[CONTRIBUTION FROM THE STERLING–WINTHROP RESEARCH INSTITUTE]

Diethyl N-Benzyl-*dl*-aspartate and Related Compounds

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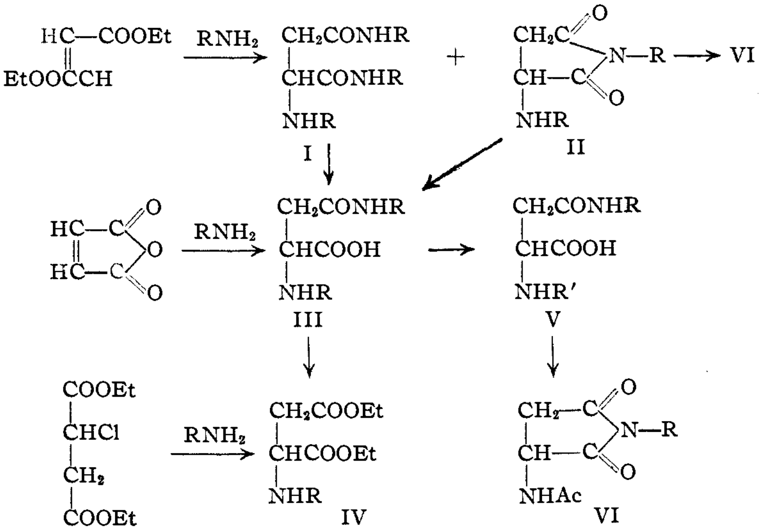
Diethyl N-benzyl-*dl*-aspartate (IV), needed in these laboratories for other syntheses, has been prepared by several routes.

It was thought that a convenient synthesis of IV might be realized by the condensation of benzylamine with maleic anhydride in water[2] to give N,N′-dibenzyl-α-aminosuccinimide (II) which could be hydrolyzed and then esterified. However, this condensation gave not II, but an acidic compound whose empirical formula differed from that of II by an additional molecule of water. This compound proved to be III.[3]

Scheme I, R is benzyl



Compound III, on hydrolysis with sodium hydroxide followed by esterification, gave IV. The over-all yield of IV from benzylamine by this series of reactions was 20%.

Diethyl N-benzyl-*dl*-aspartate was also prepared from *dl*-malic acid by esterification (67%), chlorination with thionyl chloride and pyridine (80%) and reaction with benzylamine (47%). An attempted preparation of IV from diethyl oxalacetate and benzylamine by reduction gave instead N,N′-dibenzylmalamide.

Maleic anhydride was treated with glycine according to the procedure of Reppe and Ufer[2] and the product was esterified without isolation to give a 20% over-all yield of N-carbethoxymethyl aspartate.

It was noted that Warren and Grose[4] reported that the condensation of benzylamine with diethyl fumarate gave a good yield of II melting at 205°. However, when this reaction was run under the conditions reported by Warren and Grose no compound melting at 205° was obtained. Instead there were obtained two compounds, one melting at 146–148° (I) and one melting at 61.5–62.5° (II). Compound I is the dibenzylamide of N-benzyl-*dl*-aspartic acid as shown by determinations of total nitrogen and amino nitrogen. Both I and II on short reflux with alcoholic potassium hydroxide gave III.

It will be noted that at least six structures may be written for II on the basis of elementary analysis and method of synthesis. However, the fact that II gives a nitroso derivative and a hydrochloride (from which II could be regenerated by treatment with alkali) limits the structure to the one given in scheme I, or to either isoimide.

Since Warren and Gross reported II as melting at 205°, it would seem that our compound is an isoimide. However, the stability of our compound, II, belies its identity as an isoimide.[5]

Furthermore, one of the theoretically possible isoimides was definitely excluded on the basis of the following experimental evidence. Reductive acetylation of II gave a compound, VI, identical to one obtained by condensing N-benzylchloroacetamide with acetamidomalonic ester.[6] Thus, II cannot be an isoimide in which the benzylimido group is adjacent to the benzylamine group.

