TABLE I

DERIVATIVES OF PHENETHYLBENZYLMETHYLAMINE HYDROCHLORIDE, 4-R($C_{16}H_{19}NCl$) AND 3,4-R_2($C_{16}H_{18}NCl$)

4-R or 3,4-R_2	Recrystn. solvent + ether	Crystal form	M. p., °C.	Formula	Percentages Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found
CH_3O	E. Al.,[c] E. Ac.[c]	Needles	170	$C_{17}H_{22}ONCl$	69.96	69.95	7.61	7.82
$(CH_3O)_2$	E. Al., E. Ac.	Leaves	205	$C_{18}H_{24}O_2NCl$	67.17	67.34	7.52	7.70
OH	M. Al.,[c] E. Ac.	Prisms	198	$C_{16}H_{20}ONCl$	69.16	69.26	7.26	7.48
$(OH)_2$	E. Al., E. Ac.[a]	Prisms	153	$C_{16}H_{20}O_2NCl$	65.40	65.50	6.87	7.05
CH_3COO	E. Al., H_2O	Spindles	211	$C_{18}H_{22}O_2NCl$	67.59	67.73	6.94	7.07
$(CH_3COO)_2$	Ac.,[a] E. Ac.	Needle prisms	174–5	$C_{20}H_{24}O_4NCl$	63.55	63.58	6.41	6.64
C_6H_5COO	Ac.[b]	Prisms	191	$C_{23}H_{24}O_2NCl$	72.33	72.37	6.34	6.67
$(C_6H_5COO)_2$	Ac.	Prisms	131–2	$C_{30}H_{28}O_4NCl$	71.76	71.93	5.62	5.87
$C_2H_5CO_3$	Ac.	Prisms	128–9	$C_{19}H_{24}O_3NCl$	65.20	65.20	6.92	7.23
DERIVATIVES OF PHENETHYLMETHYLAMINE HYDROCHLORIDE, 4-R($C_9H_{13}NCl$) AND 3,4-R_2($C_9H_{12}NCl$)								
CH_3COO	Ac.,[b] E. Ac.	Leaves	194	$C_{11}H_{16}O_2NCl$	57.49	57.71	7.02	7.20
$(CH_3COO)_2$	Ac., E. Ac.	Leaves	142–3	$C_{13}H_{18}O_4NCl$	54.24	54.16	6.31	6.64
C_6H_5COO	Ac.[b]	Leaves	198	$C_{16}H_{18}O_2NCl$	65.84	65.80	6.22	6.30
$(C_6H_5COO)_2$	Ac.[b]	Needles	163–4	$C_{23}H_{22}O_4NCl$	67.05	66.87	5.39	5.55
$C_2H_5CO_3$	Ac.	Leaves	138.5–139	$C_{12}H_{18}O_3NCl$	55.47	55.65	6.99	7.06
$(C_2H_5CO_3)_2$	Ac., E. Ac.	Leaves	115	$C_{15}H_{22}O_6NCl$	51.78	51.99	6.38	6.68

[a] No ether. [b] Moist acetone. [c] Ac. = acetone, E. Al. = ethyl alcohol, M. Al. = methyl alcohol and E. Ac. = ethy acetate.

and was debenzylated directly. The yields of both substances are improved somewhat by using greater excesses of alkali and of acylating agent.

Debenzylations.—These were performed by catalytic hydrogenation of the hydrochlorides in 80% acetic acid solution, using a Burgess–Parr apparatus, at room temperature and three atmospheres pressure. Palladized charcoal (from 1.2 g. of palladium chloride and 6 g. of Darco G60) was used as catalyst. The theoretical amount of hydrogen was taken up in two to three hours (from 10 g. of starting material). The solutions were filtered and evaporated to dryness *in vacuo* before recrystallization. The yields were excellent. The secondary amine hydrochlorides are colorless solids, soluble in water and alcohol, moderately soluble in acetone, sparingly soluble in ethyl acetate and insoluble in ether and non-polar solvents.

