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The Chemistry of Chloral†

F. I. LUKNITSKII

USSR Vitamin Research Institute, Moscow, USSR

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Contents

I. Introduction

Over a century has passed since the discovery of chloral by Liebig,[1] who named it, and also since the first Dumas[2] experiments with it. But new horizons in the chemistry of chloral are being opened to this day, despite the great amount of knowledge already attained in this realm. In recent years a catalytic function of chloral has been discovered, as well as its reactivity toward element- (Pb-, Sn-, Si-) organic compounds, ketene and its hetero analogs, and so on.

† EDITOR'S NOTE: This manuscript required extensive language editing before it could be published. The editor tried to follow the author's presentation as closely as possible and apologizes for any changes in meaning that may have crept in as the English was being clarified.

Well known are such key syntheses based on chloral as dichloroacetic acid and its derivatives (for example, syntomicine), vanillin, isatin, DDT, phosphororganic pesticides, etc.

The presence of two functional groups—carbonyl and trichloromethyl—in the chloral molecule and their mutual activating influence extend the synthetic capabilities of chloral as a compound with dual reactivity. It can be transformed into dichlorovinyl and formyl derivatives.

Regretfully, reviews dealing with the chemistry of aldehydes[3,4] do not give chloral sufficient consideration, and even short reviews[5,6] do not supply any knowledge about the research for the last 30 years or so. Perhaps this accounts for duplications in research, and for a certain inaccuracy in outlining some of chloral's properties in organic chemistry courses and in reference books.

The object of the present review is to generalize our knowledge of the chemistry of chloral up to 1971 inclusive. With the aim of drawing the reader's attention to the chemistry of chloral, it has been expedient to omit several early physical results, as well as numerous publications about the biological action of chloral.

The reactivity of the trichloromethyl group (reduction, radiolysis, photolysis, the relation to nucleophilic agents, etc.) is not treated separately but is discussed together with that of the carbonyl group in the relevant sections of the review.

II. Methods of Preparation

The result of chlorination of ethanol or other substrates depends on the nature of the chlorinating agent. When ethanol is heated with calcium hypochlorite, one obtains chloral and also chloroform, dichloroacetaldehyde, and the hemiacetal of chloroacetaldehyde.[7] Ethyl hypochlorite was proposed[7] as the intermediate chlorinating agent in this reaction and acetaldehyde (with vinylic alcohol) as intermediates. At 20° trichloroacetic acid is obtained instead of chloral.[7]

Liebig[1] was the first to obtain chloral by passing chlorine through absolute ethanol. This method is in principle the most widespread to this day. The best results are achieved by chlorinating directly with chlorine. Many intermediates and by-products can be converted to chloral, a yield up to 70–80% being attainable in the presence of traces of water and by chlorinating until the specific weight reaches 1.57–1.635.[8,9] A Japanese patent[10] points to the necessity of traces of water, in the absence of which the yield of chloral diminishes more than three

times. The reaction is not enhanced by uv irradiation[11] or by vapor-phase chlorination in an electric field;[12] in the last case many by-products are obtained (paraldehyde and dichloroacetaldehyde and their acetals, perchloroethane, di- and trichloroethyl ethers, and so on). Even when the reaction in an electric field (3–8 kV) is carried out with recirculation of the intermediate compounds, the yield is not increased.[13] Electrochemical oxidation of ethanol at 110–115° in the presence of NaCl[14] or $CaCl_2$[15] leads to moderate yields of chloral (61% with cyanuric acid as catalyst[15]).

Many chemists recorded a gradual course of chlorination in stages through mono- and di- to trichloroacetaldehyde at temperatures of 0–100°. Even prolonged chlorination of ethanol at 35° does not lead to a high yield of chloral,[16] only mono- and dichloroacetaldehydes being obtained. Too high a temperature (120–200°, with catalysis by $FeCl_2$, $FeCl_3$) is also undesirable.[17]

Several catalysts of heterolytic chlorination of ethanol were tested. Lewis acids,[18-20] iodo, sulfur, and phosphorus chlorides,[21] or a mixture of borax with SnI_4, H_3PO_4, $AlCl_3$ (3:1:3:3)[22] are effective, but the temperature (80–100° at the end of the process,[23] as a rule) plays a decisive role.

Acetaldehyde is one of the intermediate products of the chlorination of ethanol, so one may consider chlorination of acetaldehyde as a modification of Liebig's method. This process is described in many articles and patents.[24-40] Noncatalytic chlorination in aqueous solutions makes it possible to obtain chloral with yields up to 83–90%[28,29,36] (preferably with addition of chloral hydrate to the initial solution). A high yield of chloral is reached in 7 *N* HCl.[34] In the absence of water and catalysts with excess of chlorine,[30] the main product is hexachloroparaldehyde. Chlorination of acetaldehyde in the presence of catalysts (Fe, Sb, Al, Zn, Sn, or P halogenides) yielded chloral, mono- and dichloroacetaldehyde,[33,35-40] and also acetic acid and α-chlorocrotonaldehyde.[40] Only chloroacetaldehyde was isolated[33] in the absence of the catalyst. Selective catalysis by Cu(II) salts is recorded;[32] the yield of chloral is as high as 93% without by-products. With regard to temperature, the conditions are similar to those for the chlorination of ethanol; intermediate mono- or dichloroacetaldehyde can be obtained with high yields if the reaction is completed at temperatures up to 30 and 60°, respectively. Chloral can be also obtained in addition to ethanol and acetaldehyde by chlorination of poly(ethylene glycol),[41] ethylene chlorohydrin,[42] chloroacetaldehyde,[43] and bis(β-chloroethyl) ether[44,45] (in the last case in the presence of uv irradiation,[44] or in darkness,[45] with heating at over 100°; in all cases, at about 80–100°). In each case the presence of water is desirable.

Chloral was also obtained by an interchange of acetic acid with chloral alcoholate[46]

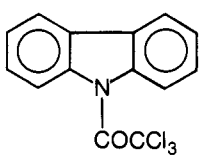
$$CCl_3CH(OH)OEt + AcOH \longrightarrow CCl_3CHO + AcOEt$$

or by the thermolysis of chloral hydrate esters[47] such as

$$CCl_3CH(OOCAlk)_2 \xrightarrow{200\text{-}220^\circ} CCl_3CHO + (AlkCO)_2O$$

The interaction between CCl_4 or alkyl halides and aliphatic aldehydes under rigorous conditions (200–500°, 20–200 atm)[48] also produces chloral.

Only recently chloral-*d*[49] and chloral-*t*[50] were synthesized. In the first case the product obtained by reducing *N*-trichloroacetylcarbazole with $LiAlD_4$ was thermolyzed:

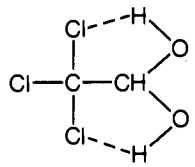


The interaction of chloral hydrate with T_2 at 12 Torr with subsequent dehydration over P_2O_5 produces CCl_3CTO.

III. Hydration. Stability of Chloral Hydrate Solutions

The high reactivity of the chloral carbonyl group toward nucleophiles is confirmed by the ease of formation of a stable hydrate, whose decomposition into the initial compounds is achieved only by distillation over concentrated H_2SO_4 or by azeotropic dehydration in toluene or benzene.[51,52] This is connected with the destabilizing effect of the CCl_3 group on the carbonyl group.

The question about the bond character of water in chloral hydrate has remained open for a long time. Even now some investigators represent it as a complex, $CCl_3CHO \cdot H_2O$, although many comprehensive physical researches confirm the *gem*-diol structure, $CCl_3CH(OH)_2$. The Raman spectrum[53] and osmometric measurements[54] confirm the presence of two hydrogen bonds in the molecule:



This is one of the reasons for the stability of chloral hydrate.

The length of the C–O bond (1.4–1.48 Å) is also evidence for the absence of a free carbonyl group.[55] Dipole moments of chloral and its hydrate,[56,57] nmr spectra,[58] and other arguments[59-61] also support the *gem*-diol structure.

In spite of the stability of chloral hydrate, its solutions are not stable. On the one hand, this is connected with the hydration equilibrium; some researchers[53,62-65] have recorded decomposition with elimination of water, as judged, for instance, by the appearance of a carbonyl band in the ir spectra of chloral hydrate solutions in benzene and CCl_4.[62]

On the other hand, chloral hydrate decomposes in neutral, acidic, and basic solutions. "Neutral" aqueous solutions are not stable for a long time;[66] after 15 weeks the pH decreases from 6.72 to 4.75–2.33 (more in light and on cooling). Uv irradiation accelerates this process; the pH decreases from 6.25 to 1.6 in 10 hr. Chloral hydrate has a low pK_a in water (10.04; in comparison the pK_a of methylene glycol is 13.27[67]) but does not produce AgCl with silver ion. Nevertheless, the large decrease in pH of aqueous solutions on standing is the result of CCl_3-group destruction, with HCl formation.[68,69] The instability of chloral hydrate in alkaline solutions is well known. But most investigators have taken into account only the heterolysis of C–C bonds or have made their studies at such pH and temperature ranges that the other reaction—hydrolysis of the trichloromethyl group without C–C bond rupture—has been repressed almost completely (see section VI.C).

The exothermic reaction

$$CCl_3CH(OH)_2 \xrightarrow{OH^-} CCl_3H + HCOO^-$$

is catalyzed by water, OH^-, and chloralate anion;[70] the energy of C–C bond dissociation is 62 kcal/mol.[71] For this bimolecular reaction, the pH, temperature, and half-life are:[72] 12, 22°, 25 min; 9, 20°, 4 days; 9, 60°, 1.5 hr; 8, 20°, 17.5 days; 8, 35°, 2 days.

IV. Oxidation and Reduction with Typical Redox Reagents

Anhydrous chloral is oxidized by air in light[73-75] with a temperature coefficient of 1.14[74] by means of a radical mechanism, forming phosgene, HCl, and CO or CO_2. It is assumed that the reaction proceeds through either formyl chloride or dichloroketene which is subsequently decomposed. The following results were obtained, depending on the completeness of oxidation:[69]

$$2CCl_3CH(OH)_2 \xrightarrow{3.5O_2} 3H_2O + 3Cl_2 + 4CO_2$$
$$2CCl_3CH(OH)_2 \xrightarrow{2O_2} 3HCl + 2CO_2$$

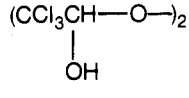
At the same time it was observed[73] that chloral in air and in darkness was stable for nearly 3 months.

Radical oxidation of chloral by heating with benzoyl peroxide in accordance with the following scheme

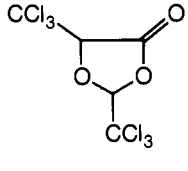
$$CCl_3CH(OH)_2 + Bz_2O_2 \longrightarrow C_6H_5Cl + p\text{-}C_6H_4(COOH)CCl_2CHO$$

was patented,[76] but Wieland and Richter[77] have failed to reproduce that result.

The use of hydrogen peroxide and also of Karo's acid enabled Baeyer and Villiger[78] to be the first to obtain chloral α,α-dioxyperoxide, a good initiator for homolytic reactions.[79]



By interaction of chloral with 30% H_2O_2 and oleum under mild conditions,[80] pertrichloroacetic acid is formed with a yield of 93%. Oleum itself oxidizes chloral to "chloralide." The reaction of concentrated H_2SO_4 with



chloral leads to a similar result.[81-83] On the other hand, Grabowski[84,85] obtained from the reaction of oleum with chloral, besides chloralide, also the compounds $C_8H_6O_{11}Cl_2S_6$ (which decomposes into H_2SO_4 and chloral alcoholate upon the action of ethanol) and $C_{10}H_9O_{16}Cl_{15}S_3$ (which does not change with ethanol). The investigator attributed to them the complex structures $4CCl_3CHO \cdot H_2S_2O_7$ and $5CCl_3CHO \cdot H_2S_2O_7 \cdot H_2SO_4$; the correct structures have not been ascertained as yet.

Oxidation of chloral with aqueous HIO_3 at 100° leads to destruction of the chloral molecule, forming CO_2, $CHCl_3$, ICl_3 and iodine.[86] Fuming nitric acid oxidizes chloral to trichloroacetic acid,[87,88] but it is possible to obtain a high (about 95%) yield as well by using 45–85% HNO_3 with gradual heating from 50 to 120°.[89] Under mild conditions dilute nitric acid reacts with chloral hydrate to give the mononitro ester.[90,91] The action of nitrogen oxides has also been[92,93] studied.

Some researchers took up the halogenation of chloral and its hydrate. Photochemical chlorination leads, through the intermediate radicals $CCl_3CO\cdot$,[94] to trichloroacetyl chloride whose yield increases with a drop in temperature (55% at −50°, 7.3% at 10°)[95] owing to the subsequent decomposition to CCl_4, CO, and HCl, which are the only reaction products at 70–90°.[94] Gautier[96] also observed the evolution of phosgene.

In the presence of aluminum chloride, heterolytic halogenation of chloral leads to hexachloroethane,[97] regardless of the nature of the halogen.

As a consequence of homolytic bromination in light at 70–90°, chloral is decomposed, forming a mixture of the following compounds:[98,99] CO, HCl, HBr, BrCl, H_2O, $CHCl_3$, $COBr_2$, $CBrCl_3$, with the activation energy amounting to about 6.5 kcal/mol. Vapor-phase bromination at 150° leads to CCl_3COBr, CCl_3Br, CO, and HBr.[100]

Chloral hydrate is oxidized with bromine in water slowly according to the scheme:[101]

$$CCl_3CH(OH)O^- + Br_2 \longrightarrow CCl_3COO^- + 2H^+ + 2Br^-$$

The activation energy is ca. 15.8 kcal/mol.

By heating chloral hydrate with solid potassium chlorate,[102] a mixture of CCl_3COOK, $COCl_2$, CO_2, Cl_2, and $CHCl_3$ is produced.

Interaction of chloral and chlorosulfonic acid at 50° for a few days produced 1,2,2,2-tetrachloroethyl ether with a yield of 65%, along with chloralide. The same product is also obtained, but in a lower yield, in the reaction of chloral with fluorosulfonic acid. The investigators[103] assumed that an intermediate adduct was formed ($CCl_3CHCl\text{–}OSO_3H$, in the first case, and $ClSO_3H$, in the second case) thereby accounting for both the identity of the reaction product and its reduced yield in the reaction with fluorosulfonic acid.

Oxidation of chloral hydrate by PCl_5 in acetone[104] leads to the formation of pentachloroethane and tetrachloroethylene. The same products are obtained[105] by heating chloral hydrate with aluminum chloride. With $SbCl_5$ chloral reacts as a Lewis base, forming an adduct in yield 80%;[106] in the presence of hydrogen chloride 56% of the onium salt is obtained:

$$CCl_3CHO + SbCl_5 \longrightarrow CCl_3CH{=}O{:}SbCl_5$$
$$CCl_3CHO + SbCl_5 \xrightarrow{HCl} [CCl_3CH{=}\overset{+}{O}H]\,SbCl_6^-$$

Phosphorus pentasulfide under severe conditions (160° or higher)[107] converts chloral to trichloroethylene.

Boron halides can be involved in different reactions: boron trifluoride adds to the chloral carbonyl group as a Lewis acid;[108] with boron trichloride at −80° tris-(1,2,2,2-tetrachloroethyl) borate is produced[109] with a yield up to 90%. The researchers noticed that, unlike chloral, bromal does not undergo this transformation, even at 20°.

In conclusion it should be noticed that only some of the oxidizing reagents in question can be used for oxidation of the chloral carbonyl group proper without the destruction of the substrate molecule. Besides the above-mentioned[87,89,101] there are some other methods;[110-115] for instance, trichloroacetic acid is obtained with good yields by the action of chloral with hypochlorites at pH 2–7,[110] cerium perchlorate solution in $HClO_4$,[112] and CrO_3,[116] and also by air oxidation but only in the presence of aqueous solutions of Cu(II) and Fe(III) salts.[113]

Electrolysis of chloral on a Pb anode[116] at a current density of 1.25 A/dm^2 gives trichloroacetic acid with a yield of 72%.

In general, chloral's capacity for heterolytic oxidation, in comparison with that of other aldehydes, is weakened

as a consequence of the reduced electron density of the C–H bond caused by the strong negative inductive influence of the trichloromethyl group.

In view of the dual capacity of chloral for reduction (of the carbonyl and/or the trichloromethyl group), it is possible to choose conditions for such processes selectively. Reduction to mono- and dichloroacetaldehyde results from electrolysis with a copper or, preferably, a lead cathode; on a Pt cathode, chloral is not reduced.[117] It is worth noting that trichloroacetic acid in each of the cases under consideration is reduced to monochloroacetic acid;[117] CCl_4 is not reduced on a Pt cathode but is transformed into chloroform and dichloroethane[118] on electrolysis with a Pb cathode.

Aluminum amalgam reduces chloral to dichloroacetaldehyde.[119] More complete reduction to acetaldehyde is possible using hydrogen generated *in situ* (from Zn and HCl).[120] Heating with powder-like zinc or iron leads to destructive reduction with the formation of methane and dichloroethane.[121]

Recently[122] reductive dehalogenation of chloral by chromium chloride in alcohol has been suggested. The trichloromethyl group is also reduced[123] by interaction of chloral with ammonium sulfide, although the structure of the product ($C_{18}H_{24}N_4O_6S_{13}$) was not established.

Upon interaction of chloral with hydrogen halides or their salts in an anhydrous medium, only potassium iodide reduces (chloroform and free iodine were isolated[124]) while hydrogen chloride and bromide form solid adducts with chloral (1:1).[125]

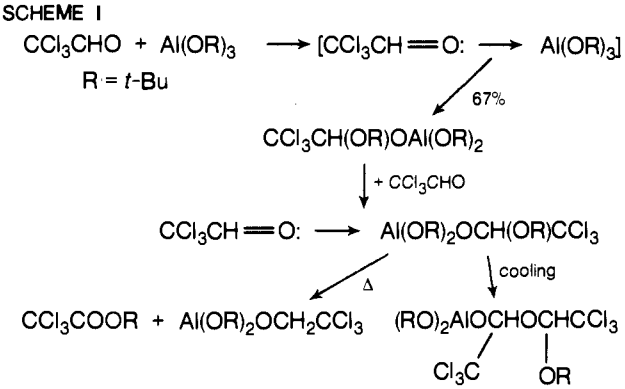
A study[126] of the oxidation-reduction interaction of chloral with Hg(I) and Hg(II) salts has shown that heating with HCOOHg produces the mixture Hg, Hg_2Cl_2, CO, CO_2, HCOOH, and H_2O; $Hg(OAc)_2$ is reduced by chloral hydrate to Hg(I).

Selective reduction of the carbonyl group to a hydroxyl group results from hydrogenation of chloral on powder-like Ni, Co, Fe, and also through nickel or copper chromite catalysis under vigorous conditions (120–150 atm, 50–150°).[127] If, however, such components as pyridine, hydrazine, acetonitrile, thiophenol, $CuSO_4$, $HgCl_2$, etc., are added to the reaction mixture, reduction of the trichloromethyl group also takes place, forming acetaldehyde and its mono- and dichloro-substituted derivatives.[127]

A complex of calcium hydride with trimethyl borate reduces chloral hydrate in water–methanol[128] with a yield of trichloroethanol up to 60%. The same product is obtained[129] after hydrolysis of chloral with siloxene ($Si_6H_6O_3$) reduction product.

The trichloromethyl group is fully preserved in the reaction of chloral with metallic alcoholates. In the aspect of Tishchenko's reaction, chloral disproportionates into trichloroethanol and trichloroacetic acid. Upon interaction with aluminum ethylate, trichloroethyl trichloroacetate is produced.[130] The same result was obtained[131] upon reaction with aluminum β-trichloroethylate. The mechanism in Scheme I is assumed[132] for the conversion of chloral under the influence of aluminum *tert*-butylate; all intermediate compounds, with the exception of the first one, were isolated and identified.

SCHEME I



Meerwein and associates,[133] repeating Tishchenko's[130] experiment in a nitrogen atmosphere, obtained trichloroethanol with a yield of 88.5%. In the reaction of excess chloral with aluminum ethylate (10:1) in benzene, a mixture of ethyl and trichloroethyl trichloroacetate was obtained.[134] When the process was carried out in ethanol, and in a nitrogen or hydrogen atmosphere, trichloroethanol and acetaldehyde were also found[135] among the reaction products.

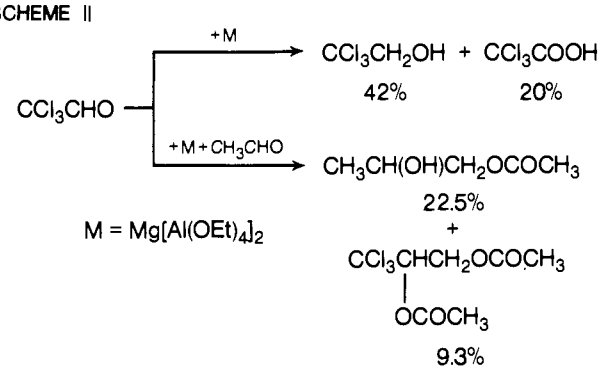
The use of magnesium and aluminum alcoholates in the interaction of chloral with acetaldehyde[136] and propionaldehyde[137] results in several products of a mixed Tishchenko reaction, for example

$$CCl_3CHO + EtCHO \xrightarrow[CCl_4]{(i\text{-}BuO)_3Al} CCl_3CH_2OH + EtCOOBu\text{-}i + EtCOOCH_2CCl_3$$

Heating with magnesium ethylate in ethanol solution leads to reduction with destruction, forming chloroform, ethyl formate, and carbon monoxide.[138]

The behavior of chloral in the presence of complex alcoholates[139] is shown in Scheme II.

SCHEME II



In conclusion, mention should be made[140] of chloral reduction by 1-benzyl-1,4-dihydronicotinamide in the presence of uv irradiation or peroxides; by that method selective homolytic reduction of the carbonyl to a hydroxyl group proceeds in cyclohexane. If nitromethane is the solvent, the carbonyl and the trichloromethyl groups are reduced simultaneously.

V. Radiolysis

Even in early research[68,69] the instability of chloral and the appearance of acidity were recorded in its aqueous solutions; in the presence of light, decomposition of chloral with evolution of hydrogen chloride increases. Andrews and Shore[141] discovered an acceleration of this process with γ-irradiation and, because of the linear conductivity dependence on dose of radiation, they recommended use of this effect for dosimetry. Even for that purpose, spectrophotometric control was suggested,[142] based on the change of indicator color with pH variation as a function of radiation dosage.

Investigations by Spinks and McIntosh and associates[143–147] have shown that on γ-irradiation (^{60}Co, ^{90}Sr), chloral decomposition has a free radical character. Decomposition to hydrogen chloride, trichloroethanol, and trichloroacetic acid[145] takes place both in the presence of oxygen and in a nitrogen or hydrogen atmo-

sphere; in the latter cases the hydrogen chloride yield decreases. Its yield depends not only on the radiation dose but also on the concentration of the chloral hydrate in solution.[148]

Other kinds of irradiation likewise destroy the chloral molecule, splitting off hydrogen chloride. By a conductometric method, possible mono- and bimolecular heterolytic mechanisms of that reaction on X-irradiation was established.[149,150] Decomposition of chloral upon the action of electron radiation[143] proceeds by a chain mechanism whose rate depends on the radiation dose and the initial substrate concentration; the hydrogen chloride yield also depends on the above factors. It has been noted[151] that this method is not suitable for dosimetric purposes.

VI. Electrophilic Reactivity

The existence of two reaction centers—carbonyl and trichloromethyl carbon atoms—leads to a dual electrophilic reactivity of chloral. As a rule addition to the carbonyl group is preferred because its carbon atom is less hindered sterically than the other carbon atom. But in some cases both functional groups take part in the reaction.

A. Interaction with Aliphatic Alcohols*

Anhydrous chloral adds vigorously monohydric alcohols, forming a hemiacetal (along with hemiacetals, products of exchange interaction may also be formed:[334] $CCl_3CH(OH)_2 + RCH_2OH \rightarrow RCHO + CCl_3CH(OH)CH_2R$ where R = Me, Ph). Chloral hydrate reacts similarly, but for the most part in the presence of a catalyst. That role, as a rule, is played by concentrated H_2SO_4 which above all apparently dehydrates and also additionally polarizes the carbonyl group of chloral. Acetals are formed only with acid catalysis and azeotropic water distillation.[152-163]

For a kinetic study,[157] the hemiacetal of (*R*)-(−)-menthol with chloral was obtained in hexane in the presence of acetic acid.

Many patents are devoted to obtaining hemiacetals and acetals from steroidal alcohols for the purpose of producing biologically active compounds and drugs. High yields are achieved by interaction of the reagents in benzene or dioxane at 20° for 17–48 hr. In such a way hemiacetals of testosterone[164-166] and some of its derivatives,[167-170] 21-hemiacetals of cortisone, hydrocortisone, and prednisolone,[171] 17-hemiacetal of estradiol, its 3-acetate and -benzoate,[172] hemiacetals of tetracycline,[173] and 16,17-acetals of pregnane series[174,175] were obtained. By interaction with cholesterol two isomeric products (mp 121 and 140°) were isolated, which are assumed to have the structure of trichloroacetates,[176] because these compounds are formed through replacement of chloral by trichloroacetic acid; with a rise in temperature, the yield of the high-melting isomer increases. The addition of monohydric unsaturated alcohols with an allylic type of multiple bond to chloral proceeds in the usual way, either with or without acidic catalysis,[177-181] forming acetals and hemiacetals.

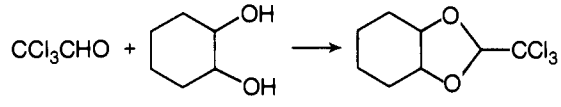
In the presence of vinylic ethers, addition of the intermediate hemiacetals to the ether C=C bond takes place; for example[179]

$$CCl_3CHO + CH_2{=}CHCH_2OH + AlkOCH{=}CH_2 \rightarrow CCl_3CHOCH(OAlk)_2CH_3 \quad (OCH{=}CH_2)$$

* Interaction with aromatic alcohols is discussed in section VI.E.

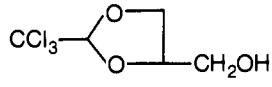
In this connection one may mention the interaction between chloral and camphor oxime. Frankforter and Mayo have isolated an adduct, from ether solution, characterized as the appropriate acetal.[182] Later van Alphen and Drost[183] obtained under similar conditions a hemiacetal of composition $C_{10}H_{16}NOCH(OH)CCl_3$ which was obtained before by Van Heyden[184] through interaction between the reagents in petroleum ether.

The products of a more complex structure are formed through interaction of chloral with polyhydric alcohols. In the case of 1,2-glycols, it is possible to obtain cyclic acetals if the process is carried out in the presence of concentrated H_2SO_4 and with azeotropic distillation of water; for instance[185]



1,3-Glycols form mono- and bis(hemiacetals) of chloral.[186]

With glycerol, depending on the reaction conditions, chloral produces a tris(hemiacetal)[187] or a cyclic acetal[188]

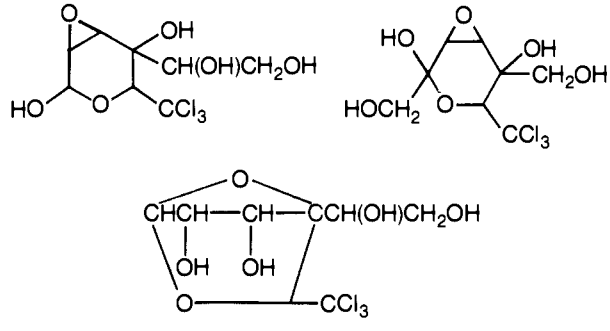


On distillation of chloral hydrate with a fivefold excess of glycerol, the following decomposition products were isolated:[189] formic acid, chloroform, and allyl formate.

Bis-, tris-, and tetrakis(hemiacetals) are formed with pentaerythritol.[187,190-192] Tetrakis(hemiacetals) are obtained by fusion of the reagents at 140° for 3 hr.[187] In this respect chloral differs from other aldehydes (and ketones) which form only bis acetals (and ketals)[190] with pentaerythritol.

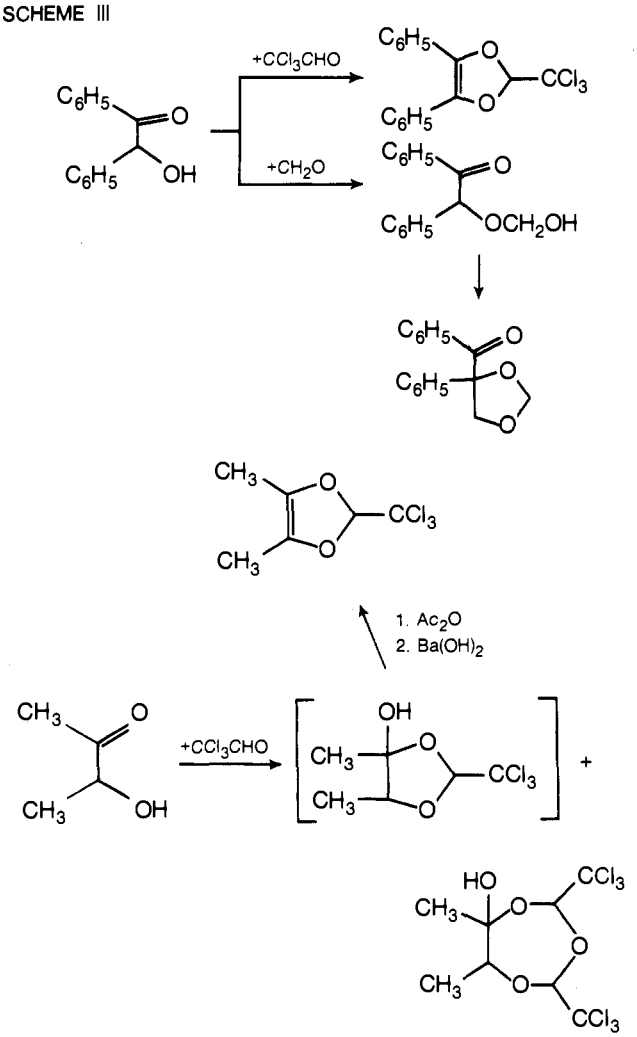
Hemiacetals containing up to six chloral fragments were obtained with mannitol and sorbitol.[187,192]

Attention of many researchers has been drawn to the structure of the interaction products between chloral and glucose. The series of early investigations[193-196] told about obtaining 1:1 adducts named α- and β-glucochloralose. Later Hixon and associates[197,198] pointed out that the structures of these compounds suggested by the earlier investigators were erroneous, and gave them the formula of acetal



Glucochloraloses may be obtained from the reagents in the presence of concentrated H_2SO_4 or with azeotropic distillation of water.[199,200] Heating at 70° of chloral, glucose, and $ZnCl_2$ produces a mixture of α- and β-glucochloralose; $[\alpha]^{20}D$ + 18.9° (EtOH) and −15.2° (Py).[201] To obtain glucose hemiacetals containing four to six frag-

SCHEME III

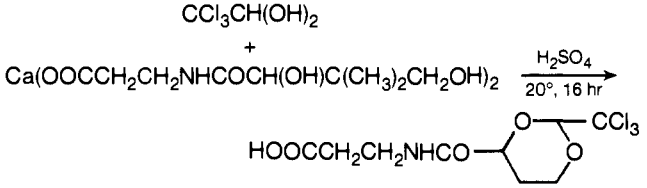


ments of chloral, the mixture of the reagents should be heated for a few hours at 120°.[202]

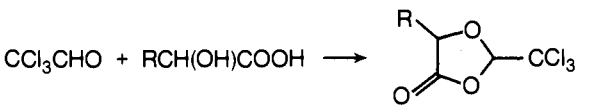
A study was also made of the formation of hemiacetals of chloral with amylose[203] and polyvinyl alcohol.[204,205]

Worth noting is the peculiar interaction of chloral with α-keto alcohols. Dietrich and Karabinos[206] isolated in 85% yield 2-trichloromethyl-4,5-diphenyl-1,3-dioxol by boiling a mixture of chloral with benzoin in benzene. It was the first instance of chloral fixation by an enediol, since the other aldehydes with benzoin or the other α-ketols with chloral do not form products of such a structure. Presented in Scheme III are trends of interactions of chloral with benzoin and acetoin and also, by way of comparison, of formaldehyde with benzoin.[206] The reaction of chloral with benzoin is favored in this direction both by high polarization of the chloral carbonyl group and stability of the enediol form of benzoin.

