

and concentrated again to about 10 cc. This liquid was left to evaporate over phosphorus pentoxide for two days and yielded 2.1 g. of crystalline strontium L'-methoxy-diglycolate. After drying the strontium salt over phosphorus pentoxide for six hours at 100° in high vacuum, it showed the optical rotation $[\alpha]^{20}_D +56.4^\circ$.

Anal. Calcd. for $C_8H_6O_6Sr$: C, 24.03; H, 2.40; Sr, 35.01. Found: C, 23.90; H, 2.53; Sr, 34.98.

Oxidation of beta-Methyl-L-arabinopyranoside.—The procedure was the same as reported for alpha-methyl-L-arabinopyranoside. The optical rotation of the D'-methoxy-diglycolic aldehyde was $[\alpha]^{20}_D +123.2^\circ$ ($\alpha^{20}_D +1.98^\circ$; $c = 1.61$, H_2O ; tube 1 dm.) and the yield determined by titration according to the method of Willstätter and Schudel was 1.53 g. = 95%. The yield of strontium salt was 71%; $[\alpha]^{20}_D -56.4^\circ$ ($\alpha^{20}_D -1.36^\circ$; $c = 2.41$, H_2O ; tube 1 dm.) for the anhydrous substance.

Anal. Calcd. for $C_8H_6O_6Sr$: C, 24.03; H, 2.40; Sr, 35.01. Found: C, 23.95; H, 2.55; Sr, 34.96.

Oxidation of Formic Acid.—A roughly 5% aqueous solution of formic acid was prepared and its exact amount of acid determined by titration; 10 cc. of this solution,

containing 0.5253 g. of formic acid, was added to 25 cc. of glacial acetic acid and 6 g. of lead tetraacetate in an apparatus suitable for the quantitative determination of carbon dioxide. The mixture was shaken gently and kept at 35°, raising the temperature to 45° within the next half hour, after which time the reaction was completed. In three such experiments 0.4952 g., 0.4843 g., 0.4978 g. of CO_2 were found; yields were 98.8, 96.4 and 99.3%.

Summary

It has been shown that the oxidative cleavage of alpha- and beta-methyl-L-arabinopyranosides can be carried out quantitatively in aqueous solution with lead tetraacetate. Three moles of the oxidizing agent, instead of two, are required to complete this reaction. The reason for this excess consumption of reagent is that in aqueous solution the one mole of formic acid formed during the first reaction is oxidized by one mole of lead tetraacetate to one mole of carbon dioxide.⁶

TORONTO, CANADA

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Mechanism of the Reaction between Phthalic Anhydride and an Aminodiol¹

BY MURRAY M. SPRUNG

Much attention has been devoted recently to the mechanism of polycondensation reactions.² Aside from the interesting theoretical deductions to which this work has led, the important practical result is that it is now usually possible to predict whether a condensation reaction will lead to the formation of low molecular weight substances, linear polymers or cross-linked types of resins. The last named are formed, in general, when the initial reactants have higher combined functionalities than 2:2.^{2b}

Esterification and amidation reactions conform to these general schemes. Bi-bi-functional esterifications lead to cyclic monomers when rings of five or six members can result; otherwise linear polymers usually are formed. Bi-tri-functional esterifications practically always lead to net-like, cross-linked polymers. As for amidations, Carothers and Berchet³ found that five and six ring

monomers are formed exclusively, that a seven ring monomer and the corresponding linear polymer appeared simultaneously, and that reactions which might lead to cyclic monomers having eight or more ring atoms led, instead, exclusively to polymers.

Hydroxy amines would be expected to react with dibasic acids in accord with these now well-established principles. An amino-alcohol should give a linear polymeric ester-amide; whereas an aminodiol should give a product having a three dimensional, network structure analogous to that of glyceryl phthalate. This product, furthermore, should show the property of passing suddenly through the sol-gel transformation at a definite, critical stage in the polycondensation reaction.

