THE REACTION OF SOME ORGANOMAGNESIUM IODIDES WITH 1, 2 - EPOXYPROPANE

Thesis for the Degree of Ph. D.
MICHIGAN STATE COLLEGE
Francis E. Evans
1955

R. C. Houston
by RLG. April 1955

THE REACTION OF SOME ORGANOMAGNESIUM IODIDES WITH 1,2-EPOXYPROPANE

By

Francis E. Evans

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Chemistry

1955

To

Dr. Ralph C. Huston

ACKNOWLEDGMENT

The author wishes to express his appreciation for the encouragement and guidance of Dr. Ralph C. Huston and Dr. Ralph L. Guile, who, after the untimely death of Dr. Huston assumed the direction of the work and whose suggestions aided materially in the completion of the problem.

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VITA

Francis Eugene Evans

candidate for the degree of

Doctor of Philosophy

Dissertation: The Reaction of Some Organomagnesium Iodides with 1,2-epoxypropane

Outline of Studies:

Major: Organic Chemistry

Minors: Analytical and Inorganic Chemistry

Biographical Items:

Born: June 18, 1928 at Olney, Illinois

Undergraduate Studies: DePauw University, Greencastle, Indiana
Received B. A. June, 1950

Graduate Studies: Michigan State College, East Lansing, Michigan

ABSTRACT

This investigation has extended the studies on the reactions of organomagnesium halides on epoxides. The object of this work was to study the relative reactivity toward 1,2-epoxypropane of the organomagnesium bond as compared to the magnesium-iodine bond. This was accomplished by varying the ratios of reacting materials, the reaction times and the reaction temperatures. It was found necessary to maintain constant temperature and stirring throughout the reaction period in order to obtain reproducible results.

The Grignard reagents were prepared using methyl, ethyl, n-propyl, i-propyl, n-butyl, s-butyl, and phenyl iodides. Also prepared were the diorganomagnesium compounds corresponding to the Grignard reagents. The yields of Grignard reagents and diorganomagnesium compounds were determined using the Gilman titration procedure. The Grignard reagent was analyzed for iodide ion content by the Volhard method.

The analyzed Grignard reagents were treated with both one and two moles of 1,2-epoxypropane under controlled conditions, while the diorganomagnesium compounds were treated with two moles of 1,2-epoxypropane under similar conditions. The alcohols produced by the above reactions were isolated by distillation in all cases. In the reactions of organomagnesium iodides with 1,2-epoxypropane the 1-iodo-2-propanol produced was not distilled, since it decomposed markedly on heating, but was

determined by decomposition with alkali and the iodide ion produced was determined by the Volhard method.

In the reaction of organomagnesium iodides with one mole of 1,2-epoxypropane, 1-iodo-2-propanol is the main product, while the expected alcohol is produced to the extent of only one or two percent. The yield of 1-iodo-2-propanol varies with time of reaction. The percentage yield is of the order of 70-80% at reaction times of one to two hours. A longer time of reaction gave lower yields although only in the cases of ethylmagnesium iodide and the secondary alkylmagnesium iodides was the yield decreased substantially.

When the ratio of organomagnesium iodide to 1,2-epoxypropane was 1:2, the yield of 1-iodo-2-propanol was of the order of 95-100% at short reaction times (up to three hours) and decreased to 70-80% after 18 hours. The yields of the alcohols produced were of the order of 20-35% except the case of s-butylmagnesium iodide which gave only about 8% of 4-methyl-2-hexanol.

The precipitate present before hydrolysis in the reaction of organomagnesium iodides with two moles of 1,2-epoxypropane was analyzed and the results indicated that the precipitate probably has a formula corresponding to a ratio of one mole of organomagnesium iodide to two moles of 1,2-epoxypropane.

The results presented show that the initial reaction is with the magnesium-iodine bond and the reaction with the organomagnesium bond is slower than that of the magnesium-iodine bond.

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INTRODUCTION

INTRODUCTION

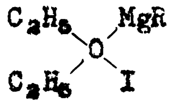
There has been some interest in recent years concerning the reaction of various epoxides with organomagnesium halides. The results of these studies have been interpreted in various ways and complete agreement has not been reached as to the mechanism of the reaction.

The object of this work was to study the relative reactivity of the organomagnesium and magnesium-iodine bonds. The method used to achieve this was a study of the reaction of organomagnesium iodides with 1,2-epoxypropane. The products of the reactions were isolated and a measure of the comparable reactivity of the two different bonds was obtained from the ratio of the alcohol (corresponding to organomagnesium bond cleavage) to 1-iodo-2-propanol (corresponding to magnesium-iodine bond cleavage). The effect of changing conditions on the ratio of products was studied by varying the length of reaction time, the reaction temperature, and the amount of 1,2-epoxypropane per mole of Grignard reagent.

HISTORICAL

HISTORICAL

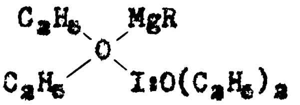
There has been much controversy over the constitution of the Grignard reagent in solution since it was first described by Grignard (1) in 1900. Both Grignard (2) and Blaise (3) have shown by analysis of the residue remaining after evaporation of the ether solution that the organomagnesium halide retains one molecule of ether even when dried under reduced pressure. Baeyer and Villiger (4) on the basis of the above data proposed that the formula of the Grignard reagent should be (A). However, Grignard (5) felt that the formulation (B) was more nearly consistent with the products formed from such compounds when used in reactions.



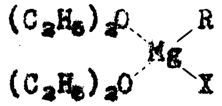
(A)

(B)

Later, in 1906, Tshelinzeff (6) on the basis of his studies of "dietherates" of isopropylmagnesium iodide proposed a formula of type (C). In 1921 Meisenheimer and Casper (7) advanced the theory that the Grignard reagents be considered not as oxonium salts but as complexes having a structure of type (D). Meisenheimer and Casper also

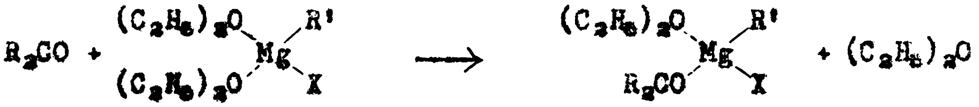


(C)



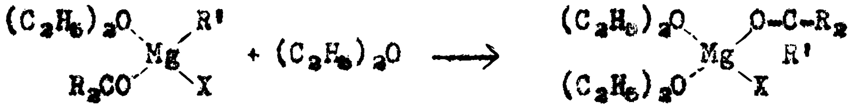
(D)

proposed that the reaction of alkylmagnesium halides proceeds by replacement of one of the coordinated ether groups by the compound reacting with the alkylmagnesium halide. The intermediate (E) formed



(E)

could then rearrange to give the magnesium halide salt of the product (F).



(F)

The theory that the Grignard reagent might be other than the species RMgX in solution was first advanced by Jolibois (8) in 1912. He had found that diethylmagnesium was insoluble in ether but was soluble in an ether solution of magnesium iodide to give a solution with all the properties of ethylmagnesium iodide. On the basis of this and other data he proposed that the Grignard reagent should be shown as $R_2Mg{\cdot}MgX_2$. There was much controversy over this formulation of the Grignard reagent and it remained for Schlenk and Schlenk (9) in 1929 to find that practically all the halogen and part of the magnesium could be precipitated from a solution of Grignard reagent in ether by the addition of 1,4-dioxane. They believed on the basis of this experiment that the Grignard reagent exists in an equilibrium which may be formulated as:

$$\begin{tikzcd}
2\ RMgX \arrow[r, shift left] \arrow[d, shift right, "or"'] & R_2Mg + MgX_2 \arrow[l, shift left] \\
R_2Mg\cdot MgX_2 \arrow[r, shift left] \arrow[u, shift right] & R_2Mg + Mg\cdot X_2 \arrow[l, shift left]
\end{tikzcd}$$

In 1931 Noller (10) proposed that the most probable equilibrium contains no organomagnesium halide, i.e.:

$$R_2Mg\cdot MgX_2 \rightleftharpoons R_2Mg + MgX_2$$

Further work by Noller and co-workers (11) indicated that the dioxane precipitation method was not valid as a means of establishing the equilibrium present in a Grignard reagent solution. They found that the diorganomagnesium content increased with time when the solution was allowed to stand in contact with the dioxane precipitate from the original organomagnesium halide solution. The general conclusion arrived at was that further disproportionation of the precipitate may occur on extended contact with the solution.

Schlenk (12) in 1932 proposed the idea that the percent of diorganomagnesium and magnesium halide varies according to the organo group present. Gilman and Fothergill (13) advanced the theory that alkylmagnesium chlorides are mainly in the form of alkylmagnesium chloride, while alkylmagnesium iodides may be more in the form of dialkylmagnesium and magnesium iodide. However, Kharash and Reinmuth (14, page 105) have listed data which indicate that in some cases there is little difference between alkylmagnesium chlorides and alkylmagnesium iodides as far as dialkylmagnesium content is concerned and in other cases the alkylmagnesium chlorides contain more dialkylmagnesium than do alkylmagnesium iodides.

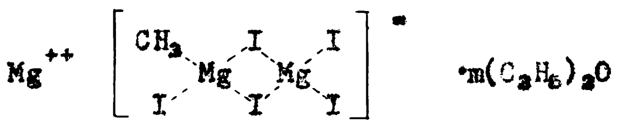
Aston and Bernhard (15) have noted the ready inflammability of dialkylmagnesium solutions and the relatively great stability of the corresponding alkylmagnesium halide solutions. Moreover, on this one fact they base their conclusion that the actual percentage of dialkylmagnesium in solution is low. They further proposed that the equilibrium be formulated as follows:

$$2\ RMgX \rightleftharpoons (R_2Mg\cdot MgX_2) \rightleftharpoons R_2Mg + MgX_2$$

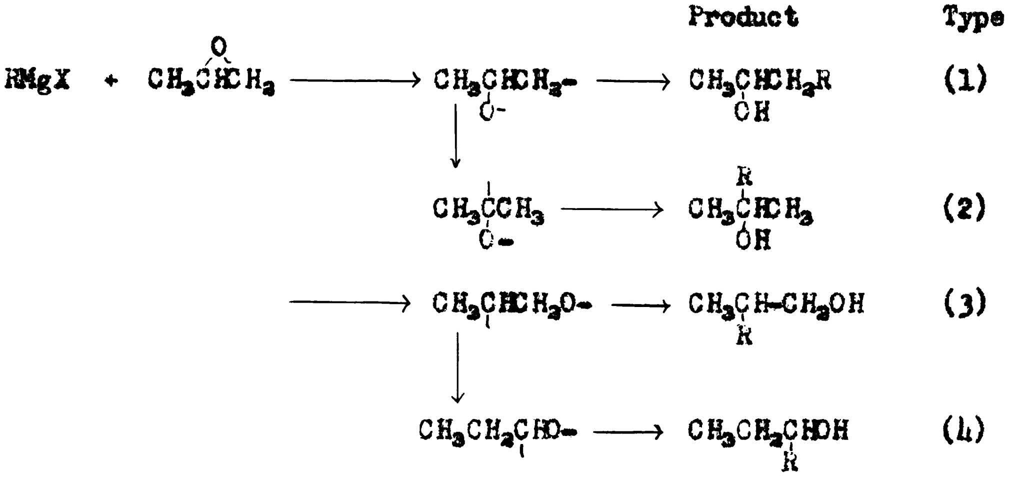
In 1949 Stewart and Ubbelohde (16) advanced the theory that instead of the Schlenk representation of the equilibrium present in solution or the representation of Aston and Bernhard, it might be better to consider the equilibrium as

$$n\ MgI_2 + CH_3MgI + m(C_2H_5)_2O \rightleftharpoons n\ MgI_2\cdot CH_3MgI\cdot m(C_2H_5)_2O$$

where n is probably two. They further picture the complex as something which can be represented in this manner:



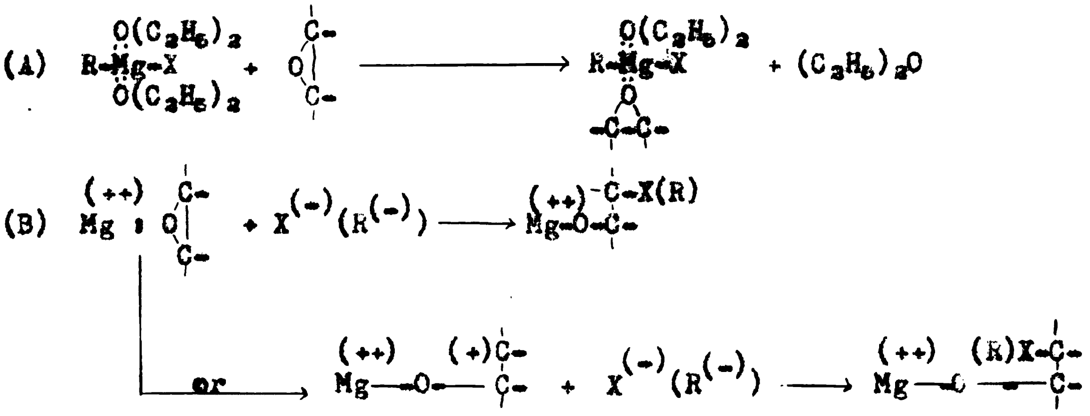
One of the earliest workers to study the action of Grignard reagents on epoxides was Henry (17) who treated 1,2-epoxypropane with alkylmagnesium halides. He postulated that several different products could be formed--depending on the point of cleavage of the epoxide ring and whether or not rearrangement occurred during the reaction.



