lary glass tubing immersed in a pan of water and extending part way up into a 50-cc. buret filled with water and standing in the water.

The evolved gas was collected in the buret and the volume, temperature, and pressure of the gas noted as the dehydrogenation was carried out. As one buret became filled with gas another was put in its place.

The test tube was placed in a Wood's metal-bath heated with a Bunsen burner to an initial temperature of 220°. Gas bubbles began to appear after a few minutes of heating and, as they began to slacken, the temperature of the bath was raised over a period of four hours. The final temperature was 320°. A total volume of 163.5 cc. of gas at standard temperature and pressure (corrected for water vapor pressure) was collected. The theoretical amount of hydrogen at standard temperature and pressure is 114 cc. for 0.00510 mole. An equal amount of carbon dioxide should be evolved, and this explains the excess over the theory for hydrogen. Most of the carbon dioxide was lost by solution in the water over which the gas was collected.

The residue in the test-tube was extracted with ether. The ether solution was filtered and evaporated. The oily residue solidified on cooling. It was dissolved in alcohol, treated with Darco, and filtered. Two successive attempts at crystallization by adding water to the hot solution and cooling yielded only gummy precipitates. The alcohol solution was transferred to a 10-cc. distilling flask, the alcohol removed, and the residue subjected to distillation at reduced pressure. Only a drop or two collected in the side-arm (b. p. 145-150° (19 mm.)), but when the distilling flask cooled, solid crystals appeared on the sides. The crystals, which were removed, amounted to 0.053 g., m. p. 98–105°. After recrystallization from alcohol-water solution, the melting point was 112°. The literature gives 110–111°[9] and 112–113°[10] for the melting point of *p*-ethylbenzoic acid. *m*-Ethylbenzoic acid is reported to melt at 47°.[11]

Anal. Calcd. for $C_9H_{10}O_2$: C, 71.98; H, 6.71. Found: C, 71.50; H, 6.99.

Esterification of the Unsaturated Dibasic Acid.—In a 50-cc., ground-glass, round-bottom flask attached to a 2-ft., water-cooled condenser were placed 0.98 g. (0.005 mole) of the unsaturated acid (m. p. 235°), 5 cc. of absolute alcohol (0.085 mole) and 2 drops of concentrated sulfuric acid. The reactants were refluxed on the steam-bath for four hours. Then 10 cc. of benzene was added, the water-cooled condenser replaced by a 10-in. Vigreux column and a total reflux-partial take-off head and the solution heated under practically total reflux as the azeotropic mixture of alcohol, benzene, and water was taken off at 65–72° over a period of four and one-half hours. The remaining traces of benzene and alcohol were removed by distillation under water pump pressure.

The residue was dissolved in 50 cc. of distilled ether and washed three times with 15-cc. portions of 5% aqueous potassium hydroxide solution, dried over anhydrous sodium sulfate, filtered, and distilled under reduced pressure in a 10-cc. distilling flask. The ester boiled at 131–133° (3 mm.) and amounted to 15–20 drops; n^{20}_D 1.4801[12]; d^{20}_4 1.0639[12]; M_D calcd. 67.04; M_D found 67.38 (exaltation of 0.34).

The ester was soluble in alcohol, ether and chloroform. It was insoluble in dilute potassium hydroxide and 10% sodium bicarbonate solution. The ester decolorized dilute aqueous potassium permanganate solution but did not decolorize bromine in chloroform solution.

Anal. Calcd. for $C_{14}H_{20}O_4$: C, 66.64; H, 7.99. Found: C, 66.54; H, 7.95.

Acidification of the potassium hydroxide wash solution with concentrated hydrochloric acid gave 0.128 g. of recovered acid, m. p. 233–234°.

Summary

2-Cyano-1,3-butadiene dimerizes on standing at 5° in the presence of a trace of picric acid to yield a solid whose structure is that of the Diels–Alder condensation product, 1-vinyl-1,4-dicyano-Δ^4-cyclohexene. Proof of the six-membered ring structure was obtained by converting the dimer to an unsaturated dibasic acid which was dehydrogenated and decarboxylated to *p*-ethylbenzoic acid.

The infrared absorption spectra of the dimer and of the diester prepared from it indicate the presence of a conjugated and an unconjugated nitrile group and ester group, respectively, thus confirming the structure assigned on the basis of degradation. No evidence for an eight-membered dimer was noted. Smaller amounts of other dimers may have been lost in working up the mixture.

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(9) Fittig and König, *Ann.*, **144**, 290 (1867).

(10) Aschenbrandt, *ibid.*, **216**, 218 (1882).

(11) "Handbook of Chemistry and Physics," 29th ed., Chemical Rubber Publishing Company, Cleveland, Ohio, 1945, p. 640.

(12) These data determined by Clark Microanalytical Laboratory, Urbana, Illinois.

Urbana, Illinois Received August 30, 1948

[Contribution from the Laboratory of Organic Chemistry of the University of Wisconsin]

Orthoesters and Related Compounds from Malono- and Succinonitriles

By S. M. McElvain and Juel P. Schroeder[1]

The study of the preparation of orthoesters from nitriles, which has been in progress for some time in this Laboratory[2] in connection with work on the ketene acetals, has been extended to malono- and succinonitriles. The present paper reports the preparation and alcoholysis of the various iminoester hydrochlorides that may be obtained from these dinitriles and describes certain related products resulting from these reactions.

Treatment of each of these dinitriles with equivalent amounts of methanol and hydrogen chloride gave the monoimino salts (I and III) readily and methanolysis of these salts gave good yields of the corresponding cyanoörthoesters (II and IV). In the case of II it was necessary to remove all traces of acid from the reaction product with aqueous sodium carbonate solution before distillation to prevent the pyrolysis of the orthoester to cyanoketene dimethylacetal.