The authors are indebted to Mr. W. S. Ide for the many microanalyses performed, including some chlorine and nitrogen analyses not recorded here.

Descriptive and analytical data are presented in the table.

Summary

A method has been developed for preparing phenolic esters wherein an unacylated secondary amino group is required on a side chain. The method involves N-debenzylation.

TUCKAHOE, NEW YORK RECEIVED JUNE 6, 1942

[CONTRIBUTION FROM THE LABORATORY OF HIGH MOLECULAR CHEMISTRY, THE HEBREW UNIVERSITY]

Poly-condensation of α-Amino Acid Esters. I. Poly-condensation of Glycine Esters[1]

BY MAX FRANKEL AND EPHRAIM KATCHALSKI

This paper deals with the poly-condensation of methyl, ethyl and isobutyl esters of glycine and with the further condensation of isolated primary reaction products.

Curtius[2] has shown that under certain conditions glycine ethyl ester yields, besides glycine anhydride, a tetraglycine ethyl ester, the so-called "Biuret Base." This tetrapeptide ester is the highest condensation product which hitherto has been obtained directly from the glycine ethyl ester. No clear results are reported in the literature concerning the formation of the corresponding tetrapeptide ester from glycine methyl ester.[3] In any case it is clear that the tetrapeptide esters were regarded as the highest peptide esters formed by condensation from the glycine ester. Nothing definite seems to be known about the condensation to chains of glycine esters other than those of methanol and ethanol.

(1) Certain minor errors in the manuscript as originally submitted were noted by the Editorial Board. Ordinarily these would have been brought to the attention of the authors prior to publication. International conditions at present are such that it appears impossible to follow this procedure except at the risk of indefinite postponement. The Editor has therefore taken the responsibility to make any corrections which appeared to be unquestionably required.—THE EDITOR.

(2) Curtius, *Ber.*, **37**, 1284 (1904).

(3) Curtius and Goebel, *J. prakt. Chem.*, [2] **37**, 159 (1888).

In a preliminary report[4] we have described some of our results obtained by C-polymerization of glycine ethyl ester. In our experiments we were able to isolate directly polypeptide esters with an average chain length of ten to thirty-five glycine units. These isolated products, when allowed to undergo additional condensation by heating, yield higher linear polymers. In the present paper we describe polymers thus obtained with an average chain length of 48–110 units.

The poly-condensations were carried out (a) with the pure liquid esters and (b) with their solutions in organic, water-free solvents. In a number of experiments in series (a) a stream of gas (nitrogen, hydrogen or oxygen) was passed through the liquid. In the experiments of series (b) solvent and temperature were varied.

The reaction mixtures contained, in addition to the higher condensation products, glycine anhydride and lower peptide esters. The separation was based mainly on the different solubility of the compounds concerned, which permitted the quantitative removal of all lower condensation products by extraction with hot water. A modified sensitive picric acid test, worked out for this purpose, was used in order to follow the complete removal of glycine anhydride. The quantitative removal of the water-soluble lower peptide esters was ascertained by the negative biuret reaction of the washings.

As is usual with products obtained by polymerization, mixtures containing polymer homologs are to be expected. The average chain length of the peptide ester form was ascertained by the determination of the terminal alkoxy group (*cf.* discussion). To avoid circumlocution, the polymerized products discussed in this paper are referred to as, *e. g.*, 20-glycine ethyl ester. It is to be understood that the specific names applied to the preparations merely indicate the average composition which corresponds most closely to the analytical results. They are not to be taken as implying that the preparations are homogeneous specimens of the substance named.

Experimental

I. **Poly-condensation of Glycine Ethyl Ester.**—The free glycine ethyl ester was liberated from its hydrochloride according to the method of Fischer[5] immediately before carrying out the condensation.

(a) **Poly-condensation of the Free Liquid Ester.**—These experiments were carried out by passing an indifferent gas through the liquid amino acid ester.