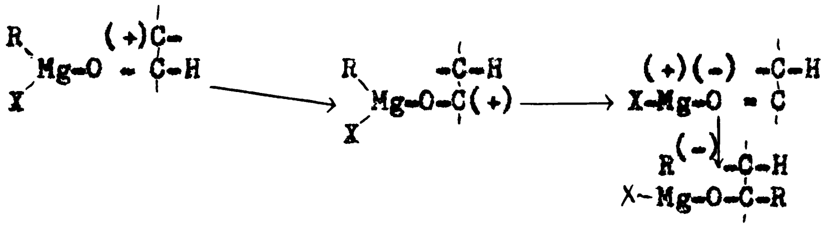
In an attempt to prove his theory, Henry treated ethylmagnesium bromide with 1,2-epoxypropane and obtained a 60% yield of 2-pentanol (reaction type 1). Other workers (18) have observed similar results using other Grignard reagents. Norton and Hass (19) in a similar reaction of ethylmagnesium bromide and 1,2-epoxypropane isolated 11% of 3-pentanol, which would result from a reaction path according to type (4). There is also work by Stevens and McCoubrey (20) who report that the product of the reaction between t-butylmagnesium chloride and 1,2-epoxypropane is 2,2-dimethyl-3-pentanol which would result again from a type (4) reaction. The majority of the reactions with 1,2-epoxypropane, however, appear to follow a type (1) reaction path.

The logical conclusion as to the mechanism of the reaction based on the data in the literature is that the products formed from the reaction of epoxides with Grignard reagents are the result of nucleophilic attack by a carbanion on the least substituted carbon atom.

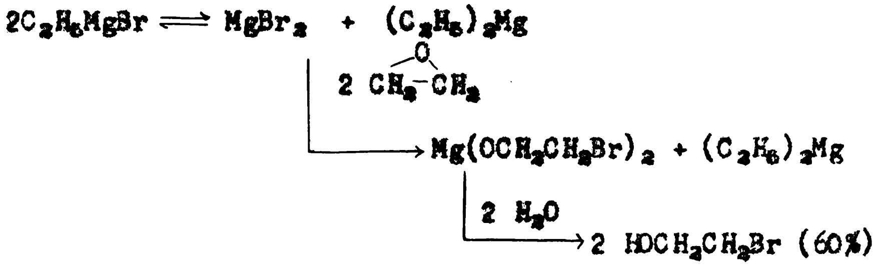
This probably occurs after the epoxide has coordinated with the magnesium (27).



It is also possible to have rearrangement.

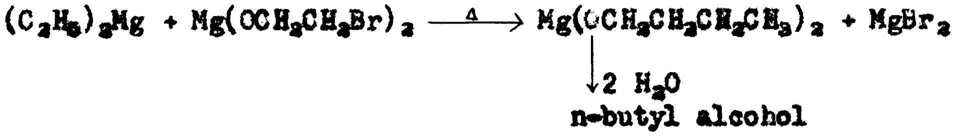


The reaction is not, however, as simple as it would appear, for Huston and Agett (21) have shown that dialkylmagnesium is probably an essential reactant. In their studies they found that the addition of one mole of ethylmagnesium bromide to ethylene oxide gives an addition complex which was identical with that obtained by passing ethylene oxide into an ether solution of magnesium bromide. Apparently the first mole of ethylene oxide reacts only with the magnesium bromide present in the Grignard reagent to form an addition complex by means of the following reaction:



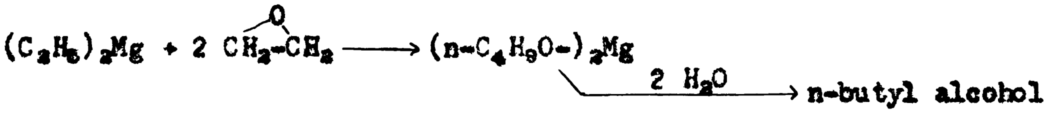
$$2C_2H_5MgBr \rightleftharpoons MgBr_2 + (C_2H_5)_2Mg \xrightarrow{2\ \overset{O}{CH_2-CH_2}} Mg(OCH_2CH_2Br)_2 + (C_2H_5)_2Mg \xrightarrow{2\ H_2O} 2\ HOCH_2CH_2Br\ (60\%)$$

In order to obtain any n-butyl alcohol it was necessary to heat the reaction mixture or else add a second mole of ethylene oxide.



$$(C_2H_5)_2Mg + Mg(OCH_2CH_2Br)_2 \xrightarrow{\Delta} Mg(OCH_2CH_2CH_2CH_3)_2 + MgBr_2 \xrightarrow{2\ H_2O} \text{n-butyl alcohol}$$

or

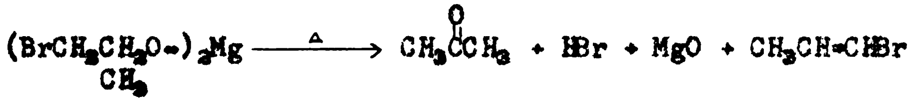


$$(C_2H_5)_2Mg + 2\ \overset{O}{CH_2-CH_2} \longrightarrow (n\text{-}C_4H_9O\text{-})_2Mg \xrightarrow{2\ H_2O} \text{n-butyl alcohol}$$

Both Huston and Agett (21) and Huston and Langham (22) have shown that the reaction of ethylmagnesium halides with ethylene oxide leads to an intermediate compound having the empirical formula $(C_4H_9O)_2Mg$ from diethylmagnesium, or an intermediate compound having the empirical formula C_4H_9OMgX from ethylmagnesium halides. Both of these intermediates upon hydrolysis give good yields of 1-butanol.

Huston and D'Arcy (23) as well as other workers (21, 22) have reported that the reaction of organomagnesium halides gives as a by-product small amounts of acetaldehyde. Cottle and Hollyday (24) in studying the reaction of n-butylmagnesium bromide with ethylene oxide found that an acetaldehyde resin was formed upon heating the product of the ethylene oxide-magnesium bromide reaction in a bomb. To account for this they postulated that the $BrCH_2CH_2O-$ ion may, when heated, lose a bromide ion and rearrange to acetaldehyde.

Additional proof of the formation of a carbonyl compound upon heating the addition complex was furnished by Huston and Bostwick (25), who also found upon reacting organomagnesium bromides with 1,2-epoxypropane that acetone was a byproduct in all of the reactions.



$$(BrCH_2\underset{CH_3}{CH_2}O-)_2Mg \xrightarrow{\Delta} CH_3\overset{O}{\overset{\|}{C}}CH_3 + HBr + MgO + CH_3CH=CHBr$$

However, Huston and Tiefenthal (26) found no evidence of acetone when they treated alkylmagnesium chlorides with 1,2-epoxypropane.

Huston and D'Arcy (23) found upon studying the reaction of alkylmagnesium iodides with equimolar amounts of ethylene oxide that the reaction was predominately at the alkylmagnesium bond although as the alkyl group increased in complexity the ethylene iodohydrin was produced in proportionately larger amounts. Huston and Langham (22) found in their studies that when alkylmagnesium chlorides were treated with an equimolar amount of ethylene oxide there was a significant reaction at the alkylmagnesium bond which in some cases exceeded the amount of reaction at the magnesium-chlorine bond. Huston and Agett (21), however, found that on treating alkylmagnesium bromides in a one to one ratio with ethylene oxide the initial reaction was predominately at the magnesium-bromine bond.

In almost all cases when the ratio of reactants was one mole of Grignard reagent to two moles of ethylene oxide, the yields of the alcohol and ethylene halohydrin were increased appreciably.

Huston and Tiefenthal (26) found that when alkylmagnesium chlorides were treated with 1,2-epoxypropane in equimolar quantities the yield of 1-chloro-2-propanol ranged from 35-65% and the yields of the alcohols varied from 0-41%. In the reaction of alkylmagnesium bromides with an equimolar amount of 1,2-epoxypropane, Huston and Bostwick (25) found that the 1-bromo-2-propanol was produced in yields of 50-67% while the yields of the alcohols ranged from 4-13%. The most striking thing apparent when comparing the yields was the much larger over-all yields of alcohols with the alkylmagnesium chlorides. In all cases the addition of two moles of epoxide to one mole of alkylmagnesium halide increased the yields of both 1-halo-2-propanol and the alcohols appreciably.

Wotiz and co-workers (28) have studied the relative reactivity of some alkylmagnesium halides by allowing them to react with 1-hexyne and measuring the volume of alkane evolved.

$$C_4H_9C{\equiv}CH \;+\; RMg\text{-}X \longrightarrow C_4H_9C{\equiv}CMgX \;+\; RH \;\;\text{(gas)}$$

They found that methylmagnesium iodide and methylmagnesium bromide are of about the same order of reactivity while methylmagnesium chloride reacts almost three times as fast. The same order of reactivity holds for the ethylmagnesium halides except that ethylmagnesium chloride reacts only twice as fast as the other two (see table below). This would seem to indicate that the alkylmagnesium chlorides should give better yields of alcohols than the other alkylmagnesium halides, and, in general, this is true. One would also expect that the yields of alcohols from the reaction of alkylmagnesium bromides and alkylmagnesium iodides would be of the same order of magnitude.

Table (Reference 28)

RMgX	Relative Reactivity
CH_3MGI	6
CH_3MgBr	6
CH_3MgCl	16
C_2H_5MgI	71
C_2H_5MgBr	100
C_2H_5MgCl	155

In studying the reaction of alkyl iodides with magnesium in ether Oldham and Ubbelohde (29) noted that organic iodides are capable of reacting to give various products.

$$(1)\quad RI + Mg \longrightarrow RMgI$$

$$(2)\quad 2RI + Mg \longrightarrow R_2 + MgI_2$$

$$(3)\quad 2RI + Mg \longrightarrow RH + RH + MgI_2$$

The authors came to the conclusion that reactions (2) and (3) are side reactions which occur more readily with organoiodides than with any other halide and that one must be very careful to have an excess of magnesium present in the reaction at all times.

