Heterocyclic Intermediates for the Preparation of Thermally Stable Polymers. II. Benzoxazoles and Benzothiazoles.

J. Preston, W. DeWinter (1) and W. L. Hofferbert, Jr.

Contribution No. 468 from the Chemstrand Research Center, Inc.

INTRODUCTION

Earlier (2) we reported the preparation of a number of heterocyclic intermediates suitable for the preparation of ordered copolymers containing heterocyclic rings. In this paper we wish to describe the method of synthesis and the properties of some benzoxazole and benzothiazole diamines and a benzoxazole diacid and its acid chloride derivative; these compounds are particularly suitable for the preparation of thermally stable ordered copolymers.

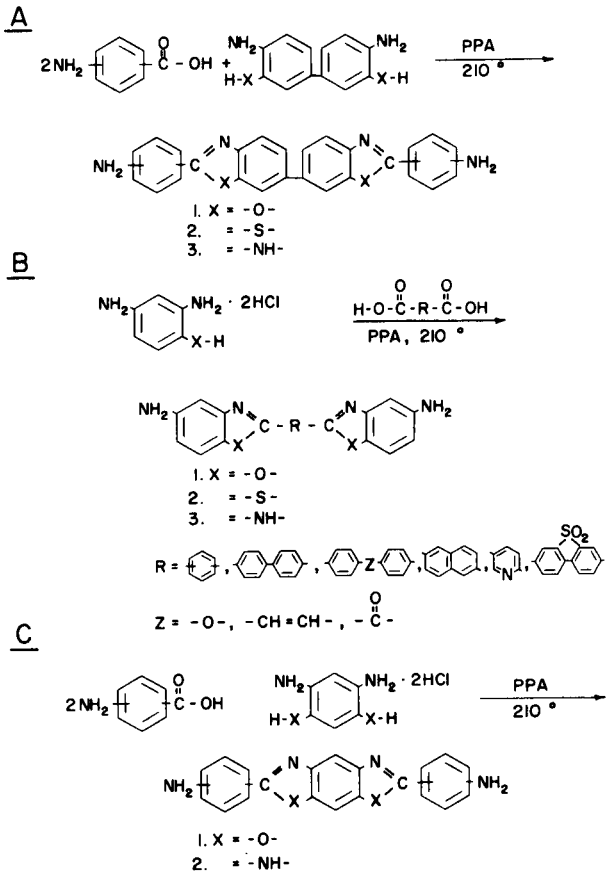
The preparation of some benzothiazole diamines has been reported (3,4) earlier but the syntheses of these compounds depended upon nitration of phenylenedibenzothiazoles and subsequent reduction of the nitro compound. From 2,2′-*o*- and 2,2′-*p*-phenylene-bis-benzothiazoles, diamines substituted in the 6,6′ position were obtained while the 2,2′-*m*-phenylene-bisbenzothiazole gave a mixture of nitration products which include nitration on the *meta*-phenylene ring. Acetylation of an amino group prior to benzothiazole formation was used to prepare the 5,5′-diacetyl compound which was hydrolyzed to the free base (3). Apparently comparably structured benzoxazole diamines could be prepared by similar syntheses but they have not been reported heretofore.

DISCUSSION AND RESULTS

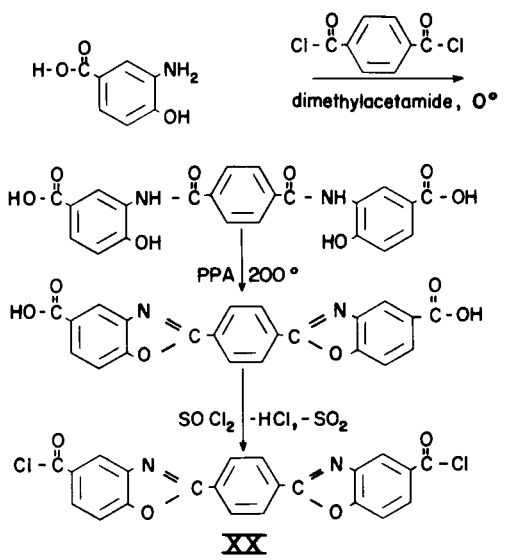
An excellent synthesis (5) for simple (or *o*-amino or *o*-hydroxy substituted) benzoxazoles, benzimidazoles and benzothiazoles employing polyphosphoric acid (PPA) as a solvent and condensing agent has been adapted in the present work to yield diamines according to the reactions shown in Scheme I. Previously it has been demonstrated that isolated amino groups are unreactive under the conditions of benzimidazole formation, Scheme I, A-3 (2,6), B-3 (7) and C-2 (8); the reaction now has been extended to benzoxazole and benzothiazole diamines (Scheme I; see also Tables I and II).