(4) Frankel and Katchalski, *Nature*, **144**, 330 (1939).

(5) Fischer, *Ber.*, **34**, 433 (1901).

1. A stream of dried nitrogen was passed through 4 g. of freshly distilled glycine ethyl ester for twenty-four hours. Access of carbon dioxide and moisture was prevented. The liquid solidifies gradually and after twenty-four hours the passage of gas had to be discontinued. The reaction mixture which was soluble in water and gave a positive biuret reaction and a positive picric acid test was kept for five months in a desiccator over soda-lime. After this time a part of the product was found to be insoluble in hot water. Traces of unchanged ethyl ester were removed by extraction with ether. The fraction insoluble in hot water was separated from the lower condensation products by repeated washing with hot water and centrifuging till the biuret reaction and the picric acid test in the washings became negative. The amount of the vacuum dried fraction insoluble in hot water was about 250 mg.

Properties.—The substance is practically insoluble in the usual organic solvents and even in hot water. In the latter characteristic swelling occurs. In concentrated alkalies and acids the substance dissolves gradually apparently by undergoing hydrolysis. It is horn-like in appearance; no melting point, decomposition at about 280–300°. On heating a suspension with ninhydrin solution the particles gradually become blue-violet in color, the fluid remaining colorless. On allowing a suspension of the substance to stand with a 30% solution of sodium hydroxide and a few drops of a dilute solution of copper sulfate, a positive biuret reaction appears within some hours. This is obviously due to the hydrolysis of the high peptide ester (which owing to its insolubility does not give a positive biuret reaction) to a lower soluble peptide chain showing the biuret reaction. Calcd. for 20-glycine ethyl ester: C_2H_5O, 3.79; N, 23.59. Found: C_2H_5O, 3.87; N, 23.24.

In order to show that during the process of separation, which consists of repeated treatment with hot water, no hydrolysis of the terminal ester group occurs, 50 mg. of the analyzed substance no. 1 was washed repeatedly with hot water and afterward reanalyzed. No change in ethoxy content was found.

Thirty mg. of the 20-glycine ethyl ester was totally hydrolyzed by refluxing with 2 ml. of 10% sulfuric acid for five hours. After quantitative removal of the sulfate by barium hydroxide solution, and boiling with cupric oxide, 54 mg. of the copper salt of glycine was obtained (calcd. amount of $Cu(NH_2CH_2COO)_2 \cdot H_2O$, 56.3 mg.).

Anal. Calcd. for $Cu(NH_2CH_2COO)_2 \cdot H_2O$: Cu, 27.68. Found: Cu, 27.38.

2. Four grams of glycine ethyl ester was treated as in 1 except that hydrogen instead of nitrogen was bubbled through the ester. The experimental details were similar to those of the previous experiment. 200 mg. of a horn-like fraction was obtained. Calcd. for 20-glycine ethyl ester: C_2H_5O, 3.79; N, 23.59. Found: C_2H_5O, 3.99; N, 23.38.

3. On repeating experiment 2 and allowing the reaction mixture to stand in contact with air after the treatment with gas, the water-insoluble fractions which were finally obtained (200 mg.) corresponded in analysis with a 25-glycine ethyl ester. Calcd. for 25-glycine ethyl ester: C_2H_5O, 3.05; N, 23.79. Found: C_2H_5O, 3.09; N, 23.40.

4. When oxygen was used, solidification of the liquid, unlike that in the above experiments, was accompanied

by the gradual appearance of a pink color. After keeping the primary reaction mixture in a desiccator for three months, the water-insoluble fraction obtained (160 mg.) corresponded to the 16-glycine ethyl ester. Calcd. for 16-glycine ethyl ester: C_2H_5O, 4.69; N, 23.37. Found: C_2H_5O, 4.66; N, 22.78.

