been present in the crude material, as a catalyst for the Grignard reaction. Anhydrous aluminum chloride did start the reaction nicely, but the yield of triphenylacetic acid was somewhat lower than when using iodine. For the preparation of triphenylacetic acid, freshly prepared crude chloride from the Friedel and Crafts reaction gives yields sufficiently high to make the purification of the halide unprofitable.

Since we were studying the effect of adding various substances to the reaction it was not convenient to carry out the reaction in an atmosphere of carbon dioxide. The procedure used was briefly as follows: 7 g. of the purified triphenylchloromethane, 0.2 g. of iodine, 2 g. of powdered magnesium and 200 cc. of sodium-dried ether were allowed to react for one hour with stirring and gentle refluxing. Carbon dioxide was then admitted and the stirring and refluxing were continued for three hours. The mixture was then decomposed and the triphenylacetic acid isolated according to Schmidlin.<sup>13</sup> In Table II are given the results of a number of experiments which have some variation from this general procedure and which show the effect of the history of the chloride used, the substitution of aluminum chloride for the iodine, etc.

The addition of triphenylcarbinol lowered the yield of triphenylacetic acid according to the results listed in Table III. The carbinol added is given in mole per cent. of the chloride used in making the reagent. The

<sup>12</sup> Gilman and Zoellner, *THIS JOURNAL*, 51, 3493 (1929).

<sup>13</sup> Schmidlin, *Ber.*, 39, 634 (1906).

TABLE II  
 RESULTS OF EXPERIMENTS

No.	Variation in the experiment	Yield of triphenylacetic acid, %
1	Chloride recryst. from $\text{CH}_3\text{COCl}$	66 and 41.5
2	Chloride recryst. from $\text{CHCl}_3\text{-Et}_2\text{O}$	16.6
3	Chloride recryst. from $\text{CHCl}_3\text{-Et}_2\text{O}$ , then gasoline	75 and 75
4	Same as No. 3 except $\text{CO}_2$ was passed in before introducing the chloride	87.5 (86.4 with 0.2 g. of triphenylmethyl peroxide in addition)
5	Same as No. 4 except that freshly made crude chloride from the Friedel and Crafts reaction was used	81.6 and 81.6
6	Used 0.1 g. of $\text{AlCl}_3$ (anhyd.) instead of iodine to start the reaction	60.8 (67.8 with 0.2 g. of $\text{I}_2$ in addition)
7	Passed in dry $\text{HCl}$ for 30 sec., no iodine	0 (29 with 0.2 g. of $\text{I}_2$ in addition)

carbinol was added with the chloride and then the experiment was treated exactly as Expt. 3, Table II.

 TABLE III  
 RESULTS OF EXPERIMENTS

	1	2	3	4	5	6	7	8
Mole per cent. of $(\text{C}_6\text{H}_5)_3\text{COH}$ added before the preparation of the Grignard reagent	0	0.8	2.4	3.1	6.2	9.2	12.3	15.3
Yield of triphenylacetic acid, %	75	63.5	58.0	52.5				
			55.3	55.3	48.4	33.2	16.6	0
	75			56.0				

In Table IV 15.3 mole per cent. of triphenylcarbinol was added in each case *after* the chloride had reacted for one hour and the Grignard reagent had formed normally, but before the carbon dioxide was passed through the flask.

 TABLE IV  
 RESULTS OF EXPERIMENTS

No.		Yield, %
1	15.3 mole per cent. of carbinol added after the reagent had been formed	0
2	Same as No. 1, except that the mixture was allowed to <i>stand</i> with carbon dioxide for about 60 hours	41.5
3	Same as No. 1 except the mixture was refluxed and stirred for 24 hours	0

The yield of acid when 50% of phenol was added was 31.9%.

In order to determine whether the chloromagnesium triphenylcarbinolate was responsible for the decreased yield of triphenylacetic acid (by causing the latter substance to decompose during the reaction), 1 g. of triphenylcarbinol and 6.86 g. of triphenylacetic acid were added to ethylmagnesium bromide made from 0.05 mole of ethyl bromide. The mixture was refluxed in ether for seven hours and the triphenylacetic acid recovered in the usual way. The weight of acid was 6.85 g., showing that very little decomposition took place.



**Reactions Involving Diphenylmethylmagnesium Chloride and Tetraphenyl Ethane.**<sup>14</sup>—The preparation of diphenylmethylmagnesium chloride was quite similar to that given by Gilman and Kirby.<sup>15</sup> The best yield of diphenylacetic acid was obtained from *freshly* distilled chloride and amounted to 23.8% in a 0.05-mole experiment. The remainder of the material was recovered practically quantitatively as tetraphenylethane (6.4 g.). The chloride was redistilled and a yield of 9.0% was obtained when 1 g. of diphenylcarbinol (0.0054 mole) was added to the same quantity of reagent.

