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

THE SYNTHESIS OF VINYLETHYLMALONIC ESTER AND INCIDENTAL COMPOUNDS

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Attempts to introduce the vinyl group indirectly into monosubstituted malonic esters and barbituric acids have been reported by Voorhees and Skinner.[1] Further attempts to introduce the vinyl group directly into malonic ester through the reaction of vinyl bromide with the sodium derivative of phenylmalonic ester also have been reported.[2] All of these efforts were unsuccessful. The present paper reports the results of further work in this direction which has resulted in the successful synthesis of vinylethylmalonic ester. However, the properties of this ester, described below and in the following paper, seem to preclude any hope of obtaining the corresponding barbituric acid from it by any of the procedures ordinarily used for the conversion.

Two methods of synthesis of vinylethylmalonic ester seemed possible. The first of these involved the preparation of the quaternary salt (II) and the decomposition of the corresponding base by distillation into the vinylethylmalonic ester. The preparation of the salt (II) was to be accomplished through the reaction of trimethylamine with ethyl (β-bromoethyl)-malonic ester (I). When this reaction was tried it was found that conditions which produced a satisfactory rate of reaction gave tetramethylammonium bromide rather than the desired salt (II). The malonic ester was isolated in the form of the hydrochloride of ethyl (β-dimethylaminoethyl)-malonic ester (III). The course which the reaction had taken is illustrated by the equations

$$(CH_3)_3N + BrCH_2CH_2-\underset{\underset{C_2H_5}{|}}{C}(COOC_2H_5)_2 \longrightarrow \underset{\underset{Br}{|}}{(CH_3)_3N}CH_2CH_2\underset{\underset{C_2H_5}{|}}{C}(COOC_2H_5)_2 \longrightarrow$$

(I) (II)

$$CH_3Br + \underset{\underset{C_2H_5}{|}}{(CH_3)_2NCH_2CH_2C}(COOC_2H_5)_2(CH_3)_3N + CH_3Br \longrightarrow (CH_3)_4NBr$$

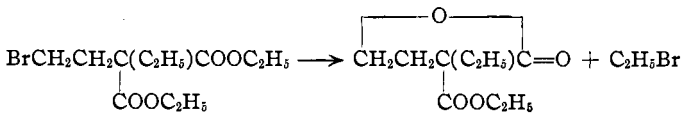
(III)

If the reactants were allowed to stand in ether solution for several weeks, a small quantity of a salt, which bromine analysis showed to be mainly (90%) (II), precipitated. However, the yield was so low and the time of formation so extended that the method was abandoned as impractical. In addition to the above difficulty it was found that the bromo ester

[1] Voorhees and Skinner, This Journal, 47, 1124 (1925).

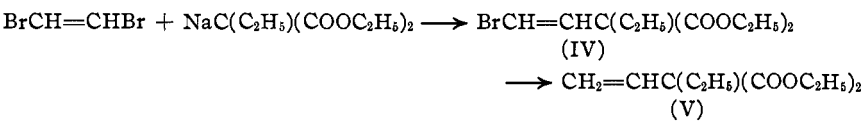
[2] Vanderveer Voorhees, Ph.D. Dissertation, University of Wisconsin, 1924.

(I) has a decided tendency to decompose on distillation into ethyl bromide and α-ethyl-α-carbethoxybutyrolactone.[3]



This decomposition takes place to a slight extent during distillation under pressures of 1–3 mm. Distillation at atmospheric pressure converts the bromo ester smoothly and completely into the lactone and ethyl bromide.

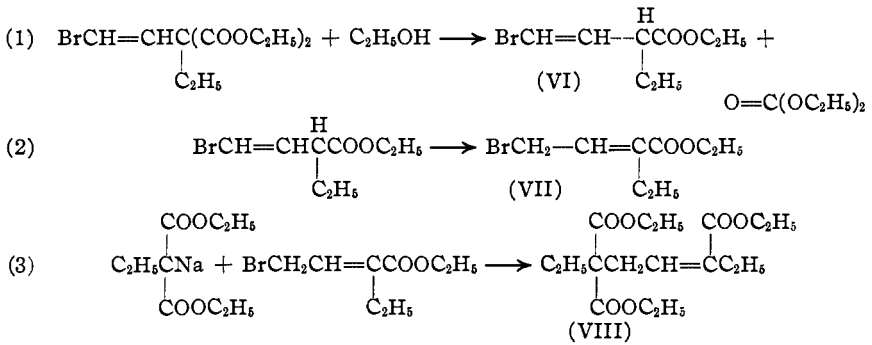
The second and successful method of synthesis of vinylethylmalonic ester involved the reaction of symmetrical dibromomethylene with sodioethylmalonic ester, followed by the reduction of the resulting ethyl (β-bromovinyl)-malonic ester (IV) with zinc dust and alcohol at 170° to vinylethylmalonic ester (V). These reactions may be illustrated thus