5. Control experiments carried out without passing gas through the esters showed that under otherwise similar conditions no high chain products insoluble in hot water were formed.

(b) **Poly-condensation of the Free Ester in Solution.**— 1. In xylene at room temperature: 3 g. of freshly distilled glycine ethyl ester was dissolved in 12 ml. of pure, water-free xylene and kept for three months at room temperature. The precipitate which developed during this time was filtered, carefully washed with ether and dried *in vacuo* (1.7 g.). It was fractionated as before; 300 mg. of a water insoluble fraction was obtained corresponding to a 12-glycine ethyl ester. This product shows the general behavior of the higher polypeptides mentioned above, including the property of swelling in hot water, except that it is amorphous and not horn-like. Calcd. for 12-glycine ester: C_2H_5O, 6.15; N, 23.00. Found: C_2H_5O, 6.12; N, 22.81.

2. In xylene at boiling temperature: The solution as in (b)1 was refluxed for eight hours and then allowed to stand for two months at room temperature. After the usual treatment, there was obtained 240 mg. of a product similar in properties to that isolated in (b)1. Its analysis indicated an average chain length of 13 units. Calcd. for 13-glycine ethyl ester: C_2H_5O, 5.72; N, 23.11. Found: C_2H_5O, 5.52; N, 23.44.

3. In benzene at room temperature: 4 g. of glycine ethyl ester in 12 ml. of water-free benzene was kept for seventy days at room temperature. The 0.5 g. of precipitate was entirely soluble in hot water and gave both the biuret reaction and the picric acid test. The analytical data correspond to an equimolecular mixture of glycine tetrapeptide ethyl ester and glycine anhydride. *Anal.* Calcd. for this mixture: N, 21.62; C_2H_5O, 11.59; amino N, 3.60. Found: N, 21.47; C_2H_5O, 11.40; amino N, 3.55.

4. In boiling benzene: A solution of the same composition as that of (b)3 was refluxed for seven hours and then kept for seventy days at room temperature. The precipitate was treated as above with hot water and 150 mg. of material corresponding to a 17-glycine ethyl ester was obtained. Calcd. for 17-glycine ethyl ester: C_2H_5O, 4.43; N, 23.44. Found: C_2H_5O, 4.47; N, 23.67.

Total hydrolysis: 30 mg. of 17-glycine ethyl ester was refluxed with 2 ml. of 25% hydrochloric acid for six hours. After approximate neutralization with concentrated alkali, the *p*H of the solution was adjusted to 6.1 with 0.1 *N* sodium hydroxide. The amount of the amino nitrogen after hydrolysis was determined by titration according to Linderstrøm-Lang.[6] *Anal.* Calcd. for total hydrolysis of 17-glycine ester: amino N, 23.43. Found: N, 22.14.

5. No high condensation products have as yet been obtained under our experimental conditions from ether, dioxane and ethanol solutions. From the ethanol solution a precipitate was obtained which, on boiling with absolute alcohol, filtering, and cooling, gave a small number of colorless needle-like crystals. Analysis indicated a mixture of one molecule of glycine anhydride for every two molecules of "biuret base." *Anal.* Calcd. for this mixture: glycine anhydride, 17.2; N, 21.13; C_2H_5O, 13.58; amino N, 4.25. Found: glycine anhydride, 20.6; N, 21.19; C_2H_5O, 13.23; amino N, 4.23. Here, as well as in experiment (b)3, the products isolated may represent molecular compounds between the two components (*cf.* Pfeiffer).[7]

II. **Poly-condensation of Glycine Methyl Ester.**[8]— Glycine methyl ester hydrochloride was prepared by the method Johnson and Rinehart[9] used for obtaining glycine ethyl ester hydrochloride from methyleneaminoacetonitrile and methanol saturated with gaseous hydrogen chloride. As hot methanol dissolves considerable quantities of ammonium chloride, a recrystallization of the crude glycine methyl ester hydrochloride from ethanol is required to free it from the inorganic salt. The yield from 100 g. of methyleneaminoacetonitrile was 164.5 g. of pure glycine methyl ester hydrochloride.

