

A STUDY OF THE PREPARATION AND PROPERTIES OF
THE HIGHER FORMALS AND CHLOROMETHYL ETHERS

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THE PREPARATION AND PROPERTIES OF THE HIGHER FORMALS
AND CHLOROMETHYL ETHERS

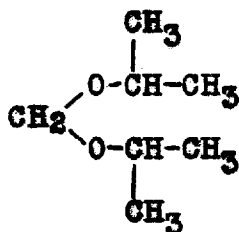
INTRODUCTION

Chloromethyl ethers and formals derived from the lower alcohols are well known, but few of them have been prepared from the higher alcohols. The alcohols through amyl, $C_5H_{11}OH$, have been used in these preparations. However, compounds of the isomeric butyl and amyl alcohols have not all been reported in the literature. With alcohols higher than amyl there are miscellaneous chloromethyl ethers and formals reported. It may be generalized that above normal amyl alcohol the series of the formals and chloromethyl ethers are practically voids.

A chloromethyl ether has the general formula CH_2ClOR , a formal $CH_2(OR)_2$, in which the "R" groups may be either aryl or alkyl. The "R" groups may be substituted or unsaturated, or both, and in the case of the formals they may or may not be alike. In this study, however, these groups were unsubstituted, saturated alkyl groups derived from their corresponding alcohols.

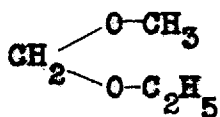
A survey of the available literature made it quite evident that the nomenclature of the formals was not systematic and consistent. Quite frequently the naming of a compound appeared to depend upon the author. It was soon

apparent that a complete search must include looking up the compound under the following headings: common names such as methylal and ethylal for the formals prepared from methyl and ethyl alcohols, respectively; acetal; acetals; the individual aldehydes and ketones corresponding to the alkyl group in question; ethers; and the various names given in Beilstein's "Handbuch Der Organischen Chemie." It was at once evident that a simple, systematic nomenclature would be not only desirable but necessary if much confusion was to be avoided. In this work, therefore, a nomenclature was used based upon the general type of compound to which formals belong, namely, acetals. In addition, the compounds from which the formal was prepared were included. For example, the formal prepared from formaldehyde and methyl alcohol was named formaldehyde di-methyl acetal, its formula being $\text{CH}_2(\text{OCH}_3)_2$. If the alcohol used was one of an isomeric series, the particular isomer used was indicated. This can be illustrated by the formal prepared from formaldehyde and isopropyl alcohol, the formal which has the following structural formula:



This compound was called formaldehyde di-isopropyl acetal.

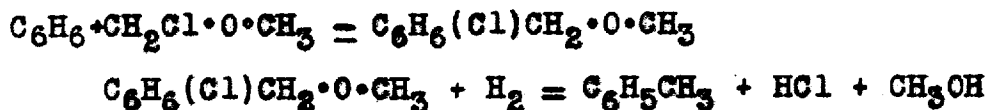
It is obvious that ambiguity and confusion were avoided. This method could be adapted conveniently to the naming of mixed formals, as can be shown by the formal prepared from formaldehyde and methyl and ethyl alcohols. The structural formula for this compound, formaldehyde methyl, ethyl acetal, follows.



The nomenclature of the chloromethyl ethers was much more consistent and systematic than that of the formals. The most obvious and convenient method of naming these compounds was to name the two groups connected to the ethereal oxygen in the usual way for ethers. One group necessarily had to be chloromethyl; the other group depended upon the alcohol from which the compound had been prepared, care being taken to indicate the isomer used and any substitution. For example, the ether prepared from formaldehyde and methyl alcohol was named chloromethyl methyl-ether. Its formula is $\text{CH}_2\text{Cl}\cdot\text{O}\cdot\text{CH}_3$. That prepared from formaldehyde and normal hexyl alcohol was named chloromethyl-normal-hexyl ether, its formula being $\text{CH}_2\text{Cl}\cdot\text{O}\cdot\text{C}_6\text{H}_{13}$.

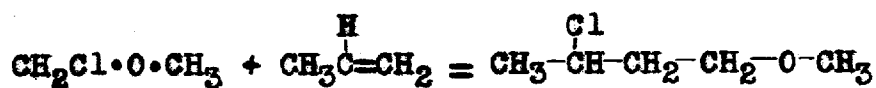
The interest in the chloromethyl ethers and formals is both theoretical and practical. Although some uses are known for these compounds, they are at present limited.

varies with the functional groups on the aromatic compound. Condensation followed by reduction affords a convenient method of methylating aromatic compounds, as shown by the following reaction:



Dykstra has reported the use of chloromethyl ethers as modifiers with rubber.²

Alpha halogenated ethers, including chloromethyl ethers, react with olefinic hydrocarbons in the presence of a readily hydrolyzable metallic halide with or without increased pressure to give mainly the gamma halo-ethers by the addition of the halogen atom and the ether residue to the unsaturated olefinic linkage.³ For example, chloromethyl ether treated with propylene in the presence of bismuth trichloride gives chlorobutyl-methyl ether together with a small quantity of heptyl-methyl ether as illustrated by the following equation:



²Dykstra, U.S. 2,053,271, 1936.

³E. I. duPont de Nemours and Company, Brit. 423,520, 1935.

