1930

Part I. The effect of ultraviolet light upon some organic compounds, Part II. The synthesis of amino compounds

Lloyd L. Heck
Iowa State College

Recommended Citation

Heck, Lloyd L., "Part I. The effect of ultraviolet light upon some organic compounds, Part II. The synthesis of amino compounds" (1930). *Retrospective Theses and Dissertations*. 14760.
https://lib.dr.iastate.edu/rtd/14760

PART I

THE EFFECT OF ULTRAVIOLET LIGHT UPON SOME ORGANIC COMPOUNDS

PART II

THE SYNTHESIS OF AMINO COMPOUNDS

BY

Lloyd L. Heck

A Thesis submitted to the Graduate Faculty
for the Degree of
DOCTOR OF PHILOSOPHY
Major subject--Organic Chemistry

Approved

Signature was redacted for privacy.

In charge of Major work.

Signature was redacted for privacy.

Head of Major Department.

Signature was redacted for privacy.

Dean of Graduate College.

Iowa State College
1930

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

ACKNOWLEDGMENT.

The author wishes to express his appreciation to Dr. Henry Gilman for the suggestion of these problems and for the generous advice and encouragement given during the progress of this work.

CONTENTS

PART I

CONTENTS (Continued)

PART II - A

CONTENTS (Continued)

CONTENTS (Continued)

PART II - B

CONTENTS (Continued)

PART I

THE EFFECT OF ULTRAVIOLET LIGHT UPON SOME ORGANIC COMPOUNDS

INTRODUCTION

There are almost innumerable references in the literature to work done upon the effect of rays emitted by mercury vapor and other so-called ultraviolet light sources on organic compounds. Any attempt to classify or organize this mass of information would be almost futile and far beyond the scope and magnitude of this undertaking. It was found that there are available two excellent books which will give a large amount of general information upon this particular subject. These are by Ellis and Wells[1] and by Morton[2].

The object of this present work was to advance studies already started by Gilman and co-workers upon the stability of the Grignard reagent toward light[3] and heat[4]. An added incentive was the fact that more recently Mme. Ramart Lucas and M. F. Salmon Legagneur[5] reported that isobutyl chloride

---

(1) Ellis and Wells, "Chemical Action of Ultraviolet Rays," Chemical Catalog Company, New York. 1925.

(2) Morton, "Radiation in Chemistry," D. Van Nostrand Company, New York, 1928.

(3) Gilman and Meyers, J. Ind. Eng. Chem., 15, 61 (1923). Gilman and Meyers, ibid., 14, 243 (1922).

(4) Gilman and Peterson, Rec. trav. chem., 48, 247 (1929).

(5) Mme. Ramart Lucas and M. F. Salmon Legagneur, Compt. rend., 186, 39 (1928).

could be changed to tertiary butyl chloride by means of ultraviolet rays. This study prompted Gilman and Heck[6] to determine whether it would be possible to cause a similar rearrangement of the corresponding organomagnesium halides[7]. The conclusion reached was that ultraviolet rays affected isobutylmagnesium chloride and tertiary butylmagnesium chloride to no appreciable extent inasmuch as any rearrangement was concerned. It might be mentioned in this connection that Berthelot and Gaudechon[7a] have reported that zinc diethyl decomposes under ultraviolet light to deposit free zinc and evolve a gas. However mercury diethyl decomposes to give free mercury simply by standing in the laboratory.

In addition to work which was attempted to ascertain the permanence of the Grignard reagent toward ultraviolet light, several other studies were made upon a miscellany of compounds.

---

(6) Gilman and Heck, Bull. soc. chim., <u>45</u>, 1095 (1929).

(7) It might be mentioned in this connection that studies are being made in this laboratory upon possible rearrangements of organomagnesium halides. See Gilman and Harris, J. Am. Chem. Soc., <u>49</u>, 1825 (1927). Also Gilman and Kirby, ibid., <u>51</u>, 1571 (1929).

(7a) Berthelot and Gaudechon, Compt. rend., <u>156</u>, 1243 (1913).

1. It has been shown by Gilman and co-workers[8] that we do not have addition of the Grignard reagent to the ethylenic double bond. Accordingly an unsuccessful attempt was made to cause phenylmagnesium bromide to react with unsym- diphenyl ethylene in the presence of ultraviolet light.

2. Gilman and Flick[9] mention the fact that tetra-p-tolyl ethylene melts lower than would be expected of such a compound. In view of the fact that a search of the literature indicates that ultraviolet light causes the substance to change from the higher to the lower melting isomer, as fumaric acid[10] m.p., sublimes at 200° to maleic acid m.p. 130° and crotonic acid[11] m.p., 71° is changed to isocrotonic acid m.p., 15.5°, it would seem that there would be slight hope of obtaining a higher melting stereoisomer. Nevertheless it was thought worth while to carry out such an experiment with both tetra-p-tolyl ethylene and furylacrylic acid. It was hoped to change the latter compound to the allo form.

3. Because of the fact that Rosemund, Luxat and Tiedmann[12]

---

(8) (a) Gilman and Crawford, J. Am. Chem. Soc., 45, 554 (1923).
(b) Gilman and Peterson, ibid., 48, 423 (1926).
(c) Gilman and McGlumphy, Rec. trav. chim., 47, 418 (1928).
(d) Gilman and Harris, Rec. trav. chim., 49, 762 (1930).

(9) Gilman and Flick, Rec. trav. chim., 48, 461 (1928).

(10) Kailan, Z. Physikal. Chem., 87, 333 (1914).

(11) Stoermer and Robert, Ber., 55, 1030 (1922).

(12) Rosemund, Luxat and Tiedmann, Ber., 56, 1950 (1923).

have recently shown that ultraviolet radiation exerts an influence on the reactivity of a halogen bound to a carbon ring, it was thought that it would be worth while to attempt the preparation of phenylmagnesium chloride from chlorobenzene and magnesium under the influence of ultraviolet light. All attempts were unsuccessful, However, this Grignard reagent has been recently prepared by Gilman and co-workers[13] by other methods.

---

(13) Gilman and St. John, Rec. trav. chim., 49, 717 (1930).
Gilman and Brown, J. Am. Chem. Soc., 52, 3330 (1930).

DESCRIPTION OF APPARATUS

The source of the ultraviolet light was a new 220 volt, 60 cycle, 5 ampere A.C., air-cooled mercury vapor lamp, manufactured by the Hanovia Chemical Company. This lamp was later replaced by another new lamp. By a method described by Anderson and Robinson[14] it was found that the second lamp was seven times as effective as the first lamp at the time the first lamp was removed from service.

Most of the work reported here was done with the first lamp while it was relatively new. Some check runs were made with the second lamp when it was entirely new. It might be added that the first lamp when removed from service was still effective for the cure of rachitic rats.

Even though the manufacturers claim that mercury vapor lamps are built to stand long periods of use it must be borne in mind that there is much work in the literature to the effect that these lamps deteriorate rather rapidly. For example Aston[15] states that after 200 hours use all lines in the ultraviolet were obliterated except those at 313 mμ and 366 mμ There are other citations in this same reference which indicate

---

(14) Anderson and Robinson, J. Am. Chem. Soc., <u>47</u>, 718 (1925).

(15) Ref., 2, p. 68.

that the emission of ultraviolet rays does not fall off greatly until after 500 hours of service.

The special flasks used in this work were made of quartz. These were obtained from the Thermal Syndicate.

The distance of flask from lamp and time of exposure to ultraviolet light will be noted later.

EXPERIMENTAL

Two classes of organomagnesium halides were used in this study. The first class was those which would evolve gaseous hydrocarbons upon hydrolysis at room temperatures. The second class was those from which solid acids could be obtained by hydrolysis after treatment with dry carbon dioxide.

For the first class of organomagnesium halides mentioned above the quantity of the Grignard reagent before and after exposure to the light was determined by the gas analysis method of Gilman, Wilkinson, Fishel and Meyers[16]. The technique used was that described by Gilman and Crawford[17] and with the improvements suggested by Gilman and Peterson[18].

The Grignard reagent was prepared in the usual manner using a three-necked flask fitted with a mercury seal stirrer and a Hopkins condenser. The strength of the reagent was calculated to be such that a 25.0 c.c. aliquot would evolve between 300 c.c. and 400 c.c. of gas. An aliquot, withdrawn by means of a pipette, was placed in a special graduated flask and immediately hydrolyzed. Good check runs were easily obtained. The amount of gas given in this constituted what will

---

(16) Gilman, Wilkinson, Fishel and Meyers, J. Am. Chem. Soc., 45, 150 (1923).

(17) Ref., 8a, p. 555 shows diagram of apparatus.

(18) Ref., 8b.

be termed a "blank."

The next procedure was to place an aliquot into each of three special graduated flasks; namely, a quartz, a pyrex and a pyrex covered with tin foil. These flasks were each fitted with a Hopkins condenser and arranged on one ring stand in such manner that all flasks were in the same system. In all cases, except those mentioned later, the system was protected by a special trap[19] for maintaining an inert atmosphere. The purpose for using each of the three flasks was: (1) Ultraviolet rays should penetrate quartz to a greater extent than they do pyrex. Accordingly it was thought if any decomposition should occur on account of the light rays it would be more marked in the quartz than in the Pyrex flask. (2) The second Pyrex flask was covered with tin foil so as to exclude any possibility of decomposition by light[20]. After exposing the contents of these flasks to the ultraviolet light for a twenty to thirty hour period each was hydrolyzed and the volume of gas given off was carefully measured. These volumes were then converted to standard conditions of pressure and temperature.

---

(19) Gilman and Hewlett, Rec. trav. chim., 48, 1124 (1929).

(20) This idea was obtained from work reported by Porter, Ramsperger and Steel, J. Am. Chem. Soc., 45, 1827, (1923) Tin foil was used to prevent penetration by ultraviolet rays.

The organomagnesium halides which gave solid acids after being treated with dry carbon dioxide prior to hydrolysis, were prepared in the customary manner. An aliquot was removed from the stock solution and placed in a three-necked flask fitted with a stirrer and Hopkins condenser. This was immediately treated with dry carbon dioxide and worked up according to generally accepted methods[21]. This served as a "blank" for determining the maximum amount of acid obtainable from an aliquot of the reagent before exposure to the light. A second aliquot was placed into a special quartz three-necked flask fitted with a stirrer, condenser, and trap[19]. This was placed near the lamp and irradiated for about twenty hours, treated with carbon dioxide and worked up as described above. The third aliquot being identical with the second, was placed in a three-necked flask with stirrer, condenser and trap[19], which permitted the same conditions of time, stirring and protection except no exposure to light. Thus information could be obtained which would enable one to determine whether any decomposition that might come about was caused by the ultraviolet light or by some other influence.

---

(21) Gilman and Parker, J. Am. Chem. Soc., 46, 2816 (1924).
Puntambeker and Zoellner, Organic Synthesis, Vol. VIII, 104 (1928).
Gilman and St. John, Rec. trav. chim., 48, 743 (1929).

The results obtained from these experiments are arranged in Tables I and II in such a manner as to make the tables largely self-explanatory.

Table III gives results obtained by using an entirely new lamp and serves as a check upon the results given in Table I.

TABLE I

Grignard Reagent	Description of Flask	Gas Evolved on Basis of 25.0cc Grignard			Gas Evolved on Basis 25.0cc Grig. St'd. Cond.	Time of Exposure to Light	Distance of Flask From Light	% Decrease in Volume of Gas Evolved	% Decomposition Blank Subtracted[e]
		cc's	Temp	Pres					
[a] Methylmagnesium Iodide	Blank	396.0	30°	736.7	346.0				
a " " "	Quartz[b,k]	220.0	27°	734.8	194.0	25.0Hrs.	10.0"	19.2	
a " " "	Pyrex[k]	332.0	27°	734.8	292.0	25.0 "	10.0"	15.6	
a " " "	Blank	328.0	30°	734.8	287.0				
a " " "	Quartz	210.0	30°	734.8	180.0	30.0 Hrs	10.0"	37.3	
a " " "	Pyrex	250.0	30°	734.8	215.0	30.0 "	10.0"	25.1	
Ethylmagnesium Chloride	Blank	351.0	26°	724.0	305.0				
" " "	Quartz	347.0	25°	726.0	303.0	20.0 Hrs	8.0"	0.0	0.0
" " "	Pyrex	303.0	25°	726.0	264.0	20.0 "	8.0"	13.4	4.5
" " "	Pyrex-tinfoil	318.0	25°	726.0	278.0	20.0 "	8.0"	8.9	
" " "	Blank	356.0	25°	726.2	311.0				
" " "	Quartz	306.0	27°	726.2	266.0	20.0 Hrs	8.0"	14.5	2.9
" " "	Pyrex	331.0	27°	726.2	288.0	20.0 "	8.0"	7.4	-
" " "	Pyrex-tinfoil	316.0	27°	726.2	275.0	20.0 "	8.0"	11.7	
Ethylmagnesium Bromide	Blank	360.0	22°	724.2	318.0				
" " "	Quartz	311.0	22°	724.0	274.0	19.0 Hrs	9.0"	13.9	
" " "	Pyrex	327.0	22°	724.0	289.0	19.0 "	9.0"	9.1	
" " "	Pyrex-tinfoil	This was not hydrolyzed successfully							
Isopropylmagnesium Bromide	Blank	253.0	29°	724.0	218.0				
" " "	Quartz	210.0	25°	730.0	185.0	20.0 Hrs	7.0"	15.2	3.3
" " "	Pyrex	193.0	25°	730.0	170.0	20.0 "	7.0"	22.0	10.1
" " "	Pyrex-tinfoil	219.0	25°	730.0	192.0	20.0 "	7.0"	11.9	
n-Butylmagnesium Chloride	Blank	370.0	25°	730.0	326.0				
" " "	Quartz	318.0	25°	724.0	278.0	18.0 Hrs	8.0"	14.7	0.3
" " "	Pyrex	312.0	25°	724.0	272.0	18.0 "	8.0"	16.6	2.2
" " "	Pyrex-tinfoil	319.0	25°	724.0	279.0	18.0 "	8.0"	14.4	
n-Butylmagnesium Bromide	Blank	381.0	25°	723.4	332.0	20.0 "	7.0"		
" " "	Quartz	311.0	22°	724.0	274.0	20.0 "	7.0"	17.5	6.7
" " "	Pyrex	This was not successfully hydrolyzed							
" " "	Pyrex-tinfoil	336.0	22°	724.0	296.0	20.0 Hrs	7.0"	10.8	

TABLE I (Continued)

Grignard Reagent	Description of Flask	Gas Evolved on Basis of 25.0cc Grignard			Gas Evolved on Basis 25.0cc Grig. St'd. Cond.	Time of Exposure to Light	Distance of Flask From Light	% Decrease in Volume of Gas Evolved	% Decomposition Blank Subtracted[e]
		cc's	Temp	Pres					
n-Butyl Magnesium Iodide	Blank	307.0	25°	740.0	274.0				
" " "	Quartz[r]	245.0	25°	744.0	219.0	20.0 Hrs	7.0"	20.1	5.9
" " "	Pyrex[r]	247.0	25°	744.0	221.0	20.0 "	7.0"	19.3	5.1
" " "	Pyrex-tinfoil	261.0	25°	744.0	235.0	20.0 "	7.0"	14.2	
Isobutyl-magnesium Bromide	Blank	372.0	26°	744.0	333.0				
" " "	Quartz[r]	314.0	25°	742.0	281.0	20.0 Hrs	7.0"	15.6	4.8
" " "	Pyrex	292.0	25°	742.0	266.0	20.0 "	7.0"	20.1	9.3
" " "	Pyrex-tinfoil	332.0	25°	742.0	297.0	20.0 "	7.0"	10.8	
Sec.Butyl-magnesium Bromide	Blank#1	352.0	26°	742.0	314.0				
" " " "	Blank#2	354.0	26°	742.0	315.0				
" " " "	Quartz	294.0	28°	732.0	257.0	20.0 Hrs	7.0"	18.4	4.7
" " " "	Pyrex	261.0	28°	732.0	228.0	20.0 "	7.0"	27.6	13.9
" " " "	Pyrex-tinfoil	311.0	28°	732.0	272.0	20.0 "	7.0"	13.7	
Ter.Butyl-magnesium Chloride	Blank	376.0	25°	747.5	337.0				
" " " "	Quartz	311.0	21°	739.5	281.0	19.5Hrs	7.0"	16.6	9.5
" " " "	Pyrex	306.0	21°	739.5	276.0	19.5 "	7.0"	18.1	11.0
" " " "	Pyrex-tinfoil	346.0	21°	739.5	313.0	19.5 "	7.0"	7.1	
CONCENTRATED SOLUTION OF GRIGNARD REAGENT[c]									
[a]Ethyl-magnesium Iodide	Blank[h]	384.0	35°	740.8	332.0				
[a] " " "	Quartz	279.0	33°	735.3	240.0	26.0 Hrs	7.0"	27.7	
[a] " " "	Pyrex	290.0	33°	735.3	250.0	26.0 "	7.0"	24.6	
[a] " " "	Pyrex-tinfoil	Destroyed by Accident				26.0 "	7.0"		
SOLID GRIGNARD REAGENT[d]									
[a]Ethyl-magnesium Iodide	Blank[i]	360.0	33°	735.3	310.0				
[a] " " "	Quartz	302.0	31°	736.2	263.0	21.0 Hrs	7.0"	11.7	1.1
[a] " " "	Pyrex	300.0	31°	736.2	261.0	21.0 "	7.0"	12.6	2.0
[a] " "" "	Pyrex-tinfoil	307.0	31°	736.2	267.0	21.0 "	7.0"	10.6	

Notes on Table I.

a. The trap[19] was not used in these runs but a constant stream of dry hydrogen was kept flowing through the system.