The liberation of the free ester from its hydrochloride by the methods used for other glycine esters is not satisfactory; poor yields result. A more satisfactory method was worked out in collaboration with Dr. F. Stern using dry ammonia gas in place of sodium hydroxide: 10 g. of glycine methyl ester hydrochloride was suspended in 60 ml. of pure, water-free ether and a stream of carefully dried ammonia was passed with constant shaking at 0° through the suspension. Moisture was excluded. One to two hours later the solution of glycine methyl ester in ether was filtered from the suspended ammonium chloride, the latter washed with ether and the solution carefully dried over anhydrous sodium sulfate. The ether distillation was carried out with an effective column, to avoid loss of the ester. The free ester was then distilled *in vacuo* at 20 mm. and 45°; yield 4.8–5.0 g. of free ester.

(a) **Poly-condensation of the Free Liquid Ester.**— 1. 0.5 g. of freshly prepared glycine methyl ester was kept in a closed vessel for a month at room temperature. The fraction insoluble in hot water corresponded on analysis to 18-glycine methyl ester. Calcd. for 18-glycine methyl ester: CH_3O, 2.93; N, 23.81. Found: CH_3O, 2.96; N, 23.42.

2. Nitrogen was passed through 1.5 g. of glycine methyl ester for twelve hours and the semi-solid reaction mixture allowed to stand at room temperature for one month. After fractionating in the way previously mentioned, about 50 mg. of material averaging 30 units was obtained. Calcd. for 30-glycine methyl ester: CH_3O, 1.78; N, 24.11. Found: CH_3O, 1.77; N, 23.85.

(b) **Poly-condensation of the Free Ester in Solution.**— 1. In ether at room temperature: 1 g. of glycine methyl ester in 3 ml. of water-free ether was allowed to stand for three months; 250 mg. of a 27-glycine methyl ester was isolated by the usual procedure. Calcd. for 27-glycine methyl ester: CH_3O, 1.97; N, 24.06. Found: CH_3O, 1.90; N, 23.89.

2. In boiling xylene: 1.5 g. of glycine methyl ester in 4 ml. of water-free xylene was refluxed for four hours and

(6) Linderstrøm-Lang, *Z. physiol. Chem.*, **173**, 32 (1928).

(7) Pfeiffer, "Organische Molekülverbindungen," second edition, 1927, p. 319.

(8) The authors are indebted to Miss A. Saperstein for collaboration in this series of experiments.

(9) Johnson and Rinehart, THIS JOURNAL, **46**, 768, 1653 (1924).

then allowed to stand for three months at room temperature. About 200 mg. of 35-glycine methyl ester was obtained. Calcd. for 35-glycine methyl ester: CH_3O, 1.52; N, 24.17. Found: CH_3O, 1.54; N, 24.00.

In general the high glycine peptide methyl esters resemble the analogous ethyl esters but they seem to be slightly more soluble in hot water.[10]

III. **Poly-condensation of Glycine Isobutyl Ester.**—Glycine isobutyl ester hydrochloride was prepared by the method of Johnson and Rinehart[9]; 20 g. of aminoacetonitrile was refluxed for three hours with a mixture of 183 g. of dry isobutanol saturated with gaseous hydrogen chloride and 380 g. of isobutanol. The alcohol was distilled *in vacuo* from the filtered solution and the residue dried in a desiccator over sulfuric acid. The glycine isobutyl ester hydrochloride crystallizes after long standing as small, hygroscopic crystals; yield 40 g.

The free ester was liberated according to the method of Glenn and Skinner.[11] Dried nitrogen was passed through 5 g. of glycine isobutyl ester for thirty hours. The biuret reaction soon became positive. The cloudy liquid was allowed to stand at room temperature for about one and a half years, during which it became solid. By the usual treatment, 300 mg. of horny, water-insoluble product, free from anhydride, was obtained. It corresponded to a 10-glycine isobutyl ester. *Anal.* Calcd. for 10-glycine isobutyl ester: N, 21.74; C_4H_9O, 11.34. Found: N, 21.83; C_4H_9O, 10.81.