Compound VI could also be obtained by reductive debenzylation of III to give V (R′ = H), followed by treatment with acetic anhydride and acetic acid at room temperature.

Hydrolysis of VI with aqueous sodium carbonate led to the formation of V (R′ = CH_3CO). Warming the latter compound regenerated VI. Treatment of V (R′ = CH_3CO) with alcoholic

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[2] Reppe and Ufer (U. S. Patent 2,200,220) state that imides are formed by the reaction of amines with maleic anhydride. However, the intermediate was characterized only in the case of aniline which gave N-phenylaspartic acid anil. Other intermediates may not have an analogous structure since aliphatic and aromatic amines may not behave the same; compare ref. 4.

[3] In the original manuscript, the structure of III was assumed by analogy and by a consideration of the electronic picture of II, basic hydrolysis of which should theoretically give III, and not an isomer. More rigorous proof of structure, requested by a referee, has been added to the revised manuscript.

[4] Warren and Grose, THIS JOURNAL, **34**, 1600 (1912).

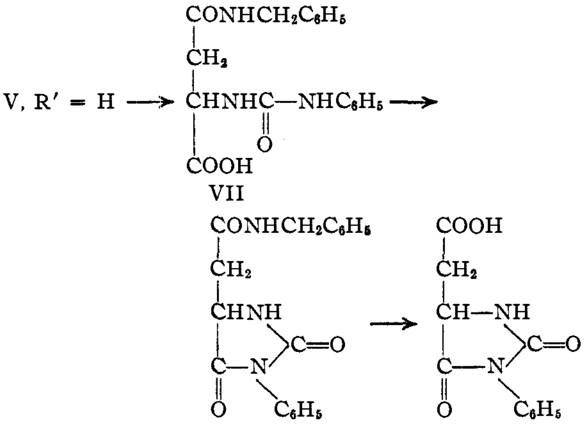
[5] *Cf.* Sherrill, Schaeffer and Shoyer, *ibid.*, **50**, 474 (1928), for a discussion of isoimides and their instability.

[6] It will be noted that this condensation involves loss of a carbethoxy group. Such a reaction is common for alkylated acetamidomalonic esters in the presence of sodium ethylate.

potassium hydroxide removed the acetyl group. The resulting α-amino N-benzylsuccinamic acid, V (R′ = H) was converted to the hydroxy acid with nitrous acid.

Compound V (R′ = H or CH_3CO) reacted with ammonium thiocyanate in acetic acid–acetic anhydride to give the N-benzylamide of 1-acetyl-2-thiohydantoin-5-acetic acid.

Proof of structure of III was achieved by reductive debenzylation of III to V (R′ = H), treatment with phenyl isocyanate to give VII, ring closure to the hydantoin, VIII, and hydrolysis to the known hydantoin acetic acid, IX. An authentic sample of IX for comparison was prepared from aspartic acid. The aspartic acid was synthesized in 53% yield from ethyl chloroacetate and acetamidomalonic ester.



VII

VIII

IX

Experimental[7]

Diethyl N-Benzyl-*dl*-aspartate (IV). A. From Maleic Anhydride and Benzylamine.—A mixture of maleic anhydride (49 g., 0.50 m.), water (200 ml.) and benzylamine (107 g., 1.00 m.) was refluxed for twenty-five hours. At this time there was added 119 g. of 35% caustic soda solution and the mixture was refluxed for an additional twenty-four hours. The hydrolysis mixture was cooled and poured into a mixture of ice and excess hydrochloric acid. The resulting solution was taken to dryness *in vacuo*. The residue was refluxed for four hours with 2% alcoholic hydrogen chloride (1000 ml.). This solution was evaporated to dryness; the residue was covered with benzene (600 ml.) and excess aqueous sodium hydroxide solution was added. When everything was in solution the mixture was shaken well and the benzene layer was separated. The benzene was removed *in vacuo* and the residue was distilled. There was obtained 28 g. (20%) of material which boiled at 148° (1 mm.). A sample which was redistilled for analysis boiled at 136° (0.5 mm.); $n^{25}\mathrm{D}$ 1.4931.

