It will be noticed that the value of ln k from iodine and oxalate is slightly higher than those from chlorine or bromine and oxalic acid. However, it checks within the experimental error with that obtained from bromine and oxalate. The reason for this may lie in that the ionization of the oxalate may not be complete.

Conclusion

An attempt has been made to show that there apparently exists a relationship between the rate of oxidation of oxalate or formate and the normal oxidation–reduction potential of the oxidants. Our previously reported empirical equation apparently describes the kinetics of reaction, as is evident from the constancy of both k and k_1 within the investigated experimental range.

In our experiments no attempts have been made to keep the ionic strength of the solution the same, nor have activities been substituted for concentration. It was also assumed that equilibrium constants of trihalides or the dissociation constants of the oxalic acid or potassium oxalate are independent of ionic strength. The error due to such assumptions may lower or raise the value of k_1 in any particular experiment some two or three fold, but the difference of k_1's for the three oxidants is very much bigger. For example, the k_1 for bromine is about a hundred thousand times bigger than that for iodine. An error of two-fold evidently does not make much difference in calculating ln k.

The author wishes to thank Prof. L. P. Hammett for his suggestions in writing this manuscript.

Summary

The rates of oxidation of oxalate ion by chlorine, bromine or iodine are apparently related to the normal oxidation–reduction potentials of the oxidants. Our empirical equation can account for the experimental results satisfactorily.

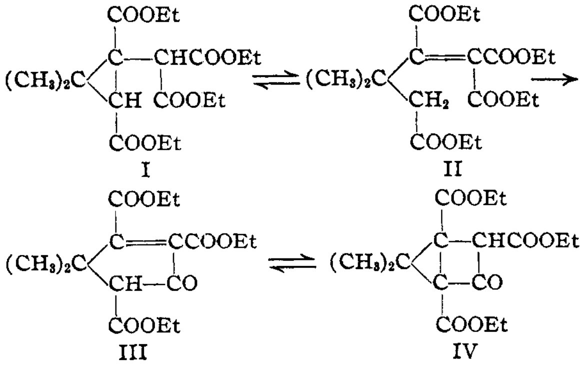
RECEIVED APRIL 11, 1935

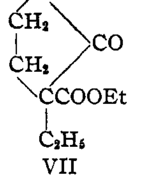
[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

The Acetoacetic Ester Condensation. X. The Condensation of Ethyl α-Ethyl-α'-carbethoxyadipate

BY E. RUSSELL MEINCKE AND S. M. MCELVAIN

The only example of an acetoacetic ester condensation involving a single hydrogen in the α-position to a carbethoxy group which has appeared in the literature is the cyclization of 1,1-dimethyl-2,3-dicarbethoxy-3-diethylmalonatecyclopropane (I) to the cyclobutane derivative[1] (IV). While this condensation has been used in support of the recently suggested[2] mechanism for the acetoacetic ester condensation, it is not absolutely certain that IV is not formed indirectly from I through the intermediate tautomeric forms II and III. In fact, Toivonen[3] has claimed that III rather than IV is the product formed by the reaction of sodium ethoxide on I. If such intermediates are involved the reaction may be considered a common type of acetoacetic ester condensation for which two α-hydrogen atoms are necessary.

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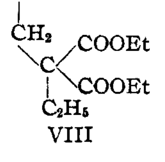
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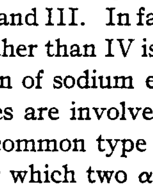
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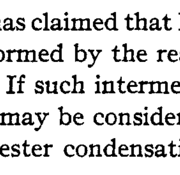
VIII

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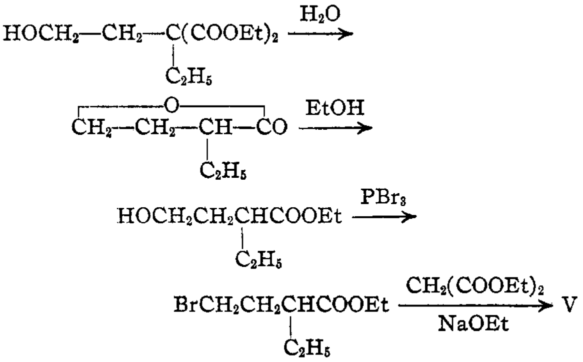
[1] Perkin and Thorpe, *J. Chem. Soc.*, **79**, 736 (1901); *cf.* also Ingold and Thorpe, *ibid.*, **115**, 330 (1919).

[2] Cox, Kroeker and McElvain, THIS JOURNAL, **56**, 1173 (1934).

[3] Toivonen, *Chem. Zentr.*, **94**, I, 1356 (1923).

It has been shown, previously,[2,4] that an intramolecular condensation will occur between a carbon atom carrying a single hydrogen in α-position to a ketone group and one of the carbethoxy groups of a mono-substituted malonic ester grouping. In view of the doubt which is associated with the condensation of I, it seemed worth while to show beyond question that a similar condensation may be effected when a single α-hydrogen is activated by a carbethoxy group.