IV. **Further Condensation of the Primary Condensation Products of Glycine Esters.**—The linear polymers obtained in the above experiments were finely ground and kept at a temperature of about 130° for varying periods of time. They underwent further condensation which was demonstrated by a decrease in the alkoxy percentage. No glycine anhydride was formed during the operation (see Table I).

TABLE I

POLY-CONDENSATION OF 20-GLYCINE ETHYL ESTER AT 130°				
Time, days	0	4	9	34
C_2H_5O, %	3.99	3.26	2.51	1.86
Calcd. av. chain length	20	24	30	42
POLY-CONDENSATION OF 16-GLYCINE ETHYL ESTER AT 130°				
C_2H_5O, %	4.66	4.10	3.77	2.65
Calcd. av. chain length	16	18	20	30
POLY-CONDENSATION OF 30-GLYCINE METHYL ESTER AT 130°				
CH_3O, %	1.77		0.49	
Calcd. av. chain length	30		110	

V. **Analytical Methods.**—Qualitative tests were made on micro and semi-micro scales. All quantitative determinations were by micro methods. Methoxy and ethoxy determinations were made according to Vieböck[12] using hydrogen iodide of d. 1.96; the determination of isobutoxy groups was carried out as in the preliminary experiments of Furter.[13] It has been found that quantitative results are obtained by extending the heating of the substance in Furter's apparatus for four hours, with hydrogen iodide of d. 1.96, and with a stream of carbon dioxide of five bubbles per second.

Amino nitrogen determinations were made by a micro modification of Linderstrøm-Lang's titration.

The picric acid tests for glycine anhydride were carried out according to a modification of the usual procedure[14] by which the sensitivity was considerably increased. It may be mentioned here that this modification served also as a basis for the quantitative determination of the anhydride in the presence of amino acids, peptides or their esters. This method will be described in detail elsewhere.

Two ml. of a saturated solution of picric acid and 0.2 ml. of 0.1 *N* sodium hydroxide solution were added to 1 ml. of the solution to be tested and the mixture boiled for thirty seconds; a brownish-red color indicates the presence of anhydride. If amino acids, peptides or their esters are present, an equivalent amount of sodium hydroxide has to be added before carrying out the determination. The quantitative determination is carried out colorimetrically.

Discussion

The well-known stability of the free amino acids, which is explicable by their zwitterionic nature, induced us to choose their esters as the starting material.

From the above experiments we conclude that the following factors favor the formation of long-chain peptide esters: elevated temperatures, use of a solvent and the passing of indifferent gases through the esters. In a later paper we shall give an explanation for certain indications (not mentioned here) that carbon dioxide promotes the condensation.

According to the general conception of poly-condensation as formulated by Carothers[15] in particular, a linear chain structure is to be attributed to the products described here. This view is supported by the following experimental indications.

(1) It is possible to prove the presence of alkoxy and amino end-groups in the glycine condensation products, although they are insoluble in water and the usual solvents. The alkoxy group can be detected according to Zeisel,[16] while the presence of the amino group is indicated by the blue coloring of the suspended particles on boiling with ninhydrin.

(2) The results of quantitative hydrolysis as

(10) Pacsu, *Nature*, **144**, 551 (1939).
(11) Glenn and Skinner, THIS JOURNAL, **46**, 731 (1924).
(12) Vieböck and Brecher, *Ber.*, **63**, 3207 (1930).
(13) Furter, *Helv. Chim. Acta*, **21**, 1144 (1938), and private communication.
(14) Abderhalden and Komm, *Z. physiol. Chem.*, **139**, 180 (1924).
(15) Carothers, *Chem. Rev.*, **8**, 353 (1931).
(16) Zeisel, *Monatsh.*, **6**, 989 (1885); **7**, 406 (1886).

carried out on substance no. 1 and no. 7, prove that the high poly-condensation products are quantitatively built up of glycine units linked by peptide bonds. The presence of the latter is also indicated by the positive biuret reaction.

