reported at this time. The parallelism between the grouping of the amino acids as catalyzers with dextrose and their grouping according to specific dynamic action is even closer than in the former experiments. Tyrosine alone, which yields slightly higher oxidation potentials than the others, is an exception. At these higher potentials whenever they were obtained in any manner with dextrose alone or with other amino acids it was noticed that the reducing power of the sugar was temporarily paralyzed and the return to more negative potentials much delayed. The connection between amino acid catalysis with levulose and specific dynamic action is much less close than with dextrose.

When insulin was added it was found that the action of hydrogen peroxide on both dextrose alone and levulose alone was retarded. For both sugars insulin had no marked effect on the amino acid catalysis. Some effect, however, was noticed in a smoothing out of the differences between the various amino acids.

Attention is called to the fact that in all cases the maximal voltage change towards a return to reducing conditions takes place in a region approximately between 0.5 and -0.15 volt and that below -0.20 volt the drop is rather quickly stopped. It is hoped in a future paper to discuss the significance of these facts in relation to the mechanism of sugar oxidation in alkaline solutions.

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A STUDY OF THE OPTIMAL CONDITIONS FOR THE PREPARATION OF TERTIARY BUTYLMAGNESIUM CHLORIDE

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Introduction

It was previously shown by Gilman and McCracken[1] that the yields of the four butylmagnesium bromides decrease in striking fashion with the increasing complexity of branching of alkyl groups, and to such an extent that *tert.*-butylmagnesium bromide gave a yield less than one-fourth of that obtained with *n*-butylmagnesium bromide. *Tert.*-butyl alcohol is now available at a low cost and the chloride is readily prepared from it in very good yield. Because alkyl chlorides give better yields of RMgCl compounds than the corresponding alkyl bromides[1] a study has been made of several factors affecting the optimal conditions for the preparation of *tert.*-butylmagnesium chloride. As a result of such studies, this tertiary Grignard reagent can now be prepared in quite satisfactory yields.

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[1] Gilman and McCracken, THIS JOURNAL, **45**, 2462 (1923). Also, Gilman and Kirby, *ibid.*, **48**, 1733 (1926) for better yields obtained from chlorides over bromides.

Experimental Part

The apparatus and technique used was essentially that of Gilman and McCracken.[1] The yields were determined quantitatively by the acid titration method of Gilman, Wilkinson, Fishel and Meyers.[2] As an additional check on the yields, several large-sized preparations of trimethylacetic acid were made from *tert.*-butylmagnesium chloride and carbon dioxide. The complex secondary reactions, involving among other things the evolution of considerable *iso*butylene and *iso*butane, will be reported later.

Temperature.—Bouveault,[3] who used *tert.*-butylmagnesium chloride in a number of reactions, recommended that the temperature be kept at from 5 to 15° in order to diminish the extent of decomposition evidenced by the evolution of *iso*butane and *iso*butylene. We found, on the contrary, that better yields are obtained when the reaction mixture is allowed to reflux as a result of the heat of reaction or is refluxed gently (by use of a water-bath) during the addition of chloride. Solvents other than diethyl ether were not used. In one preparation, the mixture was refluxed after removing aliquots for analysis, and there was practically no change in the concentration of RMgCl compound from that originally present.

Number of Moles of Ether.—Gilman and McCracken[4] have very recently shown that the number of moles of ether required for an optimal yield of Grignard reagent varies with the RX compound. For example, they showed that *n*-butylmagnesium bromide could be prepared in highest yield with but one mole of ether per mole of halide. With benzylmagnesium chloride 6–7 moles of ether was recommended and with phenylmagnesium bromide 4–5 moles of ether.

With gentle refluxing of the ether solution and a given rate of addition (about 90 drops or 1.4 cc. per minute), the best yield was obtained with about 7–8 moles of ether per mole of chloride.

Rate of Addition of RX Compound.—Gilman and Meyers[5] showed that ethylmagnesium iodide is formed with best yields when the halide in ether is added slowly to the magnesium and ether. This is particularly true in the preparation of *tert.*-butylmagnesium chloride. When the rate of addition is very slow (less than 0.7 cc. per minute) then the yield does not increase but actually decreases to a slight extent. This may be due to the evolved gases (and particularly the circulating hydrogen atmosphere[4,5]) carrying off more of the chloride before it had a chance to reach the magnesium.

[2] Gilman, Wilkinson, Fishel and Meyers, This Journal, **45**, 150 (1923). For further data on the reliability of this method and a criticism of another method of analysis see Gilman and Meyers, *Rec. trav. chim.*, **45**, 314 (1926).

[3] Bouveault, *Compt. rend.*, **138**, 1108 (1904). See, also, Madelung and Volker, *J. prakt. Chem.*, **115**, 24 (1927).

[4] Gilman and McCracken, *Rec. trav. chim.*, **46**, 463 (1927).

[5] Gilman and Meyers, This Journal, **45**, 159 (1923).

