[CONTRIBUTIONS FROM THE KEDZIE CHEMICAL LABORATORY OF MICHIGAN STATE COLLEGE]

THE REACTION OF ETHYLENE OXIDE WITH SOME ALKYLMAGNESIUM IODIDES

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Received July 10, 1952

Earlier work in this laboratory has shown in general, when alkylmagnesium bromide was treated with an equal molecular proportion of ethylene oxide or propylene oxide, that the initial reaction was predominently with the magnesium bromide bond (1, 2).

When ethylene oxide or propylene oxide was added to alkylmagnesium chloride, in equal molecular proportion, there was a definite reaction with the alkylmagnesium bond. It was in most cases extensive and sometimes greater than with the magnesium chloride bond (3, 4).

TABLE I

PERCENTAGE YIELDS OF ALCOHOLS AND ETHYLENE IODOHYDRIN BASED UPON THE TITRATED GRIGNARD REAGENTS

R IN RMgI	RMgI + C_2H_4O No Heat		RMgI + 2 C_2H_4O No Heat		RMgI + C_2H_4O Heat	
	Alcohol	Iodohydrin	Alcohol	Iodohydrin	Alcohol	Iodohydrin
Methyl	54.	36.	64.	29.	Exploded	
Ethyl	53.7	20.	72.	40.	40.	13.5
n-Propyl	36.3	30.	61.5	53.	35.	15.
Isopropyl	32.6	21.5	49.3	51.	30.	18.4
n-Butyl	35.2	24.3	64.3	58.1	36.9	22.2
sec-Butyl	18.	26.2	35.	43.		
Isobutyl	18.5	30.1	26.3	54.3		

The addition of the second mole of propylene oxide to alkylmagnesium bromide gave on standing a considerable reaction with the alkylmagnesium bond (2). The addition of the second molecular quantity of either ethylene oxide or propylene oxide to alkylmagnesium chloride increased in general the yields of both chlorohydrin and alcohol (3, 4).

This paper reports the study of the addition of ethylene oxide to various alkylmagnesium iodides. Examination of Table I will show that, when ethylene oxide was added to a molecular equivalent of alkylmagnesium iodide, in most cases the reaction with the alkylmagnesium bond predominated. The addition of the second mole of ethylene oxide in general increased the yields of both iodohydrin and alcohol.

When a mixture of one mole of methylmagnesium iodide and one mole of ethylene oxide was *heated* decomposition took place with explosive violence. Heating of a higher alkylmagnesium iodide with an equi-molecular quantity of ethylene oxide gave evidence of decomposition with the elimination of ethylene oxide and a marked decrease in the yield of iodohydrin (4).

These decreases are attributed to the decomposition of such intermediates as

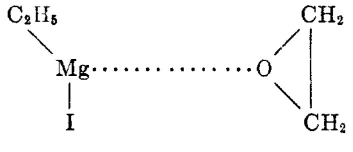
$$RMgOCH_2CH_2I,\ (ICH_2CH_2O)_2Mg,\ \text{and}\ IMgOCH_2CH_2I.$$

When ethylmagnesium iodide was the reactant heat gave a distinct decrease in yield of alcohol indicating decomposition of the Meisenheimer complex (see below) before rearrangement. When a higher alkylmagnesium iodide was the reactant the increase or decrease in yield of alcohol was not significant.

When a two-mole quantity of ethylene oxide was reacted with one mole of ethylmagnesium iodide a precipitate was obtained which gave the correct analysis for $C_6H_{13}IMgO_2$. Hydrolysis gave excellent yields of both 1-butanol and iodohydrin indicating that the Grignard reagent had been attacked at both the ethylmagnesium and magnesium iodide bonds to give $C_2H_5CH_2CH_2OMgOCH_2CH_2I$. The simultaneous formation of $(C_2H_5CH_2CH_2O)_2Mg$ and $(ICH_2CH_2O)_2Mg$ is probable.

