o-dichlorobenzene and anhydrous aluminum chloride into 3',4'-dichloro-2-benzoylbenzoic acid, and the conversion of this acid, by means of sulfuric acid, into 2,3-dichloro-anthraquinone. Upon fusion with alkali the dichloro-anthraquinone is converted into alizarin.

(2) The claim of Sprent and Dodd[1] that 2-chloro-anthraquinone is obtained by the condensation of phthalic anhydride and *o*-dichlorobenzene could not be confirmed.

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THE PREPARATION OF CRYSTALLINE *d*-TALONIC ACID

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Introduction

In 1885 Kiliani[1] prepared crystalline *d*-galactonic acid. So far as the authors are aware, this is the only crystalline hexonic acid described in the literature. Later, Nef and one of us[2] made a study of the substance and prepared some of its derivatives.

It is known that when a freshly prepared, aqueous solution of *d*-gluconic acid, or its epimer *d*-mannonic acid, is rapidly concentrated at low temperature and pressure, the resulting gum yields on trituration with absolute alcohol the so-called β-lactone of the corresponding acid.[3]

When, however, a freshly prepared solution of *d*-galactonic acid is treated in the same manner, crystalline *d*-galactonic acid is obtained.[4]

This work was undertaken to determine whether the epimer of *d*-galactonic acid, that is, *d*-talonic acid, on treatment as described above, would yield a β-lactone or an acid. Our results have shown that talonic acid solutions, similarly to solutions of galactonic acid, yield a crystalline acid on evaporation. From an examination of the space formulas of the hexose sugars it is evident that they may be classified in two series on the basis of the configuration of the groups attached to Carbon Atoms 3 and 4. One of these series, characterized by the fact that the hydroxyl groups, in the conventional representation of the sugar molecule, are found on opposite sides of the carbon atoms, may be called the glucose series. It includes also mannose, idose and gulose. The other series, characterized by hydroxyl groups on the same side of the carbon atoms, may be termed the galactose series and embraces also talose, allose and altrose. The monobasic acids corresponding to glucose and mannose-gluconic and

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[1] Kiliani, *Ber.*, **18**, 1551 (1885).

[2] (a) Nef, *Ann.*, **403**, 277 (1914). (b) Hedenburg, THIS JOURNAL, **37**, 364 (1915).

[3] Ref. 2 a, pp. 310, 323; 2 b, pp. 347, 355,

[4] Ref. 2 b, p. 364.

mannonic, as indicated above, lose water readily and have been isolated only in the form of their lactones. On the contrary, the monobasic acids, galactonic and talonic, holding water more firmly, may be obtained as such in crystalline form.

On the basis of these considerations, the possibility presents itself that the other epimeric pair of acids belonging to the galactonic series *d*-allonic and *d*-altronic acids will yield crystalline acids, while *d*-gulconic and *d*-idonic acids may be expected to yield β-lactones when freshly prepared aqueous solutions are concentrated as described. The authors hope to investigate this point later on.

Experimental Part

***d*-Galactonic Acid.**—This acid was prepared by oxidation of *d*-galactose with bromine according to the method of Kiliani[5] modified by Kay[6] for the production of gluconic acid. Kay's procedure was published after our work had been completed.

***d*-Talonic Acid.**—Talonic acid was prepared from *d*-galactonic acid by epimerization with pyridine. It was found that Fischer's method[7] for bringing about this rearrangement could be simplified somewhat, at the same time making a purer product. It was discovered that the ratio of pyridine to hexonic acid could be materially lowered and also that the reaction would take place on prolonged heating at water-bath temperature, thereby reducing to a minimum the decomposition and formation of by-products always associated with this type of reaction if conducted at the temperatures previously recommended (120–160°). It is obvious that if the process is carried on at the lower temperature the use of pressure equipment—sealed tubes or autoclaves—is unnecessary. The method as finally modified was as follows.

Eighty g. of pure *d*-galactonic lactone monohydrate, 36 g. of pyridine and 500 cc. of water were placed in a 1-liter flask which was then tightly closed with a rubber stopper wired in position. The flask was heated on a water-bath for 115 hours. The solution was then evaporated to about 100 cc. under reduced pressure. The distillate gave off a strong odor of pyridine. The undistilled solution was diluted to 1000 cc. with water, and 25 g. of cadmium carbonate was added. The resulting suspension was boiled under a hood, keeping the volume constant, until the carbonate had practically dissolved. The solution was then concentrated under reduced pressure to half its volume. By this means most of the pyridine was removed. A small amount of decolorizing carbon ("Nuchar") was added, the solution diluted to 1000 cc., boiled to dissolve all cadmium galactonate, and filtered. Fifteen g. of cadmium hydroxide was added, the solution was boiled for some time, filtered hot, evaporated to about 400 cc. and allowed to stand overnight. The crystalline precipitate of cadmium galactonate was then removed by filtration. The solution was again concentrated to about 100 cc. and allowed to stand for some hours. A small amount of cadmium galactonate was again obtained. The

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[5] Kiliani, *Ber.*, **13**, 2307 (1880).

[6] Kay, *Biochem. J.*, **20**, 322 (1926).