Attempts to convert II to the corresponding iminoester with equivalent amounts of methanol

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(2) McElvain and (a) Nelson, This Journal, **64**, 1825 (1942); (b) Clarke, *ibid.*, **69**, 2661 (1947); (c) Stevens, *ibid.*, **69**, 2663 (1947).

$$CH_2(CN)_2 \xrightarrow{94\%} \underset{I}{CNCH_2C(OCH_3){=}NH_2Cl} \xrightarrow{65\%} \underset{II}{CNCH_2C(OCH_3)_3}$$

$$(CH_2CN)_2 \xrightarrow{80\%} \underset{III}{CN(CH_2)_2C(OCH_3){=}NH_2Cl} \xrightarrow{77\%} \underset{IV}{CN(CH_2)_2C(OCH_3)_3}$$

and hydrogen chloride gave none of the iminoester hydrochloride but instead the corresponding normal esters in the yields shown

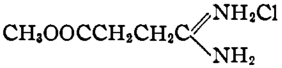
$$II \xrightarrow[HCl]{CH_3OH} \underset{73\%}{CNCH_2COOCH_3} + \underset{21\%}{CH_2(COOCH_3)_2} + \underset{18\%}{NH_4Cl}$$

It appears that most of the hydrogen chloride was consumed in cleavage of II to the cyano-ester, methanol and methyl chloride before it reacted with nitrile and methanol to give the iminoester hydrochloride. The orthoester IV showed a similar tendency to be cleaved by hydrogen chloride prior to reaction of the nitrile group. In an attempt to prepare the diorthoesters directly from the dinitriles, each of the latter was dissolved in sufficient methanol to retain the intermediate salts (I and III) in solution and treated with two equivalents of hydrogen chloride. From these reactions also normal esters were the sole reaction products.

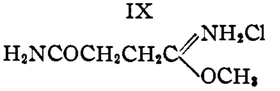
These results indicate that orthoesters of malonic and succinic acids cannot be prepared by a stepwise alcoholysis of the corresponding nitriles. Consequently, their preparation from the diiminoester hydrochlorides was undertaken. The preparation of diethyl iminomalonate dihydrochloride (VI) in high yields has been reported[3] from the reaction of malononitrile with equivalent amounts of ethanol and hydrogen chloride *in ether solution*. This preparation could not be duplicated in the present work using either methanol or ethanol; instead, the only reaction products obtained were the monohydrochlorides corresponding to I or mixtures of the mono and dihydrochlorides, which precipitated from the reaction mixture. However, the preparation of the di-iminoester salt (VI) in quantitative yield was accomplished by treating the nitrile and alcohol in dioxane solution with a large excess of hydrogen chloride. The melting point of VI (119–120°) so obtained did not correspond to that (138°) previously reported,[3a] but its structure was shown beyond doubt by its halogen content and by its pyrolysis to ethyl chloride (93%) and malonamide (81%). Attempts to prepare the homologous methyl iminoester salt by this procedure gave a mixture of I and V. However, the use of a mixture of chloroform and dioxane as solvent gave V in reasonably pure form. The preparation of the di-iminoester salt VIII from succinonitrile has been reported.[4] Both VII and VIII were readily prepared in practically quantitative yields in the present work using dioxane as a solvent.

$ClNH_2{=}(RO)C(CH_2)_nC(OR){=}NH_2Cl$

V. R is CH_3, n is 1
VI. R is C_2H_5, n is 1
VII. R is CH_3, n is 2
VIII. R is C_2H_5, n is 2



IX



X

Methanolysis of VII by the procedures used for the cyanoörthoesters II and IV gave dimethyl succinate (45%), ammonium chloride (57%), and β-carbomethoxypropionamidine hydrochloride,[5] IX (36%). The structure of the latter compound was proved by the following synthesis, which eliminates the alternative isomeric structure (X) that might conceivably be a product of this reaction.

$$CH_3OOCCH_2CH_2CN \xrightarrow[HCl]{CH_3OH} CH_3OOCCH_2CH_2C(OCH_3){=}NH_2Cl \xrightarrow{NH_3} IX$$

Alkaline hydrolysis converts the amidine salt (IX) to ammonia and succinic acid; acid hydrolysis converts it to β-carboxypropionamidine, which, as the free base, appears to exist as an inner salt, judging from its high melting point and insolubility in water and other inert solvents.

An attempt to prepare the free base from the diiminoester hydrochloride VII furnished some insight into the mechanism by which IX is formed during the alcoholysis of VII. When VII was treated with an excess of aqueous sodium bicarbonate solution, a clear solution[6] resulted and only one of the hydrochloride functions was decomposed, as shown by the amount of carbon dioxide evolved. When this solution was acidified and subjected to mild hydrolysis for several hours, β-carboxypropionamidine (56%), succinimide (25%) and succinic acid (12%) were isolated. From these results it would appear that the bicarbonate converted VII to a monohydrochloride VIIa, which by loss of methanol passed into the cyclic amidino-ester hydrochloride (VIIb), the structure of which accounts for the failure of the weaker alkali to neutralize but one of the hydrochloride functions of VII as well as the water-solubility of the resulting product. The compounds isolated from the acidic hydrolysis of the half-

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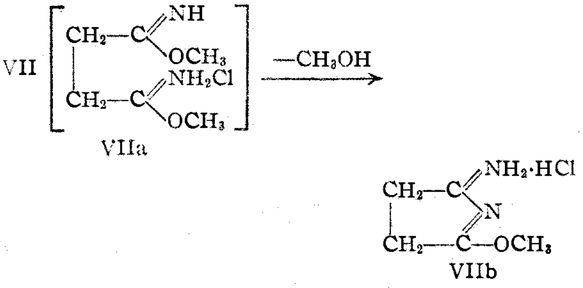
(3) (a) Houben and Blaise, Houben, "Die Methoden der organischen Chemie," 3rd Ed., Vol. VI, p. 436; (b) Kenner, Lythgoe, Todd and Topham, *J. Chem. Soc.*, 574 (1943).

(4) Pinner, *Ber.*, **16**, 352 (1883). No yield of VIII was reported; this method used ether as a solvent and it started with a two-phase system (succinonitrile is sparingly soluble in ether) which was reported to change, as the hydrogen chloride was absorbed, to a homogeneous solution, from which the salt finally precipitated.

(5) Pinner, ref. 4, noted the concurrent formation of an amidine salt and an ester during the pyrolysis of ethyl iminoformate hydrochloride.

(6) With sodium hydroxide solution a resinous product was precipitated; Pinner (ref. 4), who attempted to isolate the free base of VIII with similar results, assumed that the clear solution obtained was due to the water solubility of the free base.

neutralized solution of VII would be expected from the intermediate cyclic salt VIIb. From these observations it seems reasonable to conclude that IX is formed during the methanolysis of VII *via* the intermediate iminoester VIIb.



