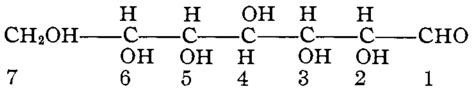
[CONTRIBUTION FROM THE NATIONAL INSTITUTE OF HEALTH, U. S. PUBLIC HEALTH SERVICE]

A Suggestion for Naming the Higher Carbon Sugars[1]

BY C. S. HUDSON

When the initial syntheses by Emil Fischer of higher carbon aldoses in the heptose, octose and nonose series were in progress it became necessary to name the new sugars by some general plan. He named them (1) according to the hexose from which they were made (D-gluco, D-manno, D-gala, etc.) and (2) according to the number of carbon atoms in the sugar chain (heptose, octose, nonose); such is the historical origin of the names D-glucoheptose, D-galaoctose, etc.[2] Since the cyanohydrin synthesis yields two D-glucoheptoses from D-glucose, it was necessary for Fischer to distinguish between them, which he did later[3] by the provisional symbols α and β, given empirically in the order of isolation. Subsequently Philippe[4] synthesized several more of the higher carbon sugars obtainable from D-glucose and found it necessary in the octose and higher series to expand the α and β naming; in consequence certain sugars today are designated D-α,α,α- and D-α,α-β-glucononose; indeed theory predicts eight as the number of aldononoses obtainable from D-glucose and by present usage they are to be distinguished by the eight possible arrangements of α and β in a three-membered term. Fischer[5] also distinguished the two forms of methyl-D-glucoside (now known to be the pyranosides[6]) by the designations α and β, assigned empirically, and today this latter use has become universal for the ring forms of the sugars and their derivatives because in a large number of cases the designations have been correlated with the stereostructures according to the plan of nomenclature that the writer proposed in 1909.[7] It can hardly be questioned that the provisional naming of higher carbon sugars by the symbols α and β and combinations of them, given empirically, should at some stage of progress be replaced by a plan that names these sugars according to their configurations. This could not be done by Fischer nor by Philippe, because only two of the configurations were then known in full (the two D-glucoheptoses). Later the configurations of the two D-mannoheptoses, the two D-galaheptoses and two of the D-mannooctoses were established by Peirce,[8] and those of the two D-guloheptoses by LaForge.[9] The discovery of several independent rules of rotation correlating direction of rotation with configuration has supplied a simple way of learning the configurations of the remaining higher carbon sugars, and these methods have been applied to D-gulomethylose[10] and to two of the D-glucooctoses[11] and D-galaoctoses[12]; thus today we know the configurations of fourteen of the higher carbon aldoses (and two of the higher carbon aldomethyloses) and possess simplified methods for determining the configurations of all the others. Would it not be well therefore to introduce some new plan for naming higher carbon sugars of known configuration by which the name of the sugar will indicate its configuration with the minimum burden upon the memory? One might give configurational definition to the terms α and β, which would be the least possible change from the present names, but this would continue the present very confusing use of these symbols in two senses in the same name, for example, α-D-α-glucoheptose. The writer has been using for about twelve years in unpublished notes a system which avoids this confusion and, as some colleagues have looked upon it with favor, it is here published.

Consider the sugar that is now known as D-α-glucoheptose.



$$\begin{array}{ccccccccccccc} & & \text{H} & & \text{H} & & \text{OH} & & \text{H} & & \text{H} & & \\ \text{CH}_2\text{OH} & — & \text{C} & — & \text{C} & — & \text{C} & — & \text{C} & — & \text{C} & — & \text{CHO} \\ & & \text{OH} & & \text{OH} & & \text{H} & & \text{OH} & & \text{OH} & & \\ 7 & & 6 & & 5 & & 4 & & 3 & & 2 & & 1 \end{array}$$

D-α-Glucoheptose (D-Gluco-D-gulo-heptose)

It is made from D-glucose and its asymmetric carbon atoms 6, 5, 4 and 3, reading from the left, have the configuration that is carried over from D-glucose. Now read the configurations of carbon atoms 2, 3, 4 and 5 from the right; they are

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[1] Publication authorized by the Surgeon General, U. S. Public Health Service.

[2] Fischer, *Ber.*, **23**, 934 (1890).