Later, Mackle and Ubbelohde (30) studied the reaction of methyl iodide with magnesium and found the following reactions occurring.

$$2\ CH_3I + Mg + (C_2H_5)_2O \longrightarrow C_2H_6 + MgI_2\cdot(C_2H_5)_2O$$

$$2\ CH_3I + Mg \longrightarrow MgI_2 + 2CH_3-$$

$$CH_3- + Et_2O \longrightarrow 2\ CH_4 + CH_3CHO + C_2H_6$$

They also found that the following reactions occur in the presence of iodine.

$$CH_3MgI + I_2 \longrightarrow CH_3I + MgI_2$$

$$2\ CH_3MgI + I_2 \longrightarrow C_2H_6 + MgI_2$$

It is also well known that appreciable quantities of biphenyl are produced in the preparation of phenylmagnesium halides. The reaction to give biphenyl presumably goes by a free radical mechanism (14, page 59).

MATERIALS

MATERIALS

1,2-epoxypropane (B.p. 33-34°C). Dow Chemical Company. Used without further purification.

Alkyl Iodides.

Methyl, Ethyl, n-Propyl, n-Butyl, s-Butyl Iodides. Eastman white label products.

i-Propyl and Phenyl Iodides. Columbia Organic Chemicals Company. Dried over anhydrous sodium or magnesium sulfate, redistilled, and stored over freshly scraped copper wire.

Ammonium iodide. Bakers' Analyzed Reagent.

Magnesium Turnings. Merck and Company. Especially for Grignard reactions.

Anhydrous Diethyl Ether. Dried over sodium ribbon for at least one week.

Dioxane. Purified according to directions of Fieser (44).

Sodium Hydroxide. C. P.

Sodium Sulfate. Anhydrous.

Magnesium sulfate. Anhydrous.

Solutions:

Silver Nitrate. Approximately 0.1 N. Prepared from Bakers' Analytical Grade silver nitrate.

Potassium Thiocyanate. Approximately 0.1 N. Standardized against the silver nitrate solution.

Sodium Hydroxide. Approximately 0.1 N. Standardized against potassium acid phthalate (Bakers' Analytical Grade).

Sulfuric Acid. Approximately 0.1 N. Standardized against the sodium hydroxide solution.

EXPERIMENTAL

I. Preparation of Grignard Reagents

Fifty grams (2.1 m.) of magnesium turnings were placed in a dry, two liter, three-necked round bottomed flask which was fitted with a mercury sealed stirrer, a Hershberg dropping funnel, and a Graham (spiral) condenser. The condenser and dropping funnel were fitted with drying tubes filled with a mixture of calcium chloride and soda lime. The flask was swept with "water pumped" nitrogen dried by bubbling through concentrated sulfuric acid. The flask was placed in a container so that external cooling could be applied if desired.

One hundred milliliters of anhydrous ethyl ether and five to ten grams of the organic iodide were added to start the reaction. Then five hundred milliliters of anhydrous ethyl ether was added to the flask and the remainder of the two moles of organic iodide was mixed with three hundred milliliters of anhydrous ether and added at the rate of one to two drops per second through the dropping funnel. In most cases external cooling was used in order to prevent too vigorous refluxing and also to cut down the time necessary for addition. The normal alkyl iodides and phenyl iodide were added at the rate of two to three drops per second while the secondary alkyl iodides were added at the rate of about one drop per second. After addition was complete, stirring was continued for an hour and then the Grignard reagent was analyzed according to the procedure described in (II) and then allowed to react with 1,2-epoxypropane immediately. Allowing the Grignard reagent to stand overnight did not appreciably increase the yields.

II. Analysis of the Grignard Reagent

The Grignard reagent was transferred through a glass tube fitted with a glass wool filter by means of nitrogen pressure into a graduated mixing cylinder which had been fitted with an inlet tube, a safety tube, and an outlet tube reaching to the bottom of the cylinder. The volume of the solution was measured and a one milliliter aliquot was taken and analyzed by the Gilman procedure (31) using phenolphthalein as the indicator. Another one milliliter aliquot was taken and analyzed for iodide by the Volhard method (32). The ether solution of the Grignard reagent was then divided in such a way that from one-third to one-half mole of organomagnesium iodide was placed in each reaction flask and then each portion was treated with either one or two mole-equivalents of 1,2-epoxypropane.

The volume of the diorganomagnesium solution remaining after precipitation of magnesium iodide and organomagnesium iodide with 1,4-dioxane was measured as described in (III-C). A one milliliter aliquot was taken and analyzed by the Gilman procedure. The ether solution of diorganomagnesium was then divided into two equal portions and each portion was treated with two mole-equivalents of 1,2-epoxypropane.

For yields of organomagnesium iodides and diorganomagnesium compounds see Table I.

III. Reactions of the Grignard Reagent

A. Reaction of one mole of Grignard reagent with one mole of 1,2-epoxypropane.

About one-third of a mole of the Grignard reagent (based on the Volhard titration) was transferred by means of nitrogen pressure to a dry one-liter, three-necked, round bottomed flask which had been swept with dry nitrogen. The flask was fitted with an Allihn (bulb) condenser, a glycerol sealed stirrer, and a dropping funnel. A thermometer was suspended through the condenser by means of a nichrome wire so that the bulb of the thermometer was covered by the solution in the flask. Both the condenser and dropping funnel were fitted with drying tubes filled with a mixture of calcium chloride and soda-lime to protect the reaction from both water vapor and carbon dioxide. The amount of 1,2-epoxypropane necessary to react with the amount of iodide ion titrated in the Grignard reagent in a mole per mole ratio was weighed out and mixed with an equal volume of anhydrous ether. The resulting solution was then added to the Grignard reagent. The reaction temperature was maintained at 15°C. by external cooling and the reaction was stirred continuously throughout the entire reaction time employed. After addition of the epoxide was completed (usually 12-15 minutes), the reaction mixture was maintained at the desired temperature by placing the flask in a constant temperature water bath (controlled to ±1°C.) and stirring was continued for the duration of the reaction.

At the end of the reaction period, the reaction mixture was hydrolysed by dropwise addition of a saturated solution of ammonium iodide.

External cooling by means of an ice bath was found to be necessary. From forty to sixty milliliters of ammonium iodide solution were required to cause complete precipitation of the magnesium salts and leave a clear ether solution. It was usually necessary to stir the reaction mixture quite vigorously during hydrolysis in order to get a smooth decomposition. The clear ether solution was decanted from the precipitate and the precipitate was washed with four portions of ether. Water was then added to the precipitate until it was a pasty mass and this paste was extracted once with ether.

The combined ether solution of organic reaction products was then dried over anhydrous sodium sulfate. The ether was removed by distillation through an 18" Vigreux column until the temperature of the pot had reached about 50°C. (The careful control of pot temperature was necessary to prevent decomposition of reaction products.)

The residue remaining after removal of the ether was placed in a five hundred milliliter, three-necked, round-bottomed flask equipped with bulb condenser and a glycerol sealed stirrer. Slightly more than the calculated amount (based on the amount of iodide present) of sodium hydroxide pellets was added and the mixture was stirred for fifteen minutes, during which time a dense precipitate of sodium iodide had usually appeared. Sixty to seventy milliliters of water were added in portions, and the resultant mixture was refluxed for five to six hours in order to convert the 1-iodo-2-propanol present into propylene oxide and sodium iodide. Stirring was continuous during both the period of addition and the period of reflux. The reaction mixture was allowed to cool to room temperature, the layers were separated, and the water layer was extracted with ether. The combined ether portions were dried over anhydrous sodium sulfate. The water layer which contained the sodium iodide produced in the reaction was boiled to expel any dissolved organic material and diluted to five hundred milliliters. In order to determine the yield of 1-iodo-2-propanol, a two milliliter aliquot of the solution was analyzed for iodide ion by the Volhard procedure.

The ether was removed from the dried mixture of organic products by distillation through an 18" Vigreux column, stopping the distillation when the pot temperature had reached 50°C. The residue was then fractionated through either an 8.0 inch helix packed column or a 9.0 inch Vigreux column fitted with a total reflux, partial take-off type head. Heat was supplied to all distillations and reactions by Glas-col mantles. After the initial fractionation, all similar runs were combined and refractionated before any attempt was made to determine the physical constants and make derivatives. For yields see Table V.

Besides 1-iodo-2-propanol and the alcohols, several by-products were isolated from the reaction mixture. Those identified are listed in Table II.

Note: In order to determine the importance of removing all of the oxygen from the reaction flask it was decided to set up identical reactions as described above--except that one flask was flushed with dry nitrogen while the second was flushed with dry air. One-half mole of ethylmagnesium iodide was placed in each flask and caused to react with one mole of 1,2-epoxypropane for 18 hours under the conditions described above. Upon working up the reaction mixture it was found that the yield of 1-iodo-2-propanol from the reaction carried out under nitrogen was 68% while the yield of 2-pentanol was 28%. The yield of 1-iodo-2-propanol from the reaction carried out under dry air was 65% and the yield of 2-pentanol was 27%. These results would seem to indicate that the presence of oxygen had very little effect on the course of the reaction.

B. Reaction of one mole of Grignard reagent with two moles of 1,2-epoxypropane.

The calculated amount (in a ratio of two moles of the epoxide to one of the Grignard reagent) of 1,2-epoxypropane in ether was added to the Grignard reagent as described in procedure (III-A). The addition usually took about thirty minutes. After addition the reaction was plased in a constant temperature bath maintained at 15°C.±1°C. and stirred throughout the course of the reaction. The reaction was usually characterized by a white precipitate which became more dense as the reaction progressed and in some cases actually became a gel which was very hard to stir.

The reactions were usually set up in a series of five and at five definite time intervals one of the five reactions was processed as follows. The reaction mixture was hydrolyzed with seventy to ninety milliliters of saturated ammonium iodide. The hydrolyzed reaction was then processed as described in (III-A). For yields see Table VI.

Besides 1-iodo-2-propanol and the alcohols several by-products were isolated from the reaction mixture. Those identified are listed in Table II.

C. The preparation of dialkylmagnesium and diarylmagnesium from the corresponding Grignard reagents (10).

About one mole of Grignard reagent was placed in a dry one liter, three-necked, round bottomed flask which had been swept with dry nitrogen and set up as described in (III-A). Approximately two to three tenths mole in excess of the calculated amount of dry 1,4-dioxane (on a mole per mole basis) was diluted with about one hundred milliliters of anhydrous ethyl ether and added dropwise so that a gentle reflux was maintained. Stirring was continuous during addition and was continued for 8-12 hours after addition was complete. Then the thick solution was transferred by means of nitrogen pressure to 250 ml. centrifuge bottles, stoppered tightly, and centrifuged at 1400-1500 r.p.m. for fifteen to twenty minutes. The clear supernatant ether solution was transferred by nitrogen pressure to the mixing cylinder described in (II) and the volume was measured. One milliliter aliquots were analyzed by the Gilman procedure using phenolphthalein as the indicator.

D. The reaction of diorganomagnesium compounds with 1,2-epoxypropane.

The supernatant ether solution (containing for the most part diorganomagnesium compounds) was then transferred by means of nitrogen pressure to a one liter, three-necked, round bottomed flask set up as in (III-A). The calculated quantity of 1,2-epoxypropane was dissolved in an equal volume of anhydrous ether and added dropwise with stirring at 15°C. (maintained by cooling in an ice bath). Addition usually was completed in about ten minutes. The reaction flask was then placed in a constant temperature water bath maintained as in (III-B) and stirred until the test with Michler's ketone (42) was negative, by which time the solution had become milky. In all cases another similar reaction was allowed to run at least twice as long in order to see if any appreciable increase in yield of the alcohol was obtained.

The hydrolysis of the reaction mixture was carried out as described in (III-A) with about 25-35 ml. of the saturated ammonium iodide solution being used. The hydrolyzed mixture was worked up, dried over anhydrous sodium sulfate and fractionated as described in (III-A). For results see Table VI.