The synthesis is effected in a one-step procedure and in essentially quantitative yield. The position of the amino groups are unequivocally established by means of the preparative route. These diamines are readily soluble in a variety of solvents and are stable towards the effects of air-oxidation and solvolysis; they are not readily decomposed by heat except at rather high temperatures (above 350°). Some data on the appearance, solubility and U.V. spectral absorption for the benzoxazole diamines are found in Table III.

Scheme I

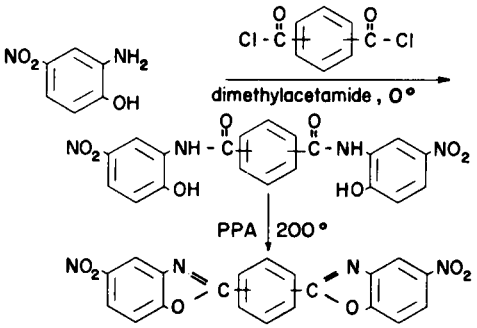


Scheme II



XX

Scheme III

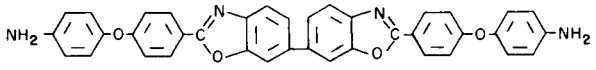


High molecular weight polymers were formed as derivatives of all of the diamines, indicating a high degree of purity for the compounds described here. (The properties of the polymers will be reported in future publications).

A somewhat different route from that above was used to prepare a benzoxazole diacid because starting materials such as 3-amino-4-hydroxybenzoic acid contain functional groups which can condense repeatedly, forming polymers. Hence, an intermediate amide-acid (Scheme II) was prepared and hot PPA was used to effect cyclodehydration to the benzoxazole-diacid; the yield in the latter reaction was virtually quantitative. High molecular weight polymers (which will be described in a forthcoming publication) were prepared from the benzoxazole diacid chloride, indicating a high degree of purity for this material.

The route of synthesis used for the benzoxazole diacid, *i. e.*, cyclodehydration of an *o*-hydroxy amide, can also be used to prepare dinitrobenzoxazoles and these can subsequently be reduced to diamines (Scheme III). However, the method suffers from the insolubility of the dinitro benzoxazoles, making complete reduction difficult or impossible.

All of the diamines of Tables I-III were yellow except for III and XXV.



m.p. 330-331°

XXV

For XXV it can be speculated that any conjugation between amino groups and benzoxazole groups is disrupted by the *-O-* bridge. Diamines bridged by sulfonyl have been reported to yield white or very light colored polymers in contrast to yellow polyimides from simple diamines.

EXPERIMENTAL (9)

A single example serves to illustrate the preparation of the crude diamines; the properties of various diamines after purification (sublimation) are given in Tables I, II and III. The synthesis of a benzoxazole diacid and its corresponding acid chloride is described below as is the preparation of the dinitro benzoxazoles.

Preparation of Crude Diamines.

(IV).

A three-necked, round bottomed 500 ml. flask, equipped with an all-glass Trubore stirrer, a nitrogen inlet and a drying tube containing Drierite was charged with 20 g. (slightly more than 0.1 mole) of 2,4-diaminophenol dihydrochloride, 8.3 g. (0.05 mole) of terephthalic acid and 70 ml. of 116% polyphosphoric acid (PPA). The flask was placed in an oil bath and heated slowly, to control excessive foaming, to 110°; the reactants were stirred continuously under an atmosphere of nitrogen. The flask was kept at 110°; for one hour, then the temperature was increased slowly to 210° and maintained at the latter temperature for three hours. The contents of the flask were allowed to cool and were then poured into 600 ml. of water, forming a brownish precipitate. The crude product was soaked overnight in 600 ml. of an aqueous ten percent sodium bicarbonate solution, filtered, washed with water and dried under vacuum at 60°; yield, 96%.

Purification of Diamines.

The crude diamine was extracted in a Soxhlet apparatus with acetone or alcohol to remove unreacted starting materials; it was next dissolved in a large quantity of hot dimethylacetamide (DMAc). The solution of the diamine was treated with charcoal and filtered; addition of water to the filtrate precipitated a purified product.