The work of Karvonen indicates that the chloromethyl ethers may be useful in analytical organic chemistry. He has reported that chloromethyl-methyl ether gave a colorless, hygroscopic pyridine compound with the formula $\text{PyCH}_2\text{Cl}\cdot\text{O}\cdot\text{Me}$ and a chloroplatinate, $(\text{PyCH}_2\text{Cl}\cdot\text{O}\cdot\text{Me})_2\text{PtCl}_4$, consisting of reddish yellow needles. Chloromethyl-ethyl ether and chloromethyl-propyl ether both gave characteristic pyridine and chloroplatinate derivatives.⁴

At present it is apparent that formaldehyde-di-methyl acetal (methylal) is the only formal which has been used to any extent in either a practical or theoretical way. Doubtless, this is a result of the other compounds' not being well known.

Methylal has been used as a solvent in extractions, advantageously replacing ether.⁵ The distribution coefficients for ether and water and for methylal and water were determined for acetic, lactic, citric, malic, succinic, and the tartaric acids. The lower values with methylal clearly indicated that these acids were more completely extracted by shaking their aqueous solutions with methylal than by shaking with ether.

Also essential oils have been extracted from plants and flowers by means of methylal.⁶

⁴Karvonen, Ann. Acad. Sci. Fennicae, 3A: 1-103.

⁵Espl, Bull. soc. chim., (5) 1: 1502-3, 1934.

⁶Groupement d'études et d'entreprises générales, Fr. 673,703, 1928.

This formal has likewise been used as a solvent and a reaction medium.⁷ Many common inorganic salts are soluble in it and certain ionic reactions take place in it. For example, mercuric chloride is reduced by stannous chloride in the usual manner.

Finally, reactions involving the Grignard reagent may be carried out in the usual manner if methylal replaces ether.⁸ However, care must be taken to use the correct amounts of solvent and alkyl magnesium halide. If this precaution is not taken, the mixture becomes partly solid. For example, normal amyl alcohol was prepared from normal butyl magnesium bromide and trioxymethylene in a 70 per cent yield, compared with the usual yield of about 60 per cent, if ethyl ether were used.

PURPOSE

The primary purpose of the problem was as nearly as possible to complete the homologous series of the formals and chloromethyl ethers. In order to accomplish this successfully, convenient methods of preparation and characterization necessarily had to be devised.

The secondary purpose was the determination of certain physical properties of the prepared compounds, the correlation of these properties with structure and size of

⁷Bourgom, Bull. soc. chim. Belg., 33: 101-15, 1924.

⁸Bourgom, loc cit.

the molecule, and the comparison of these properties with those of the previously known compounds.

The investigation was undertaken primarily from an academic viewpoint; no effort was made to find practical uses for the compounds prepared.

APPARATUS

Constant Temperature Water Bath

The constant temperature water bath was of the general type described in Findlay's Practical Physical Chemistry.⁹ However, instead of toluene, air was the expansion medium.

This bath was used for the preparations of the formals and chloromethyl ethers. The reaction flask was immersed in the bath, and the temperature kept at 60°C until homogeneity of the reactants resulted.

Hydrogen Chloride Generator

The generator was that described in Inorganic Syntheses.¹⁰

⁹ Findlay, Practical Physical Chemistry (New York: Longmans, Green, and Company, 1923), p 429.

¹⁰ Inorganic Syntheses (first edition, New York: McGraw-Hill Book Company, Inc., 1939), p 147.

Apparatus for the Removal of Excess Hydrogen Chloride

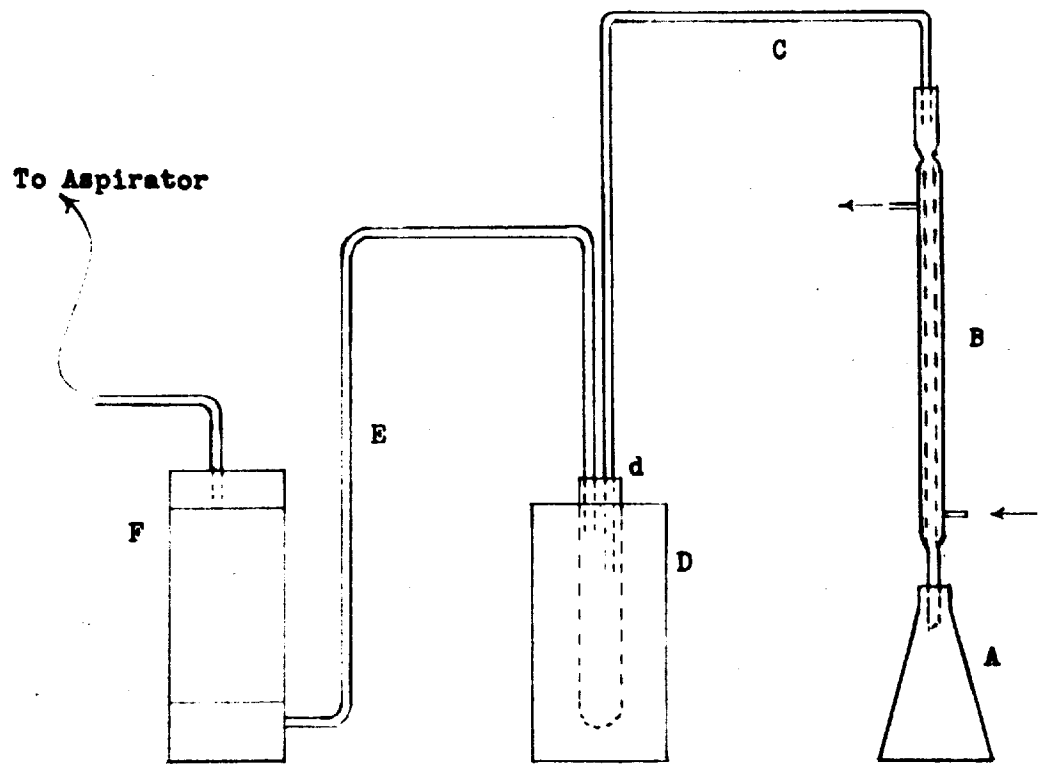
This piece of equipment, designed by the investigator, is shown in Fig. 1. A 300 cc Erlenmeyer flask (A) containing the reaction mixture was connected with a 16 in. reflux condenser (B), to the top of which was connected a piece of 6 mm glass tubing (C) extending down into a 10 in. test tube (d) 1-1/8 inches in diameter, contained in a 2 liter vacuum bottle (D), containing a dry-ice - chloroform mixture. The test tube was connected by 6 mm glass tubing (E) through a stopper in its top to a calcium chloride tower (F) connected to an aspirator. The reaction flask and its contents were heated to 30-40°C, during which time suction from the aspirator was applied. By this means most of the excess hydrogen chloride was quickly and efficiently removed without any decomposition of the compound. Any material not condensed by the reflux condenser was recovered from the test tube in the dry-ice bath.