b. On account of a mishap the first aliquot placed in this flask was destroyed. This necessitated leaving the stock solution of the Grignard reagent stand over night protected only by a calcium chloride soda-lime tube. Another aliquot was then taken, also another "blank" run was made. The blank for this flask only was 24.7 cc of RMgx gave 269 cc gas at 25° and 730 mm. This corresponds to 240 cc gas (when corrected to a 25.0 cc aliquot of RMgx solution) under standard conditions of pressure and temperature. If a comparison is made between this "blank" and the "blank" given in the table, it is readily seen that this particular Grignard reagent underwent a 27.5% decomposition during an over night interval. This illustrates how ineffective the calcium chloride soda-lime tubes are for the protection of these reagents.

c. On account of mechanical difficulties encountered during hydrolysis, it is impossible to take a 20 cc to 25 cc aliquot of a concentrated solution of the Grignard reagent and hydrolyze it in the special flasks used here. Therefore the organomagnesium halide solutions were made up as those in the first part of the table. The aliquot was placed in a flask and subsequently concentrated to about one-fifth the original volume. The ether was evaporated by passing a stream of dry hydrogen through the system for a twenty-four period prior to exposure to the light. Dry hydrogen was passed through the system during the exposure to ultraviolet light.

d. The solid organomagnesium halide was obtained as follows: The flasks containing the several aliquots were arranged as usual. Dry hydrogen was passed through the system for twenty-four hours. This operation removed about four-fifths of the ether. The flasks were put in an oil-bath heated to 150° to 160° for another twenty-four hour period. Dry hydrogen was passed through the system during this heating on the oil-bath. The ethylmagnesium bromide appeared to be very dry. Dry hydrogen was swept through the system during exposure.

e. The "blank" in this column refers to the Pyrex-tin foil-covered flask, which served as a "blank" in that the contents of this flask were under all the conditions as the other flasks with the exception of exposure to the ultraviolet light.

h and i. By comparing (h) and (i) respectively, some idea may be obtained as to the effectiveness of the trap[19]. (h) and (i) refer to the same stock solution of the Grignard reagent except that in (i) it was permitted to stand fifty-eight hours after taking aliquot (h). The flask which held the RMgx solution (before aliquot (i) was taken out) was protected by a trap[19]. This shows that the Grignard reagent underwent a 6.6% decomposition over the fifty-eight hour period. If you compare this decomposition with that of 27.5% over a twenty-hour period in (b) where calcium-chloride-soda-lime tube was used, it is seen that when the trap was used there was only about one-fourth as much decomposition in a fifty-eight hour period as in a twenty-hour period with calcium-chloride-soda-lime tube, other conditions being equal.

k. In these flasks there was some indication of decomposition as indicated by the fact that a brown-colored substance appeared on the side of the flask where the ether had evaporated. In cases where this decolorization appeared it was more pronounced in the quartz flask than in the Pyrex one. In all other cases there was no physical indication of any decomposition.

l. "Blank immediate" indicates that an aliquot was treated immediately with carbon dioxide. "Blank laboratory" means the aliquot was treated in a manner similar to the exposed aliquot except for the irradiation before treating it with carbon dioxide.

TABLE II

Grignard Reagent	Amount Used		Description of Flask and Cond.	Time of Exposure to Light and Distance	Details Concerning Acid Obtained					
	cc's	Moles			Kind	Grams	M.P.	Yield % Based on Halide	Neutral Equiv.[f]	Neutral Equiv. (Calc.)
Phenyl-magnesium Bromide	110.0	0.169	Blank[1] (immediate)		Benzoic	16.0	120-1°	77.6	130.9	122.05
" " "	110.0	0.169	Quartz	20.0Hrs-7.0"	"	16.5	120-2°	81.0	135.6	122.05
" " "	110.0	0.169	Blank[1] (lab)		"	14.0	121-2°	68.0	131.3	122.05
Benzyl-magnesium Chloride	110.0	0.169	Blank[1] (immediate)		Phenyl acetic	14.2	75-6°	49.0	146.6	136.06
" " "	110.0	0.169	Quartz	20.0Hrs-7.0"	" "	16.7	76-7°	57.7	144.1	136.06
" " "	110.0	0.169	Blank[1] (lab)		" "	16.0	76-7°	55.3	137.5	136.06
Triphenyl-methyl Mg Chloride		0.02	Blank[1] (lab)		Triphenyl acetic	3.97	265-7°	68.9	322.0	288.13
" " " "		0.02	Quartz	20.0Hrs-7.0"	" " "	3.77	265-7°	65.4	296.0	288.13

Notes on Table II.

f. The neutralization equivalent but not the melting points of these acids may give a measure of the inorganic impurities which affect the yields. Pure benzoic acid gave a neutral equivalent of 122.0 with the reagents used for this purpose. Alcohol (95%) was used as a solvent for the acids.

g. The method used for the preparation of triphenylmethylmagnesium chloride was that described by Gilman and Zoellner, J. Am. Chem. Soc., 50, 425 (1928). The "blank" was run in the laboratory under similar conditions to those of the exposed run excepting of course exposure to the ultraviolet light.

TABLE III

Grignard Reagent	Description of Flask	Changed to 25.0cc			Gas Evolved on Basis 25.0cc St'd. Cond.	Time of Exposure	Distance From Light	% Decrease in Volume	% Decomposition
		cc's	Temp	Pres					
Run #1									
n-Butylmagnesium Bromide	Blank	372.0	25°	735.0	329.6				
" " "	Quartz	303.0	25°	726.0	265.1	12.0 Hrs	5.0"	19.5	12.5
" " "	Pyrex	341.0	25°	726.0	296.4	12.0 "	5.0"	7.04	1.28
" " "	Pyrex-tinfoil	355.0	25°	726.0	310.6	12.0 "	5.0"	5.76	
Run #2									
" " "	Blank		25°	732.0	287.6				
" " "	Quartz		25°	732.0	202.4	12.0 Hrs	5.0"	35.4	12.4
" " "	Pyrex	252.0	25°	732.0	222.0	12.0 "	5.0"	32.2	9.2
" " "	Pyrex-tinfoil	275.0	25°	732.0	242.6	12.0 "	5.0"	23.0	
Run #1									
n-Butylmagnesium Chloride	Blank	303.0	25°	743.0	271.0				
" " "	Quartz	233.0	25°	743.0	208.0	12.0 Hrs	5.0"	23.24	11.79
" " "	Pyrex	251.0	25°	743.0	225.0	12.0 "	5.0"	16.97	5.52
" " "	Pyrex-tinfoil	268.0	25°	743.0	240.0	12.0 "	5.0"	11.45	
Run #2									
" " "	Blank	270.0	25°	736.0	239.0				
" " "	Quartz	249.0	25°	732.0	219.0	12.0 Hrs	5.0"	8.37^r	
" " "	Pyrex	247.0	25°	732.0	219.0	12.0 "	5.0"	8.37^r	
" " "	Pyrex-tinfoil	Destroyed during hydrolysis							

Notes on Table III.

r. It is seen that this run doesn't check the previous one. This is just one of the many inconsistencies in this work. There was no apparent reason for this, as the same apparatus and precautions were used in all runs.

s. The percent decomposition in this column means the amount of decomposition shown by subtracting the decrease in volume of gas evolved upon hydrolysis in Pyrex-tin foil aliquot from the decrease in the volume of gas evolved upon hydrolysis of the other aliquots.

The following experiments were carried out with the new lamp to check results in Table II.

A stock solution of phenylmagnesium bromide was made in the customary manner from 24.3 grams (one atom) magnesium, 157 grams (one mole) bromobenzene, and sufficient ether to make about 600 cc solution.

Two 200 cc aliquots were taken, one of which was placed into a three-necked quartz flask, fitted with stirrer and condenser. This was placed five inches from the lamp, protected by trap[19], and exposed to ultraviolet light for a total of twelve hours. Dry carbon dioxide was passed in and worked up in the customary manner. In this way 27.0 grams benzoic acid m.p. 120-1° was obtained.

The second 200 cc aliquot was placed in a Pyrex three-necked flask, fitted with stirrer, condenser and trap[19]. This was kept in the laboratory throughout the time aliquot one was being exposed to light. Dry carbon dioxide was passed in and the benzoic acid was obtained in the customary manner. The yield of acid was 26.0 grams m.p. 120-1°. This was approximately a 65% yield.

In this case there was certainly no evidence of decomposition of the Grignard reagent from exposure to ultraviolet light.

In previous experiments (in Tables I, II and III) the amount of Grignard reagent taken was relatively large in comparison with the amount of light, therefore some experiments were carried out in which it was thought that the minimum possible concentration was used.

This work was carried out, using phenylmagnesium bromide and benzylmagnesium chloride.

A stock solution of phenylmagnesium bromide was added to 600 cc ether, with stirring until just enough had been added to give a positive color test[22] that would barely persist over night. Then an equal amount of Grignard reagent was added and three 200 cc aliquots were taken as follows:

Aliquot 1. This was exposed to light for ten hours at a distance of five inches. This gave a positive color test before carbon dioxide was added. When worked up seven-tenths of a gram benzoic acid m.p. 120-1° was obtained.

Aliquot 2. This was treated with carbon dioxide and worked up immediately. This gave five-tenths gram benzoic acid m.p. 120-1°.

Aliquot 3. This was treated in laboratory under conditions similar to aliquot one, except no light exposure. This gave no color test and also gave no acid.

The trap[19] was used in all cases.

---

(22) Gilman and Schulze, J. Am. Chem. Soc., 47, 2002 (1925).
Gilman and Schulze, Bull. soc. chim., 41, 1479 (1927).
Gilman and Heck, Rec. trav. chim., 48, 193 (1929).

Benzylmagnesium chloride in very dilute concentration was prepared and two 200cc aliquots taken exactly as described above for phenylmagnesium bromide.

Aliquot 1. This was placed in a three-necked quartz flask, fitted with stirrer, condenser and trap[19] and exposed to ultraviolet light for eleven hours at a distance of three inches. After exposure carbon dioxide was passed into the solution and worked up in the usual manner. The acid thus obtained wouldn't crystallize from water, hence it was extracted with ether. Three-tenths of a gram of phenylacetic acid m.p. 75-6° was obtained.

Aliquot 2. This was placed into a three-necked flask and treated immediately with carbon dioxide. This was worked up exactly as aliquot 1 and three-tenths of a gram of phenylacetic acid m.p. 75-6° was obtained.

It is evident that the new lamp caused no decomposition of benzylmagnesium chloride even in dilute solution.

Attempts to Prepare Phenylmagnesium Chloride Under Influence of Ultraviolet Light.

The following represent attempts to prepare phenylmagnesium chloride:

1. Three volumes of ether, two volumes chlorobenzene, ordinary magnesium turnings, and a small crystal of iodine were placed in a quartz three-necked flask fitted with stirrer and condenser. No color test[22] could be obtained

after two and one-half hours exposure at seven inches from lamp.

2. Exactly same as above except a small amount of Naturkupfer "C" was used. No test[22] after two and one-half hours.

3. One volume ether, two volumes of chlorobenzene, ordinary magnesium (100 mesh), and iodine were placed into a special quartz three-necked flask, fitted with stirrer and condenser. Four hours exposure to light at seven inches gave no positive test[22] for phenylmagnesium chloride.

4. Exactly the same as above (3) except no solvent other than chlorobenzene was used. Four hours exposure at seven inches from lamp gave no test [22].

5. Equal parts by volume of chlorobenzene and *n*-butyl ether and ordinary magnesium (100 mesh) were used. This was placed into special quartz three-necked flask fitted with stirrer and condenser. A small crystal of iodine was added. This was refluxed over a hot-plate during a three and one-half hour exposure to the light. The test[22] showed no Grignard reagent to be present.

Unsym. Diphenyl Ethylene, with Phenylmagnesium Bromide Under the Influence of Ultraviolet Light.

The Grignard reagent was prepared in the customary manner, using such proportions of reactants that each 100 cc of solution would contain about 0.06 mole of phenylmagnesium bromide.

One hundred cc (approximately 0.06 mole) of the above solution was treated with carbon dioxide and worked up in the customary manner[20]. This gave 5.6 grams benzoic acid m.p. 120-1°. This was to serve as a "blank".

Another 100 cc aliquot of the phenylmagnesium bromide solution was placed into a special quartz three-necked flask, fitted with a stirrer, condenser and trap[19]. To this was added 9 grams (0.05 mole) of unsym.-diphenyl ethylene. The flask was then exposed to the ultraviolet light for thirty-nine hours at a distance of seven inches. Dry carbon dioxide was then passed into the flask. This was hydrolyzed and worked up in the customary manner. In this manner 3.6 grams benzoic acid m.p. 121-2° was obtained. From the amount of benzoic acid obtained here, in comparison with the amount obtained in the "blank", it would seem that there is evidence of some sort of reaction.

An unsuccessful attempt was made to recover the unsym.-diphenyl ethylene by distillation under diminished pressure. The following fractions were obtained.

Fraction I	B.P. 40-125°/3 mm	5.0 grams
Fraction II	B.P. 125-70°/3 mm	1.0 gram
Fraction III	B.P. above 170°/3 mm	1.0 gram

No constant boiling portion could be obtained, However, it is possible that the unsym.-diphenyl ethylene had been polymerized under the influence of the light according to Ferrer[23].

From the facts that the yield of benzoic acid was low, and that no constant boiling fraction of unsym. diphenyl ethylene could be recovered, it would seem that some sort of a reaction might have taken place. No products were identified which would confirm this opinion.

The Effect of Ultraviolet Light Upon Tetra-p-tolyl Ethylene.

Tetra-p-tolyl ethylene was exposed to ultraviolet light under several conditions as described:

1. Dry tetra-p-tolyl ethylene[24] m.p. 142° was placed in a small quartz flask and exposed to the light for twenty four hours at a distance of five inches. The melting point after irradiation was 142°.

2. Two-tenths of a gram of tetra-p-tolyl ethylene m.p. 142° was dissolved in 10 cc glacial acetic acid placed in quartz flask and exposed to the light for eight hours at a distance of one and one-half inches. The compound when recovered melted at 140-2°.

3. Two-tenths of a gram of tetra-p-tolyl ethylene was

---

(23) Ferrer, Anales soc. espan. fis'. quim., 20, 459 (1922); C.A., 17, 3177 (1923).

(24) This was obtained from J. E. Kirby, This Laboratory.

dissolved in 25 cc acetic acid-alcohol mixture placed in a quartz flask and exposed to the light for twenty hours at a distance of one and one-half inches. This was fractionally recrystallized. The first portion to crystallize out melted at 140-1°, while the last portion melted at 137-8°.

The Effect of Ultraviolet Light Upon Furylacrylic Acid.

The following attempts were made to change furylacrylic acid to a different melting isomer:

1. Furylacrylic acid[25] m.p. 141-2° was dissolved in 15.0 cc absolute alcohol, placed in a quartz flask and exposed to the light for twenty hours at a distance of one and one-half inches. The portion which crystallized out on the sides of flask (while standing at the lamp) melted at 138°. The portion which crystallized out upon removing the alcohol melted at 140°. The very last portion to crystallize out melted at 130-4°, but this had the appearance of being somewhat impure.

2. About 0.5 gram furylacrylic acid, m.p. 141-2° was dissolved in 10 cc glacial acetic acid, placed into a quartz flask and exposed to the light for twenty hours at one and one-half inches. The first crystals to separate out melted at 140°. The next portion came out in nice crystals which

---

(25) This was obtained from A. P. Hewlett, This Laboratory.

melted at 141°.

Attempt to Form Grignard Reagent from Diphenyl, Magnesium Iodide and Magnesium Under Influence of Ultraviolet Light.

Magnesium iodide was prepared by placing 8 grams (0.33 atom) of 100-mesh magnesium in a special three-necked quartz flask fitted with stirrer, condenser and trap[19]. To this was added dropwise 12.7 grams (0.1 atom) of iodine dissolved in ether. After the iodine had all been used up 15.4 grams (0.1 mole) of pure diphenyl m.p. 70° was placed in flask. The flask was then placed two and one-half inches from a new ultraviolet lamp, and exposed with stirring for eight hours. After this exposure portions of clear solution above magnesium were withdrawn for purpose of making a color test[22] for organomagnesium halides. The result of the color test showed no Grignard reagent to be present.

DISCUSSION

By inspection of Tables I and II it is readily seen that there is evidence of appreciable decomposition of those Grignard reagents which give gases upon hydrolysis. The results do not show the consistency that should be expected of such an undertaking. In view of the fact that the work was being carried out upon a very reactive substance, which was held over during long periods of manipulation (generally two days), it should be kept in mind that too great a regularity could not be expected.

Gilman and Peterson[26] in carrying out experiments relative to the non-addition of the Grignard reagent to ethylenic compounds refluxed various unsaturated hydrocarbons with Grignard reagents of the type discussed here. They used an apparatus similar to one used by the author of this work. Although the refluxing period was only fifteen minutes, the decrease in volume, for a given amount of a particular Grignard reagent, varied from 0.8% to a maximum of 8.6%. It was concluded on this evidence that the Grignard reagent would not add to the ethylenic linkage.

Gilman and Peterson[27] also show that heating an aliquot

---

(26) Ref., 8b.

(27) See Ref., 4.

of ethylmagnesium bromide, for periods of one hour at 200° to 300°, the volume decrease ranges from 6.7% to 14.3%. Here also the time interval is relatively short. The amount of decomposition noted in this present work is not inconsistent with the results obtained by the above mentioned authors when we consider the increased amount of time required to carry out this work.

It is claimed that the present work has some merit for the following reasons: (1) The Grignard reagent was not utterly destroyed by the light. (2) The decomposition of those reagents which are derived from highly reactive alkyl halides (such as tertiary-butyl chloride) are affected to no greater extent than those of the more stable halides. (3) Isomerism apparently has nothing to do with whatever decomposition that may take place, and (4) The halogen in the organomagnesium halide has no effect upon the amount of decomposition caused by the light. That is, there was no marked difference in the amount of decomposition of the three n-butylmagnesium halides.