The diamines could also be sublimed under high vacuum at 340-350°; diamines purified via the sublimation method were of higher purity than those produced by the extraction and precipitation method described above. The properties reported here are for sublimed diamines.

TABLE I

Benzoxazole Diamines

	Compound	M.P., °C (a)	Molecular Formula	Anal. Calcd.	Anal. Found
Type A (b)					
I	2,2′-bis(*m*-Aminophenyl)-5,5′-bibenzoxazole	308-309	$C_{26}H_{18}N_4O_2$	C, 74.64 H, 4.30 N, 13.39	C, 74.52, 74.47 H, 4.73, 4.46 N, 13.45, 13.70
II	2,2′-bis(*p*-Aminophenyl)-5,5′-bibenzoxazole	346-349 (dec.)	$C_{26}H_{18}N_4O_2$	C, 74.64 H, 4.30 N, 13.39	C, 74.70, 74.89 H, 4.89, 4.98 N, 13.52, 13.59
III	2,2′-bis(*m*-Aminophenyl)-5,5′-bibenzoxazole sulfone	305-310	$C_{26}H_{18}N_4O_4S$	N, 11.69	N, 11.73, 11.57
Type B (b)					
IV	2,2′-*p*-phenylene-bis(5-aminobenzoxazole)	382-384	$C_{20}H_{14}N_4O_2$	C, 70.08 H, 4.11 N, 16.46	C, 70.36, 70.16 H, 4.22, 4.29 N, 16.53, 16.59
V	2,2′-*m*-phenylenebis-(5-aminobenzoxazole)	300-302	$C_{20}H_{14}N_4O_2$	C, 70.08 H, 4.11 N, 16.46	C, 70.31, 70.53 H, 4.15, 4.30 N, 16.34, 16.33
VI	2,2′-*o*-Phenylenebis-(5-aminobenzoxazole)	188-190	$C_{20}H_{14}N_4O_2$	C, 70.08 H, 4.11 N, 16.46	C, 70.62, 70.20 H, 5.01, 4.68 N, 16.08, 15.93
VII	2,2′-bis(5-Aminobenzoxazole)-4,4′-diphenyl ether	360-363	$C_{26}H_{18}N_4O_2$	C, 74.56 H, 4.33 N, 13.47	C, 74.50, 74.40 H, 4.75, 4.61 N, 13.57, 13.29
VIII	2,2′-bis(5-Aminobenzoxazole)-4,4′-diphenyl ether	314-316	$C_{26}H_{18}N_4O_3$	C, 71.81 H, 4.17 N, 13.00	C, 72.38, 72.22 H, 4.24, 4.20 N, 12.61, 12.36
IX	2,2′-bis(5-Aminobenzoxazole)-4,4′-stilbene	363 (dec.)	$C_{22}H_{20}N_4O_2$	C, 75.61 H, 4.51 N, 12.69	C, 75.58, 75.48 H, 4.68, 4.63 N, 12.63, 12.62
X	2,2′-bis(5-Aminobenzoxazole)-4,4′-biphenyl-3,3′-sulfone	365 (dec.)	$C_{26}H_{16}N_4O_4S$	N, 11.73	N, 12.40, 12.25
XI	2,6-Naphthalene-2,2′-bis-(5-aminobenzoxazole)	368-370	$C_{24}H_{16}N_4O_2$	N, 14.36	N, 13.82, 13.81
XII	4,4′-Benzophenone-2,2′-bis-(5-aminobenzoxazole)	332-334	$C_{27}H_{18}N_4O_3$	C, 72.57 H, 4.06 N, 12.63	C, 72.63, 72.55 H, 4.15, 4.29 N, 12.50, 12.33
XIII	2,5-Pyridine-2,2′-bis-(5-aminobenzoxazole)	373-375	$C_{19}H_{13}N_5O_2$	C, 66.46 H, 3.82 N, 20.40	C, 66.38, 66.32 H, 3.72, 3.62 H, 20.20, 20.15
Type C (b)					
XIV	2,6-Di(*m*-aminophenyl)-benzo[1.2.5.4]bisoxazole	407-410	$C_{20}H_{14}N_4O_2$	C, 70.08 H, 4.11 N, 16.46	C, 70.11, 70.28 H, 4.37, 4.40 N, 16.35, 16.27
XV	2,6-Di(*p*-aminophenyl)-benzo[1.2.5.4]bisoxazole	417-420	$C_{20}H_{14}N_4O_2$	C, 70.08 H, 4.11 N, 16.46	C, 69.47, 69.10 H, 4.26, 4.21 N, 16.51, 16.65

(a) (9). (b) For formula types, see Scheme I.