Reduced Pressure, Constant Temperature Fractionating System

Two different systems were used, one for the initial fractionation, the other for the second fractionation to obtain very pure fractions for analysis and determination of the physical constants. The differences between the two lay in the sizes of the systems and the methods of collecting the fractions.

FIGURE 1

Apparatus To Remove Excess Hydrogen Chloride



The larger system, used for the first fractionation, is shown in Fig. 2. The material to be fractionated was contained in a 150 cc round-bottomed flask (A) connected to a 10 in. modified Widmer column (B) of 12 mm diameter.¹¹ The column was connected to a 16 in. all-glass condenser (D) leading into a Wisconsin-type fraction cutter (E) which permitted fractions to be drawn off without altering the pressure of the system. The stopcocks e', e, and e'' were of oblique bore; e and e'' were of the one-way type, e' of the two-way type. While a fraction was coming over, e and e' were open to the system, e'' closed. To collect a fraction, e and e' were kept open to the system, and e'' was opened to the system, permitting the fraction to run from E into F. Then e and e'' were closed to the system, cutting off the system from E to B from the vacuum pump. The two-way stopcock, e', was then opened to the atmosphere, cutting off the system e', e'', F entirely from any other part of the main system and making its pressure equal to that of the surroundings. The flask (F) could then be removed, and another attached in its place. Then e' was opened to the system, and the pressure allowed to attain its previous value. At this point, e was opened to the system; thus the entire system was again in contact with the pump.

¹¹Smith and Adkins, J. Am. Chem. Soc., 60: 662-3, 1938.

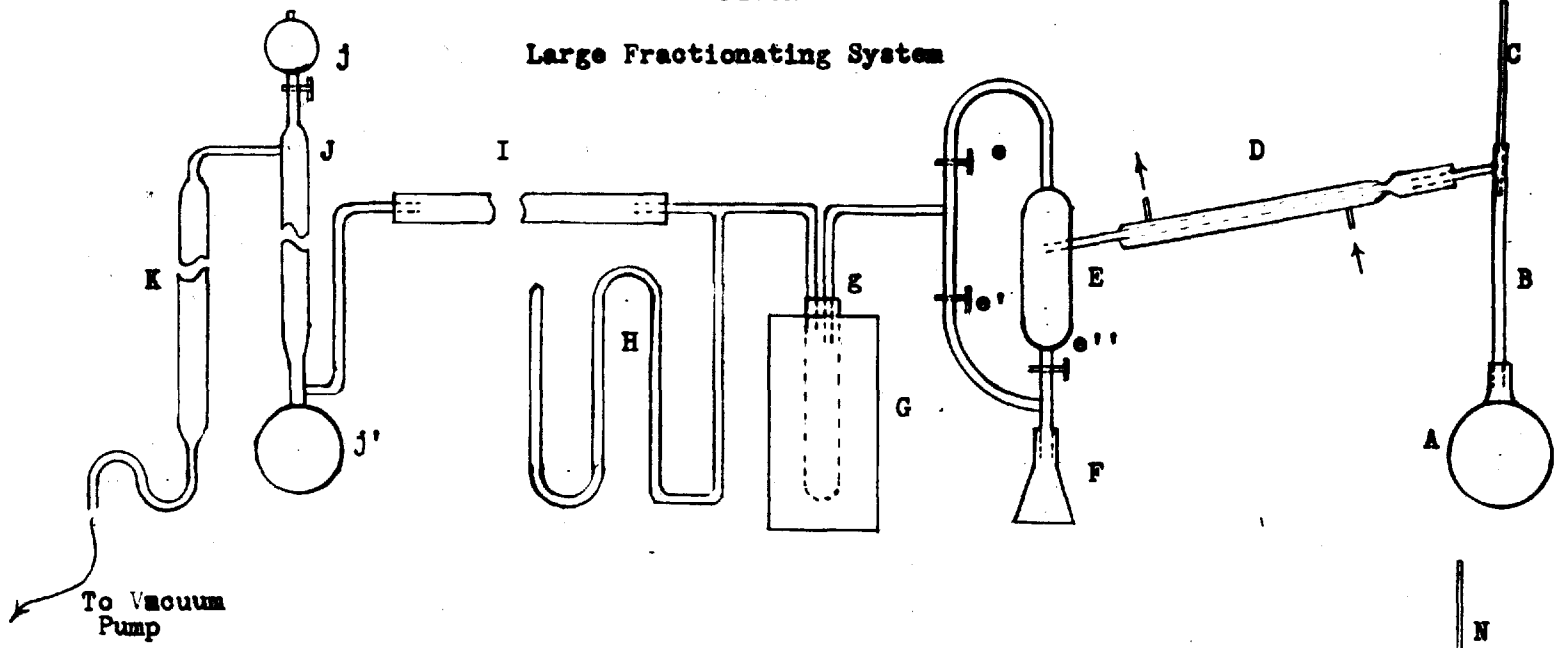
Connected to the fraction cutter was the dry-ice - chloroform trap (G) containing the large test tube (g) to collect the volatile, neutral materials; the test tube was the same size as that described on p 9. There followed a mercury manometer (H) reading to \pm 0.5 mm; a 24 in. 37 mm horizontal glass tube (I) containing flake sodium hydroxide; and the usual sulfuric acid and sodium hydroxide-calcium chloride towers (J and K) just preceding the vacuum pump.