Preliminary Results.—The reactions of 2-amino-2-methyl-1-propanol with adipic acid, and of 2-amino-2-methyl-1,3-propanediol with succinic, maleic, adipic and sebacic acids gave the results anticipated on the basis of these considerations. In the first case, the product was a thermoplastic resin and apparently a linear polymer. In the latter cases, cross-linked resins were formed which were converted to insoluble, infusible materials when the combined esterification and amidation

(1) Presented at the Boston meeting of the American Chemical Society, September 11-16, 1939.

(2) See, for example, (a) Carothers, *THIS JOURNAL*, **51**, 2548 (1929); (b) *Trans. Faraday Soc.*, **32**, 39 (1936); (c) Dostal and Raff, *Monatsh.*, **66**, 188 (1936); (d) Flory, *THIS JOURNAL*, **58**, 1877 (1936); **59**, 466 (1937); (e) Dreher, *Kunststoffe*, **28**, 35 (1938); (f) Stoll and Bouvé, *Helv. Chim. Acta*, **18**, 1087 (1935).

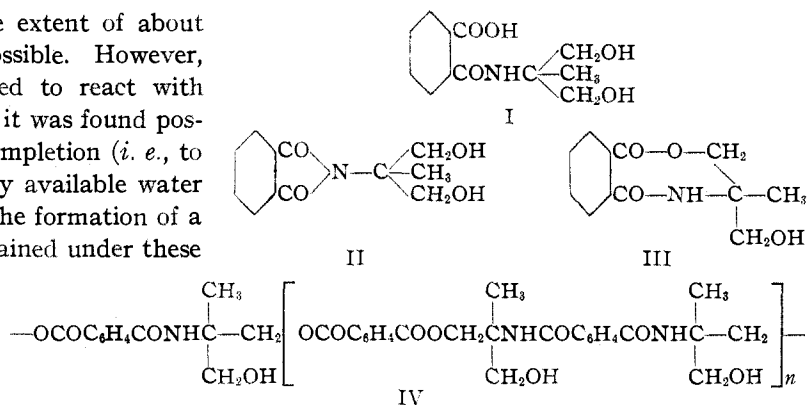
(3) Carothers and Berchet, *THIS JOURNAL*, **52**, 5289 (1930); see also Carothers, U. S. Patents 2,071,253, 2,130,523, 2,130,947 and 2,130,948 (1937 and 1938).

reactions had proceeded to the extent of about 65-75% of that theoretically possible. However, when the aminodiol was caused to react with phthalic acid (or its anhydride), it was found possible to carry the reaction to completion (*i. e.*, to collect 100% of the theoretically available water of reaction) without observing the formation of a gel structure. The product obtained under these conditions was a colophony-like, brittle, amorphous solid, which appeared to be a mixture of several ingredients. In order to obtain an explanation of this rather unexpected result, attempts were made to break down the reaction into distinct stages and to isolate the low molecular weight intermediates involved.

First Stage: Opening of the Anhydride Ring.—Phthalic anhydride and 2-amino-2-methyl-1,3-propanediol, heated to a temperature of 135-145° for two and one-half hours, gave a soft, stringy, sticky, resinous-appearing material which could not be purified by crystallization or solvent extraction (and which naturally could not be distilled without further reaction occurring). However, analysis of the crude reaction product for acidity, saponification equivalent, and hydroxyl indicated that it consisted mainly of the substituted phthalamic acid, namely, N-(1,1-dimethylol)-ethylphthalamic acid (I). The first step in the reaction therefore consists essentially in addition of the amino group of the aminodiol to the anhydride linkage of phthalic anhydride.

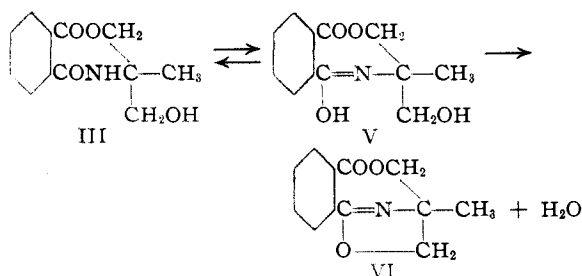
Second Stage: Ring Closure.—When the reactants were mixed in equimolar proportions and heated at 150-200° for two hours, almost exactly one mole of water was collected. The product was very similar in appearance to that described above, and could not be separated into crystalline fractions by solvent treatment. However, in this case over 50% of the crude reaction product was distillable. The main portion of the distillate consisted of a sluggish, pale yellow liquid boiling at 207-220° at 6 mm., and at 172-177° at about 50 microns. The undistillable portion was a dark colored, hard, brittle, fusible and soluble resin.