[3] Fischer, *Ann.*, **270**, 64 (1892).

[4] Philippe, *Ann. chim. phys.*, [8] **26**, 289 (1912).

[5] Fischer, *Ber.*, **28**, 1145 (1895).

[6] Charlton, Haworth and Peat, *J. Chem. Soc.*, 100 (1926).

[7] Hudson, THIS JOURNAL, **31**, 66 (1909).

[8] Peirce, *J. Biol. Chem.*, **23**, 327 (1915).

[9] LaForge, *ibid.*, **41**, 251 (1920).

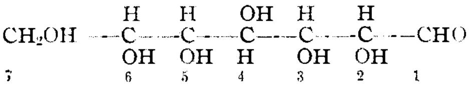
[10] Levene and Compton, *J. Biol. Chem.*, **111**, 335 (1935).

[11] Hudson, THIS JOURNAL, **39**, 463 (1917); Hockett and Hudson, *ibid.*, **60**, 622 (1938).

[12] Maclay, Hann and Hudson, *ibid.*, **60**, 1035 (1938).

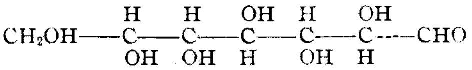
the same as in D-gulose. This is more than a formal analogy because it is known from many examples that the higher carbon sugars have properties closely resembling those of the hexoses of like configuration for carbon atoms 2, 3, 4 and 5. It is suggested therefore that the sugar be named D-gluco-D-gulo-heptose. This name defines the configuration unequivocally, indicates that the sugar is made from D-glucose and reminds one that it may be expected to resemble D-gulose in properties.[13] Although the prefix gulo- does not require the D-symbol, since the D-gluco term is not compatible with an L-gulo term in a heptose, octose or nonose, it seems preferable to retain it because of its plain expression of the fact that the heptose resembles D- rather than L-gulose. Most of the higher carbon sugars of known configuration are listed below with the designation of the proposed new name, following the system just described.

HEPTOSES



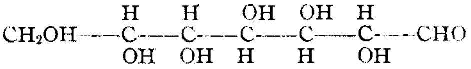
$$\underset{7}{CH_2OH}—\underset{\underset{6}{OH}}{\overset{H}{C}}—\underset{\underset{5}{OH}}{\overset{H}{C}}—\underset{\underset{4}{H}}{\overset{OH}{C}}—\underset{\underset{3}{OH}}{\overset{H}{C}}—\underset{\underset{2}{OH}}{\overset{H}{C}}—\underset{1}{CHO}$$

(D-α-Glucoheptose)
D-Gluco-D-gulo-heptose



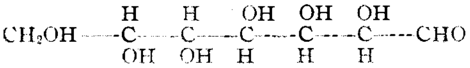
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

(D-β-Glucoheptose)
D-Gluco-D-ido-heptose



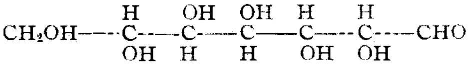
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—CHO$$

(D-α-Mannoheptose)
D-Manno-D-gala-heptose



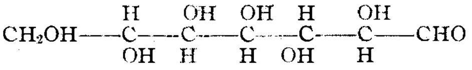
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

(D-β-Mannoheptose)
D-Manno-D-talo-heptose



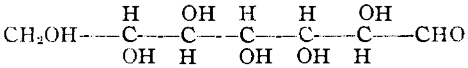
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—CHO$$

(D-α-Galaheptose)
D-Gala-L-manno-heptose



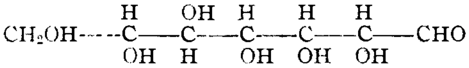
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

(D-β-Galaheptose)
D-Gala-L-gluco-heptose



$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

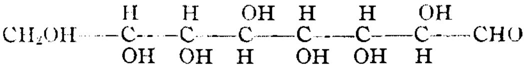
(D-α-Guloheptose)
D-Gulo-L-gala-heptose[14]



$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—CHO$$

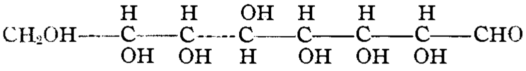
(D-β-Guloheptose)[14]
D-Gulo-L-talo-heptose