The isolation of normal esters instead of orthoesters in the above alcoholyses indicated that the latter esters were being destroyed during the removal of the alcohol from the alcoholysis solution prior to the alkaline wash. This supposition was confirmed when the two orthoesters XI and XII were obtained by the procedure[2b] in which the solution, resulting from the alcoholysis of VII, was neutralized with sodium methoxide prior to the removal of the alcohol. In this manner methyl ortho-β-carbomethoxypropionate (XI) and methyl orthosuccinate (XII) were obtained in 11 and 15% yields, respectively.

$CH_3OOCCH_2CH_2C(OCH_3)_3$ XI $(CH_3O)_3CCH_2CH_2C(OCH_3)_3$ XII

The ester XI, which may be obtained in much higher yield (63%) from methyl β-cyanopropionate, is a liquid with marked stability to heat; for example, no change was noted in a sample after refluxing (b. p. 210°) for one and one-half hours. This is in marked contrast to the β-cyano-orthoester (IV) which slowly but steadily loses methanol under similar conditions. The di-orthoester XII is a crystalline solid, m. p. 50–51°. It loses methanol slowly on heating and is converted to a high-boiling, viscous oil which was not studied further.

An attempt was made to obtain the diorthoester XII from the trichloroörthoester XIII, which was prepared in good yields from γ,γ,γ-trichlorobutyronitrile. However, XIII failed to undergo a replacement reaction with sodium methoxide; instead it was dehydrohalogenated to a product which gave analytical data approximating those calculated for the structure XIV.

$$\underset{\text{XIII}}{Cl_3CCH_2CH_2C(OCH_3)_3} \xrightarrow{NaOCH_3} \underset{\text{XIV}}{ClC{\equiv}CCH_2C(OCH_3)_3}$$

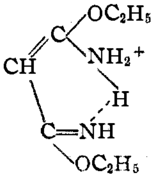
The preparation of ethyl orthocarbethoxyacetate (XV), a malonic ester corresponding to XI, was accomplished from ethyl cyanoacetate using the same procedure that proved successful for II.[7] However, the alcoholysis of the diiminoester hydrochloride VI by the procedure that produced XI and XII in the succinic series failed to yield either XV or ethyl orthomalonate (XVI). Instead, ethyl malonate, carbethoxyacetamide, ethyl cyanoiminoacetate (XVII) and ethyl orthocarbiminoethoxyacetate (XVIII) were the products isolated from the reaction.

$C_2H_5OOCCH_2C(OC_2H_5)_3$ XV $(C_2H_5O)_3CCH_2C(OC_2H_5)_3$ XVI

$CNCH_2C(OC_2H_5){=}NH$ XVII $CNCH{=}C(OC_2H_5){-}NH_2$ XVIIa

$HN{=}(C_2H_5O)CCH_2C(OC_2H_5)_3$ XVIII

A singular feature of this alcoholysis was the separation of only 50–55% of the expected ammonium chloride, regardless of the time (twenty to one hundred thirty hours) allowed for the alcoholysis. However, the alcoholic solution from which the ammonium chloride was filtered still contained sufficient hydrochloride salt to require 0.5 of an equivalent of sodium ethoxide (25%) for neutralization after correction for the dissolved ammonium chloride. This fact, the relatively low yield of ammonium chloride, together with the isolation of such products as XVII and XVIII, suggest that a considerable portion of the dihydrochloride VI, which is very insoluble in alcohol, is converted to a more soluble monohydrochloride,[8] which resists alcoholysis by virtue of the resonance stabilization of the ene-amine form of its cation



The neutralization of this cation by sodium ethoxide would produce XVII.[9] The iminoester-orthoester (XVIII) could be formed by the partial alcoholysis of VI and possibly also by the slower alcoholysis of the above cation of the monohydrochloride.

The exaltation of the molar and specific refractivities of ethyl cyanoiminoacetate indicate that it exists in the ene-amine from (XVIIa) as does the corresponding carbiminoethoxyester,[10] $C_2H_5OOC\text{-}CH{=}C(OC_2H_5)NH_2$.

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[7] In this connection it is of interest to note that Reitter and Weindel (*Ber.*, **40**, 3358 (1907)) reported that the alcoholysis of ethyl carbiminoethoxyacetate hydrochloride yielded carbethoxyketene diethylacetal instead of the expected orthoester (*cf.* also ref. 10).

[8] This conclusion is indicated by the fact that the dihydrochloride (21.5 g.) goes into solution immediately when treated with the same amount (250 ml.) of alcohol containing sufficient pyridine (7.4 g.) to neutralize one of the hydrochloride functions. One reaction by which a monohydrochloride might be formed during alcoholysis is through cleavage of an orthoester by the dihydrochloride: $RC(OC_2H_5)_3 + CH_2(C(OC_2H_5){=}NH_2Cl)_2 \rightarrow RCOOC_2H_5 + C_2H_5Cl + C_2H_5OH + HN{=}(C_2H_5O)CCH_2C(OC_2H_5){=}NH_2Cl$. This reaction is under investigation in this Laboratory.

[9] Neutralization of the dihydrochloride (VI) with sodium ethoxide yields XVII also; with aqueous sodium carbonate, however, VI is converted to diethyl iminomalonate.

[10] Glickman and Cope, This Journal, **67**, 1017 (1945).