The dissociation of tetraphenylethane in the presence of magnesium iodide was attempted in an atmosphere of carbon dioxide in a boiling ether-benzene mixture, in boiling xylene, in a kerosene fraction at 200°, and in a mixture of isoamyl ether and anthracene at 300°, but in no case was any diphenylacetic acid isolated. The tetraphenylethane was recovered unchanged.

**Reactions Involving Benzylmagnesium Chloride.**—The method of preparation of benzylmagnesium chloride was that of Gilman and McCracken.<sup>16</sup> The benzyl chloride of a c. p. grade was shaken with cold concentrated sulfuric acid to remove any benzyl alcohol or other easily sulfonated substances, neutralized with anhydrous potassium carbonate, filtered and fractionated. The fraction used boiled constantly at 91° under diminished pressure. An excess of magnesium clippings and 0.2 g. of iodine were used with 0.1 mole of benzyl chloride in all of the reactions. The chloride was allowed to react with the magnesium for one hour and the carbon dioxide was passed over the surface of the liquid for three hours. The temperature control was found to be very important. The best procedure was to cool the reaction mixture to 10° as the benzyl chloride was added over a period of forty-five minutes, followed by a fifteen-minute refluxing, then cooling again to 10° while the carbon dioxide was passed into the flask.

TABLE V  
EXPERIMENTAL RESULTS

Amount of benzyl alcohol added, mole per cent.	0	2	10	30
Yield of phenylacetic acid, %	84.5	74.3	65.8	46.3

The yield of phenylacetic acid obtained upon adding 10% of benzyl alcohol after the preparation of the reagent was 62.5%.

**Reactions Involving Phenylmagnesium Bromide.**—The method of preparing the phenylmagnesium bromide was that given by Gilman and Parker.<sup>17</sup> The bromobenzene was a c. p. grade and was fractionated twice through an efficient column filled with Lessing contact rings. The fraction used boiled at 146° at 640 mm. pressure. One-tenth mole experiments were made with an excess of magnesium clippings and 0.2 g. of iodine. The yield of benzoic acid was determined by extracting the alkali-soluble material with potassium hydroxide solution, followed by acidification, and repeated ether extraction. The ether solution was evaporated and the yield of benzoic acid determined

TABLE VI  
EXPERIMENTAL RESULTS

	1	2	3	4	5	6	7
Mole per cent. of phenol added	0	0.5	1	2	5	20	35
Yield of benzoic acid, %	72.1	58.6	46.8	45.1	43.7	35.9	29.1
			47.2				

<sup>14</sup> Experimental work done by David P. Langlois.

<sup>15</sup> Gilman and Kirby, *THIS JOURNAL*, **48**, 1735 (1926).

<sup>16</sup> Gilman and McCracken, *ibid.*, **45**, 2462 (1923).

<sup>17</sup> Gilman and Parker, *ibid.*, **46**, 2816 (1924).

by subtracting the weight of phenol added to the reaction from the crude weight of benzoic acid.

The yield of benzoic acid obtained by adding 1% of phenol after the reagent had been prepared was 61.4 and 63.5% when 15.3 mole per cent. of triphenylcarbinol was added in the same way. In the latter experiment 40% of the triphenylcarbinol was recovered as triphenylmethyl peroxide.<sup>18</sup>

**Reactions Involving Butylmagnesium Bromide.**—The preparation was essentially that of Gilman and Parker.<sup>17</sup> The butyl bromide was a c. p. grade and was further purified by shaking with cold concentrated sulfuric acid and by fractionation through a column filled with Lessing contact rings. The bromide boiled at 94.5° at 640 mm. pressure. An excess of magnesium clippings and 0.2 g. of iodine were used with 0.1 mole of butyl bromide in each experiment. The yield was determined by extracting the acid with alkali, liberating the acid with hydrochloric acid, collecting the product with ether and finally fractionating the ether-valeric acid mixture.

TABLE VII  
EXPERIMENTAL RESULTS

	1	2	3	4
Mole per cent. of butyl alcohol added	0	2.43	9.46	24.3
Yield of valeric acid, %	78.4	63.5	50.0	26.2

The yield of valeric acid obtained by adding 9.5% of butyl alcohol after the reagent had been prepared was 48.0%.

The normal reaction of butylmagnesium bromide with benzaldehyde gave a yield of 62.2% of phenylbutylcarbinol. Upon adding 2.43 mole per cent. of butyl alcohol after the reagent had been prepared, but before the addition of the benzaldehyde, the yield was lowered to 59.7%, a loss of 2.5%.

### Summary

Curves are given showing the depression in yield of the reaction of several Grignard reagents with carbon dioxide caused by the addition of relatively small quantities of the alcohols corresponding to the reagents. Reactions are given which indicate an equilibrium relationship between triphenylmethylmagnesium chloride and triphenylmethyl. Cleavage of tetraphenylethane with magnesiuous iodide was not successful.

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<sup>18</sup> The explanation of this result may be found in Gomberg and Bachmann's paper, Ref. 4.