The horizontal sodium hydroxide trap was necessary to prevent the system's becoming clogged. Not all of the hydrogen chloride could be removed from the unfractionated compounds, and some probably resulted from the decomposition of the ethers during fractionation. The hydrogen chloride would react with the sodium hydroxide in the vertical sodium hydroxide-calcium chloride tower, forming a solid mass of sodium chloride and thus cutting off most of the system from the vacuum. The sodium hydroxide was placed in the horizontal trap in such a way as to leave a free channel between it and the top of the trap. The system would therefore always remain open, and all remaining hydrogen chloride was easily removed by reaction with the sodium hydroxide. The trap was readily removed, recharged with fresh sodium hydroxide, and replaced.

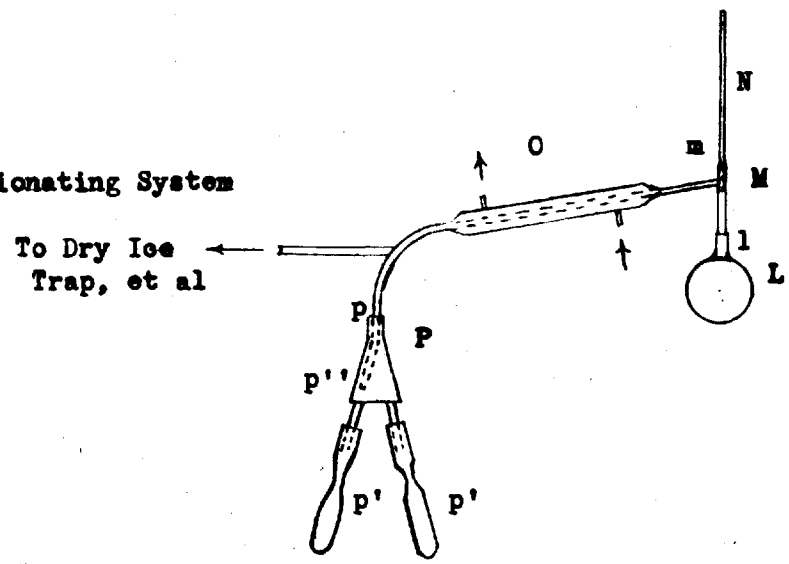
In the smaller system, also shown in Fig. 2, the material to be fractionated was contained in a round-bottomed