OCTOSES



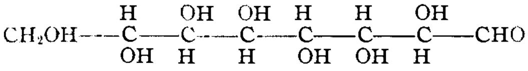
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

(D-α,α-Glucooctose)
D-Gluco-L-gala-octose



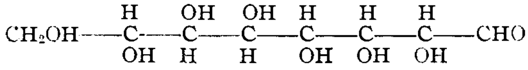
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—CHO$$

(D-α,β-Glucooctose)
D-Gluco-L-talo-octose



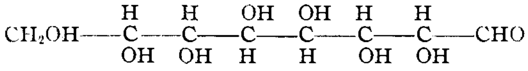
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

(D-α,α-Galaoctose)
D-Gala-L-gala-octose



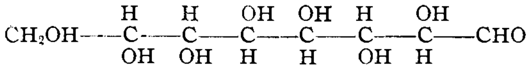
$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—CHO$$

(D-α,β-Galaoctose)
D-Gala-L-talo-octose



$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—CHO$$

(D-α,α-Mannooctose)[15]
D-Manno-L-manno-octose



$$CH_2OH—\underset{OH}{\overset{H}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—\underset{H}{\overset{OH}{C}}—\underset{OH}{\overset{H}{C}}—\underset{H}{\overset{OH}{C}}—CHO$$

(D-α,β-Mannooctose)
D-Manno-L-gluco-octose

The names of derivatives are readily formed in the usual way, for example: D-gala-L-gala-octitol, octopyranoside, octonic and octaric acids, octal, octosazone, etc.

In Fischer's era rhamnose and fucose were designated substituted pentoses (substitution of methyl for a hydrogen atom directly attached to

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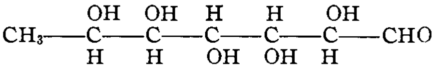
(13) I considered years ago the name D-glycero-D-gulo-heptose as an alternative for D-gluco-D-gulo-heptose, but discarded it in favor of the name that specifically indicates the hexose from which the higher carbon sugar is prepared.

(14) The D-guloheptoses were named by their discoverer (LaForge[9]) α and β as here written; LaForge proved their configurations by showing that D-α-guloheptitol is identical with D-β-galaheptitol. Isbell [*J. Research Nat. Bur. Standards*, **19**, 639 (1937)] recently has proposed reversal of the symbols in a plan which gives configurational definition to α and β; the disadvantage of this plan already has been mentioned.

(15) This configuration follows from the observation by George Peirce[8] that the sodium salt of D-manno-L-manno-octaric acid is optically inactive, but obviously it needs substantiation. The corresponding D-manno-L-manno-octitol was crystallized by Fischer and Passmore [*Ber.*, **23**, 2226 (1890)] but there is no mention of a rotatory measurement; the substance is probably inactive in accordance with the above provisional configuration of the sugar. We expect to be able to present data soon that will permit decision regarding the formula.

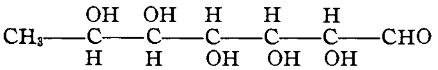
the carbon atom of the terminal group CH_2OH), a usage which persists in the class name methylpentose; the practice is now becoming general to consider them as 6-desoxyhexoses, under the class name methylose,[16] with an appropriate prefix to designate the configuration. Thus natural rhamnose is L-mannomethylose and natural fucose is L-galamethylose (or L-galactomethylose, if one chooses to use the full prefix). By combining this plan of nomenclature with that which is suggested in this article, the two 7-desoxyheptoses whose configuration is known may be given the following systematic names.

METHYLO-HEPTOSES[17] (OR 7-DESOXYHEPTOSES)



$$CH_3-\overset{OH}{\underset{H}{C}}-\overset{OH}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-CHO$$

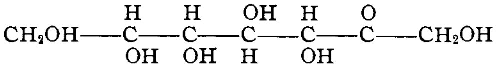
(α-L-Rhamnohexose of Fischer)
L-Manno-L-gala-methylo-heptose



$$CH_3-\overset{OH}{\underset{H}{C}}-\overset{OH}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-CHO$$

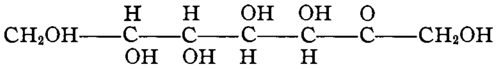
(β-L-Rhamnohexose of Fischer)
L-Manno-L-talo-methylo-heptose