With hydroxy acids, chloral reacts differently. When the hydroxyl group is remote from the carboxyl group, hemiacetals (and occasionally acetals) are formed, as in the case with pantothenic acid[207]:



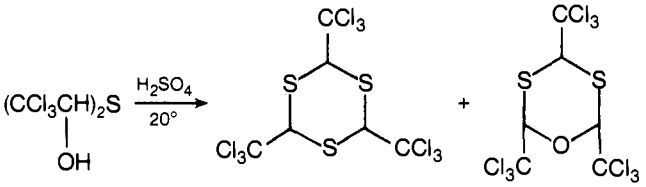
Aliphatic α-hydroxy acids form, with chloral or its hydrate, compounds named "chloralides":



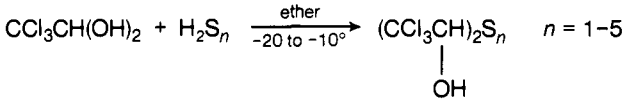
Glycolic, lactic, malic, tartaric, and other α-hydroxy acids[208-216] react with chloral in this way. In the case of α-tartaric acid two isomers of bis(chloralide) (with mp 160° and 173°) are formed, which can be separated by crystallization from benzene or toluene.[211] The first chloralides were obtained by Wallach[208] after long heating of the reactants in sealed tubes. Subsequently higher yields of chloralides were obtained by boiling the reactants in benzene or by heating them without solvent in the presence of sulfuric acid.

B. Interaction with Hydrogen Sulfide and Thiols

Hydrogen sulfide with chloral easily forms adducts of a composition 1:1[217] and 1:2.[218] By treatment with H_2SO_4 the latter is transformed partly to acyclic trimer of thiochloral (yield ca. 2%) and to two isomeric 1,3,5-oxadithians (total yield up to 18%).[219]

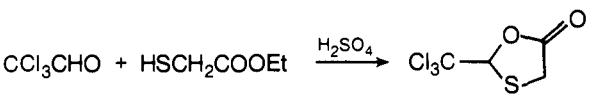


The stability of the reaction products diminishes with an increase in n.[218]

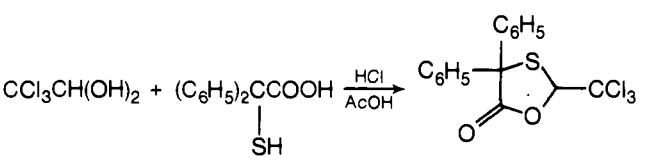


Chloral easily reacts with thiols either with or without acid catalysis. As a rule, the products are hemithioacetals in case of both aliphatic[220-223] and aromatic[224-227] thiols. For example, the reaction with dodecylmercaptan[221] in boiling methanol gives 88% of the hemithioacetal. Good yields (60–94%) arise by the interaction of chloral with para-substituted thiophenols[225] at 20° in benzene. Thioacetals of chloral are formed[226] with thiophenols in the presence of acidic catalysts. Dry hydrogen chloride improves the reaction between chloral and p-nitrothiophenol; the hemithioacetal is not stable, so it is preferable to carry out this reaction in acetic anhydride[227] which acetylates the hemithioacetal to a stable product.

With ethyl thioglycolate, chloral reacts in refluxing benzene in the presence of H_2SO_4, forming the monothio analog of chloralide with a yield of 90%:[228]

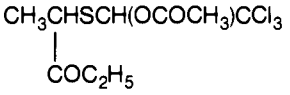


A product of similar structure was also obtained from the reaction between chloral and mercaptobenzilic acid.[229]

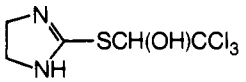


With a representative compound of α-ketothiols (2-mercaptocyclopentanone), chloral reacts in ether in

the presence of pyridine, forming an acyclic hemithioacetal,[230] which can be stabilized by acetylation:



The melting of chloral hydrate with ethylenethiourea hydrochloride (with two nucleophilic centers, N and S) leads to the formation of an adduct of hemithioacetal structure[231]



High nucleophilicity of the sulfur atom also allows adducts of a similar structure to be formed by the interaction of chloral with thioacetic and aromatic thioacids.[232]

C. Interaction with Alkalies and Aliphatic Nitrogen Bases

The decomposition of chloral and its hydrate under the influence of strong alkalies, to form chloroform and formates, is common knowledge; it is outlined in every course of organic chemistry and has found its application in the production of chloroform (notably of "chloroform pro narcosi") as well as for the quantitative determination of chloral hydrate as a drug.[233] The use of D_2O as the solvent permits one to obtain[234,235] deuteriochloroform with a 90% yield and with isotopic purity up to 95%. The reaction apparently proceeds according to the following scheme:[234]

$$CCl_3CHO + OD^- \longrightarrow CCl_3^- + HCOOD$$
$$HCOOD + OD^- \longrightarrow D_2O + HCOO^-$$
$$CCl_3^- + D_2O \longrightarrow CDCl_3 + OD^-$$

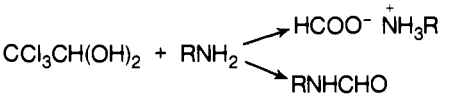
In 1948 Nesmeyanov and associates[236] found that in the degradation of chloral hydrate to chloroform, potassium fluoride can play the part of the base (the base function being fulfilled by fluoride anion). (It should be noted for the sake of comparison that heating of chloral with anhydrous hydrogen fluoride with catalysis by chromium oxide leads to fluoral without C–C bond rupture.[237]) In this case the yield of chloroform is quantitative.

However, under certain conditions simultaneous hydrolysis of the trichloromethyl group is observed, forming glyoxylic acid.[238,239] Similarly, in the alkaline hydrolysis of 4,4,4-trichloro-3-hydroxybutyric acid or its lactone,[233] only malic acid is formed, without C–C bond cleavage to give chloroform. In the case of phenyltrichloromethylcarbinol[238] the rate of trichloromethyl group hydrolysis depends only on the hydroxide concentration, and not on the nature of the cation; solvents with low dielectric constants hinder the reaction. These influences are of quite a different nature:[238] the above solvents favor chloroform splitting off and the cation influence is in accordance with the series: Li < Na ≪ K ≪ Cs < Ca < Sr < Ba ≪ Tl; consequently with the use of excess potassium hydroxide, the reaction is greater than first order. In case of thallic hydroxide, the order of the reaction is greater than one if the base is in excess; with equivalent proportions of reagents C–C bond cleavage takes place with chloroform formation being second order. With excess chloral, hydrolysis to glyoxylic acid is the main reaction.

On treatment of chloral with strongly basic aliphatic amines, the main reaction is formylation with the simultaneous formation of chloroform.[240-246] This appears to be one of the best methods for obtaining formamides, whose yields (in organic solvents) reach 80%.

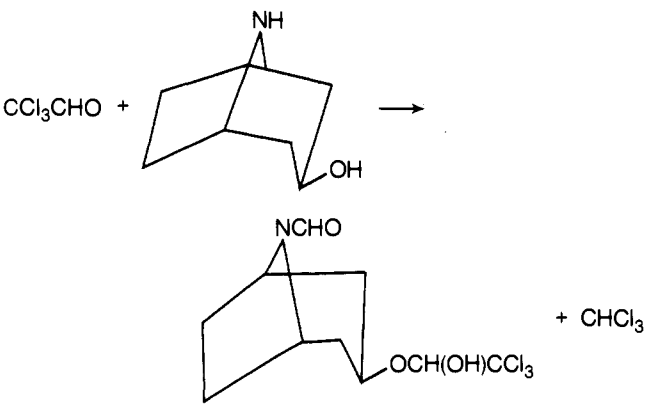
$$CCl_3CHO + HNR_1R_2 \longrightarrow CHCl_3 + R_1R_2NCHO$$

In water it is also possible to isolate ammonium formate;[240] the nature of the reaction products is determined mainly by steric factors. For example, in the reaction between chloral and *tert*-butylamine, formamide is not formed at all.



Yield, %	R = cyclo-C_6H_{11}	R = *n*-Bu	R = *tert*-Bu
Ammonium salt	2	6	92
Formamide	72.5	73	0

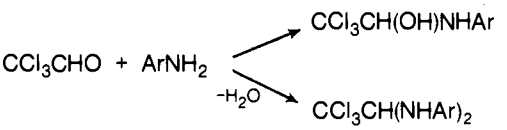
A kinetic study of the reaction between chloral hydrate and piperidine[243] has shown that it is first order in the case of excess base, and is bimolecular with equimolar proportions or with an excess of chloral. With brief heating at 100° of the mixture of chloral and nor-ψ-tropine both formylation of nitrogen and hemiacetal formation[245] take place:



Under conditions of azeotropic distillation of the water or still better with the use of a catalyst such as $ZnCl_2$, it is possible to obtain azomethines of chloral upon the interaction with several primary strongly nucleophilic amines[247-249]

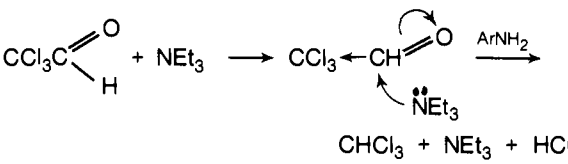
$$CCl_3CHO + RNH_2 \xrightarrow[-H_2O]{ZnCl_2} CCl_3CH{=}NR$$

Amines of medium nucleophilicity may react with chloral in the ratio 1:1 or 2:1, as in the case of some substituted anilines:[250,251]



Upon boiling for 72 hr in a mixture of AcOH–AcONa products of both structures are formed, but no definite dependence of the reaction trend on amine structure[251] was revealed.

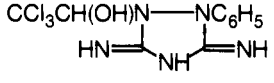
The interaction of chloral with aromatic amines in the presence of equimolar amounts of triethylamine[252] follows a different course; formamides are formed according to the following suggested scheme:



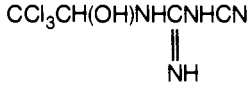
$$CHCl_3 + NEt_3 + HCONHAr$$

One should notice the difference between the reactions of aromatic alcohols and of amines with chloral: owing to the considerable nucleophilicity of the latter, chloral does not alkylate the carbon atoms of the benzene ring (as in the case of phenols; see section VI.E) but the nitrogen atom of the amino group. However o,o′-diaminobiphenyl is alkylated by chloral on the aromatic rings[253] because of the steric hindrance to alkylation of the nitrogen atoms.

Boiling of chloral with phenylguanazole in an aqueous solution leads to alkylation in position 1 of the heterocycle[254]

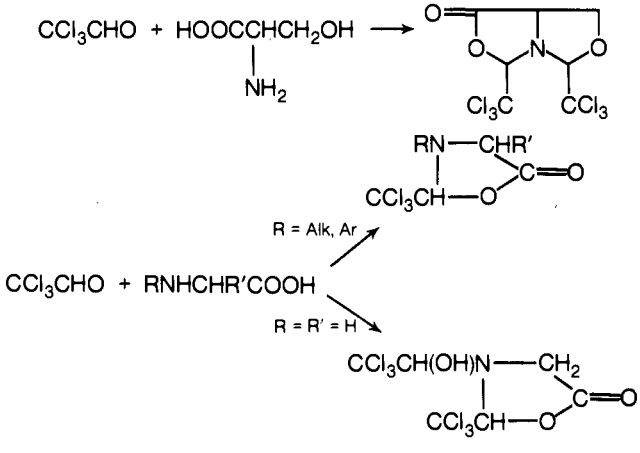


With dicyandiamide[255] chloral reacts in boiling acetone with the formation of an adduct:

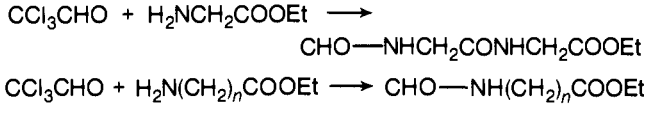


Treatment of chloral with weakly nucleophilic amino acids gives 5-oxazolidones;[256-259] also, products of a peptide nature[258] are formed. In the latter case catalysis by triethylamine[252] is advantageous (see Scheme IV).

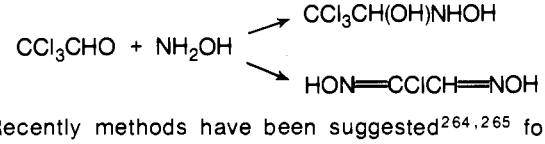
SCHEME IV



The esters of amino acids may be formylate on the nitrogen by chloral:[258,259]

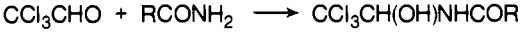


Chloral reacts differently with hydroxylamine. Naegeli[260] obtained, instead of the anticipated chloral oxime, chloroglyoxal dioxime ("chloroglyoxime"). Mayer[261] isolated chloral oxime (mp 39–40°) but Hantzsch[262,263] failed to reproduce that result and obtained only a 1:1 adduct and chloroglyoxime.

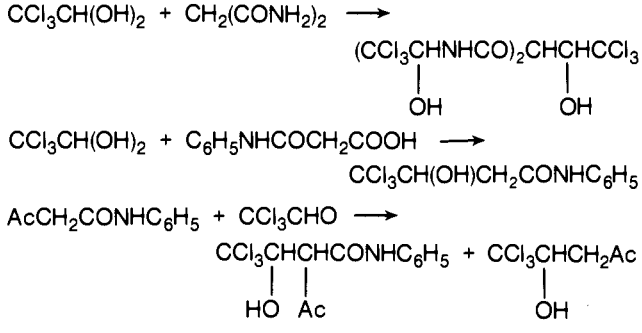


Recently methods have been suggested[264,265] for obtaining chloral oxime in high yield by heating chloral hydrate with an aqueous solution of hydroxylamine hydrochloride in the presence of an excess of calcium chloride, which appears to play the part not only of a salting agent. By this method an isomer with mp 56° and bp 76–78° (11 Torr) is obtained.[264] The test with β-trichloromethyl-β-propiolactone[266] shows that the latter isomer is the anti oxime, in contrast with the syn oxime which has mp 39–40°.

There is a series of papers about the interaction of chloral with acid amides,[267-277] resulting most frequently in 1:1 adducts ("chloralamides"):



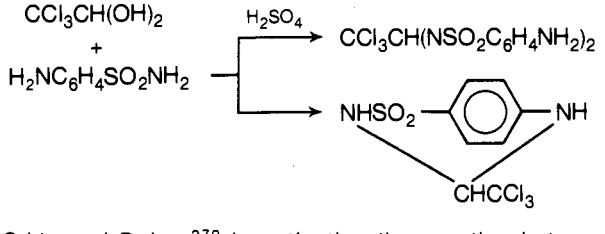
In the case of urea and similar bis-amides,[272] bis(chloralamides) are formed. Acid amides containing activated methylene groups are alkylated by chloral both on nitrogen and carbon atoms, or only on carbon if the nucleophilicity of the nitrogen is decreased by a substituent.[274-276] (The results of Chattaway and James[274] are in disagreement with those of Meldrum and Deodhar,[273] who observed only N-alkylation of malonamide by chloral.)



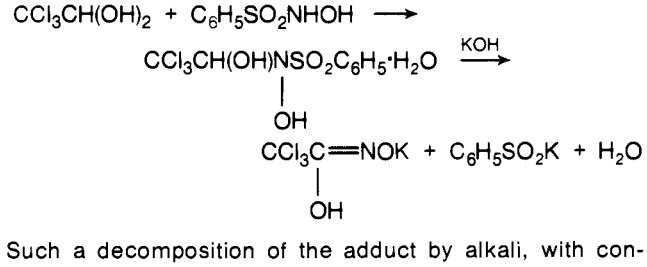
All the reactions of chloral with acid amides are realized upon prolonged heating of the reagents without a solvent, or under more mild conditions using an acid catalyst.

There are a few examples of the interaction between chloral and sulfonamides. Upon heating chloral hydrate with sulfanilamide in concentrated H_2SO_4, salt formation by the aromatic amino group causes chloral to alkylate the amidic nitrogen; the cyclic structure proposed for the condensation product formed[278] in the absence of acid seems unlikely (Scheme V)

SCHEME V

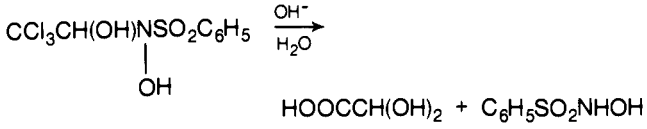


Oddo and Deleo,[279] investigating the reaction between chloral hydrate and benzenesulfohydroxamic acid at 20°, have obtained an adduct which gave a negative reaction with $FeCl_3$ (hydroxamic acid test), but this reaction was positive after treatment of the reaction mixture with alkali. The investigators have proposed the following scheme of transformations:



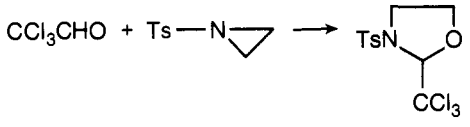
Such a decomposition of the adduct by alkali, with conservation of the trichloromethyl group, may be put to

question. More probable is a hydrolytic cleavage with regeneration of the sulfohydroxamic acid, thus rationalizing the positive $FeCl_3$ test:



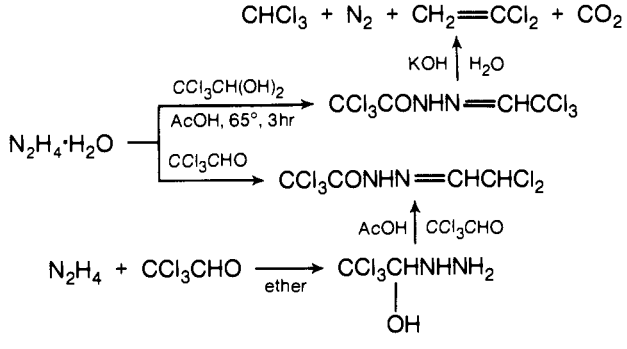
Furthermore, it is important to note that Cambi[280] failed to reproduce the above results: during 8 days at 20° no changes in the reaction mixture were observed.

N-Tosylethylenimine reacts with chloral with the enlargement of its ring to an oxazolidine:[281]



Eccentricity of chloral reactivity in comparison with other aldehydes is particularly displayed in its interaction with hydrazines. Knöpfer[282,283] found that by treatment of chloral hydrate with hydrazine hydrate or with hydrazinium salts in acetic acid, depending upon the temperature, compounds $C_9H_8Cl_2N_2O$ or $C_4H_2Cl_6N_2O$ (named "anhydrochloral") are obtained; the latter is also formed on heating chloral hydrate and hydrazine salts in water. Only in 1968 did Karabinos and his associates[284] ascertain that the structure of "anhydrochloral" is the *N*-trichloroacetyl-*N'*-hydrazone of chloral. As the reaction between hydrazine hydrate (or its sulfate) and chloral proceeds, a product is formed which differs from the above by a molecule of HCl; it is decomposed by aqueous alkali. In contrast, the formation of the identical compound was confirmed by the action of a second mole of chloral on the adduct obtained by the reaction of chloral with hydrazine in ether (Scheme VI).

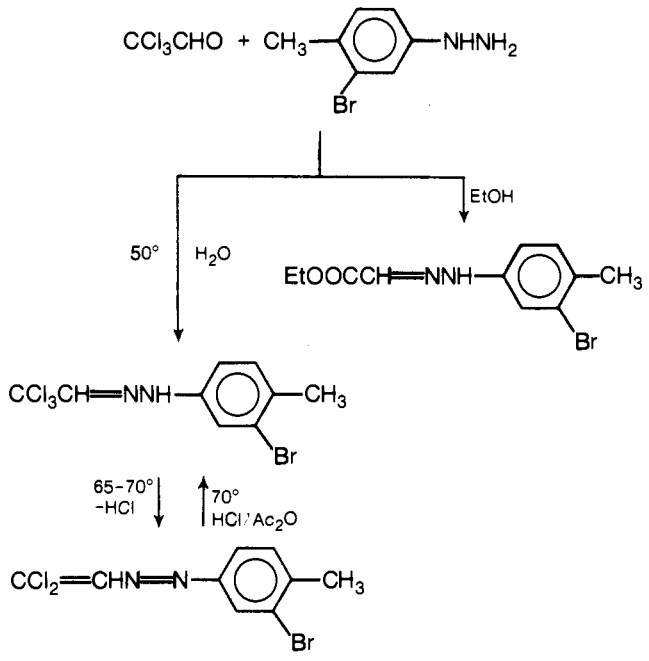
SCHEME VI



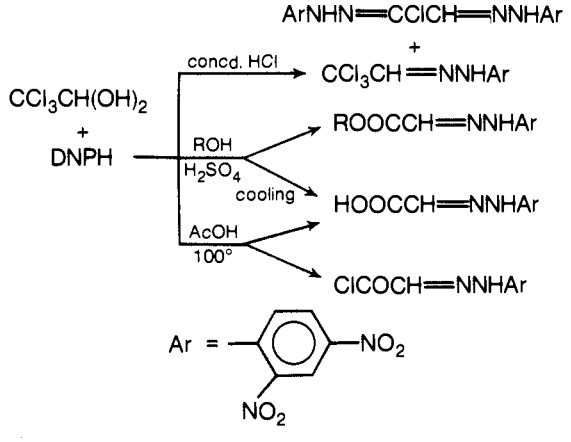
Substituted hydrazines react with chloral in various ways. Phenylhydrazines with electronegative substituents in the aromatic ring give unstable hydrazones which evolve HCl on heating. But this interaction is very specific and depends on many factors: the kind of substituent, solvent, medium acidity, proportion of reagents and temperature. For instance, with 3-bromo-4-methylphenylhydrazine, chloral reacts as shown in Scheme VII.[285]

The less nucleophilic 2,4-dinitrophenylhydrazine (DNPH) and 2,4,6-trichlorophenylhydrazine are even more receptive to the above-mentioned factors in their reaction with chloral.[286-291] Torres and Brosa[286] and Rabassa[287] obtained, after briefly heating chloral hydrate with DNPH in acetic acid, a mixture of chloroglyoxal and glyoxylic acid dinitrophenylhydrazones. The latter was also obtained by treatment of a cooled mixture of the reagents with sulfuric acid in alcohol;[289] on heating in concentrated HCl a mixture of chloral dinitrophenylhydrazone

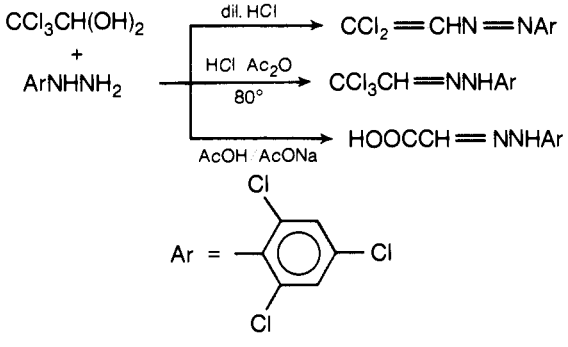
SCHEME VII



(mp 152–153° **) and chloroglyoxal bis(dinitrophenylhydrazone) was formed.[289]



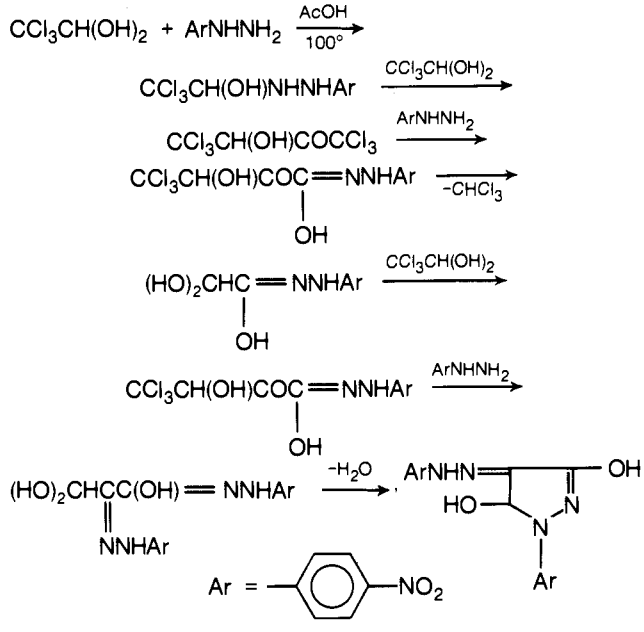
Products of the same structure were also obtained by the interaction between chloral and 2,4,6-trichlorophenylhydrazine:



Heating chloral hydrate with *p*-nitrophenylhydrazine in acetic acid, according to Stepanov and Kuzin,[292] leads to

** Ross and Ring[290] confirmed that one obtains chloral dinitrophenylhydrazone with the same melting point by treatment of the reagents with 12 *N* HCl; meanwhile earlier[288] it was communicated that the named compound was obtained, but with mp 131° by treatment of chloral with DNPH in methanol with H_2SO_4 catalysis. That erroneous melting point has been given by mistake in well-known references[304,305] for identification of chloral in the form of its dinitrophenylhydrazone.

SCHEME VIII



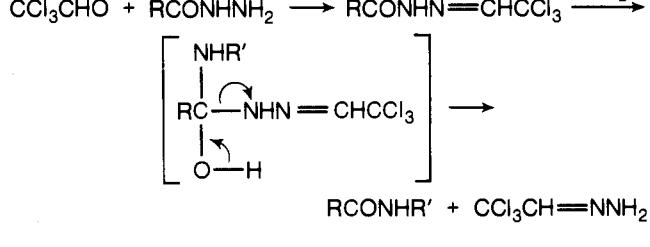
a product of composition $C_{15}H_{12}O_6N_2$, to which they assign the structure of a substituted pyrazoline, and propose the mechanism in Scheme VIII for its formation.

Torres and associates[286,293] have doubted that mechanism and attempted to confirm the structure of the reaction product, but these investigators[293] have succeeded only in isolating *p*-nitrophenylhydrazones of glyoxylic acid and dichloroglyoxal.

Interaction between chloral and acid hydrazides (benzoic,[294,295] isonicotinic[296]) leads to appropriate *N*-acyl-*N'*-hydrazones of chloral.

Chloral with thiosemicarbazide forms thiosemicarbazone[297] or its hydrate.[298] The interaction with *S*-methylthiosemicarbazide has been used by Chang and Ulbricht[299] for the synthesis of 6-azauracil. They have also obtained its 2-^{14}C-analog through the interaction between chloral and ^{14}C-semicarbazide (Scheme IX).

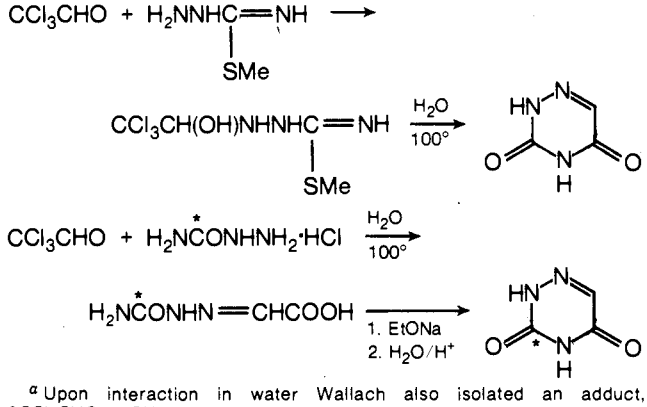
An interesting use of chloral was discovered by Kametani and associates.[300-303] Appropriate acid amides or esters are formed by boiling chloral with acid hydrazides in the presence of nucleophiles (amines, alcohols). In the authors' opinion dehydrazination takes place through the intermediate chloral hydrazone which in some cases was isolated:



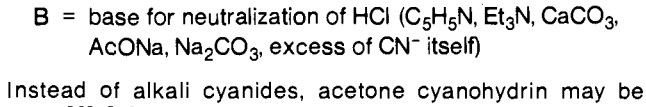
D. Interaction with HCN in Alkaline Media

Wallach's discovery[306,307] of the transformation of chloral hydrate into dichloroacetic acid or its esters by the action of aqueous or alcoholic potassium cyanide has much practical importance because of the limited accessibility of such compounds in other ways. This reaction (named sometimes "Wallach's reaction") plays a decisive role in dichloroacetylation, for instance in syntomycin and laevomycetin synthesis.[308]

SCHEME IX[a]



[a] Upon interaction in water Wallach also isolated an adduct, $3CCl_3CHO \cdot HCN$.



B = base for neutralization of HCl (C_5H_5N, Et_3N, $CaCO_3$, AcONa, Na_2CO_3, excess of CN^- itself)

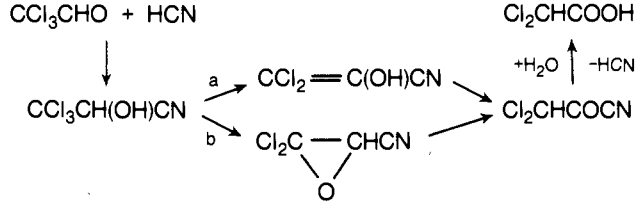
Instead of alkali cyanides, acetone cyanohydrin may be used;[309,310] in this way the yield of syntomycin (at that stage) can be increased to 95.5%.

The mechanism of Wallach's reaction has been investigated only recently. Questions which arise are the following:

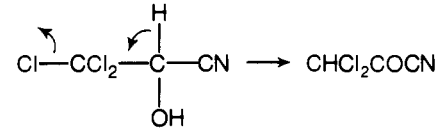
1. Does the carbonyl carbon atom of the dichloroacetic acid come from the chloral molecule or from cyanide ion?

2. What is the origin of the hydrogen atom in the dichloromethyl group of the acid molecule: is it a result of hydrogen migration from chloral or does it come from the protonic solvent in which the reaction is carried out?

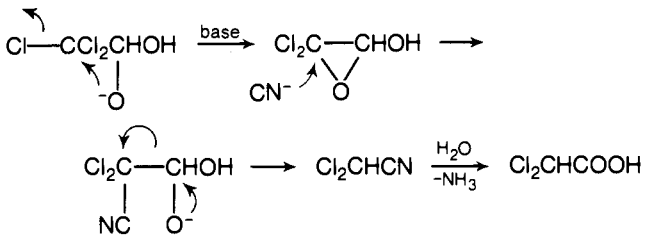
In particular it was supposed[309,311-314] that cyanide ions perform only a catalytic function. Kötz[312] and Pinner[313] thought that at first chloral cyanohydrin is formed, with two directions of reaction then becoming possible: "a" and "b", leading to dichloropyruvic acid nitrile with subsequent elimination of HCl:



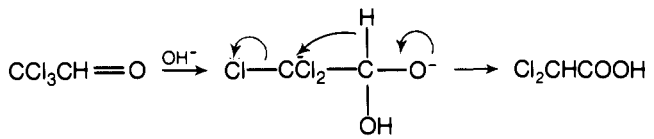
Francis and Davis[315] have confirmed the intermediate cyanohydrin formation; by carrying out the reaction in the presence of benzoyl chloride they obtained the benzoyl derivative of chloral cyanohydrin. Concerning the further transformation by path "a",[309,311,316] the possibility of the following redistribution of electron density was supposed[311]:



Cram and Hammond[317] proposed a mechanism for Wallach's reaction that included attack by cyanide ion on an epoxide ring which is formed by basic catalysis:

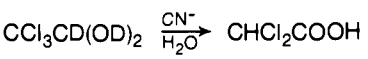


A mechanism proposed by Müller[318] neglects the participation of cyanide ion and foresees only hydride transfer in accordance with the scheme:



From the above discussion the viewpoints of investigators on two main questions are clear. Most of them agree that the carbonyl group of chloral is transformed into the carbonyl group of the dichloroacetic acid. In Cram and Hammond's opinion, the carboxyl group is formed by hydrolysis of the initially added cyanide ion.

Concerning the hydrogen atom of the dichloromethyl group in the acid, all investigators except Müller assume that the solvent is the hydrogen donor. The reaction between deuteriochloral hydrate and KCN and also the reaction between chloral and $K^{14}CN$ play a decisive role in resolving these questions. By NMR analysis the following course of the reaction[49] was suggested:



The isotopic purity of the hydrogen atom in the $CHCl_2$ group was ca. 90% protium. In this way, path "b" (of the Kötz and Pinner scheme) and the hydride transfer mechanism[318] were rejected.

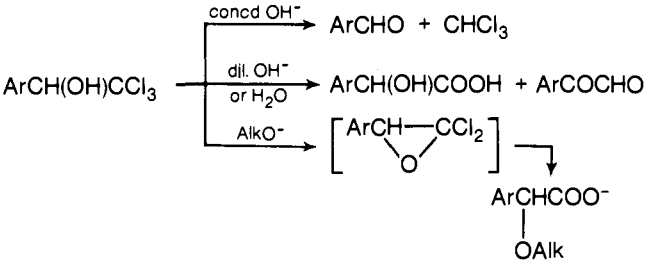
Interaction between chloral and $K^{14}CN$ in methanol[319] (by analogy with unlabeled KCN[320]) leads to methyl dichloroacetate without ^{14}C in the carbonyl group. Thus the catalytic function of the cyanide ion was confirmed.