It has been assumed in previous publications that the reaction with either alkylmagnesium or magnesium halide bond took place through preliminary addition of the magnesium and oxygen to form a complex suggested by Meisenheimer and his coworkers (5). In one case in the present study, ethylmagnesium iodide, we have been able to isolate a precipitate which gives every indication of being a complex of the Meisenheimer type. When one-half molecular quantity of ethylene oxide was added to one molecular quantity of ethylmagnesium iodide a precipitate was formed which showed an iodine and magnesium content approximating that of the empirical formula C_4H_9IMgO. This empirical formula corresponds to:

(a.) $C_2H_5CH_2CH_2OMgI$ which upon hydrolysis would give 1-butanol,
(b.) $C_2H_5MgOCH_2CH_2I$ which upon hydrolysis would give ethylene iodohydrin, or
(c.) Meisenheimer's complex



Hydrolysis gave neither 1-butanol nor ethylene iodohydrin. However, if the complex was gently heated, ethylene oxide was given off. By careful cooling and redistillation the amount of ethylene oxide recovered was approximately 93% of the theoretical required by the above simple addition complex; neither the alkylmagnesium nor the magnesium iodide bonds had been attacked. When the addition of ethylene oxide was continued until a full molecular quantity had been added, the precipitate completely disappeared and hydrolysis gave both 1-butanol and ethylene iodohydrin.

The reactions were carried out with the alkylmagnesium iodides shown in Table I.

EXPERIMENTAL

Preparation of alkylmagnesium iodides. Methylmagnesium iodide and the higher alkylmagnesium iodides were prepared by techniques similar to those used in the preparation of the alkylmagnesium chlorides for reaction with ethylene oxide (3). The concentrations of the RMgI were carefully determined by titration (6). It was found that a long period of standing did not enhance the yield of the Grignard reagent.

Reaction of one mole of ethylene oxide with one mole of Grignard reagent. The measured Grignard reagent was placed in a dry nitrogen-filled 1-l. three-neck flask, fitted with a reflux condenser, stirrer, a small glass tube for the introduction of dry nitrogen, and a separatory-funnel equipped with an outer metal jacket. The Grignard reagent was cooled in an ice-salt bath (−6°). Then 50 ml. of anhydrous ether with the calculated amount of ethylene oxide was placed in the separatory-funnel surrounded by Dry Ice. The contents were protected from moisture with a $CaCl_2$ tube. The ethylene oxide and ether were added *cautiously* and the mixture was allowed to remain in the reaction flask for 5 or 6 hours; then the ice-bath was removed and the stirring process was continued for an hour. Hydrolysis was accomplished by adding an aqueous solution of $(NH_4)_2SO_4$ in chipped ice. After hydrolysis the ether layer was decanted. The pasty residue was extracted 3 or 4 times with small portions of ether. If the ether-water extract was basic (litmus), it was neutralized with a small amount of dilute HCl (ice), and again extracted with three (100-ml.) portions of ether. The ether extracts were combined, then fractionated through a short Fenske-type column, fitted with a total reflux, partial take-off type head. In later reactions iodohydrin was determined by boiling the combined ether extracts over 40 g. of NaOH in 100 ml. of water and titration of the iodide ion by the Vohlard Method (3). The alcohol was then fractionated from the ether portion.

Reaction of one mole of ethylene oxide with one mole of Grignard reagent followed by heating. The addition of ethylene oxide was carried out as described above. The reflux condenser was then set for distillation and the flask containing the reaction mixture was placed in a Glas-Col heating mantle. About 300 ml. of ether was distilled off and the residue (containing approximately 600 ml. of ether) was allowed to cool. Then 300 ml. of C_6H_6 was added. The condenser was reversed, a Dry-Ice trap was connected to the exit, and a gentle reflux was continued for six hours with continuous stirring. In all cases ethylene oxide was recovered. The addition product was hydrolyzed, and the yields or products determined by titration and distillation as before. Polymerization was indicated by the highly viscous residue left after distilling off the alcohol.

We were unable to carry out this reaction with methylmagnesium iodide because of the explosive decomposition of the semisolid intermediate.