A priori, three substances might be formed under these conditions: the dimethylol phthalimide (II), the cyclic ester-amide (III), or a linear polymeric structure of which (IV) represents one possibility.



Analyses of the main fraction of the distillate gave results reasonably well in accord with those demanded by structures (II) or (III). However, the hydroxyl analyses (using the acetic anhydride-pyridine method) failed to give consistent results, indicating structure (II) in some cases, and something intermediate between (II) and (III) in others. This main fraction, when exhaustively purified by crystallization, gave a well-defined solid, analyzing as expected for $\text{C}_{12}\text{H}_{13}\text{NO}_4$. The formation of a *dibenzoyl derivative* (with benzoyl chloride in pyridine) favors the dimethylol phthalimide structure (II), but leaves unanswered the question as to why the pyridine-acetic anhydride method does not give results consonant with this structure.

Third Stage: Effect of Excess Phthalic Anhydride.—The colophony-like resin obtained when the reactants were used in the ratio 3 phthalic:2 aminodiol, was subjected to vacuum distillation. Over 50% of it distilled over as a thick, viscous, pale reddish liquid. Redistillation under very low pressure yielded two crystalline fractions which, on further purification, gave colorless solids of the composition $\text{C}_{12}\text{H}_{11}\text{NO}_3$ and $\text{C}_{19}\text{H}_{17}\text{NO}_3$, respectively. The latter substance has not been identified as yet. The substance $\text{C}_{12}\text{H}_{11}\text{NO}_3$ is obviously a dehydration product of the substance $\text{C}_{12}\text{H}_{13}\text{NO}_4$. The only reasonable structure which can be assigned to it is one that could result from



the ester amide (III), by enolization to the isoamide (V) and subsequent dehydration to an oxazoline derivative (VI).

On the other hand, it is difficult to see how a substance of the composition $C_{12}H_{11}NO_3$ could be formed from the dimethylol phthalimide structure (II). The structure (VI) represents the very rare case of a five, a six and an eight ring, fused conjointly.⁴

Attempts to reduce the compound $C_{12}H_{11}NO_3$ to a derivative of phthalaldehydic acid ethylene imino acetal failed. Nevertheless, the presence of a basic nitrogen atom was established by the formation of a picrate (m. p. 146–147°). In absolute alcoholic solution an abnormal picrate (m. p. 225–226°, composed of two moles of the "oxazoline" and one of picric acid) was obtained, even in the presence of excess picric acid. This peculiar observation has no obvious explanation.

It is now possible to interpret the observations made during acylation of the compound $C_{12}H_{13}NO_4$. This substance probably has the 8 ring ester-amide structure (III), but is capable of forming a diacyl derivative of the isoamide form (V). Acetic anhydride (in pyridine) does not acylate the "enol" hydroxyl completely, thus giving analytical results between those expected for the normal and iso structures. On the other hand, benzoyl chloride, a more vigorous acylating agent, forces the enol hydroxyl to react completely.

The oxazoline (VI) might be formed from the esteramide (III) during distillation. However, there was no evidence of its presence in the distillate from the 1:1 reaction product. When, however, this product was heated to 200° with an equivalent amount of phthalic anhydride (but without allowing water to distil out), it was possible to isolate the "oxazoline," by means of solvent extraction and fractional crystallization, and without distillation.