The yield of the bromovinyl ester (IV) amounted to 25% of the theoretical, while the yield of vinylethylmalonic ester from the reduction of the bromo ester was 54%. In marked contrast to ethyl (β-bromoethyl)-malonic ester (I), ethyl (β-bromovinyl)-malonic ester (IV) shows no tendency to lose ethyl bromide and change into a lactone; in fact it distils (264–266°) at atmospheric pressure without the slightest decomposition. The vinylethylmalonic ester was characterized by analyses, the amount of hydrogen absorbed in a quantitative catalytic hydrogenation and the conversion of this reduction product, diethylmalonic ester, into di-*p*-nitrobenzyl diethylmalonate, which was compared with an authentic specimen.

The reaction for the preparation of the bromovinyl ester (IV) is somewhat more complicated than is shown above. Under the most favorable conditions of reaction there was obtained along with (IV) an approximately equal quantity of a high boiling, bromine-free *tricarboxylic* ester. This compound was shown to be 3,6,6-tricarbethoxyoctene-3 (VIII), which had been formed from the bromovinyl ester (IV) by the reactions

[3] This compound corresponds in its physical properties to the compound reported as ethyl (β-hydroxyethyl)-malonic ester by Shonle, Keltch and Swanson, THIS JOURNAL, **52**, 2440 (1930). They obtained their hydroxy ester by the ethylation of β-hydroxyethylmalonic ester. It is probable that this latter compound was also the lactone rather than the hydroxy ester since decomposition during the distillation of the reaction product of ethylene chlorohydrin and sodiomalonic ester was noted. This supposition is strengthened by earlier observations of the instability of β-hydroxyethylmalonic ester by Traube and Lehmann, *Ber.*, **32**, 720 (1899) and Cretcher, Koch and Pittinger, THIS JOURNAL, **47**, 3083 (1925).



The characterization of (VIII) as described below was completed long before it was possible to find an explanation for its formation. The origin of the necessary alcohol for reaction (1) was at first a mystery since the reaction between dibromoethylene and sodioethylmalonic ester had been carried out in absolute ether and this sodio derivative had been prepared by the action of powdered metallic sodium on the ethylmalonic ester in ether. However, an investigation of this latter reaction showed that only 77% of the theoretical quantity of hydrogen was evolved, hence 23% of the sodium used had reduced the malonic ester instead of forming the sodium derivative. This amount of reduction is capable of producing the alcohol necessary for the formation of the triester (VIII). The validity of the above reactions is shown also by the following facts, (a) a considerable amount of ethyl carbonate was isolated from the reaction, (b) ethyl (β-bromovinyl)-malonic ester (IV) reacts vigorously and, within a few minutes, completely with an equivalent of sodium ethoxide in alcohol to form ethyl α-ethyl-γ-ethoxycrotonate, $C_2H_5OCH_2CH{=}C(C_2H_5)COOC_2H_5$, and sodium bromide; the speed of this reaction definitely points to a shift in the double bond of the bromo ester (VI) to the more reactive allyl type (VII). The identity of this substituted ethyl crotonate was established by reduction and comparison of the reduction product with an authentic specimen of ethyl α-ethyl-γ-ethoxybutyrate.

The triester (VIII) was characterized by reduction to 3,6,6-tricarbethoxyoctane and by the conversion of this latter ester through saponification and decarboxylation into α,α'-diethyladipic acid.

Several attempts to condense vinylethylmalonic ester with urea by means of sodium ethoxide in alcoholic solution were made. However, the only product isolated from the reaction mixture was α-ethylcrotonamide,[4] $CH_3CH{=}C(C_2H_5)CONH_2$. The formation of this compound is due to the alcoholysis of the vinylethylmalonic ester, the rearrangement of the resulting unsaturated ester to ethyl α-ethylcrotonate and the reaction of this latter ester with urea (or ammonia) to form the above amide.

