yields obtained, and simplicity of operation. The reaction proved to be unsatisfactory in the cases of several *o*-substituted phenyl thiocyanates, *e.g.*, the *o*-carboxyl-, *o*-methoxy- and *o*-nitro-derivatives; aryl thiocyanates sensitive to concentrated sulfuric acid, *e.g.*, thiocyanophenols, also gave unfavorable results. Thus, the corresponding thiocarbamates are, in these cases, best prepared by one of the older procedures.[4]

Thirty aryl thiocarbamates have been prepared by the sulfuric acid method; descriptive and analytical data for these compounds are listed in the table I. The compounds give precipitates with alcoholic silver nitrate.

Experimental

The aryl thiocyanate (2 g.) is treated slowly with shaking, and with ice cooling, with 10 cc. of 95% sulfuric acid. The mixture is allowed to stand at 0° to 5° for 15 hours, and is poured on ice. The precipitate is collected, washed with water, and dried in air, or, in some cases, in vacuum with slight warming. If a high-boiling solvent, *e.g.* phenetole, is used for recrystallization, the solution should be heated for as brief a period as possible in order to avoid decomposition of the solutes. The procedure given has been applied to quantities up to 10 g. of aryl thiocyanate, with correspondingly increased volumes of sulfuric acid.

Chem., [2] **10**, 28 (1874); M. Battegay and R. Krebs, *Compt. rend.*, **206**, 919 (1938); Badische Anilin und Soda Fabrik, A. G., German Patent 175,070; *Chem. Zentr.*, **77**, 1466 (1906).

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New Benzimidazoles from Polyhydroxy Acids[1]

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Incidental to other researches now in progress we have prepared several benzimidazoles whose descriptions may well be presented together at this time. The first of these is derived from the condensation of *o*-phenylenediamine with D-glyceric acid. Although the benzimidazole from the simplest hydroxy acid, glycolic acid, has long been known,[2] and that of the 3-desoxyglyceric, *i.e.*, lactic acid even longer,[3] a benzimidazole of a glyceric acid has not been reported previously.

In one of Griess and Harrow's classic papers[4] on the action of aromatic diamines on sugars they included the reaction between D-glucose and 3,4-diaminotoluene acetate. The product crystallized as "small white warts" and from its composition is presumed to be identical[1] with the benzimidazole that we have now obtained by the condensation of D-gluconic acid with 3,4-diaminotoluene in the presence of concentrated hydrochloric acid by the procedure of Moore and Link.[5] The melting point and specific rotation are here recorded for the first time.

Benzimidazoles derived from "L-α-rhamnohexonic" and "D-β-galaheptonic" acids are also described. The rotations of these four new benzimidazoles are in accord with the "benzimidazole rule," which states[6]: "Whenever the hydroxyl group on the second (or alpha) carbon atom of an aldonic acid is on the right in the conventional projection formula of Fischer, the rotation of the derived benzimidazole is positive and, conversely, when the hydroxyl group is on the left, the rotation of the benzimidazole is negative."

Lohmar, Dimler, Moore and Link[7] have prepared the dibenzimidazoles and the respective dihydrochlorides from galactaric (= mucic), D-glucaric (= D-saccharic) and D-mannaric (= D-mannosaccharic) acids. We have now extended this list, for purposes of characterization and identification, by adding data for the corresponding derivatives of L-threaric acid (= L(+)-tartaric acid, the ordinary dextrorotatory tartaric acid commonly present in grapes).

Experimental

2-(D-*glycero*-1,2-Dihydroxyethyl)-benzimidazole.—Two grams of calcium D-glycerate dihydrate, prepared from methyl α-D-mannopyranoside by periodate oxidation followed by bromine oxidation and subsequent hydrolysis as described by Jackson and Hudson,[8] was refluxed for 3 hours with 1.6 g. of *o*-phenylenediamine in 40 ml. of 4 *N* hydrochloric acid by heating in an oil-bath kept at 130 ± 5°. Because no crystallization occurred when the solution was made ammoniacal and concentrated, the product was isolated through its copper salt by the procedure of Moore and Link.[5] The benzimidazole thus obtained weighed 0.70 g. (28%). It was recrystallized from a mixture of 30 parts of water and 5 parts of ethanol, forming slightly tan-colored needles with m.p. 184–186° (dec.) and $[\alpha]^{20}\text{D}$ +39.6° in *N* hydrochloric acid (*c* 3.6).

Anal. Calcd. for $C_9H_{10}N_2O_2$: C, 60.66; H, 5.66; N, 15.72. Found: C, 60.78; H, 5.67; N, 15.54.

5-Methyl-2-(D-*gluco*-1,2,3,4,5-pentahydroxypentyl)-benzimidazole.—Calcium D-gluconate and 3,4-diaminotoluene dihydrochloride were condensed in the presence of a small excess of hydrochloric acid according to the general procedure of Moore and Link.[5] The product, obtained in 70% yield, was recrystallized thrice from 15 parts of water as clusters of tiny needles which united to form larger masses of "warts," as Griess and Harrow[4] had described them earlier. The benzimidazole melted at 212–214° (dec.) and showed $[\alpha]^{20}\text{D}$ +9.2° in *N* hydrochloric acid (*c* 2).