Anal. Calcd. for $C_{15}H_{21}NO_4$: N, 5.02. Found: N, 5.01.

B. From Diethyl *dl*-Chloro-succinate and Benzylamine.—Crude diethyl-*dl*-chlorosuccinate containing 15.98% chlorine (theory, 17.02%) was prepared from malic ester, thionyl chloride and pyridine in 80% yield and used directly for this reaction. A mixture of diethyl *dl*-chlorosuccinate (41.7 g., 0.20 m.), benzylamine (42.8 g., 0.40 m.) and benzene (200 ml.) was refluxed with stirring for one hour. This mixture was filtered and the filtrate was washed with water. The benzene was removed under vacuum and the residue was distilled. There was obtained 26.3 g. (47%) of material which boiled at 147–148° (1 mm.); $n^{25}\mathrm{D}$ 1.4932.

N-Benzyl-*dl*-aspartic Acid.—Five milliliters of the diester, IV, was refluxed with 100 ml. of concentrated hydrochloric acid for five hours and concentrated to dryness. The residue was dissolved in 10 ml. of water, diluted with 100 ml. of ethanol and made basic with a slight excess of pyridine. Since no crystals separated on standing, the solution was concentrated to dryness and the residual oil dissolved in 100 ml. of hot ethanol. Crystals separated on chilling; m. p. 194–197°, dec.

Anal. Calcd. for $C_{18}H_{13}NO_4$: C, 59.19; H. 5.87; N, 6.28. Found: C, 59.38; H, 5.82; N(K), 6.09.

N,N′-Dibenzylmalamide.—Benzylamine (10.7 g., 0.1 m.) was added with cooling to a solution of ethyl oxalacetate (18.8 g., 0.1 m.) in ethyl acetate (125 ml.) and the solution shaken with hydrogen in the presence of Adams platinum catalyst. The hydrogen uptake was 83%. The reaction mixture was filtered, concentrated *in vacuo* and distilled. The boiling point varied over a wide range. On standing overnight the distillate crystallized. Recrystallization from ethanol gave a solid melting at 130–140°. Recrystallization from benzene raised the melting point to 144–145°. This compound, which was not further investigated, is presumably N,N′-dibenzylmalamide.

Anal. Calcd. for $C_{18}H_{20}N_2O_3$: N, 8.97. Found: N, 8.78.

Diethyl N-Carbethoxymethyl-*dl*-aspartate.—One mole of maleic anhydride and two moles of glycine were refluxed with 400 ml. of water for twenty hours.[2] Then 4.6 moles of 40% sodium hydroxide and 200 ml. of water was added and refluxing was continued for an additional twenty hours. The solution was poured into 700 ml. of concentrated hydrochloric acid and ice, and concentrated *in vacuo*, the last traces of water being removed by distillation with toluene. The residue was dissolved in one liter of ethanol, saturated with hydrogen chloride and refluxed three hours. The solution was then filtered and concentrated *in vacuo*. The residue was decomposed with aqueous potassium carbonate and the product extracted with ether. The ether solution was dried with potassium carbonate, filtered and concentrated to give 85 g. of oil. Distillation gave 55 g. (20%), boiling at 130–140° (0.3 mm.); $n^{25}\mathrm{D}$ 1.4429.

Anal. Calcd. for $C_{12}H_{21}NO_6$: N, 5.08. Found: N(AP), 5.01.

Benzoyl Derivative of Diethyl N-Carbethoxymethyl-*dl*-aspartate.—A solution of 27.5 g. (0.1 m.) of the above amine in 40 ml. of dry benzene was refluxed with 16.0 g. (0.115 m.) of benzoyl chloride for eight hours. Then 7 ml. of ethanol was added and the solution refluxed for an additional one-half hour. The solution was washed with 10% sodium hydroxide, 10% hydrochloric acid and dilute sodium bicarbonate. The benzene was removed *in vacuo* and the residue distilled at a bath temperature of 170° and 5×10^{-4} mm. to give a good yield of very viscous benzoyl derivative.

Anal. Calcd. for $C_{19}H_{25}NO_7$: N, 3.69. Found: N, 3.62.