[4] Von Auwers, *Ann.*, **432**, 76 (1923).

The marked readiness with which the vinylethylmalonic ester undergoes alcoholysis, together with its susceptibility to cleavage by sodium ethoxide, as described in the following paper, would seem to indicate that the synthesis of vinylethylbarbituric acid could not be effected through this ester.

Experimental

Mono-ethylmalonic ester was kindly furnished in liberal quantities by Mr. H. A. Shonle of the Lilly Research Laboratories, to whom the authors wish to acknowledge their indebtedness, not only for this and other valuable materials, but for his interest and many valuable suggestions.

Ethyl (β-Bromoethyl)-ethylmalonate and α-Ethyl-α-carbethoxy Butyrolactone.—The bromo ester was prepared by a procedure used by Shonle,[5] which involved the reaction of 2 moles of ethylene bromide with 1 mole of sodio-ethylmalonic ester prepared from ethylmalonic ester and powdered sodium under benzene. The yield of product boiling at 128–130° (3 mm.), n_D^{25} 1.4541, amounted to 35–40%. If the distillation of this product is not carried out at quite low pressures and superheating avoided, there is a considerable evolution of ethyl bromide (with a resultant rise in pressure) and the distillate shows a halogen content much lower than the value calculated for the bromo ester. When such material is distilled under atmospheric pressure ethyl bromide is evolved rapidly and the distillate, which is α-ethyl-α-carbethoxybutyrolactone, contains no bromine.

This lactone[6] boils at 265–267° (740 mm.); 135–138° (9 mm.); n_D^{25} 1.44421; d_{25}^{25} 1.1045; M_D calcd. 45.16, observed 44.87. Saponification equivalent, calcd. 93, found 95.5.

Anal. Calcd. for $C_9H_{14}O_4$: C, 58.02; H, 7.58. Found: C, 58.06; H, 7.85.

Reaction of Ethyl (β-Bromoethyl)-ethylmalonate with Trimethylamine.—A solution of 29.6 g. (1 mol) of the bromo ester and 6.5 g. (1.1 mol) of trimethylamine in 25 cc. of absolute alcohol was sealed in a bomb tube and heated at 130° for eighteen hours. After this time the tube was opened and the contents diluted with ether. The precipitated salt showed a bromine content of 51.55% (calcd. for tetramethylammonium bromide, 51.30%). The ether–alcohol solution from which this salt had precipitated was evaporated to dryness and the residue taken up in dry ether. The hydrochloride of ethyl (β-dimethylaminoethyl)-ethylmalonate was precipitated with dry hydrogen chloride. After recrystallization the hydrochloride melted at 147–148°. Voorhees[2] records a similar melting point for this compound after recrystallization but states that after sublimation it melts at 154°.

Anal. Calcd. for $C_{13}H_{26}O_4NCl$: Cl, 12.01. Found: Cl, 12.00.

When the above reaction was carried out in alcohol at 100° for eighteen hours, a salt containing 29.86% bromine was obtained (calcd. for the quaternary salt (II), 23.0%). When a solution of the reactants in dry ether was allowed to stand for several weeks a small yield of a salt containing 26.17% bromine was obtained.

Ethyl (β-Bromovinyl)-ethylmalonate.—To 115 g. (5 moles) of powdered sodium, covered with 3 liters of absolute ether in a 5-liter three-necked flask carrying a dropping funnel, a mercury-seal stirrer and a reflux condenser, was added slowly 940 g. (5 moles) of ethylmalonic ester. When all of the sodium had reacted, 1860 g. (10 moles) of sym-

[5] Private communication.

[6] The physical constants reported for ethyl (β-hydroxyethyl)-malonic ester[3] are b. p. 128–131° (6 mm.), n_D^{20} 1.4444. No analyses were given.

metrical dibromoethylene[7] was added and the ether refluxed with stirring for six hours on a steam-bath. Then the reaction mixture was stirred at room temperature for ninety hours. After this time the ethereal solution was washed with dilute hydrochloric acid and a 10% salt solution. The ether was then removed by distillation and the residue fractionated through a Widmer column. The boiling points and amounts of the fractions collected were

Fraction	Compound	B. p., °C.	Weight, g.	Recovery or yield, %
1	Dibromoethylene	107–111	1008	54.1
2	Diethyl carbonate	124–126	62	7.1
3	Ethylmalonic ester	106–110 (25 mm.)	119	12.7
4	Ethyl (β-bromovinyl)-malonic ester	117–120 (1 mm.)	362	24.8
5	3,6,6-Tricarbethoxyoctene-3	152–155 (1 mm.)	251	30.7

Intermediate fractions between 3 and 4 and 4 and 5 amounted to 39 g. and 48 g., respectively; 123 g. of a non-distillable residue remained. Ethyl (β-bromovinyl)-malonic ester (fraction 4) had the following constants: n_D^{25} 1.46195; d_{25}^{25} 1.2645; M_D calcd. 63.95; observed, 63.89.