TABLE I

IMINOESTER HYDROCHLORIDES, $RC(OR')=NH_2Cl$

R is	R′ is	Nitrile, moles		Solvent, ml.	HCl used, moles	Yield, %, in (days)	Formula	Anal., % ionic Cl Calcd.	Found
$CNCH_2$	CH_3 (I)	1.5	Ether	850	1.6	87 (1)	$C_4H_7ClN_2O$	26.4	26.4
$CNCH_2$	C_2H_5	0.05	Ether	30	0.07	98 (1)	$C_5H_9ClN_2O$	23.9	24.4
$CNCH_2CH_2$	CH_3 (III)	1.0	Ether	700	1.2	80 (15)	$C_5H_9ClN_2O$	23.9	24.0
			Dioxane	90					
$C_2H_5OOCCH_2$	C_2H_5	0.35	None		0.44	93 (16)	[a]		
$CH_3OOCCH_2CH_2$	CH_3	0.34	Ether	200	1.0	93 (3)[b]	$C_6H_{12}ClNO_3$	19.5	19.9
$Cl_3CCH_2CH_2$	CH_3	0.16	Ether	100	0.21	92 (21)	$C_5H_9Cl_4NO$	14.7	15.0
$ClH_2N=(CH_3O)CCH_2$	CH_3 (V)	0.01	..[d]		..[c]	100 (1)	$C_5H_{12}Cl_2N_2O_2$	34.9	34.2
$ClH_2N=(C_2H_5O)CCH_2$	C_2H_5 (VI)	0.10	Dioxane	120	..[c]	95 (1)	$C_7H_{16}Cl_2N_2O_2$	30.7	30.7
$ClH_2N=(CH_3O)C(CH_2)_2$	CH_3 (VII)	0.20	Dioxane	80	..[c]	96 (2)	$C_6H_{14}Cl_2N_2O_2$	32.7	32.6
$ClH_2N=(C_2H_5O)C(CH_2)_2$	C_2H_5 (VIII)	0.20	Dioxane	4[e]	..[c]	95 (2)	[f]		

[a] Reported by Reitter and Weindel.[7] [b] Product separated as an oil which crystallized after decantation of the supernatant liquid and washing the precipitate with ether. [c] Two moles of the alcohol corresponding to R′ per mole of nitrile used and the solution saturated with hydrochloric acid. [d] A mixture of 15 ml. of chloroform and 15 ml. of dioxane as solvent; when dioxane alone was used as the solvent the product was contaminated with methyl cyanoiminoacetate hydrochloride. [e] This amount of dioxane was required to cause a homogeneous solution of the nitrile in the alcohol. [f] Reported by Pinner, ref. 4.

Experimental

Nitriles.—Malononitrile was prepared by the method of Surrey,[11] succinonitrile by that of Fauconnier,[12] γ,γ,γ-trichlorobutyronitrile by that of Bruson, *et* al.[13] Ethyl cyanoacetate was purchased from the Eastman Kodak Company. Methyl β-cyanopropionate was prepared in the following manner. A mixture of 66.5 g. of methyl β-cyanoiminopropionate hydrochloride (see Table I) and 100 ml. of water was swirled until solution was complete. This process was accompanied by marked cooling; after about two minutes, the solution evolved considerable heat and the ester began to separate. The mixture was allowed to stand at room temperature overnight after which the product was extracted with ether and dried over potassium carbonate. Distillation gave a yield of 38.2 g. (75%) of methyl β-cyanopropionate,[14] b. p. 93–103° (8 mm.), which was collected almost entirely at 95–97°.

Preparation of the Iminoester Hydrochlorides.—The general method of preparation described by Pinner[15] was used throughout this work. Strict precautions were always taken to ensure that the reagents were anhydrous and were protected from atmospheric moisture during the reaction. The nitrile and an equimolar quantity of the alcohol were dissolved in an inert solvent, the solution cooled in ice-water, and then treated with dry hydrogen chloride. Pinner and most of the previous workers in this Laboratory used ether as the inert solvent. In the present work anhydrous dioxane was found to be an excellent solvent for the preparation of certain of these salts because of a combination of desirable properties. First, it is a much better solvent for malononitrile and succinonitrile than is ether, *e. g.*, 75 ml. of ether per gram of succinonitrile is necessary to produce a homogeneous solution; however, a mixture of 0.6 ml. of dioxane and 5 ml. of ether dissolves 1 g. of this nitrile. Secondly, the iminoester hydrochlorides precipitate much more slowly from the dioxane than from ether.

The delayed precipitation of the salts from dioxane had two advantages: (a) in the preparation of di-iminoester dihydrochlorides it permitted both nitrile groups to react before any precipitation occurred and (b) it prevented clogging of the gas inlet tube by an early precipitation of the salt. Recently, anhydrous chloroform has been found to exert a similar solvent action on iminoester hydrochlorides and has been used in their preparation.[16] With this solvent, however, these salts often do not precipitate on standing, but must be recovered by evaporation of the solvent. Unfortunately, chloroform is a poor solvent for hydrogen chloride and experience in the present work has shown that a 1:1 mixture of chloroform and dioxane is for this reason a better solvent. This mixed solvent had to be used for the preparation of dimethyl iminomalonate dihydrochloride (V).

The pertinent data concerning the iminoester hydrochlorides prepared in this work are summarized in Table I.

Ethyl Cyanoiminoacetate.—To an ice-cooled mixture of 200 ml. of 40% aqueous potassium carbonate and 200 ml. of ether in a separatory funnel was added 26.5 g. (0.178 mole) of ethyl cyanoiminoacetate hydrochloride. The mixture was shaken for one minute and the ether layer separated and poured over anhydrous potassium carbonate. A little ice-water and 100 cc. of cold ether were added to the aqueous layer and the extraction procedure repeated as above. After two additional extractions, the combined extracts were decanted on to a fresh portion of drying agent and allowed to stand several hours. The ether was carefully evaporated on the steam-bath in a stream of dry air and the residue dried to constant weight in the vacuum desiccator. The yield of slightly impure, tan ethyl cyanoiminoacetate, m. p. 75–77°, was 19.4 g. (97%). Recrystallization from ether gave beautiful, white plates, m. p. 78–79°, b. p. 102–103° (10 mm.).

Anal. Calcd. for $C_5H_8N_2O$: C_2H_5O, 40.2; N, 25.0. Found: C_2H_5O, 40.8; N, 24.8.

In order to estimate the molar refraction, the densities and refractive indices at 25° were determined for known mixtures of ethyl cyanoiminoacetate with dioxane and with pyridine. These values were plotted against the corresponding concentrations and the straight lines obtained were extrapolated to 100% iminoester. The values thus obtained were: $n^{25}D$ 1.501 (with dioxane), 1.510 (with pyridine), average 1.506; d^{25}_4 1.063 (with dioxane), 1.060 (with pyridine), average 1.062. *M*D, calcd. for XVII 28.71, for XVIIa 29.71; found: 31.36. Thus the molar exaltation of XVIIa is 1.65, and the specific exaltation 1.47, which are comparable to the corresponding values of 1.80 and 1.13 reported[10] for ethyl carbethoxyiminoacetate.