IV. Preparation of 1-iodo-2-propanol from 1,2-epoxypropane and Magnesium Iodide Etherate

A. Preparation of magnesium iodide in ether (16).

Thirteen grams (0.53 m.) of magnesium were placed in a dry one liter, three-necked, round bottomed flask swept with dry nitrogen and equipped with condenser, glycerol sealed stirrer and dropping funnel. About five grams of iodine was dissolved in 50 ml. of ether and slowly added to the magnesium with vigorous stirring. The reaction was often difficult to start, but once started it was necessary to keep the initial amount of iodine low in order to prevent too vigorous a reaction from taking place. It was found best to have an ice bath handy to cool the flask rapidly if necessary. Once the reaction had started 450 ml. of anhydrous ether was added and the dropping funnel was replaced by a powder addition funnel. The remainder of the iodine to make 0.5 mole was added slowly by means of the powder funnel while stirring the reaction mixture vigorously. It was necessary to cool the flask intermittently to prevent the ether solvent from refluxing too vigorously. Addition was usually completed in about two hours. Stirring was continued for about one hour and the reaction mixture was allowed to stand overnight.

B. Preparation of 1-iodo-2-propanol.

The magnesium iodide etherate (0.5 m.) was transferred by means of nitrogen pressure to a dry nitrogen-swept one liter, three-necked, round bottomed flask equipped as in (III-A) and one mole (58.0 g.) of 1,2-epoxypropane in one hundred milliliters of anhydrous ether was added over a period of one hour with stirring. A dense white precipitate formed as the oxide was added. The reaction was placed in a constant temperature water bath maintained at 15±1°C. and stirred for twenty-four hours at that temperature. The reaction was hydrolyzed as in (III-A) using about eighty to ninety milliliters of the saturated ammonium iodide solution, which completely precipitated the magnesium salts. The ether solution of organic reaction products (mainly 1-iodo-2-propanol) was dried over anhydrous sodium sulfate and the ether was removed by distillation. The amount of 1-iodo-2-propanol present in the residue was then determined by means of the method discussed in the following section.

C. The physical properties and the method of determination of yields of 1-iodo-2-propanol.

It was found that the 1-iodo-2-propanol was difficult to distil since a large portion of the 1-iodo-2-propanol decomposed during distillation. Therefore instead of isolating the 1-iodo-2-propanol a method of analysis which would allow determination of all the 1-iodo-2-propanol present in the reaction mixture was needed. Since the alkali decomposition procedure has been shown to be an acceptable method for determination of 1-iodo-2-propanol it was decided to use it as the method for determining the yield of this compound. Consequently, the hydrolyzed reaction mixture was processed according to the procedure described in (III-A, page 17) and the yield of 1-iodo-2-propanol was determined by means of alkali decomposition and titration of the iodide ion which was produced. This was done by means of the Volhard procedure as in (III-A, page 18).

The maximum yield of 1-iodo-2-propanol from the reaction of magnesium iodide with two moles of 1,2-epoxypropane was of the order of 75-83% based on the amount of iodine used in preparing the magnesium iodide.

A quantity of 1-iodo-2-propanol was distilled (41-43°C. at 3 mm.) and the physical properties were determined.

Refractive Index		Density	
Found	Lit.	Found	Lit.
n_D^{20}: 1.5453		d_{20}^{30}: 1.9359	d_4^{30}: 1.8999
n_D^{30}: 1.5417	n_D^{30}: 1.5365		

The molecular refraction at 30°C. was determined and found to be 30.40 (calc'd.: 30.39). The values found for both the refractive index and density remained constant upon repeated distillation of the compound.

In order to determine the purity of the 1-iodo-2-propanol the percent iodine was determined by both alkali decomposition and Parr bomb fusion. Both methods gave the same results.

1-iodo-2-propanol: Calc'd.: 68.2% I; Found: 67.9% I.

The precipitate present before hydrolysis in the reaction of magnesium iodide with two moles of 1,2-epoxypropane was analyzed by the procedure in (V).

Calc'd. for $(C_3H_6OI)_2Mg$: 6.19% Mg; 64.38% I.

Found: 6.11% Mg; 62.03% I.

D. Attempts to prepare derivatives of 1-iodo-2-propanol.

An attempt was made to prepare the 3,5-dinitrobenzoate of 1-iodo-2-propanol according to the procedure described in (VI-A). Two initial trials (one with pyridine and one without) failed to produce a derivative which could be recrystallized to a constant melting point. A third trial was made using the procedure described by Stewart and VanderWerf (45). This procedure also failed to give a pure derivative. A fourth trial was made using the procedure described in (VI-A) with the exception that no pyridine was used and the reaction was heated only one-half hour. Then it was allowed to stand overnight. This procedure gave a derivative which, after recrystallization to a constant melting point, melted at 83.5-84.0°C. An analysis of this derivative resulted in the following values.

3,5-dinitrobenzoates

	Unknown % found	1-iodo-2-propanol % calc'd.	1-chloro-2-propanol % calc'd.
C	41.73	31.55	41.65
H	3.18	2.38	3.12
N	9.47	7.38	9.70
Halogen	12.49	33.35 % I	12.28 % Cl

The derivative gave a positive qualitative test for chlorine and a negative test for iodine.

From the analysis and the qualitative tests it is evident that halogen exchange occurred during the reaction of the 3,5-dinitrobenzoyl chloride with 1-iodo-2-propanol. It is interesting that the melting points of the 3,5-dinitrobenzoates of 1-iodo-2-propanol and 1-chloro-2-propanol have been reported as being very nearly the same (45).

An attempt was made to prepare the phenyl urethane of 1-iodo-2-propanol according to the procedure described by McElvain (33). The resulting compound was a viscous oil which refused to crystallize.

In a further effort to prepare a derivative of the 1-iodo-2-propanol an attempt was made to prepare the α-naphthyl urethane according to the procedure described in McElvain (33). The product resulting from this reaction was recrystallized from ligroin until a constant melting point was obtained. The melting point of this derivative was 131.8-132.9°C.

α-naphthylurethane

	% calc'd.	% found
C	47.50	48.00
H	3.97	4.12
N	3.94	3.87
I	35.60	34.97

V. Analysis of the Precipitate Formed in the Reaction of One Mole of Grignard Reagent with Two Moles of 1,2-epoxypropane

The reaction mixture containing one mole of organomagnesium iodide and two moles of 1,2-epoxypropane was stirred at 15°C. until the reaction gave a negative test with Michler's ketone. The precipitate was then collected on a sintered glass filter funnel (the precipitate was forced over into the funnel through a glass tube by means of nitrogen pressure). The precipitate was quickly freed from most of the ether by means of an aspirator; then placed in a vacuum desiccator and, in order to remove the last traces of ether, was dried at 20 mm. for one-half hour and then dried at 3 mm. for another half hour.

The dry precipitate was analyzed for magnesium by igniting weighed samples to magnesium oxide. The precipitate was also analyzed for iodine by the alkali decomposition procedure and Volhard titration of the iodide present in an aliquot. Some precipitates showed a tendency to ignite if exposed to the air for periods longer than five minutes; particularly the precipitates derived from the methyl and ethyl Grignard reagents. Therefore, it was necessary to make rapid weighings on these substances. For results see Table VII.

VI. Determination of a Mass Balance on the Reaction of n-Propylmagnesium Iodide with 1,2-epoxypropane

A. Reaction of one mole of n-propylmagnesium iodide with one mole of 1,2-epoxypropane.

The reaction was set up as in (III-A) with the exception that a trap immersed in a Dry Ice-isopropyl alcohol mixture was connected to the condenser in order to collect any gases evolved during the course of the reaction and during hydrolysis. The reaction was carried out at 15±1°C. for 24 hours and hydrolysed by addition of ice cold 25% sulfuric acid dropwise (80 ml.) until all the magnesium salts had precipitated. (Sulfuric acid was used to avoid addition of iodine to the reaction mixture.)

The reaction was then worked up as described in (III-A) with the exception that the precipitated magnesium salts were dissolved in acid and titrated for iodide ion by the Volhard method. The ether solvent was removed and titrated for epoxide content by the method listed in Siggia's <u>Quantitative Organic Analysis Via Functional Groups</u> (43). The results are listed in Table VIII.

B. Reaction of one mole of n-propylmagnesium iodide with two moles of 1,2-epoxypropane.

The reaction flask was set up as described in (VII-A) and the reaction was allowed to proceed in the manner described in (III-B) with the exception that the reaction was hydrolyzed and worked up as described in (VIII-A). The results are listed in Table IX.

VII. Preparation of Derivatives

A. 3,5-Dinitrobenzoates (33,34).

One milliliter of the alcohol was placed in a dry ten ml. round bottomed flask and to it was added about one gram of 3,5-dinitrobenzoyl chloride and two milliliters of anhydrous pyridine. The flask was fitted with a small reflux condenser loosely stoppered to prevent moisture from entering the flask and heated on the steam bath for one to two hours.

The reaction mixture was removed from the steam bath and allowed to cool, after which it was poured into water in order to hydrolyze any excess acid chloride. The water-organic mixture was extracted with ether and the water layer was discarded. The ether extract was washed twice with five percent sulfuric acid, twice with ten percent sodium carbonate solution, and once with water. Then the ether was evaporated and the residue was dissolved in hexane. The resulting solution was decolorized by boiling with Norit and the Norit was removed by filtration. The 3,5-dinitrobenzoates were allowed to crystallize at room temperature and then recrystallized from hexane to a constant melting point.

B. Phenylurethane

The phenylurethane of 1-phenyl-2-propanol was prepared according to the procedure described in McElvain's Characterization of Organic Compounds (33).

VIII. Calculation of Yields

The alcohol was isolated by fractionation (III-A, page 18). The percent yield of each alcohol was calculated by taking the ratio of the moles of alcohol produced to the moles of organic radical present in the unreacted Grignard reagent.

The yields of 1-iodo-2-propanol were determined by alkaline decomposition and titration of the iodide ion produced using the Volhard method. The percent yield of 1-iodo-2-propanol was calculated by taking the ratio of the moles of iodide ion found to the moles of iodide ion found in the unreacted Grignard reagent.

Yields of 1-iodo-2-propanol were reproducible to within three percent or less except in the cases of the methyl and s-butyl Grignards which were reproducible to within about four percent. At longer reaction periods the yields were somewhat less reproducible than at shorter reaction periods. Yields of the alcohols were reproducible to within two to three percent in most cases--here again depending on the Grignard used. The yields of the alcohols from the methyl and ethyl Grignards were reproducible to the extent of about three to five percent.

TABLES AND FIGURES

TABLE I

YIELDS OF GRIGNARD REAGENTS[1] AND DIORGANOMAGNESIUM[2] COMPOUNDS

Alkyl Iodide	Percent Alkyl	Percent Iodine	Percent R_2Mg
Methyl	100	100	18.3
Ethyl	96-97	100	47.5
n-Propyl	93	100	64.3
i-Propyl	73-79	100	48.0
n-Butyl	90-94	100	41.5
s-Butyl	68-75	100	50.8
Phenyl	91-94	99	73.6

[1] Calculations based on amount of organic iodide used.
[2] Calculations based on amount of alkylmagnesium iodide used.

TABLE II

THE REACTION OF ORGANOMAGNESIUM IODIDES WITH 1,2-EPOXYPROPANE

(By-products Isolated from the Reaction)

Grignard Reagent	By-products[*]
Methyl	Acetone,[1] isopropyl alcohol[2]
Ethyl	Acetone, isopropyl alcohol
n-Propyl	Acetone, isopropyl alcohol, n-propyl alcohol,[2] n-propyl iodide,[3] isopropyl iodide (?)
i-Propyl	Acetone, isopropyl alcohol, isopropyl iodide[3]
n-Butyl	Acetone, isopropyl alcohol (trace), n-butyl alcohol[2]
s-Butyl	Acetone, s-butyl iodide,[3] s-butyl alcohol[2]
Phenyl	Acetone, benzene,[3] diphenyl[4]

[1] Identified by means of 2,4-dinitrophenyl hydrazone.
[2] Identified by means of 3,5-dinitrobenzoate.
[3] Identified by means of boiling points and refractive index.
[4] Identified by means of boiling point and melting point.
[*] Traces of unsaturation were found in all reactions and were tested for with bromine in carbon tetrachloride.