(3) The average chain length of the glycine polymers was ascertained by quantitative alkoxy determinations, as in the series of polymer homologs the alkoxy content varies distinctly with growing chain length. NH_2 determinations, although also indicative of the chain length, could not be carried out here owing to the insolubility of the glycine polymers.

(4) The results of alkoxy determinations were throughout in agreement with total nitrogen determinations (Kjeldahl). Moreover, as will be shown in the following paper, in the case of similar alanine poly-condensation products, soluble in water, the results of additional amino group determinations were throughout in very satisfactory agreement with those of alkoxy determinations and fully confirmed the conclusions drawn from the latter as regards the chain length.

Carbon and hydrogen determinations are not suitable means to assess the chain length; the differences in their values for the higher homologs lie within the experimental error.

It appears that high polymers can be obtained more easily and in better yields from the methyl ester than from isobutyl or the ethyl ester of glycine.

Our linear synthetic glycine products resemble in some properties the poly-amides obtained by Carothers[15] by the poly-condensation of di-amines and di-carboxylic acids.

Summary

On condensation under various conditions, glycine ethyl ester yielded a series of water insoluble polymers. The preparations were amorphous and contained ethoxyl in amounts corresponding, respectively, to 12-, 13-, 16-, 17- and 20-glycine peptide ethyl esters. From glycine methyl ester analogous preparations were obtained that contained methoxyl corresponding to 18-, 27- and 30-glycine methyl esters, respectively. Glycine isobutyl ester yielded a product of which the isobutoxy content corresponded to 16-glycine isobutyl ester.

On being heated to 130°, several of these products underwent further polymerization as indicated by decrease in alkoxy content. Preparations that corresponded in composition to 42-glycine ethyl ester and 110-glycine methyl ester were thus secured.

On being subjected to hydrolysis with acid, several of these polymers gave high yields of glycine suggesting that the polymers are in fact polypeptide esters. It appears that high polymers are more easily obtained from glycine methyl ester than from glycine ethyl and isobutyl esters.

The poly-condensation products described are (except the amorphous 12- and 13-glycine ethyl esters) horn-like, practically insoluble in water, in which they show characteristic swelling. They give positive ninhydrin and biuret reactions.

JERUSALEM, PALESTINE RECEIVED DECEMBER 19, 1941

[CONTRIBUTION FROM THE LABORATORY OF HIGH MOLECULAR CHEMISTRY, THE HEBREW UNIVERSITY]

Poly-condensation of α-Amino Acid Esters. II. Poly-condensation of Alanine Ethyl Ester[1]

BY MAX FRANKEL AND EPHRAIM KATCHALSKI

Alanine ethyl ester is a stable compound as compared with glycine ethyl ester. According to Fischer[2] and more recent literature, condensation to a peptide ester giving the biuret reaction has never been observed; moreover, even the formation of alanine anhydride, the so-called lactimide, takes place slowly.

Thus it seemed less probable that alanine ethyl ester would give polymers. We tried therefore to establish experimental conditions specially favorable to intermolecular reaction. Thus, although we obtained clear indications for poly-condensation of alanine ethyl ester on using experimental conditions similar to those described

(1) Certain minor errors in the manuscript as originally submitted were noted by the Editorial Board. Ordinarily these would have been brought to the attention of the authors prior to publication. International conditions at present are such that it appears impossible to follow this procedure except at the risk of indefinite postponement. The Editor has therefore taken the responsibility to make any corrections which appeared to be unquestionably required.—THE EDITOR.

(2) Fischer, *Ber.*, **34**, 433 (1901).