FIGURE 2

Large Fractionating System



Small Fractionating System

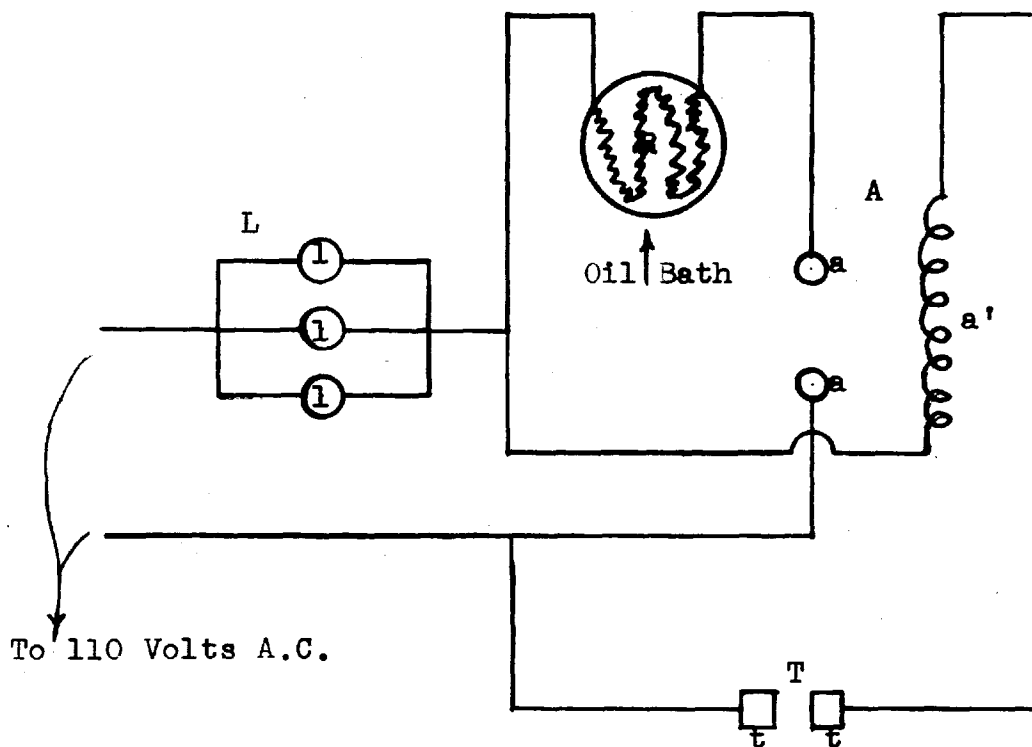


flask (L) of 150 cc capacity connected by a ground-glass joint (l) to a small Vigreux column (M), which was little more than a still head. The column, which was 4 in. long and 12 mm in diameter, was fitted with a ground-glass joint (m) at its top, into which fitted an all-glass thermometer (N) with a similar joint. The condenser (O) was an 8 in. all-glass type, permanently sealed to the column. The end of the condenser had a right-angled bend and was drawn out to approximately 2 mm, as shown at p''. This small end was connected by a ground-glass joint (p) to a small flask (P) having four openings at its bottom to which constricted test tubes (p') could be attached. The drawn-out end of the condenser extended almost to the bottom of the flask. In this way, the different fractions were directed into different tubes by merely turning the flask. The tubes were then sealed off under vacuum by means of an oxygen-gas torch. The remainder of the system was as described for the larger system.

During fractionation, heat was obtained from a constant temperature system, shown in Fig. 3. A Cenco-DeKhotinsky bimetallic thermo-regulator (T) and a heating coil (R) both immersed in the oil bath containing the material to be fractionated, were connected in series with a double-pole, single-throw relay (A). This circuit was connected in series to a lamp bank (L) arranged in parallel leading

FIGURE 3

Constant Temperature System



- A Relay
- a Relay contacts
- a' Relay coil, on 110 volts A.C.
- T Cenco-DeKhotinsky thermo-regulator
- t Thermo-regulator contacts
- R 600-watt heating coil
- L Lamp bank, in parallel
- l 110-volt, 60-watt electric light bulbs

to a 110-volt A.C. line. The lamp bank contained three 110-volt, 60-watt electric light bulbs as resistances (1). The bulbs were augmented with 600-watt resistances as needed to obtain the necessary temperature.

EXPERIMENTAL PROCEDURE

General Discussion

Many methods are known for the preparation of chloromethyl ethers and formals. The more important ones are described in Beilstein's Handbuch Der Organischen Chemie.¹²

It was naturally desired to utilize methods of preparation as simple as possible which would give good yields of the pure compounds and yet which would not necessitate the use of elaborate apparatus. The method used was that suggested by Dr. E. E. Reid.¹³ These methods appeared suitable and readily adaptable to the equipment on hand.

To determine how suitable these methods would be, it seemed reasonable to prepare several known compounds and to compare their physical constants with those given in the literature. Chloromethyl ethers and formals were prepared, therefore, from the following alcohols: normal

¹² Beilstein, Handbuch Der Organischen Chemie, Vierte Auflage, Band I, pp 574-582.

Ibid, Erstes Ergänzungswerk, pp 301-305.

¹³ Private communication from Dr. E. E. Reid.

propyl, isopropyl, and normal butyl. It was found that their physical constants and calculated molar refractions checked closely with the values given in the literature. These results are summarized in tables IA and IB. Consequently, it was concluded that the methods of preparation were suitable and should be adaptable to the preparations of similar compounds from the higher alcohols.

Preparations of new chloromethyl ethers were attempted from the following alcohols: allyl, tertiary butyl, normal amyl, secondary normal amyl, hexyl, heptyl, and octyl; formals from tertiary butyl, secondary normal amyl, hexyl, and heptyl alcohols. It is now known that the following new chloromethyl ethers have been prepared: chloromethyl-normal hexyl, chloromethyl-normal heptyl, and chloromethyl-normal octyl. New formals prepared were formaldehyde-di-secondary-normal-amyl acetal, formaldehyde-di-normal-hexyl acetal, and formaldehyde-di-normal-heptyl acetal.

Preparation of Chloromethyl Ethers

To prepare a chloromethyl ether, one equivalent of U.S.P. paraformaldehyde was added to one mole of the alcohol in a 500 cc three-necked flask. Approximately 10 mg of C.P. potassium hydroxide was added as catalyst, and the mixture heated at 60°C with mechanical stirring in the constant temperature water bath until homogeneity resulted. The time required for homogeneity to result was usually not

TABLE IA

Properties of the Known, Prepared Chloromethyl Ethers

Compound	b.p. °C		d_4^{25}		n_D^{25}		M_D	
	Lit.	Found	Lit.	Found	Lit.	Found	Calcd.	Found
Chloromethyl normal pro- pyl ether	109- 109.3	107- 109	0.9884 ^(a)	0.9713	1.4125 ^(b)	1.4070	27.75	27.50
Chloromethyl isopropyl ether	97- 98	95- 98	0.9790 ^(a)	0.9563	1.4592 ^(c)	1.4022	27.75	27.64
Chloromethyl normal butyl ether	134	132- 133.5	-----	0.9457	-----	1.4150	32.44	32.37

(a) Values given in the literature were at d_4^{20} .

(b) Values given in the literature were at n_D^{20} .

(c) Values given in the literature were at n_D^{16} .