Reaction of Diethyl Fumarate with Benzylamine at 250°.—A mixture of diethyl fumarate (17.2 g., 0.10 m.) and benzylamine (21.9 g., 0.20 m.) was heated in an open flask to 250° over a forty-five minute period. The mixture was cooled and diluted with ether. There was obtained 3 g. of solid which, after recrystallization from a very large volume of ethanol, melted at 294–296°.

Anal. Calcd. for $C_{18}H_{18}N_2O_2$: N, 9.53. Found: N, 9.35.

Although molecular weight data could not be obtained because of the extreme insolubility of this compound, it is very probably N,N′,N″,N‴-tetrabenzyldiketopiperazine diacetamide.[8]

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[7] N(AP) refers to determination of basic nitrogen by titration in acetic acid with perchloric acid. N(K) refers to Kjeldahl nitrogen.

[8] *Cf.* Dunn and Fox, *J. Biol. Chem.*, **101**, 493 (1933), for the preparation of diketopiperazine diacetamide from ammonia and diethyl fumarate.

The same high melting compound could be obtained in poor yield by heating I to 250° for ten minutes, cooling and recrystallizing from alcohol.

Reaction of Diethyl Fumarate with Benzylamine at 150°.—In an open container a mixture of diethyl fumarate (43 g., 0.25 m.) and benzylamine (53.5 g., 0.50 m.) was heated at 150–160° for four hours. The mixture was cooled and treated with 500 ml. of ether. The solid (I) which remained undissolved was removed by filtration. It weighed 18 g. and melted vaguely from 130° upward. The filtrate on evaporation and chilling gave 28 g. of a solid (II) which melted at about 55°. The filtrate from II gave, after removal of all the solvent under vacuum, an oil (25 g.) which gave no crystals.

The dibenzylamide of N-benzyl-*dl*-aspartic acid, I, after four crystallizations from xylene melted at 146–148°.

Anal. Calcd. for $C_{25}H_{27}N_3O_2$: N(AP), 3.49; N(Total), 10.49. Found: N(AP), 3.48; N(Total), 10.37.

N,N'-Dibenzyl-α-aminosuccinimide, II, after three crystallizations from ether, melted at 61.5–62.5°.

Anal. Calcd. for $C_{18}H_{18}N_2O_2$: C, 73.47; H, 6.12; N, 9.52. Found: C, 73.95; H, 6.06; N, 9.50.

Hydrochloride of N,N'-Dibenzyl-α-aminosuccinimide.—Treatment of II with aqueous hydrochloric acid gave a hydrochloride which, after crystallization from ethanol, melted at 193–195°.

Anal. Calcd. for $C_{18}H_{18}N_2O_2 \cdot HCl$: N, 8.47; Cl, 10.72. Found: N, 8.45; Cl, 10.78.

This hydrochloride on treatment with dilute sodium hydroxide gave back the starting amine (mixed m. p.).

Nitrosation of N,N'-Dibenzyl-α-aminosuccinimide.—The general method of Warren and Grose[2] gave a product which, after two crystallizations from ethanol, melted at 129.5–130.5°.

Anal. Calcd. for $C_{18}H_{17}N_3O_3$: N, 13.00. Found: N, 12.99.

α-Benzylamino-N-benzylsuccinamic Acid (III): A. From II.—II (1.94 g., 0.0066 m.) was boiled for four hours with 30 ml. of 10% alcoholic potassium hydroxide. The mixture was filtered, poured into 200 ml. of water, and neutralized with dilute hydrochloric acid. The solid which precipitated weighed 1.2 g. (81%); m. p. 212°, dec. After crystallization from water it melted at 215° dec.

Anal. Calcd. for $C_{18}H_{20}N_2O_3$: C, 69.23; H, 6.41; N(AP), 4.48; N(total), 8.96. Found: C, 69.26; H, 6.34; N(AP), 4.46; N(total), 8.87.

Compound I and the oil remaining after the removal of I and II each gave III on boiling with alcoholic potassium hydroxide. I gave a 50% yield and the oil gave one-third its weight.