Ethyl cyanoiminoacetate also was obtained from diethyl iminomalonate dihydrochloride (VI) in the following manner. To a solution of 4.1 g. (0.06 mole) of sodium ethoxide in 50 ml. of absolute ethanol containing phenolphthalein

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(11) "Organic Syntheses," **25**, 63 (1945).

(12) Fauconnier, *Bull. soc. chim.*, **50**, 214 (1888).

(13) Bruson, Niederhauser, Riener and Hester, THIS JOURNAL, **67**, 601 (1945).

(14) Karvonen, *Ann. Acad. Sci. Fennicae*, **20**, no. 9 (1924).

(15) Pinner, "Die Imidoaether und ihre Derivate," Oppenheim, Berlin, 1892; *cf.* also McElvain and Nelson, THIS JOURNAL, **64**, 1825 (1942).

(16) Djerassi and Scholz, *ibid.*, **69**, 1691 (1947).

as an indicator was added 6.9 g. (0.03 mole) of diethyl iminomalonate dihydrochloride. The mixture warmed slightly and the red color of the indicator disappeared. An additional 2 ml. of the sodium ethoxide solution was added to restore the alkalinity of the mixture and the latter was stirred for ten minutes. The precipitated sodium chloride was filtered by suction and the filtrate concentrated. Distillation of the residue gave 1.8 g. (54%) of ethyl cyanoiminoacetate, b. p. 101–102° (10 mm.), which crystallized on cooling. Recrystallization from ether gave the pure iminoester, m. p. 79–80°

When a warm solution of 5.6 g. (0.05 mole) of ethyl cyanoiminoacetate in 20 ml. of anhydrous benzene was mixed with a warm solution of 5.0 g. (0.051 mole) of freshly distilled maleic anhydride in 10 ml. of dry benzene, the mixture heated spontaneously and had to be cooled under the tap; a voluminous precipitate began to separate immediately and after digestion for fifteen minutes on the steam-bath the mixture was cooled and filtered. The yield of crude **ethyl N-(β-carboxyacrylyl)-cyanoiminoacetate**, m. p. 132–134° dec., was 10.4 g. (99%). Recrystallization from either acetone or dioxane gave 5.3 g. of a light yellow product, m. p. 141–142° dec. An additional recrystallization from dioxane yielded 4.1 g. of the pure material, m. p. 152–152.5° dec.; neutral equiv., 203 216 (calcd. 210).

Anal. Calcd. for $C_9H_{10}N_2O_4$: N, 13.3; C_2H_5O, 21.4. Found: N, 13.2; C_2H_5O, 20.4.

Diethyl Iminomalonate.—This di-iminoester was obtained in 44% yield by treatment of the salt VI with a cold, saturated aqueous solution of potassium carbonate and immediate extraction with ether. After drying over sodium sulfate, it distilled as a colorless liquid, b. p. 62–63° (0.4 mm.); $n^{25}\text{D}$ 1.4530, d^{25}_4 1.011. Houben and Blaise[3a] reported this iminoester to boil at 58° (0.2 mm.), but gave no yield or analytical data for it.

Anal. Calcd. for $C_7H_{14}N_2O_2$: N, 17.7. Found: N, 17.9.

On standing this iminoester discolored rapidly and, after several weeks, became a dark brown semi-solid mass.

Pyrolysis of Diethyl Iminomalonate Dihydrochloride (VI).—When 2.5 g. of VI was heated in a bath at 150–160°, 1.3 g. (93%) of ethyl chloride, b. p. 12°, was condensed in a trap immersed in a Dry Ice–alcohol mixture. Recrystallization of the pyrolysis residue from absolute alcohol gave 0.9 g. (81%) of malonamide, m. p. 170–172°.

Attempted Preparation of Dimethyl Iminosuccinate.—When dimethyl iminosuccinate dihydrochloride was treated with cold, aqueous sodium carbonate or sodium bicarbonate and the mixture shaken with ether, a negligible amount of liquid was found in the ether layer.[6] Stronger bases such as sodium hydroxide or potassium carbonate yielded only resinous material in the ether layer and a dark-colored aqueous phase. The following experiments were performed in order to explain this anomalous behavior.

A mixture of 4.1535 g. of dimethyl iminosuccinate dihydrochloride and 8.0 g. of sodium bicarbonate was placed in a 200-ml. round-bottomed flask immersed in ice-water and equipped with a dropping funnel and delivery tube. On addition of 10 ml. of ice-water from the funnel, carbon dioxide was evolved and collected over mineral oil. The yield of carbon dioxide thus obtained amounted to 42.8% based on complete neutralization of the dihydrochloride. The residue was acidified with dilute nitric acid and the quantity of chloride ion determined. A 6.8% loss of chloride ion indicated the formation of this amount of methyl chloride. The combined yield of carbon dioxide and methyl chloride was, therefore, 49.6%, indicating that only one hydrochloride group per molecule had been neutralized.

To 200 ml. of ice-cooled 10% aqueous sodium carbonate was added 15.5 g. (0.071 mole) of dimethyl iminosuccinate dihydrochloride. The clear solution was acidified with 75 ml. of concentrated hydrochloric acid and evaporated nearly to dryness at a temperature of 50–70° in a stream of dry air. The slightly moist, solid residue was extracted with four 50-ml. portions of boiling acetone. To the acetone-insoluble residue was added 35 ml. of concentrated hydrochloric acid in 100 ml. of water and the evaporative hydrolysis repeated over a period of three hours. After acetone extraction of the residue, the latter was subjected to a third hydrolysis. The amounts of brown, crystalline solid extracted in each of these three acetone treatments were: (1) 10.5 g., (2) 1.5 g. and (3) 0.5 g.