Finally, the research by Khaskin and associates[310] on the influence of amine structure on the yield of dichloroacetylated aromatic amines using chloral with acetone cyanhydrin is pertinent. These authors have shown that the yield of amide increases with increasing basicity of the amine, taking into account the hydrolysis of the intermediate dichloropyruvonitrile in aqueous medium. In the case of β-naphthylamine and *o*-chloroaniline it is necessary to carry out the reaction in the absence of water (triethylamine is used to neutralize the HCl).

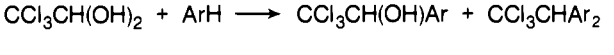
E. Interaction with Aromatic Compounds

Much research on chloral has been devoted to its interaction with aromatic compounds. But in some cases the structure of products and the reaction mechanism are still in doubt and constitute a subject for future research.

It is interesting that aryltrichloromethylcarbinols, which are obtained as a consequence of alkylating aromatic compounds by chloral, may be transformed into aldehydes and α-hydroxy acids by solvolysis of the trichloromethyl group.[321] These reactions have both preparative and industrial interest.

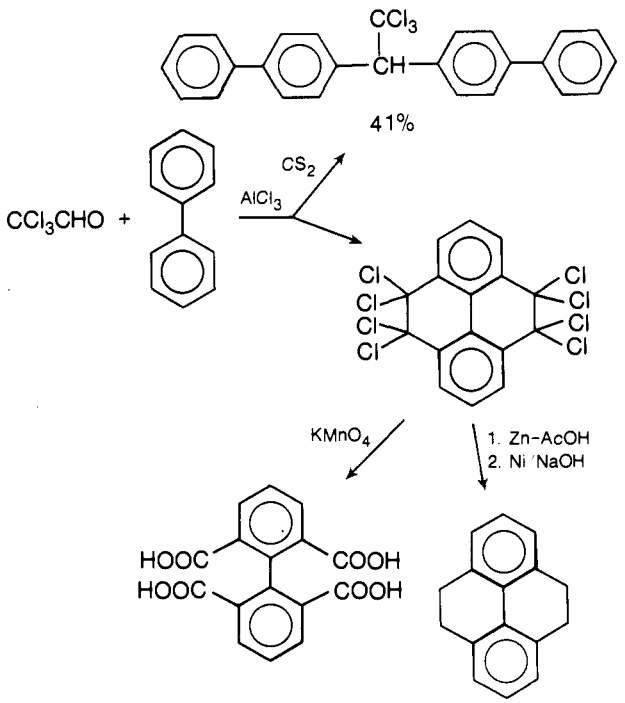


Chloral and its hydrate react with benzene and its alkylated homologs only in the presence of acidic catalysts. In concentrated H_2SO_4 or as the monohydrate, the reaction takes place with the formation of trichloroethane and trichloroethanol derivatives.[322-328]



In the presence of aluminum chloride the reaction with benzene leads to different products depending on the quantity of catalyst and the solvent. By heating in CS_2 mainly a mixture of the following compounds is obtained:[329] $(Ph_2CH-)_2$, $Ph_2C{=}CPh_2$, Ph_2CH_2, Ph_3CH, $PhCH{=}CCl_2$, $Ph_2C{=}CCl_2$. In the absence of CS_2 other products are obtained: CCl_3CHPh_2, $PhCCl_2CHO$, HCl;[330] CCl_3CHPh_2, $Ph_2CClCHPh_2$[331] (in the last case a compound was also isolated which was assigned the structure of a "salt": $C_6H_4(CCl_2CHPh_2)_2 \cdot HCl$).

Musante and Giraldi,[332,333] who studied the interaction between chloral and biphenyl with $AlCl_3$ as a catalyst, depending on the solvent, have obtained either a condensation product (1:2) or a compound lacking a trichloromethyl group (its structure was established by reduction and oxidation to the known products).

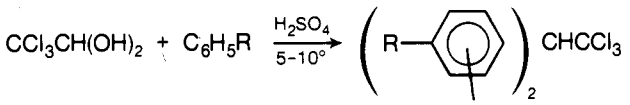


The reaction product from chloral and *p,p'*-dichlorobiphenyl in CS_2 in the presence of $AlCl_3$ also has no trichloromethyl group (as deduced by the test with alcoholic KOH[332]).

Treatment of chloral with naphthalene in the presence of Lewis acids[334-337] leads to a mixture of 1- and 2-naphthyl derivatives of trichloroethanol and trichloroethane, whose composition depends upon solvent, temperature, and proportion of initial reagents. So by NMR analysis it

was detected that the main product is not β- (as claimed in earlier papers) but α-naphthyltrichloroethanol (up to 90%).[337]

It is clear that the course of the reaction between chloral and substituted aromatic compounds is subject to orienting influence of substituents. Bis(aryl)trichloroethanes are formed[338] from chloral and monosubstituted benzenes in the presence of H_2SO_4:



The aromatic ring reactivity decreases in the series R = MeO, Me, Cl, NHAc, COOH, NO_2.

The reaction between chloral and chloro- or other halobenzenes has been broadly investigated[339-355] because of the practical use of DDT. The reaction proceeds under mild conditions with acid catalysis according to the above-mentioned scheme. For the synthesis of DDT, sulfuric acid or oleum was used[343,346-350,352-354] as the preferred catalysts; however, in such cases the crude DDT may include up to 14 (!) by- and secondary products.[352] The use of solvents such as CS_2, CCl_4, chloroform, or petroleum ether hardly decreases the yield of DDT.[346]

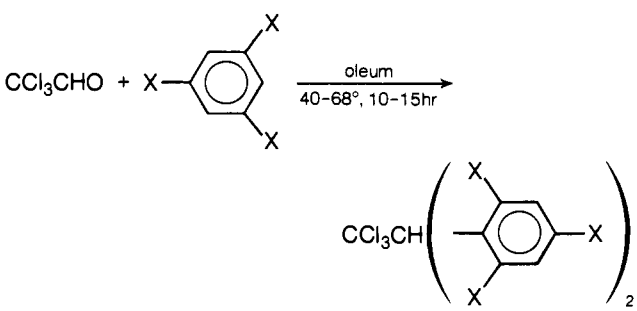
Concerning the use of Lewis acids such as $AlCl_3$ or $ZnCl_2$,[334,355,356] there is a communication about obtaining DDT under such conditions; however, the main products were bis(*p*-dichlorodiphenylmethane) and *p*-chlorophenyltrichloroethanol; the last was also obtained by Ettel and Weichet.[356] Musante and Parrini[355] have isolated, using $AlCl_3$, a little 9-phenyltrichlorophenanthrene.

The following catalysts failed to give DDT in this reaction: $SOCl_2$, SO_2Cl_2, P_2O_5, H_3PO_4,[346] and also hydrogen chloride.[349] Up to 1947, in the presence of HSO_3Cl, the industrial yield of DDT was[339] 67–69% (compared to 62% with H_2SO_4 and 58% with HF[351] as catalysts). At the same time a method for DDT synthesis was published in which, on heating chloral with chlorobenzene at 30–50° in monohydrate medium, the yield increased to 80%. Later the use of oleum increased the yield of DDT up to 92–93%.[354]

There is an opinion[349] that the role played by the H_2SO_4 involves formation of *p*-chlorobenzenesulfonic acid, which is then condensed with chloral to give DDT, but more probably one may account for the catalytic effect as a consequence of protonating the chloral carbonyl group by strong acid.[340] However, the mechanism of catalysis in DDT synthesis seems not so simple or unique.

The acid-catalyzed reaction of fluorobenzene with chloral gives[341-343] the fluoro analog of DDT and also some *o*- and *p*-fluorophenyl derivatives of trichloroethane; the yield of "fluoro-DDT" decreases at lower temperatures.[343]

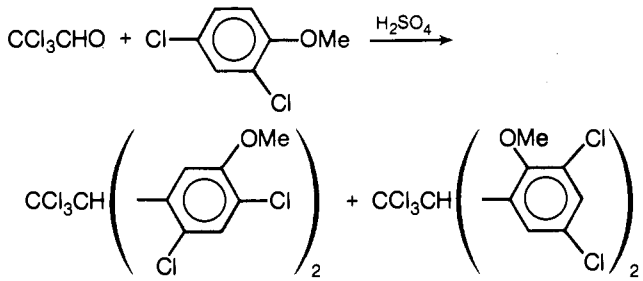
Polyhalobenzenes react with chloral to give trichloroethane derivatives, for example[357]



The temperature and yield increase in the series X =

$$Cl < Br < I$$

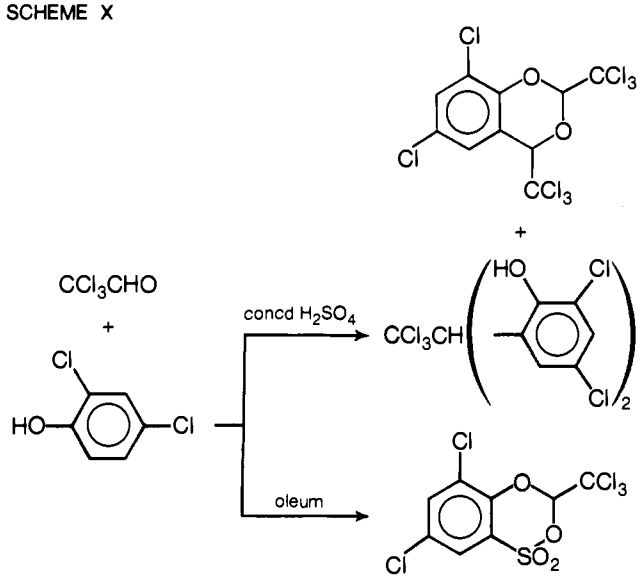
The interaction of chloral hydrate with 2,4-dichloroanisole in concentrated H_2SO_4 leads to alkylation in the 5 and 6 positions of the aromatic ring:[358,359]



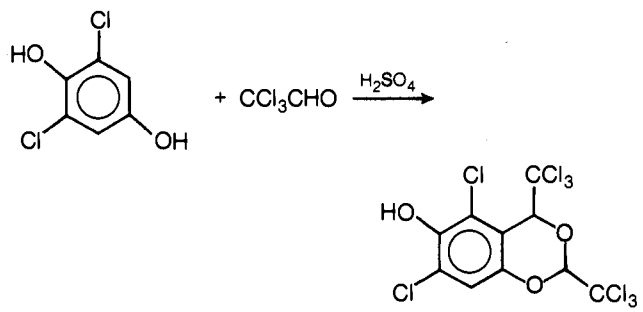
Hamada[359] obtained the same compounds by the interaction between chloral and 2,4-dichlorophenol with subsequent methylation.

Ettel and Weichet found[360] that in sulfuric acid, besides the products of alkylation by chloral, a condensation product was formed which has the benzodioxane structure; in oleum the reaction leads mainly to benzothiadioxane *S,S*-dioxide (Scheme X).

SCHEME X



2,6-Dichlorohydroquinone condenses with chloral in the presence of sulfuric acid to form a benzodioxane:[361]



The reaction between chloral and 2,4-dichlorophenol with $AlCl_3$ catalysis[362] gives 1-(2-hydroxy-3,5-dichlorophenyl)-2,2,2-trichloroethanol.

Chlorinated acetophenones are not alkylated in the aromatic ring with chloral. On long boiling in acetic acid the activated methyl group reacts[363] with the formation of a suitably ring-substituted 3-hydroxy-4,4,4-trichlorophenylbutanone.

The acid-catalyzed interaction of chloral with anisole has been studied by many investigators; H_2SO_4,[364,365,368,370] BF_3,[366] and $EtSO_3H$[367] were used as catalysts. This reaction was investigated[354,364-370] both at high temperatures (with azeotropic distillation of water) and at low temperatures. The product obtained is the appropriate bis(aryl)trichloroethane (bromal does not react with anisole to form a product with such a structure[364]), but an intermediate derivative of trichloroethanol may also be isolated.[366]

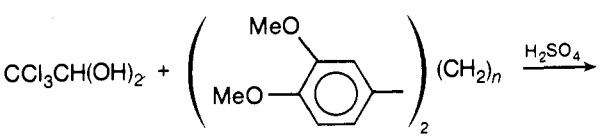
With electronegatively substituted anisoles (for example, *o*- or *p*-COOH, $-NO_2$) chloral reacts almost entirely in one way[361,371-373] to give 2-methoxy-4-methyl-5-(1-hydroxy-2,2,2-trichloroethyl)benzoic acid. However, at high temperatures (100°) and by using a mixture of H_2SO_4 and HCl as a catalyst, the yield of that compound decreases because of by-product formation, particularly sulfonated derivatives.[371] o-Nitroanisole reacts easily with chloral in the presence of H_2SO_4 without heating,[374] forming a mixture of aryltrichloromethylcarbinol and bis(aryl)trichloroethane derivatives (the latter predominates in the absence of a solvent) and also traces of 2,6-dimethoxy-3,7-dinitro-9,10-bis(trichloromethyl)dihydroanthracene.

Veratrol with chloral on heating in the presence of $AlCl_3$ forms bis(veratryl-4)trichloroethane, whereas on cooling the appropriate trichloroethanol derivative is formed.[375,376] In CS_2, bis(veratryl-4)dichloroethylene was obtained.[377] Under the influence of H_2SO_4 this reaction is more complex.[364,375,376,378-381] Arcoleo and associates[379] carried out this process in acetic acid and obtained, besides the main product, bis(veratryl-4)trichloroethane and also 4,5-bis[1-(3,4-dimethoxyphenyl)-2,2,2-trichloroethyl]-1,2-dimethoxybenzene, 1,1-bis{2-[1-(3,4-dimethoxyphenyl)-2,2,2-trichloromethyl]-4,5-dimethoxyphenyl}-2,2,2-trichloroethane, 2,3,6,7-tetramethoxy-9,10-bis(trichloromethyl)-9,10-dihydroanthracene, its 9,10-bis(dichloromethylene) derivative, and also a hydrocarbon (containing no chlorine) which was further[379] characterized as an anthracene derivative.

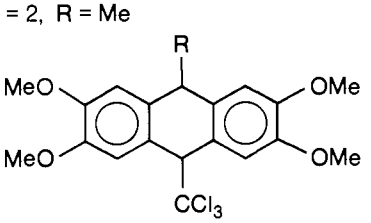
By the action of twofold excess of veratrol up to 85% bis(veratryl-4)trichloroethane is formed and in case of excess chloral a large quantity of dihydroanthracene is obtained.[375,376]

2,3,6,7-Tetramethoxy-9,10-dihydro-9-anthracene-9-carboxaldehyde has also been isolated as a reaction product from the interaction between chloral and veratrol with H_2SO_4 catalysis.[380]

Chloral reacts with 4-methylveratrol in a mixture of acetic and sulfuric acids to form mainly bis(aryl-5)trichloroethane.[382] With bis(veratryl)methane and -ethane, chloral hydrate yields anthracene derivatives.[380]

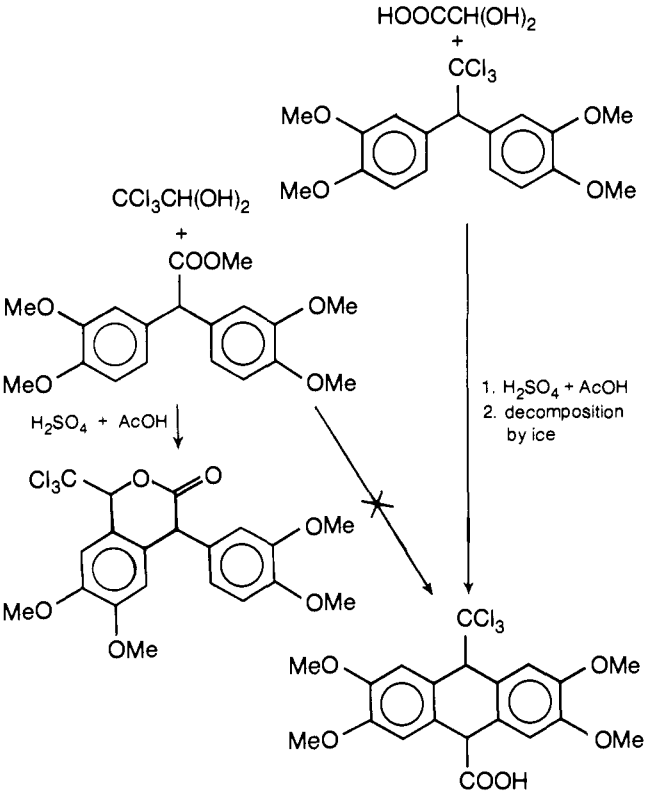


n = 1, R = H
n = 2, R = Me



But with the methyl ester of bis(veratryl)acetic acid[381] the expected 2,3,6,7-tetramethoxy-9-trichloromethyl-9,10-dihydro-10-carboxyanthracene is not formed; this has been confirmed by independent synthesis (Scheme XI).

SCHEME XI

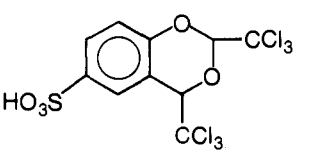


Thioanisole[383,384] and thiophenetole[385] condense with chloral on cooling in the presence of H_2SO_4 or $AlCl_3$ in CS_2 with the formation of the corresponding *p*-bis(aryl)trichloroethanes in high yields. A publication[386] about the analogous interaction between chloral and phenyl thiocyanate was disproved later by the same authors[387] and also by Rimschneider and associates;[388] in fact, the reaction takes the following course

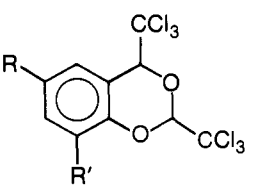
$$CCl_3CH(OH)_2 + ArSCN \longrightarrow CCl_3CH(NHCOSAr)_2$$

with a quantitative yield (Ar = C_6H_5) using the catalyst H_2SO_4 and in 57% yield in the presence of oleum.[386]

Reactions of chloral with aromatic alcohols have been investigated using both acid and basic catalysts. Chloral condenses with phenol in the presence of aluminum chloride to form bis(*p*-hydroxyphenyl)trichloroethane;[334] if chloral hydrate is added to a solution of phenol in sulfuric acid,[389] chloralidesulfonic acid is obtained:

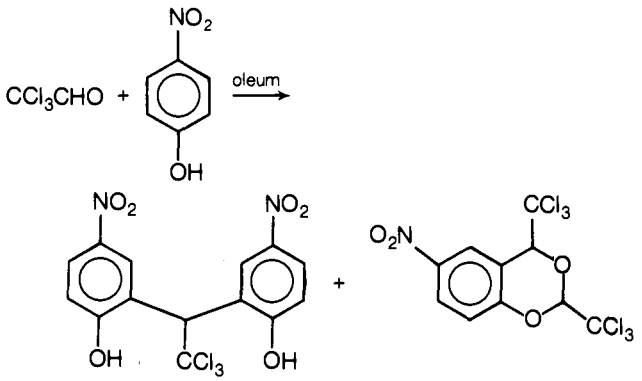


Derivatives of chloralide are also obtained by the interaction of chloral with some 2,4-disubstituted phenols in the presence of H_2SO_4.[390]



R	R′
Cl	Cl
Me	NO_2
NO_2	Me
Cl	NO_2

Backeberg[390] failed, however, to obtain the products of established structure from chloral and hydroquinone: *p*-cresol, 4-chloro-, 2-chloro-4-nitro-, 2,4- and 3,4-dimethyl-, 4-bromo-2-methyl-, and 4-nitrophenols under the same conditions. Later Haskelberg and Lavie[391] obtained reaction products from chloral and 4-nitrophenol according to the following scheme:

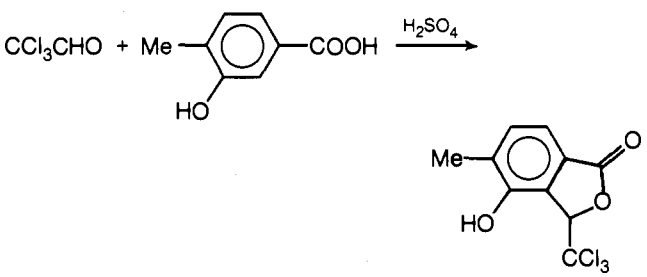


According to Chattaway,[392] the above formed benzochloralide has the 7-nitro structure.

The products obtained from the interaction of chloral with resorcinol depend on the acidic catalyst used. They include 4-resorcyltrichloroethanol,[393] 1,1-bis(resorcyl-4)-2,2-dichloroethylene (in CS_2 in the presence of $AlCl_3$[334]), and 6-hydroxyfluorene-10-carboxylic acid.[394]

Guaiacol with chloral and an acidic catalyst forms the adduct 4-hydroxy-3-methoxyphenyltrichloroethanol[393,395] (in yields up to 85%[395]) and bis(aryl)trichloroethane (at 0°, in acetic acid[396]).

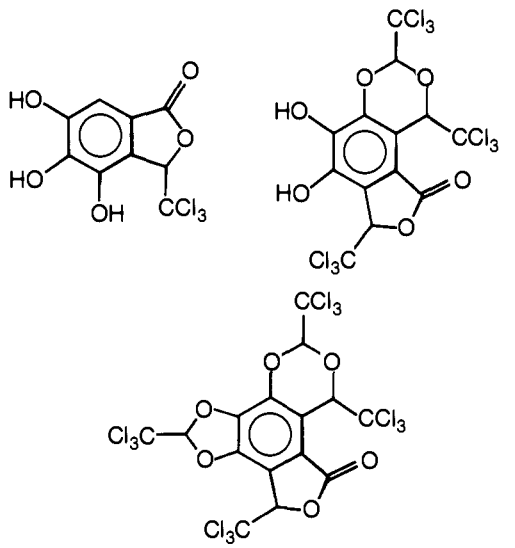
Phenolic acids react with chloral in the presence of strong mineral acids differently depending on the ring substituents. *p*-Hydroxybenzoic acid[397,398] is condensed to a cyclic product, 2,4-bis(trichloromethyl)-6-carboxy-1,3-benzodioxane (similar to the reaction with 4-nitrophenol[392]). By the interaction with *m*-hydroxybenzoic acid[399] chloral alkylates the aromatic ring in the 2-position.



The reaction between chloral and salicylic acid, its esters, and substituted derivatives[371,372,400-403] in the presence of H_2SO_4 leads as a rule to the formation of 4-(1-hydroxy-2,2,2-trichloromethyl)salicylic acid and its substituted derivatives; with an excess of salicylic acid a derivative of trichloroethane is formed.[401,402] In the presence of a mixture of H_2SO_4 and NaCl, suitable 1,2,2,2-tetrachloroethane derivatives are obtained.[403] 4-Methylsalicylic acid is alkylated by chloral in position 5.[404]

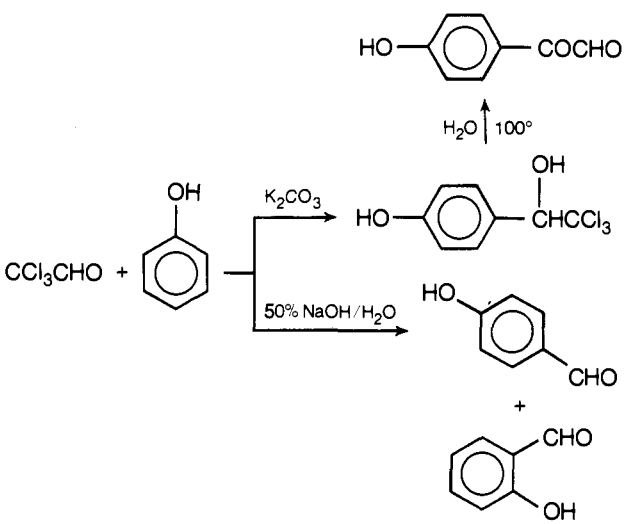
Gallic acid[405] reacts with chloral (H_2SO_4 catalysis) to give, depending on proportion of reagents, the condensation products shown at the top of the next column.

Strongly electronegative substituents hinder such reactions. For example, 3- and 5-nitrosalicylic acids do not react with chloral even on heating with sulfuric acid in a sealed tube.[372]

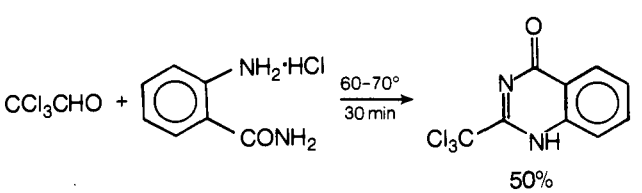


Base catalysis of the reaction of chloral with phenols leads to *p*-hydroxyaryltrichloroethanols[406-408] (and some ortho isomer[408]) which, by boiling in water[407] or reaction with aqueous alkali,[408] leads to aromatic hydroxy aldehydes (Scheme XII). [Balfe and Webber,[409] who carried out the reaction between chloral and phenol in chloroform with potassium carbonate or acetate, obtained 7.5% chloral hemiacetal. They also obtained a hemiacetal in the reaction with *p*-cresol (yield 35%); in solution, it isomerized to (3-*p*-cresyl)trichloroethanol.] Thus chloral can successfully replace chloroform in the Reimer–Tiemann reaction; thus arises its use as a formylating agent, particularly in the vanillin synthesis.

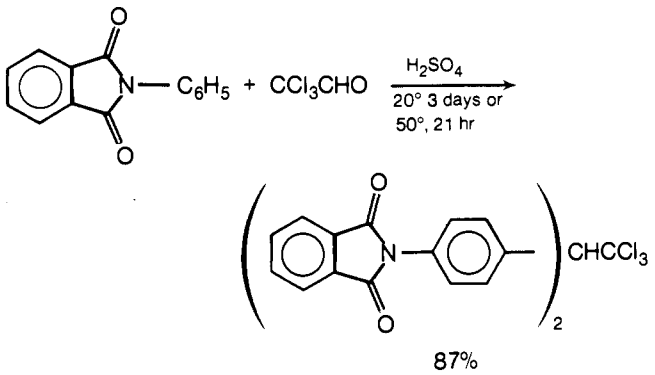
SCHEME XII



The reaction of chloral with aromatic amides takes two paths. Heat without a catalyst leads to alkylation of the amidic nitrogen by chloral, for instance, with naphthoic acid amides[410] and substituted salicylic,[411,412] toluylic,[413] and some other acid amides.[414-419] Chloral condenses with anthranilic acid amide[415] to give a quinazolone:



On the other hand, if the amide nitrogen is bound to an aromatic ring, it is not alkylated, but substitution of a hydrogen in the para position of the ring proceeds (when it is not hindered by other substituents);[420-427] sulfuric acid plays a catalytic function, for example:[426-428]

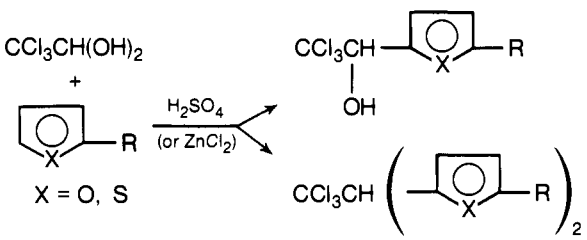


87%

Under such conditions succinimide does not react with chloral.[426-428] With excess of phthalanilide, 1-(*p*-phthalanilido)-1,2,2,2-tetrachloroethane also has been isolated.[428] Derivatives of the last compound are also formed by the interaction of chloral with acetanilide in the presence both of H_2SO_4[424,427] and its mixture with phosphorus oxychloride.[422] The interaction with *N*-acetyl-*p*-toluidine[420,421,423,428,429] is accompanied by many side reactions. *p*-Nitro- and *p*-bromoacetanilides do not react with chloral in the presence of H_2SO_4.[424]

To conclude this part of the review we will discuss the interaction between chloral and heteroaromatic compounds.

Derivatives of furan[430,431] and thiophene,[432,433] under acidic catalysis and cooling, are alkylated with chloral in the α-position, forming trichloroethanol and trichloroethane derivatives, depending on the proportion of reagents and on the kind of substituent R:



With 2,5-dichlorofuran in oleum, bis(2,5-dichlorofuryl-3)trichloroethane is obtained in 60% yield.[432] The reaction of chloral with 2-*tert*-octyl-, 2,5-di-*tert*-butyl-, and 2,3,5-trichlorofurans failed.[432]

2-Isothiocyano-,[434] -thiocyano-, and -thiocarbamido-[435] thiophenes react with chloral hydrate by the routes shown in Scheme XIII

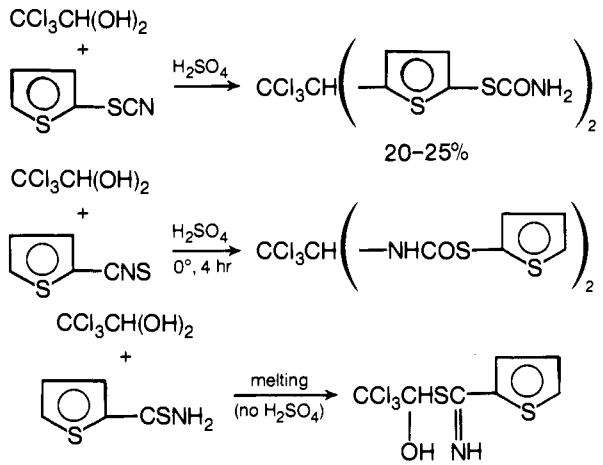
4-Hydroxycoumarin is alkylated by chloral in the 3 position to the corresponding trichloroethanol derivative.[436,437]

Addition of chloral to 8-hydroxyquinoline also occurs, not on the weakly nucleophilic oxygen[438] but on position 5 of the ring.[439]

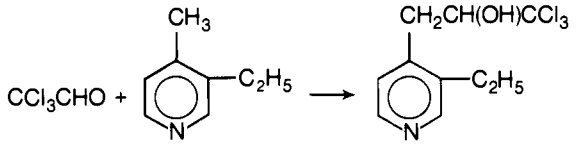
Heating chloral and 4-hydroxypyrimidines[440] in pyridine gives hetero 5-trichloroethanols, from which one obtains pyrimidine-5-carboxaldehydes in a modified Reimer–Tiemann reaction.

Aromatic compounds with activated methyl groups react with chloral at that site rather than on the ring. Reactions of this type take place with collidine (both in the presence of soda as a catalyst[441] and by heating without a catalyst[442]), 3-ethyl-γ-picoline,[443] 4-methyl-2-phenyl- and

SCHEME XIII

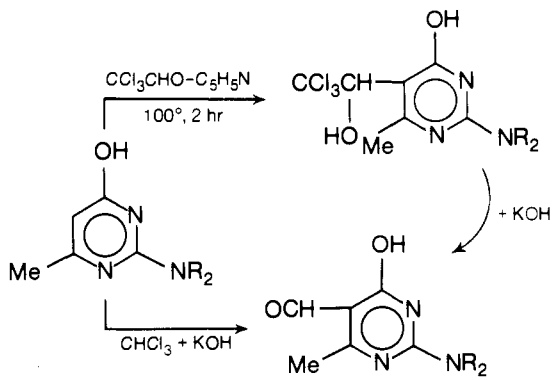


6-methoxy-4-methyl-2-phenylquinoline,[444] 2-methylquinazolone-4,[445,446] and 2-methylthiazole.[447] The first stage of the synthesis of dihydroquinotoxine and dihydroquinine proceeds in such a way:[441]



In contrast to these compounds, quinaldine reacts with chloral to form (2-methylquinolyl-3)-trichloroethanol,[447-450] but 2-amino-4-hydroxy-6-methylpyrimidine and its N-substituted derivatives are alkylated by chloral in pyridine medium at position 5; this has been confirmed[451] with alternate synthesis via the Reimer–Tiemann reaction (Scheme XIV).

SCHEME XIV



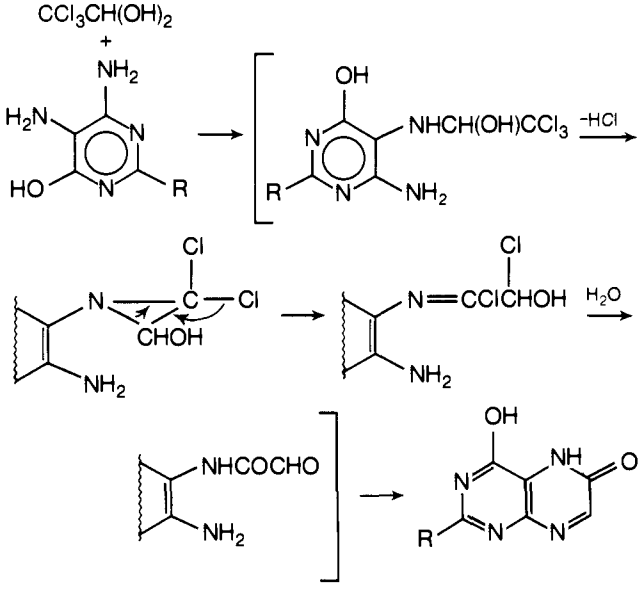
In the synthesis of pteridines from chloral and 4,5-diamino-6-hydroxypyrimidines with the acidic or basic catalysts, the investigators[452] proposed the following mechanism (through such a mechanism the above-mentioned results of Hantzsch in the reaction between chloral and hydroxylamine[262,263] were explained), Scheme XV (based on the results of Fields and Sandri[453] concerning chlorine transfer in aziridines).