Anal. Calcd. for $C_{11}H_{17}O_4Br$: Br, 27.27. Found: Br, 27.32.

The bromovinyl ester was further characterized by catalytic reduction to diethylmalonic ester; 12 g. in 30 cc. of alcohol absorbed 2 moles of hydrogen in fifteen minutes in the presence of 0.1 g. of Adams' platinum catalyst. The reduction product was converted into di-*p*-nitrobenzyl diethylmalonate,[8] m. p. 90–91°.

The bromovinyl ester may be distilled at atmospheric pressure without any noticeable decomposition, b. p. 264–266°. With alkali it gives immediately an intense red color. This color reaction is a convenient test for the purity of fraction 5, since pure 3,6,6-tricarbethoxyoctene-3 remains colorless in the presence of alkali.

When the condensation between dibromoethylene and sodioethylmalonic ester was carried out in benzene instead of ether, the chief product was the bromine-free fraction 5, although a small amount of the bromovinyl ester (fraction 4) was obtained. Besides the unfavorable ratio of reaction products, this condition of reaction has a further disadvantage. At the reflux temperature of benzene, the dibromoethylene is decomposed by the alkali present into bromoacetylene, which ignites spontaneously when it comes in contact with air at the top of the reflux condenser.

Ethyl Vinylethylmalonate.—A solution of 25 g. of ethyl (β-bromovinyl)-malonic ester in 60 cc. of 95% alcohol was placed in the glass liner of a steel bomb[9] and 10 g. of zinc dust added. The liner was then placed in the bomb under an initial pressure of 1200 lb. of nitrogen and the bomb heated with shaking at 170° for ten hours. After the removal of the zinc by filtration, the combined alcoholic solutions from eight such runs were distilled under diminished pressure to remove the alcohol. The residue was then taken up in ether and the resultant solution washed with dilute hydrochloric acid and dried over anhydrous sodium sulfate. After removal of the ether the material was fractionated. That portion of the distillate (46 g.) which boiled above 124° (24 mm.) was again treated as described above with zinc and alcohol in the bomb and the resultant product combined with the low boiling (below 124° (24 mm)) portion from the first distillation and the combined product redistilled through a Widmer column. The yield of vinyl ethylmalonic ester from the reduction of 200 g. of the bromovinyl ester was 79 g. (54%); b. p. 122–124 (30 mm.); n_D^{25} 1.4341; d_{25}^{25} 1.0110; M_D calcd., 56.07; observed, 55.15.

[7] *Chem. Zentr.*, [II] **84**, 1375 (1913).

[8] Lyman and Reid, This Journal, **39**, 711 (1917).

[9] *Cf.* Adkins and Cramer, *ibid.*, **52**, 4349 (1930).

Molecular weight (in benzene). Found: 212.4; calcd., 214.

Anal. Calcd. for $C_{11}H_{18}O_4$: C, 61.64; H, 8.47. Found: 61.80; 8.47.

The vinylethylmalonic ester was definitely characterized by quantitative catalytic reduction with Adams' platinum catalyst; 0.4150 g. of ester required for complete reduction 43.48 cc. (100.06%) of hydrogen. The reduction product, diethylmalonic ester, was converted into di-*p*-nitrobenzyl diethylmalonate.[8]

3,6,6-Tricarbethoxyoctene-3.—This ester (fraction 5 in the preparation of the bromovinyl ester, see above) on redistillation boiled at 150–152° (2 mm.) or 304–306 (740 mm.); n_D^{25} 1.45212; d_{25}^{25} 1.0534; molecular weight in benzene and dioxane 320, 321.2. Zeisel determination showed 2.90 ethoxyl groups per mole. Saponification equivalent with 0.2 *N* potassium hydroxide (sodium hydroxide does not give complete saponification due to the separation of an insoluble, resinous material) 107.8; calcd., 109.3; M_D calcd., 85.56; observed, 84.28.