Review of Pertinent Literature

The mechanism outlined above is amply supported by existing literature. A substance very closely related to the structure (III) was obtained as early as 1905 by Gabriel⁵ by treating N- β -bromoethyl phthalimide with dilute aqueous potassium hydroxide. The corresponding eight-ring thioamide was formed when N- β -thioethyl

(4) The only analogous structure known to the writer is that of an oxy-lactam recently reported as formed from a diketo cholanolic acid monoxime by reductive amidation (Barnett and Reichstein, *Helv. Chim. Acta*, **21**, 926 (1938)).

(5) Gabriel, *Ber.*, **38**, 2389 (1905).

phthalamic acid was treated with concentrated hydrobromic acid,⁶ and a homologous substance was similarly obtained from N- β -methyl- β -carbethoxythiophthalimide by Mylius.⁷ Richard Meyer as early as 1903⁸ prepared cyclic diamides having 7, 8 and 14 ring atoms by condensing *o*-phenylenediamines with malonic, succinic, isosuccinic, adipic and phthalic acids, their anhydrides or esters. Very little attention seems to have been devoted to these interesting results of Meyer, or to the equally significant observations of Gabriel and co-workers.^{5,6,7}

The assumption that the ester-amide reacts in the isoamide form is also in accord with previous observations. Hantzsch has demonstrated,⁹ on the basis of spectroscopic measurements, that trichloroacetamide and benzamide exist in solution largely in the isoamide form. Further, it has long been known that N- β -bromoethyl benzamides are converted to 2-aryloxazolines by boiling with hot water or dilute alkali.¹⁰ Closely related to the present case are the formation of 2-phenylbenzoxazoline by heating *o*-benzaminophenol above its melting point¹¹; of *o*-benzoylphenylurethan from urethan, benzoyl chloride and sodium¹²; and of phenylalkyloxazolones from benzoylglycine and its homologs.¹³ Similarly, intramolecular acylations, leading to the formation of benzoxazones, occur when anthranilic acid or its derivatives are treated with dehydrating agents such as acetic anhydride.¹⁴

Conclusions

The mechanism of the reaction of 2-amino-2-methyl-1,3-propanediol on phthalic anhydride is accordingly believed to involve the following steps (1) opening of the anhydride ring to give a dimethylol phthalamic acid; (2) intramolecular esterification to give an 8 ring esteramide; (3) dehydration, through the isoamide form of the esteramide, to yield an oxazoline; (4) simultaneous occurrence of intermolecular condensation reac-

(6) Gabriel and Colman, *ibid.*, **45**, 1643 (1912).

(7) Mylius, *ibid.*, **49**, 1091 (1916).

(8) Richard Meyer, *Ann.*, **327**, 1 (1903).

(9) Hantzsch, *Ber.*, **64**, 661 (1931); cf. Ramart-Lucas and Wohl *Compt. rend.*, **196**, 120 (1933).

(10) Elfelat, *Ber.*, **24**, 3222 (1891); Gabriel and Neumann, *ibid.*, **25**, 2385 (1892); Soloman, *ibid.*, **26**, 1322 (1893); Saulmann, *ibid.*, **33**, 2639 (1900).

(11) Hübner, *Ann.*, **210**, 385 (1882).

(12) Hantzsch, *Ber.*, **26**, 928 (1893).

(13) Mohr and Stroschein, *ibid.*, **42**, 2521 (1909).

(14) Anschütz, Schmidt and Greiffenberg, *ibid.*, **35**, 3474, 3480 (1902); Mohr and Köhler, *ibid.*, **40**, 997 (1907); Erlenmeyer, *Ann.*, **337**, 265 (1904); Heller and Fiesselmann, *ibid.*, **324**, 134 (1902); Angeli and Angelico, *Gazz. chim. ital.*, **30**, II, 278 (1900); Bogert and Seil, *This Journal*, **29**, 529 (1907).