Benzotriazole is alkylated with chloral in refluxing benzene to a (heteryl-1)trichloroethanol.[454]

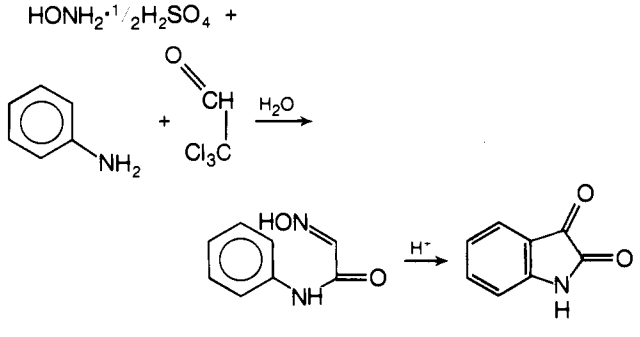
F. Synthesis of Isatin

By adding to an aqueous solution of chloral hydrate an equimolar quantity of aniline (the use of excess aniline leads to amidine,[457] $HON{=}CHC(NHC_6H_5){=}NC_6H_5$), followed by a hydroxylamine salt with subsequent boiling of reaction mixture, Sandmeyer[455] obtained isonitrosoace-

SCHEME XV

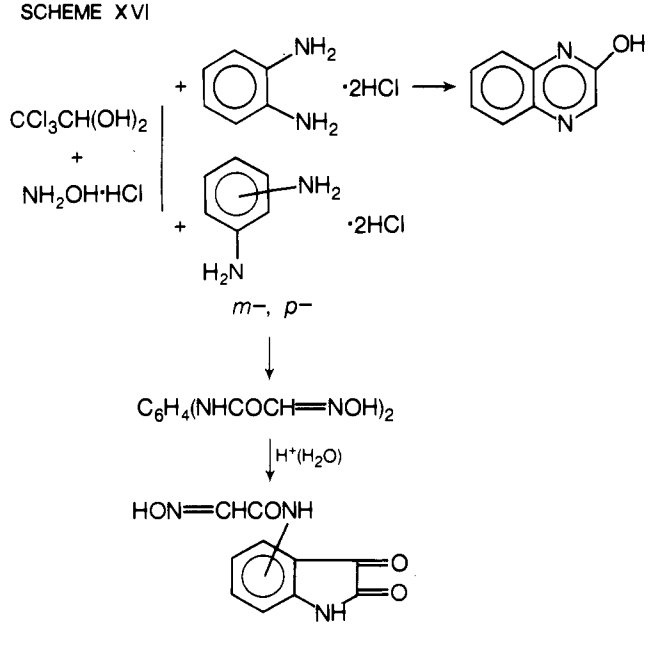


tanilide with a high yield; the product is transformed into isatin in acidic media:[456]



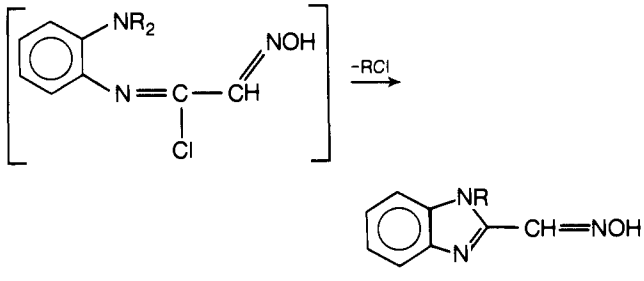
Instead of chloral and hydroxylamine one can use chloral oxime.[458] The yield increases to 60–90%[458] with an increase in the basicity of the aniline; a pH increase acts inversely as does the presence of salts with the same anion. Sandmeyer's reaction takes place in the presence of sodium sulfate, chloride, and bromide, but it does not take place in the presence of other sulfates or sodium acetate, formate, citrate, fluoride, and dihydrophosphate. The salts may play a buffer role, but there is no firm understanding of their function.

SCHEME XVI



Starting with o-, *m*-, and *p*-phenylenediamines, Morsch[459] has shown that only the latter two react with chloral to give substituted isatins; *o*-phenylenediamine is cyclized to a hydroxyquinoxaline (Scheme XVI).

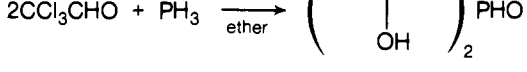
Petrov, Somin, and Kuznetsov,[460-462] who studied the interaction of aromatic diamines with hydroxylamine and chloral or its oxime, have established that in the case of gem-N,N-disubstituted o-phenylenediamines the end product is a derivative of 2-formylbenzimidazole (as oxime) as a consequence of intermediate imidochloride formation:



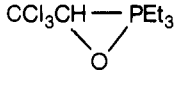
G. Interaction with Phosphorus Derivatives

With phosphorus derivatives chloral reacts as a rule as an oxidizing agent and transforms phosphorus from P(III) to P(V).

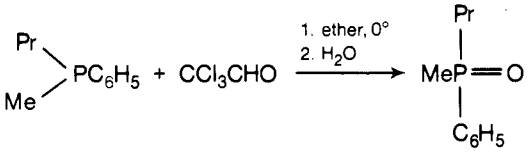
Phosphine adds two molecules of chloral[463]



In contrast, Girard[464] has assigned the product of the reaction between chloral hydrate and phosphonium iodide the structure bis(α-hydroxy-β,β,β-trichloroethyl)-phosphine. For the adduct of chloral and triethylphosphine, Collie[465] has proposed the structure



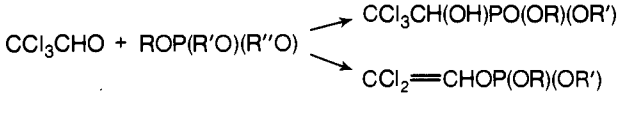
The reaction between chloral and methylpropylphenylphosphine[466] produces a compound which, on hydrolysis, gives a pentavalent phosphorus product lacking chlorine:



Most aldehydes, on being heated (190–200°) with phosphorus trichloride, condense to give $RCHCl-PCl_2$ (R = alkyl or, better, aryl). In contrast, chloral does not react even on heating to 270° for 5 hr.[467] In methanol a reaction takes by the following path:[468]

$$CCl_3CHO + PCl_3 + MeOH \longrightarrow CCl_3CH(OH)PO(OMe)_2$$

Compounds with the same structure or their dichlorovinyl derivatives are obtained by heating chloral with trialkyl phosphites, with or without a solvent;[469-474] dichlorovinyl esters are preferred when there are different substituents in the initial phosphite:



Before Perkov's[473] and Kharasch's[474] investigations (by analysis of ir spectra), it was considered[475-477] that the above transformation involves an Arbuzov rearrangement[475]

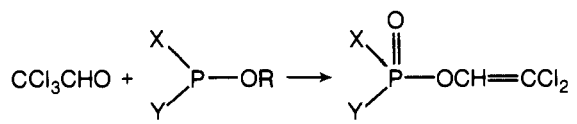
$$CCl_3CHO + (EtO)_3P \xrightarrow[-EtCl]{\text{dioxane, } 50^\circ} (EtO)_2P(O)CCl_2CHO$$

The same result, in Arbuzov and Alimov's opinion,[475] arises in the exothermic reaction between chloral and ethyl pyrophosphite, which usually reacts with other aldehydes in a different way:

$$(EtO)_2P{-}O{-}P(OEt)_2 + RCHO \longrightarrow (EtO)_2P{-}OCHR{-}P(O)(OEt)_2$$

$$R = CCl_3$$

The reaction between chloral and mono- and diesters of di- and monoalkylphosphonic acids proceeds according to the following scheme, in good yields.[473,478-482]



With dialkylphosphonic acid itself, according to Arbramov and D'yakonova,[483] chloral forms the appropriate trichloroethanol derivative.

On the action of chloral with amidodialkyl phosphites, trans-esterification to dichlorovinyl derivatives[484] takes place.

$$CCl_3CHO + (RO)_2HNR'R'' \longrightarrow Cl_2C{=}CHOP(O)(OR)NR'R''$$

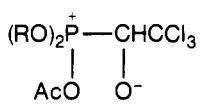
In this reaction, in the place of amido phosphites, one may also use dialkyl chlorophosphites, suitable amines, and triethylamine.

With organic compounds including a pentavalent phosphorus, chloral forms mainly trichloroethanol derivatives. Dialkyl phosphites add easily to the chloral carbonyl group;[485-492] basic catalysis, which is necessary for addition to other aldehydes,[3] is not required.[491] The yield of the reaction

$$CCl_3CHO + (RO)_2PHO \longrightarrow (RO)_2P(O)CH(OH)CCl_3$$

decreases from 100 to 56% on changing R from Me to Pr.[491] In alkaline media rearrangement takes place, leading to dichlorovinylic esters which accompany the main reaction product. Specific catalysis of the addition of chloral to dialkyl phosphites by ethylene oxide does not cause isomerization with hydrogen chloride elimination.[492]

The reaction between chloral and dibutyl acetyl phosphite[493] gives dimers, whereas with other dialkyl acetyl phosphites mainly α-acetoxy-β,β,β-trichloroethyl- dialkyl phosphites are obtained (products from HCl elimination were not isolated). The authors[493] proposed for the above reaction the following structure for the activated complex:



The reaction with pentavalent phosphorus acid amides[494] results in nucleophilic addition of the amino group to the chloral carbonyl group.

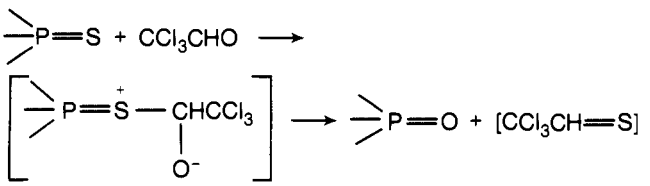
Organic phosphates[495] react with chloral on cooling to give reesterification products with hydrogen chloride elimination (mixed dichlorovinyl phosphates).

From the interaction between chloral and hypophosphorous acid, its potassium salt and esters, mono- and bis(α-hydroxy-β,β,β-trichloroethyl) phosphonites are formed.[463,496,497] High yields of the latter are obtained on refluxing in an anhydrous solvent or by heating the reactants without a solvent.[498,499]

Dialkyl thiophosphites differ from their oxygen analogs by forming, with chloral, dichlorovinylic thioesters:[498,499]

$$CCl_3CHO + (RO)_2PH{=}S \longrightarrow Cl_2C{=}CHOP(S)(OR)_2 \longrightarrow Cl_2C{=}CHSPO(OR)_2$$

Sohr and Lohs[500] have observed an interesting transformation of chloral with thio derivatives of pentavalent phosphorus leading to the replacement of the carbonyl oxygen by sulfur; the investigators proposed a dipolar intermediate:



VII. Interaction with Metallorganic Compounds

Metallorganic compounds as a rule add to the chloral carbonyl group to form an O–metal bond which, on hydrolysis, leads to a substituted trichloroethanol. For instance, from potassium acetylenide[501] α-hydroxy-β,β,β-trichloroethylacetylene is obtained in 27% yield. However, with phenyl- and methyllithium the trichloromethyl group shows greater reactivity than the carbonyl group, and interaction of those compounds with chloral at -30° leads to phenyl or methyl chloride formation; the authors proposed[502] the formation of an intermediate complex with charge transfer in the anion from carbon to oxygen. Such high reactivity of the trichloromethyl group has also been detected[502] in the reactions of chloral with butylmagnesium chloride and dibutylmagnesium; in both cases butyl chloride was obtained.

With dimethylzinc, chloral forms (depending on the ratio of reactants) trichloropropanol-2 or the reduction product, 3,3-dimethylbutanol-2.[503]

Interaction between chloral and aromatic and heteroaromatic magnesium derivatives[335,337,504] gives 2-substituted trichloroethanols in high yields. Aliphatic Grignard reagents react with chloral differently, forming in addition to trichloroethanol and its 2-substituted derivatives some by-products whose proportion depends on the structure of the reagents, the order of mixing, the temperature, the solvent, and other factors. So on the treatment of chloral with methylmagnesium iodide the ratio of trichloroethanol/trichloropropanol-2 depends on the kind of catalyst and decreases in the series: $FeCl_3$, CuCl, $MnCl_2$.[505] In the reaction with ethylmagnesium bromide, Gilman and Abbott,[506] contrary to earlier data, failed to obtain chloral alcoholate; in many variations of the reaction conditions they isolated only trichloroethanol. However, Hamelin[507,508] has contested the above conclusion and confirmed the formation of both named products and also of trichloropropanol-2; the ratio is sensitive to temperature changes.

With amyl-[509] and cyclohexylmagnesium bromide,[509,510] chloral forms, besides trichloroethanol, the appropriate 1,2-dibromoalkenes. Compounds such as $C_6H_5(CH_2)_nMgBr$ (n = 2–4) with chloral lead to trichloroethanol, suitable phenylalkenes, and dimers with the formula $C_6H_5(CH_2)_{2n}C_6H_5$,[511] but no substituted trichloromethylcarbinol. The latter, however, are formed in the

reaction with benzylmagnesium halides,[512] but their yield is decreased with excess Grignard reagent because of bibenzyl and polymer formation.

Two communications relate to the interaction between chloral and organic boron compounds. Triethylboron[133] reduces chloral to a trichloroethanol derivative in 90% yield:

$$CCl_3CHO + BEt_3 \longrightarrow CCl_3CH_2OBEt_2$$

Phenylboronic acid[513] forms, with chloral under mild conditions, a cyclic ester which by prolonged heating at 150–160° (under N_2) is dehydrated.

Silylacetals are formed on the interaction of chloral hydrate with mono- and dichloroorganosilanes in the presence of nitrogen bases;[514-516] their SiO–C bond is strengthened by the inductive influence of the trichloromethyl group.[516] Substituted α-phenyl-β,β,β-trichloroethylsiloxanes are obtained by the successive action on chloral of phenylmagnesium bromide, then trialkylchlorosilanes at 2–30°.[517]

Trimethylsilyldimethylamine adds exothermically to chloral with Si–N bond rupture:[518]

$$CCl_3CHO + Me_3SiNRR' \longrightarrow Me_3SiO-\underset{\displaystyle CCl_3}{\underset{|}{CH}}NRR'$$

R = R′ = Me

however, with R = R′ = Et, Pr, $(CH_2)_n$ or R = Me, R′ = C_6H_{11}; R = Et, R′ = C_6H_{11}, on heating (80°) trichloromethyltrimethylsilane is formed with β-elimination from the resulting siloxane; appropriate formamides RR′NCHO are also formed in that reaction. The ratio of the reaction products depends mainly on the steric nature of R and R′.

With trimethylstannylamines chloral forms only formamides and substituted stannanes[518] (the reaction takes in the same way as in the interaction with strong aliphatic nitrogen bases):

$$CCl_3CHO + Me_3SnNR_2 \longrightarrow CHO-NR_2 + Me_3SnCCl_3$$

R = Me, Et

In contrast with the Si–O bond, the Sn–O[519] and Pb–O[520] bonds are easily subject to heterolysis, adding to the chloral carbonyl group:

$$CCl_3CHO + Et_3SnOC{\equiv}CMe \longrightarrow CCl_3CH(OSnEt_3)OC{\equiv}CMe$$

$$CCl_3CHO + Ph_3PbOMe \longrightarrow CCl_3CH(OMe)OPbPh_3 + CCl_3CH(OPbPh_3)_2$$

Under more severe conditions the Sn–C bond[521] is heterolyzed (providing a convenient route to ethinylcarbinols):

$$CCl_3CHO + Et_3SnC{\equiv}CPh \xrightarrow[10\ hr]{150-200^\circ}$$

$$CCl_3CHC{\equiv}CPh \xrightarrow[ether]{HCl} Et_3SnCl + CCl_3CH(OH)C{\equiv}CPh$$

$$\underset{\displaystyle OSnEt_3}{\underset{|}{CH}}$$

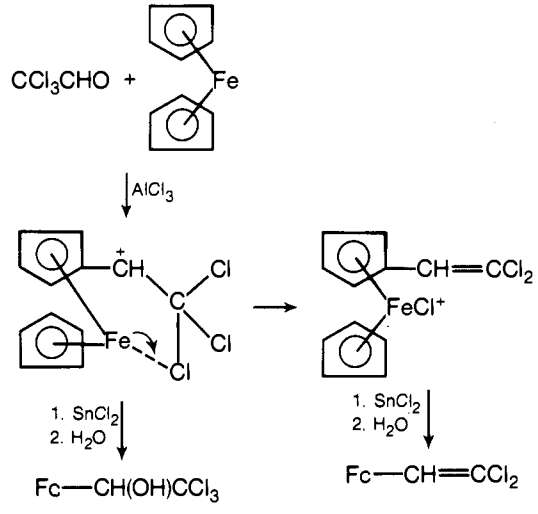
70%

Organosilyl sulfides[522] form adducts with chloral with cleavage of the Si–S bond. With bis(trimethylgermyl) oxide chloral easily gives an adduct[523] (by analogy with the interaction between chloral and acetic anhydride):

$$CCl_3CHO + (Me_3Ge)_2O \xrightarrow{25^\circ} CCl_3CH(OGeMe_3)_2$$

Ferrocene reacts with chloral in the presence of $AlCl_3$ (1:3:3 at 0°) to form a mixture which includes 5% ferrocenyltrichloromethylcarbinol and (after treatment of the reaction mixture with aqueous $SnCl_2$ solution) 21% ferrocenyldichloroethylene. The investigators[254] proposed the reaction mechanism shown in Scheme XVII.

SCHEME XVII



With the carbonyl derivatives of ferrocene[525] chloral forms not carbinols but polymeric products (by interaction with the cyclopentadienyl fragments).

VIII. Interaction with Compounds Containing Multiple Bonds

A. Carbon–Carbon

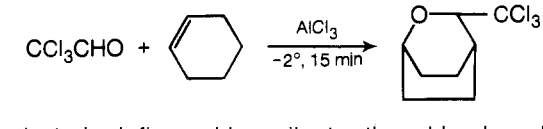
Chloral reacts with alkenes in the presence of acidic catalysts[526] to form mainly 1-alkenyl-2,2,2-trichloroethanols.

sym-Dichloroethylene condenses with chloral in the presence of $AlCl_3$ to form trichloroacetyl-2-chloroethylene; under the same conditions with chloral hydrate, other products are also isolated:[527]

$$CCl_3CH(OH)_2 + ClCH{=}CHCl \longrightarrow Cl_2CHCHClCHClCOCl + Cl_2CHCOCHClCHCl_2 + CCl_3COCH{=}CHCl + Cl_2CHCOCCl{=}CHCl$$

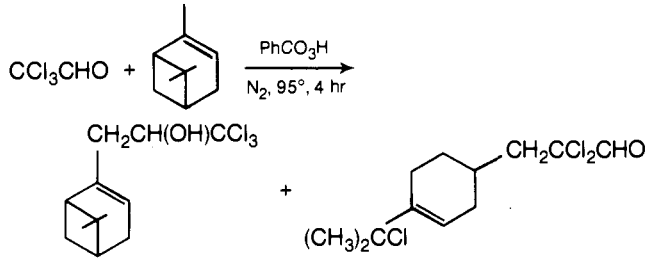
By the action of ethylene and $Hg(OAc)_2$ on chloral the hemiacetal $CCl_3CH(OH)OCH_2CH_2HgOAc$ was obtained.[528]

Chloral reacts with mesitylene in the presence of H_2SO_4 to give the ester of 1-mesityl-2,2,2-trichloroethanol and 2-mesitylenesulfonic acid.[529] Cyclohexene reacts with chloral to give a 2-oxabicyclo[2.2.2]octane derivative.[530]

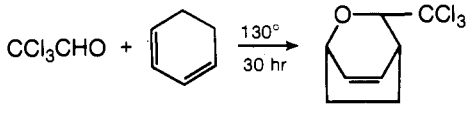


Activated olefins add easily to the chloral carbonyl group. Thus vinyl ethers react with chloral hydrate exothermically, forming 1:1, 1:2, or 2:1 adducts.[531,532]

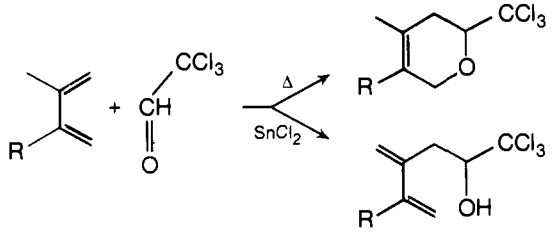
By heating (90°, 4 hr) chloral with β-pinene in the presence of benzoyl peroxide,[533] a cyclohexene derivative is obtained; the same bicyclic product is formed by heating in a nitrogen atmosphere with perbenzoic acid:[534]



With 1,3-dienes chloral reacts as a dienophile,[530,535,536] for example:[530]



Dale and Sisti[535] obtained from chloral and isoprene, 2,3-dimethyl-1,3-butadiene, or piperylene under similar conditions (150°, 24 hr) the appropriate 2-trichloromethyl-2*H*-5,6-dihydropyrans in yields of 30, 53, and 32%, respectively. Recently[536,537] the products of the thermal and catalytic reactions of chloral with 2,3-dimethyl-1,3-butadiene and piperylene were determined; it was shown that both the dihydropyran derived from the Diels–Alder reaction and the acyclic trichloroethanol derivative are formed. The latter compounds are the major

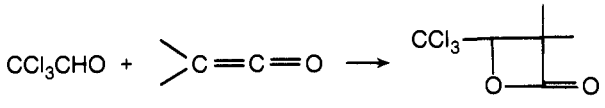


products on catalysis by $SnCl_2$ (20°, 18 hr) but they constitute only 10% of the product mixture in the thermal reaction (150°).

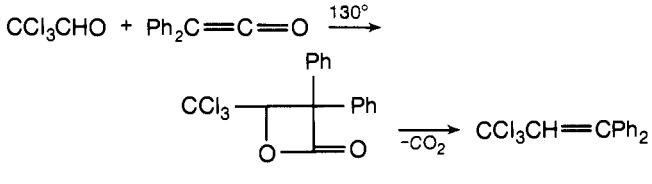
Dale and Sisti[538] found that cyclopentadiene failed to add to chloral (100°, 21 hr). Polychlorocyclopentadienes react with chloral only at 200–300° under high pressure;[539] in that case compounds C_6Cl_8 or hexachlorobenzene were obtained from hexachlorocyclopentadiene and chloral (at 200–260° or at 300–320°).

Heterolytic addition up to 30 molecules of chloral to 100 isoprene fragments with the formation of trichloroethanol derivatives[540-542] takes place on heating chloral with *cis*-1,4-polyisoprenes in the presence of Lewis acids.

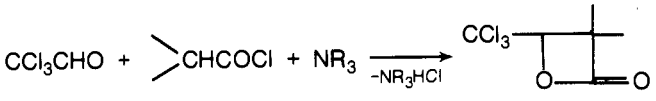
Chloral is one of the few carbonyl acceptors of the carbon–carbon double bond in ketenes. On the interaction between chloral and ketene, either with a catalyst (Lewis acids[543]) or without,[544,545] β-trichloromethyl-β-propiolactone is formed in yields up to 79% (in the presence of 2 equiv of ketene[545]). Other ketenes also form β-lactones with chloral, but in some cases only the appropriate ole-



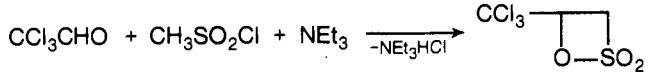
fins are obtained (as a result of decarboxylation of the β-lactones); for instance[546]



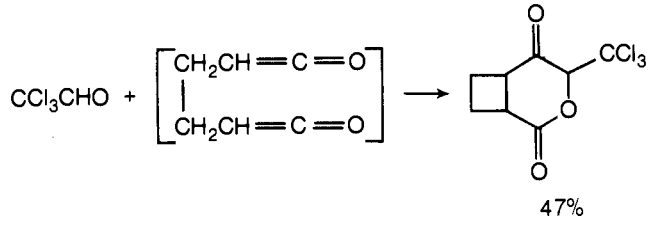
As the choice of stabile ketenes is limited, methods have been proposed[547-553] for obtaining β-trichloromethyl-β-propiolactones in high yields by using chloral to trap ketenes generated in situ by the reaction of acyl chlorides with strongly basic tertiary amines. Possible reaction mechanisms have been discussed.[554]



In the same way, sulfenes have been trapped with chloral as β-sultones.[549,550,555,556]

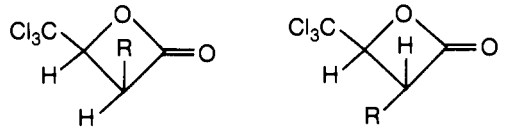


Some bis(ketenes) generated in situ may form cyclic adducts with chloral, for example:[549]



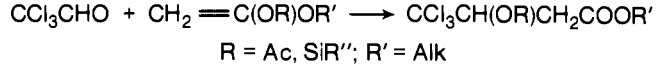
47%

Brady and Smith[557] have established by NMR analysis that methyl- or chloroketene generated in situ with chloral gives a mixture of isomeric β-lactones, with the cis isomer predominant:

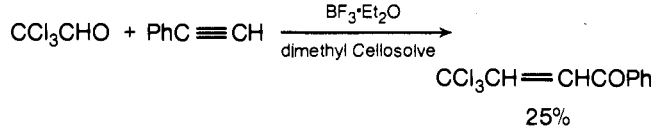


R = Me, Cl

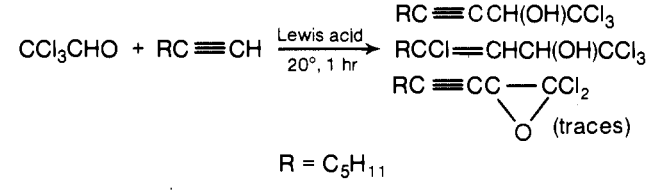
Ketene acetals react with chloral according to the scheme:[558,559]



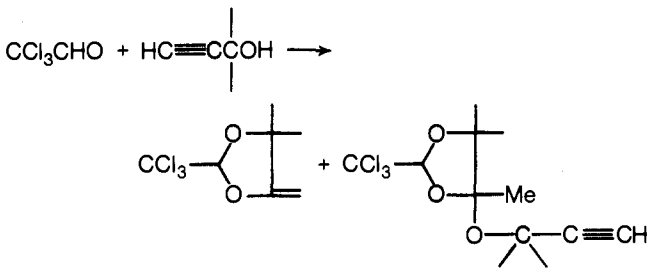
The interaction between chloral and alkynes may take place in two ways: chloral may add to the C≡C bond to form α,β-unsaturated ketones,[560] for example, with phenylacetylene:



On the other hand, 1-heptyne reacts with chloral in the presence of aluminum chloride or boron fluoride etherate to form a mixture of products (with acetylene derivatives among them[561]):



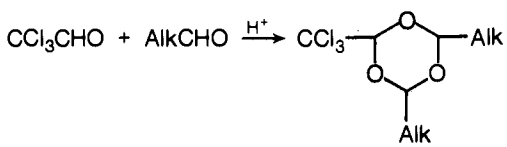
1-Substituted propargyl alcohols add to chloral in the presence of catalysts (HCl,[562] BF_3, HgO,[563,564] $CaCl_2$[565]) to form hemiacetals, which in situ may exothermically cyclyze[563] to oxolanes (1:1 or 2:1, with prevalence of the latter on catalysis by BF_3)



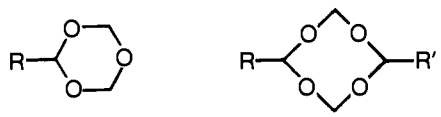
The C≡C bond remains in the reaction products in the interaction between chloral and sodium[501] and tin[519,521] alkynyl derivatives, as was noted in section VII.

B. Carbon–Oxygen

Chloral easily reacts with aliphatic aldehydes on catalysis by strong acids, usually forming trioxanes.[566,567]



A more intricate reaction takes between chloral hydrate and formaldehyde, from which Pinner[568,569] has isolated many cyclic compounds such as the following



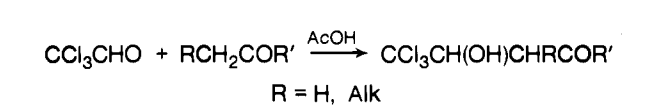
R and R′ = H, CCl_3, $CHCl_2$, $=CCl_2$

in addition to the monoadduct, chloral hydroxymethylacetal.

Products of unestablished structure were obtained[570] by the interaction of chloral hydrate with terpenic aldehydes, in particular, with citral in the presence of H_2SO_4.

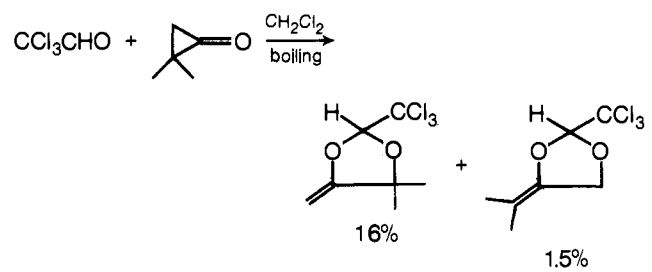
Chloral reacts in a special way with anthrone.[571] In contrast with other aldehydes, which condense with dehydration (the oxygen from the carbonyl group of the aldehydes and the meso hydrogens of anthrone take part in this process), chloral reacts to form a mixture of α,β-bis(9,9′-anthronylidene)ethylene and dihydrodianthrone (the catalysts are zinc chloride and tin or cupric acetate); in the presence of pyridine or sulfuric acid the latter product is obtained.

Methyl- and α-methylene ketones (the latter more difficultly; for reaction with acetoacetic acid derivatives see section IX) react with chloral as a consequence of their activated hydrogens[572,573]

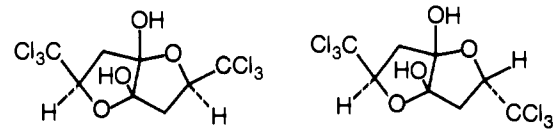


R = H, Alk

Cyclopropanones[574,575] add chloral with ring enlargement to give dioxolanes:

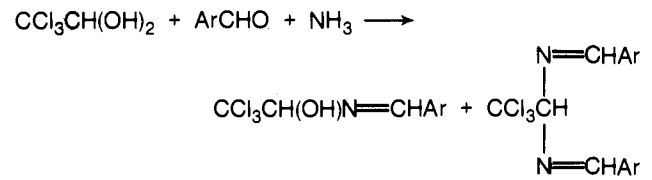


Research on the interaction of chloral or aromatic aldehydes with biacetyl in acetic acid in the presence of piperidine has given conflicting results. Schlenk[576] assigned to all the reaction products the unique structure $[CCl_3CH{=}CHC(OH)_2{-}]_2$. However, later[577] this viewpoint was disproved; the products were assigned the structures *cis,cis,cis*- and *cis,cis,trans*-3,7-bis(trichloromethyl)-2,6-dioxabicyclo[3.3.0]octane-1,5-diol (their composition corresponds to Schlenk's compounds, $C_8H_8Cl_6O_4$):

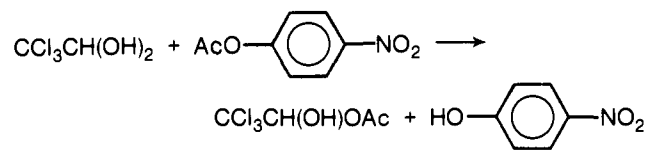


The interaction between chloral and acetyl- and *gem*-diacetylferrocene was discussed above.[525]

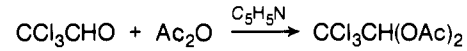
Spasov and Ivanov established[578] an interesting specificity of aromatic aldehydes for chloral hydrate in the presence of ammonia; the products are azomethines:



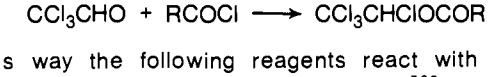
The reactions of chloral with carboxylic acids and their functional derivatives takes place without the participation of their carbonyl groups (see also section IX). Most of the reactions involve the acetylation of chloral hydrate.[579,580] A kinetic investigation of the reaction of chloral hydrate with acetyl-*p*-nitrophenol in water has shown[580] that the reaction is first order in each reagent, according to the scheme:



In the presence of the base, chloral reacts with acetic anhydride in the following way:[581]



Acyl chlorides add chloral according to the scheme:



In this way the following reagents react with chloral: phosgene with tertiary-amine catalysis,[582] carbamoyl chloride,[583] acetyl chloride with catalysis by silver malonate[584] or by triethylamine.[538]

2,6-Bis(trichloromethyl)tetrahydropyron-4 is obtained[585] on the treatment of chloral with bis(carboxymethyl) ketone.