B. Directly from Diethyl Fumarate and Benzylamine.—A mixture of diethyl fumarate (43 g., 0.25 m.) and benzylamine (80.5 g., 0.75 m.) was heated at 150–160° for four hours. The crude reaction mixture was refluxed with one liter of 10% alcoholic potassium hydroxide for two hours, poured into a liter of water, and neutralized with 1:1 hydrochloric acid. The solid which formed weighed 44.5 g. (57%); m. p. 210–212°, dec. When two moles of benzylamine were used instead of three the yield was 45%.

C. From Maleic Anhydride and Benzylamine.—A mixture of maleic anhydride (49 g., 0.50 m.), benzylamine (107 g., 1.00 m.) and water (200 ml.) was refluxed for sixteen hours. The mixture was cooled and filtered. The sticky solid was triturated with ether and filtered, to give 75 g. (48%) of nice white crystals; m. p. 205°, dec. Recrystallization from a large volume of ethanol raised the m. p. to 210–211°, dec. undepressed, when mixed with the samples obtained by procedure A or B.

α-Amino-N-benzylsuccinamic Acid.—III (6.24 g., 0.02 m.) was dissolved in acetic acid (100 ml.); there was added 0.3 g. charcoal containing 10% palladium chloride and the mixture was shaken with hydrogen at 60°. One mole of hydrogen was taken up in three hours at which time reduction ceased. The reduction mixture was filtered hot and the acetic acid was removed by distillation *in vacuo*. The residue crystallized. It weighed 4.0 g. (90%) and melted at about 250° with decomposition. Recrystallization from water (700 ml.) raised the m. p. to 265°. A small portion for analysis, after another recrystallization, melted at 265° with decomposition.

Anal. Calcd. for $C_{11}H_{14}N_2O_3$: N(AP), 6.30; N(total), 12.60. Found: N(AP), 6.33; N(total), 12.30.

Ethyl α-Benzylamino-N-benzylsuccinamate Hydrochloride.—Dry hydrogen chloride was bubbled into a suspension of 15.6 g. (0.05 m.) of α-benzylamino-N-benzylsuccinamic acid (III) in 100 ml. of ethanol until the solution was saturated at the boiling point. The solution was refluxed for one-half hour, cooled and diluted with 1500 ml. of ether. There was obtained 17.0 g. (90%) of product, m. p. 147–151°. A sample recrystallized from ethanol melted at 154°, dec.

Anal. Calcd. for $C_{20}H_{24}N_2O_3 \cdot HCl$: N, 7.44. Found: N, 7.64.

Dilute caustic precipitated the base from water.

N-Benzyl-α-hydroxysuccinamic Acid.—A suspension of 3 g. of α-amino-N-benzylsuccinamic acid in 25 ml. of water was dissolved by the addition of 5 ml. of hydrochloric acid. A solution of 0.8 g. of sodium nitrite in 5 ml. of water was added dropwise to the cold amino acid solution. A yellow oil separated from solution and readily crystallized on scratching. It was recrystallized from benzene to give a white solid; m. p. 113°.

Anal. Calcd. for $C_{11}H_{13}NO_4$: N, 6.28. Found: N, 6.02.

α-Acetamino-N-benzyl-succinimide (VI). A. From II.—A solution of 3.2 g. of N,N'-dibenzyl-α-aminosuccinimide (II) in 100 ml. of acetic acid was reduced at 50° with buffered 5% palladium–carbon catalyst. The theoretical amount of hydrogen was taken up in twenty-five minutes. The catalyst was removed and the acetic acid distilled off *in vacuo*. The residue was refluxed with acetic anhydride for twenty minutes and concentrated to dryness *in vacuo*. Ice was added to the residue which caused immediate crystallization. The product was filtered, washed with water and recrystallized from methanol to give 1.3 g. melting at 172°. A second recrystallization raised the m. p. to 173° not depressed when mixed with the product from procedure B or C below.