The extracted material was dissolved in water, and sodium bicarbonate added until no further effervescence occurred. The white precipitate which had separated during this neutralization was filtered off and identified as β-carboxypropionamidine, m. p. 255.5° dec.; the yield was 4.6 g. (56%). This product was identical with that prepared from β-carbomethoxypropionamidine hydrochloride (see below). The filtrate was evaporated to dryness and extracted with boiling acetone to yield 1.8 g. (25.5%) of succinimide, m. p. 121.5–124°, which was separated from a small amount of inorganic contaminant by extraction with ether. Recrystallization from absolute ethanol gave the pure imide, m. p. 125–126°. The residue from this acetone extraction was acidified with hydrochloric acid and evaporated to dryness. Extraction with acetone removed a solid, which was recrystallized from water to give 1.0 g. (12%) of succinic acid, m. p. 185–186°.

Preparation of Orthoesters.—The following preparation of methyl orthocyanoacetate illustrates the method by which the monoiminoester hydrochlorides of Table I were converted to the corresponding orthoesters; following this preparation are descriptions of procedures used with the di-iminoester dihydrochlorides, VII and VI.

Methyl Orthocyanoacetate (II).—A mixture of 385 g. (2.85 moles) of methyl cyanoiminoacetate hydrochloride and 3 l. of absolute methanol was shaken until the salt had dissolved. This process was accompanied by marked cooling. After three hours ammonium chloride began to separate and the reaction appeared to be complete after standing overnight at room temperature. The methanol was removed by distillation through a fifteen-inch Vigreux column. Severe bumping invariably accompanied distillation of the methanol in the conventional manner due to the ammonium chloride that continued to separate. The bumping could be avoided by blowing a gentle stream of *dry* air through the mixture as it was heated on the steam-bath at such a rate that the temperature of the vapors was about 50°. When all the methanol had been removed, the residue was cooled and 500 ml. of dry ether added. The mixture was filtered by suction and the white solid residue washed with 200 ml. of dry ether. Extraction of the solid with hot absolute alcohol dissolved 38.3 g. (16%) of cyanoacetamide, m. p. 110–115°, and left a residue of 114.5 g. (75%) of ammonium chloride. The crude amide was recrystallized from water and the purified material melted at 118–119°.

The ether filtrate and washings from the ether-insoluble solid were combined and washed with a saturated aqueous solution of sodium carbonate. After drying over solid potassium carbonate, the ether layer was distilled to yield 269 g. (65%) of methyl orthocyanoacetate.

Methyl Orthosuccinate (XII) and Methyl Ortho-β-carbomethoxypropionate (XI).—A slurry of 38.0 g. (0.175 mole) of dimethyl iminosuccinate dihydrochloride in 250 ml. of absolute methanol was stirred mechanically for forty-two hours while immersed in a bath held at 13–15°. The resulting light green mixture was made alkaline to phenolphthalein with methanolic sodium methoxide and allowed to stand for one hour. The methanol then was distilled under reduced pressure and 200 ml. of anhydrous ether added to the residue. The precipitated solid was filtered and washed with dry ether, after which the filtrate and washings were evaporated to 50 ml. and more solid filtered and washed as before. The filtrate and washings were concentrated and distilled. After collecting a forerun, b. p. 82–104° (5 mm.), a fraction, b. p. 104–108° (5 mm.), which crystallized on standing and melted at 48–50°, was collected. Two recrystallizations from ethyl acetate, which required cooling in a Dry Ice–acetone mixture, gave pure methyl orthosuccinate, m. p. 50–51°. On cooling the forerun, b. p. 82–104° (5 mm.), in ice, additional

TABLE II

ORTHOESTERS $RC(OR')_3$

R is	R' is	B. p. °C.	B. p. Mm.	$n^{25}D$	d^{25}_4	Yield, %	Formula	Analyses, % Calcd. R'O	Calcd. N	Calcd. C	Calcd. H	Found R'O	Found N	Found C	Found H
$CNCH_2$	CH_3 (II)	98-102	13	1.4215	1.079	65	$C_6H_{11}NO_3$	64.2	9.7			64.4	9.7		
$CNCH_2$	C_2H_5	83-84	2	1.4189	0.978	62[a,b]	$C_9H_{17}NO_3$	72.2	7.5			71.9	7.5		
$CNCH_2CH_2$	CH_3 (IV)	73-74	0.5	1.4269	1.055	77[b]	$C_7H_{13}NO_3$	58.5	8.8			58.1	8.9		
$C_2H_5OOCCH_2$	C_2H_5	120-121	18	1.4220	0.995	82	$C_{11}H_{22}O_5$	76.9		56.4	9.5	75.9		56.0	9.3
$CH_3OOCCH_2CH_2$	CH_3 (XI)	64-65	1	1.4230	1.084	63	$C_8H_{16}O_5$	64.6		50.0	8.4	64.1		49.5	8.1
$Cl_3CCH_2CH_2$	CH_3 (XIII)	91-92	4	1.4578	1.277	84	$C_7H_{13}Cl_3O_3$	37.0	...[c]			37.5	...[c]		
$(CH_3O)_3CCH_2CH_2$	CH_3 (XII)	104-108	5	1.4261[d]	...	15	$C_{10}H_{22}O_6$	78.1		50.4	9.3	76.9		50.2	9.2
$HN{=}(C_2H_5O)CCH_2$	C_2H_5 (XVIII)	94-95	3	1.4272	0.979	8	$C_{11}H_{23}NO_4$	77.2	6.0			75.9	5.6		

[a] Alcoholysis solution neutralized with sodium ethoxide before removal of alcohol; when the alcohol was removed before neutralization as in the preparation of II, the yield was 36%. [b] This orthoester was freed of normal ester by treatment with aqueous ammonia (sp. gr. 0.90). [c] Calcd.: Cl, 42.3. Found: Cl, 42.7. [d] This compound melts at 50–51°; the $n^{25}D$ was determined on the supercooled liquid.

orthoester was obtained and redistillation of the filtrate from this crop provided still more. The total yield of methyl orthosuccinate was 6.4 g. (15%).

From this second distillation of the forerun, b. p. 82–104°, 3.7 g. (11%) of XI, b. p. 91–98° (6 mm.), was obtained.