C. Carbon–Nitrogen

The interaction between chloral and nitriles was inves-

tigated in limited examples. Reaction is realized only on acidic catalysis according to the following scheme:

$$CCl_3CHO + RCN \xrightarrow{H^+} CCl_3CH(NHCOR)_2$$

R = Ph,[391] Pr, CH=CH$_2$,[586] >CH[587]

In the case of substituted acetonitriles[587] the yield of such products varies (from 19 to 94%) and the appropriate acid amides are formed concurrently. These amides are not intermediates in the main reaction. Thus in the reaction with chloral, the C≡N bond itself takes part, with subsequent hydrolysis of the adduct.

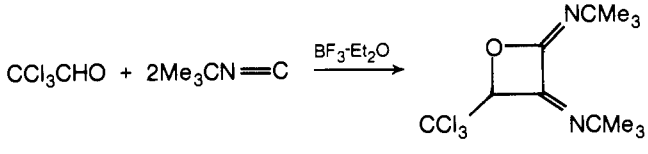
Isonitriles (phenylisonitrile,[588] isodiazomethane[589]) add vigorously to chloral to form trichloroethanol derivatives. However, the mechanisms of these reactions differ. In the first case, chloral hydrate adds to the carbenic carbon atom and trichlorolactic acid anilide is formed:

$$CCl_3CH(OH)_2 + PhN{=}C \longrightarrow CCl_3CH(OH)CONHPh$$

In the reaction of chloral with isodiazomethane, it was supposed[589] that condensation occurs first, followed by dehydration. Then a second chloral molecule (as hydrate) adds to the intermediate carbene (as shown for phenylisonitrile):

$$CCl_3CHO + H_2NN{=}C \xrightarrow[-H_2O]{} CCl_3CH{=}NN{=}C \xrightarrow{CCl_3CH(OH)_2} CCl_3CH(OH)CONHN{=}CHCCl_3$$

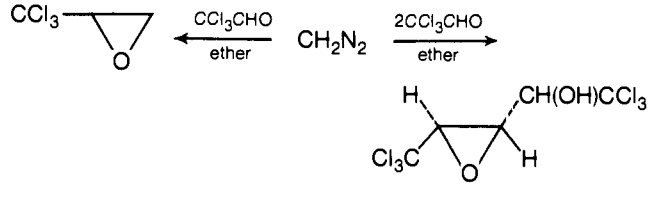
Kabbe[590] established that chloral adds 2 equiv of *tert*-butylisonitrile forming an oxacyclobutane derivative in 68% yield.



D. Interaction with Diazomethane and Diazoacetic Acid Ester

Schlotterbeck[591] has proposed that the reaction product of chloral and diazoacetic acid ester is ethyl trichloroacetoacetate. Later, he[592] isolated a compound $C_3H_3Cl_3O$ (which he characterized as *gem*-trichloroacetone) from the interaction of equimolar amounts of chloral and diazomethane in cooled ether. A little α-hydroxy-β,β,β-trichloroethylacetone (using excess of chloral) was also isolated. This result was disproved by a series of later researches.[593-595] By the action of diazomethane on chloral[593,594] or on its hydrate[595] the main product was trichloromethylethylene oxide. Besides that, Meerwein and his associates[595] detected among reaction products also chlorine, methanol, dimethyl ether, chloral dimethylacetal, and a nitrogen compound of unestablished structure.

The use 2 equiv[596] of chloral leads to a substituted trichloroethanol:



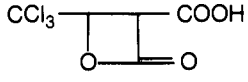
IX. Interaction with Activated C–H Bonds*

Malonic acid and its mono- and diethyl esters react with chloral with the participation of activated hydrogen atoms.[597-602]

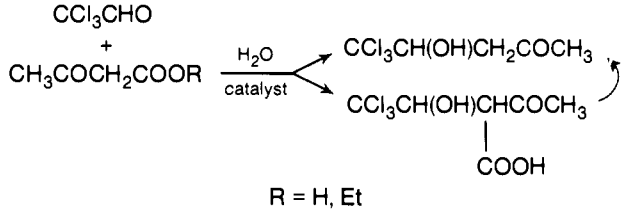
$$CCl_3CHO + CH_2(COOR)COOR' \xrightarrow[-CO_2]{pH\ 7} CCl_3CH(OH)CH_2COOR(R')$$

R, R' = H, Et

Vul'fson and Shemyakin[603,604] incorrectly assigned a β-lactone structure to the product of interaction between chloral and malonic acid:

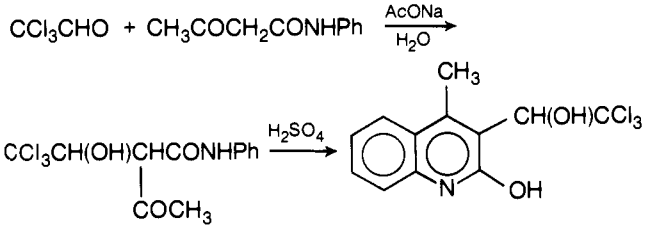


With acetoacetic acid and its esters, chloral reacts analogously in the presence of acidic or basic (pyridine) catalysts.[585,605,606] In all cases trichloroethanol (but not trichloroethane[607]) derivatives are formed, both with decarboxylation[585,605] and without it.[605,606]

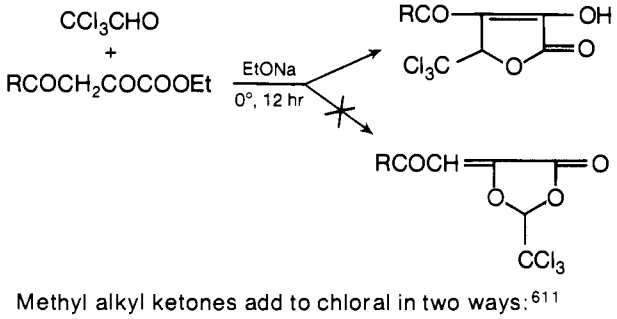


R = H, Et

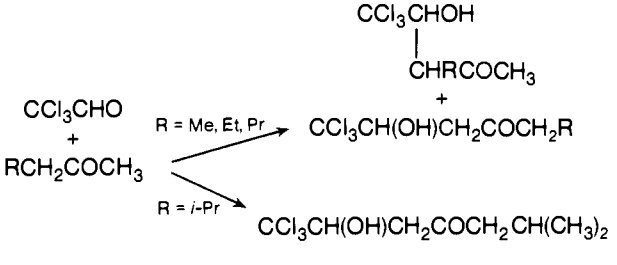
An adduct of chloral with acetoacetanilide[608] obtained in this way (in the presence of sodium acetate) may be cyclized to a quinoline derivative with acid:



The interaction between chloral and ethyl esters of ketopyruvic acid leads to a α-butyrolactone[609] (not to a ketodioxolane[610] as Bergel and associates had proposed):



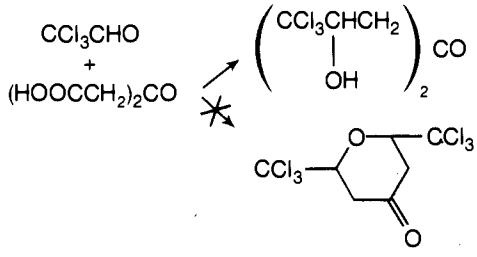
Methyl alkyl ketones add to chloral in two ways:[611]



* See also section VI.E.

Indandione is alkylated[612] in the 2 position by chloral hydrate.

Judging from its ir and NMR spectra[613] the product of the interaction of chloral with acetonedicarboxylic acid has the structure not of 4-ketopyran[614] but of a trichloroethanol derivative.

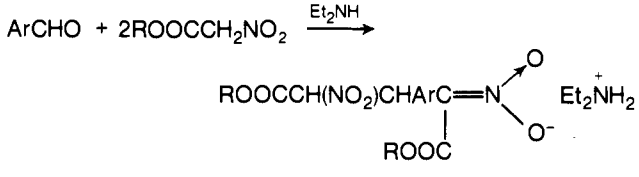


Reactions of chloral or its hydrate with aliphatic nitro compounds, as many investigators have shown,[615-623] are realized easily with basic catalysts both in water and in anhydrous media. 3,3,3-Trichloronitropropanol-2 derivatives are obtained in good yields; they can be dehydrated under more severe conditions.

$$CCl_3CHO + RCH_2NO_2 \xrightarrow{base} CCl_3CH(OH)CHRNO_2$$

R = H,[615-620] Me,[621] Et,[622] Pr,[621] COOR′,[623] and others.[622]

In contrast with chloral, other aliphatic and also aromatic aldehydes react directly to form nitro olefins.[624] In further contrast to chloral, aromatic aldehydes can react with nitroacetic acid esters[623] in the following way:



X. Stabilization, Polymerization, and Copolymerization

The high reactivity of the chloral carbonyl group as a consequence of the strongly negative inductive effect of the trichloromethyl substituent, also accounts for the low stability of monomeric chloral and for its capacity to homo- and copolymerize with other monomers (usually in the presence of ionic initiators). Chloral is kept with difficulty.

To stabilize chloral one uses formamide or dimethylformamide (0.2–1%[625]), tetraalkylthiuram disulfide and azobisisobutyronitrile (0.1–0.2%[626]).

Sulfuric,[627-629] phosphoric, and polyphosphoric[630] acids induce the formation of polychloral with several degrees of polymerization—from tetrameric (2,4,6,8-tetrakis(trichloromethyl)-1,3,5,7-tetroxane[628]) to an amorphous polyether with a molecular weight up to 25,000.[630] Chloral polymerization in the presence of aluminum chloride was patented,[631] but later[632] that catalyst was rejected as were NEt_3, Ph_3P, $AsCl_3$, MeONa, $(i\text{-}PrO)_3Al$, $Fe(CO)_5$.

Low-temperature polymerization of chloral is catalyzed by pyridine,[633] magnesium and aluminum diethylaminates,[634] some organometallic compounds (as BuLi,[635,636] Et_3Al,[632,636-639] Bu_3B,[636,638] Et_2Zn,[638-643] sodium naphthalene[644] and others[636,638,640-642]), metal alkoxides,[642,645] and also metal ketyls (compounds of Mg, Ca, and Ba with benzil, benzophenone, Michler's ketone;[646] Mn(II), Co, Mg, and Cu acetylacetonates[647]).

In the catalysis by metal ketyls, yields of polymers are decreased with an increase in temperature.[640]

A high degree of crystallinity of polychloral is achieved[638] using $MAlk_n$ (M = Mg, Zn, B, Al, Cd).

It was shown[639] by ir spectra and X-ray diffraction that polychloral, which is obtained at −78° in the presence of Et_2Zn, Et_3Al, or BuLi, has an isotactic tetragonal structure. By these methods a spiral conformation was established[648] for a polyether-alcohol obtained from chloral by several methods.

Chloral itself or its acetals are copolymerized with formaldehyde (as the monomer or as 1,3-dioxolane and 1,3,5-trioxane[649,650]) in the presence of Et_xM_y (M = Zn, Al, Cd),[632] amines, phosphines,[651] diazonium salts,[652] Lewis acids,[652-655] sulfuric acid,[655] polyphosphoric esters,[656] and other acidic catalysts.[650,657-659] Attempts to copolymerize chloral and paraformaldehyde were unsuccessful.[658,659]

At low temperatures copolymers of chloral with dichloroacetaldehyde are formed;[629,660-662] the best catalysts are compounds such as Et_2Zn. Boron trifluoride etherate initiates the copolymerization of chloral with adipaldehyde (in a 1:1 ratio).[663]

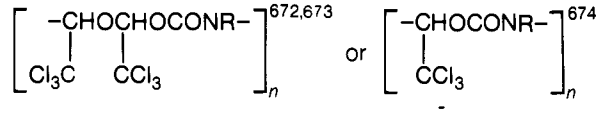
By heating at 100° with concentrated H_2SO_4,[664] a copolymer of chloral with oxetane was obtained.

Vinyl monomers are copolymerized with chloral in the presence of M_xAlk_y[665] (M = Li, Na, Be, Mg, Ca, Sr) and Lewis acids.[666] Heating (150–220°) polystyrene or polystyrene–butadiene with chloral leads to the formation of polymer, including up to 20.6% α-hydroxy-β,β,β-trichloroethyl groups.[666]

Recently the high catalytic activity of the system $CCl_3CH(OH)_2$ with Et_3Al was established for the polymerization and copolymerization of vinyl monomers[667] and acetaldehyde[668] with chloral.

On interaction with some terpenic olefins, chlorine-containing polymeric resins are formed in addition to monomer adducts (trichloroethanol derivatives).[669]

Under the influence of ionic polymerization catalysts (BuLi, BF_3) at −78° a copolymer of chloral with ketene[670] was successfully obtained. Other heterocumulenes such as isocyanates[671-674] and thionylaniline[674] are also copolymerized with chloral in the presence of anionic polymerization catalysts: BuLi, NaCN, sodium fluorene,[672,673] tertiary amines,[674] with several ratios of monomers over a large temperature interval (−90 to +60°[673,674]). The products have the structures (in case of isocyanates):



All polymers of chloral are characterized by high thermal stability, and they are fireproof.

XI. Identification

There is a series of well-established methods for identifying and detecting chloral in mixtures with other aldehydes or polyhalo compounds, used in analytic chemistry, pharmacology, and toxicology.

Among these, iodometric methods predominate: the oxidation of chloral by iodine to trichloroacetic acid in the presence of sodium thiosulfate[675-677] or hydrazine hydrochloride[678] as titrants. Several colorimetric methods[679-683] are based on specific color reactions with chloral (for example, cyanine dye formation from chloral and quinaldinium ethyl iodide and ethylamine,[681] or the cherry-color obtained on treatment of chloral with hydroxylamine hydrochloride and diaminopyridine[683]) and also on general color reactions of polyhalo compounds (with

pyridine[680] and resorcinol[682] in alkaline or acidic media); the latter obscure the detection of chloral by the named reactions in mixtures with chloroform, trichloroethanol, and so on.[684-689]

Additional color reactions for the identification of chloral include its interactions with fluoroglucine in alkaline solution,[690] with molybdenic acid and phenol,[691] with dimethylaniline,[692] with *m*-dinitrobenzene (the violet color in alkali solutions is disguised by other aldehydes[693]), with sodium nitroprusside, and with ferric chloride (violet coloration, native to all polyhalo compounds[694]). Chloral does not form a complex with cupric ethylenediaminetetraacetate[695] or a precipitate of AgCl with Ag^+.[696]

Among different methods for the analysis of chloral one may notice potentiometric titration by alkaline solution,[697] microcrystalloscopy (as *o*-, *m*-, and *p*-nitrophenylhydrazones[698]) and bichromatometric detection;[699] in the last case the error is not more than 0.15%.

In spite of the high sensitivity (up to 5×10^{-9} mol)[700] of some qualitative reactions of chloral, their low specificity in the presence of masking contaminants (which have been discussed above) requires the use of differential analytical methods for chloral in mixtures.

Elving and Bennett[701] failed to detect chloral with a polarographic method in the presence of chloro- and dichloroacetaldehydes; the investigators explained[702] that result by continuous multielectronic reduction of chloral on a dropping Hg electrode in accordance with the scheme:

$$CCl_3CH(OH)_2 \longrightarrow Cl_2CHCH(OH)_2 \longrightarrow Cl_2CHCHO \longrightarrow$$
$$ClCH_2CHO \longrightarrow CH_3CHO \longrightarrow [CH_3CH(OH)-]_2 + C_2H_5OH$$

This process is expressed by only one wave ($E_{1/2}$ = −1.4 V). In the presence of hydroxylamine sulfate in the polarographic reduction of chloral, two waves are observed[703] (−0.55 and −1.2 V), but they belong to the reduction of chloral oxime. The polarography of mixtures of chloral with other chloroacetaldehydes has been studied.[704,705]

In the presence of dichloroacetaldehyde, chloral is determined by colorimetry of a phenylhydrazone mixture,[706] or after alkaline work-up.[680,707]

Lately chromatographic methods (mainly GLC) have been used to determine chloral in the presence of polyhalo compounds (aldehydes, alcohols, chloroform, and others);[708-710] these methods are used in particular as a control in chloral production by the chlorination of ethanol.[711]

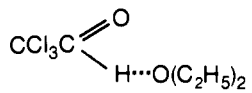
XII. Molecular Complexes with Chloral

Chloral's capacity to form molecular complexes with many compounds (especially those which are basic) is well known. So chloral hydrate gives complexes with some drugs: amidopyrine (1:1 or 2:1),[712-714] phenacetin (3:1),[715,716] antipyrine (1:1, 2:1),[717-719] salol (3:1),[715,720] quinine,[721] and others.[715,719,722-724]

In the chloral hydrate–antipyrine system,[725] the 2:1 complex was observed only at low temperatures; the 1:1 complex is more stable. According to Taboury,[718] the amino and carbonyl groups of antipyrine do not take part in its formation (based on Raman spectral investigations).

A subject for special review is the research on complexes of chloral in two- and three-component systems, made by measurements of surface tension,[726,727] viscosity,[728-739] ultrasonic velocity,[740-742] and other parameters.[743-750]

Data about the nature of the intermolecular bonding in chloral complexes are limited and contradictive. So Sandell[751] explained association between chloral and diethyl ether by a strong hydrogen bond:



but other investigators[752] have explained the same phenomenon by donor–acceptor interaction, with the chloral carbonyl group as the acceptor.

The interaction between chloral and iodine and its chloride and bromide is explained (by ir spectroscopy[753-755]) through the formation of a 1:1 charge-transfer complex.

XIII. Physical and Physical-Chemical Studies

Bond lengths and energies in chloral and its hydrate have been measured by several methods (see ref 54, 55, 64, 71, 756–758). Judging from the carbon–oxygen bond length,[756] the chloral carbonyl group has a 100% C=O double bond; it is disposed in a pyramidal plane of symmetry formed by the trichloromethyl group.[756] A molecule of chloral hydrate includes two chelate rings, formed with H···Cl hydrogen bonds (from osmometric data[54]). According to the chloral dipole moment (1.58 D,[757] 1.96 D[56]), angles in a molecule have been enlarged. The dipole moment of chloral hydrate (2.07 D in benzene and 2.65 D in dioxane;[57] the increase is due to intermolecular hydrogen bonding between chloral hydrate and dioxane) once more confirms that chloral hydrate is a *gem*-diol, and not a molecular complex with water.

There are many measurements of the Raman,[53,759-763] ir,[60-62,764,765] uv,[752,766-768] NMR,[58,59,769] NQR ^{35}Cl[770-775] spectra of chloral and its hydrate, and of their polarographic behavior.[701-705,767] It is interesting that the NQR spectrum[772] does not confirm the existence of H···Cl hydrogen bonds in the chloral hydrate molecule and that the nonequivalence of the three chlorine atoms in the trichloromethyl group is the result of a field effect.

Vapor pressure (from −20 to −240°), heat of vaporization (from −80 to +290°), heat of formation (from −80 to +1000°), heat of conduction (from −80 to +120°), viscosity (−80 to +500°), and surface tension (from −80 to +120°) of chloral are tabulated.[776]

XIV. Applications

In many pharmacopoeas chloral hydrate has been approved for many years as a hypnotic, sedative, and sleeping drug. The LD_{50} is 710 mg/kg for mice.[777] The biological activity of chloral and its hydrate has been studied in many aspects, but is outside the scope of the present review.

Besides the well-known uses of chloral—in the synthesis of dichloroacetic acid and its derivatives (syntomycine among them), vanillin, DDT, organophosphorus insecticides—there are also many others. Chloral hydrate activates the bleaching of cotton and textile.[778-780] It is used in the electroprecipitation of nickel,[781-787] for fungicidal wood protection,[788] for the detection of a series of glucosides,[789] for the detection of zinc in insulin,[790] and for the isolation of water-soluble starch[791] and amylose[792] from potato starch. Similar to actinomycin D, chloral hydrate inhibits the synthesis of ribonucleic acid and proteins: [793] it is also an inhibitor of steel, copper, and tin corrosion[794] in perchloric acid solutions.

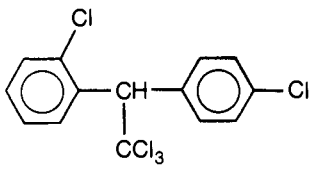
A modifying effect of chloral and its hydrate on polyenes,[795,796] polyols,[797-801] polyamides,[802-806] and also

on their high solvating capacity toward polyamide resins,[806-811] polyalkylene terephthalates,[812] and polysaccharides[813] has been found.

The behavior of chloral on radiolysis has allowed it to be used, on the one hand, as a radiopotentiator (on γ-irradiation of *Escherichia coli*[814,815]) and, on the other hand, as a radioprotector[816] and also for detection and dosimetry of γ-irradiation;[143,817-819] one can measure[820] γ-irradiation up to 30 krads at pH 5–5.5.

High catalytic activity of chloral is recorded in the polymerization of alkenes[821] and other vinyl monomers,[822] in the preparation of urea–formaldehyde plastics,[823] and in some dehydration reactions (in particular in the condensation of amines and ketones).[824-826] Chloral is an activator of a catalytic π complex in cis-stereospecific butadiene polymerization.[827-829]

Still more common is the use of chloral transformation products. Chloral hemiacetals with polyols are used for the preparation of synthetic fibers and ion-exchange resins,[188,191,204] and they also have a sedative action.[187,192] Products from the interaction between chloral and hydroxy steroids have a selective biological activity.[167,168,173] The strong oestrogenic action[830] of so called "ortho-para-DDT"



which constitutes up to 20% of crude (technical) DDT, does not except such action of the latter on warmblooded animals.

A sedative and hypnotic effect is associated with the reaction products from chloral with bromoisovalerylurea,[269] cholin,[831] betaine,[832] and carnitine.[833]

Chloral itself has a little insecticidal and herbicidal activity; "meta-chloral" is, however, a good herbicide.[834] High herbicidal properties have been exhibited by chloral adducts with amides and nitroparaffins,[835] chloral 2,4-dichlorophenoxyacetylhydrazone,[836] and some chloral mercaptals.[231,235,837]

The known pesticides, "triphan",[152] "methoxychor",[367,368] "methiochlor",[381] and *N*-(α-hydroxy-β,β,β-trichloroethyl)acetamide,[838] are also chloral derivatives. An adduct of chloral with nitromethane was patented[839] as a systemic fungicide.

Effective insecticides were synthesized from chloral and polychlorocyclopentadienes.[539] Attempts to obtain analogs of DDT with enhanced activity by introduction of a series substituents into the aromatic rings or by their replacement with heteroaromatic rings did not lead to positive results.[353,430,433,840]

Insecticides with strong activity have been obtained from phosphororganic derivatives of chloral including both trichloromethyl and dichlorovinyl groups (see ref 470, 490, 494, 495, 499, 841–844).

Nowadays chloral is used widely as a monomer for copolymerization because all its polymers have high thermal stability and fire resistance.[655,660,661,666] For these purposes one uses some other chloral derivatives, in particular those which include multiple bonds[181,845-847] and others.[848,849]

Chloral acetals with dodecylmercaptan[221] are recommended for use in butadiene–styrene rubber production.

Reaction products between chloral and benzidine or *p*-phenylenediamine[850] and also copolymers with several oxetanes[664] are good adhesive additions to resins and abrasives. *gem*-Diaryltrichloroethanes are excellent anticorrosive agents for lubricants.[851]

Chloral complexes including Fe[852,853] are used in particular[853] for dyeing of chromosomes.

To conclude, one may note that research concerning the use of chloral and its derivatives were based mainly on the properties of known model compounds.

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XV. References and Notes

(1) J. Liebig, *Justus Liebigs Ann. Chem.*, 1, 189 (1832).
(2) J. Dumas, *Ann. Chim.*, **56**, 123 (1848).
(3) Houben-Weyl, "Methoden der organischen Chemie," Vol. 7, 1st ed, Georg Thieme, Stuttgart, 1954.
(4) S. Patai, Ed., "The Chemistry of the Carbonyl Group," Interscience, London, 1966.
(5) F. Ullmann, "Enzyklopädie der technischen Chemie," Vol. 3, 2nd ed, 1929, p 232; Vol. 5, 3rd ed, 1954, p 323.
(6) H. Hirwe, *J. Univ. Bombay*, **6**, (II) 182 (1937); *Chem. Abstr.*, **32**, 2862 (1938).
(7) I. Suknevitsch and A. Tschilingarjan, *Ber.*, **68**, 1210 (1935).
(8) J. Rosin, U.S. Patent 2616929 (1952); *Chem. Abstr.*, 47, 9347 (1953).
(9) L. Coster, U.S. Patent 2669585 (1954); *Chem. Abstr.*, **49**, 3242 (1955).
(10) N. Matsuo, Japanese Patent 7519 (1951); *Chem. Abstr.*, **48**, 1421 (1954).
(11) O. Cass, U.S. Patent 2443183 (1948); *Chem. Abstr.*, **42**, 7318 (1948).
(12) O. Malhotra and B. Trivedi, *Curr. Sci. (India)*, **24**, 337 (1955).
(13) O. Malhotra, *J. Indian Chem. Soc.*, **35**, 99 (1958).
(14) J. Ghosh, S. Bhattacharyya, M. Muthanna, and R. Parikh, *Curr. Sci.*, **16**, 88 (1947).
(15) J. Ghosh, S. Bhattacharyya, M. Muthanna, and R. Parikh, *J. Sci. Ind. Res. (India)*, **118**, 371 (1952).
(16) W. Kochmann and S. Reinholz, German Patent 39799 (1965); *Chem. Abstr.*, **64**, 597 (1966).
(17) A. Brothman, U.S. Patent 2478741 (1949); *Chem. Abstr.*, 44, 1129 (1950).
(18) A. Roche and G. Engel, German Patent 955589 (1957); *Chem. Abstr.*, **53**, 13058 (1959).
(19) A. Shouten, Dutch Patent 63013 (1949); *Chem. Abstr.*, **43**, 5412 (1949).
(20) N.V. de Bataafsche Petroleum Maatschappij, British Patent 644916 (1950); *Chem. Abstr.*, **45**, 4739 (1951).
(21) E. Vail and B. Jasnitsky, USSR Patent 69720 (1947); *Chem. Abstr.*, 44, 287 (1950).
(22) A. P. Antykov, M. N. Kucherova, Ya. P. Skavinsky, Yu. V. Motzya, and Yu. A. Repik, USSR Patent 160172 (1964); *Chem. Abstr.*, **61**, 15518 (1964).
(23) A. Englin and E. Sergeev, USSR Patent 106251 (1957); *Chem. Abstr.*, **51**, 16516 (1957).
(24) W. Hagge and W. Richter, German Patent 1210781 (1966); *Chem. Abstr.*, **64**, 17427 (1966).
(25) J. Otto and B. Veldhuis, U.S. Patent 2702303 (1955); *Chem. Abstr.*, **50**, 2655 (1956).
(26) M. Shchukina, *J. Gen. Chem. (USSR)*, **18**, 1653 (1948).
(27) E. Gilbert, U.S. Patent 2697120 (1954); *Chem. Abstr.*, **50**, 396 (1956).
(28) P. Lecompte, French Patent 1038461 (1953); *Chem. Abstr.*, **52**, 9193 (1958).
(29) H. Petri and E. Mahler, German Patent 874303 (1954); *Chem. Abstr.*, **52**, 7345 (1958).
(30) Michigan Chemical Corp., U.S. Patent 2768173 (1956); *Chem. Abstr.*, **51**, 8129 (1957).
(31) F. Potts, British Patent 644914 (1950); *Chem. Abstr.*, **45**, 5176 (1951).
(32) H. Strangl and J. Schmidt, German Patent 1175218 (1964); *Chem. Abstr.*, **61**, 11894 (1964).
(33) N. Ohta and J. Imamura, *J. Chem. Soc. Jpn., Ind. Chem. Sect.*, **55**, 394 (1952).
(34) H. Guinot and J. Tabuteau, *C. R. Acad. Sci.*, **231**, 234 (1950).
(35) J. Pianfetti and D. Porter, U.S. Patent 2615048 (1952); *Chem. Abstr.*, **48**, 2763 (1954).
(36) W. Cave and G. Haddeland, U.S. Patent 2552934 (1951); *Chem. Abstr.*, **45**, 9556 (1951).
(37) J. Pianfetti and D. Porter, U.S. Patent 2615049 (1952); *Chem. Abstr.*, 47, 3869 (1953).
(38) J. Imamura, Japanese Patent 4713 (1952); *Chem. Abstr.*, 47, 11224 (1953).
(39) N. Ohta and J. Imamura, *J. Chem. Soc. Jpn., Ind. Chem. Sect.*, **56**, 528 (1953).
(40) J. Pianfetti and D. Porter, U.S. Patent 2863924 (1958); *Chem. Abstr.*, **53**, 9062 (1959).
(41) W. Stumpf, German Patent 1024952 (1958); *Chem. Abstr.*, **54**, 7563 (1960).