TABLE III

THE REACTION OF ORGANOMAGNESIUM IODIDES WITH 1,2-EPOXYPROPANE
THE EFFECT OF CONTROLLED CONDITIONS ON THE REACTION

Grignard Reagent	Conditions Controlled[1] % Iodo-hydrin	% Alc.	Reaction Time	Conditions Not Controlled[2] % Iodo-hydrin	% Alc.	Reaction Time	Ratio of Epoxide: RMgI
Methyl	77.4	--	24 hrs	70.2(68.6)	--	23 hrs	1:1
Methyl	77.0	--	24 hrs	63.7(57.0)	--	44 hrs	1:1
Methyl	87.4	26.2	18 hrs	81.1(71.3)	25.1(23.)	18 hrs	2:1
Ethyl	70.7	33.0	18 hrs	59.1	22.3	19 hrs	2:1
Ethyl	63.2	28.5	19 hrs	70.8	29.2	23 hrs	2:1
Ethyl	--	--	--	72.0	29.9	45 hrs	2:1
Ethyl	--	--	--	49.7	27.2	48 hrs	2:1
Ethyl	--	--	--	71.6	33.8	90 hrs	2:1
Ethyl	--	--	--	39.8	31.2	118 hrs	2:1
Ethyl	26.8	--	24 hrs	29.0	--	22 hrs	1:1
Ethyl	24.0	--	24 hrs	60.0	--	36 hrs	1:1
Ethyl	--	--	--	58.0	--	36 hrs	1:1
Ethyl	--	--	--	50.0	--	36 hrs	1:1
Ethyl	--	--	--	37.0	--	36 hrs	1:1
Ethyl	--	--	--	9.0	--	36 hrs	1:1
Ethyl	--	--	--	20(18)	--	45 hrs	1:1
Ethyl	--	--	--	43.0	--	54 hrs	1:1
Ethyl	--	--	--	2.0	--	30 hrs[3]	1:1
Ethyl	--	--	--	11.8	35.2	30 hrs[3]	2:1

[1] Constant temperature (15°C.) and stirring throughout the reaction period.

[2] Allowed to stir one hour after addition of epoxide, then stand at room temperature throughout the rest of the reaction period.

[3] Refluxed at boiling point of ether for five hours, then allowed to stand for 25 hours.

TABLE IV

THE REACTION[1] OF ORGANOMAGNESIUM IODIDES WITH 1,2-EPOXYPROPANE THE EFFECT OF CONTROLLED CONDITIONS ON THE REACTION

Reaction Time	Conditions Controlled[2]		Conditions Not Controlled[3]	
	% Iodohydrin	% Alcohol	% Iodohydrin	% Alcohol
0	94.5	11.0	87.0	9.9
1/4 hr	100.0	11.9	100.0	12.1
3/4 hr	98.7	16.3	88.0	12.1
3 hrs	86.4	22.9	73.0	14.7
18 hrs	70.7	33.0	68.0	32.4

[1] One mole of ethylmagnesium iodide and two moles of 1,2-epoxypropane.

[2] Constant temperature (15°C.) and stirring throughout the reaction period.

[3] Allowed to stir one hour after addition of epoxide, then stand at room temperature throughout the rest of the reaction period.

TABLE V

THE REACTION[1] OF ORGANOMAGNESIUM IODIDES WITH 1,2-EPOXYPROPANE
EFFECT OF TIME AND TEMPERATURE ON YIELDS[a]

Temperature °C.	Time (Hrs.)	Yields of 1-iodo-2-propanol from RMgI and Epoxide						
		Methyl	Ethyl	n-Propyl	i-Propyl	n-Butyl	s-Butyl	Phenyl
5	1	71.3	79.8	68.8	69.0	75.5	68.8	72.8
15	1	76.0	79.6	72.1	65.8	72.4	57.7	72.0
15	1	80.6	77.5	74.8	65.9	72.4	52.0	73.0
15	2	80.1	76.7	78.1	60.0	77.7	45.6	73.0
15	4	78.2	74.8	73.1	42.3	72.8	37.0	73.0
15	6	80.4	66.4	72.1	37.1	70.2	34.8	74.0
15	12	78.8	37.6	64.2	29.5	65.3	27.5	69.2
15	24	77.4	26.8	54.6	28.9	45.2	22.5	65.0
25	1	70.1	64.4	64.9	50.3	75.4	41.9	70.1
25	12	77.4	25.7	43.6	25.0	58.7	22.8	62.7
25	24	78.1	18.0	23.9	17.7	38.1	18.0	53.2

Note: The yield of alcohol in all cases was of the order of one to two percent.

[1] One mole of organomagnesium iodide and one mole of 1,2-epoxypropane.

[a] Yields are listed in percent of 1-iodo-2-propanol found.

TABLE VI

THE REACTION OF ORGANOMAGNESIUM IODIDES (ONE MOLE) WITH 1,2-EPOXYPROPANE (TWO MOLES)
THE EFFECT OF TIME[1] ON YIELDS

Reaction Time[2]	Yields of 1-iodo-2-propanol (%I) and the alcohols													
	Methyl		Ethyl		n-Propyl		i-Propyl		n-Butyl		s-Butyl		Phenyl	
	% I	% Alc.	% I	% Alc.	% I	% Alc.	% I	% Alc.	% I	% Alc.	% I	% Alc.	% I	% Alc.
0	94.3	10.1	94.5	11.0	96.8	2.2	100.0	7.2	90.1	7.9	85.0	2.6	95.5	9.2
1/4 hr	97.2	16.0	100.0	11.9	99.0	5.4	90.6	9.4	95.0	12.9	80.4	2.8	100.0	12.3
3/4 hr	91.0	16.0	98.7	16.3	99.2	9.4	78.6	11.2	87.4	13.4	69.6	3.2	92.1	21.6
3 hrs	85.8	23.6	86.4	22.9	83.3	14.9	63.0	16.2	77.1	16.1	59.1	7.4	83.0	23.6
18 hrs	87.4	26.2	70.7	33.0	71.4	22.9	58.7	17.7	78.8	23.9	52.6	7.9	80.2	30.1
(A) Test Negative[3]	85.2	16.7(8)	76.0	21.8(6.7)	69.5	16.4(12)	61.0	13.8(5)	60.1	22.9(25)	60.8	8.0(4.5)	87.2	37.7(9.5)
(B) At least 2 x (A)	85.6	21.6(18)	63.2	28.5(19)	73.9	27.6(24)	56.0	15.6(12)	51.4	24.7(48)	56.0	9.8(9.5)	87.5	34.7(23)

THE REACTION OF DIORGANOMAGNESIUM WITH TWO MOLES OF 1,2-EPOXYPROPANE
THE EFFECT OF TIME[1] ON YIELDS OF THE ALCOHOLS

Reaction Time	Yields of the Alcohols						
	Methyl	Ethyl	n-Propyl	i-Propyl	n-Butyl	s-Butyl	Phenyl
(C) Test Negative[3]	14.8 (4.5)	15.7 (5)	11.7 (6)	10.2 (4.5)	11.1 (4.5)	3.4 (5)	31.5 (7)
(D) At least 2 x (C)	16.3 (10)	41.3 (24)	32.9 (12)	22.2 (9.5)	18.3 (10)	6.3 (9)	39.0 (21)

[1] Temperature was held constant at 15±1°C.

[2] Reaction time after addition of 1,2-epoxypropane (all additions took about 30 minutes).

[3] The reaction was hydrolyzed when the Michler's ketone test was negative. The times of hydrolysis (hours) of all reactions in lines A, B, C & D are given in parentheses with the yields of alcohol.

TABLE VII

ANALYSIS OF PRECIPITATE PRESENT BEFORE HYDROLYSIS IN THE REACTION OF ORGANOMAGNESIUM IODIDE WITH TWO MOLES OF 1,2-EPOXYPROPANE

Grignard Reagent	Magnesium (%)		Iodine (%)		Formula Used	M.W.
	Calc'd.	Found	Calc'd.	Found		
Methyl	8.62	8.71	45.1	48.2	$CH_3MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}$	282.3
Ethyl	8.22	9.67	42.8	40.1	$C_2H_5MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}$	296.3
n-Propyl	7.83	8.32	40.8	38.5	$C_3H_7MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}$	310.3
n-Propyl*	8.14	8.32	42.5	38.5	$\left\{\begin{array}{l}90\%\ C_3H_7MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}\\ 5\%\ MgI_2\cdot 2CH_3\overbrace{CHCH_2}^{O}\end{array}\right.$	298.7
i-Propyl	7.83	8.68	40.8	45.7	$C_3H_7MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}$	310.3
i-Propyl*	8.46	8.68	44.1	45.7	$\left\{\begin{array}{l}80\%\ C_3H_7MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}\\ 10\%\ MgI_2\cdot 2CH_3\overbrace{CHCH_2}^{O}\end{array}\right.$	287.9
s-Butyl	7.50	8.77	39.2	41.8	$C_4H_9MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}$	324.3
s-Butyl*	8.54	8.77	44.4	41.8	$\left\{\begin{array}{l}70\%\ C_4H_9MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}\\ 15\%\ MgI_2\cdot 2CH_3\overbrace{CHCH_2}^{O}\end{array}\right.$	286.1
Phenyl	7.15	7.71	37.4	38.7	$C_6H_5MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}$	340.3
Phenyl*	7.40	7.71	38.7	38.7	$\left\{\begin{array}{l}92\%\ C_6H_5MgI\cdot 2CH_3\overbrace{CHCH_2}^{O}\\ 4\%\ MgI_2\cdot 2CH_3\overbrace{CHCH_2}^{O}\end{array}\right.$	328.7

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* The second values calculated are based on the assumption that the molecular weight of the precipitate was a mixture of the organomagnesium iodide complexed with two moles of 1,2-epoxypropane and magnesium iodide complexed with two moles of 1,2-epoxypropane in the ratios of the percentage yields of organic radical and iodide ion found in each of the Grignard reactions.

TABLE VIII

RESULTS OF MASS BALANCE

One Mole n-Propylmagnesium Iodide and One Mole 1,2-epoxypropane

To Account For	Found
1. n-Propyl Iodide	26.4 g. Iodine (magnesium salts)
a. 76.5 g. Iodine	38.0 g. Iodine (1-iodo-2-propanol)
b. 24.2 g. n-Propyl Residue	17.0 g. Propane (trace of propene)
2. 35.4 g. Epoxide	29.0 g. Epoxide (1-iodo-2-propanol)
	22.3 g. Organic Residue
135.8 g. Total	132.7 g. Total

Total Recovery: about 97%

Breakdown of Organic Residue (No Clear Cut Fraction)

B.P. °C.	Amount	Probable Constituents
50-78	7.0 g.	Acetone,[1] unsaturates,[2] trace of iodine[3]
78-85	6.45 g.	i-Propyl alcohol,[4] i-propyl iodide(?)[5]
85-98	4.65 g.	n-Propyl alcohol,[4] unsaturates,[2] n-propyl iodide[5]
98-125	0.50 g.	trace of iodine
125-136	1.10 g.	2-hexanol,[4] trace of iodine
residue	2.6 g.	tar

[1] Identified by means of the 2,4-dinitrophenylhydrazone.
[2] Tested for by means of bromine in carbon tetrachloride.
[3] Tested for by means of the Beilstein test.
[4] Identified by means of the 3,5-dinitrobenzoate.
[5] Identified by means of boiling point and refractive index.