Alcoholysis of Diethyl Iminomalonate Dihydrochloride (VI).—A mixture of 107 g. (0.46 mole) of this salt and 1300 ml. of absolute ethanol was stirred in a bath held at 40°. The salt was quite insoluble in the alcohol and disappeared very slowly. After twenty-one hours, the precipitate of ammonium chloride (18.2 g., 0.34 mole) was filtered off and the filtrate titrated to the phenolphthalein end-point with 168 ml. (0.365 mole) of 2.173 *N* ethanolic sodium ethoxide. Thus the total amount of hydrochloride salts still present in the solution and as precipitated ammonium chloride was 0.705 mole or 77% of the ionic chlorine of the original iminoester hydrochloride. (In a similar run the ionic chlorine in this alcoholic solution was determined by titration with standard silver nitrate; the soluble chloride together with that precipitated as ammonium chloride was found to be 80% of that present in the iminoester salt used, which is in good agreement with the value obtained by neutralization with alkali.) The amount of ammonium chloride which dissolves in 1300 ml. of absolute ethanol is 7.9 g. so that the total yield of that salt was estimated to be 26.1 g. (53%).

The neutralized reaction mixture was made distinctly alkaline by addition of 5 ml. of the alcoholic sodium ethoxide solution and the precipitated sodium chloride removed by filtration. The filtrate was refluxed under a condenser which was connected to a trap immersed in a Dry Ice–alcohol mixture. After fifteen minutes a liquid had collected in the trap; on fractionation it yielded 3.5 g. (6%) of ethyl chloride, b. p. 12–15°, and small amounts of ammonia and ethanol. The alcohol then was distilled at about 100 mm. from the reaction mixture through an efficient column after which the following fractions were collected: (a) 25.0 g. of liquid boiling below 110° (2 mm.) and (b) 12.7 g. (21%) of carbethoxyacetamide, b. p. 130–135° (2 mm.), which was obtained as an oil that crystallized completely on seeding with an authentic sample of the amide. Washing with ether gave white crystals, m. p. 48–49°, which contained 34.5% ethoxyl and 10.8% nitrogen (calcd. 34.4 and 10.7%, respectively). The non-volatile residue from the distillation amounted to 22.0 g.

Fraction (a) was taken up in 400 ml. of 60–68° petroleum ether and the mixture allowed to stand in the refrigerator overnight. Filtration removed 2.4 g. (5%) of crude ethyl cyanoiminoacetate, which after recrystallization from ethyl acetate melted at 78–79°.

The petroleum ether filtrate from the iminoester was fractionated into: (1) 6.9 g. (9%) of diethyl malonate, b. p. 81–90° (4 mm.); (2) 3.4 g., b. p. 90–100° (4 mm.); (3) 8.4 g. (8%) of **ethyl orthocarbiminoethoxyacetate** (XVIII), b. p. 100–105° (4 mm.); and (4) 1.4 g. of residual oil. Redistillation of fraction (3) gave the pure iminoester-orthoester, b. p. 94–95° (3 mm.), the properties and analysis of which are listed in Table II. The identity of this compound was further established by treatment of 1.2 g. of fraction (3) in ice-cooled ether with an ether solution of anhydrous hydrogen chloride of known concentration. The addition of 0.8 mole of hydrogen chloride per mole of nitrogen present caused heat evolution but no precipitation; however, further addition of the reagent up to 2.0 moles per mole of nitrogen caused a separation of a white solid which was not increased by further addition of hydrogen chloride. The precipitate was filtered off and found to be 0.9 g. (90%) of ethyl carbethoxyiminoacetate hydrochloride, m. p. 92–94° dec. (reported,[10] 99–101° dec.), which contained 17.7% chlorine (calcd. 18.1%). Since the melting point did not agree with the value reported in the literature, the salt was further characterized by pyrolysis of a 1.0-g. sample to 0.2 g. (60%) of ethyl chloride, b. p. 11–12°, and 0.7 g. of residual oil which crystallized on seeding with carbethoxyacetamide. Recrystallization from ether gave the pure amide, m. p. 49–50°.

A similar treatment of fraction (2) with hydrogen chloride gave an 80% yield of ethyl carbethoxyiminoacetate hydrochloride indicating that this fraction also was largely XVIII.

Low yields of ammonium chloride were obtained invariably in the alcoholysis of diethyl iminomalonate dihydrochloride. Thus, at 30° the yields were 56, 50 and 53.5% for reaction periods of sixty-five, eighty and one hundred and thirty hours, respectively, while at 50° a yield of only 56% was obtained after twenty-one hours.

Alcoholysis of Diethyl Iminomalonate Dihydrochloride in the Presence of Pyridine.—To a solution of 7.4 g. (0.094 mole) of anhydrous pyridine in 250 ml. of absolute ethanol was added 21.5 g. (0.093 mole) of diethyl iminomalonate dihydrochloride (VI). After five minutes of shaking the salt had dissolved completely. The solution was heated under reflux in a bath at 40° for twenty-seven hours. During this time no ethyl chloride was collected in a trap provided for that purpose and only a small amount of crystalline solid precipitated.

The reaction mixture was titrated to the phenolphthalein end-point with 2.173 *N* ethanolic sodium ethoxide and required 78.5 ml. (92%) for neutralization. The precipitated sodium chloride was filtered off and the alcohol distilled from the filtrate through an efficient column at about 100 mm. pressure. Fractionation of the residue gave: (a) 0.9 g. (4%) of XVIII; (b) 0.8 g. (7%) of carbethoxyacetamide; and (c) 6.4 g. of a non-volatile tar. Fraction (a) showed only a slight opalescence in 60–68° petroleum ether, indicating that very little ethyl cyanoiminoacetate was present.

The properties and analyses of the orthoesters prepared by the above procedures are summarized in Table II.

When the alcoholic solution resulting from the methanolysis of dimethyl iminosuccinate dihydrochloride (VII) was distilled without the addition of sodium methoxide, a viscous, yellow oil remained as a residue. After trituration with dry ether, the oil was dissolved in water and this solution extracted with ether. From the combined ether extracts a 45% yield of dimethyl succinate was isolated. The aqueous solution was evaporated to dryness, extracted with boiling absolute ethanol and the insoluble ammonium chloride filtered off. Evaporation of the alcohol filtrate left a 36% yield of crude **β-carbomethoxypropionamidine hydrochloride (IX)**, which after recrystallization from absolute ethanol melted at 131–132°.