TABLE IB

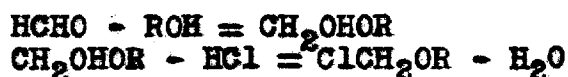
Properties of the Known, Prepared Formals

Compound	b.p. °C		d_4^{25}		n_D^{25}		M_D	
	Lit.	Found	Lit.	Found	Lit.	Found	Calcd.	Found
Formaldehyde di-normal propyl acetal	137.8	136	0.8345 ^(d)	0.8293	1.391 ^(g)	1.3911	38.00	37.69
Formaldehyde di-iso- propyl acetal	118.5	117- 119	0.831 ^(e)	0.8133	-----	1.3822	38.00	37.69
Formaldehyde di-normal butyl acetal	180- 181	179- 180	0.8340 ^(f)	0.8313	1.4072 ^(h)	1.4032	47.00	46.90

(d), (e), & (f) Values given in the literature were at d_{20}^{20} , d_{20}^{20} , & d_0^{20} respectively.

(g) & (h) Values given in the literature were at n_D^{19} & n_D^{17} respectively.

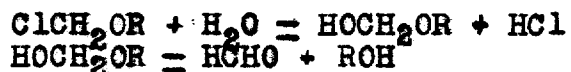
more than one hour, and frequently only ten minutes to one-half hour. The reaction flask was then placed in an ice bath and 1.1-1.2 moles of dry hydrogen chloride was passed into the homogeneous mixture, causing the separation of a layer of water. The weight of hydrogen chloride generated from known amounts of the reagents had been determined by previous experiments. It had been found that 150 cc of commercial, concentrated sulfuric acid and 150 cc of commercial, concentrated hydrochloric acid would give one mole of hydrogen chloride. Theoretically, one mole of the hydrogen chloride would have been all that was necessary for the completion of the reaction. The excess gas was necessary to force the reaction more nearly to completion and to force the separation of the water layer. The formation of the chloromethyl ethers took place according to the following reaction in which "R" is an alkyl group.¹⁴



The water layer was separated from the ether by means of a separatory funnel. The product was dried over anhydrous calcium chloride and the excess hydrogen chloride removed as described on p 9. The dry chloromethyl ether was fractionated in the larger apparatus at 2-4 mm pressure as

¹⁴Richter, Textbook of Organic Chemistry, (New York: John Wiley and Sons, Inc., 1938), p 166.

described on p 11. Water had to be carefully excluded at all times, since hydrolysis readily took place, even upon exposure to the atmosphere. The hydrolysis of the chloromethyl ethers in neutral or alkaline medium took place according to the following equations:



The hemiacetal first formed is unstable and immediately decomposes into formaldehyde and the alcohol from which the ether had been prepared.¹⁵

Preparation of Formals

To prepare a formal, one equivalent of U.S.P. para-formaldehyde was mixed with two moles of the alcohol and about 10 mg of C.P. potassium hydroxide in a 500 cc three-necked flask, and the mixture made homogeneous at 60°C in the same way as the chloromethyl ethers (p 20). The reaction flask was then placed in an ice bath and enough dry hydrogen chloride passed in to saturate the separated water layer. The two layers were separated in a separatory funnel and any acid remaining in the lighter formal layer neutralized at once with 10 per cent sodium carbonate solution, since the formals were stable in the presence of water and alkali

¹⁵ Ibid, p 103.

but unstable in the presence of acid. The product was dried over anhydrous calcium chloride and fractionated at 7 mm pressure, the larger system being used (p 11). The formation of the formals took place according to the following equation in which "R" was an alkyl group:¹⁶



According to Skrabal and Schiffrer,¹⁷ alkyl acetals are hydrolyzed only in an acid solution, as illustrated by the following equations in which the "R" group is, as usual, an alkyl group:



Characterization of Chloromethyl Ethers

To determine whether or not the desired ether had been prepared, it appeared logical to determine quantitatively the percentage of chlorine and calculate the molar refraction. If the found values checked reasonably with the theoretical values, it could be assumed that the desired compound had been prepared, since the method of preparation had been proved previously to be satisfactory.

¹⁶ Richter, loc cit.

¹⁷ Skrabal and Schiffrer, Z. physik. chem., 99: 290-313, 1921.

The chlorine in a chloromethyl ether is very active and readily hydrolyzed either by water or alkali to hydrogen chloride or the corresponding alkali chloride, respectively. This fact suggests a convenient method of obtaining the chlorine in a form in which it can be determined easily.

The following procedure was first used in the quantitative determination of chlorine. To about 1.0000 g of the ether was added 100 cc of distilled water. A measured volume of 0.7474 N sodium hydroxide solution was then added and the excess base determined by titration with 0.5692 N hydrochloric acid solution, phenolphthalein indicator being used. The results were not at all satisfactory. Upon addition of the distilled water it was observed that some hydrogen chloride was lost, regardless of the precautions taken to prevent it. To overcome this loss, a burette was connected directly through a cork to an Erlenmeyer flask containing the ether, and the distilled water added through the burette. The pressure of the evolved hydrogen chloride gas was great enough to prevent the addition of all but a small volume of the water. Again this result was unsatisfactory.

Direct addition of the base to the ether likewise presented the same difficulty, since the volume of solvent then present was too small to absorb all of the gas evolved.

In addition, it was noticed that hydrogen chloride was evolved when the glass-stoppered bottles in which the

ethers had been kept were opened. Evidently the ethers had been hydrolyzed by moisture from the atmosphere. The only course left was to refractionate each ether and seal off the containers under vacuum. Then as samples were needed, the seal could be broken, the sample quickly removed, and the container re-sealed. For this purpose the smaller fractionating system was used, as described on p 14.