TABLE IX

RESULTS OF MASS BALANCE

One Mole of n-Propylmagnesium Iodide and Two Moles of 1,2-epoxypropane

To Account For	Found
1. n-Propyl Iodide	
a. 76.2 g. Iodine	12.1 g. Iodine (magnesium salts)
	43.6 g. Iodine (1-iodo-2-propanol)
b. 24.2 g. n-Propyl residue	2.0 g. Propane
2. 67.8 g. Epoxide	14.4 g. Epoxide (titrated epoxide in ether solvent)
	25.7 g. Epoxide (1-iodo-2-propanol)
	50.05 g. Organic Residue
168.2 g. Total	147.85 g. Total

Total Recovery: about 88%

Breakdown of Organic Residue

B.P. °C.	Amount	Probable Constituents
50-80	13.1 g.	Acetone,[1] unsaturates,[2] trace of iodine[3]
80-85	2.85 g.	i-Propyl alcohol,[4] i-propyl iodide (?)[5]
85-100	5.6 g.	n-Propyl alcohol,[4] n-propyl iodide[5]
100-127	3.6 g.	traces of 2-hexanol[4] and iodine[3]
127-132	1.7 g.	2-hexanol,[4] trace of iodine (?)
132-142	12.1 g.	2-hexanol
142-180	42.0 g.	unsaturates, traces of iodine
vacuum	1.7 g.	trace of iodine
residue	5.0 g.	tar

[1] Identified by means of the 2,4-dinitrophenylhydrazone.

[2] Tested for by means of bromine in carbon tetrachloride.

[3] Tested for by means of the Beilstein test.

[4] Identified by means of the 3,5-dinitrobenzoates.

[5] Identified by means of the boiling point and refractive index.

TABLE X

PHYSICAL CONSTANTS OF THE ALCOHOLS

Alcohol	B.P.*°C. (Atm. Pressure)	n_D^{23}	Reference
2-Butanol	97-99	1.3937	33,47,38
2-Pentanol	117-119	1.4064	33,26,19
2-Hexanol	137-139	1.4152	26,37
4-Methyl-2-pentanol	128-130	1.4154	26,38
2-Heptanol	157-159	1.4225	26,37,39
4-Methyl-2-hexanol	151-153	1.4247	26,40
1-Phenyl-2-propanol	211-214	1.3264	36

* All boiling points uncorrected.
All boiling points agreed with the values reported in the literature to within one to two degrees.

TABLE XI

DERIVATIVES OF THE ALCOHOLS

Alcohol	Derivatives	Melting Point °C. Found*	Melting Point °C. Lit.	Reference
2-Butanol	3,5-dinitrobenzoate	75-76	76	33,35
2-Pentanol	3,5-dinitrobenzoate	60.5-61.5	62	33,26,39
2-Hexanol	3,5-dinitrobenzoate	37.5-38.0	38	26,41
4-methyl-2-pentanol	3,5-dinitrobenzoate	62.5-63.5	64-65	26,33,41
2-Heptanol	3,5-dinitrobenzoate	48.8-49.5	49	33,39
4-Methyl-2-hexanol	3,5-dinitrobenzoate	50-51	50-51	40
1-Phenyl-2-propanol	Phenylurethane	87.8-88.2	88.2-88.8	36

* All melting points uncorrected.

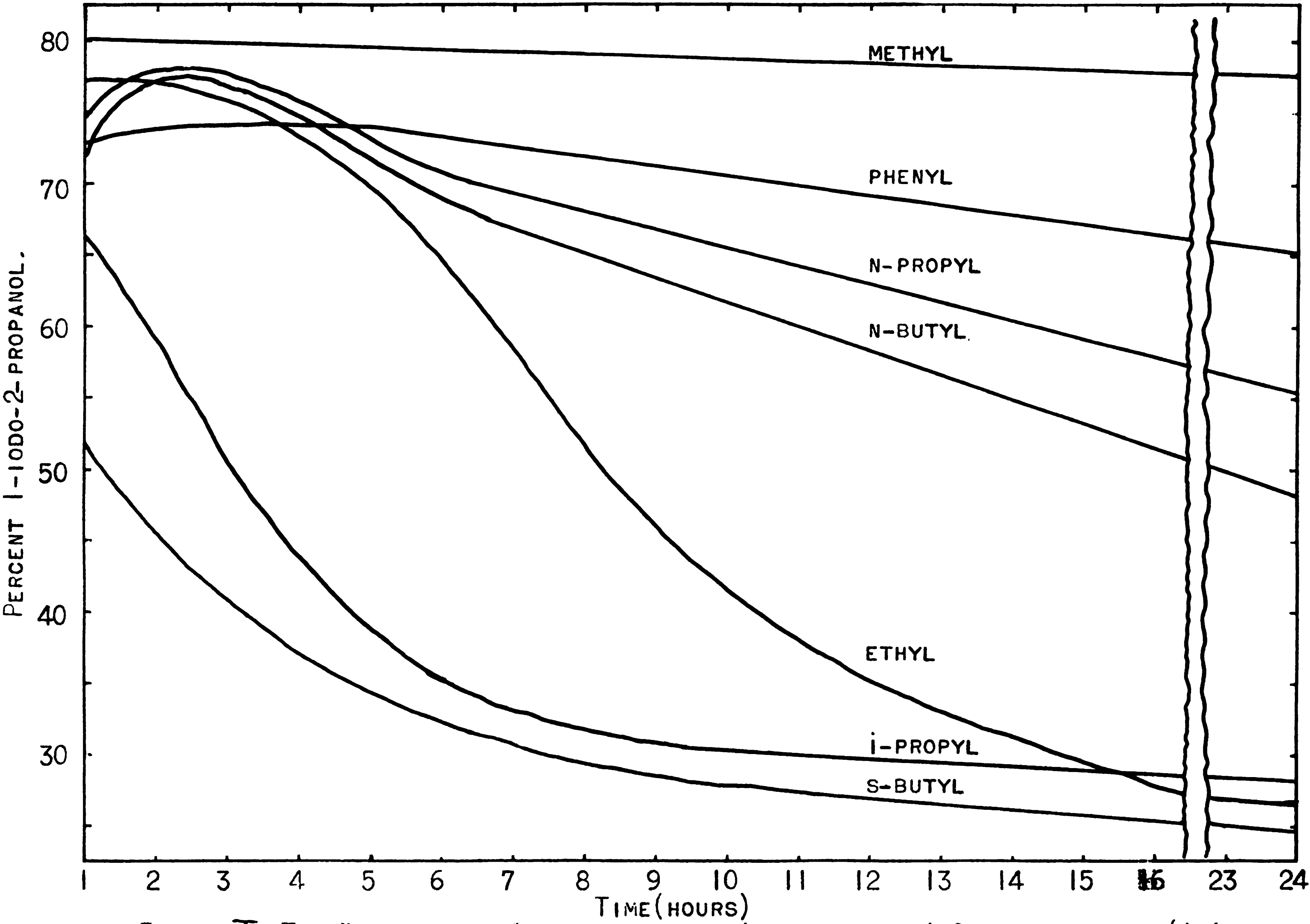


Figure I. The Reaction of Organomagnesium Iodides with 1,2-epoxypropane (1:1 ratio).

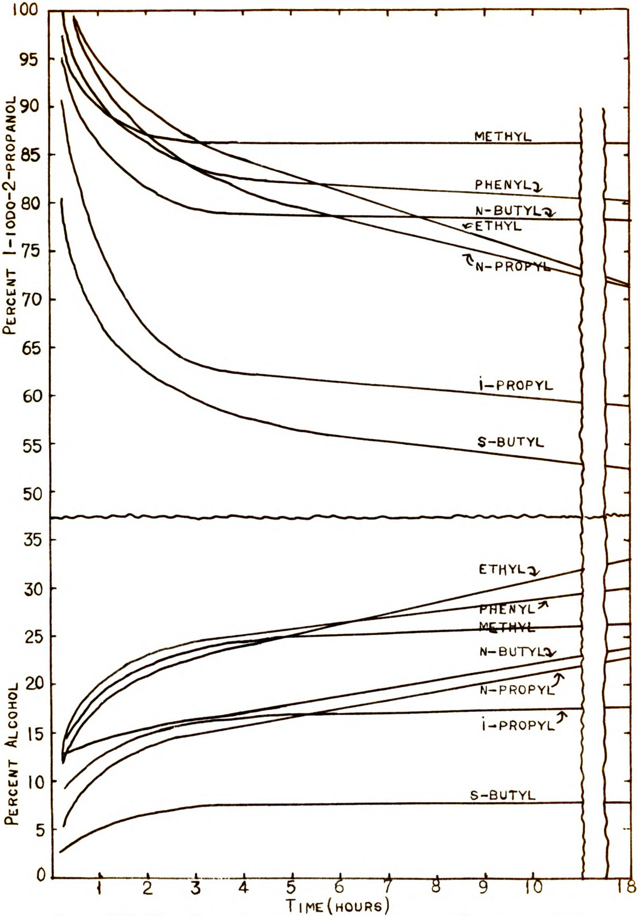


FIGURE II. THE REACTION OF ORGANOMAGNESIUM IODIDES WITH 1,2-EPOXYPROPANE (1:2 RATIO)

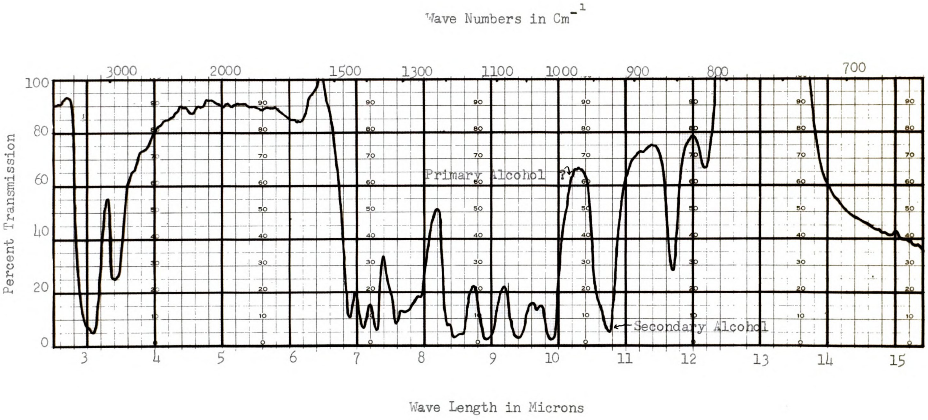


Figure III. Infrared Absorption Spectrum of 1-iodo-2-propanol.

DISCUSSION

DISCUSSION

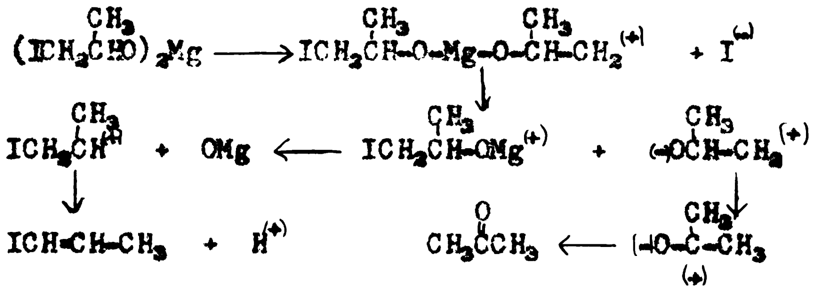
When organic halides are caused to react with magnesium in the presence of ether, an organomagnesium halide (Grignard reagent) is the product. A survey of the literature (14, page 32) has shown that, in general, the Grignard reagents derived from organic chlorides are produced in better yields than those derived from organic bromides, while organic iodides give the poorest yield of Grignard reagent. In the course of this work it has been found that, if they were properly purified, the organic iodides gave good yields of organomagnesium iodides (Table I). Only in the case of i-propyl and s-butyl Grignard reagents was the yield below 90%. The yield of iodine (Volhard method) was found to be 100% for all cases except the phenylmagnesium iodide and in this case it was 99%. This indicated that even if part of the Grignard reagent decomposed the halogen remained in the ionic form presumably as magnesium iodide.

The yields of diorganomagnesium compounds remaining in solution after the precipitation of the organomagnesium iodide and magnesium iodide are listed in Table I. It is felt that the yields listed are probably not the maximum possible since both the temperature of the reaction mixture and the time of digestion of the precipitate with the ether solution have been reported to affect the yield of diorganomagnesium compounds (see HISTORICAL, page 4). No attempt was made to find the optimum conditions for the separation of the diorganomagnesium compounds from the magnesium iodide and organomagnesium iodide.