The present paper describes the preparation and intramolecular condensation of ethyl α-ethyl-α'-carbethoxyadipate (V). This ester was prepared by the following series of reactions



$$HOCH_2—CH_2—\underset{C_2H_5}{C}(COOEt)_2 \xrightarrow{H_2O}$$

$$\overbrace{CH_2—CH_2—\underset{C_2H_5}{CH}—CO}^{O} \xrightarrow{EtOH}$$

$$HOCH_2CH_2\underset{C_2H_5}{C}HCOOEt \xrightarrow{PBr_3}$$

$$BrCH_2CH_2\underset{C_2H_5}{C}HCOOEt \xrightarrow[NaOEt]{CH_2(COOEt)_2} V$$

When the ester (V) was heated with sodium ethoxide about 25% excess of one equivalent of alcohol distilled from the reaction mixture. On working up the latter a fraction which gave a strong ferric chloride coloration and boiled within the range of 2-ethyl-2,5-dicarbethoxycyclopentanone[5] (VII) was obtained. This fraction on hydrolysis yielded 2-ethylcyclopentanone, the amount of which (isolated as the semicarbazone) indicated that the condensation of V to VII had taken place to the extent of 22%.

The formation of VII from V as well as from the ethyl substituted ethylene dimalonic ester[5] (VIII) offers additional support to the proposal that a hemiacetal type of intermediate (VI) is involved in the condensation. In the condensation of V, VII may form from VI only by the elimination of alcohol and this is the only product which distils from the reaction mixture. In the case of VIII, however, the corresponding intermediate (VI in which the α-hydrogen is replaced by COOEt) can pass into VII only by the elimination of ethyl carbonate and it was found that one equivalent of this product did distil out of the reaction mixture. But in the case of the diethyl substituted ethylene dimalonic ester (VIII in which the α-hydrogen is substituted by C_2H_5) which has no activated hydrogen available for the formation of such an intermediate as VI the condensation cannot be made to take place.

Experimental

α-Ethyl-butyrolactone.—To a boiling solution of 160 g. of sodium hydroxide in 200 cc. of water in a 2-liter flask was added from a dropping funnel 364 g. of ethyl β-hydroxyethyl-ethyl-malonate[6] at such a rate that two layers were not formed. After this addition was completed the flask was fitted with a reflux condenser and a cooled mixture of 110 cc. of concentrated sulfuric acid and 150 cc. of water slowly added. The resulting reaction mixture was refluxed for five hours. After this time the layer of α-ethyl-butyrolactone was separated from the aqueous solution and the latter extracted with 75 cc. of benzene. This aqueous layer was then distilled until 250 cc. had been collected. This distillate was extracted with two 75-cc. portions of benzene. The combined lactone layer and benzene extracts, after drying over anhydrous sodium sulfate, was distilled. The yield of α-ethyl-butyrolactone, b. p. 213–216° (740 mm.)[7] amounted to 156 g. (88%).

Ethyl α-Ethyl-γ-hydroxybutyrate.—A solution of 150 g. of the above lactone in 500 cc. of absolute alcohol was saturated with dry hydrogen chloride. After standing for three days the alcohol was distilled off under diminished pressure and the remaining residue poured into 500 cc. of ice water. The ester layer was separated and the aqueous layer extracted with five 50-cc. portions of ether. These extracts were added to the ester which was separated and this ethereal solution, after drying over anhydrous sodium sulfate, distilled. The yield of ethyl α-ethyl-γ-hydroxybutyrate was 175 g. (84%); b. p. 78–80° (3 mm.); d^{25}_4 0.9609.

Anal. Calcd. for $C_8H_{16}O_3$: C, 60.00; H, 10.00. Found: C, 60.13; H, 10.07.

Ethyl α-Ethyl-γ-bromobutyrate.—To 170 g. (1.07 mole) of ethyl α-ethyl-γ-hydroxybutyrate, contained in a 500-cc. flask fitted with a stirrer, reflux condenser and dropping funnel, was added dropwise, over a period of four hours, 68.4 g. (0.4 mole) of phosphorus tribromide. During this addition the reaction flask was immersed in ice water. The reaction mixture was then allowed to warm up to room temperature and stirred for ten hours. After this time it was poured onto a mixture of 150 g. of ice and 100 g. of water and the resulting two layers separated. The aqueous layer was extracted with three 75-cc. portions of ether and after combining these extracts with the ester layer, and drying, the ethereal solution was distilled. The yield of bromo ester boiling at 90–93° (8 mm.) amounted to 183 g. (78%).

Anal. Calcd. for $C_8H_{15}O_2Br$: Br, 35.87. Found: Br, 35.41.

Ethyl α-Ethyl-α'-carbethoxyadipate.—To a solution of 17.3 g. (0.75 atom) of sodium in 200 cc. of absolute alcohol

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[4] Cox and McElvain, This Journal, **56**, 2459 (1934).

[5] Meincke, Cox and McElvain, *ibid.*, **57**, 1133 (1935). The fact that the reaction product gave a ferric chloride coloration indicated that it was the 2,5- rather than the 2,2-dicarbethoxy derivative.

[6] Shonle, Keltch and Swanson, *ibid.*, **52**, 2440 (1930).