Reaction of two moles of ethylene oxide with one mole of Grignard reagent. The procedure was the same as described above, with the exception that two moles of ethylene oxide were added. In order to have the reaction go to completion, it was necessary to add the ethylene oxide very slowly and to stir the reacting mixture briskly. The reaction product gelled when allowed to stand overnight. Hydrolysis, analysis and distillation were carried out as previously described. As in the preceding series a viscous residue remained after the alcohol had been distilled.

The determination of completion of the reaction of two moles of ethylene oxide with one mole of alkylmagnesium iodide by the use of Michler's ketone was not successful in case of alkylmagnesium iodides. A dark brown color developed which masked the reaction. The reaction mixture of these proportions decomposed on long standing with formation of free iodine and very high-boiling products.

The intermediate addition product formed from methylmagnesium iodide tended to decompose violently on standing in contact with air.

The reaction of one-half mole of ethylene oxide with one mole of ethylmagnesium iodide. It was noted that a fine precipitate was formed when ethylene oxide was allowed to react with the C_2H_5MgI. As the amount of ethylene oxide was increased to one-half mole the cloudiness disappeared with the formation of a fine precipitate. This precipitate was separated with a high speed centrifuge.

A sample of the addition product was placed in a 500-ml. flask with 250 ml. of dry ether. The flask was placed in a Glas-Col mantle and connected to a reflux condenser, which at the top was connected with condensing bulbs surrounded by an acetone-Dry Ice mixture in a large thermos bottle. The temperature in the thermos bottle was maintained at −10° to −15°. The addition product was heated gently allowing the ether to reflux. After two hours, the condenser water was partially shut off to permit the temperature to rise so that both ether and ethylene oxide passed over. As the condensing bulbs became full their contents were emptied into an Erlenmeyer flask and kept cool by refrigeration.

TABLE II

Analysis of Addition Product from 0.5 Mole of Ethylene Oxide and 1 Mole of C_2H_5MgI

CONDENSATION	IODINE, %	MAGNESIUM, %
1	53.8	10.
2	55.1	9.8
Calculated for C_4H_9IMgO	56.7	10.7
	RECOVERY OF ETHYLENE OXIDE, %	
1	93.	
2	91.4	

TABLE III

Characterization of Alcohols

ALCOHOL	B.P., °C. (740 mm.)	n_D^{20}	3,5-DINITROBENZOATE M.P., °C.
1-Propanol	97.2 (7, 8)	1.38543	74. (11)
1-Butanol	117.7 (1, 7, 8)	1.39931	64. (11)
1-Pentanol	137.9 (1, 9)	1.40963	46.4 (11)
3-Methyl-1-butanol	132.0 (1, 10)	1.4084	61. (11)
1-Hexanol	157.5 (1, 8)	1.4161	58.4 (11)
3-Methyl-1-pentanol	152.4 (1, 10)	1.4115	38. (11)
4-Methyl-1-pentanol	152.0 (1, 10)	1.4490	72. (11)

Near the end of refluxing the water was completely shut off in the condenser. The balance of the ethylene oxide-ether was collected in the bulbs. About 50 ml. of ether and ethylmagnesium iodide remained in the flask.

The ethylene oxide-ether solution was repeatedly fractionated.

Identification of products. The alcohols were identified by the boiling point, refractive indices, and the mixture melting points of their 3,5-dinitrobenzoates.

SUMMARY

1. The reaction of alkylmagnesium iodide and ethylene oxide in one to one mole ratio gave both alcohol and iodohydrin indicating reaction with both alkylmagnesium and magnesium iodide bonds.

2. Heating of the one to one mole mixture of ethylene oxide and alkylmagnes-

ium iodide did not materially change the yield of alcohol except in the case of ethylmagnesium iodide where a distinct decrease was found. In general heating caused a distinct decrease in the yield of iodohydrin. Mixtures of ethylene oxide and methylmagnesium iodide decomposed with explosive violence.

3. The yields of the alcohol and ethylene iodohydrin were increased by the addition of the second mole of ethylene oxide.

4. The addition of one-half mole of ethylene oxide to one mole of ethylmagnesium iodide gave a precipitate of the empirical formula C_4H_9IMgO. Hydrolysis and decomposition by warming indicated a complex of the type suggested by Meisenheimer.

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