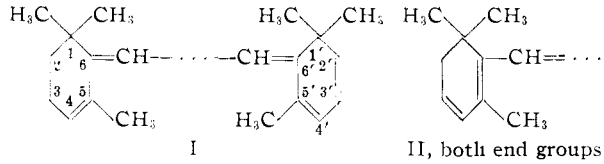
structural possibilities for it were narrowed down to a symmetrical (normal) II and a non-symmetrical (retro) formula I. Since recently, Inhoffen and Raspé[2] have obtained II, *i.e.*, 3,4,3′,4′-bisdehydro-β-carotene by total synthesis and have found it different from our "bisdehydro-β-carotene," the structure I should now be adopted for the latter.



I II, both end groups

It seems to be of some theoretical interest that, in contrast to II, compound I, now termed, retro-bisdehydro-carotene, shows the following characteristics: the retro structure increases the adsorbability; it involves extensive fine structure in the main spectral band; and upon iodine catalysis it produces a stereoisomeric mixture that shows no marked *cis* peak, although *cis* forms are preponderant in it.

Inhoffen's synthetic compound mentioned has, however, now been identified with a minor product of the dehydrogenation of either α- or β-carotene,[3] *viz.*, "dehydrocarotene III" ($E^{mol}_{1cm.}$ 12.6 × 10^4 at λ_{max} 471 mμ, in hexane). Hence, both I and II may result from a direct dehydrogenating attack on carotenes.

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(3) G. Karmakar and L. Zechmeister, THIS JOURNAL, **77**, 55 (1955).

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Synthesis[1] of L-Iduronic Acid and an Improved Production[1] of D-Glucose-6-C^{14}

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In the synthesis of D-glucose-6-C^{14} described by Sowden,[2] the main step is the introduction of the radioactive label by condensation of 1,2-*O*-isopropylidene-D-*xylo*-dialdopentofuranose with C^{14}-labeled sodium cyanide followed by the isolation of 1,2-*O*-isopropylidene-D-glucofuranuronic-6-C^{14} acid from the reaction mixture by hydrolysis of the cyanohydrins, decationization with exchange resin and extraction from the aqueous solution with ethyl acetate. We experienced some difficulty in isolating the above product in this manner and found it desirable to reinvestigate the reaction.

Preparation of 1,2-*O*-isopropylidene-D-glucofuranuronic acid is complicated by the possible impurities of the sirupy starting material, the decomposition of the products during hydrolysis, sensitivity of the isopropylidene group to acid hydrolysis, and finally by the formation of the two epimeric *O*-isopropylidene derivatives of D-glucuronic acid and L-iduronic acid as well as their lactones. We failed to crystallize 1,2-*O*-isopropylidene-D-*xylo*-dialdopentofuranose, but modified its purification. The alkaline hydrolysis of the cyanohydrins was conducted at a low temperature according to the general conditions outlined by Isbell and co-workers,[3] and the use of an ion exchange resin for generating the free acids was abandoned in favor of the method described by Mehltretter and associates[4] which is simpler and enables the extraction of the products from a more concentrated solution. 1,2-*O*-Isopropylidene-D-glucofuranuronic acid readily crystallizes from the evaporated extract, which also contains 1,2-*O*-isopropylidene-L-idurono-γ-lactone and some 1,2-*O*-isopropylidene-D-glucurono-γ-lactone; but the purification of the latter by recrystallization is a wasteful process and efficient recovery of the remaining material in the mother liquors as D-glucurono-γ-lactone-6-C^{14}, according to the method of Sowden,[2] requires isotopic dilution. To avoid this it was found possible to by-pass the isolation of 1,2-*O*-isopropylidene-D-glucofuranuronic acid by converting the mixture of the epimeric products to the corresponding lactones, which could be separated by chromatography on clay according to the general technique of Lew, Wolfrom and Goepp.[5] In this way a clear-cut separation of the two products was achieved without isotopic dilution and the resulting pure 1,2-*O*-isopropylidene-D-glucofuranurono-γ-lactone-6-C^{14} was converted readily to D-glucose-6-C^{14} by reduction with lithium aluminum hydride according to Roseman.[6]

The identity of the second product as 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone was proved by the reduction of this compound to 1,2-*O*-isopropylidene-L-idofuranose, the constants of which were in good agreement with those recorded by Meyer and Reichstein,[7] who prepared this substance by a different method. Mild acid hydrolysis of the isopropylidene group yielded crystalline L-iduronic acid. To our knowledge, this is the first recorded uronic acid in the idose series.