(42) T. Vaughn, U.S. Patent 2456545 (1958); *Chem. Abstr.*, **43**, 2632 (1949).
(43) Compagnie de produits chimiques et électrometallurgiques Alais, Froges & Camargue, French Patent 999412 (1952); *Chem. Abstr.*, **51**, 5818 (1957).
(44) J. Churchill and B. Schaeffer, U.S. Patent 2680092 (1954); *Chem. Abstr.*, **49**, 6301 (1955).
(45) E. Sergeev, A. Englin, and V. Fleishman, USSR Patent 167849 (1965); *Chem. Abstr.*, **62**, 16061 (1965).
(46) W. Smithuysen and C. Eerbeek, Dutch Patent 63012 (1949); *Chem. Abstr.*, **43**, 5412 (1949).
(47) N. Parlee, J. Dacey, and C. Coffin, *Can. J. Res., Sect. B*, **15**, 254 (1937).
(48) P. Frolich and P. Wiezevich, U.S. Patent 2042303 (1936); *Chem. Abstr.*, **30**, 4871 (1936).
(49) G. Fodor and A. Katritsky, *Chem. Ind. (London)*, 1530 (1961).
(50) H. Koch and K. Wenzel, *Atompraxis*, **13**, 256 (1967).
(51) H. Guinot, French Patent 1033574 (1953); *Chem. Abstr.*, **52**, 14655 (1958).
(52) R. Bell and A. McDondall, *Trans. Farad. Soc.*, **56**, 1281 (1960).
(53) R. Fonteyne, *Natuurw. Tijdschr. (Ghent)*, **24**, 69 (1942); *Chem. Abstr.*, **37**, 5653 (1943).
(54) B. Stehlik and A. Tkač, *Chem. Zvesti*, **3**, 164 (1949).
(55) S. Kondo and I. Nitta, *X-Sen*, **6**, 53 (1950); *Chem. Abstr.*, **45**, 3237 (1951).
(56) P. Bievre, G. v. d. Kelen, G. Cormille, and Z. Eeckhaut, *Bull. Soc. Chim. Belg.*, **68**, 550 (1959).
(57) S. Jain and S. Soundarajan, *Tetrahedron*, **20**, 1589 (1964).
(58) D. McGreer, R. Stewart, and M. Mocek, *Can. J. Chem.*, 41, 1024 (1963).
(59) E. Bishop and R. Richards, *Trans. Farad. Soc.*, **55**, 1070 (1960).
(60) M. Davies, *Trans. Farad. Soc.*, **36**, 333 (1940).
(61) N. Searle, *Diss. Abstr.*, **27**, 1866 (1966).
(62) A. Piquet and A. Jacot-Guillarmod, *Helv. Chim. Acta*, **46**, 406 (1963).
(63) S. Pathasarathy, M. Pancholy, V. Bündal, and T. Saksena, *Indian J. Pure Appl. Phys.*, 1, 137 (1963).
(64) K. Ogawa, *Bull. Chem. Soc. Jpn.*, **36**, 610 (1963).
(65) L. Gruen and P. McTigne, *J. Chem. Soc.*, 5217 1963).
(66) P. Danckwott, *Arch. Pharm.*, **280**, 197 (1942).
(67) R. Bell and D. Onwood, *Trans. Farad. Soc.*, **58**, 1557 (1962).
(68) A. Kotz, *Chem. Zentrallbl.*, II, 2136 (1909).
(69) N. Schoorl and L. v. d. Berg, *Pharm. Weekblad*, **43**, 42 (1906).
(70) Ch. Gustafsson and M. Johanson, *Acta Chem. Scand.*, **2**, 42 (1948).
(71) H. Pritchard and H. Skinner, *J. Chem. Soc.*, 1928 (1950).
(72) N. Tuchel, V. Antonescu, V. Gheorghe, L. Necula, and St. Moisescu, *Farmacia (Bucharest)*, **9**, 205 (1961).
(73) Ch. Moureu, Ch. Dufraisse, and G. Berchet, *Bull. Soc. Chim. Fr.*, **43**, 942 (1928).
(74) W. Alexander and H. Schumacher, *Z. Phys. Chem.*, 44, 313 (1939).
(75) V. Aurich and K. Schnegerl, *Entropie*, **30**, 120 (1969).
(76) H. Gelissen, German Patent 480362 (1929); *Chem. Zentrallbl.*, II, 2831 (1929).
(77) H. Wieland and D. Richter, *Justus Liebigs Ann. Chem.*, **495**, 284 (1932).
(78) A. Baeyer and V. Villiger, *Ber.*, **33**, 2481 (1900).
(79) A. Shreibert, E. Kozlov, and A. Khardin, *Zh. Prikl. Khim. (Leningrad)*, 41, 2323 (1968).
(80) A. Popova, A. Khardin, and I. Shreibert, *Mat. Nauch. Konf. Sov. Nar. Khoz. Nizhne. Volzh. Ekon. Raiona, Volgograd.*, N 2, 18 (1965); *Chem. Abstr.*, **66**, 85409 (1967).
(81) A. Stadeler, *Justus Liebigs Ann. Chem.*, **61**, 104, 106, 253 (1847).
(82) A. Kekule, *Justus Liebigs Ann. Chem.*, **105**, 293 (1858).
(83) O. Wallach, *Justus Liebigs Ann. Chem.*, **193**, 5, 12 (1878).
(84) J. Grabowski, *Ber.*, **6**, 225 (1873).
(85) J. Grabowski, *Ber.*, **6**, 1070 (1873).
(86) D. Amato, *Jahresber.*, 473 (1875).
(87) H. Kolbe, *Justus Liebigs Ann. Chem.*, **54**, 183 (1845).
(88) O. Leminger, M. Farsky, and J. Vacha, *Chem. Prumysl.*, **13**, 454 (1963).
(89) Z. Biernacki, S. Jerzak, and T. Ostrowski, Polish Patent 46841 (1963); *Chem. Abstr.*, **61**, 4222 (1964).
(90) J. Gaathaug, French Patent 791159 (1935); *Chem. Abstr.*, **30**, 2990 (1936).
(91) J. Gaathaug, German Patent 614101 (1935); *Chem. Abstr.*, **29**, 5995 (1935).
(92) F. Verhoek, *Trans. Farad. Soc.*, **31**, 1521 (1935).
(93) C. Hinshelwood, C. Fletcher, F. Verhoek, and C. Winkler, *Proc. Roy. Soc. London*, **146**, 327 (1934).
(94) W. Alexander and H. Schumacher, *Z. Phys. Chem.*, 44, 57 (1939).
(95) B. Yasnitskii, E. Dol'berg, and Yu. Aronov, *Zh. Org. Khim.*, 1, 448 (1965).
(96) H. Gautier, *Bull. Soc. Chim. Fr.*, [2] **45**, 87 (1886).
(97) A. Mouneyrat, *Bull. Soc. Chim. Fr.*, [3] 17, 794, 796 (1897).
(98) H. Klug and H. Schumacher, *Z. Phys. Chem.*, 47, 67 (1940).
(99) J. Stauff and H. Schumacher, *Z. Phys. Chem.*, **48**, 154 (1941).
(100) A. Oglialoro, *Ber.*, 7, 1461 (1874).
(101) A. Kappana and B. Ramchandra, *J. Indian Chem. Soc.*, **27**, 91 (1950).
(102) C. Seubert, *Ber.*, **18**, 3337 (1885).
(103) K. Fuchs and E. Katscher, *Ber.*, **62**, 2381 (1929).
(104) E. Paterno, *Justus Liebigs Ann. Chem.*, **151**, 116 (1869).
(105) A. Mouneyrat, *Bull. Soc. Chim. Fr.*, [3] **19**, 260 (1898).
(106) F. Klages, H. Träger, and E. Mühlbauer, *Chem. Ber.*, **92**, 1819 (1959).
(107) E. Paterno and A. Oglialoro, *Ber.*, **7**, 81 (1874).
(108) H. Brown, H. Schlesinger, and A. Burg, *J. Am. Chem. Soc.*, **61**, 673 (1939).
(109) M. Frazer, W. Gerard, and M. Lappert, *J. Chem. Soc.*, 739 (1957).
(110) R. Plump, U.S. Patent 2443118 (1948); *Chem. Abstr.*, **42**, 7320 (1948).
(111) L. Taylor and F. Morris, British Patent 649123 (1951); *Chem. Abstr.*, **46**, 1028 (1952).
(112) M. Rangaswamy and M. Santappa, *Acta Chim. Acad. Sci. Hung.*, **56**, 413 (1968).
(113) Wacker-Chemie G.m.b.H., French Patent 1396906 (1965); *Chem. Abstr.*, **64**, 1964 (1966).
(114) C.-Y. Tseng, *Chemistry (Taiwan)*, 333 (1955); *Chem. Abstr.*, **50**, 9671 (1956).
(115) J. Roček, *Tetrahedron Lett.*, N5, 1 (1959).
(116) J. Bespalova, M. Fioshin, and V. Smirnov, *Electrochimiya (USSR)*, **8**, 157 (1972).
(117) C. Sandonnini and V. Borghello, *Atti Accad. Lincei*, **21**, 30 (1935).
(118) C. Sandonnini and V. Borghello, *Atti Accad. Lincei*, **20**, 334 (1934).
(119) G. Deodhar, *J. Indian Chem. Soc.*, 11, 83 (1934).
(120) J. Perzonne, *Justus Liebigs Ann. Chem.*, **157**, 113 (1871).
(121) S. Cotton, *Bull. Soc. Chim. Fr.*, [2] **42**, 622 (1884).
(122) H. Lux, D. Sarre, and J. Schaffelhofer, *Chem. Ber.*, **97**, 2301 (1964).
(123) E. Davy, *Jahresber. Pharm.*, 473 (1875).
(124) D. Amato, *Jahresber. Pharm.*, 471 (1875).
(125) D. Vorländer, *Justus Liebigs Ann. Chem.*, **341**, 22 (1905).
(126) H. Kunz-Krause and P. Manicke, *Ber. Deut. Pharm. Ges.*, **31**, 235, 238, 344 (1921).
(127) B. Teichmann, *J. Prakt. Chem.*, **29**, 51 (1965).
(128) G. Hesse and H. Jäger, *Chem. Ber.*, **92**, 2022 (1959).
(129) H. Kautsky, H. Keck, and H. Kunze, *Z. Naturforsch. B.*, **9**, 165 (1954).
(130) V. Tishchenko and A. Grigor'ev, *Zh. Russ. Fiz.-Khim. Obshchestva*, **38**, 482 (1906); *Chem. Zentrallbl.*, II, 1554 (1906).
(131) T. Saegusa and T. Ueshima, *J. Org. Chem.*, **33**, 3310 (1968).
(132) T. Saegusa, T. Ueshima, K. Kauchi, and S. Kitagawa, *J. Org. Chem.*, **33**, 3657 (1968).
(133) H. Meerwein, G. Hinz, H. Maiert, and H. Sönke, *J. Prakt. Chem.*, **147**, 226 (1936).
(134) R. Dworzak, *Monatsh. Chem.*, 47, 11 (1926).
(135) H. Meerwein and R. Schmidt, *Justus Liebigs Ann. Chem.*, 444, 234 (1925).
(136) R. Nakai, *Biochem. Z.*, **152**, 272 (1924).
(137) J. Lin and A. Day, *J. Am. Chem. Soc.*, 74, 5133 (1952).
(138) H. Meerwein and R. Schmidt, *Justus Liebigs Ann. Chem.*, 444, 238 (1925).
(139) F. Villani and F. Nord, *J. Am. Chem. Soc.*, **69**, 2605 (1947).
(140) D. Dittmer and R. Fouty, *J. Am. Chem. Soc.*, **86**, 91 (1964).
(141) H. Andrews anP. Shore, *J. Chem. Phys.*, **18**, 1165 (1950).
(142) R. Murphy and E. Le Brum, *Rev. Sci. Instrum.*, **28**, 329 (1957).
(143) R. Platford and J. Spinks, *Can. J. Chem.*, **37**, 1022 (1959).
(144) G. Freeman, A. v. Cleave, and J. Spinks, *Can. J. Chem.*, **32**, 322 (1954).
(145) R. Woods and J. Spinks, *Can. J. Chem.*, **38**, 77 (1960).
(146) R. McIntosh, R. Eager, and J. Spinks, *Can. J. Chem.*, **43**, 3490 (1965).
(147) R. McIntosh, R. Eager, and J. Spinks, *Can. J. Chem.*, **42**, 2033 (1964).
(148) K. Sugimoto and S. Musha, *Bull. Univ. Osaka Prefect., Ser. A*, 11, 67 (1962); *Chem. Abstr.*, **58**, 4073 (1963).
(149) A. Lotz and K. Schmidt, *Biophysik*, 1, 96 (1963).
(150) A. Lotz and K. Schmidt, *Nature (London)*, **201**, 493 (1964).
(151) Sh. Okabe, K. Tsumori, and K. Surimoto, *Annu. Rep. Radiat. Cent. Osaka Prefect.*, 4, 65 (1963); *Chem. Abstr.*, **62**, 3624 (1965).
(152) Sh. Mamedov and G. Lerner, *Azerb. Khim. Zh.*, 87 (1961).
(153) Sh. Mamedov and G. Lerner, *Zh. Obshch. Khim.*, **32**, 403 (1962).
(154) Sh. Mamedov and F. Gadzhi-zade, *Dokl. Akad. Nauk Arm. SSR*, **17**, 203 (1961).
(155) V. Dovlatyan and D. Kostanyan, *Arm. Khim. Zh.*, **19**, 59 (1966).
(156) Sh. Mamedov and G. Lerner, USSR Patent 121121 (1959); *Chem. Abstr.*, **54**, 3844 (1960).
(157) R. Boejensen, *Acta Chem. Scand.*, **17**, 1463 (1963).
(158) R. Jensen and E. Munksgaard, *Acta Chem. Scand.*, **23**, 79 (1969).
(159) R. Jensen and S. Pedersen, *Acta Chem. Scand.*, **25**, 2894 (1971).
(160) R. Jensen and E. Munksgaard, *Acta Chem. Scand.*, **18**, 1896 (1964).
(161) R. Jensen, *Acta Chem. Scand.*, **22**, 2050 (1968).
(162) Neth. Appl. 6614085 (1967); *Chem. Abstr.*, **67**, 63753 (1967).
(163) T. Summerford and F. Maier-Cronic, *J. Am. Chem. Soc.*, 70, 448 (1948).
(164) K. Abildgaard, British Patent 924014 (1963); *Chem. Abstr.*, **61**, 4426 (1964).
(165) K. Abildgaard, British Patent 920750 (1963); *Chem. Abstr.*, **61**, 3172 (1964).
(166) P. Borrevang, U.S. Patent 2933514 (1960); *Chem. Abstr.*, **54**, 17480 (1966).
(167) R. Huettenrauch, German Patent 32971 (1964); *Chem. Abstr.*, **63**, 11029 (1965).
(168) P. Borrevang, German Patent 1114488 (1961); *Chem. Abstr.*, **57**, 5985 (1962).
(169) P. Borrevang, *Acta Chem. Scand.*, **16**, 883 (1962).
(170) R. Huettenrauch, *Arch. Pharm.*, **297**, 124 (1964).

(171) P. Borrevang, U.S. Patent 3132163 (1964); *Chem. Abstr.*, **61**, 8381 (1964).
(172) P. Borrevang, U.S. Patent 3096328 (1963); *Chem. Abstr.*, **61**, 4426 (1964).
(173) C. Stefens, U.S. Patent 2974167 (1961); *Chem. Abstr.*, **55**, 18022 (1961).
(174) J. Fried, U.S. Patent 2941997 (1960); *Chem. Abstr.*, **54**, 19771 (1960).
(175) J. Fried, U.S. Patent 3197469 (1965); *Chem. Abstr.*, **64**, 2145 (1966).
(176) E. Montignie, *Bull. Soc. Chim. Fr.*, [4] **47**, 1323 (1930).
(177) I. Shichiev, B. Gusein-zade, M. Kulibekov, and B. Yusufov, *Uch. Zap. Azerb. Gos. Univ., Ser. Khim. Nauk*, 19 (1964); *Ref. Zh. Khim.*, 5Zh76 (1965).
(178) G. Mast and F. Anderson, U.S. Patent 2657241 (1953); *Chem. Abstr.*, **48**, 12168 (1954).
(179) M. Shostakovskii, A. Atavin, G. Lenskich, R. Prelovskaja, and E. Kozicina, *Dokl. Akad. Nauk SSSR*, **175**, 375 (1967).
(180) M. Shostakovskii, A. Atavin, M. Al'pert, and G. Lenskich, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1113 (1965).
(181) I. Shichiev, B. Yusufov, and B. Gusein-zade in "Sintez i prevrashchenija monomernych soedinenii," Baku, 1967, p 179.
(182) G. Frankforter and A. Mayo, *J. Am. Chem. Soc.*, **21**, 471 (1899).
(183) J. van Alphen and G. Drost, *Recl. Trav. Chim. Pays-Bas*, **67**, 82 (1948).
(184) German Patent 66877 (1893); *Chem. Zentrallbl.*, 452 (1893).
(185) R. Roberts, J. Corse, R. Boschan, D. Seymour, and S. Winstein, *J. Am. Chem. Soc.*, **80**, 1247 (1958).
(186) Danske Medicinal Kemikalie-Kompagni Aktieselskab, Danish Patent 86631 (1959); *Chem. Abstr.*, **53**, 14943 (1959).
(187) W. Bruce, U.S. Patent 2784237 (1957); *Chem. Abstr.*, **51**, 12133 (1957).
(188) J. R. Geigy A.-G., Neth. Appl. 6601476 (1966); *Chem. Abstr.*, **65**, 18790 (1966).
(189) H. Byasson, *Jahresber. Pharm.*, 441 (1872).
(190) T. Shachtachtinskii and L. Andreev, *Dokl. Akad. Nauk Azerb. SSR*, **18**, N 12, 17 (1962).
(191) F. Sexsmith, U.S. Patent 3100135 (1963); *Chem. Abstr.*, **59**, 8933 (1963).
(192) American Home Products Corp., British Patent 768778 (1957); *Chem. Abstr.*, **51**, 15555 (1957).
(193) A. Hefter, *Ber.*, **22**, 1050 (1889).
(194) M. Hanriot and Ch. Richet, *C. R. Acad. Sci.*, **117**, 736 (1893).
(195) M. Hanriot, *Ann. Chim.*, [8] **18**, 477, 497 (1909).
(196) A. Petit and M. Polonovski, *Ann. Chim.*, [3] 11, 132 (1894).
(197) H. Coles, L. Goodhue, and R. Hixon, *J. Am. Chem. Soc.*, **51**, 519 (1929).
(198) A. White and R. Hixon, *J. Am. Chem. Soc.*, **55**, 2439 (1933).
(199) C. Oprisin and F. Dansin, *Acad. Repub. Pop. Rom., Stud. Cercet. Stiint.*, **3**, 345 (1952); *Chem. Abstr.*, **50**, 11247 (1956).
(200) A. Borovansky and A. Sekera, Czech Patent 85596 (1956); *Chem. Abstr.*, **52**, 2902 (1958).
(201) U. Mixtais, V. Zirulis, and L. Yakobson, USSR Patent 287918 (1971); *Ref. Zh. Khim.*, 21N340P (1971).
(202) R. Tislow and W. Bruce, U.S. Patent 2784180 (1957); *Chem. Abstr.*, **51**, 13913 (1957).
(203) K. Meyer and C.-P. Feng, *Chem. Ber.*, **85**, 590 (1952).
(204) A. Maximov, Yu. Kharit, L. Wolf, and A. Meos, *Zh. Prikl. Khim.*, **38**, 1638 (1965).
(205) F. Sexsmith, U.S. Patent 3085910 (1963); *Chem. Abstr.*, **59**, 1816 (1963).
(206) H. Dietrich and J. Karabinos, *J. Org. Chem.*, **31**, 1127 (1966).
(207) Haco Gesellschaft A.-G., Swiss Patent 267813 (1950); *Chem. Abstr.*, **45**, 7140 (1951).
(208) O. Wallach, *Justus Liebigs Ann. Chem.*, **193**, 42 (1878).
(209) E. Vinkler and E. Bõresek, *Acta Univ. Szeged., Acta Phys. Chem.*, 1, 70 (1942); *Chem. Abstr.*, **42**, 1192 (1948).
(210) N. Shah and R. Alimchandani, *J. Univ. Bombay*, **5**, 132 (1936).
(211) F. Yorston, *Recl. Trav. Chim. Pays-Bas*, **46**, 711 (1927).
(212) J. Kaupp, E. Hambsch, and E. Welte, German Patent 1059710 (1959); *Chem. Abstr.*, **55**, 9772 (1961).
(213) M. Baron and D. Hollis, *Recl. Trav. Chim. Pays-Bas*, **84**, 1109 (1965).
(214) M. Baron and D. Hollis, *Bol. Soc. Quim. Peru*, **31**, 19 (1965).
(215) L. Chia and H. Huang, *J. Chem. Soc. B*, 1369 (1968).
(216) E. Fourneau and M. Brygowna, *Bull. Soc. Chim. Fr.*, **43**, 1023 (1928).
(217) J. Harris, *J. Org. Chem.*, **30**, 2190 (1965).
(218) F. Feher and G. Winkhaus, *Chem. Ber.*, **91**, 217 (1958).
(219) F. Chattaway and E. Kellett, *J. Chem. Soc.*, 2968 (1929).
(220) W. Schulze, G. Short, and W. Cronch, *Ind. Eng. Chem.*, **42**, 916 (1950).
(221) R. Frank, S. Drake, P. Smith, and C. Stevens, *J. Polym. Sci.*, **3**, 50 (1948).
(222) I. Johnes and R. Hixon, *J. Am. Chem. Soc.*, **56**, 1333 (1934).
(223) A. Kuliev and A. Aliev, *Azerb. Khim. Zh.*, N 5, 18 (1966).
(224) A. Kuliev, E. Usubova, and A. Aliev, *Azerb. Khim. Zh.*, 77 (1966).
(225) A. M. Kuliev and A. V. Kuliev, *Azerb. Khim. Zh.*, N 1, 28 (1965).
(226) G. Schrader, German Patent 1063152 (1959); *Chem. Abstr.*, **55**, 13378 (1961).
(227) I. Kh. Feldman and T. Gurevich, *Zh. Obshch. Khim.*, **21**, 1656 (1951).
(228) A. Luttringhaus and H. Prinzbach, *Justus Liebigs Ann. Chem.*, **610**, 33 (1957).
(229) A. Bistrzycki and B. Brenken, *Helv. Chim. Acta*, **3**, 455 (1920).
(230) F. Asinger, M. Thiel, and G. Esser, *Justus Liebigs Ann. Chem.*, **610**, 33 (1957).
(231) R. Bimber, U.S. Patent 3001860 (1961); *Chem. Abstr.*, **56**, 13229 (1962).
(232) W. Schäffer, M. Zimmermann, and R. Wegler, German Patent 943484 (1956); *Chem. Abstr.*, **52**, 21047 (1958).
(233) Gosudarstvennaya Pharmacopeya USSR, Ed. X, p 183.
(234) I. Lauder and S. Wright, *Nature (London)*, **158**, 381 (1946).
(235) B. Kluger, *J. Org. Chem.*, **29**, 2045 (1964).
(236) A. N. Nesmeyanov, K. A. Pecherskaya, and G. Ya. Uretskaya, *Izv. Akad. Nauk USSR, Otd. Khim. Nauk*, 240 (1948).
(237) E. I. du Pont de Nemours, Neth. Appl. 6508807 (1966); *Chem. Abstr.*, **64**, 17427 (1966).
(238) E. Pfeil, H. Stache, and F. Lömker, *Justus Liebigs Ann. Chem.*, **623**, 74 (1959).
(239) F. Luknitskii, D. Taube, and B. Vovsi, *Zh. Org. Khim.*, **5**, 1358 (1969).
(240) E. Poziomek, *J. Org. Chem.*, **28**, 243 (1963).
(241) F. Blicke and C.-J. Lu, *J. Am. Chem. Soc.*, **74**, 3933 (1952).
(242) E. Merck, Chemische Fabrik, German Patent 334555 (1921); *Chem. Zentrallbl.*, II, 1020 (1921).
(243) L. Yang and P.-F. Hu, *J. Chin. Chem. Soc.*, **20**, 190 (1943); *Chem. Abstr.*, **38**, 3187 (1944).
(244) A. Hoffmann, *Ber.*, **5**, 247 (1872).
(245) E. Hardegger and H. Ott, *Helv. Chim. Acta*, **37**, 685 (1954).
(246) G. Smith, M. Silver, and E. Becker, *J. Am. Chem. Soc.*, **70**, 4254 (1948).
(247) S. Dorman, U.S. Patent 2468493 (1949); *Chem. Abstr.*, **43**, 7499 (1949).
(248) S. Dorman, U.S. Patent 2468592 (1949); *Chem. Abstr.*, **43**, 5154 (1948).
(249) D. Borrmann and R. Wegler, *Chem. Ber.*, 100, 1814 (1967).
(250) E. Blanck, German Patent 527713 (1929); *Chem. Abstr.*, **25**, 5177 (1931).
(251) W. Summerford and D. Dalton, *J. Org. Chem.*, **9**, 81 (1944).
(252) F. Luknitskii and D. Taube, *Zh. Org. Khim.* **8**, 427 (1972).
(253) R. Weiss and L. Chledowski, *Monatsh. Chem.*, **65**, 357 (1935).
(254) P. Papini and M. Manganelli, *Gazz. Chim. Ital.*, **80**, 855 (1950).
(255) A. Kretov and G. Tikhonova, *Zh. Obshch. Khim.*, **34**, 2428 (1964).
(256) D. Cosulich, U.S. Patent 2694065 (1954); *Chem. Abstr.*, **50**, 5041 (1956).
(257) A. Davis and A. Levy, *J. Chem. Soc.*, 3479 (1951).
(258) E. Dane, R. Heiss, and H. Schäfer, *Angew. Chem.*, 71, 339 (1959).
(259) E. Dane, R. Heiss, and H. Schäfer, German Patent 1079648 (1960); *Chem. Abstr.*, **55**, 25784 (1961).
(260) E. Naegeli, *Ber.*, **19**, 499 (1886).
(261) V. Mayer, *Justus Liebigs Ann. Chem.*, **264**, 119 (1891).
(262) A. Hantzsch, *Ber.*, **25**, 702 (1892).
(263) A. Hantzsch, *Ber.*, **25**, 708 (1892).
(264) H. Brintzinger and R. Titzmann, *Chem. Ber.*, **85**, 344 (1952).
(265) Ch. Tieman and M. Legator, U.S. Patent 3169989 (1965); *Chem. Abstr.*, **62**, 11691 (1965).
(266) F. Luknitskii and B. Vovsi, *Zh. Org. Khim.*, **4**, 2055 (1968).
(267) J. Reinhardt, R. Metzer, and J. King, *J. Am. Pharm. Assoc.*, **46**, 359 (1957).
(268) G. Vasilev, *Farmatsiya (Sofia)*, **13**, 40 (1963).
(269) E. Blanck, German Patent 572358 (1929); *Chem. Abstr.*, **27**, 3036 (1933).
(270) S. Gaitandjiev, *C. R. Acad. Bulg. Sci.*, **16**, 45 (1963).
(271) F. Chattaway, G. Kerr, and C. Lawrence, *J. Chem. Soc.*, 30 (1933).
(272) F. Chattaway and E. James, *Proc. Roy. Soc. London*, **134**, 372 (1931).
(273) A. Meldrum and G. Deodhar, *J. Indian Chem. Soc.*, 11, 529 (1934).
(274) F. Chattaway and E. James, *J. Chem. Soc.*, 109 (1934).
(275) A. Boucherle, G. Carraz, and J. Vigier, *Bull. Trav. Soc. Pharm. (Lyon)*, 10, 3 (1966); *Chem. Abstr.*, **67**, 11154 (1967).
(276) J. Decombe and M. Pretot, *C. R. Acad. Sci.*, **239**, 1502 (1954).
(277) B. Drach, A. Sinitsa, and A. Kirsanev, *Zh. Obshch. Khim.* **39**, 1480, 2192 (1969).
(278) G. Rodighiero, *Gazz. Chim. Ital.*, **81**, 80 (1951).
(279) G. Oddo and E. Deleo, *Ber.*, **69**, 294 (1936).
(280) L. Cambi, *Ber.*, **69**, 2027 (1936).
(281) V. Markov and D. Danileiko, USSR Patent 272304 (1970); *Ref. Zh. Khim.*, 11N351P (1970).
(282) G. Knöpfer, *Monatsh.*, 41, 455 (1920).
(283) G. Knopfer, *Monatsh.*, **34**, 773 (1913).
(284) C. Yannios, A. Hazy, and J. Karabinos, *J. Org. Chem.*, **33**, 2076 (1968).
(285) F. Chattaway and T. Browne, *J. Chem. Soc.*, 1088 (1931).
(286) C. Torres and S. Brosa, *An. Soc. Esp. Fis. Quim.*, **32**, 509 (1934); *Chem. Abstr.*, **28**, 6104 (1934).
(287) S. Rabassa, *Rev. Acad. Cienc. Madrid*, **31**, 417 (1934).
(288) F. Roduta and G. Quibilan, *Rev. Filipina Med. Farm.*, **27**, 123 (1936); *Chem. Abstr.*, **31**, 98 (1937).
(289) C. Crane, J. Forrest, O. Stephenson, and W. Waters, *J. Chem. Soc.*, 827 (1946).
(290) A. Ross and R. Ring, *J. Org. Chem.*, **26**, 579 (1961).
(291) R. Holbrook, U.S. Patent 2970941 (1961); *Chem. Abstr.*, **55**, 11747 (1961).
(292) A. Stepanov and A. Kuzin, *Ber.*, **65**, 1239 (1932).
(293) C. Torres and B. Oller, *An. Fis. Quim.*, 40, 825 (1944); *Chem. Abstr.*, **43**, 1324 (1949).
(294) H. Stroh and G. Liepelt, *Z. Chem.*, 7, 230 (1967).
(295) B. Adarwal and C. Haksar, *Vikram*, **2**, 30 (1958); *Chem. Abstr.*,