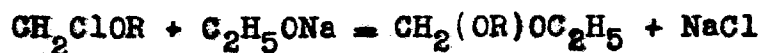
The method of analysis finally used was essentially a combination of modified Stepanow and Volhard procedures as described by Drogin and Rosanoff¹⁸ and Cook and Cook.¹⁹ The reagents were prepared as described in those articles, but slight modifications in procedure were used as necessary.

For the analysis 0.2000-0.6000 g of the refractionated, pure ether was sealed in a small glass ampule made by drawing out glass tubing to the diameter of a large melting-point tube and blowing a bulb on the end which would hold 0.2-0.6 g of the liquid. The ampule was dropped into a 500 cc Kjeldahl flask containing 75 cc of absolute alcohol. The impact of the drop was great enough to break the ampule, and a solution of the ether and alcohol resulted. The flask was stoppered immediately, shaken, and allowed to stand for several minutes. A reflux condenser was attached, and through

¹⁸Drogin and Rosanoff, J. Am. Chem. Soc., 38: 711, 1916.

¹⁹Cook and Cook, Ind. and Eng. Chem., 5: 186-88, 1933.

it was added, a little at a time, 5 g of oxide-free, dry sodium cut into thin strips about one in. long. The addition of the sodium took about one-half hour. The mixture was heated gently during the addition of the last half of the sodium and refluxed from a water bath for one hour after the addition of all of the sodium. The following reaction took place:



The mixture was cooled, diluted with 200 cc of distilled water, and acidified with pure 1:2 nitric acid, care being taken to add not more than 10 cc excess. The volume of C.P. 0.2108 N silver nitrate solution calculated to precipitate all of the chlorine was added slowly, and then 10 cc in excess. One cubic centimeter of nitrobenzene was added for each 50 mg of chlorine in the original ether to coagulate the precipitated silver halide. The mixture was shaken vigorously until flaky silver chloride separated from the remaining liquid. The mixture was quantitatively transferred from the Kjeldahl flask to a one-liter porcelain evaporating dish, and 10 cc of a saturated solution of ferric-alum-nitric acid indicator was added. The excess silver nitrate was determined by titration with a 0.2036 N solution of C.P. potassium thiocyanate until the first visible, permanent pink coloration of the liquid mixture

appeared.

A blank determination was run on the reagents for each set of analyses. In the calculations, this blank value was added to the volume of excess silver nitrate solution as determined from the back titration with potassium thiocyanate, and the resulting sum was subtracted from the volume of the standard silver nitrate originally added. This difference was equivalent to the chlorine in the sample.

The results of these analyses are summarized in Table II.

Characterization of the Formals

The formals were characterized entirely by physical methods. At first it was thought they could be proved by quantitative analyses of formaldehyde and the alcohol from which the formal had been prepared, these being the products of acid hydrolysis of the compound.²⁰ However, upon further consideration it became evident that this method would be unsatisfactory, since it would have been very difficult to prevent loss of formaldehyde upon hydrolysis and similarly difficult to obtain the alcohol in a quantitative yield in the dry condition necessary for its determination. As a result of the foregoing considerations the identity of the formals was shown by determining their molecular weights by the method of freezing-point lowering and calculating their

²⁰Skral and Schiffrer, op cit.

TABLE II

PROPERTIES OF THE PREPARED CHLOROMETHYL ETHERS

COMPOUND		Chloromethyl n-hexyl ether	Chloromethyl n-heptyl ether	Chloromethyl n-octyl ether
FORMULA		$\text{CH}_2\text{Cl}\cdot\text{O}\cdot\text{C}_6\text{H}_{13}$	$\text{CH}_2\text{Cl}\cdot\text{O}\cdot\text{C}_7\text{H}_{15}$	$\text{CH}_2\text{Cl}\cdot\text{O}\cdot\text{C}_8\text{H}_{17}$
DIST.	TEMP. °C	38-40	61	75
	PRESS. mm	2	4	4
PER CENT Cl	FOUND	23.62	21.53	19.67
	CALCD.	23.54	21.53	19.84
d_4^{25}		0.9395	0.9280	0.9194
n_D^{25}		1.4227	1.4312	1.4341
M_D	FOUND	41.42	45.95	50.63
	CALCD.	40.95	45.55	50.15
YIELD	THEOR.	150.6 g	70.9 g	178.7 g
	FOUND	95.0 g	32.0 g	95.0 g
	PER CENT	63.1	45.1	53.2

molecular refractions. The results of these determinations are summarized in Table III.

The apparatus and method used in the molecular weight determinations are described in Findlay's Practical Physical Chemistry.²¹ The molecular weights were calculated from the following formula:

$$M = k \cdot \frac{w}{dW}$$

where M is the molecular weight sought, w the weight of solute, d the freezing-point depression, W the weight of solvent, and k a constant depending only upon the solvent. Benzene was the solvent used, k for it having the value 5120.

The observed molecular refractions were calculated by means of the Lorenz-Lorentz equation,²²

$$M_D = \frac{n^2 - 1}{n^2 + 2} \cdot \frac{m}{d}$$

in which M_D is the observed molecular refraction, n the refractive index, m the molecular weight of the compound in question calculated from the atomic weights, and d the density determined experimentally.

²¹ Findlay, op cit, p 112.

²² Shriner and Fuson, The Systematic Identification of Organic Compounds (second edition, New York: John Wiley and Sons, Inc., 1940), p 107.