In many or most instances the decomposition in the Pyrex flask was greater than in the quartz. This is not alarming because Pyrex has a large percentage (80.75%) of silica and may transmit the rays of proper wave length to cause decomposition to as great an extent as does the quartz flask.

From the fact that in all cases the decomposition was greater in the quartz and in the Pyrex flasks than in those covered with tin foil, even though all flasks were in the same system, it is claimed that there was some decomposition due to ultraviolet light rays.

When concentrated ether solutions were exposed to light the decomposition was higher than usual. In the case of exposure of solid Grignard reagent to rays there is almost no decomposition caused by rays. This would lead one to believe that any decomposition would be caused by the ether or ether-organomagnesium halide complex[28] rather than the organomagnesium halide itself.

As for those Grignard reagents that give solid acids by hydrolysis, after treatment with dry carbon dioxide, there is no indication that any decomposition had taken place. In all cases the yield of acid after exposure of an aliquot of the Grignard reagent was equal to or possibly slightly in excess to the amount of acid obtained from the "blank".

In one case in which very dilute solutions of the Grignard reagent were used the portion which was exposed to light gave a positive color test[22] and a small amount of acid, whereas the "blank" under similar conditions except for the light gave no color test and no acid. This seems to indicate that

---

(28) For a discussion of structure of Grignard reagent in ether solution and also studies upon dry Grignard reagent, see L. C. Heckert, Doctoral Thesis, Iowa State College (1927).

possibly the light was enhancing the formation of the Grignard reagent rather than decomposing it.

The slight amount of evidence accumulated in this work would indicate that there might be an equilibrium existing as:

$$R - R + Mg\,X_2 + Mg \rightleftharpoons 2\ RMgX$$

The facts that would support this are: (1) Those compounds which give a gas by hydrolysis would have an R - R compound that was a gas. This gas would be continually given off, thus causing an apparent decomposition of the RMgx compound. (2) The more concentrated the ether solution of the organo-magnesium halide became the more gas would be evolved, and the greater the decomposition would appear. This actually was the case. (3) In those Grignard reagents which give a solid acid upon hydrolysis subsequent to treatment with dry carbon dioxide the R - R compound would be a high boiling liquid and would not be removed from the solvent. Thus the reaction might have an opportunity to go to the right as:

$$R - R + Mg\,X_2 + Mg \longrightarrow 2\ R\,MgX$$

In this case the formation of RMgx would be enhanced and seems to fit the case because the runs with phenylmagnesium bromide, benzylmagnesium chloride, and triphenylmethyl-magnesium chloride, indicate a greater amount of the Grignard after exposure than before. This was proven not to be the case because diphenyl, magnesium iodide and magnesium in ether solution will not give phenylmagnesium iodide when exposed to the ultraviolet light. Admittedly the time of exposure to the light, in this case, was shorter than in most of the experiments. However the amount of exposure, described in this work, should be sufficient to give an amount of RMgX that could be detected by the sensitive color test[22].

All attempts to change tetra-p-tolyl ethylene and furylacrylic acid to different melting isomers brought out no significant facts.

There is some indication that a reaction might have taken place between unsym-diphenylethylene and phenylmagnesium bromide under the light, because the diphenylethylene could not be recovered, and the amount of benzoic acid obtained was much less than would be expected from the amount of the Grignard reagent used.

No products could be isolated that would definitely establish the fact that a reaction had taken place.

Nothing of importance was observed in the several attempts to prepare phenylmagnesium chloride under the influence of the light, other than the fact that the Grignard reagent was not formed.

SUMMARY

There is slight evidence that ultraviolet light does decompose those Grignard reagents which evolve gases upon hydrolysis.

There is no evidence that the ultraviolet light does decompose those Grignard reagents which give solid acids by hydrolysis after treatment with dry carbon dioxide.

Ultraviolet light does not *definitely* cause addition of the Grignard reagent to the ethylenic linkage, although some indication of a reaction having taken place is observed.

Ultraviolet light will not induce chlorobenzene to react with magnesium to form the Grignard reagent.

Neither tetra-p-tolyl ethylene nor furylacrylic acid could be changed into a different melting isomer by means of ultraviolet light.

Diphenyl, magnesium iodide, and magnesium in ether solution could not be induced to form phenylmagnesium iodide by ultraviolet light.

II

THE SYNTHESIS OF AMINO COMPOUNDS.

PART A. STUDIES ON THE MIGRATION OF THE -MgX GROUP.

INTRODUCTION.

Recently a method for preparing halogenated tertiary amines was described by Gilman and Heck[29]. This study showed that halogenated tertiary amines of the type $RR'NCH_2CH_2Cl$ and $RR'NCH_2CH_2CH_2Cl$, in which R and R' were either alkyl or aryl groups, could be easily prepared. The method consisted in treating the appropriate secondary amine with an organomagnesium halide in order to get an -MgX group attached to the nitrogen atom. The $\begin{matrix}R\\R\end{matrix}\!\!>$N-MgX group was subsequently treated with β-chloroethyl p-toluenesulfonate[30] or γ-chloropropyl p-toluenesulfonate depending upon whether it was desired to replace the -MgX group with the β-chloroethyl or the γ-chloropropyl group. In order to determine whether or not the above mentioned reactions were general, a large number of representative halogenated tertiary amines of the type $RR'NCH_2CH_2Cl$ and $RR'NCH_2CH_2CH_2Cl$ were prepared[31].

---

[29] Gilman and Heck, Ber., 62, 1379 (1929).

[30] For leading references upon the reaction between organomagnesium halides and alkyl p-toluenesulfonates see Gilman and Heck, J. Am. Chem. Soc., 50, 2223 (1928).

[31] Unpublished work by L. L. Heck, This Laboratory.

Another very interesting fact concerning this type of halogenated tertiary amine is that an ether solution of the amine will react readily with activated magnesium[32] to give the Grignard reagent as indicated by the color test[22]. It is easily seen that a Grignard reagent of this type would be particularly valuable for introducing the nitrogen atom into a very large number of organic compounds.

Gilman and King[33] undertook a study to ascertain the reactions that would take place between the -SMgX group and several typical reactants, such as phenylisocyanate, iodine, and others.

Gilman and Schulze[34] made an effort to find some reaction whereby the -OMgX group could be readily and generally characterized. It was found that no one reactant would characterize all types of the -OMgX grouping.

A study[35] is now being made to determine the reactions which the -NMgX group will undergo.

In connection with these several studies it was thought quite desirable to ascertain, if possible, the course taken

---

(32) Gilman, Peterson and Schulze, Rec. trav. chim., 47, 19 (1928).

(33) Gilman and King, J. Am. Chem. Soc., 47, 1136 (1925).

(34) Gilman and Schulze, Rec. trav. chim., 47, 752 (1928).

(35) This work is being undertaken by W. F. Schulz. This Laboratory.

by the -MgX group when it was given the opportunity to attach itself to elements other than the one to which it was originally bound.

It is generally considered that the -MgX will move from a single bonded carbon atom to a triple bonded carbon atom. That is phenylacetylenylmagnesium halides are prepared by adding a Grignard reagent to phenylacetylene[36]. It is also known that in some cases the -MgX will move from a single bonded carbon atom to a methylenic carbon that is situated between two sets of double bonded carbon atoms. Examples of this type of reaction were observed when indene, fluorene and cyclopentadiene were treated with alkylmagnesium halides[36a].

Organomagnesium halides can be decomposed by treating them with water or an alcohol. This of course would be a case of the -MgX group migrating from whatever element it was bound, to the oxygen atom of water or the alcohol.

We know that an -MgX group attached to a carbon will migrate to any other atom that has a hydrogen atom attached to it but we do not know the order of migration when the -MgX group is attached to some atom other than to a carbon. Therefore the purpose of this study is to attempt to ascertain the course taken by the -MgX group when it has an opportunity to become attached to an element other than the one to which it is already attached (excluding of course the carbon atom).

---

(36) For references to this work see Gilman and Schumaker, J. Am. Chem. Soc., **47**, 514 (1925).

(36a) Courtot, "Le Magnesium en Chimie Organique". Nancy, 1926, p. 57.

EXPERIMENTAL

The general plan for carrying out this work is given briefly as follows. An accurately weighed amount of a compound (generally one-tenth mole) containing one active hydrogen per mole was dissolved in ether and placed in a 500 cc three-necked flask fitted with a stirrer and condenser. To this was added, accurately from a burette, the calculated amount of an inexpensive Grignard reagent, generally ethylmagnesium chloride. The strength of the Grignard reagent was determined by the titration method of Gilman, Wilkinson, Fishel and Meyers.[16] After adding the Grignard reagent a color test[22] was made to determine whether or not an excess were present. In case there was no excess, more Rmgx compound was added slowly and numerous tests[22] made until there was shown to be a bare excess. The theoretical amount of a different compound which also contained one active hydrogen per mole was dissolved in ether and added dropwise to the contents of the flask. It was always noted whether or not there was any indication of a reaction taking place by the refluxing of ether from the condenser. The flask was then warmed over a hot-plate for one-half an hour and the theoretical two equivalents of an alkyl p-toluenesulfonate[30], dissolved in ether, were added dropwise.

The mixture was refluxed for an hour, then worked up by first filtering the magnesium p-toluenesulfonate through a Büchner funnel by suction. This procedure is quite desirable because the filtration is easily carried out and saves much time and trouble in attempting to dissolve the none too soluble magnesium p-toluenesulfonate in water. The ether filtrate was washed with water, dried over potassium carbonate and worked up in a manner that would be required to identify the expected compounds.

Two separate reactions were carried out in each set of experiments. The purpose of this procedure was to ascertain whether migration of the -MgX group had taken place or whether the -MgX group merely became attached to an element and remained there. In one reaction the compound which had an active hydrogen (for example an R_2NH compound) was added to an organomagnesium halide (for example an ROMgX compound). In the second reaction this order of addition was reversed or the ROH compound was added to the R_2N-MgX.

Reaction between Diphenylamine, Ethylmagnesium Chloride, n-Butyl Alcohol and n-Butyl p-Toluenesulfonate.

A solution consisting of 16.9 grams (0.1 mole) diphenylamine m.p. 54° and 100 cc of dry ether was placed in a 500 cc three-necked flask fitted with a stirrer and condenser. To this was slowly added some ethylmagnesium chloride solution until a positive color test[22] could be obtained. A solution composed of 7.4 grams (0.1 mole) dry *n*-butyl alcohol in 50 cc ether was then added dropwise to the contents of the flask. A vigorous reaction took place as indicated by the refluxing of the ether. Apparently *n*-butoxymagnesium chloride is soluble in ether as only a slight amount of precipitate formed after the reaction had ceased, 45.0 grams (0.2 mole) *n*-butyl *p*-toluenesulfonate was added. The mixture was refluxed for three hours over a hot-plate. A large amount of magnesium *p*-toluenesulfonate precipitated out.

The mixture was filtered through a Büchner funnel, and the precipitate was discarded. This was magnesium *p*-toluenesulfonate. The ether filtrate was treated with dry HCl. In this manner 17.0 grams dry crystalline hydrochloride were obtained. This was decomposed with a twenty percent sodium hydroxide solution and extracted with ether. The ether was removed by evaporation and 14.5 grams diphenylamine m.p. 52° were recovered. This corresponds to an 85% recovery of the amine.

The ether filtrate, after removing the dry diphenyl amine hydrochloride, was washed with dilute sodium hydroxide and dried over potassium carbonate. This gave 29.0 grams of material which had a b.p. 175°-80°/7 mm. This corresponds to a 65% recovery of the ester.

Reaction between n-Butyl Alcohol, Methylmagnesium Iodide, Diphenylamine, and Ethyl p-Toluenesulfonate.

A solution composed of 7.4 grams (0.1 mole) dry n-butyl alcohol and 100 cc dry ether was placed in a 500 cc three-necked flask. Methylmagnesium iodide was added until a positive color test[22] was obtained. The end of the reaction can almost be ascertained without making a color test, because the ether ceases refluxing from the condenser at that time. The n-butoxymagnesium iodide formed a clear solution. A solution composed of 16.9 grams (0.1 mole) pure diphenylamine in 100 cc ether was added. No indication that a reaction was taking place could be observed. This mixture was refluxed over a hot-plate for one-half an hour and 40.0 grams (0.2 mole) ethyl p-toluenesulfonate in 75. cc ether were added. The mixture was refluxed over a hot-plate for two hours.

The magnesium p-toluenesulfonate was filtered off and discarded. Dry hydrogen chloride was passed through the ether filtrate. The dry amine hydrochloride was decomposed with dilute sodium hydroxide and extracted with ether. The ether extract was dried over potassium carbonate. The ether was removed by evaporation and 12.0 grams (a 71% recovery) of crystalline diphenylamine m.p. 51°-2° was obtained. A mixed melting point with known diphenylamine gave an m.p. 52°-3°.

No attempt was made to recover the ester in this experiment.

Reaction between Phenol, Methylmagnesium Iodide, Diphenyl amine and Ethyl p-Toluenesulfonate.

A solution which contained 9.4 grams (0.1 mole) phenol dissolved in 100 cc ether was placed in a 500 cc three-necked flask, fitted with condenser and stirrer. Methylmagnesium iodide was then added until a positive color test[22] was obtained. To this was added 16.9 grams (0.1 mole) pure diphenyl amine in 100 cc ether. There was no indication whatever that a reaction had taken place. This mixture was refluxed over a hot-plate for one-half an hour. A solution consisting of 40.0 grams (0.2 mole) of ethyl p-toluenesulfonate in 75.0 cc ether were added and the contents of the flask were refluxed for two hours over a hot-plate.

The magnesium p-toluenesulfonate was filtered out. The ether filtrate was extracted several times with sodium hydroxide to remove the phenol. These combined sodium hydroxide extracts were acidified with hydrochloric acid and treated with bromine. The resulting sym-tribromophenol weighed 20.0 grams when dry and melted at 88°. A mixed melting point with known sym-tribromophenol m.p. 91° gave no depression in the m.p. This amount represents a 60% recovery of the phenol.

The ether solution, after removal of the phenol, was dried over sodium sulfate. The dry ether soltuion was treated with dry HCl. The dry diphenylamine hydrochloride was decomposed with dilute sodium hydroxide, and extracted with ether. This ether extract when evaporated gave 14.0 grams diphenylamine m.p. 52°. A mixed melting point with known diphenylamine gave an m.p. 53°-4°. This was an 82% recovery of the diphenylamine.

The ether filtrate, after removal of the diphenylamine hydrochloride, was washed with dilute sodium hydroxide, dried over potassium carbonate and distilled. In this manner 11.0 grams(27.5%)of the ester b.p. 15 7/8 mm was recovered.

Reaction between Diphenylamine, Ethylmagnesium Chloride, Phenol and Ethyl p-Toluenesulfonate.

A solution composed of 16.9 grams (0.1 mole) pure diphenylamine in 100 cc ether was placed in a 500 cc three-necked flask fitted with stirrer and condenser. Ethylmagnesium chloride was carefully added to this solution from a burette until a color test was obtained. An ether solution which contained 9.4 grams (0.1 mole) phenol was then added dropwise and a vigorous reaction took place. The contents of flask were stirred for one hour without refluxing.

A solution composed of 40.0 gram (0.2 mole) ethyl p-toluenesulfonate was then added and refluxed over a hot-plate for four hours.

This run was hydrolyzed with a dilute hydrochloric acid solution instead of filtering out the magnesium p-toluenesulfonate as was described for the previous experiments.

The ether layer was worked up in exactly the same manner as that described in the experiment immediately preceding this one. The following compounds were obtained:

14.5 grams, 44% recovery, tribromophenol m.p. 87°.

6.3 grams, 37% recovery, diphenylamine m.p. 52°.

10.0 grams, 25% recovery, ester b.p. 158°-63°/6 mm.

The low recovery of the phenol and diphenylamine is attributed to the fact that a large amount of water was required to dissolve the magnesium p-toluenesulfonate. This would probably cause much of these compounds to be lost.

Reaction between n-Butyl Alcohol, Methylmagnesium Iodide and Phenol.

A solution composed of 7.4 grams (o.1 mole) of dry n-butyl alcohol in 100 cc ether was placed in a 500 cc three-necked flask fitted with a stirrer and a condenser. Methylmagnesium iodide solution was added to the contents of the flask until a positive color test was obtained. An ether solution containing 9.4 grams (o.1 mole) phenol was added. A vigorous reaction took place and a white precipitate settled out. Phenoxymagnesium iodide is insoluble.

The ester was not added in this run because the alkyl group of the ester will not replace the -MgX in an -OMgX group[34].

The contents of the flask were hydrolyzed with dilute hydrochloric acid and the water layer was extracted several times with small portions of ether. The combined ether portions were extracted with dilute (10%) sodium hydroxide. The sodium hydroxide was then acidified with hydrochloric acid and treated with bromine. In this manner 22.0 grams, 67% recovery, of dry sym- tribromophenol m.p. 87°-9° was obtained. This was identified by a mixed melting point determination with known tribromophenol m.p. 92°.

Reaction between Diphenylamine, Ethylmagnesium Chloride, p-Thiocresol and Ethyl p-Toluenesulfonate.

A solution composed of 16.9 grams of pure diphenylamine in 100 cc ether was placed in a 500 cc three-necked flask with stirrer and condenser. Ethylmagnesium chloride was added to this slowly from a burette until a positive color test was obtained. A solution consisting of 12.4 grams (0.1 mole) p-thiocresol in 75.0 cc of ether was then added. A rather vigorous reaction took place and a white precipitate settled out. p-Thiocresylmagnesium chloride is insoluble in ether. A solution consisting of 40.0 grams (0.2 mole) ethyl p-toluenesulfonate and 100 cc ether was then added. The mixture was refluxed over a hot-plate for three hours. The mixture was then hydrolyzed by pouring it into water acidified with hydrochloric acid. The water layer was extracted one time with 75. cc of ether.