B. From α-Amino-N-benzylsuccinamic Acid.—One-half gram of amino acid was suspended in 60 ml. of acetic acid and 5 ml. of acetic anhydride, and shaken until a clear solution resulted (six hours). The solvent was removed at room temperature *in vacuo* and the residual sirup was triturated with ethyl acetate to induce crystallization. The solid was recrystallized from ethyl acetate to give white crystals melting at 173–174°.

C. From N-Benzylchloroacetamide and Acetamidomalonic Ester.—To a solution of 3.8 g. of sodium in 300 ml. of ethanol was added 36 g. of acetamidomalonic ester, 31.5 g. of benzyl chloroacetamide and 0.5 g. of sodium iodide. The solution was allowed to stand at room temperature for forty-eight hours and was then concentrated *in vacuo* to remove most of the alcohol. The product was poured onto ice and water, filtered, and dried to give 43.6 g. of solid. This was extracted several times with benzene at room temperature leaving a residue (25.5 g., m. p. 165–168°) which on recrystallization from methanol gave 22 g. melting at 169–172°. This was identical with the products of procedure A and B above. An analytical sample from aqueous ethanol melted at 174–175.6°, cor.

Anal. Calcd. for $C_{13}H_{14}N_2O_3$: C, 63.39; H, 5.73; N, 11.38. Found: C, 63.56; H, 5.94; N(K), 11.25.

When the benzene solution obtained above was concentrated to small volume and cooled there was obtained 16.6 g. of crude solid which, on recrystallization from butanol, melted at 119.5–121°. Further recrystallization from aqueous acetone and from benzene-petroleum ether raised the m. p. to 125–126°. This compound proved to be α-acetamido-α-carbethoxysuccinbenzylimide.

Anal. Calcd. for $C_{16}H_{18}N_2O_5$: C, 60.37; H, 5.70; N, 8.80. Found: C, 60.71; H, 5.64; N, 8.59.

α-Acetamido-N-benzylsuccinamic Acid (V, R' = CH_3CO).—When either α-acetamino-N-benzylsuccinimide (VI) or α-acetamido-α-carbethoxysuccinbenzylimide was refluxed for three hours with 10% sodium carbonate and the solution made acid to congo paper with hydrochloric acid there was obtained an acid which, on crystallization from a large volume of ethyl acetate, melted at 153–155°. This proved to be α-acetamido-N-benzylsuccinamic acid.

Anal. Calcd. for $C_{13}H_{16}N_2O_4$: N, 10.60; neut. equiv., 264.3. Found: N, 10.43; neut. equiv., 266.5.

When about 15–20 mg. of this acid was warmed above its m. p. it evolved water and gave an oil. Upon trituration with water to which several drops of ammonium hydroxide had been added a white solid, m. p. 169–172°, was obtained. This proved to be VI.

One gram of V (R' = CH_3CO) was refluxed with 15 ml. of 10% alcoholic potassium hydroxide for two hours. The alcohol was removed *in vacuo*, the residue dissolved in water and made just acid with hydrochloric acid. The solution was then brought to *p*H 8 with ammonium hydroxide to precipitate an amino acid. This was recrystallized from water and identified as α-amino-N-benzylsuccinamic acid by mixed m. p. and nitrogen analysis.

1-Acetyl-2-thiohydantoin-5-(N-benzyl)-acetamide.—A mixture of 4 g. of α-acetamido-N-benzylsuccinamic acid, 3 g. of ammonium thiocyanate, 18 ml. of acetic anhydride and 2 ml. of acetic acid was warmed for one and one-half hours on the steam-bath. The solution was poured onto 100 g. of ice and water and stirred to induce crystallization of 4.1 g. of product. Two recrystallizations from butanol gave a solid melting at 162–164°. It dissolved in ammonium hydroxide, but not in sodium bicarbonate. The same product was obtained by starting with α-amino-N-benzylsuccinamic acid.

Anal. Calcd. for $C_{14}H_{15}N_3O_3S$: N, 13.78; S, 10.50. Found: N, 13.21; S, 10.23.