[7] Fittig and Chanlaroff, *Ann.*, **226**, 337 (1884).

contained in a one-liter three-necked flask fitted with stirrer, dropping funnel and reflux condenser, was added 160 g. (1 mole) of malonic ester. After standing for one hour, 166.5 g. (0.75 m.) of ethyl α-ethyl-γ-bromobutyrate was added and the reaction mixture refluxed with stirring for twelve hours. The alcohol then was distilled off and the residue poured into 200 cc. of cold water which contained 30 cc. of acetic acid. The two layers were separated, the water extracted with three 75-cc. portions of ether and these together with the non-aqueous layer were dried over anhydrous sodium sulfate and distilled. The yield of ethyl α-ethyl-α′-carbethoxyadipate was 108 g. (47%); b. p. 170–172° (8 mm.); n^{25}_D 1.4379; d^{25}_4 1.0888.

Anal. Calcd. for $C_{15}H_{26}O_6$: C, 59.60; H, 8.61. Found: C, 59.66; H, 8.54.

Reaction of Ethyl α-Ethyl-α′-carbethoxyadipate with Sodium Ethoxide.—A mixture of 6.04 g. (0.09 mole) of sodium ethoxide and 81.6 g. (0.27 mole) of ethyl α-ethyl-α′-carbethoxyadipate was placed in a flask fitted with a stirrer for operation under diminished pressure and a condensing coil surrounded by an ice–salt mixture. The flask was heated in an oil-bath for twelve hours at 100° and under 200 mm. pressure. During this time 5.25 g. (0.114 mole) of alcohol distilled from the reaction. The reaction mixture in the flask was treated with 75 cc. of ice water, the layers separated, and the aqueous layer extracted with an equal volume of ether. The aqueous layer was acidified with acetic acid and extracted with two 50-cc. portions of ether. On distillation of this ether extract 5.54 g. of a fraction boiling at 137–165° was obtained. This fraction gave a strong coloration with ferric chloride. When refluxed with 85% acetic acid[8] for five hours this fraction yielded 2-ethyl cyclopentanone which was converted to the semicarbazone. The yield of the semicarbazone, m. p. 188–189°,[9] was 2.52 g. (22% based on the sodium ethoxide used in the reaction).

The alkali insoluble portion obtained when the original reaction mixture was treated with ice water yielded on fractionation 67.4 g. of the unchanged starting ester.

Summary

It is shown that ethyl α-ethyl-α′-carbethoxyadipate undergoes an intramolecular acetoacetic ester condensation to the corresponding cyclopentanone derivative. This condensation involves one of the carbethoxy groups of a monosubstituted malonic ester structure and a single hydrogen in the α-position to another carbethoxy group.

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[8] Dieckmann and Kron, *Ber.*, **41**, 1266 (1908).

[9] Case and Reid, THIS JOURNAL, **50**, 3062 (1928).

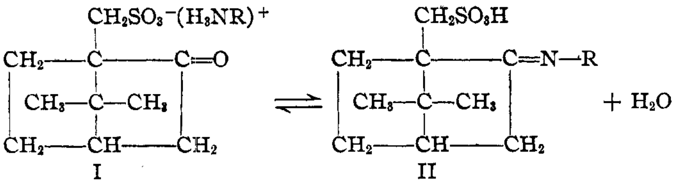
MADISON, WISCONSIN RECEIVED JUNE 10, 1935

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF ILLINOIS]

Anomalous Mutarotation of Salts of Reychler's Acid. II. Ketimine Formation from Amine Salts of *d*-Camphor-10-sulfonic Acid

BY R. S. SCHREIBER AND R. L. SHRINER

The observation that certain salts of *d*-camphor-10-sulfonic acid exhibited anomalous mutarotations in non-aqueous solvents[1] led to the suggestion that this phenomenon was due to an equilibrium between the salt (I) and a compound of the anil or ketimine type (II).



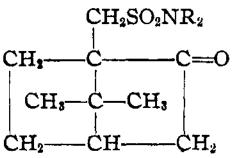
I II

If this explanation is correct, then salts of *d*-camphor-10-sulfonic acid with secondary and tertiary amines should not undergo the reaction. Accordingly, the *d*-camphor-10-sulfonic acid salts of the following secondary and tertiary amines were prepared.

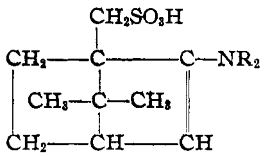
(1) $C_6H_5NHCH_3$
(2) $C_6H_5N(CH_3)_2$
(3) $(CH_3)_2NH$
(4) $(CH_3)_3N$
(5) $(n\text{-}C_4H_9)_3N$
(6) C_5H_5N
(7) $C_5H_{10}NH$

The salts of these seven amines did not exhibit mutarotation in absolute methanol, ethanol or chloroform solutions. The compounds were stable and did not undergo dehydration upon being heated.

The fact that the secondary amine salts did not undergo dehydration practically excludes two other possible structures, *viz.*, the substituted sulfonamide, Formula III, and the product with the Formula IV which



III



IV

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[1] Schreiber and Shriner, THIS JOURNAL, **57**, 1306 (1935).