TABLE II

Benzothiazole Diamines (a)

	Compound	M.P., °C (b)	Molecular Formula	Anal. Calcd.	Anal.
Type A (c)					
XVI	2,2′-bis(*m*-Aminophenyl)-5,5′-bibenzothiazole	292-293	$C_{26}H_{18}N_4S$	C, 69.24 H, 4.02 N, 12.51	C, 69.29, 69.52 H, 3.82, 4.27 N, 12.53, 12.56
XVII	2,2′-bis(*p*-Aminophenyl)-5,5′-bibenzothiazole	373-374	$C_{26}H_{18}N_4S$	C, 69.24 H, 4.02 N, 12.51	C, 69.37, 68.95 H, 3.99, 3.73 N, 12.74, 12.79
Type B (c)					
XVIII	2,2′-*m*-Phenylene-bis(5-aminobenzothiazole) (d)	290-292 (e)	$C_{20}H_{14}N_4S_2$	C, 64.08 H, 3.76 N, 15.05	C, 64.12, 64.03 H, 3.85, 3.73 N, 15.06, 15.34
IXX	2,2′-bis(5-Aminobenzothiazole)-4,4′-diphenyl Ether	267-268	$C_{26}H_{18}N_4OS_2$	C, 66.87 H, 3.88 N, 12.08	C, 66.87, 67.15 H, 4.01, 4.28 N, 11.88, 11.72

(a) All of the benzothiazole diamines were yellow crystals readily soluble in dimethylacetamide. (b) (9). (c) For formula types, see Scheme I. (d) Also called (4) 5,5′-diamino-2,2′-(*m*-phenylene)dibenzothiazole. (e) Lit. (4) m.p. 270°.

TABLE III

Some Properties of Benzoxazole Diamines

Diamine	Appearance	U.V. Spectrum Max. mμ	Solubility (a)
I	yel. cryst.	334-sh. (b) 365	Sol. DMAc
II	yel. cryst.	----	V. Sol. DMAc
III	white cryst.	----	Sol. DMAc
IV	bright yel. cryst.	320-395	Sl. DMAc
V	yel. cryst.	287-362	Sol. DMAc
VI	yel. cryst.	sh. (b) 330	Sol. ethanol V. sol. DMAc
VII	yel. cryst.	323-379	Sl. DMAc
VIII	yel. cryst.	297-354	V. sol. DMAc Sol. pyridine
IX	bright yel. cryst. (orange-red upon heating)	332-395	Sl. DMAc; Sol. DMAc-HPT
X	yel. cryst.	----	Sl. DMAc
XI	yel. cryst.	----	----
XII	yel. cryst.	----	----
XIII	yel.-orange cryst.	----	----
XIV	yel. cryst.	----	----
XV	yel. cryst.	----	----

(a) V. = very; sol. = soluble; sl. = slightly; DMAc = dimethylacetamide; HPT = hexamethylphosphoric triamide. (b) Sh. = shoulder.

Synthesis of Certain Starting Materials.

In general, the starting materials were the readily available commercial products. However, a few of these were prepared according to published procedures:

4,4′-dicarboxydiphenyl ether (10)

3,3′-dihydroxybenzidine dihydrochloride (11)

3,3′-dimercaptobenzidine dihydrochloride (12).

The preparation of 2,4-diaminothiophenol dihydrochloride from 4-nitro-2-chloroaniline was based on suitable modifications in the published procedures for the synthesis of 2-amino-4-chlorothiophenol hydrochloride (13,14). Diaminoresorcinol dihydrochloride was prepared via nitration and subsequent reduction of resorcinol (15).

Preparation of Benzoxazole Diacid and Diacid Chloride.

(XX).

To a solution of 15.3 g. (0.1 mole) of 3-amino-4-hydroxybenzoic acid in 200 ml. of DMAc cooled to 0° was added 10.15 g. (0.05 mole) of terephthaloyl chloride. The reaction mixture was held at 0° for 15 minutes then allowed to warm to room temperature; after 1 hour at room temperature, the mixture was heated to 100° and held at this temperature for 1 hour, then heated at reflux temperature (165°) for 1 hour. Upon cooling the solution, 15 g. of *N,N′*-bis(2-hydroxy-5-carboxyphenyl)terephthalamide, m.p. 405-410°, separated.