The combined ether layers were extracted once with sodium hydroxide to remove any unreacted p-thiocresol. When this sodium hydroxide portion was subsequently acidified with hydrochloric acid and extracted with ether, no p-thiocresol could be recovered.

The ether layer, after extraction with the dilute sodium hydroxide was dried over sodium sulfate. The dry ether portion was then treated with dry hydrogen chloride for the purpose of removing the amino compounds. About 20.0 grams of dry crystalline hydrochloride was obtained. The dry hydrochloride was decomposed with dilute sodium hydroxide extracted with ether and dried over potassium carbonate. The ether was removed and 15.5 grams, a 91% recovery of diphenylamine m.p. 48°-50°, was obtained. This was identified by making a mixed melting point with known diphenylamine m.p. 54°.

The remaining ether layer after the hydrochloride had been removed was washed with dilute sodium hydroxide, dried over potassium carbonate and distilled. In this manner 11.0 grams b.p. 110°-12°/10 mm was obtained. This was shown to be p-tolyl ethyl sulfide[37] b.p. 101°-2/2 mm by fact that it could be oxidized by hydrogen peroxide in glacial acetic acid

---

(37) Gilman and Beaber, J. Am. Chem. Soc., 47, 1449 (1925).

to p-tolyl ethyl sulfone m.p. 53°-4°. This was identified by making a mixed melting point determination with an authentic specimen[38].

No unreacted ester was recovered in this experiment.

Reaction between p-Thiocresol, Ethylmagnesium Chloride, n-Butyl Alcohol and Ethyl p-Toluenesulfonate.

A solution composed of 12.4 grams (0.1 mole) p-thiocresol and 150 cc of ether was placed in a 500 cc three-necked flask fitted with stirrer and condenser. Ethylmagnesium chloride was added to this until a positive color test[22] was obtained. A white crystalline material separated out. An ether solution which contained 7.4 grams (0.1 mole) dry n-butyl alcohol was added. A mild reaction appeared to take place and the white precipitate dissolved. Then 40.0 grams (0.2 mole) ethyl p-toluenesulfonate were added to the flask. The mixture was refluxed over a hot-plate for four hours. This was hydrolyzed by pouring into water. The ether layer was extracted with sodium hydroxide to remove the p-thiocresol. This sodium hydroxide layer was acidified and extracted with ether. The ether was evaporated and 1.6 grams (about 10%) of the p-thiocresol were recovered.

---

(38) From J. E. Kirby Collection, This Laboratory.

The ether layer after extraction with sodium hydroxide was dried over potassium carbonate. The ether was removed and the residue was distilled. In this manner the following was obtained.

Fraction I. 8.0 grams b.p. 100°-10°/6 mm.

Fraction II. 6.0 grams b.p. 158°-63°/7mm.

Fraction I was successfully oxidized to give ethyl p-tolyl sulfone, m.p. 53°-4°. Identified by method of mixed melting points. This was a 40.0% yield of ethyl p-tolyl sulfide.

Fraction II was thought to be unreacted ester. This was a 15% recovery of the ester.

A second run of this experiment was made and the results checked with those obtained in the above experiment.

Reaction between n- Butyl Alcohol, Methylmagnesium Iodide, p-Thiocresol and Ethyl p-Toluenesulfonate.

This experiment was carried out and worked up exactly the same as the one preceding this. No precipitate was formed prior to the addition of the ester and no p-thiocresol was recovered.

The main product obtained, was 11 grams of an oily material which boiled at 107°-11°/10 mm. This was oxidized to ethyl p-tolyl sulfone[37] m.p. 53°-4° and identified by method of mixed melting points. This corresponds to a 72% yield of ethyl p-tolyl sulfide.

Reaction between Phenol, Methylmagnesium Iodide, p-Thiocresol and Ethyl p-Toluenesulfonate.

A solution that was composed of 9.4 grams (0.1 mole) of phenol in 100 cc dry ether was placed in a 500 cc three-necked flask fitted with stirrer and condenser. An ether solution of methylmagnesium iodide was added, until a positive color[22] was obtained. A white crystalline precipitate settled out. An ether solution which contained 12.4 grams (0.1 mole) of p-thiocresol was added. There was no visible sign that a reaction had taken place. This mixture was refluxed for one hour over a hot-plate. An ether solution which contained 40.0 grams (0.2 mole) of ethyl p-toluenesulfonate was then added. The mixture was refluxed for three hours over a hot-plate.

The mixture was hydrolyzed by pouring it into an acidified water solution. The water layer was extracted with small portions of ether. The combined ether layers were then extracted with dilute sodium hydroxide. This should remove the phenol and p-thiocresol. The sodium hydroxide layer was acidified and treated with iodine in order to change p-thiocresol to di-p-tolyl disulfide, and again extracted with ether. This ether extract was treated with sodium hydroxide to remove phenol. No phenol was identified in this experiment. The ether layer from this gave 5.0 grams (41% yield) of di-p-tolyl disulfide m.p. 43°-4°. This was identified by making a mixed melting point with an authentic specimen.

The original ether layer, after the pehnol and p-thiocresol had been removed, was dried over potassium carbonate and distilled. The only material obtained by the distillation was 10 grams (25% recovery) of ethyl p-toluenesulfonate b.p. 167/13 mm. There was no indication of any ethyl p-tolyl sulfide having been formed.

Reaction between p-Thiocresol, Ethylmagnesium Chloride, Phenol and Ethyl p-Toluenesulfonate.

This experiment was carried out and worked up in the same manner as the preceding one except p-thiocresol was placed in flask, first, while in the above the phenol was placed in the flask first, then the Rmgx compound was added.

The following compounds were obtained from this experiment.

1. 14.7 grams tribromophenol m.p. 86°-8°. This corresponds to a 45% recovery of the phenol.

2. 4.5 grams di-p-tolyl disulfide m.p. 43°-4°. This corresponds to a 37% recovery of p-thiocresol.

3. 4.5 grams material b.p. 100-25/9mm. This material was within the boiling range of ethyl p-tolyl sulfide but it could not be oxidized to the corresponding sulfone.

4. 16.0 grams material b.p. 160-2/6mm. This corresponds to a 40% recovery of ester.

The Reaction between p-Thiocresol, Methylmagnesium Iodide, n-Butyl Mercaptan and Ethyl p-Toluenesulfonate.

An ether solution, which had 12.9 grams (0.1 mole) of p-thiocresol dissolved in it, was placed in a 500 cc three-necked flask. Forty cc of methylmagnesium iodide (2.48 M) were added from a burette. The reaction proceeded vigorously until almost the theoretical amount of the Grignard reagent had been added. The reaction apparently ceased but a positive color test[22] could not be obtained. An insoluble oil similar in appearance to magnesium iodide etherate separated out. An ether solution which contained 9.0 grams (0.1 mole) of n-butyl mescaptan was then added. A mild reaction appeared to take place, and the oily layer disappeared. An ether solution which contained 40.0 grams (0.2 mole) of ethyl p-toluenesulfonate was added to this mixture. A reaction appeared to take place and a white precipitate soon separated out.

This mixture was hydrolyzed by pouring it in to an acidified and iced water solution. The water layer was extracted two times with ether. The combined ether extracts were in turn extracted with twenty percent sodium hydroxide in order to remove the p-thiocresol. The sodium hydroxide layer was acidified with hydrochloric acid and extracted with ether. The ether was dried and removed by distillation.

No p-thiocresol was recovered.

The original ether portion, after extraction with sodium hydroxide, was dried over calcium chloride and distilled.

No n-butyl mercaptan was recovered although its presence was easily detected by the odor.

There was no indication that any ethyl butyl sulfide had been formed as the temperature, during the distillation, rose very rapidly from 120° to 160°. Ethyl butyl sulfide boils at 143°-5°. The pump was then used and 14.0 grams of material which boiled at 105°-6°/6 mm was obtained. This was readily oxidized to ethyl p-tolyl sulfone m.p. 53°-4°. The sulfone was identified by making a mixed melting point determination with an authentic specimen. The amount of ethyl p-tolyl sulfide corresponds to a 91% yield.

The Reaction between n-Butyl Mercaptan, Ethylmagnesium Chloride, p-Thiocresol and Ethyl p-Toluenesulfonate.

This experiment was identical with the preceding one except the n-butyl mercaptan was added prior to the Grignard reagent while in the above run p-thiocresol was added first.

The results in this experiment check those obtained in the one immediately preceding. These results indicate that the -MgX group will migrate from an alkyl mercaptan to an aryl mercaptan.

The Reaction between Diphenylamine, Methylmagnesium Iodide, Di-*n*-Butylamine and Ethyl *p*-Toluenesulfonate.

An ether solution which contained 16.9 grams (0.1 mole) of diphenylamine was placed in a 500 cc three-necked flask fitted with a stirrer and a condenser. Methylmagnesium iodide solution was added until a positive color test could be obtained. A solution which consisted of 12.9 grams (0.1 mole) di-*n*-butylamine in 50 cc of dry ether was added. There was a mild refluxing of the ether. This would indicate that a reaction might be taking place. After refluxing the mixture over a hot-plate for half an hour, an ether solution which contained 45.6 grams (0.2 mole) of *n*-butyl *p*-toluenesulfonate was added. The mixture was refluxed over a hot-plate for two hours. A heavy white precipitate of magnesium *p*-toluenesulfonate separated out.

The magnesium *p*-toluenesulfonate was filtered out by means of a Büchner funnel. The ether filtrate was washed with a 20% hydrochloric acid solution for the purpose of removing the alkyl amines. The hydrochloric acid solution was in turn washed two times with ether. The hydrochloride layer was then made basic with strong sodium hydroxide, and the resulting free amine was extracted with ether. This ether layer was dried over potassium carbonate and distilled.

Fraction I. 5.0 grams b.p. 55°-60°/9mm, $n_{30^{\circ}} = 1.4140$.

Pure di-n-butylamine boils at 55°-7°/9mm and n_{30^o} = 1.4122.

Fraction II. 3.5 grams b.p. 85°-95°/10 mm, n_{30^o} = 1.4247

Tri-n-butylamine (as synthesized from di-n-butylamine, ethylmagnesium chloride and n-butyl p-toluenesulfonate) boils at 91°-2°/7 mm and n_{34^o} = 1.4235.

The original ether layer, after being washed with the 20% hydrochloric acid solution, was washed with dilute sodium hydroxide and dried over potassium carbonate. When this was distilled, 15.0 grams of material b.p. 158°-65°/8 mm were obtained. A refractive index reading could not be obtained. An ether solution was treated with dry HCl, but a gummy mass resulted instead of a crystalline substance. When a pure amine is present a crystalline hydrochloride is obtained but when a mixture of amines is present a gummy mass results.

A Zerewitinoff determination was made upon this compound in order to ascertain whether any diphenylamine were present. The results of this determination are:

Sample #1 - 0.4756 grams gave 32.2 cc gas at 741 mm and 32° C. This corresponds to 28.0 cc gas under standard conditions. This amount of pure diphenylamine would give 63.0 gas (standard conditions).

Sample #2 - 0.4388 grams gave 26.8 cc of gas at 741 mm and 32°C. This corresponds to 23.5 cc gas under standard conditions. This amount of pure diphenylamine would give 58.2 cc gas under standard conditions.

The results of these determinations show that a mixture of amines was apparently obtained.

An unsuccessful attempt was made to separate the diphenylamine from the possible diphenyl n-butylamine by treating the mixture with potassium to remove the secondary amine so that the tertiary amine could be distilled off.

The Reaction between Di-n-Butylamine, Methylmagnesium Iodide, Diphenylamine and n-Butyl p-Toluenesulfonate.

This experiment was identical with the preceding one except a solution of di-n-butylamine was placed in the three-necked flask before the methylmagnesium iodide was added, whereas in the preceding experiment diphenylamine was added first. This was worked up in the same manner as the preceding experiment and the results and yields obtained were almost identical.

A second run was made in which ethylmagnesium chloride was substituted for methylmagnesium iodide. The results were practically identical with the other two experiments.

A Zerewitinoff determination was made upon the portion

(17.0 grams) which boiled at 160°-2°/6 mm. The results of this determination are as follows:

Sample #1 - 0.2698 grams gave 14.6 cc gas at 741 mm and 31° C. This amount of pure diphenylamine would give 35.8 cc gas under standard conditions.

Sample #2 - 0.2970 grams gave 16.2 cc gas at 741 mm and 31°C. This amount of pure diphenylamine would give 39.4 cc gas under standard conditions.

It is quite evident that a pure fraction was not obtained.

An attempt was made to prepare some pure diphenyl n-butylamine by the reaction between diphenylamine, methylmagnesium iodide and n-butyl p-toluenesulfonate. The results of this experiment showed that a pure compound could not be prepared. A good yield (practically quantitative) of material which boiled at 158°-65°/5 mm was obtained. This gave indications of being impure because a crystalline hydrochloride could not be obtained, no refractive index reading could be made and a Zerewitinoff determination showed a large amount of active hydrogen to be present. The result of a Zerewitinoff determination is:

Sample #1 - 0.7103 grams of material gave 53.0 cc gas at 741 mm and 33° C. This corresponds to 46.4 cc gas under standard conditions.

This quantity of pure diphenylamine would give 94.2 cc gas under standard conditions.

This work indicates that tertiary amines in which there are two aryl groups and one alkyl can not be prepared free from impurities by the method described here.

The Reaction between Di-*n*-Butylamine, Methylmagnesium Iodide, *n*-Butyl Mercaptan, and Ethyl *p*-Toluenesulfonate.

A solution of 12.9 grams (0.1 mole) di-*n*-butylamine and 100 cc of ether was placed in a 500 cc three-necked flask fitted with a stirrer and a condenser. The theoretical amount (28.0 cc of 3.51 molar solution) of methylmagnesium iodide was added. The reaction in this case does not proceed as vigorously as when ethylmagnesium chloride is used. The mixture was refluxed over a hot-plate for one-half an hour. A negative color test was obtained at this time. An ether solution of 9.0 grams (0.1 mole) *n*-butyl mercaptan was added dropwise. A vigorous reaction took place. The mixture was refluxed over a hot-plate for one-half an hour and an ether solution of 40.0 grams (0.2 mole) of ethyl *p*-toluenesulfonate was added. A rather vigorous reaction took place and a rather large amount of white precipitate (magnesium *p*-toluenesulfonate) settled out. This was stirred without refluxing for twenty minutes.

The mixture was filtered through a Büchner funnel and the precipitate (magnesium p-toluenesulfonate) was discarded. The ether filtrate was extracted with 20% hydrochloric acid solution in order to remove the amino compounds. The hydrochloric acid solution was then made alkaline with dilute sodium hydroxide. The free amine was extracted with ether. The ether was dried over potassium carbonate and distilled. Eight grams of material b.p. 158°-63° and $n_{30^\circ} = 1.4140$ were obtained. The refractive index reading for known pure di-n-butylamine is $n_{30^\circ} = 1.4145$. The original di-n-butylamine was recovered in 61% yield.

The original ether layer, after the removal of the amino compounds, was washed with dilute sodium hydroxide, dried over potassium carbonate and distilled. Five grams of material b.p. 142°-8° and $n_{30^\circ} = 1.445$ was obtained. Gilman and Beaber[39] report that ethyl butyl sulfide boils at 142°-5° and can be oxidized with hydrogen peroxide in glacial acetic acid to give ethyl butyl sulfone m.p. 50°-50.5°. The compound obtained above was oxidized as described and gave the sulfone m.p. 50°-51°. This was further identified as ethyl butyl sulfone by making a mixed melting point determination with an authentic specimen[40]. The amount of material obtained here corresponds to a 41% yield of ethyl butyl sulfide.

---

(39) Gilman and Beaber, J. Am. Chem. Soc., 47, 1449 (1925).

(40) From N. J. Beaber Collection, This Laboratory.

The Reaction between *n*-Butyl Mercaptan, Methylmagnesium Iodide, Di-*n*-Butylamine and Ethyl *p*-Toluenesulfonate.

This experiment is identical with the preceding one with the exception that the *n*-butyl mercaptan solution was placed in the flask first, instead of the di-*n*-butylamine solution.

This experiment was worked up exactly as described in the preceding one. The amounts of the materials obtained check ed with those described above.

The Reaction between *n*-Butyl Alcohol, Methylmagnesium Iodide, *n*-Butyl Mercaptan and Ethyl *p*-Toluenesulfonate.

A solution of 7.4 grams (0.1 mole) *n*-butyl alcohol in 100 cc of dry ether was placed in a 500 cc three-necked flask. Methylmagnesium iodide was added until a positive color test[22] could be obtained. An ether solution which contained 9.0 grams (0.1 mole) of *n*-butyl mercaptan was added. There was no indication that a reaction had taken place. The mixture was refluxed over a hot-plate for one-half an hour and an ether solution of 40.0 grams (0.2 mole) ethyl *p*-toluenesulfonate was added. A white precipitate of magnesium *p*-toluenesulfonate soon separated out. The mixture was refluxed for two hours over a hot-plate and [redacted] filtered through a Büchner funnel. The ether filtrate was washed with water, dried over potassium carbonate and distilled. No effort was made to separate the *n*-butyl alcohol, *n*-butyl mercaptan and ethyl iodide in this experiment. Nine grams of material b.p. 169°-74°/9 mm and $n_{30°}$= 1.5070 was obtained[41]. This corresponds to 22.5% recovery of the ester. There was no indication whatever that any ethyl butyl sulfide b.p. 142°-5° had been formed, because no fraction which corresponded to this boiling range was obtained.

The Reaction between *n*-Butyl Mercaptan, Methylmagnesium Iodide, *n*-Butyl Alcohol and Ethyl*p*-Toluenesulfonate.