Isbell and co-workers[3] have shown that the proportion of the two epimeric aldonic acids formed in the cyanohydrin synthesis involving the glycosidic group depends in part on the conditions under which the reaction takes place. This is also true for the formation of D-glucuronic and L-iduronic acids, since in the presence of sodium hydrogen carbonate and excess carbon dioxide a higher proportion of the L-iduronic derivative could be isolated, while the presence of sodium carbonate in the reaction mixture reversed the proportion. However, in the latter case, the over-all yield of the epimeric products was found to be lower.

These variations readily provide an improved yield of 1,2-*O*-isopropylidene-D-glucofuranurono-γ-lactone-6-C^{14} as well as the corresponding L-idose

(1) This work was carried out under contract (DA-33-019-ord-1476; supervising agency, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland) between the Ordnance Corps and The Ohio State University Research Foundation (Project 591).

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(4) C. L. Mehltretter, B. H. Alexander, R. L. Mellies and C. E. Rist, THIS JOURNAL, **73**, 2424 (1951).

(5) B. W. Lew, M. L. Wolfrom and R. M. Goepp, Jr., *ibid.*, **68**, 1149 (1946).

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derivative which may be convertible to other interesting C^{14}-labeled compounds. Furthermore, nonradioactive 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone appears to be an interesting starting material for the synthesis of L-idose and its derivatives.

Experimental[8]

Preparation of 1,2-*O*-Isopropylidene-D-*xylo*-dialdopentofuranose.—A solution of 22 g. of 1,2-*O*-isopropylidene-D-glucofuranose and 5 g. of sodium hydrogen carbonate in 150 ml. of water was oxidized with 22 g. of sodium metaperiodate according to Sowden.[9] The reaction mixture was then filtered and the filtrate was extracted with five 300-ml. portions of chloroform. The combined extracts were dried (sodium sulfate) and evaporated under reduced pressure to a sirup which was kept for several days in a desiccator evacuated with an oil-pump to remove the traces of formaldehyde and chloroform. The resulting sirupy 1,2-*O*-isopropylidene-D-*xylo*-dialdopentofuranose (8.4 g.) furnished a semicarbazone derivative, m.p. 202–205° dec. (recorded[9] 202–202.5°).

1,2-*O*-Isopropylidene-D-glucofuranono-γ-lactone and 1,2-*O*-Isopropylidene-L-idofuranurono-γ-lactone.—A solution of 0.8 g. of sodium cyanide in 30 ml. of water was cooled to 0° and added to an equally cold solution of approximately 4 g. of 1,2-*O*-isopropylidene-D-*xylo*-dialdopentofuranose and 1.2 g. of sodium hydrogen carbonate in 40 ml. of water containing several lumps of solid carbon dioxide. After evaporation of the carbon dioxide, the mixture was kept at 0° for 2 days, then at room temperature for 3 days, and was finally heated at 60° for 5 hr. with aeration and concentration of the solution. The concentrated solution was then evaporated under diminished pressure to dryness and the residue was boiled briefly with 50 ml. of methanol, cooled, 100 ml. of diethyl ether was added, and the precipitate of the sodium salts and sodium hydrogen carbonate filtered, washed with ether and dried. The dry precipitate was dissolved in 20 ml. of water and the solution, after adjustment to *p*H 2 with 4 *N* hydrogen chloride, was extracted 10 times with 50-ml. portions of ethyl acetate. The combined extracts, after drying (sodium sulfate) and evaporation of the solvent, furnished a partly crystalline residue which was lactonized, according to the method of Sowden,[2] by heating under reflux with 40 ml. of toluene for 3 hr. The resulting clear solution was decanted from the small amount of insoluble material, cooled and gradually diluted with petroleum ether (b.p. 35–55°). The crude mixture of the lactones which separated (1.47 g.) was dissolved in 6 ml. of ethyl acetate, 1.5 ml. of petroleum ether was added, and the solution was added to a 2 (diam.) × 25 cm. column of Florex XXX[10] and Celite[11] (4:1). The column was then developed with a mixture of the same solvents (4:1) and (using a fraction collector) the effluent was collected in 5-ml. fractions and evaporated with an infrared lamp. Fractions 10–13 contained crystalline 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone, which was recrystallized from acetone–petroleum ether. Fraction 13 gave a mixture, and fractions 14–20 furnished crystalline 1,2-*O*-isopropylidene-D-glucofuranurono-γ-lactone, which was recrystallized from ethyl acetate and petroleum ether. Further amounts of products were obtained on rechromatography of the combined mother liquors and of fraction 13, followed by recrystallization as before; total yield 0.546 g. of 1,2-*O*-isopropylidene-D-glucofuranurono-γ-lactone, m.p. 120°, and 0.568 g. of 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone, m.p. 137–138°, $[\alpha]^{26}D$ +91° (*c* 1.82, acetone). Sowden,[2] in certain variations of his procedure, has found this compound contaminating 1,2-*O*-isopropylidene-D-glucofuranurono-γ-lactone and reports m.p. 128–130° and $[\alpha]_D$ +87.5° (water).