The 2-ketoheptoses need to carry the name of the appropriate hexose only; the five known ketoheptoses are the following



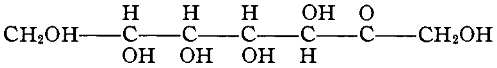
$$CH_2OH-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-\overset{O}{C}-CH_2OH$$

D-Glucoheptulose[18]
(Its mirror image is L-Glucoheptulose)[19]



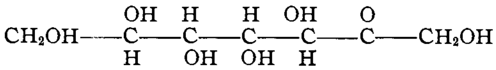
$$CH_2OH-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-\overset{OH}{\underset{H}{C}}-\overset{O}{C}-CH_2OH$$

D-Mannoheptulose
(Originally named D-Mannoketoheptose)[20]



$$CH_2OH-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-\overset{O}{C}-CH_2OH$$

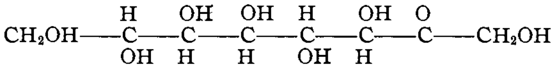
D-Altroheptulose[21]
(Originally named Sedoheptose)[22]



$$CH_2OH-\overset{OH}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-\overset{O}{C}-CH_2OH$$

L-Galaheptulose[23]
(Originally named Perseulose)[24]

Beginning with the 2-keto-octoses, of which none are now known, prefixes of two hexoses would be required, leading for example to the unequivocal name D-gala-L-gluco-octulose for a ketose of the configuration



$$CH_2OH-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-\overset{OH}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-\overset{OH}{\underset{H}{C}}-\overset{O}{C}-CH_2OH$$

In designating the α- and β-forms of ring derivatives (*e. g.*, the methyl glycosides) it seems to the writer advisable to follow the simplest rule that is adequate, which is to name the more dextrorotatory member of a pair in the D-sugar series as α (or, in full, α-D-); its enantiomorph is an α-L-form, which represents the more levorotatory member of a pair in the L-sugar series. I made this suggestion in 1909 and it has been generally adopted, but there recently has come from Isbell[25] the proposal to modify it and to reverse the α-β- naming in the arabinose and fructose series, and in a recent article Schlubach and Graefe[26] question the naming of a certain new methyl sorboside as an α-L-form because it closely resembles in certain peculiarities a β-D-methylfructoside. The recent experimental work of Jackson and Hudson[27] in correlating the configurations of carbon atom 1 in many of the aldohexopyranosides, aldopentopyranosides and an aldopentofuranoside furnishes proof of stereostructures which confirm in all cases the nomenclature that I originally proposed. The system of naming α- and β-methyl glycosides, etc., is best understood if one writes the skeleton stereostructures for the rings. The pyranoid forms are derived from the structures (I) and (II), as proved by Jackson and Hudson.

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(16) Votoček, *Bull. soc. chim.*, **43**, 18 (1928).

(17) The order methylo-heptose seems preferable to hepto-methylose because, as pointed out in an analogous case by Freudenberg and Raschig [*Ber.*, **62**, 376 (1929)], hepto-methylosazone is an ambiguous name since it can apply to either the phenylosazone of a hepto-methylose or the methyl phenylosazone of a heptose; methylo-heptosazone is not ambiguous. To overcome the objection raised by Freudenberg and Raschig in the case of the name altro-methylose, it may be well to use altro-methylohexose instead. Rhamnose would then be L-manno-methylohexose and its osazone would be L-manno-methylo-hexosazone. The ambiguity could also be avoided by naming osazones with two words (*e. g.*, altromethylose osazone), as is in fact often done, especially with osazones from substituted phenylhydrazines.

(18) Austin, THIS JOURNAL, **52**, 2106 (1930).

(19) Bertrand and Nitzberg, *Compt. rend.*, **186**, 925, 1172 (1928).

(20) LaForge, *J. Biol. Chem.*, **28**, 511 (1917).

(21) Ettel, *Collection Czechoslov. Chem. Communications*, **4**, 504, 513 (1932).

(22) LaForge and Hudson, *J. Biol. Chem.*, **30**, 61 (1917).

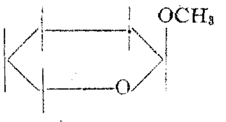
(23) This configuration for perseulose was made highly probable by LaForge;[20] definitive proof has been established recently by Raymond M. Hann and the writer and it will be published shortly.