[7] Fischer, *Ber.*, **23**, 799 (1890); **24**, 2136 (1891).

total weight of cadmium galactonate monohydrate recovered was 68 g., corresponding to 63% of the lactone used in the experiment. On further concentration under vacuum, practically all water was removed before any solid separated from the solution. The evaporation was carried to dryness. Forty g. of solid, crude cadmium talonate was obtained. One-half g. of this material was dissolved in water, made acid with hydrochloric acid and diluted to volume. The specific rotation was approximately +11°, indicating that it contained little of the levorotatory *d*-galactonic acid. The main fraction was then dissolved in water and the cadmium removed as sulfide, using just sufficient hydrogen sulfide to precipitate the metal, as an excess makes filtration very difficult. The solution was immediately filtered and concentrated almost to dryness under reduced pressure. To accomplish the evaporation the containing flask was heated in a water-bath, the temperature of which was not allowed to go higher than 50°. Five hundred cc. of absolute alcohol was added and the solution allowed to stand in the ice box overnight. After filtering and air drying, 20 g. of crystalline talonic acid was obtained; m. p., 113°. The material was then finely ground under 94% alcohol in a mortar, filtered, and dried in a vacuum; m. p., 117°. The rotation in 4% water solution was $[\alpha] = +14.9°$. For final purification, the substance was dissolved in the least possible water at 40°, cooled and precipitated by pouring into absolute alcohol. After thus recrystallizing thrice, the rotation did not change. Pure *d*-talonic acid melts at 125°.

Anal. Calcd. for $C_{12}H_{26}O_{15}$: C, 35.1; H, 6.3. Found: C, 34.9; H, 6.0.

On titration with sodium hydroxide, in the cold, the substance behaved as a free acid containing no lactone; 0.1296 g. required 6.26 cc. of 0.1 *N* NaOH (phenolphthalein). Calcd. for $C_{12}H_{26}O_{15}$: 6.32 cc.

The analytical figures clearly indicate that the substance is a free hexonic acid crystallizing with one-half a molecule of water, corresponding in composition to the crystalline galactonic acid previously mentioned.

The acid loses water with great difficulty; 1.0668 g., in a vacuum over sulfuric acid for three days, lost only 0.0005 g.

Optical Rotation.—1.0085 g. of talonic acid was dissolved in water and diluted to 25 cc. The tube used was 2 dcm. in length. The specific rotation three minutes after solution was found to be +16.73° at 25°.

Table I

Optical Rotation Determinations

Time after solution, hrs.	Observed angle	$[\alpha]_D$
0.05	+1.35°	+16.73°
.18	+1.35°	+16.73°
.37	+1.35°	+16.73°
.53	+1.32°	+16.35°
.98	+1.29°	+15.99°
4.00	+1.19°	+14.75°
20.50	+0.46°	+ 5.70°
45.81	− .43°	− 5.33°
94.81	−1.18°	−14.61°
145.31	−1.54°	−19.09°
192.00	−1.69°	−20.95°
239.15	−1.74°	−21.57°
263.15	−1.74°	−21.57°

Subsequent observations made with the same tube at room temperature are given in Table I.

As soon as the rotation became constant, the solution was titrated in the cold with standard alkali. The results indicated that at equilibrium the solution contained 28% of free acid, and the remainder (72%) titrated as lactone. Knowing the rotation of the acid and of the equilibrium mixture as well as the percentage of acid and lactone at equilibrium, the specific rotation of the lactone was calculated; $[\alpha]_D$, —41°.

Phenylhydrazide of *d*-Talonic Acid.—The phenylhydrazide was prepared from talonic acid and phenylhydrazine and purified in the usual manner; 0.2516 g. in 10 cc. of water gave $[\alpha]_D$ = —0.64° in a 1dcm. tube; $[\alpha]_D^{25}$ = —25.43°. The compound melts at 159°. Previously recorded values for the specific rotation are as follows: Anderson,[8] —24.91°; Nef,[9] —25.1°; and Levene and Meyer,[10] +4.34°.

Our finding for the specific rotation of this substance agrees well with the value of Anderson and of Nef. Hudson[11] has remarked that the value of Nef, while agreeing with the theory in direction, is higher than would be expected for a hexonic phenylhydrazide. We believe, however, that Nef's value, which is closely checked by our own, is very near to the actual rotation.

Brucine Salt of *d*-Talonic Acid.—Levene[12] has reported that there has always existed among investigators a certain skepticism as to whether or not this compound had ever been prepared in pure condition. For this reason the authors were interested in a study of its properties. After considerable work with the salt, which is hygroscopic and very difficult if not impossible to purify, we have concluded that it is not a compound suitable for the characterization of *d*-talonic acid.

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Summary

d-Talonic acid has been prepared in crystalline form. The specific rotation of the acid has been determined as well as the rotation of the mixture of acid and lactone at equilibrium. An approximate value for the specific rotation of talonic lactone has been calculated from the data presented. The indirect measurement of the rotation of the lactone agrees with Hudson's lactone rule.[13]

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[8] Anderson, *Am. Chem. J.*, **42**, 416 (1909).

[9] Ref. 2 a, p. 281.

[10] Levene and Meyer, *J. Biol. Chem.*, **31**, 625 (1917).

[11] Hudson, THIS JOURNAL, **39**, 466 (1917).

[12] Ref. 10, p. 624.

[13] Hudson, THIS JOURNAL, **32**, 338 (1910).