This experiment was carried out as the preceding one except the solution of *n*-butyl mercaptan was placed in the flask before the methylmagnesium iodide was added. In the above experiment the solution of *n*-butyl alcohol was placed in the flask first.

There was no indication that any ethyl butyl sulfide b.p. 142°-5° was formed in this experiment. About 25% of the ester was recovered.

It is readily seen from these experiments that the -MgX will not migrate from an alkyl oxygen to an alkyl sulfur.

---

(41) It might be mentioned that some of the original ester was distilled and the following constants were observed: b.p. 169°-74°/9 mm and $n_{30°}$= 1.5080.

The Reaction between Diphenylamine, Ethylmagnesium Chloride, Diphenylhydroxylamine and Ethyl p-Toluenesulfonate.

An ether solution of 8.45 grams (0.05 mole) of diphenylamine was placed in a 500 cc three-necked flask fitted with a stirrer and condenser. Ethylmagnesium chloride solution was added until a positive color test[22] was obtained. An ether solution of β,β-diphenylhydroxylamine[42] was then added dropwise to the mixture. A vigorous reaction took place, which would indicate that -MgX group had shifted from $^{R}_{R}\!\!>N - MgX$ to $^{R}_{R}\!\!>N - O\,MgX$. The mixture was refluxed over a hot-plate for one hour and a solution of 20.0 grams (0.1 mole) of ethyl p-toluenesulfonate was added. There was no indication that a reaction had taken place (no magnesium p-toluenesulfonate had precipitated out) even after the mixture had been refluxed over a hot-plate for thirty-six hours.

The mixture was hydrolyzed by pouring it into an iced ammonium chloride solution. The water layer was extracted with several small portions of ether and the combined ether layers were dried over potassium carbonate. Dry HCl gas was

---

(42) This compound was easily prepared as described by Gilman and McCracken, J. Am. Chem. Soc., 49, 1052 (1927). See also, Wieland and Roseeu, Ber., 45, 494 (1912); Wieland and Roth, Ber., 53, 210 (1920).

passed into the dry ether solution and 3.0 grams of crystalline hydrochloride were obtained. If any of the -MgX had stayed on the $^{R}_{R}\!>$N- a gummy mass would have in all probability been obtained. The dry amine hydrochloride was decomposed with 30% sodium hydroxide and extracted with ether. Two and one-half grams (about 30% recovery) of diphenylamine m.p. 49°-50° were obtained. The identity of this compound was proved by making a mixed melting point determination with an authentic specimen of pure diphenylamine. There was no indication that any diphenylethylamine had been formed.

No other products from this experiment could be recovered, however, β,β-diphenylhydroxylamine is not very stable and could scarcely be recovered by the treatment described here.

The Reaction between *p*-Thiocresol and Ethyl *p*-Toluenesulfonate in Ether.

Gilman and Kinney[43] have reported that *p*-thiocresol can be alkylated to the extent of 60% in ether solution with diethyl sulfate. If this same thing should be found true of ethyl *p*-toluenesulfonate, then the work reported here would be without value. The following experiment showed that ethyl *p*-toluenesulfonate would not alkylate *p*-thiocresol at the

---

(43) Gilman and Kinney, J. Am. Chem. Soc., 46, 494, (1924).

boiling point of ether.

A solution of 25.0 grams (0.2 mole) p-thiocresol in 100 cc of ether was placed in a 500 cc three-necked flask, fitted with stirrer and condenser. A solution of 40.0 grams (0.2 mole) ethyl p-toluenesulfonate in 100 cc ether was added and the mixture was refluxed over a hot-plate for four hours. There was no indication whatever that any reaction had taken place.

The mixture was treated with several small portions of 20% sodium hydroxide in order to remove the p-thiocresol. This sodium hydroxide portion was subsequently acidified, and extracted with ether. The ether was dried over calcium chloride and distilled. Seventeen grams of material b.p. 189°-90° were recovered. This was further identified as being p-thiocresol which had been recovered in 68% yield.

The original ether layer, after the sodium hydroxide extraction, was dried over calcium chloride and distilled. Thirty-three grams (an 83% recovery) of the ester was obtained.

The Reaction between Di-n-Butylamine and n-Butyl p-Toluenesulfonate in Ether.

The purpose of this experiment was to ascertain whether di-alkylamines could be further alkylated by an alkyl p-toluenesulfonate in ether solution.

A solution of 12.9 grams (0.1 mole) of di-*n*-butylamine in 100 cc of ether was placed in a 500 cc three-necked flask. A solution of 22.8 grams (0.1 mole) *n*-butyl *p*-toluenesulfonate in 100 cc ether was also added to the flask. The mixture was then refluxed for six hours over a hot-plate.

The ether solution was extracted with several small portions of 20% hydrochloric acid in order to remove the amino compounds. The hydrochloric acid solution was subsequently made basic with a 20% sodium hydroxide solution and extracted with ether. This ether portion was dried over potassium carbonate and distilled. Eleven grams of di-*n*-butylamine (85% recovery) b.p. 53°-5°/8 mm and $n_{30^\circ} = 1.4140$.

The original ether solution, after having been extracted with hydrochloric acid, was washed with dilute sodium hydroxide and distilled. Seventeen grams (76% recovery) of the ester b. p. 175°-80°/11 mm were obtained.

Secondary alkylamines apparently are not further alkylated by alkyl *p*-toluenesulfonates in ether.

The Reaction between *n*-Butyl Mercaptan and *n*-Butyl *p*-Toluenesulfonate in Ether.

The purpose of this experiment was to determine whether alkyl mercaptans could be alkylated by alkyl *p*-toluenesulfonates in ether solution.

A solution of 9.05 grams (0.1 mole) of *n*-butyl mercaptan and 22.8 grams (0.1 mole) of n-butyl p-toluenesulfonate in 200 cc of dry ether were placed in a 500 cc three-necked flask, fitted with a stirrer and condenser. The mixture was refluxed over a hot-plate for six hours. There was no visible indication that a reaction had taken place.

The mixture was then distilled. Four grams (44% recovery) of n-butyl mercaptan b.p. 96°-8° were obtained. No other product could be isolated because the material left in the flask started to decompose at 100°. This decomposition continued even though a vacuum pump was used. It is thought that the mercaptan did not react with the alkyl p-toluenesulfonate at the boiling point of ether, but did react at a higher temperature.

DISCUSSION

Table IV has been prepared, in order to make the results of this work more readily accessible. An attempt has been made to make the Table with its accompanying notes as nearly self-explanatory as possible.

TABLE IV

DATA ON MIGRATION OF -NMGX

First Compound[a]			RMgX Used	Second Compound[b]			Apparent Reaction[f]	*p*-Toluenesulfonate Used			Compound Indicative of Migration[c]		Material Recovered[g]	
	Grams	Moles			Grams	Moles			Grams	Moles		% Yield		% Yield
Diphenylamine	16.9	0.1	C_2H_5MgCl	*n*-Butyl Alcohol	7.4	0.1	Yes	*n*-Butyl	45.0	0.2	None	-	Diphenylamine	85.0
n-Butyl Alcohol	7.4	0.1	CH_3MgI[e]	Diphenylamine	16.9	0.1	No	Ethyl	40.0	0.2	None	-	Diphenylamine	71.0
Phenol	9.4	0.1	CH_3MgI[e]	Diphenylamine	16.9	0.1	No	Ethyl	40.0	0.2	None	-	Diphenylamine	82.0
Diphenylamine	16.9	0.1	C_2H_5MgCl	Phenol	9.4	0.1	Yes	Ethyl	40.0	0.2	None	-	Diphenylamine	37.0
n-Butyl Alcohol	7.4	0.1	CH_3MgI[e]	Phenol	9.4	0.1	Yes	--	-	-	--	-	Phenol	67.0
Diphenylamine	16.9	0.1	C_2H_5MgCl	*p*-Thiocresol	12.4	0.1	Yes	Ethyl	40.0	0.2	Ethyl	-	-	-
p-Thiocresol	12.4	0.1	C_2H_5MgCl	*n*-Butyl Alcohol	7.4	0.1	No	Ethyl	40.0	0.2	*p*-Tolyl Sulfide	70.0	Diphenylamine	91.0
											Ethyl *p*-Tolyl sulfide	50.0	*p*-Thiocresol	10.0
n-Butyl Alcohol	7.4	0.1	CH_3MgI[e]	*p*-Thiocresol	12.4	0.1	Yes	Ethyl	40.0	0.2	Ethyl *p*-Tolyl sulfide	70.0	None	-
Phenol	9.4	0.1	CH_3MgI[e]	*p*-Thiocresol	12.4	0.1	No	Ethyl	40.0	0.2	None	-	*p*-Thiocresol	41.0
p-Thiocresol	12.4	0.1	C_2H_5MgCl	Phenol	9.4	0.1	Yes	Ethyl	40.0	0.2	None	-	*p*-Thiocresol	37.0
p-Thiocresol	12.4	0.1	CH_3MgI[e]	*n*-Butyl Mercaptan	9.0	0.1	No	Ethyl	40.0	0.2	Ethyl *p*-Tolyl sulfide	91.0	None	-
n-Butyl Mercaptan	9.0	0.1	C_2H_5MgCl	*p*-Thiocresol	12.4	0.1	Yes	Ethyl	40.0	0.2	Ethyl *p*-Tolyl sulfide	91.0	None	-
Diphenylamine	16.9	0.1	CH_3MgI[e]	Di-*n*-Butylamine	12.9	0.1	Slight	*n*-Butyl	45.0	0.2	Tri-*n*-Butylamine	15.0	None	-

Table IV (Continued)

First Compound[a]			RMgX Used	Second Compound[b]			Apparent Reaction[f]	*p*-Toluenesulfonate Used			Compound Indicative of Migration[c]		Material Recovered[g]	
	Grams	Moles			Grams	Moles			Grams	Moles		% Yield		% Yield
Di-*n*-Butylamine	12.9	0.1	CH_3MgI[e]	Diphenylamine	16.9	0.1	Slight	*n*-Butyl	48.0	0.2	??? [d]		Tri-*n*-Butylamine	15.0
Di-*n*-Butylamine	12.9	0.1	CH_3MgI[e]	*n*-Butyl Mercaptan	9.0	0.1	Yes	Ethyl	40.0	0.2	Ethyl *n* Butyl sulfide	41.0	Di-*n*-Butylamine	61.0
n-Butyl Mercaptan	9.0	0.1	CH_3MgI[e]	Di-*n*-Butylamine	12.9	0.1	No	Ethyl	40.0	0.2	None	-	Ethyl Butyl Sulfide	400
n-Butyl Alcohol	7.4	0.1	CH_3MgI[e]	*n*-Butyl Mercaptan	9.0	0.1	No	Ethyl	40.0	0.2	None	-	None	-
n-Butyl Mercaptan	9.0	0.1	CH_3MgI[e]	*n*-Butyl Alcohol	7.4	0.1	Yes	Ethyl	40.0	0.2	None	-	None	-
Diphenylamine	8.45	0.05	C_2H_5MgCl	Diphenyl hydroxylamine	9.25	0.05	Yes	Ethyl	20.0	0.1	Diphenylamine	30.0	None	-

Notes on Table IV.

a. This column refers to the compound that was placed in the flask prior to the addition of the Grignard reagent.

b. This column refers to the compound that was added to the flask subsequent to the addition of the Grignard reagent.

c. This column refers to the compound that was isolated which would indicate quite conclusively that migration of -MgX had taken place.

d. There is some indication, although not entirely conclusive, that some diphenyl n-butylamine was formed in this experiment.

e. The reason for using methylmagnesium iodide instead of the less expensive ethylmagnesium chloride was because the resulting organomagnesium iodides were more soluble in ether than were the corresponding organomagnesium chlorides.

f. The purpose of this column is to show whether or not there was any visible indication that a reaction had taken place after the second compound had been added to the flask.

g. This column does not show all the products that were recovered, but it does show the compound, the recovery of which, would indicate that a migration of the -MgX group had taken place.

A criticism of this work is that the recovery of some of the materials was far from satisfactory, however it should be kept in mind that rather small amounts of material had to be recovered from a mixture which contained many compounds. No attempt was made to recover such compounds as n-butyl alcohol and n-butyl mercaptan.

No characteristic derivative was prepared to show that the -MgX group had become attached to the oxygen atom in n-butyl alcohol or in phenol. Gilman and Schulze[32] have already shown that these compounds can not be readily characterized. On the other hand, we have the knowledge that the substance from which the-MgX group would have migrated to the oxygen atom would have been readily characterized by the treatment described in this work. For example, when diphenylaminomagnesium chloride was treated with n-butyl alcohol and then ethyl p-toluenesulfonate, pure diphenylamine would not have been recovered, but diphenyl ethylamine would have been obtained. The fact that a good recovery of diphenylamine was obtained, would indicate that the -MgX group had migrated from the nitrogen atom of the diphenylaminomagnesium chloride to the oxygen atom of n-butyl alcohol.

The results that were obtained are more or less clear cut with the exception of those experiments which involved the migration of the -MgX group from a di-aryl nitrogen atom to a dialkyl nitrogen atom. In this case there was a good indication that alkylated tertiary amines from each of the secondary amines had been obtained. This might indicate that an equilibrium existed as shown by the following equation:

$$R'R'N\text{-}MgX + RRNH \rightleftarrows R'R'NH + RRNMgX$$

Where R is an alkyl group and R' is an aryl group. Some experiments were carried out which showed that the compounds used in this work could not be alkylated by the ester in ether.

If there was an indication that an equilibrium did exist in one case, then there was the possibility that it did exist in all cases, but the resulting compounds were not isolated or recovered with sufficient care to ascertain this fact.

The results obtained by the work described here, indicated that the -MgX group will migrate from an atom which has alkyl groups attached to a corresponding atom which has aryl groups attached, with the possible exception of the dialkylamines to the diarylamines. The -MgX group will migrate from an alkyl oxygen atom to an aryl sulfur atom, that is, p-thiocresylmagnesium iodide was obtained by treating n-butoxymagnesium iodide with p-thiocresol in ether solution.

For a given series of compounds, alkyl or aryl, the order of migration has been found to be from a carbon atom to a triple bonded carbon atom to a nitrogen atom to a sulfur atom to an oxygen atom. All possible cases of migration have not been tried in this work. It is thought, however, that sufficient information has been obtained to make the work of some value. An experiment was not carried out to determine whether the -MgX group would migrate from an alkyl nitrogen atom to an aryl sulfur atom, but a prediction could be made that the -MgX group would migrate from an alkyl nitrogen atom to an aryl sulfur atom, because it was found that migration took place from an alkyl oxygen atom to an aryl sulfur atom and from an alkyl nitrogen atom to an alkyl oxygen atom. Therefore, the -MgX group should migrate from an alkyl nitrogen atom to an aryl sulfur atom.

The results obtained from this study suggest the possibility that there might be a migration of the -MgX group from an alkyl carbon atom to an aryl carbon atom (probably under forced conditions). For example, an alkylmagnesium halide when treated with toluene (under forced conditions) might give benzylmagnesium halide and the hydrocarbon corresponding to the alkyl group. However, there is little hope that this could actually be accomplished because Gilman and Leermakers[43] found that there was no reaction between

---

(43) Gilman and Leermakers, Rec. trav. chim., 48, 577 (1929).

diphenylmethane or triphenylmethane and benzylmagnesium chloride or ethylmagnesium bromide under protracted refluxing at elevated temperatures. If there were no interchange of radicals between an alkylmagnesium halide an aryl - CH in which there are three aryl groups, it is quite unlikely that there would be such an interchange with only one aryl group attached to a - CH. Gilman and Jones[44] also found that no interchange of radicals could be obtained by refluxing a series of RX compounds with some organomagnesium halides.

---

(44) Gilman and Jones, J. Am. Chem. Soc., 51, 2840 (1929).

SUMMARY

An attempt has been made to determine the course of migration of the -MgX group between some various oxy, thio and amino groupings of some organic compounds.

PART B. A STUDY UPON THE REACTION OF -NMgX AND -SMgX COMPOUNDS WITH PHENYL ISOCYANATE AND PHENYL ISOTHIOCYANATE[45].

INTRODUCTION

Aryl isocyanates and isothiocyanates especially the phenyl and α naphthyl are often used for the characterization of organic compounds. Hofmann[46] first obtained phenyl isocyanate, and it was soon thought the compound was characterized by its ability to form addition products with the N=C double bonding.

Neuberg and Rosenberg[47] and Kansky[48] found that alcohols reacted with phenyl isocyanate to give urethanes. Bichel and French[49] showed α napthyl isocyanate to be a satisfactory reagent for the purpose of identifying alcohols (including tertiary alcohols). French and Wirtel[50] used α naphthyl isocyanate for the purpose of identifying phenols and aliphatic

---

(45) The author acknowledges that a copy of a required thesis submitted by J. Hal Carter in Chemistry 658b, Iowa State College, was used during the progress of this work.

(46) Hofmann, Ann., <u>74</u>, 9 (1850); Ber., <u>3</u>, 653, (1870).

(47) Neuberg and Rosenberg, Biochem. Zeitschrift., <u>5</u>, 456 (1907).

(48) Neuberg and Kansky, <u>ibid</u>., <u>20</u>, 446 (1909).

(49) Bichel and French, J. Am. Chem. Soc., <u>48</u>, 747 (1926).

(50) French and Wirtel, J. Am. Chem. Soc., <u>48</u>, (1926).

amines.Otterbacher and Whitmore[51] described the use of phenyl isothiocyanate and o-tolyl isothiocyanate as a reagent for the identification of primary aromatic amines.Neuberg and Manasse[52] described a mthod for the isolation of amino acids by use of naphthyl isocyanate.