α-Phenylureido-N-benzylsuccinamic Acid (VII).—Prepared by treating 2.2 g. of α-amino-N-benzylsuccinamic acid with 1.9 ml. of phenyl isocyanate in basic solution in the usual manner; m. p. 180–181.5° from aqueous ethanol.

Anal. Calcd. for $C_{18}H_{19}N_3O_4$: N, 12.31; neut. equiv., 341.3. Found: N, 12.16; neut. equiv., 337.5.

3-Phenylhydantoin-5-(N-benzyl)-acetamide (VIII).—A suspension of 1.7 g. of VII was refluxed with 45 ml. of 12% hydrochloric acid for forty-five minutes. It was then cooled, filtered, washed with dilute bicarbonate and then with water. Recrystallization from aqueous ethanol gave a product melting at 166–167°, dec.

Anal. Calcd. for $C_{18}H_{17}N_3O_3$: N, 13.00. Found: N(K), 12.77.

3-Phenylhydantoin-5-acetic Acid (IX).—One-half gram of VIII was refluxed with 60 ml. of hydrochloric acid for two hours, evaporated *in vacuo* and the residue recrystallized from water to give a compound melting at 218–220°. A sample prepared from aspartic acid melted at 223–224°,[9] and the mixture melted at 219–221°.

***dl*-Aspartic Acid.**—Condensation of ethyl chloroacetate (0.52 m.) with acetamidomalonic ester (0.48 m.) and hydrolysis of the condensation product in the manner employed by Galat for the corresponding formamidomalonic ester,[10] gave a 53% yield of *dl*-aspartic acid melting above 300°.

Anal. Calcd. for $C_4H_8NO_4$: N, 10.52. Found: N, 10.52.

Acknowledgment.—The authors are indebted to Mr. Morris E. Auerbach and his staff for the analytical results.

Summary

1. Diethyl N-benzyl-*dl*-aspartate was synthesized from maleic anhydride and benzylamine, and from diethyl *dl*-chlorosuccinate and benzylamine.

2. The reaction of benzylamine with diethyl fumarate at 150° gave the dibenzylamide of N-benzyl-*dl*-aspartic acid, and a compound melting at 62.5° which was identified as N,N'-dibenzyl-α-aminosuccinimide. These results differ from those of Warren and Grose who reported that the reaction gave N,N'-dibenzyl-α-aminosuccinimide melting at 205°.

[9] Gaunt and Wormall, *Biochem. J.*, **30**, 1915 (1936).

[10] Galat, This Journal, **69**, 965 (1947).

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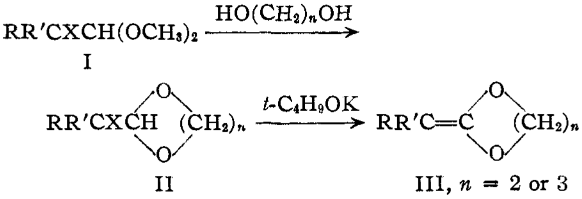
[Contribution from the Laboratory of Organic Chemistry of the University of Wisconsin]

Ketene Acetals. XIX. 2-Methylene-1,3-dioxolanes and 1,3-Dioxanes

By S. M. McElvain and Michael J. Curry[1]

As an extension of previous work on the ketene acetals in This Laboratory, the preparation of a variety of ketene cyclic acetals derived from ethylene and trimethylene glycols was undertaken. The rather unusual properties of these compounds are now reported.

The ketene cyclic acetals, 2-methylene-1,3-dioxolanes and 1,3-dioxanes (III), were obtained by the dehydrohalogenation of the corresponding halogenated cyclic acetals (II). The latter compounds, with the exception of the chloral cyclic acetals, were prepared by an alcohol exchange between the glycol and the methyl (or ethyl) acetals (I).



It was found advantageous to prepare the ethylene glycol acetals from the methyl rather than the ethyl acetals (I) because of the proximity of the boiling points of the latter to those of the cyclic acetals (II, *n* is 2). The trimethylene glycol acetals, because of their higher boiling points, could be prepared from either the methyl or ethyl acetals. Chloral diethyl acetal did not undergo this type of alcohol exchange; instead higher boiling products, which appeared to have the structures

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