54, 4481 (1960).
(296) Sh. Ozawa, *Kyoto Daigaku Kekkaku Kenkyusho Nempo*, 4, 284 (1956); *Chem. Abstr.*, **51**, 5898 (1957).
(297) Sh. Avramovici, *An. Stiint. Univ. "Al. I. Cuza", Iasi, Sect. 1*, 1, 315 (1955); *Chem. Abstr.*, **51**, 1054 (1957).
(298) N. Turkevich and E. Vladzimirskaya, *Zh. Obshch. Khim.*, **28**, 1205 (1958).
(299) P. Chang and T. Ulbricht, *J. Am. Chem. Soc.*, **80**, 976 (1958).
(300) T. Kametani and O. Umezawa, *Chem. Pharm. Bull.*, **12**, 379 (1964).
(301) T. Kametani and O. Umezawa, *Yakugaku Zasshi*, **85**, 518 (1965); *Chem. Abstr.*, **63**, 6959 (1965).
(302) T. Kametani, S. Takano, O. Umezawa, H. Agai, K. Kanno, Y. Konno, F. Sato, H. Nemoto, and K. Yamaki, *Yakugaku Zasshi*, **86**, 823 (1966); *Chem. Abstr.*, **65**, 20093 (1966).
(303) T. Kametani and O. Umezawa, *Chem. Pharm. Bull.*, 14, 369 (1966).
(304) R. Shriner and R. Fuson, "The Systematic Identification of Organic Compounds. A Laboratory Manual," 3rd ed, Wiley, London, 1948; Russian Edition: Moskwa, 1950, p 225.
(305) "Slovar' Organicheskikh Soedinenii," Moskwa, "IL," 1949, 1, p 418 (English edition: "Dictionary of Organic Compounds").
(306) O. Wallach, *Justus Liebigs Ann. Chem.*, **173**, 288 (1874).
(307) O. Wallach, *Justus Liebigs Ann. Chem.*, **173**, 295 (1874).
(308) B. Heywood, British Patent 692265 (1953); *Chem. Abstr.*, **48**, 8260 (1954).
(309) I. Khaskin, *Ukr. Khim. Zh.*, **26**, 740 (1960).
(310) I. Khaskin and A. Stolper, *Zh. Org. Khim.*, 4, 1394 (1968).
(311) V. Frantzen and L. Fikentscher, *Justus Liebigs Ann. Chem.*, **623**, 68 (1959); **613**, 1 (1958).
(312) A. Kötz, *J. Prakt. Chem.*, **88**, 531 (1913).
(313) A. Pinner, *Ber.*, 17, 1997 (1884).
(314) M. Delepine, *Bull. Soc. Chim. Fr.*, **45**, 827 (1929).
(315) F. Francis and O. Davis, *J. Chem. Soc.*, 407 (1909). In a later edition the authors have renounced that viewpoint and agree that cyanide ion plays a catalytic function.
(316) W. Cocker, A. Lapworth, and A. Peters, *J. Chem. Soc.*, 1382 (1931).
(317) D. Cram and G. Hammond, "Organic Chemistry," McGraw-Hill, New York, N.Y., 1959, p 255.
(318) E. Müller, "Neuere Anschauungen der organischen Chemie fur Fortgeschrittene," 2nd ed, Springer, Berlin, 1957; Russian Edition: "Novye vozzreniya v organicheskii khimii," Moskwa, "IL," 1960, p 367.
(319) C. Rosenblum, C. Taverna, and N. Wendler, *Chem. Ind. (London)*, 718 (1960).
(320) F. Chattaway and H. Irving, *J. Chem. Soc.*, 1038 (1929).
(321) O. Bayer in ref 3, p 330.
(322) A. Bayer, *Ber.*, **5**, 25 (1872).
(323) O. Fischer, *Ber.*, 7, 1190 (1874).
(324) S. Cristol, R. Hayes, and H. Haller, *J. Am. Chem. Soc.*, **68**, 913 (1946).
(325) K. Elbs, *J. Prakt. Chem.*, [2] **39**, 300 (1889).
(326) G. Hennion and J. Walsh, *J. Am. Chem. Soc.* 70, 866 (1948).
(327) H. Wild, *Helv. Chim. Acta*, **29**, 497 (1946).
(328) F. Chattaway and R. Muir, *J. Chem. Soc.*, 701 (1934).
(329) H. Blitz, *Ber.*, **26**, 1952 (1893); **38**, 203 (1905).
(330) G. Frankforter and W. Kritchevsky, *J. Am. Chem. Soc.*, **36**, 1511 (1914).
(331) M. v. Laer, *Bull. Soc. Chim. Belg.*, **28**, 346 (1919).
(332) C. Musante and P. Giraldi, *Gazz. Chim. Ital.*, **78**, 662 (1948).
(333) P. Giraldi and C. Musante, *Gazz. Chim. Ital.*, **93**, 1623 (1963).
(334) G. Frankforter and W. Kritchevsky, *J. Am. Chem. Soc.*, **36**, 1518 (1914).
(335) R. Quelet, C. Borgel, and R. Durand, *C. R. Acad. Sci.*, 240, 1900 (1955).
(336) C. Broquet-Borgel, *Ann. Chim.*, [13] **3**, 204 (1958).
(337) W. Reeve, J. Hoffsommer, and P. Aluotto, *Can. J. Chem.*, **46**, 2233 (1968).
(338) M. Yasue and Y. Takai, *Yakugaku Tasshi*, 77, 829 (1957); *Chem. Abstr.*, **52**, 116 (1957).
(339) W. Cook, K. Cook, and W. Rueggeberg, *Ind. Eng. Chem.*, **31**, 868, 683 (1947).
(340) T. Eastwood, D. Garmaise, D. Morantz, and C. Winkler, *Can. J. Res., Sect. B*, **25**, 509 (1947).
(341) H. Bradlow and C. v. d. Werf, *J. Am. Chem. Soc.*, **69**, 662 (1947).
(342) R. Cross, U.S. Patent 2581174 (1952); *Chem. Abstr.*, **46**, 4165 (1952).
(343) I. Balaban and F. Sutcliffe, British Patent 603685 (1948); *Chem. Abstr.*, **42**, 9063 (1948).
(344) O. Gottlieb and T. Morais, *Rev. Quim. Ind. (Rio de Janeiro)*, **15**, N 173, 21 (1946); *Chem. Abstr.*, 41, 2715 (1947).
(345) H. Murai, *J. Agric. Chem. Soc. Jpn.*, **23**, 35 (1949).
(346) T. Castonquay and R. Ferm, *Trans. Kansas Acad. Sci.*, **49**, 433 (1947).
(347) G. Gladden and W. Cocker, British Patent 580224 (1946); *Chem. Abstr.*, 41, 2084 (1947).
(348) M. Shchukina, A. Berlin, and E. Sazonova, USSR Patent 66326 (1946); *Chem. Abstr.*, 41, 2084 (1947).
(349) J. Giral and M. Rangel, *Bol. Inst. Invest. Cient., Univ. Nuevo Leon*, 205 (1945); *Chem. Abstr.*, 41, 2715 (1947).
(350) H. Mosher, M. Cannon, E. Conroy, R. v. Strien, and D. Spalding, *Ind. Eng. Chem.*, **38**, 916 (1946).
(351) J. Simons, J. Bacon, C. Bradley, J. Cassaday, E. Hoegberg, and P. Tarrant, *J. Am. Chem. Soc.*, **68**, 1613 (1946).
(352) H. Haller, P. Bartlett, N. Drake, M. Newman, S. Cristol, Ch. Eaker, R. Hayes, G. Kilmer, B. Magerlein, G. Mueller, A. Schneider, and W. Wheatby, *J. Am. Chem. Soc.*, **67**, 1591 (1945).
(353) J. R. Geigy A.-G., Swiss Patent 226180 (1943); 232483 (1944); *Chem. Abstr.*, **43**, 6358 (1949).
(354) S. Ryklis and C. Shein, *Zh. Prikl. Khim.*, **31**, 1114 (1958).
(355) C. Musante and V. Parrini, *Farmaco, Ed. Sci.*, **15**, 583 (1960).
(356) V. Ettel and J. Weichet, *Collect. Czech. Chem. Commun.*, **15**, 520 (1950).
(357) J. Bhattacharyya, *Ann. Biochem. Expl. Med.*, **9**, **5** (1949).
(358) R. Riemschneider and W. Cohnen, *Chem. Ber.*, **91**, 2600 (1958).
(359) M. Hamada, *Botyu-Kagaku*, **22**, 231 (1957); *Chem. Abstr.*, **52**, 10972 (1958).
(360) V. Ettel and J. Weichet, *Collect. Czech. Chem. Commun.*, **13**, 433 (1948).
(361) F. Chattaway and F. Calvet, *J. Chem. Soc.*, 2913 (1928).
(362) W. Reeve, J. Mutchler, and Ch. Liotta, *Can. J. Chem.*, 44, 575 (1966).
(363) J. Druey, U.S. Patent 2659757 (1953); *Chem. Abstr.*, **49**, 2496 (1955).
(364) G. Shah, K. Kshtriya, S. Patel, and R. Wargund, *Curr. Sci.*, 14, 321 (1945).
(365) L. Harris, U.S. Patent 2572141 (1951); *Chem. Abstr.*, **46**, 5088 (1952).
(366) R. Riemschneider, *Monatsh. Chem.*, **84**, 1228 (1953).
(367) C. Johnson and Ch. Adams, U.S. Patent 2560173 (1951); *Chem. Abstr.*, **46**, 1044 (1952).
(368) G. Schneller and G. Smith, *Ind. Eng. Chem.*, 41, 1027 (1949).
(369) J. Niederl and A. Bothner-By, *J. Am. Chem. Soc.*, **69**, 1172 (1947).
(370) D. Shirley, U.S. Patent 2477665 (1949); *Chem. Abstr.*, **43**, 9085 (1949).
(371) A. Meldrum and R. Alimchandani, *J. Indian Chem. Soc.*, **6**, 253 (1929).
(372) R. Alimchandani, N. Shah, and S. Deo, *Curr. Sci.*, **3**, 354 (1935).
(373) N. Nurry and A. Meldrum, *J. Indian Chem. Soc.*, 11, 535 (1934).
(374) M. Zakutskaya and Kh. Yuldashev, *Zh. Obshch. Khim.*, **29**, 429 (1959).
(375) R. Qelet, J. Cavarret, and R. Pineau, *C. R. Acad. Sci.*, **238**, 1427 (1954).
(376) R. Qelet, J. Cavarret, and R. Pineau, *Bull. Soc. Chim. Fr.*, 932 (1954).
(377) J. Weichet, *Collect. Czech. Chem. Commun.*, **15**, 946 (1951).
(378) A. Arcoleo and A. Olivero, *Ann. Chim. (Rome)*, **47**, 415 (1957).
(379) A. Arcoleo, G. Werber, and G. Lombardo, *Ann. Chim. (Rome)*, **50**, 1242 (1960).
(380) G. Werber, A. Arcoleo, and T. Garofano, *Ann. Chim. (Rome)*, **50**, 1488 (1960).
(381) A. Arcoleo, T. Garofano, and M. Aversa, *Ann. Chim. (Rome)*, **58**, 1116 (1968).
(382) A. Arcoleo, T. Garofano, and M. Aversa, *Ann. Chim. (Rome)*, **58**, 850 (1968).
(383) T. Vitali, *Chimica*, 7, 84 (1952).
(384) A. Caccia-Bava and T. Vitali, *Chimica*, **5**, 173 (1950).
(385) T. Vitali and B. Magnani, *Chimica*, **8**, N 2, 12 (1953).
(386) Th. Wagner-Jauregg, H. Vonderbenk, and H. Witzel, *Chem. Ber.*, **81**, 417 (1948).
(387) Th. Wagner-Jauregg, H. Vonderbenk, and H. Witzel, *Chem. Ber.*, **82**, 246 (1949).
(388) R. Riemschneider and F. Wojahn, *Pharmazie*, **4**, 460 (1949).
(389) F. Chattaway and A. Morris, *J. Chem. Soc.*, 2014 (1927).
(390) O. Backeberg, *J. S. Afr. Chem. Inst.*, **3**, 13 (1950); *Chem. Abstr.*, **45**, 6638 (1951).
(391) L. Haskelberg and D. Lavie, *J. Org. Chem.*, 14, 498 (1949).
(392) F. Chattaway, *J. Chem. Soc.*, 2722 (1926).
(393) A. Meldrum and K. Lonkar, *J. Univ. Bombay*, **6**, (2) 116 (1937).
(394) R. Sem and N. Sinha, *J. Am. Chem. Soc.*, **45**, 2993 (1923).
(395) R. Shagalova, N. Daev, N. Gel'perin, and M. Kuznetsova, *Tr. Vses. Nauchno-Issled. Inst. Sint. Nat. Dushistykh Veshchestv*, N4, 34 (1958); *Chem. Abstr.*, **53**, 13094 (1959).
(396) H. Pauly and H. Schanz, *Ber.*, **56**, 983 (1923).
(397) A. Kamal, J. Bchatty, and M. Butt, *Pak. J. Sci. Ind. Res.*, **15**, 132 (1963).
(398) F. Chattaway and F. Calvet, *J. Chem. Soc.*, 687 (1927).
(399) A. Meldrum and B. Kapadia, *J. Indian Chem. Soc.*, **9**, 483 (1932).
(400) N. Shah and R. Alimchandani, *J. Indian Chem. Soc.*, **13**, 475 (1936).
(401) F. Calvet and M. Mejnto, *An. Soc. Esp. Fis. Quim.*, **34**, 641 (1936); *Chem. Abstr.*, **31**, 5756 (1937).
(402) F. Calvet and M. Mejnto, *J. Chem. Soc.*, 554 (1936).
(403) N. Shah and R. Alimchandani, *J. Indian Chem. Soc.*, **8**, 261 (1931).
(404) C. Schleussner and H. Voswinkel, *Justus Liebigs Ann. Chem.*, **422**, 111 (1921).
(405) R. Alimchandani and A. Meldrum, *J. Chem. Soc.*, 201 (1921).
(406) G. Tokar and I. Simonyi, *Magy. Kem. Foly.*, **62**, 53 (1956).
(407) G. Gal, G. Tokar, and I. Simonyi, *Magy. Kem. Foly.*, **60**, 273 (1954).
(408) Ch. Hamada, *Nippon Kagaku Zasshi*, **76**, 993 (1955).
(409) M. Balfe and W. Webber, *J. Chem. Soc.*, 718 (1942).
(410) C. Broquet-Borgel, *C. R. Acad. Sci.*, **250**, 1075 (1960).
(411) N. Hirwe and F. Gawankar, *J. Univ. Bombay*, **6**, (2) 123 (1937).
(412) N. Hirwe and K. Rana, *Ber.*, **72**, 1346 (1939). No reaction occurred between chloral and *m*- and *p*-hydroxybenzamides even by heating with acidic catalysts.
(413) N. Hirwe and B. Patil, *Proc. Indian Acad. Sci., Sect. A*, **13**, 275 (1941).

(414) K. Rana, *J. Indian Chem. Soc.*, **19**, 299 (1942).
(415) N. Hirwe and P. Kulkarni, *Proc. Indian Acad. Sci., Sect. A*, **13**, 49 (1941).
(416) A. Meldrum and M. Bhojraj, *J. Indian Chem. Soc.*, **13**, 185 (1936).
(417) J. la Rocca and W. Byrum, *J. Am. Pharm. Assoc.*, **43**, 63 (1954).
(418) R. Riemschneider, *Z. Naturforsch. B*, 7, 277 (1952).
(419) A. Meldrum and D. Pandya, *J. Univ. Bombay*, **6** (2) 114 (1937).
(420) M Yasue, *J. Pharm. Soc. Jpn.*, **75**, 615 (1955).
(421) M. Yasue, *J. Pharm. Soc. Jpn.*, **76**, 95, 693 (1956).
(422) M. Yasue and Y. Takai, *Bull. Nagoya City Univ., Pharm. Sch.*, 4, 23 (1956); *Chem. Abstr.*, **51**, 7318 (1957).
(423) M. Yasue, *Yakugaku Zasshi*, **77**, 434 (1957); *Chem. Abstr.*, **51**, 12029 (1957).
(424) M. Yasue, M. Itaya, Y. Takai, and S. Hamai, *Bull. Nagoya City Univ., Pharm. Sch.*, **3**, 19 (1955); *Chem. Abstr.*, **50**, 1672 (1956).
(425) M. Yasue, *Bull. Nagoya City Univ., Pharm. Sch.*, **6**, 23 (1958); *Chem. Abstr.*, **53**, 706 (1959).
(426) E. Graef and A. Burger, *J. Am. Chem. Soc.*, **68**, 2400 (1946).
(427) M. Yasue, *Bull. Nagoya City Univ., Pharm. Sch.*, **6**, 27 (1958); *Chem. Abstr.*, **53**, 706 (1959).
(428) A. Berlin, M. Shchukina, and E. Sazonova, *Zh. Obshch. Khim.*, **19**, 677 (1949).
(429) M. Yasue and Y. Kato, *J. Pharm. Soc. Jpn.*, 74, 116 (1954); *Chem. Abstr.*, **49**, 1665 (1955).
(430) D. Dinelli and S. Carbotti, *Ann. Chim.*, 41, 391 (1951).
(431) J. Willard and C. Hamilton, *J. Am. Chem. Soc.*, 73, 4805 (1951).
(432) J. Freeman, J. Dove, and E. Amstutz, *J. Am. Chem. Soc.*, 70, 3136 (1948).
(433) P. Truitt, M. Mattison, and E. Richardson, *J. Am. Chem. Soc.*, 70, 79 (1948).
(434) E. Cherbuliez and C. Giddey, *Helv. Chim. Acta*, **35**, 160 (1952).
(435) R. Riemschneider, *Monatsh. Chem.*, **84**, 883 (1953).
(436) M. Ikawa and K. Link, *J. Am. Chem. Soc.*, **72**, 4373 (1950).
(437) J. Klosa, *Arch. Pharm.*, **288**, 545 (1955).
(438) K. Chakravarti, *J. Sci. Ind. Res. Sect. B*, **9**, 305 (1950). The author failed to establish the position of trichloroethyl substituent in the ring of reaction product.
(439) K. Matsumura and M. Ito, *J. Am. Chem. Soc.*, **77**, 6671 (1955).
(440) R. Hull, *J. Chem. Soc.*, 4845 (1957).
(441) T. Takahashi and H. Saichachi, *J. Pharm. Soc. Jpn.*, **62**, 38 (1942).
(442) T. Takahashi, *J. Pharm. Soc. Jpn.*, **49**, 1048 (1929).
(443) E. Koenigs and W. Ottman, *Ber.*, **54**, 1345 (1921).
(444) H. John, *Ber.*, **58**, 2799 (1925).
(445) V. Zota, A. Berechnet, V. Isbasoiu, J. Scare, E. Grigorescu, and E. Constantinescu, *Farmacia (Bucharest)*, **13**, 551 (1965).
(446) P. Kulkarni, *J. Indian Chem. Soc.*, **19**, 180 (1942). With 2-methyl-3-aminoquinazolone-4 chloral reacts at the amino group.
(447) H. Erlenmeyer, O. Weber, P. Schmidt, G. Künig, Ch. Zinsstag, and B. Prijs, *Helv. Chim. Acta*, **31**, 1142 (1948).
(448) A. Einchorn, *Ber.*, **19**, 904 (1886).
(449) R. Woodward and E. Kornfeld, *J. Am. Chem. Soc.*, 70, 2508 (1948).
(450) B. Brown, D. Hammick, and R. Robinson, *J. Chem. Soc.*, 780 (1950).
(451) R. Hull, British Patent 741667 (1955); *Chem. Abstr.*, **51**, 2063 (1957).
(452) F. Bergmann and M. Tamari, *J. Chem. Soc.*, 565 (1964).
(453) E. Fields and J. Sandri, *Chem. Ind. (London)*, 1216 (1959).
(454) B. Teichmann, *Z. Chem.*, 4, 230 (1964).
(455) T. Sandmeyer, *Helv. Chim. Acta*, **2**, 234 (1919).
(456) "Sintezy Organicheskii Preparatov," Vol. 1, Moskwa, 1949, p 216.
(457) German Patent 113848; *Chem. Zentralbl.*, II, 927 (1900).
(458) G. Favini and F. Piozzi, *Atti Accad. Naz. Lincei, Rend. Cl. Sci. Fiz., Mat. Nat.*, **19**, 44 (1955).
(459) K. Morsch, *Monatsh. Chem.*, **55**, 144 (1930).
(460) A. S. Petrov, M. N. Somin, and S. G. Kuznetsov, *Zh. Org. Khim.*, 1, 1434 (1965).
(461) I. N. Somin and A. S. Petrov, *Zh. Obshch. Khim.*, **34**, 3131 (1964).
(462) A. S. Petrov, Dissertation (Kand. Khim. Nauk), Leningrad, 1967.
(463) V. Ettel and J. Horak, *Collect. Czech. Chem. Commun.*, **26**, 2087 (1961).
(464) De Girard, *Bull. Soc. Chim. Fr.*, [2] **46**, 338 (1886).
(465) J. Collie, *J. Chem. Soc.*, 965 (1925).
(466) D. Denney and N. Gerschman, *Tetrahedron Lett.*, 3899 (1965).
(467) M. I. Kabachnik and E. S. Shepeleva, *Dokl. Akad. Nauk SSSR*, **75**, 219 (1950).
(468) G. Fricke and W. Georgi, *J. Prakt. Chem.*, **20**, 250 (1963).
(469) B. A. Arbuzov, E. P. Dianova, V. S. Vinogradova, and A. K. Shamsutdinov, *Dokl. Akad. Nauk SSSR*, **160**, 99 (1965).
(470) R. Sallmann, German Patent 975902 (1961); *Chem. Abstr.*, **59**, 1044 (1963).
(471) G. Schrader, Belgian Patent 627327 (1963); *Chem. Abstr.*, **60**, 6748 (1964).
(472) R. Whetstone and D. Harman, U.S. Patent 3116201 (1963); *Chem. Abstr.*, **60**, 6748 (1964).
(473) W. Perkov, *Chem. Ber.*, **87**, 755 (1954).
(474) M. Kharasch and I. Bengelsdorf, *J. Org. Chem.*, **20**, 1356 (1955).
(475) A. E. Arbuzov and P. I. Alimov, *Izv. Akad. Nauk SSSR, Otd. Khim. Nauk*, 530 (1951).
(476) CIBA Ltd., British Patent 744360 (1956); *Chem. Abstr.*, **51**, 470 (1957).
(477) E. Ladd and M. Harvey, U.S. Patent 2631162 (1953); *Chem. Abstr.*, **48**, 7048 (1954).
(478) G. Kamai, F. Kharrasova, R. Sultanova, and S. Tuchvatullina, *Izv. Vyssh. Ucheb. Zaved., Khim. Khim. Tekhnol.*, **5**, 759 (1962); *Chem. Abstr.*, **58**, 13985 (1963).
(479) F. Kharrasova, G. Kamai, and R. Shagidullin, *Zh. Obshch. Khim.*, **35**, 1993 (1965).
(480) F. Kharrasova, G. Kamai, R. Sultanova, and R. Shagidullin, *Zh. Obshch. Khim.*, **37**, 687 (1967).
(481) F. Kharrasova and G. Kamai, *Zh. Obshch. Khim.*, **34**, 2195 (1964).
(482) F. Kharrasova, G. Kamai, and R. Shagidullin, *Zh. Obshch. Khim.*, **36**, 1987 (1966).
(483) V. S. Abramov and N. I. D'yakonova, *Zh. Obshch. Khim.*, **38**, 1502 (1968).
(484) L. Antochina and P. Alimov, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 2135 (1966).
(485) CIBA Ltd., Swiss Patent 303656 (1955); *Chem. Abstr.*, **51**, 11374 (1957).
(486) CIBA Ltd., Swiss Patent 305939 (1955); *Chem. Abstr.*, **51**, 11374 (1957).
(487) CIBA Ltd., Swiss Patent 305940 (1955); *Chem. Abstr.*, **51**, 11374 (1957).
(488) V. I. Barabanov and V. S. Abramov, *Zh. Obshch. Khim.*, **35**, 2225 (1965).
(489) B. Teichmann, *J. Prakt. Chem.*, **28**, 94 (1965).
(490) W. Lorenz, A. Henglein, and G. Schrader, *J. Am. Chem. Soc.*, **77**, 2554 (1955).
(491) W. Barthel, P. Giang, and S. Hall, *J. Am. Chem. Soc.*, **76**, 4186 (1954).
(492) N. K. Bliznyuk, L. M. Solntseva, and Z. N. Kvasha, *Zh. Obshch. Khim.*, **36**, 1710 (1966).
(493) A. Pudovik, T. Gazizov, Yu. Samitov, and T. Zykova, *Dokl. Akad. Nauk SSSR*, **166**, 615 (1966).
(494) P. I. Alimov, *Izv. Akad. Nauk SSSR, Otd. Khim. Nauk*, 61 (1961).(495) R. Sering and K. Zeile, German Patent 1156275 (1963); *Chem. Abstr.*, **60**, 9150 (1964).
(496) K. V. Nikonorov, E. A. Guryljov, and F. F. Fachrislamova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1095 (1966).
(497) B. Ivanov and L. Kudryavtseva, USSR Patent 218177 (1968); *Chem. Abstr.*, **69**, 87180 (1968).
(498) Z. Pelchowicz, *J. Chem. Soc.*, 241 (1961).
(499) W. Lorenz and G. Schrader, Belgian Patent 623551 (1963); *Chem. Abstr.*, **60**, 6748 (1964).
(500) H. Sohr and K. Lohs, *Z. Chem.*, 7, 153 (1967).
(501) S. Shapiro, H. Soloway, and L. Freedman, *J. Am. Chem. Soc.*, **77**, 4874 (1955).
(502) W. Reeve and L. Fine, *J. Am. Chem. Soc.*, **86**, 880 (1964).
(503) K. Garzarolli-Thurnlackh, *Justus Liebigs Ann. Chem.*, 210, 76 (1881).
(504) V. Floutz, *J. Am. Chem. Soc.*, **71**, 2859 (1949).
(505) M. Kharash, C. Kleiger, J. Martin, and F. Mayo, *J. Amer. Chem. Soc.*, **63**, 2307 (1941).
(506) H. Gilman and R. Abbott, *J. Org. Chem.*, **8**, 224 (1943).
(507) R. Hamelin, *C. R. Acad. Sci.*, **250**, 1081 (1960).
(508) R. Hamelin, *Bull. Soc. Chim. Fr.*, 926 (1961).
(509) V. Floutz, *J. Am. Chem. Soc.*, **67**, 1615 (1945).
(510) V. Floutz, *J. Am. Chem. Soc.*, **65**, 2255 (1943).
(511) P. Dean and W. Wolf, *J. Am. Chem. Soc.*, **58**, 332 (1936).
(512) R. Benkeser and Th. Johnston, *J. Am. Chem. Soc.*, **88**, 2200 (1966).
(513) R. Letzinger and S. Hamilton, *J. Org. Chem.*, **25**, 592 (1960).
(514) I. A. Shichiev, M. I. Aliev, and B. M. Gusein-zade, *Zh. Obshch. Khim.*, **32**, 1646 (1962).
(515) F. Henglein and H. Niebergall, German Patent 1053186 (1959); *Chem. Abstr.*, **55**, 5347 (1961).
(516) F. Henglein and H. Gräser, *Makromol. Chem.*, **26**, 236 (1958).
(517) I. A. Shichiev, R. Yu. Gasanova, M. M. Rafiev, and G. Yu. Achundova, *Azerb. Khim. Zh.*, N 6, 87 (1967).
(518) K. Itoh, M. Fukui, and Y. Isshii, *Tetrahedron Lett.*, 3867 (1968).
(519) M. F. Shostakovskii, B. M. Vlasov, R. G. Mirskov, and A. N. Mirskova, USSR Patent 180593 (1966); *Chem. Abstr.*, **65**, 12240 (1966).
(520) A. Davies and R. Puddephatt, *J. Organometal. Chem.*, **5**, 590 (1966).
(521) R. G. Mirskov and B. M. Vlasov, *Zh. Obshch. Khim.*, **36**, 562 (1966).
(522) S. Kobayashi, K. Itoh, and Y. Ishii, *Kogyo Kagaku Zasshi*, **74**, 2342 (1971); *Chem. Abstr.*, **76**, 58530 (1972).
(523) K. Itoh, I. Matsuda, T. Katsuura, S. Kato, and Y. Ishii, *J. Organometal. Chem.*, **34**, 75 (1972).
(524) M. Shiga, I. Motojama, and K. Hata, *Bull. Chem. Soc. Jpn.*, 41, 1891 (1968).
(525) M. Furdik, S. Toma, M. Dzurilla, and J. Suchy, *Chem. Zvesti*, **18**, 607 (1964).
(526) J. Colonge and A. Perrot, *C. R. Acad. Sci.*, **239**, 541 (1954).
(527) H. Prins and H. Haring, *Recl. Trav. Chim. Pays-Bas*, **73**, 479 (1954).
(528) Schering-Kahlbaum, A.-G., British Patent 459462 (1937); *Chem. Abstr.*, **31**, 3942 (1937).
(529) R. Riemschneider, *Monatsh. Chem.*, **83**, 828 (1952).
(530) Yu. Smushkevich, V. Belov, B. Kleev, and A. Akimova, *Zh. Org. Khim.*, **3**, 1036 (1967).
(531) M. Shostakovskii, A. Atavin, 9 Lenskich, and M. Al'pert, *Dokl. Akad. Nauk SSSR*, **154**, 657 (1964).
(532) I. Shichiev, Yu. Gusein-zade, and L. Aliev, *Zh. Obshch. Khim.*, **32**, 3630 (1962).
(533) M. Vilkas, *C. R. Acad. Sci.*, **238**, 1598 (1954).

(534) M. Vilkas, G. Duport, and R. Dulon, *Bull. Soc. Chim. Fr.*, 799 (1955).
(535) W. Dale and A. Sisti, *J. Am. Chem. Soc.*, **76**, 81 (1954).
(536) E. Klimova, E. Treshchova, and Yu. Arbuzov, *Dokl. Akad. Nauk SSSR*, **180**, 865 (1968).
(537) E. Klimova, E. Treshchova, and Yu. Arbuzov, *Zh. Org. Khim.*, **6**, 419 (1970).
(538) W. Dale and A. Sisti, *J. Org. Chem.*, **22**, 449 (1957).
(539) J. Luvisi, U.S. Patent 2929850; 2929851 (1960); *Chem. Abstr.*, **55**, 6437 (1961).
(540) Ch. Pinazzi, R. Pautrat, and R. Cheritat, *Rev. Gen. Caout. Plast.*, **42**, 571 (1965).
(541) Ch. Pinazzi and R. Pautrat, *C. R. Acad. Sci.*, **256**, 2390 (1963).
(542) Ch. Pinazzi and R. Pautrat, *C. R. Acad. Sci.*, **256**, 2607 (1963).
(543) K. Schimmelschmidt and E. Mundlos, German Patent 1136323 (1962); *Chem. Abstr.*, **58**, 3321 (1963).
(544) Shell Internationale Research Maatschappij N.V., British Patent 1025469 (1966); *Chem. Abstr.*, **64**, 19425 (1966).
(545) H. Ohse, R. Palm, H. Cherdron, and F. Korte, German Patent 1252653 (1968); *Ref. Zh. Khim.*, 11N94P (1969).
(546) H. Staudinger and N. Kon, *Justus Liebigs Ann. Chem.*, **384**, 87 (1911).
(547) F. I. Luknitskii and B. A. Vovsi, USSR Patent 176882 (1965); *Chem. Abstr.*, **64**, 12554 (1966).
(548) F. I. Luknitskii and B. A. Vovsi, *Zh. Org. Khim.*, **2**, 1895 (1966).
(549) D. Borrman and R. Wegler, German Patent 1214211 (1962); *Chem. Abstr.*, **64**, 19425 (1966).
(550) D. Borrmann and R. Wegler, *Chem. Ber.*, **99**, 1245 (1966).
(551) D. Borrmann and R. Wegler, *Chem. Ber.*, 100, 1575 (1967).
(552) W. Brady and A. Patel, *J. Chem. Soc. D*, 1642 (1971).
(553) W. Brady and A. Patel, *J. Heterocycl. Chem.*, **8**, 739 (1971).
(554) F. I. Luknitskii and B. A. Vovsi, *Usp. Khim.*, **38**, 1072 (1969).
(555) F. I. Luknitskii and B. A. Vovsi, USSR Patent 187013 (1967); *Chem. Abstr.*, **67**, 73176 (1967).
(556) F. I. Luknitskii and B. A. Vovsi, *Dokl. Akad. Nauk SSSR*, **172**, 1327 (1967).
(557) W. Brady and L. Smith, *Tetrahedron Lett.*, 2963 (1970).
(558) L. Nesterov and R. Sabirova, *Zh. Org. Khim.*, **6**, 625 (1970).
(559) G. Burlachenko, Yu. Baukov, and I. Lutsenko, *Zh. Obshch. Khim.*, **38**, 2815 (1968).
(560) H. Bos and J. Arens, *Recl. Trav. Chim. Pays-Bas*, **82**, 845 (1963).
(561) N. Kologrivova and V. Belov, *Zh. Obshch. Khim.*, **28**, 3105 (1958).
(562) I. Shichiev, B. Gusein-zade, M. Aliev, M. Salimov, R. Rzaeva, and M. Nasyrova, *Zh. Obshch. Khim.*, **34**, 1218 (1964).
(563) A. Atavin, A. Mirskova, and G. Kalabin, *Zh. Org. Khim.*, **3**, 1779 (1967).
(564) A. S. Atavin and A. N. Mirskova, USSR Patent 192826 (1967); *Chem. Abstr.*, **68**, 77748 (1968).
(565) W. Ellis, D. Rowlands, and D. Uhl, U.S. Patent 2860963 (1958); *Chem. Abstr.*, **53**, 9065 (1959).
(566) B. Helferich and E. Basler, *Ber.*, **57**, 1279 (1924).
(567) H. Hibbert, W. Gillespie, and R. Mohtonna, *J. Am. Chem. Soc.*, **50**, 1953 (1928).
(568) A. Pinner, *Ber.*, **31**, 1927 (1898).
(569) A. Pinner, *Ber.*, **33**, 1432 (1900).
(570) J. Zeehnisen, *J. Sci. Res. Indonesia*, 1, 9 (1952); *Chem. Abstr.*, **49**, 238 (1955).
(571) E. Clar, *Ber.*, **72**, 2134 (1939).
(572) W. Reeve and E. Riehlmann, *J. Org. Chem.*, **31**, 2164 (1966).
(573) F. Canjolle, P. Couturier, and C. Dulaurans, *Bull. Soc. Chim. Fr.*, 19 (1950).
(574) N. Turro, S. Edelson, J. Williams, and Th. Darling, *J. Am. Chem. Soc.*, **90**, 1926 (1968).
(575) N. Turro, S. Edelson, J. Williams, Th. Darling, and W. Hammond, *J. Am. Chem. Soc.*, **91**, 2283 (1969).
(576) H. Schlenk, *Chem. Ber.*, **85**, 901 (1952).
(577) N. Leonard, J. Little, and A. Kresge, *J. Am. Chem. Soc.*, **79**, 2642 (1957).
(578) A. Spasov and I. Ivanov, *Annu. Univ. Sofia, Fac. Phys.-Math.*, **38**, N 2, 85 (1941-1942); *Chem. Abstr.*, **42**, 2584 (1948).
(579) Sh. Mamedov and F. Gadzhi-zade, *Zh. Obshch. Khim.*, **32**, 799 (1962).
(580) O. Gawron and F. Draus, *J. Am. Chem. Soc.*, **80**, 5392 (1958).
(581) P. Baudett and C. Otten, *Helv. Chim. Acta*, **53**, 1330 (1970).
(582) F. Bayer & Co., German Patent 121223 (1901); *Chem. Zentrallbl.*, II, 69 (1901).
(583) Vereinigte Chininfabr. Zimmer & Co. GmbH, German Patent 225712 (1910); *Chem. Zentrallbl.*, II, 1009 (1910).
(584) N. S. Vul'fson, *Zh. Obshch. Khim.*, **20**, 435 (1950).
(585) F. Gaujiolle, P. Couturier, and M. Doumerc, *Bull. Soc. Chim. Fr.*, 22 (1950).
(586) E. Magat, B. Faris, J. Reith, and L. Salisbury, *J. Am. Chem. Soc.*, **73**, 1028 (1951).
(587) Z. Eckstein and E. Grochowski, *Przem. Chem.*, **38**, 693 (1959).
(588) M. Passerini, *Gazz. Chim. Ital.*, **52**, 433 (1922).
(589) E. Müller, P. Kaestner, R. Beutler, W. Rundel, H. Suhr, and B. Zeeh, *Justus Liebigs Ann. Chem.*, **713**, 87 (1968).
(590) H. Kabbe, *Chem. Ber.*, **102**, 1404 (1969).
(591) F. Schlotterbeck, *Ber.*, 40, 3001 (1907).
(592) F. Schlotterbeck, *Ber.*, **42**, 2561 (1909).
(593) F. Arndt and B. Eistert, *Ber.*, **61**, 1121 (1928).
(594) K. Auwers, *Ber.*, **62**, 1319 (1929).
(595) H. Meerwein, Th. Bersin, and W. Burneleit, *Ber.*, **62**, 999 (1929).
(596) R. Bowman, A. Cambell, and W. Williamson, *J. Chem. Soc.*, 3846 (1964).
(597) P. Couturier, *Bull. Soc. Chim. Fr.*, 25 (1950).
(598) "Organicheskii Reaktsii," Vol. 8, Moskwa, 1956, p 405.
(599) O. Doebner and L. Segelitz, *Ber.*, **38**, 2733 (1905).
(600) K. Auwers and M. Schmidt, *Ber.*, **46**, 487 (1913).
(601) K. Garzarolli-Thurnlackh, *Monatsh. Chem.*, **12**, 556 (1891).
(602) C. Hurd and S. Hayao, *J. Am. Chem. Soc.*, **76**, 5563 (1954).
(603) N. S. Vul'fson and M. M. Shemyakin, *Dokl. Akad. Nauk SSSR*, **29**, 206 (1940).
(604) M. M. Shemyakin and N. S. Vul'fson, *Dokl. Akad. Nauk SSSR*, **30**, 812 (1941).
(605) H. Gault and G. Mennicken, *C.R. Acad. Sci.*, **229**, 1239 (1949).
(606) D. Kulkarni and N. Shah, *J. Univ. Bombay*, 10, 120 (1941); *Chem. Abstr.*, **36**, 3795 (1942).
(607) L. Claisen and J. Matthews, *Justus Liebigs Ann. Chem.*, **218**, 175 (1883).
(608) J. Decombe, *C. R. Acad. Sci.*, **237**, 336 (1953).
(609) A. Rossi and H. Schinz, *Helv. Chim. Acta*, **32**, 1967 (1949).
(610) F. Bergel, A. Morrison, A. Moss, and H. Rinderknecht, British Patent 592283 (1947); *Chem. Abstr.*, **42**, 1603 (1948).
(611) P. Mastagli and F. de Champs, *C. R. Acad. Sci., Ser. C*, **270**, 1247 (1970).
(612) J. Paulins and E. Gudriniece, *Latv. PSR Zinat. Akad. Vestis, Kim. Ser.*, 226 (1971); *Chem. Abstr.*, **75**, 8740 (1971).
(613) F. Caujolle, P. Couturier, and M. Doumerc, *Bull. Soc. Chim. Fr.*, 22 (1950).
(614) R. Bowman and W. Williamson, *J. Chem. Soc.*, 101 (1970).
(615) L. Henry, *Bull. Acad. Roy. Belg.*, [3] **32**, 17 (1896).
(616) O. Nicodemus and O. Wulff, U.S. Patent 2123556 (1938); *Chem. Abstr.*, **32**, 6667 (1938).
(617) S. Malkiel and J. Mason, *J. Am. Chem. Soc.*, **64**, 2515 (1942).
(618) M. Compton, H. Higgins, L. MacBeth, J. Osborn, and H. Burkett, *J. Am. Chem. Soc.*, 71, 3229 (1948).
(619) F. Chattaway and P. Witherington, *J. Chem. Soc.*, 1178 (1935).
(620) F. Villani and F. Nord, *J. Am. Chem. Soc.*, **69**, 2608 (1947).
(621) F. Chattaway, J. Drewitt, and G. Parkes, *J. Chem. Soc.*, 1294 (1936).
(622) G. Bachman and M. Atwood, *J. Am. Chem. Soc.*, **78**, 484 (1956).
(623) A. Dornow and G. Wiehler, *Justus Liebigs Ann. Chem.*, **578**, 113 (1952).
(624) V. V. Perekalin and A. S. Sopova, "Nepredel'nye nitrosoedineniya," Izdanie 2, "Khimija," 1966.
(625) G. Friecke, W. Georgi, and K. Wachsmuth, German Patent 41528 (1965); *Chem. Abstr.*, **64**, 9597 (1966).
(626) H. Renner and L. Kaltenborn, German Patent 31848 (1964); *Chem. Abstr.*, **63**, 13082 (1965).
(627) F. Chattaway and E. Kellett, *J. Chem. Soc.*, 2709 (1928).
(628) M. Baron, *Nature (London)*, **192**, 258 (1961).
(629) Diamond Alkali Co., British Patent 984998 (1965); *Chem. Abstr.*, **62**, 13274 (1965).
(630) I. Rosen, Japanese Patent 10431 (1965); *Chem. Abstr.*, **64**, 5233 (1966).
(631) E. Erdmann, German Patent 139392 (1902); *Chem. Zentrallbl.*, I, 743 (1903).
(632) W. Thuemmler, G. Lorenz, and K. Thimius, *Plaste Kautsch.*, 11, 386 (1964).
(633) W. Busfield and E. Whalley, *Trans. Faraday Soc.*, **59**, 679 (1963).
(634) R. Wakasa and Sh. Ishida, Japanese Patent 4986 (1967); *Chem. Abstr.*, **67**, 44272 (1967).
(635) D. Ilyina, B. Kreutsel, and G. Semenido, *J. Polym. Sci., Part C*, 999 (1964).
(636) Japan Chemical Textile Institute and Bridgestone Tire Co., Ltd. (K. Kaisha), British Patent 902790 (1962); *Chem. Abstr.*, **58**, 588 (1963).
(637) H. Daimon, K. Kamio, and Sh. Koyita, Japanese Patent 27884 (1964); *Chem. Abstr.*, **63**, 1903 (1965).
(638) J. Furukawa and T. Saegusa, U.S. Patent 3183210 (1965); *Chem. Abstr.*, **63**, 18299 (1965).
(639) G. Wassai, T. Iwata, K. Hirano, M. Suragano, T. Saegusa, and J. Furukawa, *Kogyo Kagaku Zasshi*, **67**, 1920 (1964); *Chem. Abstr.*, **62**, 13249 (1965).
(640) K. Kamio, Sh. Kojima, and H. Daimon, *Kogyo Kagaku Zasshi*, **66**, 246 (1963); *Chem. Abstr.*, **59**, 10241 (1963).
(641) G. McCain and D. Hudgin, Belgian Patent 633031 (1963); *Chem. Abstr.*, **61**, 741 (1964).
(642) Sh. Ishida, German Patent 1228805 (1966); *Chem. Abstr.*, **66**, 38355 (1967).
(643) J. Furukawa, *Makromol. Chem.*, **37**, 149 (1960).
(644) H. Takida and K. Noro, *Kobunshi Kagaku*, **21**, 467 (1964); *Chem. Abstr.*, **62**, 10537 (1965).
(645) T. Saegusa and H. Fujii, *Makromol. Chem.*, **44**, 398 (1961).
(646) H. Takida and K. Noro, *Kobunshi Kagaku*, **22**, 724 (1965); *Chem. Abstr.*, **64**, 17725 (1966).
(647) T. Otsu, Y. Nishikawa, and S. Wakamima, *Makromol. Chem.*, **115**, 278 (1968).
(648) A. Novak and E. Whalley, *Trans. Faraday Soc.*, **55**, 1490 (1959).
(649) C. Lorenz, German Patent 11817 (1964); *Chem. Abstr.*, **62**, 9262 (1965).
(650) R. Webb and A. Duke, *J. Chem. Soc.*, 4320 (1962).
(651) E. White, British Patent 902602 (1962); *Chem. Abstr.*, **57**, 12739 (1962).
(652) Farbwerke Hoechst A.-G., Belgian Patent 644189 (1964); *Chem. Abstr.*, **63**, 10090 (1965).
(653) British Industrial Plastics Ltd., Belgian Patent 609208 (1962); *Chem. Abstr.*, **58**, 2516 (1963).
(654) British Industrial Plastics, Ltd., Neth. Appl. 6511436 (1966); *Chem. Abstr.*, **65**, 2370 (1966).
(655) H. Dietrich, J. Karabinos, and M. Raes, U.S. Patent 3336397