Blaise[53] showed that phenyl isocyanate reacted with RMgX compounds to give anilides. In a similar study Sachs and Loevy[54] found that RMgX compounds with isothiocyanates gave thioanilides. Gilman and Furry[55] used α naphthyl isocyanate as a reagent for preparing derivatives of organomagnesium halides. Gilman and Schulze[56] also used phenyl isocyanate for the characterization of ROMgX compounds. Gilman and King[57] found that -SMgX compounds could be characterized with phenyl isocyanate.

In view of the fact that the isocyanates and isothiocyanates

---

(51) Otterbacher and Whitmore, J. Am. Chem. Soc., <u>51</u>, 1909 (1926).

(52) Neuberg and Manasse, Ber., <u>38</u>, 2359 (1905).

(53) Blaise,Compt. rend., <u>132</u>, 40 (1901).

(54) Sachs and Loevy, Ber., <u>36</u>, 585 (1903).

(55) Gilman and Furry, J. Am. Chem. Soc., <u>50</u>, 1214 (1928).

(56) Gilman and Schulze, Rec. trav. chim., <u>47</u>, 752 (1928).

(57) Gilman and King, J. Am. Chem. Soc., <u>47</u>, 1136 (1925).

amines.Otterbacher and Whitmore[51] described the use of phenyl isothiocyanate and o-tolyl isothiocyanate as a reagent for the identification of primary aromatic amines.Neuberg and Manasse[52] described a mthod for the isolation of amino acids by use of naphthyl isocyanate.

Blaise[53] showed that phenyl isocyanate reacted with RMgX compounds to give anilides. In a similar study Sachs and Loevy[54] found that RMgX compounds with isothiocyanates gave thioanilides. Gilman and Furry[55] used α naphthyl isocyanate as a reagent for preparing derivatives of organomagnesium halides. Gilman and Schulze[56] also used phenyl isocyanate for the characterization of ROMgX compounds. Gilman and King[57] found that -SMgX compounds could be characterized with phenyl isocyanate.

In view of the fact that the isocyanates and isothiocyanates

---

(51) Otterbacher and Whitmore, J. Am. Chem. Soc., 51, 1909 (1926).

(52) Neuberg and Manasse, Ber., 38, 2359 (1905).

(53) Blaise, Compt. rend., 132, 40 (1901).

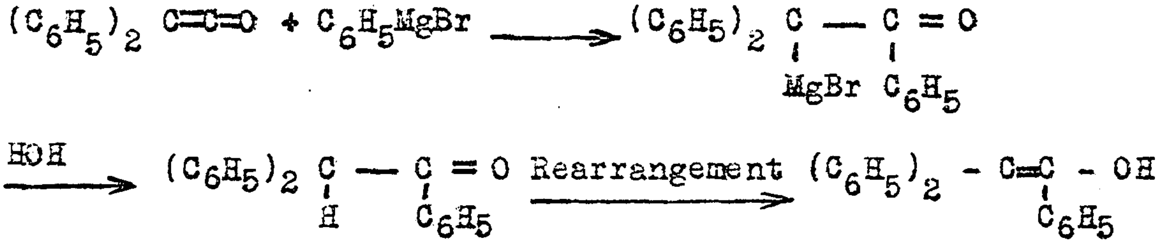
(54) Sachs and Loevy, Ber., 36, 585 (1903).

(55) Gilman and Furry, J. Am. Chem. Soc., 50, 1214 (1928).

(56) Gilman and Schulze, Rec. trav. chim., 47, 752 (1928).

(57) Gilman and King, J. Am. Chem. Soc., 47, 1136 (1925).

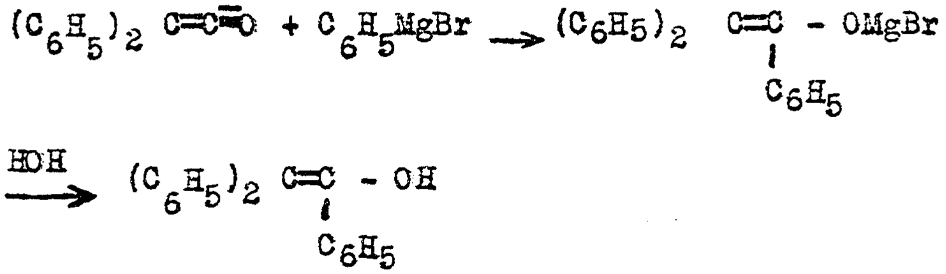
contain two reactive groups namely $-N{=}C$ and $C{=}O$ or $C{=}S$, a controversy has arisen as to the mechanism of addition of certain compounds to isocyanates or isothiocyanates. Ketenes are quite like the isocyanates in that they have two reactive groups, $C{=}C$ and $C{=}O$. Any study that would throw light upon the mechanism of addition to ketenes might aid in determining the mechanism of addition to isocyanates. Staudinger[57] carried out a reaction between diphenyl ketene and phenylmagnesium bromide and obtained triphenyl vinyl alcohol. The Grignard reagent might have added to either the ethylenic or carbonyl linkages. Staudinger preferred to explain the reaction as addition to the ethylenic linkage.



$$(C_6H_5)_2C{=}C{=}O + C_6H_5MgBr \longrightarrow (C_6H_5)_2\underset{MgBr}{C}-\underset{C_6H_5}{C}=O$$

$$\xrightarrow{HOH} (C_6H_5)_2\underset{H}{C}-\underset{C_6H_5}{C}=O \xrightarrow{\text{Rearrangement}} (C_6H_5)_2-C{=}\underset{C_6H_5}{C}-OH$$

Another mechanism would also account for the formation of triphenyl vinyl alcohol according to the following:



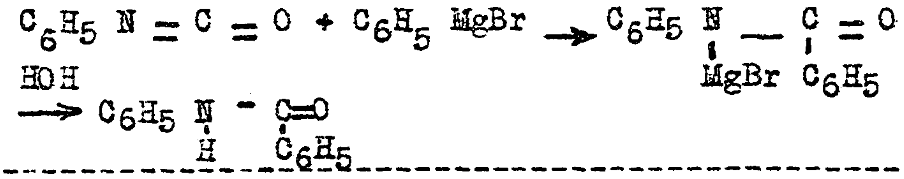
$$(C_6H_5)_2C{=}C{=}O + C_6H_5MgBr \longrightarrow (C_6H_5)_2C{=}\underset{C_6H_5}{C}-OMgBr$$

$$\xrightarrow{HOH} (C_6H_5)_2C{=}\underset{C_6H_5}{C}-OH$$

Gilman and Heckert[58] showed that the latter mechanism was undoubtedly the correct one.

Blaise[53], without sufficient experimental data interpreted the reaction between phenyl isocyanate and phenylmagnesium bromide as one involving primary addition to the carbonyl linkage.

Taboury[59] showed that an -MgBr group attached to a sulfur would suffer displacement by a methyl group when treated with dimethyl sulfate. Gilman and Hoyle[60] found that diethyl sulfate would behave in a manner similar to dimethyl sulfate. Gilman and Beaber[61] found that alkyl esters of p-toluenesulfonic acids were not satisfactory for characterizing the OMgX group. These facts lead Gilman and Kinney[62] to make a study of the mechanism of reaction for addition of phenylmagnesium bromide to phenyl isocyanate. Two mechanisms are theoretically possible:



$$C_6H_5N=C=O + C_6H_5MgBr \rightarrow C_6H_5\underset{\underset{MgBr}{|}}{N}-\underset{\underset{C_6H_5}{|}}{C}=O \xrightarrow{HOH} C_6H_5\underset{\underset{H}{|}}{N}-\underset{\underset{C_6H_5}{|}}{C}=O$$

I

---

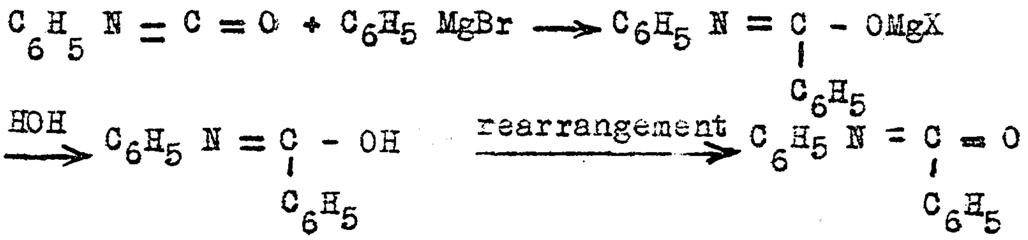
(58) Gilman and Heckert, ibid., 42, 1010 (1920).

(59) Taboury, Ann. chim. phys., 15, 33 (1908).

(60) Gilman and Hoyle, J. Am. Chem. Soc., 44, 2621 (1922).

(61) Gilman and Beaber, ibid., 45, 839 (1923).

(62) Gilman and Kinney, ibid., 46, 493 (1924).



$$C_6H_5N=C=O + C_6H_5MgBr \longrightarrow C_6H_5N=\underset{\displaystyle C_6H_5}{\underset{|}{C}}-OMgX$$

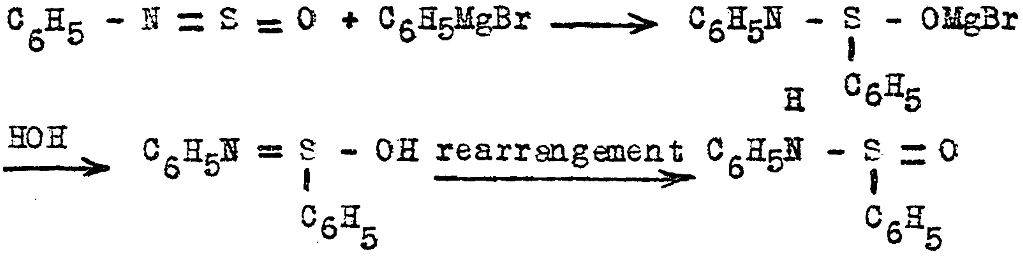
$$\xrightarrow{HOH} C_6H_5N=\underset{\displaystyle C_6H_5}{\underset{|}{C}}-OH \xrightarrow{\text{rearrangement}} C_6H_5N=\underset{\displaystyle C_6H_5}{\underset{|}{C}}=O \qquad II$$

These authors (Gilman and Kinney[62]) used the sulfur analog of phenyl isocyanate namely phenyl isothiocyanate. Phenyl isothiocyanate was first treated with phenylmagnesium bromide and then with an alkylating agent, dimethyl or diethyl sulfate. If (II) is correct the -SMgX intermediate compound would be replaced by an alkyl group. This would be ascertained by working up the products of the reaction. The products obtained were found to be S-methyl or S-ethyl-thiobenzanilide, depending upon the alkylating agent. This was rather definite proof that the Grignard reagent had added to the thiocarbonyl group. Thus by analogy it was quite certain that the Grignard reagent did add to the carbonyl group in isocyanates.

Gilman and Morris[63] showed that the mode of addition of phenylmagnesium bromide to thionyl aniline could probably be expressed by the equation:

---

(63) Gilman and Morris, <u>ibid</u>., <u>48</u>, 2399 (1926).



$$C_6H_5-N=S=O+C_6H_5MgBr\longrightarrow C_6H_5N-\underset{C_6H_5}{S}-OMgBr$$

$$\xrightarrow{HOH} C_6H_5N=\underset{C_6H_5}{S}-OH\xrightarrow{\text{rearrangement}} C_6H_5\overset{H}{N}-\underset{C_6H_5}{S}=O$$

It might be mentioned here that a forced reaction between phenyl isocyanate, or benzophenone-anil and phenylmagnesium bromide, was found by Gilman, Kirby and Kinney[64] to give an unusual case of 1,4 addition with the benzene ring.

In the case of ketenes and isocyanates we have adequate proof that addition takes place at the carbonyl linkage. In spite of this fact there are several who seem to favor the possibility that addition to these compounds does take place at the $C=C$ or $N=C$ linkage instead of the carbonyl linkage.

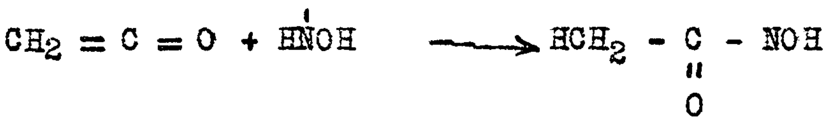
Hurd and Cochran[65] in a work relative to the reaction between ketene and isocyanates with hydroxylamines and hydroxamic acids, favor the idea that addition takes place at the $N=C$ linkage.

For ketene and hydroxylamine the following is proposed:

---

(64) Gilman, Kirby and Kinney, ibid., 51, 2252 (1929). See also Kohler and Nygaard, ibid., 52, 4129 (1930).

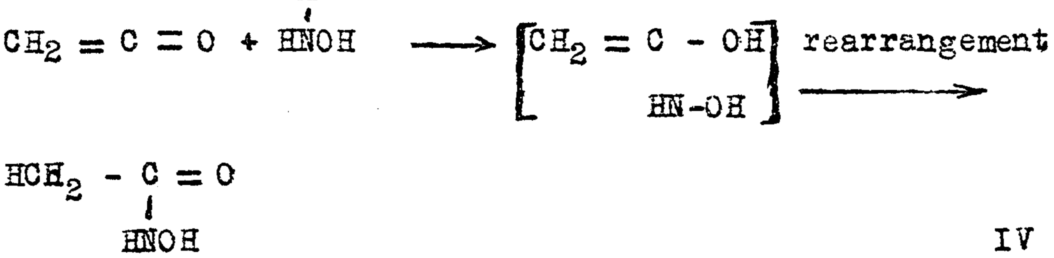
(65) Hurd and Cochran, ibid., 45, 515 (1923). See also Hurd, ibid., 45, 1472 (1923); Jones and Hurd, ibid., 43, 2423 (1921).



$$CH_2 = C = O + H\overset{H}{N}OH \longrightarrow HCH_2 - \underset{\underset{O}{\|}}{C} - NOH$$

III

This could just as readily be explained by this equation:

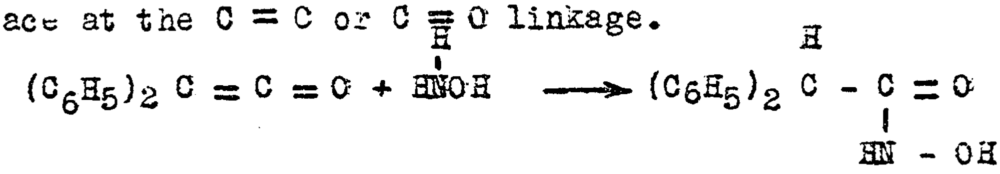


$$CH_2 = C = O + H\overset{H}{N}OH \longrightarrow \left[\begin{array}{l} CH_2 = C - OH \\ \qquad\quad HN-OH \end{array}\right] \xrightarrow{\text{rearrangement}} HCH_2 - \underset{\underset{HNOH}{|}}{C} = O$$

IV

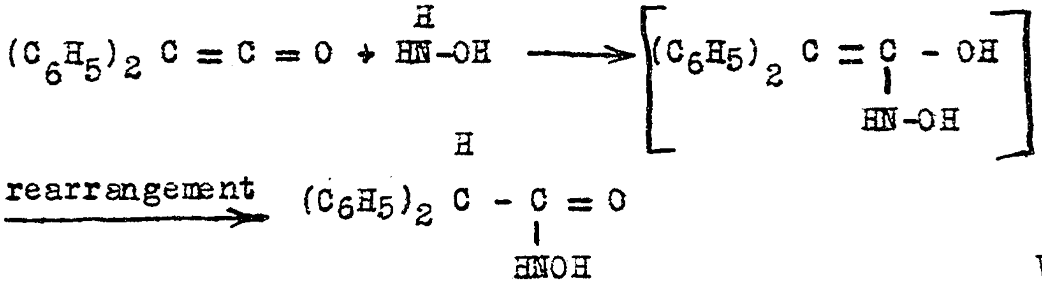
The final product in either (III) or (IV) would be identical.

For the reaction between diphenyl ketene and hydroxylamine the following reactions will show that the same product, diphenyl-acethydroxamic acid, is formed whether addition takes place at the $C = C$ or $C = O$ linkage.



$$(C_6H_5)_2C = C = O + H\overset{H}{N}OH \longrightarrow (C_6H_5)_2\overset{H}{C} - \underset{\underset{HN-OH}{|}}{C} = O$$

V

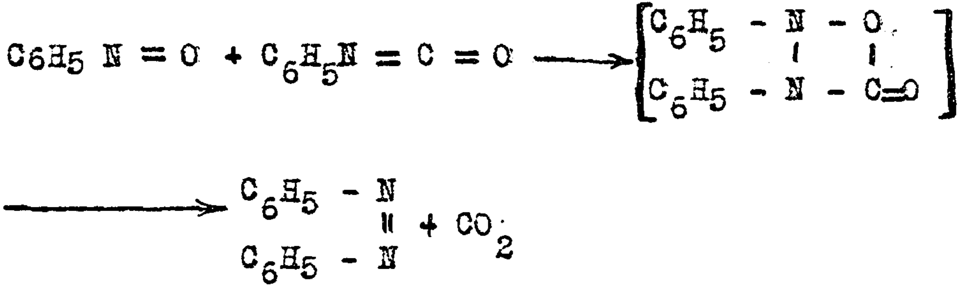


$$(C_6H_5)_2C = C = O + H\overset{H}{N}-OH \longrightarrow \left[(C_6H_5)_2C = \underset{\underset{HN-OH}{|}}{C} - OH\right] \xrightarrow{\text{rearrangement}} (C_6H_5)_2\overset{H}{C} - \underset{\underset{HNOH}{|}}{C} = O$$

VI

Other experiments, involving similar reactions, were carried out by Hurd and co-workers[65], and could be explained just as satisfactorily by postualting addition to the $C = O$ linkage followed by a subsequent rearrangement, as by direct addition to the $N = C$ or $C = C$ linkages.