(24) Bertrand, *Compt. rend.*, **147**, 201 (1908); **149**, 225 (1909).

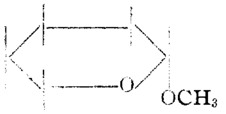
(25) Isbell, *J. Chem. Ed.*, **12**, 96 (1935); *J. Research Nat. Bur. Standards*, **18**, 505 (1937). Isbell appears to have considered only the pyranoid ring forms; if his plan were adopted it would require that in aldohexoses having *cis-trans* configuration for the hydroxyl groups on carbon atoms 4 and 5 (galactose, talose, gulose and idose) a pyranoside would be named α in the D series if it is the more dextrorotatory member of a pair, but a furanoside that is the more dextrorotatory member of its pair would have to be named a β-D-form, which seems objectionable; with septanosides and with tetrofuranosides it is not clear how one would name them by Isbell's plan. I warn against the confusion that must ultimately result if Isbell's modification of my simple, generally applicable rule is followed.

(26) Schlubach and Graefe, *Ann.*, **532**, 211 (1937).

(27) Jackson and Hudson, THIS JOURNAL, **59**, 994 (1937).

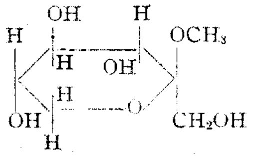


(I) α-D- β-L- } Methyl glycosides (C$_1$ is dextrorotatory)

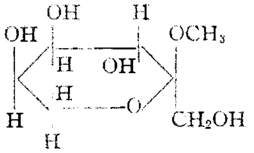


(II) β-D- α-L- } Methyl glycosides (C$_1$ is levorotatory)

These skeleton structures permit one to write the stereo pyranoid formulas for any given case from the name of the substance; formula (I) pertains to α-D- and β-L-forms, where C$_1$ is dextrorotatory, and formula (II) to β-D- and α-L-forms, where C$_1$ is levorotatory. Thus the formulas for the methyl pyranosides of L-sorbose and D-fructose that were discussed by Schlubach and Graefe[26] take the forms (III) and (IV)

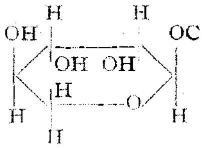


(III) β-Methyl-L-sorbopyranoside

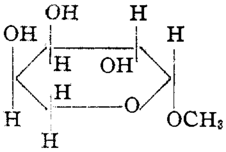


(IV) α-Methyl-D-fructopyranoside

and their close stereo similarity is apparent; their only difference is in respect to the configuration of their carbon atom 5, and it is to be concluded that their common peculiar behavior is independent of the stereo form of this particular carbon atom. The following is an interesting case in this connection. In acid methyl alcoholic solution D-lyxose finally reaches equilibrium when its α-methyl pyranoside is the predominating substance; under like conditions D-arabinose forms its β-methyl pyranoside principally; the stereo formulas (V) and (VI) show that the stereo form of carbon atom 3 for these substances has a great influence upon the stability of the grouping on carbon atom 1. The same influence from carbon atom 3 is noticed in the configurations of the more stable forms of the acetohalogen sugars and the fully acetylated forms, of ring configuration.

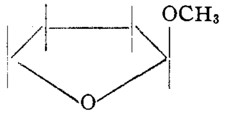


(V) α-Methyl-D-lyxopyranoside

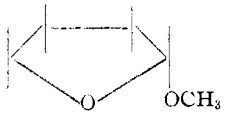


(VI) β-Methyl-D-arabinopyranoside

The skeleton formulas for the furanoid ring are (VII) and (VIII), as proved by Jackson and Hudson.

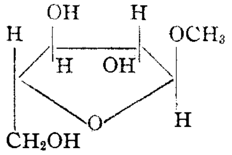


(VII) α-D- β-L- } Methyl glycosides (C$_1$ is dextrorotatory)

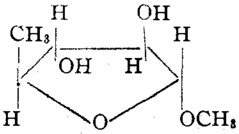


(VIII) β-D- α-L- } Methyl glycosides (C$_1$ is levorotatory)

The known[28] α-methyl-D-arabinofuranoside is written as (IX) and the known[29] α-methyl-D-arabinomethylopentoside as (X); it is seen that closely approach mirror-image forms, which accounts for their opposite signs and near magnitudes of rotation.