The crude amide-acid, 11 g., was heated with 50 ml. of PPA to 100° and held at 100° for 30 minutes, then at 200° for 3 hours. The PPA solution was cooled and poured into water; the crude product, 2,2′-*p*-phenylene-bis(5-carboxybenzoxazole), had a m.p. of 445-450°; yield, 10.9 g.

The crude diacid, 4 g., was heated with 90 ml. of thionyl chloride for 6 hours; the crude product, 3.3 g., was filtered off after the solution was cooled. After recrystallization from 500 ml. of dry toluene, a pure diacid chloride (XX), m.p. 308-310° (rapid heating) was obtained; yield, 1.1 g.

Anal. Calcd. for $C_{22}H_{10}Cl_2N_2O_4$: N, 6.41. Found: N, 6.17, 6.21.

Preparation of Dinitrobenzoxazoles.

(XXIII-XXIV).

To a solution of 56.98 g. (0.37 mole) of 2-amino-4-nitrophenol in 300 ml. of DMAc at 0° was added 37.6 g. (0.185 mole) of isophthaloyl chloride. After 30 minutes the solution was heated to 80° and held at 80° for 2 hours. The product, *N,N′*-bis(2-hydroxy-5-nitrophenyl)isophthalamide, was precipitated into 1.2 l. of water, washed and dried; the yellow product (XXI), m.p. 309-310°, was obtained in a 76 g. yield.

The same product was also prepared via a Schotten-Baumann reaction using aqueous sodium bicarbonate solution as acid acceptor and tetrahydrofuran as solvent for the acid chloride; the terephthalamide (XXII) prepared in solution or by the Schotten-Baumann reaction did not melt up to 450°.

Compounds XXI and XXII were converted to dinitrobenzoxazoles by heating them in 200 g. of PPA at 200° for 2 hours. For example, the reaction mixture prepared from XXI (45 g.) was poured into 1.5 l. of water and the crude product washed and dried: yield, 41 g. The melting points of the 2,2′-*m*-phenylene-bis(5-nitrobenzoxazole) (XXIII) and 2,2′-*p*-phenylene-bis(5-nitrobenzoxazole) (XXIV) were 279-280°, and 358-360°, respectively.

Compound XXIII was catalytically reduced in DMAc to pure diamine V; the solubility of XXIV in DMAc was so low that reduction was not attempted.

Acknowledgment.

The authors wish to express their appreciation to Mr. M. T. Bryant for his excellent technical assistance. The aid afforded by C. W. Tate, H. E. Hinderer, L. W. Crovatt and H. C. Bach in supplying certain starting materials is gratefully acknowledged as is the encouragement given by Dr. W. B. Black.

REFERENCES

(1) Present address: UCB Lab Central, Drogenbos, Belgium.

(2) J. Preston, *J. Heterocyclic Chem.*, 2, 441 (1965).

(3) P. Petitcolas, R. Sureau, J. Frenkiel, and R. Goupil, *Bull. Soc. Chim. France*, 103 (1949).

(4) French Patent 854,156 (1940); *Chem. Abstr.*, 40, 1662 (1946).

(5) D. W. Hein, R. S. Alheim and J. J. Leavitt, *J. Am. Chem. Soc.*, 79, 427 (1957).

(6) Y. Iwakura, K. Uno, Y. Imai and M. Fukui, *Makromol. Chem.*, 77, 41 (1964).

(7) T. Kurosaki, Private Communication.

(8) T. Kurosaki and P. R. Young, Preprints of IUPAC International Symposium on Macromolecular Chemistry, Tokyo-Kyoto, V-5 (1966).

(9) All melting points (uncorrected) were taken on a Mel Temp integrated capillary melting point apparatus.

(10) British Patent 835,283 (1960).

(11) C. J. Vogt, U. S. Patent 2,497, 248 (1950).

(12) "Methoden der Organischen Chemie," Houben-Weyl, IX, 39, Georg Thieme Verlag, Sttuttgart, 1955.

(13) J. J. Blanksma, *Rec. Trav. Chim.*, 20, 131 (1901).

(14) H. P. Lankelma and A. E. Knauf, *J. Am. Chem. Soc.*, 53, 309 (1931).

(15) P. G. W. Typke, *Ber.*, 16, 552 (1883).

Received October 2, 1967 Durham, N. C. 27702