TABLE III

PROPERTIES OF THE PREPARED FORMALS

COMPOUND		Formaldehyde di-sec.-n- amyl acetal	Formaldehyde di-n-hexyl acetal	Formaldehyde di-n-heptyl acetal
FORMULA		$\begin{array}{c} \text{H} \\ \text{HCH} \\ \text{CH}_2(\text{OCC}_3\text{H}_7)_2 \\ \text{H} \end{array}$	$\text{CH}_2(\text{OC}_6\text{H}_{13})_2$	$\text{CH}_2(\text{OC}_7\text{H}_{15})_2$
DIST.	TEMP. OC PRESS. mm	68-69 7	103-107 7	131-132 7
MOL. WGT.	FOUND CALCD.	185.4 188.30	213.0 216.37	249.3 244.41
d_4^{25}		0.8340	0.8372	0.8365
n_D^{25}		1.4182	1.4220	1.4269
M_D	FOUND CALCD.	56.20 56.10	65.67 65.30	75.00 74.50
YIELD	THEOR. FOUND PER CENT	188.30 97.0 51.5	216.37 135.0 62.4	244.41 ----- -----

The calculated molecular refractions were obtained by adding the atomic refractions given in Smiles.²³

DISCUSSION OF SOME OF THE INDIVIDUAL PREPARATIONS

General Discussion

Although it will not be necessary to discuss each preparation, it does seem wise at this point to consider some of the preparations with which difficulty was encountered. Many of the preparations took place in a straight manner as was expected; consequently, there remains nothing to be discussed. Some of the preparations, especially those from which no satisfactory product was obtained, were attended by much difficulty. It is with the latter that this brief discussion is concerned.

Chloromethyl Allyl Ether

At the outset, difficulty was expected with this preparation, since, as was well known, allyl alcohol polymerizes in the presence of hydrogen chloride. The attempted preparation was carried out in the usual way, and it was found that the solution remained colorless upon passing in

²³Smiles, The Relation between Chemical Constitution and Some Physical Properties (London: Longmans, Green and Company, 1910), p 280.

dry hydrogen chloride if kept in an ice bath. This result indicated little if any polymerization. However, when the product was dried over anhydrous calcium chloride and fractionated, there was a decided blackening of the mixture and a large increase of its viscosity. Definite polymerization was indicated. Fractionation produced a colorless, chlorine-free liquid with a sharp odor. The product was not further characterized.

The reaction was then carried out in a Carius furnace with ferric chloride as catalyst, the mixture being heated for six hours at 120°C. There resulted two immiscible liquids, the lighter one being a pale amber color present in much larger quantity than the heavier, deep brown liquid. This result indicated a reaction of some kind. It is not known whether the reaction was one of polymerization in which the heavier liquid had polymerized to a greater degree. Again no satisfactory product could be isolated.

There were indications that this compound could be prepared by the method used if the mixture were kept continually in an ice bath and all the excess hydrogen chloride were removed at the ice temperature. Great care would have to be taken to prevent the reaction mixture and product from coming in contact with moisture with the consequent release of hydrogen chloride and probable polymerization.

Chloromethyl Tertiary Butyl Ether

This preparation carried out in the usual way definitely indicated that there was very little if any reaction between paraformaldehyde and the alcohol, since upon fractionation the alcohol was recovered in an almost quantitative yield. This situation appeared very unusual, since the reactivity of tertiary alcohols was well known. Whitmore stated, "A study of the rate of acetal formation with a variety of alcohols in the presence of hydrogen chloride gives surprising results. Methyl alcohol acts most slowly, and tertiary alcohols more rapidly."²⁴ Although acetals were not being prepared, the formation of acetals and chloromethyl ethers is very similar, and it therefore appeared reasonable that conditions favoring one reaction would also favor the other. The following were suggested as good catalysts: calcium chloride, ferric chloride, and ammonium chloride.²⁵ The suggested catalysts were tried and the reaction permitted to proceed for as long as 76 hours. Still there resulted no apparent reaction between the aldehyde and the alcohol.

The reaction was carried out in the Carius furnace under the same conditions as the attempted preparation of chloromethyl allyl ether. No product was isolated.

²⁴ Whitmore, Organic Chemistry (third printing, New York: D. Van Nostrand Company, Inc.), p 293.

²⁵ Ibid.

Formaldehyde Di-Tertiary Butyl Acetal

As in the preceding preparation, no reaction took place between the aldehyde and the alcohol.

Chloromethyl Normal Amyl Ether

This reaction was carried out in the usual way, ferric chloride being used for the catalyst. There was no apparent difficulty encountered, and a definite indication of a reaction. The product had a very sweet odor, similar to that of ethyl acetate. Upon analysis no chlorine was found to be present. The compound was not further characterized. No explanation has been found for the abnormal behavior of this normal alcohol.

Chloromethyl Secondary-Normal Amyl Ether

Outward appearances indicated a reaction had taken place, but upon analysis no chlorine was found. Again no explanation can be offered for the behavior of this alcohol.

SUMMARY

The following heretofore unreported compounds have been prepared and some of their common physical properties determined: chloromethyl-normal-hexyl ether, chloromethyl-normal-heptyl ether, chloromethyl-normal-octyl ether, formaldehyde-di-secondary-normal-amyl acetal, formaldehyde-di-

normal-hexyl acetal, and formaldehyde-di-normal-heptyl acetal. The structures and physical properties of these compounds are summarized in Tables II (p 27) and III (p 29).

A convenient method of quantitative analysis for chlorine in chloromethyl ethers has been perfected. The identification of formals by physical means has been described.

With the method of preparation used, it was found that allyl, normal amyl, secondary-normal amyl, and tertiary butyl alcohols did not react with paraformaldehyde to form their chloromethyl ethers. Tertiary butyl alcohol did not react with paraformaldehyde to form its formal.

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