(1967); *Chem. Abstr.*, **67**, 82552 (1967).
(656) Farbwerke Hoechst A.-G., French Patent 1391539 (1969); *Chem. Abstr.*, **63**, 11809 (1965).
(657) H. Dietrich, J. Karabinos, and M. Raes, *J. Polym. Sci., Part A*, **5**, 1395 (1967).
(658) J. Rosen, D. Hudgin, C. Sturm, G. McCain, and R. Wilhjelm, *J. Polym. Sci., Part A*, **3**, 1535 (1965).
(659) J. Rosen, C. Sturm, G. McCain, R. Wilhjelm, and D. Hudgin, *J. Polym. Sci., Part A*, 1545 (1965).
(660) Diamond Alkali Co., Neth. Appl. 6410272 (1965); *Chem. Abstr.*, **63**, 5843 (1965).
(661) Diamond Alkali Co., Neth. Appl. 6408673 (1965); *Chem. Abstr.*, **63**, 1903 (1965).
(662) G. McCain, D. Hudgin, and J. Rosen, *J. Polym. Sci., Part A*, **15**, 975 (1967).
(663) Ch. Aso and Y. Y. Aito, *Makromol. Chem.*, 100, 100 (1967).
(664) B. Song, U.S. Patent 3213064 (1965); *Chem. Abstr.*, **64**, 883 (1966).
(665) K. Noro and H. Takida, Japanese Patent 7633 (1967); *Chem. Abstr.*, **68**, 3390 (1968).
(666) Ch. Pinazzi, R. Pautrat, and R. Cheritat, French Patent 1377280 (1965); *Chem. Abstr.*, **65**, 3995 (1966).
(667) T. Saegusa, H. Fujii, T. Ueshima, and K. Tanaka, *Bull. Chem. Soc. Jpn.*, 41, 1188 (1968).
(668) T. Saegusa, H. Fujii, and K. Tanaka, *Bull. Chem. Soc. Jpn.*, 41, 1192 (1968).
(669) S. Vitex, French Patent 986520 (1951); *Chem. Abstr.*, **49**, 16524 (1955).
(670) Y. Yamashita and A. Uchikawa, *Kogyo Kagaku Zasshi*, 71, 758 (1968); *Chem. Abstr.*, **69**, 59608 (1968).
(671) H. Takida and K. Noro, *Kobunshi Kagaku*, **22**, 463 (1965); *Chem. Abstr.*, **64**, 2174 (1966).
(672) Yu. Getmanchuk, Yu. Spirin, and R. Dryagileva, *Dokl. Akad. Nauk SSSR*, **171**, 1105 (1966).
(673) Yu. Getmanchuk, Yu. Spirin, and R. Dryagileva, *Vysokomol. Soedin., Ser. A*, 10, 139 (1968); *Chem. Abstr.*, **68**, 69379 (1968).
(674) M. Roes, J. Karabinos, and H. Dietrich, *J. Polym. Sci., Part A*, **6**, 1067 (1968).
(675) J. Kolthoff, *Pharm. Weekblad.*, **60**, 2 (1923).
(676) A. Schwiecker, *Z. Anal. Chem.*, 110, 161 (1937).
(677) N. Stauciu and V. Stoicescu, *Farmacia (Bucharest)*, 4, 313 (1956).
(678) K. Panwar, S. Rao, and J. Gaur, *Anal. Chim. Acta*, **25**, 218 (1961).
(679) A. Meyer and P. Lee-Motter, *Arzneim.-Forsch.*, **7**, 194 (1957).
(680) O. Malhotra and V. Anand, *J. Indian Chem. Soc.*, **34**, 501 (1957).
(681) A. Archer and E. Haugas, *J. Pharm. Pharmacol.*, **12**, 754 (1960).
(682) L. Ryabykh, *Aptechn. Delo*, 14, 49 (1965).
(683) O. Stehwien and H. Kuhmstedt, *Pharmazie*, 10, 482 (1955).
(684) H. Griffon, N. Mossaneu, and J. Legault-Demare, *Ann. Pharm. Fr.*, 7, 578 (1949).
(685) M. Pesez, *J. Pharm. Chim.*, **22**, 68 (1935).
(686) A. Ware, *Chem. Drug.*, **123**, 282 (1935).
(687) M. Fridman and F. Calderone, *J. Lab. Clin. Med.*, **19**, 133 (1934).
(688) P. Friedman and J. Cooper, *Anal. Chem.*, 30, 1674 (1958).
(689) E. Bovalini and A. Casini, *Ann. Chim.*, 41, 745 (1951).
(690) L. M. Kul'berg and Sh. E. Prasman, *Pharm. Zh. (USSR)*, **13**, N 3, 12 (1940).
(691) A. Tripattu, *Labdev*, 4, 53 (1966); *Chem. Abstr.*, **64**, 17366 (1966).
(692) V. Arregnine, *Rev. Asoc. Bioquim. Argent.*, **16**, 452 (1951); *Chem. Abstr.*, **46**, 6324 (1952).
(693) M. Perronet and R. Truhaut, *J. Pharm. Chim.*, **18**, 339 (1933).
(694) M. Passerini, P. Papini, and A. Longo, *Sperimentale*, **2**, 70 (1951).
(695) H. Wagreich and B. Harrow, *Anal. Chem.*, **25**, 1925 (1953).
(696) A. Stadeler, *Justus Liebigs Ann. Chem.*, **106**, 253 (1858).
(697) S. Sizov and Yu. Babina, *Zavod. Lab.*, **31**, 666 (1965).
(698) C. Griebel and F. Weiss, *Z. Unters. Lebensm.*, **56**, 158 (1928).
(699) O. N. Karpov, *Tr. Kom. Anal. Khim. Akad. Nauk SSSR*, **13**, 132 (1963).
(700) K. Leibman and J. Hindman, *Anal. Chem.*, **36**, 348 (1964).
(701) P. Elving and C. Bennett, *Anal. Chem.*, **26**, 1572 (1954).
(702) P. Elving and C. Bennett, *J. Electrochem. Soc.*, 101, 520 (1954).
(703) J. Barlot and C. Albisson, *Chim. Anal. (Bucharest)*, **38**, 313 (1956).
(704) P. Federlin, *C. R. Acad. Sci.*, **232**, 60 (1951).
(705) A. Kirrmann and P. Federlin, *Bull. Soc. Chim. Fr.*, 7, 949 (1958).
(706) A. Antykov, USSR Patent 166529 (1964); *Chem. Abstr.*, **62**, 8395 (1965).
(707) O. Malhotra and V. Anand, *Z. Anal. Chem.*, **160**, 10 (1958).
(708) M. Canale and E. Tiscornia, *Zacchia*, **27**, 504 (1964).
(709) R. Anderson, C. Anderson, and T. Olson, *J. Agric. Food Chem.*, 14, 508 (1966).
(710) E. Garrett and H. Lambert, *J. Pharm. Sci.*, **55**, 812 (1966).
(711) L. S. Boguslavskaya, N. A. Kartashova, and A. N. Baramsina, *Zh. Prikl. Khim.*, **39**, 232 (1966).
(712) Societe Chimique de l'Yvette, French Patent 1347235 (1963); *Rhem. Abstr.*, **60**, 15884 (1964).
(713) E. F. Zhuravlev, A. D. Shevleva, and I. A. Vseselukhina, *Izv. Vyssh. Uchebn. Zaved., Khim. Khim. Technol.*, **2**, 891 (1959).
(714) E. F. Zhuravlev, *Zh. Obshch. Khim.*, **29**, 3178 (1959).
(715) G. Piroli and I. Montanini, *Bull. Chim. Farm.*, **103**, 351 (1964).
(716) A. Murtazov, S. Avakyants, and Kh. Khakimov, *Dokl. Akad. Nauk Uzb. SSR*, N 10, 34 (1953).
(717) E. Ferroni, G. Gabrielli, and M. Giarfuglia, *Ric. Sci.*, **25**, 539 (1955).
(718) F. Taboury, *C. R. Acad. Sci.*, **214**, 764 (1942).
(719) P. Pfeifer and R. Seydal, *Z. Physiol. Chem.*, **178**, 97 (1928).
(720) S. Avakyants, A. Murtazov, and M. Usubaev, *Tr. Tashk. Farm. Inst.*, **3**, 411 (1962); *Rhem. Abstr.*, **60**, 15683 (1964).
(721) Chemisch.-Pharmazeutische A.-G. Bad Homberg, German Patent 590312 (1933); *Chem. Abstr.*, **28**, 2127 (1934).
(722) E. Degerholm, A. Harison, T. Leidman, and N. Sterner, *Farm. Revy*, **62**, 601 (1963); *Chem. Abstr.*, **60**, 3945 (1964).
(723) P. Ekeblad, *Acta Pharm. Suec.*, **2**, 239 (1965).
(724) Aktiebolag "Ferrasan," Belgian Patent 632128 (1963); *Chem. Abstr.*, **60**, 15736 (1964).
(725) E. F. Zhuravlev, *Uch. Zap. Permsk. Gos. Univ., Math., Phys., Khim.*, **8**, N 3, 3 (1954); *Chem. Abstr.*, **54**, 12760 (1960).
(726) V. I. Syuzyaev, I. Redzhepov, and L. S. Serukhova, *Izv. Akad. Nauk Turkm. SSR*, N 3, 10 (1958).
(727) V. I. Syuzyaev, A. A. Berdyev, and N. I. Kolando, *Izv. Akad. Nauk Turkm. SSR*, N 6, 81 (1957).
(728) N. K. Voskresenskaya, M. I. Ravich, and E. B. Shtenina, Konferentsiya po vjazkosti zhidkich i kolloidnych rastvorov, Akademii Nauk USSR, Vol. 1, 1941, p 31.
(729) V. V. Udovenko, E. I. Kalabanovskaya, and M. F. Prokof'eva, *Zh. Obshch. Khim.*, **19**, 165 (1949).
(730) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **26**, 2959 (1956).
(731) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **27**, 37 (1957).
(732) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **27**, 583 (1957).
(733) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **27**, 322 (1957).
(734) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **26**, 3001 (1956).
(735) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **26**, 3639 (1956).
(736) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **26**, 3291 (1956).
(737) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **27**, 41 (1957).
(738) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **27**, 357 (1957).
(739) V. V. Udovenko and R. I. Khomenko, *Zh. Obshch. Khim.*, **26**, 3270 (1956).
(740) V. I. Syuzyaev and A. A. Berdyev, *Izv. Akad. Nauk Turkm. SSR*, N 6, 9 (1957); *Chem. Abstr.*, **52**, 13393 (1958).
(741) V. I. Syuzyaev, *Primen. Ul'traakustiki k Issled. Veshchestva*, N 13, 199 (1961); *Chem. Abstr.*, **58**, 10751 (1963).
(742) V. I. Syuzyaev, *Uch. Zap. Turkmen. Gos. Univ.*, N 15, 113 (1959); *Ref. Zh. Khim.*, 4132 (1960).
(743) P. Tutundzic and D. Rancic, *Glas. Hem. Drus. Beograd*, **25/26**, 455 (1960); *Chem. Abstr.*, **59**, 2146 (1963).
(744) V. Lostaglio, *Diss. Abstr.* **24**, 4008 (1964).
(745) I. L. Krupatkin, *Zh. Obshch. Khim.*, **29**, 3523 (1959).
(746) I. L. Krupatkin, *Zh. Obshch. Khim.*, **29**, 2490 (1959).
(747) E. F. Zhuravlev and M. N. Bychkova, *Uch. Zap. Permsk. Gos. Univ., Math., Phys., Khim.*, **8**, N 3, 15 (1954); *Chem. Abstr.*, **54**, 10482 (1960).
(748) V. V. Udovenko and S. F. Babak, *Zh. Obshch. Khim.*, **18**, 586 (1948).
(749) V. V. Udovenko, Konferentsiya po vyazkosti zhidkich i kolloidnych rastvorov, Akademii Nauk USSR, Vol. 2, 1944, p 89; *Chem. Abstr.*, 44, 9229 (1950).
(750) N. A. Trifonov, V. F. Ust'-Kachkintsev, and V. Ja. Teitel'baum, *Zh. Phys. Khim.*, **21**, 735 (1947).
(751) K. Sandell, *Naturwissenschaften*, **51**, 336 (1964).
(752) L. P. Krasnomolova, Yu. A. Kushnikov, and L. V. Levchenko, *Izv. Akad. Nauk Kaz. SSR, Ser. Khim.*, 55 (1959).
(753) E. Augdhal and P. Klaboe, *Acta Chem. Scand.*, **16**, 1655 (1962).
(754) E. Augdhal and P. Klaboe, *Acta Chem. Scand.*, **16**, 1647 (1962).
(755) E. Augdhal and P. Klaboe, *Acta Chem. Scand.*, **16**, 1637 (1962).
(756) Ch. Degard, *Bull. Soc. Roy. Sci. Liege*, **7**, 36 (1938).
(757) D. Coombe and J. Partington, *J. Chem. Soc.*, 1444 (1938).
(758) G. Glockler, *J. Phys. Chem.*, **63**, 828 (1959).
(759) H. Seemann-Abbart, *Acta Phys. Austriaca.*, 1, 346 (1948).
(760) A. Dadien and K. Kohlrausch, *Monatsh. Chem.*, **57**, 225 (1931).
(761) Yu. A. Kushnikov, L. V. Levchenko, and L. P. Krasnomolova, *Izv. Akad. Nauk Kaz. SSR, Ser. Khim.*, N 1, 68 (1961).
(762) Yu. A. Kushnikov, L. V. Levchenko, and L. P. Krasnomolova, Physich. problemy spectroskopii, Academii Nauk USSR, Materialy 13-go soveshchaniya, Leningrad, Vol. 1, p 402; *Chem. Abstr.*, **59**, 14766 (1963).
(763) M. Matsushima, *Tokyo Kogyo Shikensho Hokoku*, **60**, 1 (1965); *Chem. Abstr.*, **63**, 5501 (1965).
(764) L. Bellamy and R. Williams, *J. Chem. Soc.*, 3465 (1958).
(765) N. Lucazbau and A. Novak, *Spectrochim. Acta, Part A*, **25**, 1615 (1969).
(766) J. Cantacuzene, *Bull. Soc. Chim. Fr.*, 741 (1962).
(767) P. Federlin, *Bull. Soc. Chim. Fr.*, N 10, 11 (1953).
(768) P. Federlin, *C. R. Acad. Sci.*, **235**, 44 (1952).
(769) G. v. d. Kelen and Z. Eckhaut, *J. Mol. Spectrosc.*, 10, 141 (1963).
(770) V. S. Grechishkin and G. B. Soifer, *Phys. Tverd. Tela*, **3**, 2791 (1963); *Chem. Abstr.*, **62**, 8541 (1965).
(771) V. S. Grechishkin and G. B. Soifer, *Tr. Estestvennonauchn. Inst. Permsk. Gos. Univ.*, **12**, 3 (1966); *Chem. Abstr.*, **68**, 110114 (1968).
(772) D. Biedenkapp and A. Weiss, *Z. Naturforsch.*, **A22**, 1124 (1967).
(773) H. Allen, *J. Phys. Chem.*, **57**, 501 (1953).

(774) K. Torizuka, *Tokyo Gakugei Daigaku Kenkyu Hokoku, 3-bu, Shizen Kagaku*, **12**, 7 (1961); *Chem. Abstr.*, **60**, 7594 (1964).
(775) K. Torizuka, *J. Phys. Soc. Jpn.*, **9**, 645 (1954).
(776) R. Gallant, *Hydrocarbon Process.*, **47**, 141 (1968).
(777) A. N. Boitsov, Yu. S. Rotenberg, and V. G. Mulenkova, *Gig. Tr. Prof. Zabol.*, 14, 26 (1970); *Chem. Abstr.*, **73**, 9634 (1970).
(778) I. Chesuer and R. Leigh, *Tex.-Rundsch.*, **20**, 217 (1965).
(779) Deutsche Gold-Silber-Scheideanstalt vorm. Roessler, Neth. Appl. 6600277 (1966); *Chem. Abstr.*, **65**, 20277 (1966).
(780) Deutsche Gold-Silber-Scheideanstalt, British Patent 828049 (1960); *Chem. Abstr.*, **55**, 2127 (1961).
(781) R. Clauss and H. Brown, French Patent 1420336 (1965); *Chem. Abstr.*, **65**, 11774 (1966).
(782) Howard Wall Ltd. and F. Taylor, British Patent 1037617 (1966); *Chem. Abstr.*, **65**, 13224 (1966).
(783) Albright & Wilson (Mfg) Ltd. and Forestal Industries (UK) Ltd., British Patent 1006333 (1965); *Chem. Abstr.*, **64**, 1665 (1966).
(784) H. Brown and D. Backing, U.S. Patent 3075898 (1963); *Chem. Abstr.*, **59**, 3555 (1963).
(785) S. Watson, *Trans. Inst. Metal Finishing*, 40, N 2, 41 (1963); *Chem. Abstr.*, **59**, 2474 (1963).
(786) H. Brown, U.S. Patent 2900707 (1959); *Chem. Abstr.*, **54**, 115 (1960).
(787) R. Hull and R. Hoffman, U.S. Patent 2417203 (1947); *Chem. Abstr.*, 41, 3004 (1947).
(788) Société anon. manufacturers des glaces et produits chimiques de St.-Gobain, Chaury & Cirey, French Patent 1012189 (1952); *Chem. Abstr.*, **51**, 11645 (1957).
(789) L. Miller, *Contrib. Boyce Thompson Inst.*, **19**, 113 (1957); *Chem. Abstr.*, **52**, 6512 (1958).
(790) P. Aumonieur, C. Dulat, and R. Quilichini, *Bull. Soc. Pharm. Bordeaux*, 102, 279 (1963).
(791) Y. Sumiki and K. Horizu, Japanese Patent 7578 (1959); *Chem. Abstr.*, **54**, 2794 (1960).
(792) J. Seidemann and W. Schliepe, *Ernaehrungsforschung*, **2**, 657 (1957).
(793) G. Laties, *Plant Physiol.*, 40, 1237 (1965).
(794) C. Poulin and G. Rice, U.S. Patent 3398031 (1968); *Chem. Abstr.*, **69**, 69246 (1968).
(795) J. Le Bras, *Kautsch. Gummi, Kunstst.*, **18**, 561 (1965).
(796) Ch. Pinazzi, R. Pautrat, and R. Cheritat, French Patent 1377280 (1964); *Chem. Abstr.*, **62**, 7980 (1965).
(797) F. A. Kryuchkov and M. V. Khristyakova, USSR Patent 175941 (1965); *Chem. Abstr.*, **64**, 8424 (1966).
(798) L. Szego, *Fibre Colori*, **18**, 2 62 (1968).
(799) A. Ogait, *Cellul.-Chem.*, **22**, 15 (1944).
(800) E. Parkin, U.S. Patent 3227578 (1966); *Chem. Abstr.*, **64**, 9945 (1966).
(801) T. Hoshino, K. Ashida, and T. Mukaijama, Japanese Patent 18648 (1962); *Chem. Abstr.*, **59**, 7742 (1963).
(802) A. Wlochowicz and M. Wlodarczyk, *Polymer*, **13**, 120 (1968); *Chem. Abstr.*, **69**, 44318 (1968).
(803) J. Green, R. How, and P. Sikorski, Belgian Patent 646902 (1964); *Chem. Abstr.*, **63**, 13474 (1965).
(804) P. Sikorski, Belgian Patent 646708 (1964); *Chem. Abstr.*, **63**, 13477 (1965).
(805) H. De Witt, British Patent 838012 (1960); *Chem. Abstr.*, **55**, 1017 (1961).
(806) E. Nagai and N. Sagane, *J. Soc. Text. Cellul. Ind.*, **8**, 429 (1952).
(807) Chemstrand Corp., British Patent 808908 (1959); *Chem. Abstr.*, **53**, 10787 (1959).
(808) P. Halbig, Swiss Patent 293440 (1953); *Chem. Abstr.*, **51**, 4757 (1957).
(809) O. Fuchs, German Patent 952130 (1956); *Chem. Abstr.*, **53**, 3777 (1959).
(810) L. Valentine, *J. Polym. Sci.*, **23**, 297 (1957).
(811) I. Rusznak, I. Goczy, and A. Ady, *Faserforsch. Textiltech.*, **7**, 490 (1956).
(812) S. Hendrirx and F. Loots, British Patent 788363 (1958); *Chem. Abstr.*, **52**, 9657 (1958).
(813) E. Bourne and H. Weigel, *Methods Carbohydr. Chem.*, **5**, 78 (1965).
(814) R. Pattillo, A. Narkates, and J. Burns, *Radiat. Res.*, **25**, 401 (1965).
(815) J. Burns, J. Garcia, M. Lukan, C. Moucrief, and R. Pattillo, *Radiat. Res.*, **25**, 460 (1965).
(816) A. Sharma and A. Sarkar, *Phyton (Buenos Aires)*, **21**, 47 (1964); *Chem. Abstr.*, **61**, 8610 (1964).
(817) G. Freeman, A. v. Cleave, and J. Spinks, *Can. J. Chem.*, **31**, 1164 (1953).
(818) R. Hummel, G. Freeman, A. v. Cleave, and J. Spinks, *Science*, **119**, 159 (1954).
(819) W. Boyd, L. Brownell, and M. Farvar, AEC Acas. 14583, Rept. No. TID-21634; *Chem. Abstr.*, **65**, 18114 (1966).
(820) W. Moos, J. Nagel, and J. Naider, *Int. J. Appl. Radiat. Isotop.*, **21**, 177 (1970).
(821) C. Sachs and J. Bond, U.S. Patent 2641576 (1953); *Chem. Abstr.*, **47**, 7824 (1953).
(822) C. Sachs and J. Bond, U.S. Patent 2548685 (1951); *Chem. Abstr.*, **45**, 6430 (1951).
(823) R. Kreton and F. Hanousek, *Chem. Prumysl*, 10, 331 (1960); *Chem. Abstr.*, **55**, 12919 (1961).
(824) I. Mankowich, U.S. Patent 2657236 (1953); *Ref. Zh. Khim.*, 24762 (1955).
(825) I. Mankowich, U.S. Patent 2663734 (1953); *Chem. Abstr.*, **48**, 4248 (1954).
(826) R. Bell and W. Higginson, *Proc. Roy. Soc., Ser. A*, **197**, 141 (1949).
(827) O. K. Sharaev, A. V. Alferov, E. I. Tinyakova, and B. A. Dolgoplosk, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 2583 (1967).
(828) O. K. Sharaev, A. V. Alferov, E. I. Tinyakova, and B. A. Dolgoplosk, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 2584 (1967).
(829) E. N. Zavadovskaya, M. P. Teterina, O. K. Sharaev, A. G. Azizov, T. K. Vydrina, E. I. Tinyakova, and B. A. Dolgoplosk, *Dokl. Akad. Nauk SSSR*, **188**, 822 (1969).
(830) J. Bitman, H. Cecil, S. Harris, and G. Fries, *Science*, **162**, 371 (1968).
(831) M. Carron, French Patent M 2647 (1964); *Chem. Abstr.*, **61**, 15942 (1964).
(832) W. Petrow, A. Thomas, and O. Stephenson, British Patent 874246 (1959); *Chem. Abstr.*, **56**, 7340 (1962).
(833) P. Dechamps, Belgian Patent 663616 (1965); *Chem. Abstr.*, **64**, 19706 (1966).
(834) S. Truchlik, V. Konecny, J. Synak, and S. Priehradny, Czech. Patent 110822 (1964); *Chem. Abstr.*, **61**, 13816 (1964).
(835) J. Pizey and A. Bates, *J. Sci. Food Agric.*, **12**, 542 (1961).
(836) V. V. Dovlatyan, *Sb. Nauchn. Tr. Army. Skh. Inst.*, N 10, 263 (1958); *Chem. Abstr.*, **54**, 22479 (1960).
(837) I. Shah and J. Trivedi, *J. Indian Chem. Soc.*, 41, 223 (1964).
(838) H. Schubert, German Patent 949946 (1956); *Chem. Abstr.*, **53**, 10039 (1959).
(839) C. Katsaros and W. Martin, U.S. Patent 3546346 (1970); *Ref. Zh. Khim.*, 16N660P (1971).
(840) V. Ettel and J. Weichet, *Collect. Czech. Chem. Commun.*, 14, 747 (1949).
(841) A. Doerken and G. Schrader, German Patent 1186467 (1965); *Chem. Abstr.*, **62**, 16149 (1965).
(842) V. K. Khairullin and T. I. Sobchik, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 2010 (1965).
(843) H. Krase and W. Dye, U.S. Patent 2786075 (1957); *Chem. Abstr.*, **51**, 13918 (1957).
(844) M. Zbirovsky and J. Myške, "Insekticidy, fungicidy, rodenticidy," Praha, 1957, p 234.
(845) I. A. Shichiev and B. G. Jusufov, *Dokl. Akad. Nauk Azerb. SSR*, **21**, 19 (1965).
(846) I. A. Shichiev, M. I. Aliev, and B. G. Jusufov, *Zh. Obshch. Khim.*, **35**, 1954 (1965).
(847) I. A. Shichiev, S. Sh. Verdieva, and I. A. Aslanov, *Azerb. Khim. Zh.* 33 (1964).
(848) F. K. Sagitullin, I. M. Kafengaus, and A. P. Kafengaus, USSR Patent 182330 (1966); *Chem. Abstr.*, **66**, 3153 (1967).
(849) K. Thinius and W. Thummler, *Chem. Tech.*, **8**, 198 (1956).
(850) E. Irany, U.S. Patent 2892811 (1959); *Chem. Abstr.*, **53**, 17584 (1959).
(851) A. M. Kuliev, A. G. Zul'fugarova, and I. I. El'ovich, *Dokl. Akad. Nauk Azerb. SSR*, **21**, 20 (1965).
(852) W. Heldt, *J. Org. Chem.*, **27**, 2608 (1962).
(853) W. Wittmann, *Stain Technol.*, 40, 161 (1965).