Anal. Calcd. for $C_{13}H_{18}N_2O_5$: C, 55.31; H, 6.43; N, 9.93. Found: C, 55.20; H, 6.44; N, 9.67.

2-(L-*manno*-L-*gala-hepto*-1,2,3,4,5-Pentahydroxyhexyl)-benzimidazole.—Crystalline "L-α-rhamnohexonic lactone" (=7-desoxy-L-manno-L-*gala*-heptonic lactone) was prepared by a modification of the method of Fischer and Tafel[9] for the addition of hydrogen cyanide to L-rhamnose. A mixture of 5.6 g. of the lactone and 3.3 g. of *o*-phenylenediamine was condensed in the presence of hydrochloric acid as catalyst according to the procedure of Moore and Link.[5] The isolated benzimidazole weighed 4.5 g. (54%) and was purified by 3 recrystallizations, as needles, from 70 parts of 50% ethanol. It then melted at 266–268° (dec.) and had the rotation $[\alpha]^{20}\text{D}$ −41.5° in *N* hydrochloric acid (*c* 2.5).

Anal. Calcd. for $C_{13}H_{18}N_2O_5$: C, 55.31; H, 6.43; N, 9.93. Found: C, 55.37; H, 6.34; N, 9.88.

The same benzimidazole was obtained in 70% yield by the condensation of 2.7 g. (0.009 mole) of 7-desoxy-L-manno-L-*gala*-heptonic phenylhydrazide[10] with 1.1 g. (0.01 mole) of *o*-phenylenediamine in a similar manner. The

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[1] For a review of the 2-(*aldo*-polyhydroxyalkyl)-benzimidazoles see N. K. Richtmyer, *Advances in Carbohydrate Chem.*, **6**, 175 (1951).

[2] A. Bistrzycki and G. Przeworski, *Ber.*, **45**, 3483 (1912).

[3] M. Georgescu, *ibid.*, **25**, 952 (1892); see R. J. Dimler and K. P. Link, *J. Biol. Chem.*, **143**, 557 (1942), for those of the optically active forms.

[4] P. Griess and G. Harrow, *Ber.*, **20**, 2205 (1887).

[5] S. Moore and K. P. Link, *J. Biol. Chem.*, **133**, 293 (1940).

[6] N. K. Richtmyer and C. S. Hudson, THIS JOURNAL, **64**, 1612 (1942).

[7] R. Lohmar, R. J. Dimler, S. Moore and K. P. Link, *J. Biol. Chem.*, **143**, 551 (1942).

[8] E. L. Jackson and C. S. Hudson, THIS JOURNAL, **59**, 994 (1937).

[9] E. Fischer and J. Tafel, *Ber.*, **21**, 1657 (1888); see also E. L. Jackson and C. S. Hudson, THIS JOURNAL, **56**, 2455 (1934).

[10] E. Fischer and F. Passmore, *Ber.*, **22**, 2728 (1889).

liberated phenylhydrazine was removed from the precipitated benzimidazole by washing the filtered product with alcohol and ether.

Barium D-Gala-L-*gluco*-heptonate.—Pure D-gala-L-*gluco*-heptonic phenylhydrazide remaining from an earlier research in this Laboratory[11] was decomposed by heating with aqueous copper sulfate and the liberated heptonic acid converted to its barium salt in the usual manner. Kiliani[12] mentioned that this salt is very beautifully crystalline but gave no further details. We found that it crystallizes readily from water in clusters of elongated prisms that are anhydrous when dried in the air at room temperature. Its rotation is negative, $[\alpha]^{20}\text{D}$ −4.1° in water (*c* 2), in accord with Levene's rule of rotation for the salts of aldonic acids.[13] For its additional characterization we have measured the mutarotation it undergoes when dissolved in an excess of *N* hydrochloric acid (Table I).

Anal. Calcd. for $C_{14}H_{26}BaO_{16}$: C, 28.61; H, 4.46; Ba, 23.37. Found: C, 28.56; H, 4.48; Ba, 23.18.

TABLE I

ROTATION OF BARIUM D-GALA-L-*gluco*-HEPTONATE IN *N* HCl (*c* 5)

Time, min.	$[\alpha]^{20}\text{D}$
3	− 5.0°
10	− 6.4
30	− 7.9
60	− 9.1
120	−10.0
180	−10.7
240	−11.0
300	−11.1
480	−11.2
1440 (constant)	−11.6