Anal. Calcd. for $C_9H_{12}O_6$: C, 50.00; H, 5.55. Found: C, 50.09; H, 5.72.

In a parallel experiment, condensation of the same amounts of sodium cyanide and 1,2-*O*-isopropylidene-D-*xylo*-dialdopentofuranose in the presence of 1.5 g. of sodium carbonate (in place of 1.2 g. of sodium hydrogen carbonate) furnished 0.204 g. of 1,2-*O*-isopropylidene-D-glucofuranurono-γ-lactone and 0.121 g. of 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone.

The above D-glucuronic acid derivative was converted to D-glucose according to the procedure of Roseman.[6]

1,2-*O*-Isopropylidene-L-idofuranose.—Reduction of 0.230 g. of 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone with lithium aluminum hydride according to the method employed by Roseman[6] for the corresponding derivative of D-glucose, furnished 1,2-*O*-isopropylidene-L-idofuranose (recrystallized from ethyl acetate); yield 0.178 g., m.p. 113–114°, $[\alpha]^{26}D$ −20° (*c* 2.7, methanol), recorded[7] m.p. 112–114° and $[\alpha]_D$ −29° (water).

L-Iduronic Acid.—A solution of 1 g. of 1,2-*O*-isopropylidene-L-idofuranurono-γ-lactone in 25 ml. of water containing 5 ml. of Amberlite IR-120-H[12] was heated over the steam-bath for 3 hr. The solution was then filtered and the filtrate was evaporated under reduced pressure. The residue was crystallized from methanol by the addition of ethyl acetate and was recrystallized in the same manner. The product, L-iduronic acid, gave a strong naphthoresorcinol test for uronic acids and its freshly prepared aqueous solution was acid to litmus; yield 0.3 g., m.p. 131–132°, $[\alpha]^{22}D$ +37° (3.5 min.) → +33° (28 min., 4 hr.) (*c* 3, water).

Anal. Calcd. for $C_6H_{10}O_7$: C, 37.11; H, 5.15. Found: C, 37.10; H, 5.38.

(8) The experiments described have been carried out with unlabeled materials but were later applied to the production of D-glucose-6-C^{14} through employment of sodium cyanide-C^{14}.

(9) K. Iwadare, *Bull. Chem. Soc. Japan*, **16**, 40 (1941); J. C. Sowden, THIS JOURNAL, **73**, 5496 (1951).

(10) Product of the Floridin Co., Warren, Pa.

(11) Product of Johns-Manville Co., New York, N. Y.

(12) Product of Rohm and Haas Co., Philadelphia, Pa.

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Purines. IV. The Infrared Spectrum of Purine and Certain Substituted Purine Derivatives[1]

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The biological importance of pyrimidine compounds has led to rather extensive studies of their infrared spectra[2] for information which might lead to their qualitative or quantitative determination or to their identification. This work has been helpful in elucidating several of the structural features of certain pyrimidine compounds and to the discovery of what may be characteristic absorption bands associated with the presence of the pyrimidine ring system.[3]

The infrared spectra of the quinazoline compounds have been studied in this Laboratory[4] and several structural problems of these compounds have been resolved.[5] It was observed in the course of this work that a group of frequencies (due to C=N and C=C structures) common to the quinazoline ring (1478–1517, 1566–1581 and 1612–1628 $cm.^{-1}$) systems did not appear in the quinazolone or quinazolinedione structures.

Recently Blout and Fields[6] have published the infrared spectral data of guanine, adenine, hypoxanthine and xanthine. All four of these purines were

(1) This work was supported in part by grants from the Division of Research Grants and Fellowships, National Institutes of Health, Public Health Service. Published with the approval of the Monographs Publication Committee, Oregon State College, as Research Paper No. 265, School of Science, Department of Chemistry.

(2) I. A. Brownlie, *J. Chem. Soc.*, 3062 (1950); C. L. Angyal and R. L. Werner, *ibid.*, 2911 (1952); H. W. Thompson, D. L. Nicholson and L. N. Short, *Faraday Soc. London*, **9**, 222 (1951).

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(5) H. Culbertson, C. Willits and B. E. Christensen, *ibid.*, **76**, 3533 (1954).

(6) E. R. Blout and M. Fields, *ibid.*, **72**, 479 (1950).