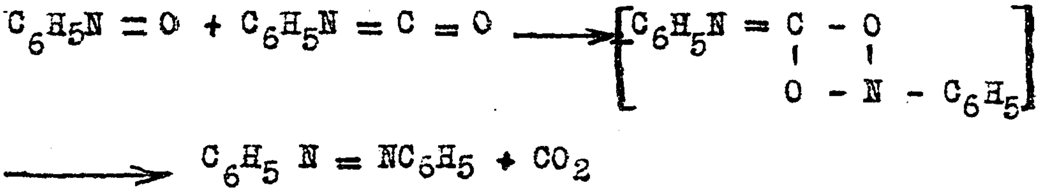
H Staudinger and Endle[66] attempted to show that various $-C=O$, $-N=O$ and structurally related compounds added to the $N=C$ linkage of phenyl isocyanate. An example of this type of reaction is:



$$C_6H_5N=O + C_6H_5N=C=O \longrightarrow \left[\begin{array}{l} C_6H_5-N-O \\ \qquad\quad | \quad\ | \\ C_6H_5-N-C=O \end{array}\right] \longrightarrow \begin{array}{l} C_6H_5-N \\ \qquad\quad \| \\ C_6H_5-N \end{array} + CO_2$$

VII

This reaction can also be explained by a reaction which involves addition to the $C=O$ linkage:



$$C_6H_5N=O + C_6H_5N=C=O \longrightarrow \left[\begin{array}{l} C_6H_5N=C-O \\ \qquad\qquad | \quad\ | \\ \qquad\qquad O-N-C_6H_5 \end{array}\right] \longrightarrow C_6H_5N=NC_6H_5 + CO_2$$

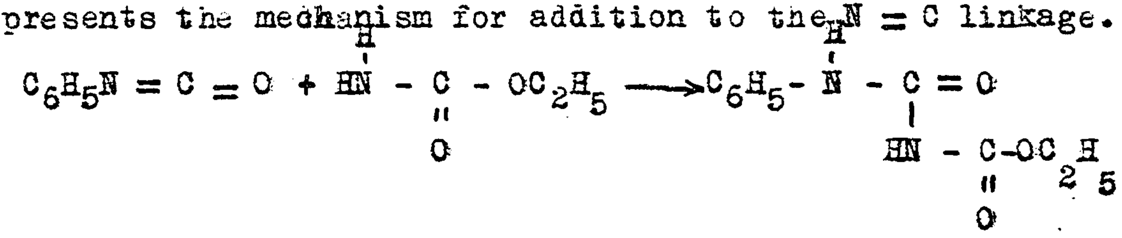
Lakra and Dains[67] in a very recent work make the following statement: "Phenyl isocyanate which was first obtained by Hofmann is *characterized by its ability to form addition products with the N = C double bonding.* Thus with alcohols urethanes are formed, while with ammonia and primary and secondary amines, substituted areas are formed."

---

(66) Staudinger and Endle, Ber., *50*, 1042 (1917).

(67) Lakra and Dains, J. Am. Chem. Soc., *51*, 2220 (1930).

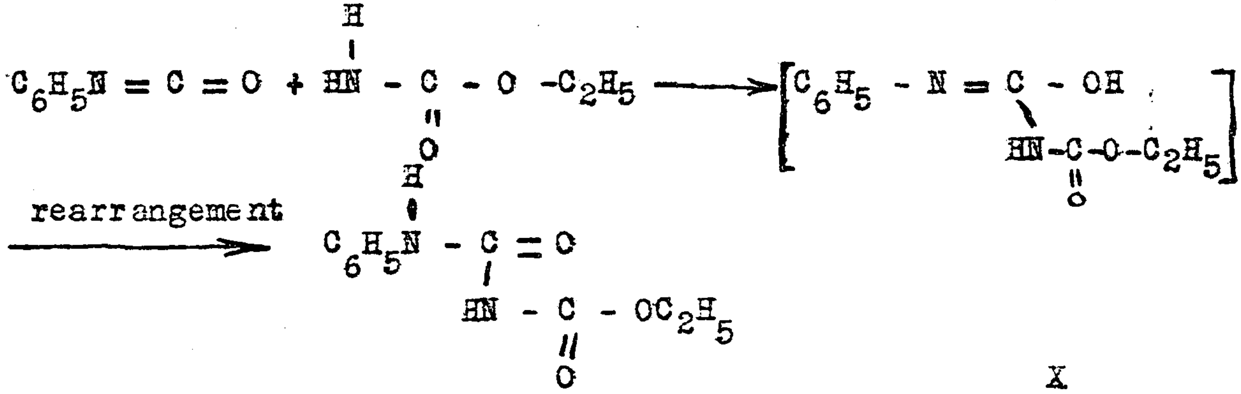
An example of the type of work discussed in the above is the reaction between phenyl isocyanate and urethane to form phenyl allophanic ester. The following equation represents the mechanism for addition to the N = C linkage.



$$C_6H_5N = C = O + \overset{H}{H N} - \underset{O}{\overset{}{C}}\!\!\overset{}{\underset{\|}{}} - OC_2H_5 \longrightarrow C_6H_5 - \overset{H}{N} - \underset{\underset{HN\ -\ \underset{\underset{O}{\|}}{C} - OC_2H_5}{|}}{C} = O$$

IX

This same reaction could just as easily be considered from the standpoint of addition to the C=O double bonding as:



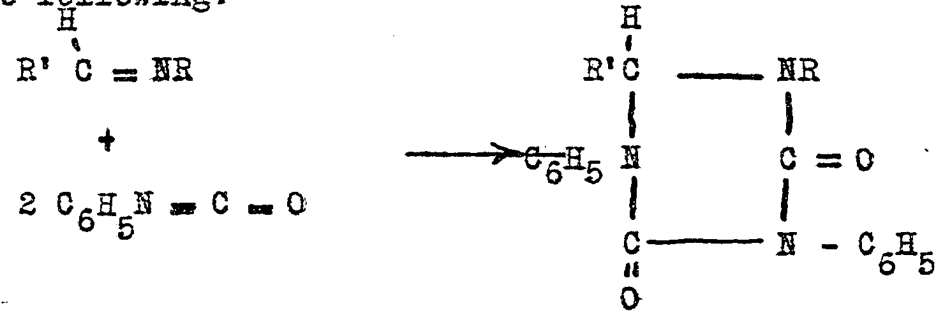
$$C_6H_5N = C = O + \overset{\overset{H}{|}}{HN} - \underset{\underset{O}{\|}}{C} - O - C_2H_5 \longrightarrow \left[C_6H_5 - N = \underset{\underset{HN - \underset{\underset{O}{\|}}{C} - O - C_2H_5}{\diagdown}}{C} - OH \right] \xrightarrow{\text{rearrangement}} C_6H_5\overset{\overset{H}{|}}{N} - \underset{\underset{HN\ -\ \underset{\underset{O}{\|}}{C}\ -\ OC_2H_5}{|}}{C} = O$$

X

It is quite obvious that the final products are identical.

Other experimental data offered by these authors could be explained in a manner after (X).

Admittedly there are cases of reactions with isocyanates that can not be explained as readily (if at all) by addition to the carbonyl linkage as by simple addition to the N = C linkage. An example of this type of reaction is brought to mind by the work of Lange[68] relative to the reaction between alkyl Schiff bases and isocyanic acid and phenyl isocyanate. Two molecular portions of phenyl isocyanate. react with one of the alkyl Schiff base to give a stable 6-membered ring, namely, a diketocyanidine according to the following:



Where R is an alkyl group.

Aryl Schiff bases do not react in this manner and if they do react at all, they probably form unstable 4-membered rings.

It is seen that it would be decidedly difficult to explain a reaction of this sort on a basis of addition to the carbonyl linkage followed by a subsequent rearrangement.

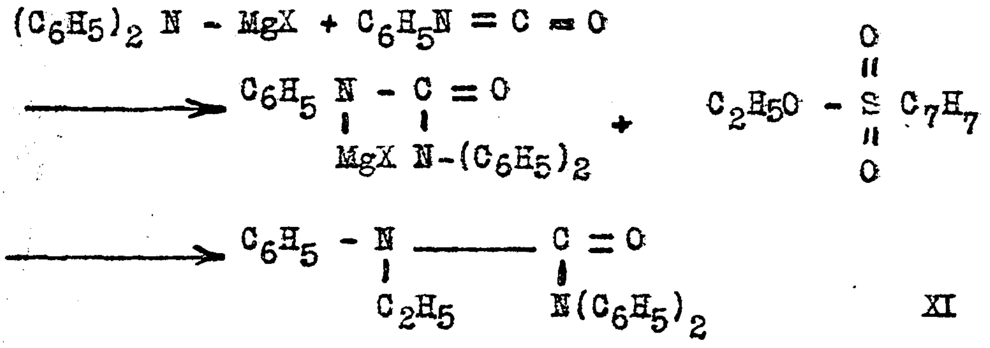
The purpose of the present work is to show that -NMgX and -SMgX compounds which may be considered as being halogenomagnesium salts of amines and mercaptans (thio alcohols) do add to the carbonyl linkage of phenyl isocyanate and phenyl

---

(68) Lange, J. Am. Chem. Soc., **48**, 2440 (1926). See also Hale and Lange, *ibid.*, **41**, 379 (1919); **42**, 107 (1920).

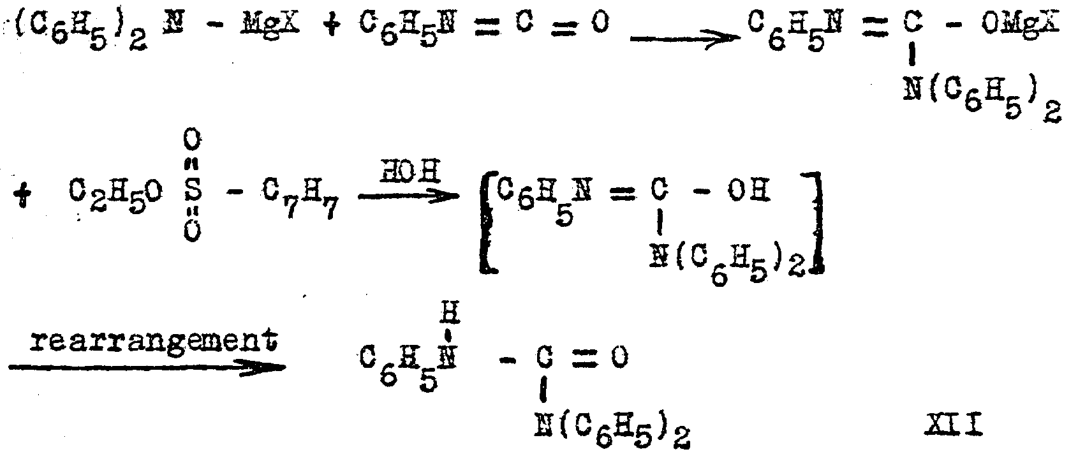
isothiocyanate. Diphenylaminomagnesium halides and p-thiocresylmagnesium halides were the typical compounds selected for this study.

Let us consider the possible reactions that may take place in this work. The possible equations for diphenylaminomagnesium halides and phenyl isocyanate are:



$$(C_6H_5)_2N-MgX + C_6H_5N=C=O \longrightarrow \underset{MgX}{C_6H_5\,N}-\underset{N-(C_6H_5)_2}{C}=O + C_2H_5O-\overset{O}{\underset{O}{S}}-C_7H_7 \longrightarrow C_6H_5-\underset{C_2H_5}{N}-\underset{N(C_6H_5)_2}{C}=O$$

XI

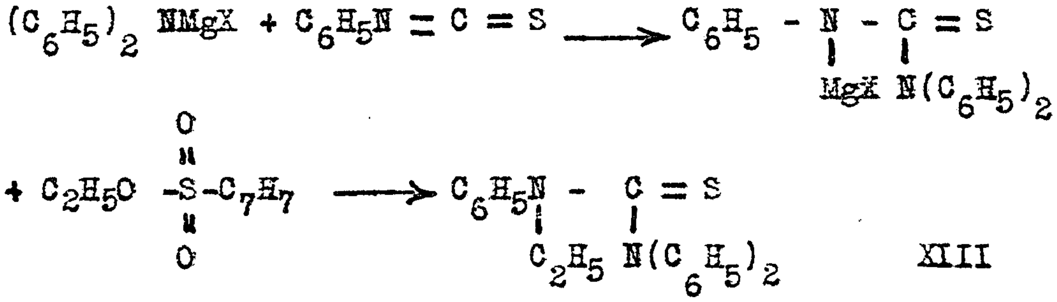


$$(C_6H_5)_2N-MgX + C_6H_5N=C=O \longrightarrow C_6H_5N=\underset{N(C_6H_5)_2}{C}-OMgX + C_2H_5O\overset{O}{\underset{O}{S}}-C_7H_7 \xrightarrow{HOH} \left[C_6H_5N=\underset{N(C_6H_5)_2}{C}-OH\right] \xrightarrow{\text{rearrangement}} C_6H_5\overset{H}{N}-\underset{N(C_6H_5)_2}{C}=O$$

XII

If equation (XI) is correct triphenyl ethyl urea would be isolated, but for equation (XII) we would expect only triphenyl urea.

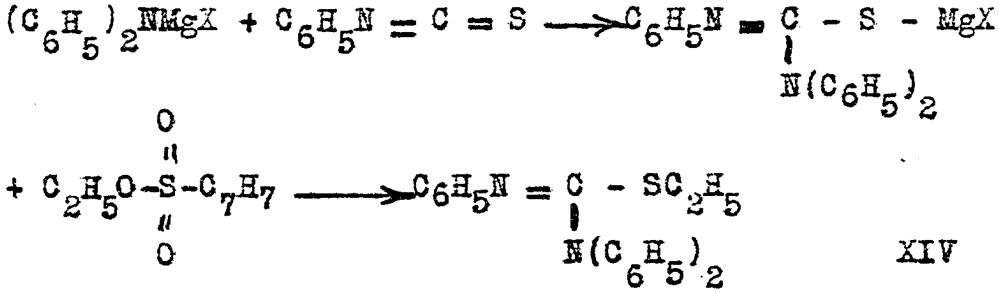
The following equations represent the possible reactions between diphenylamino-magnesium halides and phenyl isothiocyanate:



$$(C_6H_5)_2NMgX + C_6H_5N{=}C{=}S \longrightarrow C_6H_5-\underset{MgX}{N}-\underset{N(C_6H_5)_2}{C}{=}S$$

$$+ C_2H_5O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-C_7H_7 \longrightarrow C_6H_5\underset{C_2H_5}{N}-\underset{N(C_6H_5)_2}{C}{=}S$$

XIII



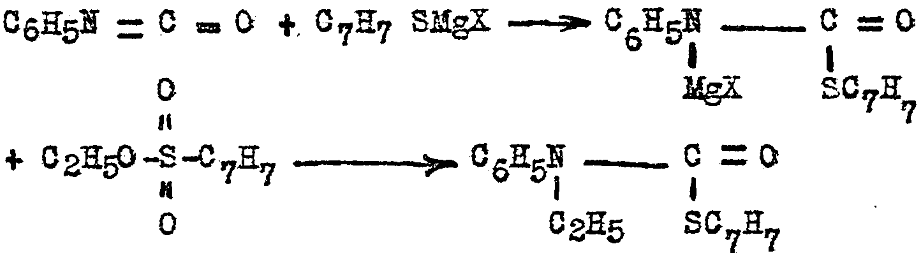
$$(C_6H_5)_2NMgX + C_6H_5N{=}C{=}S \longrightarrow C_6H_5N{=}\underset{N(C_6H_5)_2}{C}-S-MgX$$

$$+ C_2H_5O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-C_7H_7 \longrightarrow C_6H_5N{=}\underset{N(C_6H_5)_2}{C}-SC_2H_5$$

XIV

According to (XIII) triphenyl ethyl thiourea would be formed, but by (XIV) S-ethyl-triphenyl-thiourea would be formed.

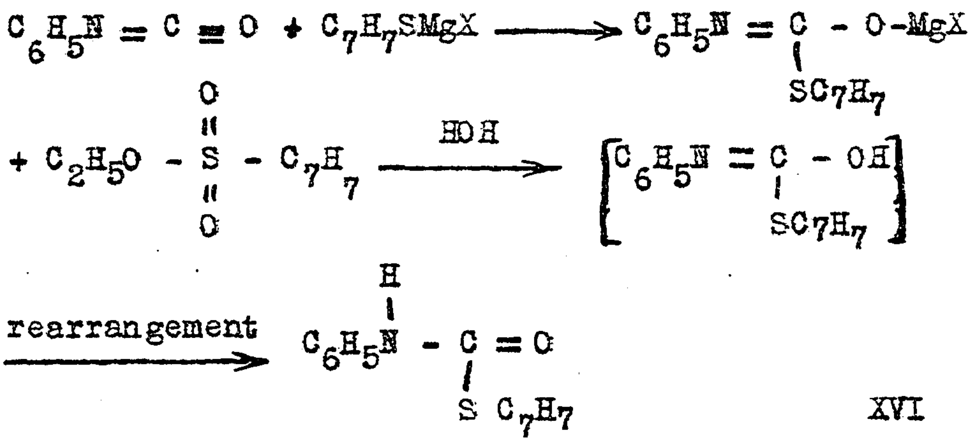
These equations represent the possible reactions that might take place between p-tolylmercaptomagnesium halides and phenyl isocyanate:



$$C_6H_5N{=}C{=}O + C_7H_7SMgX \longrightarrow C_6H_5\underset{MgX}{N}-\underset{SC_7H_7}{C}{=}O$$

$$+ C_2H_5O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-C_7H_7 \longrightarrow C_6H_5\underset{C_2H_5}{N}-\underset{SC_7H_7}{C}{=}O$$

XV



$$C_6H_5N=C=O + C_7H_7SMgX \longrightarrow C_6H_5N=\underset{SC_7H_7}{C}-O-MgX$$

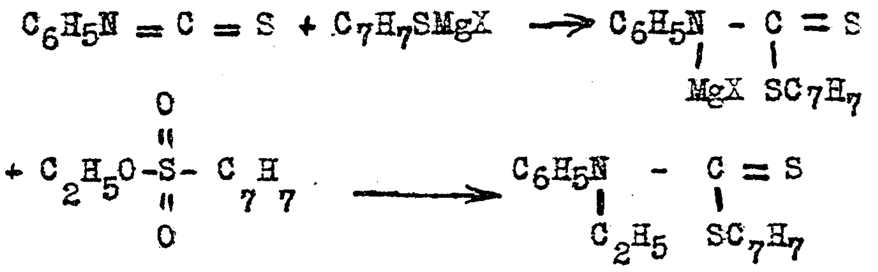
$$+\ C_2H_5O-\overset{O}{\underset{O}{S}}-C_7H_7 \xrightarrow{HOH} \left[C_6H_5N=\underset{SC_7H_7}{C}-OH\right]$$

$$\xrightarrow{\text{rearrangement}} C_6H_5\overset{H}{N}-\underset{S\,C_7H_7}{C}=O$$

XVI

According to (XV) p-tolyl phenyl-ethyl-thiolcarbamate would be isolated but by (XVI) p-tolyl phenyl-thiolcarbamate would be obtained.