TABLE I
REACTIONS OF 2-AMINO-2-METHYL-1-PROPANOL AND 2-AMINO-2-METHYL-1,3-PROPANEDIOL WITH VARIOUS ACIDS (OR DERIVATIVES)

Reactants		Molar ratio	Time, hr.	Temp., °C.	Water formed, cc.			Nature of product
Amine component	Acid component				Obsd.	Calcd.	% of Calcd.	
Amino alcohol	Diethyl adipate	2/1	7	170-190	111 ^a	110	99 ^b	Thick sirup
Amino alcohol	Adipic acid	2/2	4	160-190	73	72	(100)	Thick balsam, thermoplastic
Amino diol	Adipic acid	1.1/1.5	2	125-195	42	54	77	Stiff balsam, thermosetting ^c
Amino diol	Adipic acid	1.1/1.5	4	154-195	46	54	85	Gelled resin
Amino diol	Sebacic acid	3.2/4.5	4	142-184	127	162	77	Stiff, hard balsam, thermosetting
Amino diol	Maleic anhyd.	1.1/1.5	1/4	110-160	4.5	27	66.5 ^d	Gelled resin
Amino diol	Succinic anhyd.	1.1/1.5	1/4	2.5	27	59.5 ^d	Soft balsam, thermosetting ^c
Amino diol	Phthalic anhyd.	2.2/3.0	3	150-220	55	54	(100) ^d	Hard, brittle, amorphous, thermoplastic
1,1,1-Trimethylol propane ^f	Phthalic anhyd.	0.55/0.75	1 1/2	195-250	7.7	13.5	78.5	Gelled resin

^a Alcohol. ^b On the basis of amine titrations, this reaction is virtually completely amidolysis, with only a small amount of alcoholysis. ^c Acid value, 152. ^d These calculations take into account the opening of the anhydride ring. ^e Acid number, 258. ^f Run for comparison with amino diol, since it has a similar structure.

tions, giving rise to the formation of resinous by-products of the soluble, fusible (non-cross-linked) type.

Experimental

General Procedure for Preparation of Resins.—The aminoalcohol or aminodiol and the appropriate acid or acid derivative were mixed in a three-necked flask fitted with a thermometer, stirrer and short column to which a condenser was attached. The mixture was heated by means of a free flame and maintained at such temperature that even distillation occurred. The course of the reaction was followed roughly by the volume of water (or alcohol) collected; and was checked qualitatively by the rapidity with which the sol-gel transformation was observed to occur when a small sample was spread on a metal surface at 200°. Table I summarizes these experiments.

First Stage of the Reaction between 2-Amino-2-methyl-1,3-propanediol and Phthalic Anhydride.—One mole each of the aminodiol (105 g.) and phthalic anhydride (148 g.) were heated in a 3-necked flask at a temperature of 135-145° for two and one-half hours, with stirring. Practically no water was formed. The acid value decreased from an initial value of 444 to a final value of 223 (calcd. 222), indicating that virtually complete addition to the anhydride linkage had been accomplished. The product was a soft, stringy, reddish resin, which became brittle at about -10°. Numerous attempts to purify this material by crystallization failed, as did attempts to obtain acyl derivatives. Acyl halides reversed the reaction by which it is formed, giving phthalic anhydride and the aminodiol as the sole recognizable products. The crude product, on analysis, gave results reasonably well in accord with those required by the dimethylol phthalamic acid (I).

Calcd. for C₁₂H₁₈N₂O₅: neutral equivalent, 253; saponification value, 0; hydroxyl equivalent, 126.5. Found: neutral equivalent, 251; saponification value, 24¹⁵; hydroxyl equivalent, 133.

Second Stage of the Reaction between 2-Amino-2-methyl-1,3-propanediol and Phthalic Anhydride.—One

mole of phthalic anhydride (148 g.) and 1.1 mole of the aminodiol (115.5 g.) were heated and stirred for two hours at a temperature of 150-200° (thermometer in the liquid). Twenty cubic centimeters of water was collected (calcd., 18 cc.). The product was a sticky, thermoplastic, resinous-appearing substance. A sample was subjected to vacuum distillation. Around 50% of it distilled over as a sluggish, pale reddish liquid (b. p. 207-220° (6 mm.)) which solidified to a stiff balsam-like material.