Anal. Calcd. for $C_{17}H_{28}O_6$: C, 62.13; H, 8.53. Found: 61.80, 8.51.

This triester slowly decolorized a solution of bromine in carbon tetrachloride, but could not be reduced catalytically over a platinum catalyst. Over nickel, however, at 175° and 2500 lb. pressure it absorbed 1 mole of hydrogen after a second addition of fresh catalyst. Over the copper–chromium oxide catalyst[10] at 175° and 2500 lb. pressure it readily absorbed 1 mole of hydrogen to give an 80% yield of 3,6,6-tricarbethoxyoctane.

3,6,6-Tricarbethoxyoctane.—This ester boiled at 154–156 (2 mm.); n_D^{25} 1.44421; d_{25}^{25} 1.0337; M_D calcd., 85.95; obs., 85.08. Saponification equivalent (0.2 *N* alcoholic KOH) 109; calcd., 110.

Anal. Calcd. for $C_{17}H_{30}O_6$: C, 61.82; H, 9.09. Found: C, 61.77; H, 8.91.

A portion of this ester was saponified with alcoholic potassium hydroxide and the resultant acid, after removal of the alcohol, decarboxylated by refluxing with 20% sulfuric acid. The α,α'-diethyladipic acid was extracted from the acid solution with ether and after three recrystallizations from water melted at 136–136.5°[11] and had a neutral equivalent of 103.4. In order to establish definitely the identity of this adipic acid, it was prepared from 3,3,6,6-tetracarbethoxyoctane which was obtained by the ethylation of ethylbutane-1,1,4,4-tetracarboxylate[12] by Lean's procedure.[11] By saponification and decarboxylation of this tetracarbethoxyoctane a mixture of the racemic and meso-α,α'-diethyladipic acids was obtained. Recrystallization from water gave the less soluble meso acid which melted at 136–136.5° and gave no depression when mixed with the diethyladipic acid obtained from the tricarbethoxyoctane.

The above data established the structure of the high boiling bromine-free fraction (V) and the isolation of ethyl carbonate from the reaction mixture indicated that the carbethoxy group was removed by alcoholysis. The alcohol necessary for a cleavage must be formed in the reaction, as all of the starting materials were dry and free from alcohol. The most probable source of the necessary alcohol seemed to be the initial reaction of powdered sodium with ethyl monoethylmalonate, as under these conditions ester reduction or acyloin condensation, which would produce alcohol or sodium ethoxide, could take place. The acyloin condensation as a side reaction would also explain the large residue obtained on fractionating the mixture.

The measurement of the quantity of hydrogen evolved in the reaction of an excess of ethyl monoethylmalonate with a weighed quantity of powdered sodium was used to determine the extent of these side reactions. The normal reaction giving the sodium

[10] Connor, Folkers and Adkins, THIS JOURNAL, **54**, 1138 (1932).

[11] Lean, *J. Chem. Soc.*, **65**, 1009 (1894).

[12] Noyes and Kyriakides, THIS JOURNAL, **32**, 1058 (1910).

enol ester evolves a molecular equivalent of hydrogen, while none is formed in the side reactions.

An apparatus similar to that employed by Moureu and Mignonac[13] for differentiating amines by the Grignard reagent was used. Approximately 1.5 g. of freshly cut sodium was weighed under mineral oil, powdered under xylene, and washed into a 500-cc. 3-necked round-bottomed flask with 60 cc. of anhydrous ether. The flask was fitted with a mercury-seal stirrer, separatory funnel, and reflux condenser, the latter protected by a calcium chloride tube which was attached to a delivery tube leading to an inverted 1-liter graduate over water. The flask was immersed to a definite level in a water-bath at 40° and, after the formation of air bubbles due to the refluxing ether had ceased, the delivery tube was placed under the graduate and a small portion of ethyl monoethylmalonate introduced through the separatory funnel. The water-bath was then removed and the ester added at such a rate as to keep the solution refluxing. Toward the end of the reaction the water-bath was replaced and the final gas volume read after the reaction ceased. The accuracy of the method was shown by the fact that ethyl alcohol gave about 103% of the theoretical amount of hydrogen when it was used instead of the malonic ester. By this procedure the average of several runs using both ether and benzene as media showed that when an excess of ethyl malonic ester was allowed to react with sodium only 77% of the theoretical amount of hydrogen was evolved. The remaining hydrogen equivalent must have been utilized for reduction which would produce the necessary alcohol (or sodium ethoxide) for the cleavage of the ethyl (β-bromovinyl) malonic ester into ethyl α-ethyl-γ-bromocrotonate (VII).