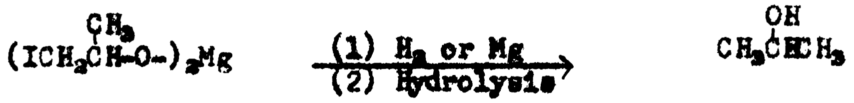
In order to study the effect of oxygen on the course of the reaction of organomagnesium iodides two different portions of ethylmagnesium iodide (0.5 mole each) were caused to react with one mole of 1,2-epoxypropane; one under a dry nitrogen atmosphere and the other under an atmosphere of dry air. No significant differences in yields of either 1-iodo-2-propanol or 2-pentanol were found. This would seem to indicate that oxygen does not effect the course of the reaction studied.

In studying the reaction of ethylmagnesium iodide with 1,2-epoxypropane the initial reactions were stirred for one hour after addition of the epoxide, and then allowed to stand at room temperature for the duration of the reaction period. The products isolated were 1-iodo-2-propanol, 2-pentanol, and several by-products (see Table II).

When the reaction mixture of ethylmagnesium iodide and 1,2-epoxypropane was stirred continuously during the course of the reaction and when the reaction was maintained at a constant temperature of 15°C., there was a definite decrease in the quantities and numbers of by-products. Only traces of acetone and isopropyl alcohol were found and the low boiling fraction (below the boiling point of 2-pentanol) was in general substantially decreased in volume. Possibly controlling the temperature at 15°C. slows down the decomposition of the iodohydrin intermediates present. It is also possible that continuous stirring may prevent "hot spots" and local action which could result in decomposition of the intermediates and polymerization of 1,2-epoxypropane initiated by cations formed according to the following reaction scheme.



Traces of polymers were observed when the reactions were allowed to stand at room temperature. Isopropyl alcohol could be formed in the reaction by reduction of the acetone by hydrogen, hydrogen iodide, or colloidal magnesium all of which are undoubtedly present in the Grignard reagent. Also it could conceivably be produced from the iodohydrin intermediate by reduction.



$$(ICH_2\overset{CH_3}{C}H\text{-}O\text{-})_2Mg \xrightarrow[\text{(2) Hydrolysis}]{\text{(1) } H_2 \text{ or } Mg} CH_3\overset{OH}{C}HCH_3$$

In all of the reactions of organomagnesium iodides with 1,2-epoxypropane under controlled conditions traces of acetone were found and in most reactions (phenyl and s-butyl Grignards were exceptions) isopropyl alcohol was found. In the case of the reaction of phenylmagnesium iodide with 1,2-epoxypropane, benzene and diphenyl were isolated in considerable amounts. These results were not unexpected (See HISTORICAL, page 12). The case of the reaction of n-propylmagnesium iodide with 1,2-epoxypropane was studied more closely than the other reactions of organomagnesium iodides with 1,2-epoxypropane for the purpose of determining a mass balance. In carrying out the reaction of n-propylmagnesium iodide with one mole of 1,2-epoxypropane (Table VIII) it was found that on hydrolyzing the reaction mixture substantial amounts of propane were formed. Presumably the formation of propane could have taken place according to the following reaction.

$$n\text{-}C_3H_7MgI + HOH \longrightarrow n\text{-}C_3H_7H + Mg(OH)I$$

When n-propylmagnesium iodide was treated with two moles of 1,2-epoxypropane only a trace of propane was found. From this data we can draw the conclusion that in the case of the reaction of one mole of organomagnesium iodide with one mole of 1,2-epoxypropane most of the 1,2-epoxypropane is tied up as the iodohydrin intermediate or in some other way so that it is not free to attack the organomagnesium bond. Moreover, if the iodohydrin intermediate decomposes (as it obviously does since the yield of 1-iodo-2-propanol decreases with time) the epoxide in whatever form it may be does not react with the organomagnesium bond to produce an alcohol.

The data in Table III summarizes the results obtained under controlled conditions (i.e., constant temperature and continuous stirring) and the results obtained when the conditions were not controlled. This data indicates the need for carefully controlled reaction conditions. It is apparent from the wide variance of iodohydrin yields that many factors are probably influencing the course of the reaction when the reaction conditions are not constant, and for this reason the reaction mixture was stirred continuously and the temperature and length of reaction time were controlled as carefully as possible. When this was done results were reproducible to within 2-5% depending on the Grignard reagent used (see EXPERIMENTAL, page 29).

When organomagnesium iodides were caused to react with 1,2-epoxypropane the yields of the alcohols were similar no matter whether the conditions were controlled or not (Tables III and IV). However, the yields of 1-iodo-2-propanol varied noticeably. This variance was extreme in the case of the ethylmagnesium iodide at short reaction periods (Table IV) and for this added reason both temperature and reaction time were controlled as closely as possible and the reaction mixture was stirred continuously during the course of the reaction.

The effect of heat on the reaction of alkylmagnesium iodides with 1,2-epoxypropane was studied in the case of ethylmagnesium iodide. It was found that heating at the reflux temperature of ether for five hours caused marked lowering of the yields of 1-iodo-2-propanol but did not appreciably increase the yield of 2-pentanol (Table III). This is in agreement with the work of Huston and Bostwick (25) who found similar tendencies exhibited in the case of alkylmagnesium bromides. On the other hand Huston and Tiefenthal (26) found that heating materially increased yields of alcohol while decreasing yields of 1-chloro-2-propanol.

The yields of 1-iodo-2-propanol from the reaction of organomagnesium iodides with 1,2-epoxypropane (Table V) are similar at low temperature (5°C.) and short reaction times. From this we might infer that there is relatively little difference between the magnesium-iodine bonds in either case. When the temperature was increased to 15°C. for one hour the yields were still similar except in the case of s-butylmagnesium iodide, where the yields of 1-iodo-2-propanol were lower. However, as the reaction time increases (temperature constant at 15°C.) the yields of 1-iodo-2-propanol decrease in no regular manner. The decrease in yield does, however, become more rapid with increased size and branching of the alkyl group. It would seem possible then that the alkyl group might play some part in the decomposition of the iodohydrin intermediate.

Similar reactions at 25°C. show that at higher temperature the rate of decomposition of the iodohydrin intermediate is speeded up, as might be expected, except in the case of the methyl Grignard reagent which shows little change in yield of iodohydrin with either time or temperature. It is apparent from a study of the series of reactions of one mole of organomagnesium iodide with one mole of 1,2-epoxypropane which were hydrolyzed at one, two, four, and six hours that the methyl and phenyl Grignards show little change in yield of iodohydrin with time. On the other hand the n-propyl and n-butyl Grignards show an increased yield of 1-iodo-2-propanol at two hours and then a decrease indicating that the reactions are slower than those of the methyl and ethyl Grignards with 1,2-epoxypropane. The isopropyl and s-butyl Grignards show a marked decrease of iodohydrin yield indicating that the maximum yield was probably reached before the first reaction in the series was hydrolyzed.

The curves in Figure I based on the reaction of one mole of organomagnesium iodide with one mole of 1,2-epoxypropane, represent the decomposition of 1-iodo-2-propanol with respect to time. Based on the comparisons of the 1-iodo-2-propanol produced in the reaction of one mole of organomagnesium iodide with one mole of 1,2-epoxypropane, one can say that the methyl Grignard reagent is unique in that it shows little change with time, and that phenyl, n-propyl, and n-butyl Grignard reagents are somewhat similar. Ethyl, on the other hand, is very unusual in that it has so wide a range between the maximum and final yield. Isopropyl and s-butyl also exhibit similar curves. In general one can say that after about twelve hours the rate of decomposition of iodohydrin intermediate seems to decrease and almost level off except in two cases (ethyl and n-butyl). Yields of alcohol in all cases were of the order of one to two percent.

It would be difficult to compare the results of this investigation with that of previous workers (25,26) since all experiments reported here were carried out under conditions of constant temperature, continuous stirring throughout the course of the reaction, and controlled reaction times, while those of the previous workers were not run under such conditions.

The results of a series of reactions of organomagnesium iodides with two moles of 1,2-epoxypropane are summarized in Table VI. A series of five reactions was set up and one reaction was hydrolyzed at each of five set time intervals. In all cases except the reaction of isopropyl and s-butyl Grignard reagents with two moles of 1,2-epoxypropane the iodohydrin yield exhibited an increase and then a decrease: the maximum yield of iodohydrin in several cases being close to 100%. The reaction of isopropylmagnesium iodide with two moles of 1,2-epoxypropane showed 100% iodohydrin yield at zero time while the maximum yield of iodohydrin from the reaction of s-butylmagnesium iodide with two moles of 1,2-epoxypropane was only 85%. Here as in the reaction of one mole of organomagnesium iodide with one mole of 1,2-epoxypropane we find decomposition of the iodohydrin intermediate occurring with time. In all cases the alcohol yield increases steadily until about 18 hours when there is a tendency for the yields of the alcohols to level off.

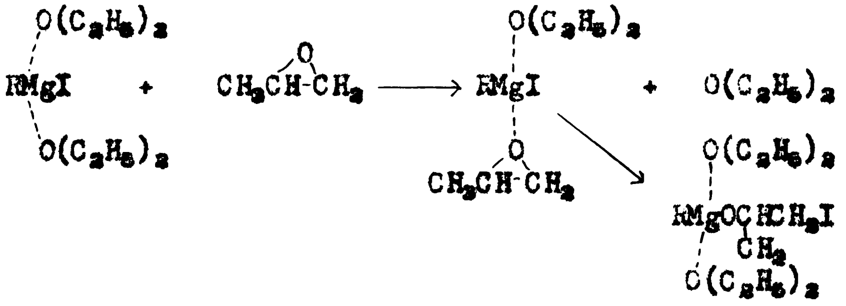
The time necessary for the reaction of the organomagnesium iodides with two moles of 1,2-epoxypropane to give a negative test is very interesting (see Table VI). The relative times for obtaining a negative test seem to depend on the number of carbons present in the alkyl groups with the longer chain normal alkyl groups reacting at the slowest rate. On this basis methyl (negative at eight hours), ethyl (negative at 6.7 hours), and phenyl (negative at 9.5 hours) have about the same order of reactivity, while the n-propyl (negative at 12 hours) and the n-butyl (negative at 25 hours) react somewhat more slowly. The isopropyl (negative at 5 hours) and s-butyl (negative at 4.5 hours) tend to react more rapidly to give a negative test but not necessarily to give the best yields of the alcohol. Presumably there would be more possibility for side reactions with a more reactive hindered alkyl group.

It is interesting to note also that in the reactions of the diorganomagnesiums with two moles of 1,2-epoxypropane all the reactions gave a negative test with Michler's ketone at about the same time (dialkylmagnesium: 4.5-6.0 hrs.; diphenylmagnesium: 7 hrs.). This would seem to indicate that there is relatively little difference between the organomagnesium bond in the cases studied.

The effect of standing after obtaining a negative Michler's ketone test was studied for each Grignard reagent. It was found that in almost all cases there was an increase in alcohol yield with increased time although only with n-propylmagnesium iodide did the increase appear to be substantial. The phenylmagnesium iodide actually exhibited a decrease in yield with increased reaction time but the small difference in yield (three percent) could be due to experimental error.