Anal. Calcd. for $C_5H_{11}ClN_2O_2$: Cl, 21.3; N, 16.8; CH_3O, 18.6. Found: Cl, 21.3; N, 16.7; CH_3O, 17.6.

This amidine salt was also prepared in the following manner: A mixture of 16.5 g. (0.091 mole) of methyl β-carbomethoxyiminopropionate hydrochloride and 20 ml. of absolute methanol was placed in a 200-ml. flask and the lumps of the salt broken up with a glass rod. Then a solution of 1.7 g. (0.10 mole) of ammonia in 12 ml. of methanol was added and the mixture swirled. There was an immediate heavy precipitation of a white solid which quickly redissolved. The mixture was kept at room temperature by cooling in an ice-bath. After standing for thirty minutes the solution was evaporated on the steam-bath in a stream of dry air and finally dried in a vacuum desiccator over sulfuric acid. The crystalline product, m. p. 126–128°, weighed 15.1 g. (99%). Recrystallization from absolute ethanol gave pure β-carbomethoxypropionamidine hydrochloride, m. p. 131–132°.

A solution of 0.54 g. of β-carbomethoxypropionamidine hydrochloride in 15 ml. of concentrated hydrochloric acid was heated at 95–100° for one hour. Evaporation of the aqueous acid under diminished pressure left 0.51 g. of crude β-carboxypropionamidine hydrochloride, m. p. 131–137°. Titration of this salt with standard alkali gave 0.305 g. (80%) of β-carboxypropionamidine, m. p. 258–260° dec.

Anal. Calcd. for $C_4H_8N_2O_2$: N, 24.1. Found: N, 24.2.

Evaporation of a solution of this amidine in dilute hydrochloric acid left β-carboxypropionamidine hydrochloride, m. p. 138–140°.

Anal. Calcd. for $C_4H_9ClN_2O_2$: Cl, 23.3; N, 18.4. Found: Cl, 23.6; N, 18.8.

Methyl Ortho-β-carbamylpropionate.—A mixture of 2 g. of methyl ortho-β-carbomethoxypropionate (XI) and 10 ml. of aqueous ammonia (sp. gr. 0.90) was stirred at room temperature until a clear solution was obtained (one-half hour). The resulting solution was extracted with chloroform and dried over Drierite. Evaporation of the solvent left 1.5 g. (82%) of methyl ortho-β-carboxamidopropionate, m. p. 90–94°. After washing with petroleum ether (b. p. 60–68°), this product melted at 94–97°.

Anal. Calcd. for $C_7H_{15}NO_4$: N, 7.91. Found: N, 7.85.

This compound is quite sensitive to recrystallization, yielding β-carbomethoxypropionamide when it was recrystallized from the ordinary organic solvents. This product was obtained also when the aqueous ammoniacal solution was evaporated to dryness under diminished pressure.

In contrast to the facile reaction of XI with aqueous ammonia, ethyl orthocarbethoxyacetate did not dissolve in aqueous ammonia even after forty-eight hours of efficient stirring. After this time approximately 75% of the unchanged orthoester was recovered.

Reaction of Hydrogen Chloride with the Cyano-orthoesters II and IV.—A solution of 11.6 g. (0.08 mole) of methyl orthocyanoacetate (II) in 2.56 g. (0.08 mole) of anhydrous methanol was cooled in ice while 2.9 g. (0.08 mole) of dry hydrogen chloride was introduced. The clear solution was placed in a refrigerator for one week during which a white solid slowly precipitated. Dry ether was added and the mixture placed in the refrigerator for an additional day. Filtration separated 0.66 g. of ammonium chloride. Distillation of the filtrate yielded 2.2 g. (21%) of dimethyl malonate and 5.8 g. (73%) of methyl cyanoacetate. From the distillation residue an additional 0.11 g. of ammonium chloride was separated, raising the total yield of this product to 0.77 g. (18%).

Dry hydrogen chloride was passed into a 6.2-g. sample of methyl ortho-β-cyanopropionate (IV). The liquid became hot and a small quantity of white solid separated. After saturation with the gas, the liquid was distilled to yield 4.1 g. (93%) of methyl β-cyanopropionate, b. p. 97–99° (9 mm.); 0.7 g. (56%) of methanol was collected in the cold trap.

Reaction of Sodium Methoxide with Methyl Ortho-γ,γ,γ-trichlorobutyrate (XIII).—A methanolic solution of sodium methoxide was prepared by dissolving 3.5 g. (0.15 atom) of sodium in 37.5 ml. of absolute methanol. On the addition of 12.6 g. (0.05 mole) of XIII the mixture heated and became dark brown. After standing overnight, 150 ml. of anhydrous ether was added and the white precipitate filtered off. The chloride and titratable alkali contents of this solid indicated that it consisted of 2.9 g. (33% yield) of sodium chloride and a trace of sodium methoxide. The solvents were removed from the filtrate at reduced pressure and the residue was distilled. It boiled over a wide range (44–85° (4–5 mm.)) and all of the fractions collected decolorized a bromine in carbon tetrachloride solution readily indicating that dehydrohalogenation had occurred. The largest fraction (2.4 g.) was a colorless liquid, b. p. 62–73° (5–4 mm.), $n^{25}{}_D$ 1.4550, $d^{25}{}_4$ 1.1435. This material had the correct analysis and molar refraction for **1-chloro-4,4,4-trimethoxybutyne-1**.

Anal. Calcd. for $C_7H_{11}ClO_3$: Cl, 19.9; CH_3O, 52.1. Found: Cl, 19.8; CH_3O, 53.5.

Summary

The preparation of cyano-orthoesters from malono- and succinonitriles *via* the mono-iminoester hydrochloride is described. Hydrogen chloride in alcohol solution cleaves each of these orthoesters to the normal ester before it converts the cyano group to the iminoester hydrochloride.

Succinonitrile has been converted *via* the di-iminoester hydrochloride to the ester-orthoester, $(CH_3O)_3CCH_2CH_2COOCH_3$, and the di-orthoester, $(CH_3O)_3CCH_2CH_2C(OCH_3)_3$, of succinic acid. Under the same conditions of reaction, malonitrile yields ethyl orthocarbiminoethoxyacetate. An explanation for this behavior is suggested.

The preparation and properties of a number of related compounds, including ethyl orthocarbethoxyacetate, are described.

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