Reaction of Ethyl (β-Bromovinyl)-malonic Ester with Alcoholic Sodium Ethoxide.—To an alcoholic solution of sodium ethoxide prepared by dissolving 3.93 g. (1 atom) of sodium in 125 cc. of absolute alcohol was added 50 g. (1 mole) of the bromovinyl ester. An intense red color developed immediately, sodium bromide was precipitated, and the reaction was sufficiently vigorous to cause the alcohol to reflux for about five minutes. When this initial reaction subsided the alcohol was refluxed for an additional five minutes. The sodium bromide was then filtered off and the alcohol removed from the filtrate by distillation under diminished pressure. The residue was taken up in ether, washed with water, dried with anhydrous sodium sulfate, and distilled A small forerun of ethyl carbonate followed by 23.6 g. (75%) of ethyl α-ethyl-γ-ethoxycrotonate was obtained, b. p. 96–99° (14 mm.), n_D^{25} 1.42800, d_{25}^{25} 0.9441; M_D calcd. 51.29; observed, 50.83. Molecular weight (in benzene): 185.4; calcd., 186. Zeisel determination gave 2.03 ethoxyl groups per mole. A sample titrated with standard bromine solution absorbed 99.3% of the calculated amount.

Anal. Calcd. for $C_{10}H_{18}O_3$: C, 64.46; H, 9.75. Found: 64.25, 9.61.

This ester appears to be quite unstable and gradually changes on standing into a number of products which were not investigated further. For example, a sample which originally boiled at 96–99° (14 mm.) distilled, after standing for five months, over a range of 75–140° (14 mm.). The fact that this distillate was distinctly acid would indicate that the change in the ester had involved an oxidation. Freshly prepared ester was used for the determination of the physical constants given above and in the following reduction experiment.

Over a copper–chromium oxide catalyst[10] and at 2500 lb. pressure this ester absorbed considerably more than the theoretical quantity of hydrogen before reaching 150°. Distillation of the reduction product from 12 g. of the unsaturated ester gave 2.8 g. of ethyl diethylacetate, b. p. 150–152°, 2.5 g. of an intermediate fraction boiling at 50–90° (14 mm.) and 2.0 g. of ethyl α-ethyl-γ-ethoxybutyrate.

[13] Moureu and Mignonac, *Compt. rend.*, **158**, 1624 (1914).

Ethyl α-Ethyl-γ-ethoxybutyrate, b. p. 90–92° (14 mm.); n_D^{25} 1.41525; d_{25}^{25} 0.9182; M_D calcd. 51.68; observed 51.35.

Anal. Calcd. for $C_{10}H_{20}O_3$: C, 63.77; H, 10.71. Found: C, 63.67; H, 10.55.

The physical properties of the above ester correspond to those of ethyl α-ethyl-γ-ethoxybutyrate prepared from ethylmalonic ester through reaction of β-ethoxyethyl bromide, followed by saponification, decarboxylation and esterification of the monocarboxylic acid. The yields, properties and analyses of the intermediates and final ethyl α-ethyl-γ-ethoxybutyrate of this synthesis are summarized in the following table.

	Compound	Yield, %	B. p., °C.	n_D^{25}	d_{25}^{25}
1	Ethyl (β-ethoxyethyl)-ethylmalonate	63	142–3 (17 mm.)	1.42925	1.0069
2	α-Ethyl γ-ethoxybutyric acid	86	138–9 (18 mm.)	1.42775	0.9774
3	Ethyl α-ethyl-γ-ethoxybutyrate	82	90–92 (14 mm.)	1.41520	.9179

	Coumpound	M_D calcd.	M_D observed	Formula	Analyses, % Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found
1	Ethyl (β-ethoxyethyl)-ethylmalonate	67.36	66.85	$C_{13}H_{24}O_5$	59.95	59.78	9.29	9.12
2	α-Ethyl γ-ethoxybutyric acid	42.31	42.22	$C_8H_{16}O_3$	59.95	60.13	10.07	10.15
3	Ethyl α-ethyl-γ-ethoxybutyrate	51.68	51.48	$C_{10}H_{20}O_3$	63.77	63.74	10.71	10.78