Anal. Found: sap. equiv., 226, 232; hydroxyl equiv., 234, 218; N (Kjeldahl), 6.15. Calcd.: sapon. equiv., 235; hydroxyl equiv., 235 (structure III), 117.5 (structure II); N, 5.95.

A second sample was distilled under high vacuum. About fifty per cent. of it (boiling point, 172-178° at about 50 microns) was thus obtained as a pale yellow, sluggish liquid which slowly solidified on standing several weeks at room temperature. (A small amount of a higher boiling fraction (b. p. 200-220° at 0.3-0.7 mm.) was also obtained.)

Anal. Found: hydroxyl equiv., 143; N (Kjeldahl), 5.72; mol. wt. (camphor), 247. Calcd.: hydroxyl equiv., 235 or 117.5; N, 5.95, mol. wt., 235.

A sample was further purified by crystallization as follows: from benzene, from ethyl acetate and carbon tetrachloride, from carbon tetrachloride, from ethyl acetate and petroleum ether. Fine, silky, colorless needles were obtained; m. p. 90.5-91.0°.

Anal. Calcd. for C₁₂H₁₈N₂O₄: C, 61.25; H, 5.57; N, 5.95; mol. wt., 235. Found: C, 60.80, 61.50, 61.09, 60.98; H, 5.55, 5.84, 5.72, 5.68; N, 5.93, 6.26; mol. wt., 256, 247.

This compound did not form a picrate nor a nitroso derivative. A benzoyl derivative was formed (in good yield) with benzoyl chloride in pyridine. It melted at 121.5°, after crystallization, once from 95% alcohol and twice from benzene.

Anal. Calcd. for C₂₀H₂₁O₆N: C, 70.43; H, 4.74; N, 3.16; mol. wt., 443. Found: C, 70.59, 70.59; H, 4.88, 4.96; N, 3.36, 3.38; mol. wt., 461, 426.

Third Stage of the Reaction between 2-Amino-2-methyl-1,3-propanediol and Phthalic Anhydride.—The reaction

(15) Saponification value, calcd. for the alternate ester structure, *i. e.*, mono-(β -methyl- β -amino- γ -hydroxy)-propyl phthalate, 223.

was carried out as indicated in Table I. A hard, brittle, amber-colored, easily friable, amorphous solid was obtained. The crude product was analyzed. *Anal.* Found: sapon. equiv., 200, 197; N (Kjeldahl), 4.98.

One hundred grams of this crude product, on vacuum distillation in a stream of nitrogen, gave *ca.* 50 g. of a hard, granular, semi-crystalline material, boiling at 195–205° at 2 mm. A portion of it was crystallized from ethyl acetate and then four times from ethylene chloride. A small amount of a colorless, micro-crystalline powder was thus obtained, having a sharp melting point of 165°. A second sample of the crude, colophony-like product was distilled at 2–6 mm. pressure (b. p. 140–219°, mainly 213–219°) and the main fraction redistilled under high vacuum. Three crystalline fractions were thus obtained: (1) b. p. 110–140° (0.07–0.10 mm.); (2) b. p., 145–160° (0.05 mm.); (3) b. p. 165–180° (0.05–0.2 mm.). Fraction (1) was crystallized four times from ethylene chloride. Beautiful, glistening crystals were obtained, melting at 160.5°. A microscopic examination showed large, nearly square, flat plates, some of them elongated to laths.

Anal. Calcd. for $C_{12}H_{11}NO_3$: C, 66.34; H, 5.11; N, 6.45; mol. wt., 217. Found: C, 66.14, 65.78; H, 5.10, 5.14; N, 6.39, 6.42; mol. wt., 235, 227.

The purified material gave a picrate, with 30% excess picric acid in absolute alcohol; melting point, 225–226° (decompn.). Analysis indicated that it contained two moles of the compound $C_{12}H_{11}NO_3$ combined with one of picric acid.

Anal. Calcd. for $2C_{12}H_{11}NO_3 \cdot C_6H_2N_3O_{10}$: N, 10.57. Found: N, 10.48, 10.55. The same substance was formed when picric acid was used in 100% excess. Found: N, 10.57, 10.34.