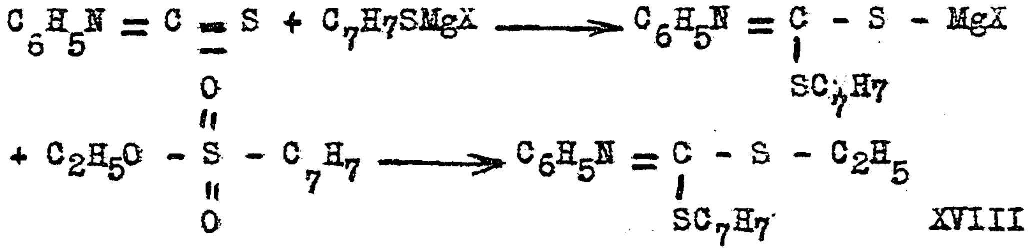
The equations which represent possible reactions between p-tolylmercapto-magnesium halides and phenyl isothiocyantae are:



$$C_6H_5N=C=S + C_7H_7SMgX \longrightarrow C_6H_5\underset{MgX}{N}-\underset{SC_7H_7}{C}=S$$

$$+\ C_2H_5O-\overset{O}{\underset{O}{S}}-C_7H_7 \longrightarrow C_6H_5\underset{C_2H_5}{N}-\underset{SC_7H_7}{C}=S$$

XVII



$$C_6H_5N=C=S + C_7H_7SMgX \longrightarrow C_6H_5N=\underset{SC_7H_7}{C}-S-MgX$$

$$+\ C_2H_5O-\overset{O}{\underset{O}{S}}-C_7H_7 \longrightarrow C_6H_5N=\underset{SC_7H_7}{C}-S-C_2H_5$$

XVIII

According to (XVII) p-tolyl phenyl-ethyl-dithiocarbamate would be isolated but by (XVIII) p-tolyl (S-ethyl) - phenyldithiocarbamate would be isolated.

The experimental work was carried out with the idea of determining, if possible, which equations (XI to XVIII) are the correct ones.

The method followed was much like that described by Gilman and Kinney[62], except alkyl p-toluenesulfonates[69] were used as alkylating agents instead of alkyl sulfates. It was found that the alkyl p-toluenesulfonates will not alkylate secondary amines or mercaptans in an ether solution but will alkylate the corresponding -MgX compounds quite readily. Gilman and Kinney[62] reported that dialkyl sulfates did alkylate p-thiocresol but not with a good yield.

Magnesium bromide etherate was added to the reaction mixture, after sufficient time had been given for complete reaction, in order to destroy any excess ester. It is seen that a method of removing the excess ester would facilitate the isolation of the final products of the reaction. An experiment was carried out to show that the ester could be completely removed by means of treating it with magnesium bromide etherate in ether solution. The corresponding alkyl bromide and magnesium p-toluenesulfonate was formed.

---

(69) For leading references to the use of alkyl p-toluenesulfonates see Gilman and Heck, J. Am. Chem. Soc., 50, 2223 (1928).

EXPERIMENTAL

The Reaction between Magnesium Bromide Etherate and Ethyl p-Toluenesulfonate.

The purpose of this experiment was to determine whether or not an excess of alkyl p-toluenesulfonate could be completely removed by refluxing the ester in ether with magnesium bromide etherate.

The magnesium bromide etherate was prepared by slowly adding an ether solution of 40.0 grams (0.213 mole) of ethylene bromide to a 500 cc three-necked flask, fitted with stirrer and condenser, which contained 6.0 grams (0.25 atom) of magnesium turnings.

An ether solution of 80.0 grams (0.40 mole) of ethyl-p-toluenesulfonate was added dropwise to the magnesium bromide etherate. A rather vigorous reaction took place and a crystalline precipitate separated out. The mixture, subsequent to complete addition of the ester, was refluxed for three hours over a hot-plate. It is considered that the long time of refluxing was unnecessary.

The magnesium p-toluenesulfonate was filtered through a Buchner funnel. The ether filtrate was washed with water, dried over sodium sulfate and distilled on a water bath. There was only one and one-half grams of material that failed to distill over on a water bath. This residue gave an excellent qualitative test for sulfur.

It is seen that practically all of the ester, (only one and one-half grams remained out of an original eighty grams) was removed by this treatment.

The Reaction between Diphenylamine, Ethylmagnesium Chloride, Phenyl Isocyanate, Ethyl *p*-Toluenesulfonate and Magnesium Bromide Etherate.

An ether solution of 16.9 grams (0.1 mole) of diphenylamine was placed in a 1 liter three-necked flask, fitted with a stirrer and condenser. An ethylmagnesium chloride solution was added until a positive color test could be obtained. An ether solution of 12.0 grams (0.1 mole) of phenyl isocyanate was added dropwise to the contents of the flask. A mild reaction appeared to have taken place upon addition of the phenyl isocyanate. The mixture was refluxed over a hot-plate for fifteen minutes and an ether solution which contained 40.0 grams (0.2 mole) of ethyl-*p*-toluene sulfonate was added. The mixture was refluxed over a hot-plate for one hour. A large amount of white precipitate separated out.

An ether solution of magnesium bromide etherate was added to the mixture in order to insure complete removal of the ester. The magnesium bromide etherate was prepared from

2.4 grams (0.1 atom) of magnesium and 18.8 grams (0.1 mole) of ethylene bromide in an ether solution.

The mixture was refluxed over a hot-plate for another hour and hydrolyzed by pouring it (the mixture) into about two liters of iced water. An amount of hydrochloric acid sufficient to dissolve the $Mg(OH)_2$ was then added. The water layer was extracted once with ether. Long needle-like crystals soon separated from the ether. The combined ether layers were evaporated and 21.0 grams of dry crystalline material was obtained. This had a melting point of 135°-7°. The melting point was unchanged by recrystallizing the material from alcohol. The literature gives a melting point of 136° for triphenyl urea. This compound was further identified as triphenyl urea by making a mixed melting point determination with an authentic specimen.[68a] The quantity of material obtained here corresponds to a 73% yield of triphenyl urea.

Triphenyl ethyl urea, the compound that should have been obtained if the -MgCl had added to the nitrogen atom of phenyl isocyanate, melts at 152°.

It is quite evident that triphenyl ethyl urea probably was not obtained in this experiment on account of the purity of the crude material.

The fact that triphenyl ethyl urea was not formed is

(68a) This was prepared after a method described by Gebhardt, Ber., 17, 2088 (1884).

offered as evidence that diphenylaminomagnesium chloride added to the C = O and not the N = C linkage of phenyl isocyanate.

The Reaction between Diphenylamine, Ethylmagnesium Chloride, Phenyl Isothiocyanate, Ethyl p-Toluenesulfonate and Magnesium Bromide Etherate.

This experiment was carried out exactly the same as the preceding one except an ether solution of 13.5 grams (0.1 mole) of phenyl isothiocyanate was used instead of the phenyl isocyanate.

The intermediate product formed by the addition of diphenylaminomagnesium chloride and phenyl isothiocyanate was insoluble in ether.

The product obtained in this experiment would not crystallize from an ether solution. Therefore it was distilled under reduced pressure and 28.0 grams of a light yellow-colored viscous oil which boiled at 243°-5°/5 mm was obtained.

Almost identical results were obtained from another run in which diphenylaminomagnesium iodide was used instead of the corresponding chloride. The intermediate compound in this case also was insoluble in ether.

The oil, when refluxed with a 20% hydrochloric acid solution, gave off carbon dioxide. The hydrochloride layer (an oily layer was present after this acid hydrolysis) was made basic with sodium hydroxide and extracted with ether. The ether layer when distilled gave a small amount of material b.p. 176°.

This material was identified as aniline by converting it to acetanilide. The oily layer that remained after hydrolysis with hydrochloric acid was thought to be ethyl thiol-diphenyl carbamate because a subsequent hydrolysis of this product with a 25% solution of potassium hydroxide gave diphenylamine and ethyl mercaptan. The ethyl mercaptan was not positively identified on account of its rather low boiling point. The odor was taken as sufficient identification in this case because ethyl mercaptan would be the only one possible. It is well known that mercaptans have a rather characteristic odor.

Accordingly, the oil boiling at 243°-50/5mm must be (after XIV) S-ethyl-triphenyl-thiourea. The yield was 33%.

Analysis. Calculated for $C_{21}H_{20}N_2S$: S, 9.64. Found: S, 9.78.

An examination of the several solutions failed to reveal any indication of ethylaniline. This compound should have been isolated if addition had taken place at the $N = C$ linkage after (XIII).

The Reaction between p-Tolymercaptan, Ethylmagnesium Iodide, Phenyl Isocyanate, Ethyl p-Toluenesulfonate and Magnesium Bromide Etherate.

An ether solation of 12.9 grams (0.1 mole) of p-tolylmercaptan was placed in a 500 cc three-necked flask, fitted with a stirrer and condenser. An equivalent amount of ethylmagnesium iodide solution was added. Even though the reaction had apparently ceased before all the Grignard reagent had been added, a color test could not be obtained[70]. The mixture was refluxed over a hot-plate for an hour subsecuent to the addition of an ether solution of 40.0 grams (0.2 mole) of ethyl p-toluenesulbfonate. The mixture was then refluxed for three hours and permitted to stand over night.

Magnesium bromide etherate (0.05 mole) was added and the mixture refluxed for another hour before it was hydrolyzed.

---

(70) It might be mentioned here that it has been noticed during the progress of this work that there is an apparent interference of some mercaptans and amines with the color test. This interference has been observed only in the case of organomagnesium iodides, and not with the bromides or chlorides.

It has been observed that about two equivalents of an organomagnesium iodide must be added before a positive color test can be obtained. In these cases an ether insoluble oil, much like magnesium iodide etherate, always separates out.

No explanation for this apparent interference is offered.

In cases where this interference has been observed, the color test has been disregarded and only the theoretical amounts of the organomagnesium iodide have been added.

The ether layer after hydrolysis was extracted with dilute sodium hydroxide in order to remove any unreacted p-tolylmercaptan. None of the mercaptan could be recovered.

The ether was evaporated and as no solid material crystallized out the substance was distilled under reduced pressure. Fifteen grams of material b.p. 105°-10°/7 mm was obtained. This had the appearance of being ethyl p-tolyl sulfide and furthermore it was successfully oxidized to ethyl p-tolyl sulfone m.p. 52°-3°. The sulfone was in turn identified by a mixed melting point determination with an authentic specimen. The amount of substance which boiled at 105°-10°/7mm corresponded to a quantitative yield of ethyl p-tolyl sulfide.

The results obtained here were unexpected. The expected compound was p-tolyl phenyl thiolcarbamate as described by Gilman and King[57].

The Reaction between p-Tolylmercaptan, Ethylmagnesium Iodide and Phenyl Isocyanate.

This experiment was carried out on account of the unexpected results obtained in the work described above.

This experiment was identical with the above as to method and amounts of materials used except no ester and no magnesium bromide etherate was added. Practically a quantitative yield of p-tolyl-phenyl-thiolcarbamate m.p. 126°-7° was obtained as described by Gilman and King[57] for this reaction.

p-Tolyl-phenyl-thiolcarbamate was refluxed with magnesium bromide etherate in order to determine whether or not the addition of magnesium bromide had any effect upon this compound. There was no indication that a reaction had taken place because practically a quantitative recovery of the unchanged p-tolyl-phenyl-thiolcarbamate was obtained.

The Reaction between p-Tolylmercaptan, Ethylmagnesium Iodide, Phenyl Isothiocyanate, and Ethyl p-Toluenesulfonate.

An ether solution of 12.4 grams (0.1 mole) of p-tolylmercaptan was placed in a 500 cc three-necked flask fitted with a stirrer and condenser. The theoretical amount (42.0cc of 2.38 M (0.1 mole)) of an ethylmagnesium iodide solution was then added. A positive color test[22] could not be obtained and as usual an oily layer separated out[70]. An ether solution of 13.5 grams 0.1 mole of phenyl isothiocyanate was added. A precipitate did not form at this stage as had been the case in the previous experiments. A mild reaction appeared to take place upon the addition of the phenyl isothiocyanate. After refluxing the solution for one hour an ether solution of 40.0 grams (0.2 mole) of ethyl p-toluenesulfonate was added.

No magnesium bromide etherate was used here because all the ester would be used up regardless of the mode of the reaction with the phenyl isothiocyanate.

Subsequent to a two-hour period of refluxing, the mixture was hydrolyzed by pouring it into an iced hydrochloric acid solution. The water layer was extracted once with ether and the combined ether layers were dried over calcium chloride. No solid material could be obtained by evaporation of the ether. Therefore, this solution, after removal of the ether, was distilled under reduced pressure. The following were obtained:

Fraction I, portion up to 100°/7mm - discarded
Fraction II, 15.0 grams b.p. 103°-5°/7 mm.
Fraction III, 10.0 grams b.p. 223°/7 mm, and m.p. 78°.

Fraction I. There was only a very small amount of material and it was discarded.

Fraction II. This was in the boiling range of ethyl p-tolyl sulfide but could not be successfully oxidized to the corresponding sulfone.

Fraction III. This portion when refluxed for several hours with a 20% hydrochloric acid solution gave an insoluble oily layer in addition to the hydrochloride layer. Aniline was the only product that was obtained after making the hydrochloride portion basic with sodium hydroxide. The insoluble oily layer, probably ethyl p-tolyl dithiocarbonate gave ethyl mercaptan upon alkaline hydrolysis, as indicated by the odor[71]. p-Thiocresol was recovered when the alkaline solution was made acid with hydrochloric acid.

Accordingly, Fraction III was p-tolyl (S-ethyl)-phenyldithiocrabamate after (XVIII). The yield was 32.0%.

Analysis. Calculated for $C_{16}H_{17}NS_2$:S, 22.32. Found: S, 22.53: S. 22.70.

The Reaction between p-Tolylmercaptan, Ethylmagnesium Iodide, and Phenyl Isothiocyanate.

This experiment was exactly like the preceding one except no ethyl p-toluenesulfonate was added. The mixture was hydrolyzed in the usual manner after it had been refluxed over a hot-plate for two hours. An ether water insoluble crystalline material was obtained upon hydrolysis. This material melted at 143° and weighed 26.0 grams when dry.

This compound, m.p. 143°, was hydrolyzed with a 25% potassium hydroxide solution. A white crystalline material separated out. This material was filtered out and recrystallized from alcohol. The melting point was 151°-2°. This product of hydrolysis was identified as being thiocarbanilide m.p. 152° by making a mixed melting point determination with

---

(71) Dr. Gilman, R. E. Brown and S. A. Harris said there was no doubt but what the odor was that of ethylmercaptan.

an authentic specimen.

The alkaline filtrate was made acid with hydrochloric and p-thiocresol was recovered. Hydrogen sulfide was also liberated at this time.

Therefore, this compound which melted at 143° was found to be p-tolyl phenyl dithiocarbamate. The yield was quantitative.

Analysis. Calculated for $C_{14}H_{13}NS_2$:S,24.74. Found:S,24.59.

DISCUSSION

The results obtained in the experimental work indicate that diphenylaminomagnesium chloride did add to the thio carbonyl linkage in phenyl isothiocyanate (after XIV) and that p-tolylmercaptomagnesium iodide did add to the thiocarbonyl linkage in phenyl isothiocyanate after (XVIII).

This study should further advance the idea that addition does generally take place at the carbonyl or thiocarbonyl linkage in phenyl isocyanate and phenyl isothiocyanate because we have adequate proof that this is the mode of addition in the case of amines and mercaptans (thio alcohols).

There is a possibility that addition may have taken place at the $N = C$ linkage, the -MgX going to the nitrogen atom and then shifting immediately to the oxygen atom or sulfur atom as the case may be. The work in another part of this thesis[72] indicates that the -MgX will move from a nitrogen atom to a sulfur atom. It should be kept in mind that it is just as reasonable to postulate an -MgX group moving from a nitrogen atom to a sulfur atom or an oxygen atom as it is to postulate a hydrogen atom migrating from a sulfur or an oxygen to a nitrogen atom.

---

(72) See PART A, This Thesis.

However, the fact remains that we have rather definite proof that addition did take place at the carbonyl and thiocarbonyl linkages. Any definite proof that addition took place at the $N = C$ double bonding has not been found in this work.

SUMMARY

It has been shown that diphenylaminomagnesium chloride and p-tolylmercaptomagnesium iodide does add to the thiocarbonyl linkage in phenyl isothiocyanate. By analogy it is almost certain that these compounds also add to the carbonyl group in phenyl isocyanate.