Reaction of Vinylethylmalonic Ester with Urea in Alcoholic Sodium Ethoxide Solution.—To a solution of 3.45 g. (3 atoms) of sodium in 50 cc. of absolute alcohol were added 10.7 g. (1 mol) of vinylethylmalonic ester and 4.5 g. (1.5 mol) of urea and the resultant solution was refluxed for eighteen hours. The ester gave a deep red color with warm sodium ethoxide solution although no color developed with cold 10% sodium hydroxide (the latter behavior is characteristic of ethyl β-bromovinylethylmalonate) The alcohol was then distilled under diminished pressure, the residue dissolved in water and the alkaline solution extracted with ether. On acidification of the aqueous solution a very small quantity of an oily precipitate was formed which showed no signs of crystallization even after long standing. The water was finally distilled and the brown residue (NaCl + some organic material) extracted with absolute ethanol in a Soxhlet extractor. A very small quantity of an oil was thus separated which could not be crystallized from any of the usual solvents. Distillation of the ether extract of the alkaline solution gave 2.2 g. of a product that boiled at 145–147° (22 mm.) and which solidified on cooling. After recrystallization from naphtha it melted at 113–114°. This product was identified as α-ethylcrotonamide by comparison with an authentic specimen of this amide prepared by the procedure of von Auwers.[4]

Summary

The synthesis of vinylethylmalonic ester is reported and it is shown that on account of the ease with which it is cleaved this ester cannot be converted into a barbituric acid by the usual method.

The following new compounds, incidental to the synthesis of vinylethylmalonic ester, are reported: α-ethyl-α-carbethoxybutyrolactone, ethyl (β-bromovinyl)-ethylmalonate, 3,6,6-tricarbethoxyoctene-3, 3,6,6-tricarbethoxyoctane, ethyl α-ethyl-γ-ethoxycrotonate, ethyl α-ethyl-γ-ethoxy-

butyrate, ethyl (β-ethoxyethyl)-ethylmalonate, α-ethyl-γ-ethoxybutyric acid.

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[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

THE CLEAVAGE OF DISUBSTITUTED MALONIC ESTERS BY SODIUM ETHOXIDE

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In the preceding paper the marked susceptibility of β-bromovinylethyl malonic ester and vinylethylmalonic ester to cleavage into the corresponding acetic esters and ethyl carbonate by means of alcoholic sodium ethoxide is pointed out. The isolation of α-ethyl crotonamide from the attempted preparation of vinylethylbarbituric acid parallels the results reported by Dox and Thomas[1] in their unsuccessful attempts to prepare diphenylbarbituric acid from diphenylmalonic ester. That the susceptibility of the malonic ester to cleavage was the cause of the failure of the synthesis in the latter case is shown by an experiment performed in the present work in which diphenylmalonic ester was split quantitatively into diphenylacetic ester and ethyl carbonate in thirty minutes by refluxing with alcoholic sodium ethoxide. This cleavage is simply a reversal of the type of acetoacetic ester condensation which Lux[2] has applied to the synthesis of malonic ester from ethyl carbonate and ethyl acetate

$$O{=}C(OC_2H_5)_2 + CH_3COOC_2H_5 \xrightarrow{NaOC_2H_5} CH_2(COOC_2H_5)_2 + C_2H_5OH$$

If there is any analogy to the cleavage of the acetoacetic ester type, it would be expected from the work of Dieckmann[3] that the disubstituted malonic esters would be more readily cleaved by alcoholic sodium ethoxide than the monosubstituted or unsubstituted malonic esters. Experiments with diethyl- and monoethylmalonic esters reported in the experimental part of the paper indicate that such is the case.

It seemed likely that barbituric acids might be prepared from these more sensitive disubstituted malonic esters by condensing them with urea by means of dry, alcohol-free sodium ethoxide.[4] Preliminary experiments with diethylmalonic ester showed that such a condensation took place at 170°, the theoretical quantity of alcohol being distilled out of the reaction mixture in eight to ten minutes, and a yield of 55–65% of barbital obtained. Under similar conditions both vinylethylmalonic ester and diphenylmalonic

[1] Dox and Thomas, THIS JOURNAL, **45**, 1811 (1923).

[2] Lux, *Ber.*, **62**, 1824 (1929).

[3] Dieckmann, *ibid.*, **33**, 2678 (1900).

[4] *Cf. Friedländer*, **7**, 655 (1903).