Final rotation, calculated as lactone, −16.3°

2-(D-*gala*-L-*gluco-hepto*-1,2,3,4,5,6-Hexahydroxyhexyl)-benzimidazole.—A solution of 5.9 g. (0.010 mole) of the barium salt just described, 2.4 g. (0.022 mole) of *o*-phenylenediamine, 8.8 ml. (0.044 mole) of 5 *N* hydrochloric acid and 10 ml. of water in a test-tube was heated at 135 ± 5° for 2.5 hours. The thick residue was dissolved in hot water, decolorized with activated carbon, and the filtered solution made alkaline with aqueous ammonia. No crystallization occurred, so the solution was concentrated to a powder and the excess *o*-phenylenediamine removed by several extractions with ether. The residue was redissolved in hot water and concentrated in a current of air, the product then separating as small, granular crystals which were filtered, washed with water, and dried at 70° to yield 3.5 g. with m.p. 185–189°. The substance was recrystallized first from water by the addition of ethanol to form long needles, and then from water alone as clusters of small, radiating needles. This benzimidazole is unusual, first, because it is hydrated and secondly, because the analyses of the samples dried to constant weight at 20° *in vacuo* indicate the presence of only three-quarters of a mole of water. It was because of the latter circumstance that we prepared the benzimidazole not only from the phenylhydrazide directly but also from the barium salt derived from a sample of carefully purified phenylhydrazide in order to minimize the possibility that we might have either a mixture or a double compound containing 75% of a monohydrated benzimidazole of D-gala-L-*gluco*-heptonic acid and 25% of the known, anhydrous benzimidazole of D-gala-L-*manno*-heptonic acid. The melting point of the hydrated benzimidazole varied with the rate of heating, a value of 198° being observed when the compound was heated slowly from room temperature. Its rotation $[\alpha]^{20}\text{D}$ −13.8° in *N* hydrochloric acid (*c* 2) is equivalent to −14.4° for the anhydrous compound.

Anal. Calcd. for $C_{13}H_{18}N_2O_6 \cdot 0.75H_2O$: C, 50.07; H, 6.31; N, 8.99; H_2O, 4.34. Found: C, 50.25, 50.36; H, 6.18, 6.32; N, 8.78, 9.11, 9.12; H_2O (100° *in vacuo*), 4.11, 4.28, 4.38.

2,2′-(L-*threo*-1,2-Dihydroxyethylene)-dibenzimidazole.—A mixture of 15 g. (0.10 mole) of L-threaric acid (the common, dextrorotatory tartaric acid), 21.6 g. (0.20 mole) of *o*-phenylenediamine and 44 ml. (0.22 mole) of 5 *N* hydrochloric acid was heated in an oil-bath at 135 ± 5° for 2.5 hours. The resulting dark blue, nearly solid mass was dissolved in 100 ml. of water and the solution made alkaline with aqueous ammonia. The original gummy precipitate became granular overnight and was then filtered and washed thoroughly with water. The air-dried, lilac-colored powder weighed 15.8 g. Two extractions with boiling ether removed only a very small amount of soluble material. Boiling methanol was then used to dissolve a large part of the remaining solid and the dark red solution was decolorized with activated carbon. Concentration of the methanol solution to 200 ml. *in vacuo* and the addition of an equal volume of water, followed by refrigeration overnight, yielded a flask full of long needles, with small clusters of compact crystals on top. When the solution was allowed to warm to room temperature the long needles dissolved and appeared to be replaced by clusters of tiny needles. After several days the product was filtered and dried; it weighed 4.0 g., and an additional smaller amount was obtained from the mother liquor. The dibenzimidazole thus prepared was recrystallized four times from methanol. The small, colorless needles began to discolor when heated to about 260°, and showed a definite melting and flowing to a red mass at about 275°; the residue solidified, and a small amount of distilled oil was observed to crystallize in the melting point tube just above the metal block used in heating the sample. The $[\alpha]^{20}\text{D}$ value was +212° in *N* hydrochloric acid (*c* 0.8).

Anal. Calcd. for $C_{16}H_{14}N_4O_2$: C, 65.29; H, 4.79; N, 19.04. Found: C, 65.48; H, 4.91; N, 19.16.

2,2′-(L-*threo*-1,2-Dihydroxyethylene)-dibenzimidazole Dihydrochloride Dihydrate.—When a solution of the dibenzimidazole in *N* hydrochloric acid was allowed to evaporate in a current of air the dihydrochloride crystallized readily as plate-like prisms; it was recrystallized from 95% ethanol by the addition of pentane. On heating, the dihydrochloride began to turn yellowish at about 200°, then gradually darkened until it melted at 270° to a red liquid with the evolution of gas.

Anal. Calcd. for $C_{16}H_{14}N_4O_2 \cdot 2HCl \cdot 2H_2O$: C, 47.65; H, 5.00; Cl, 17.58; N, 13.89; H_2O, 8.93. Found: C, 47.94; H, 5.17; Cl, 17.48; N, 14.12; H_2O (100° *in vacuo*), 9.38.

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The Reaction of 2-Aminobenzenethiol with Aldoses and with Hydroxymethylfurfural

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Benzothiazolines are readily formed when 2-aminobenzenethiol reacts with aldehydes[2] and it was therefore considered that a corresponding reaction with aldoses might also take place. We find that the reaction goes quantitatively with D-mannose, D-glucose, D-arabinose and with hydroxymethylfurfural. The formation of thiazolidine derivatives of aldoses has been reported by Schu-

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[2] H. P. Laukelma and P. X. Sharnoff, THIS JOURNAL, **53**, 2654 (1931); M. T. Bogert and B. Naiman, *ibid.*, **57**, 1529 (1935).