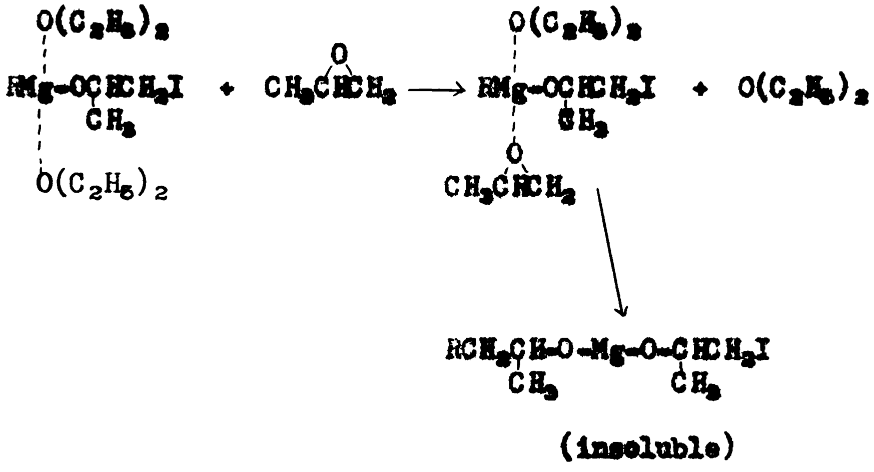
The reaction of diorganomagnesium with two moles of 1,2-epoxypropane gave yields which were of the same order as those obtained for the reaction of the alkylmagnesium iodide with 1,2-epoxypropane. Four of the diorganomagnesium compounds (ethyl, n-propyl, isopropyl, and phenyl) when reacted with two moles of 1,2-epoxypropane gave larger yields of the expected alcohols than did the organomagnesium iodides upon standing for periods of time up to double the time necessary for the test with Michler's ketone to become negative. On the other hand three of the diorganomagnesium compounds (methyl, n-butyl, s-butyl) when reacted with two moles of 1,2-epoxypropane gave lower yields of the expected alcohols than did the corresponding alkylmagnesium iodides. There is some basis for expecting this lowered yield--at least in the case of the dimethylmagnesium--since Wright (46) has come to the conclusion that dimethylmagnesium is less reactive toward carbonyl groups than methylmagnesium iodides. The reaction of dinormalpropylmagnesium with two moles of 1,2-epoxypropane showed the greatest increase in alcohol yield on standing (from 12% at six hours to 33% at 12 hours), but a similar reaction allowed to run for 24 hours gave only a 38% yield of alcohol. It appears from this fact that there was very little reaction occurring during the period from 12 to 24 hours.

From the data discussed above one can at least draw the conclusion that in the reaction of organomagnesium iodides with 1,2-epoxypropane the first reaction (fast) is to give the iodohydrin intermediate. This reaction is accompanied by little if any precipitation of solid material.



(A) (soluble)

The intermediate (A) is somewhat unstable and will decompose on standing. The rate of its decomposition is much greater at higher temperature. The products of its decomposition may be acetone, isopropyl alcohol, propylene oxide, or unsaturates. When a second mole of the epoxide is present the slower reaction to give the alcohol intermediate will occur in appreciable amounts and a thick white precipitate is formed during the course of the reaction.



It is interesting to note that it was necessary to have the second mole of epoxide present in order to get any appreciable amount of the alcohols and that only in the reaction of organomagnesium iodides with two moles of 1,2-epoxypropane did a heavy precipitate appear. It is also noteworthy that in the reaction of diorganomagnesium with two moles of 1,2-epoxypropane a white precipitate gradually appeared, which continued to increase even after a negative Michler's ketone test was obtained.

Figure II is a series of graphs showing how the yields of 1-iodo-2-propanol and the alcohols vary with time. Since only four points were available these graphs can do no more than give an indication of the over-all rate of increase of the alcohol yield and decrease in iodohydrin yield. In general methyl, isopropyl, and s-butyl show about the same type of curve for rate of production of the alcohols while all the rest are somewhat alike. In all cases there is a tendency for the rate of production of the alcohols to level off after 18 hours or less. The graph of iodohydrin yields shows that in general ethyl and n-propyl probably form more unstable intermediates than the rest, for they do not level off after about three hours as the rest do. All of the other curves are essentially similar after three hours although the initial rate of decomposition of iodohydrin intermediate varies.

The reaction of magnesium iodide with 1,2-epoxypropane could, theoretically at least, produce 1-iodo-2-propanol or 2-iodo-1-propanol or a mixture of the two. Both 2-iodo-1-propanol and 1-iodo-2-propanol have characteristic absorption bands in the infrared spectrum. The primary alcohol gives an absorption peak at about 980 cm.$^{-1}$ while the secondary alcohol gives an absorption peak at about 935 cm.$^{-1}$. From the relative heights of each of these peaks the percentage of each of the isomeric halohydrins present in a mixture could be determined (45). From an examination of the infrared absorption spectrum of a pure sample of the product obtained from the reaction of magnesium iodide with two moles of 1,2-epoxypropane it was determined by means of the method cited above that at least 90% of the iodohydrin was present as 1-iodo-2-propanol, and actually the value was probably closer to 100% (see Figure III).

The physical properties were determined and it was found that there was some disagreement with the values listed in the literature. Both the refractive index and the density found were higher than those reported by Stewart and VanderWerf (see EXPERIMENTAL, IV-B).

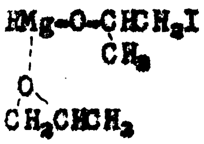
An attempt was made to prepare the 3,5-dinitrobenzoate of the 1-iodo-2-propanol but the only product obtained from the reaction of 3,5-dinitrobenzoyl chloride with 1-iodo-2-propanol was the 3,5-dinitrobenzoate of 1-chloro-2-propanol. It is believed that halogen interchange occurred during the reaction of the acid chloride with the iodohydrin. Since the melting points of the two derivatives are essentially the same, one cannot use this criterion to differentiate between them. The work does, however, tend to indicate that the iodine is in the 1-position of the halohydrin.

The precipitate present in the reaction of organomagnesium iodides with two moles of 1,2-epoxypropane has been analyzed (see Table VII) for all cases except the reaction of n-butylmagnesium iodide with two moles of 1,2-epoxypropane which set to a gel that retained ether so tenaciously that the precipitate began to decompose before all the ether could be removed.

The results of the analyses seem to indicate that the formula of the precipitate is probably (A). It is, of course, possible that the actual species present could take several forms (B, C, D) and any one or all of these might be present.

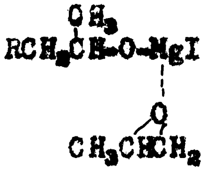
$RMgI \cdot 2CH_2\overset{O}{CHCH_2}$

(A)



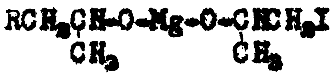
$\begin{array}{l} RMg\text{-}O\text{-}CHCH_2I \\ \quad\quad\;\; CH_3 \\ \;\vdots \\ O \\ CH_2CHCH_3 \end{array}$

(B)



$\begin{array}{c} CH_3 \\ RCH_2CH\text{-}O\text{-}MgI \\ \vdots \\ CH_3\overset{O}{CHCH_2} \end{array}$

(C)



$\begin{array}{l} RCH_2CH\text{-}O\text{-}Mg\text{-}O\text{-}CHCH_2I \\ \quad\;\; CH_3 \quad\quad\quad\quad CH_3 \end{array}$

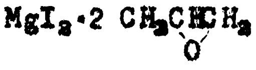
(D)

$(R_2Mg \cdot 2\ CH_3\overset{O}{CHCH_2} + MgI_2 \cdot 2\ CH_3\overset{O}{CHCH_2})$

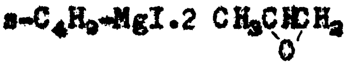
(E)

Moreover, part of the precipitate might be the result of the epoxide reacting with the other two species present in the Schlenk equilibrium (E). However, since the reaction of 1,2-epoxypropane with magnesium iodide (slightly soluble in ether) gives a dense precipitate and the reaction of alkylmagnesium iodides with one mole of epoxide is fast and gives no precipitate, one would probably be able to state that most of the precipitate is in the form of (D) or possibly (B).

It is interesting that a recalculation of the theoretical molecular weight of the precipitate in some cases gives a better comparison of the calculated percentage of magnesium and iodine with that actually found. This recalculation is based on the fact that in some Grignard reagents the titrated alkyl ($R^{(-)}$) percentage is much less than the titrated iodine percentage and therefore some of the iodine must be present as magnesium iodide (in excess of that produced by means of the Schlenk equilibrium) instead of organomagnesium iodide. Accordingly, it was assumed for the s-butylmagnesium iodide, for example, that seventy percent of the iodine was present as s-butylmagnesium iodide (alkyl found was 68-75%) and the other thirty percent of the iodine was present as magnesium iodide. This means that fifteen percent of one mole of (F) and seventy percent of one mole of (G) could be considered to be present in the precipitate.


$MgI_2 \cdot 2\ CH_3\underbrace{CHCH_2}_{O}$

(F)


$s\text{-}C_4H_9\text{-}MgI.2\ CH_3\underbrace{CHCH_2}_{O}$

(G)

In the case of the precipitate from the reaction of ethylmagnesium iodide with two moles of 1,2-epoxypropane the poor agreement of the magnesium analysis (9.67%) with the calculated (8.22%) was not explainable.

All repeated analyses for magnesium for this precipitate gave the same results. In general it was felt that of the two analyses performed (magnesium and iodine) the magnesium analyses were the most accurate since the smaller percentage of magnesium resulted in a greater sensitivity.

An attempt was made to run a mass balance on the reaction of n-propylmagnesium iodide with 1,2-epoxypropane. The results of the reaction of n-propylmagnesium iodide with one mole of epoxide are listed in Table VIII. About 97% of the reacting materials were recovered with 81% being definitely identified and the remaining 16% being qualitatively identified (see Table VIII). It is evident from the results indicated in the table that most of the n-propyl residue is reduced to give propane during hydrolysis. Also much of the iodine is lost to the magnesium salts during hydrolysis.

The reaction of n-propylmagnesium iodide with two moles of epoxide was also studied and the results of the mass balance are given in Table IX. Here only 88% of the reacting materials were recovered with 67% being definitely identified and the remaining 21% being qualitatively identified (see Table IX). It is evident that a small portion of the iodine is lost to the magnesium salts and that about 20% of the epoxide is unreacted. It is also apparent that iodine is not limited to the formation of 1-iodo-2-propanol since traces of iodine could be found in most of the fractions.

Physical constants and derivatives of the alcohols produced in the reaction of organomagnesium iodides with 1,2-epoxypropane were determined and are listed in Tables X and XI. There appears to be some error in reporting the melting point of the 3,5-dinitrobenzoate of 4-methyl-2-hexanol in earlier studies (25,26) of the reaction of organomagnesium halides with 1,2-epoxypropane. The melting point of 50-51°C. obtained for the 3,5-dinitrobenzoate of the 4-methyl-2-hexanol from the reaction of s-butylmagnesium iodide with 1,2-epoxypropane checks with the value reported in the literature (40) for this derivative.

SUMMARY

SUMMARY

1. It has been shown that oxygen probably has little effect on the course of the reaction of organomagnesium iodides with 1,2-epoxypropane.

2. In order to get reproducible results in the reaction of organomagnesium iodides with 1,2-epoxypropane it was found necessary to control the reaction condition carefully with respect to temperature, reaction time, and stirring.

3. It was found that refluxing the reaction mixture containing an organomagnesium iodide and 1,2-epoxypropane gave no appreciable increase in the yield of the alcohol and that the yield of 1-iodo-2-propanol was greatly reduced.

4. The results presented show that in the reaction of organomagnesium iodides with 1,2-epoxypropane the reaction at the organomagnesium bond is slow and that an initial fast reaction takes place at the magnesium-iodine bond.

5. When organomagnesium iodides are caused to react with two moles of 1,2-epoxypropane the yields of both the alcohol and 1-iodo-2-propanol are increased.

6. The physical properties of 1-iodo-2-propanol have been determined and the α-naphthyl urethane has been prepared.

7. Analysis of the precipitate present before hydrolysis in the reaction of organomagnesium iodides with two moles of 1,2-epoxypropane indicates that the precipitate probably has a formula corresponding to a ratio of one mole of organomagnesium iodide to two moles of 1,2-epoxypropane.

8. Mass balances were determined for the reaction of n-propylmagnesium iodide with both one and two moles of 1,2-epoxypropane.

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