The rate of addition in a moderate-sized run is of more significance for ordinary laboratory work than that in the small-sized runs made in the special apparatus. The best yield of trimethylacetic acid, prepared from *tert.*-butylmagnesium chloride and carbon dioxide, was realized when one-half mole of the chloride in 7 moles of ether was added to the magnesium during three hours. This slow addition was at the rate of 2 cc. of halide solution per minute. Unquestionably this time can be decreased, for in the small 0.1 mole runs a maximum yield was obtained when the solution was added over a period of two hours.

A possible reason for the better yields when the rate of addition is low is the diminution of a secondary reaction between *tert.*-butylmagnesium chloride and *tert.*-butyl chloride. This finds support in an experiment where the addition of *tert.*-butyl chloride to a solution of *tert.*-butylmagnesium chloride (free from unused magnesium) produced a significant decrease in the quantity of Grignard reagent from that originally present.

Stirring.—In view of the decidedly helpful effect of stirring noted in earlier work, no study was made of this factor and stirring was used throughout all the preparations.[5,6]

Kind of Magnesium.—Gilman and Meyers[5] in their study of the optimal conditions for the preparation of ethylmagnesium iodide used magnesium turnings of three arbitrary grades, coarse, medium and fine. They showed that under a given set of conditions the finer the grade of turnings the higher the yield, but that the factor most affected was the *rate* of reaction, inasmuch as coarse turnings used over a *longer* period of reaction gave the same yield as the fine turnings.

No study was made of any reaction rates with *tert.*-butylmagnesium chloride, but there is no question concerning the decided improvement in yield that comes with the use of very fine turnings approximating a powder. This fine material of about 150 mesh was freshly turned and kept in a tightly rubber-stoppered bottle when not in use. A coarser metal of about 30 mesh is also quite satisfactory. Some of the ordinary coarse turnings commercially available for Grignard reactions should not be used for the preparation of *tert.*-butylmagnesium chloride if a finer metal can be had. Fine turnings that give good yields are commercially available in this country.

The finer turnings are recommended largely on the basis of the better yields of trimethylacetic acid from fair-sized preparations of *tert.*-butylmagnesium chloride. The finer turnings, however, would be recommended on the basis of the much smaller runs carried out in the special flasks for estimating quantitatively the yield of RMgX compound. The improvement in yield with the use of finer turnings was more marked in the larger runs.

[6] Grignard used a shaking device very early in his studies of organomagnesium halides.

The yield of *tert.*-butylmagnesium *bromide* in one of the smaller-sized runs was 33.1%. Under corresponding conditions the yield of *tert.*-butylmagnesium *chloride* was 49.71%. Earlier results by Gilman and McCracken under different conditions showed *tert.*-butylmagnesium *bromide* to be formed in a 20.6% yield.

The maximum yield of *tert.*-butylmagnesium chloride obtained in the several experiments was 58%. In large-sized runs the yield is improved as is evidenced by a 62% yield of trimethylacetic acid from a two and one half mole run of *tert.*-butyl magnesium chloride and carbon dioxide in which fine commercial turnings were used, and by a 69–70% yield when 200 mesh magnesium powder was used.

The authors gratefully acknowledge a liberal supply of *tert.*-butyl alcohol from the Petroleum Chemical Corporation of New York.

Summary

As a result of a study of several factors in the preparation of *tert.*-butylmagnesium chloride it is now possible to obtain this Grignard reagent in quite satisfactory yields.

AMES, IOWA

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF COLUMBIA UNIVERSITY NO. 564]

A FURTHER STUDY OF THE INTERACTION OF SULFUR AND PARA-TOLUIDINE IN THE PRESENCE OF LITHARGE: THIO-PARA-TOLUIDINE AND RELATED COMPOUNDS[1]

BY MARSTON TAYLOR BOGERT AND LEONARD SMIDTH[2]

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Introductory

Sulfur dissolves freely in molten *p*-toluidine to a perfectly clear, transparent, pale yellow solution, which can be heated to about 180° before there is evidence of any reaction, when a slow evolution of hydrogen sulfide begins, gradually increasing as the temperature rises and accompanied by a darkening of the solution, with the ultimate production of dehydrothio-*p*-toluidine (V), primulines (VI), and other substances.

In the presence of litharge, or other hydrogen sulfide absorbents, however, the reaction begins at much lower temperature (130–145°), as shown first by Merz and Weith,[3] with thio-*p*-toluidine (III) as the chief product.

This Merz and Weith process has been investigated by Bogert and Mandelbaum,[4] who found that the melt contained both thio- and dithio-

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[1] Presented in abstract before the Division of Dye Chemistry at the Baltimore Meeting of the American Chemical Society, April 8, 1925.

[2] DuPont Fellow at Columbia University for the academic year 1923–1924.

[3] Merz and Weith, *Ber.*, **4**, 393 (1871).

[4] Bogert and Mandelbaum, THIS JOURNAL, **45**, 3045 (1923).