A little warm water was added to the filtrate from which the 2:1 picrate separated and the solution was again cooled. A second crystalline picrate was thus obtained which melted sharply at 146–147°, and analyzed for the 1:1 compound.

Anal. Calcd. for $C_{12}H_{11}NO_3 \cdot C_6H_2N_3O_{10}$: N, 12.54. Found: N, 12.45, 12.17.

An attempted reduction of the compound $C_{12}H_{11}NO_3$ with zinc and acetic acid failed. Treatment with sodium in absolute alcohol resulted in hydrolysis to 2-amino-2-methyl-1,3-propanediol and sodium phthalate (identified by analysis of the sodium salt, and conversion to phthalic acid, m. p. 187.5°; mixed m. p. 189°; positive fluorescein test).

Anal. Calcd. for $C_8H_4O_4Na_2 \cdot 2H_2O$: Na, 18.9. Found: Na, 19.1, 19.2.

The second fraction obtained on distillation was crystallized as follows: twice from ethyl acetate, once from ethylene chloride and once from benzene and ethyl acetate. Fine, dense, colorless, powdery crystals resulted; m. p. 165–165.2°; mixed m. p. with the compound $C_{12}H_{11}NO_3$, 160–160.5°. Under the microscope it appeared as small clusters of laths, arranged radially, having an extinction coefficient of 38° (sample a). A small amount was purified further by twice crystallizing it from absolute

alcohol. The melting point was unchanged (sample b). *Anal.* Calcd. for $C_{19}H_{17}NO_6$: C, 67.32; H, 5.02; N, 4.13; mol. wt., 339. Found: (a) C, 66.90, 66.77; H, 5.33, 5.33; N, 4.20, 4.18; mol. wt., 280, 302. (b) C, 67.15, 67.09; H, 5.33, 5.25; N, 4.22, 4.14; mol. wt., 281, 294.

This substance does not form a picrate. Treatment with sodium and alcohol, followed by acidification, gave some phthalic acid and a small amount of a substance of m. p. 227–228° (decomp.) which has not been identified. Benzoic acid could not be detected, although the analytical composition points to this substance as a possible component of the compound.

Reaction of the Second Stage Product with Excess Phthalic Anhydride.—Forty-five grams of the 1:1 reaction product was heated in a long-necked flask with 50 g. of phthalic anhydride for twenty minutes at 170–200°. The resinous product which resulted was extracted successively with hot ethylene chloride and hot ethyl acetate, and each solution was shaken with sodium carbonate solution to remove phthalic acid and unreacted phthalic anhydride. The ethylene chloride solution was evaporated and treated with warm heptane. Five grams of a colorless powder was obtained which was crystallized several times from a mixture of ethylene chloride and carbon tetrachloride. The small amount of purified material obtained was identified as the oxazoline derivative, $C_{12}H_{11}NO_3$, by melting point and mixed melting point. From the ethyl acetate solution, a substance was obtained (by concentration and precipitation with heptane) which melted unsharply at 155–165° after crystallization from carbon tetrachloride, and which was not identical with any of the substances previously described.

Anal. Found: N, 3.70, 3.71.

This may possibly be a substance derived from two moles of phthalic anhydride and one mole of the aminodiol. Such a compound would have the composition $C_{20}H_{13}NO_6$ (calcd.: N, 3.83).

Summary

1. Succinic, maleic, adipic and sebacic acids react with 2-amino-2-methyl-1,3-propanediol to give "heat convertible" resins.
2. Phthalic anhydride, under the same conditions, gives a mixture of crystalline compounds and, as by-products, resins which are probably linear polymers.
3. This reaction has been shown to involve the following stages: (a) addition to form a dimethylol phthalamide (I); (b) intramolecular esterification to an 8-ring ester-amide (II); (c) dehydration, through the isoamide form, to give an oxazoline derivative (VI) which contains a five, a six and an eight ring fused together.

RESEARCH LABORATORY
GENERAL ELECTRIC CO.,
SCHENECTADY, N. Y.

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