(IX) α-Methyl-D-arabinofuranoside ([α]$_D$ + 123)



(X) α-Methyl-L-arabinomethylopentoside ([α]$_D$ −129)

Lastly, the skeleton formulas for the septanoid ring glycosides, etc., obviously are to be written in similar conventional form; detailed examples may be omitted.

[28] Montgomery and Hudson, THIS JOURNAL, **59**, 992 (1937).

[29] Swan and Evans, *ibid.*, **57**, 200 (1935).

Summary

It is proposed to abandon the use of the symbols α and β as parts of the actual names of the higher carbon sugars and to designate these by the abbreviated names of two hexoses, one of which indicates the hexose that is used in the synthesis and the other of which shows the hexose that the new sugar resembles in its ring configurations. Examples are shown for the proposed names and for the use of the symbols α and β in designating the stereostructures of the pyranoid, furanoid and septanoid ring forms.

WASHINGTON, D. C.

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[CONTRIBUTION NO. 239, DEPARTMENT OF CHEMISTRY, KANSAS STATE COLLEGE]

The Reaction of Kojic Acid with Aldehydes[1,2]

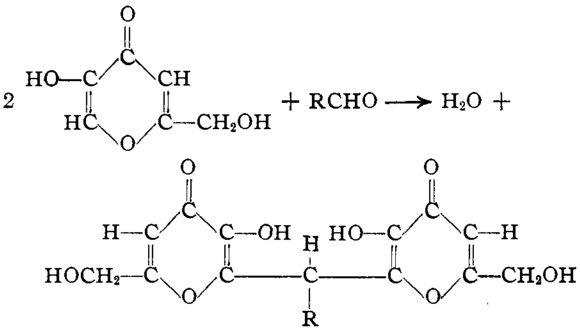
BY H. N. BARHAM AND G. NATHAN REED

Kojic acid, 2-hydroxymethyl-5-hydroxy-γ-pyrone, was first obtained by Saito[3] in a culture of *Aspergillus oryzae* grown upon steamed rice. Since then it has been found to be produced when different species of *Aspergilli* are grown upon a variety of organic substances.[4] The acid used in this research was produced in the laboratories of Kansas State College by the growth of *Aspergillus flavus* upon a glucose medium.

While investigating the properties of kojic acid it was observed that a solid reaction product was obtained readily with formaldehyde. This reaction was extended to other aldehydes until a series of solid derivatives was obtained which included derivatives from all of the normal, saturated, aliphatic aldehydes up to heptaldehyde, as well as acrolein, benzaldehyde, hydrocinnamaldehyde, cinnamaldehyde, and α-furfuraldehyde.

An investigation of these derivatives was made in order to establish their constitution. The molar quantities involved in their preparation, together with other quantitative data, indicated that the products were formed by the elimination of one molecule of water from two molecules of kojic acid and one molecule of aldehyde. The aldehyde products gave red colorations with ferric chloride, could be titrated with standard alkali and formed insoluble copper salts which contained the calculated per cent. of copper. Upon treating with thionyl chloride, chloro compounds were formed which could be produced also by the reaction of the corresponding aldehydes with 2-chloromethyl-5-hydroxy-γ-pyrone (obtained from kojic acid with thionyl chloride). Acetate esters were prepared and when hydrolyzed gave acetyl values corresponding to four hydroxyl groups per molecule. Attempts to hydrolyze the aldehyde products with dilute acid or alkali were unsuccessful. When the aldehyde products were treated with phenyldiazonium chloride and the resulting mixture neutralized with alkali, colored compounds were produced which appeared to be unstable diazonium salts of the phenolic hydroxyls. Under similar conditions, kojic acid coupled with phenyldiazonium chloride to form a stable dye.

It was concluded, therefore, that these aldehyde products were formed according to the equation



Experimental Data

Reagents.—The crude kojic acid obtained by concentrating the fermentation liquor was recrystallized twice from water, using Norite in the first recrystallization to decolorize the solution. The final purification was accomplished by chilling hot alcoholic solutions with rapid stirring. Prepared in this manner, the acid was obtained as fine, light cream-colored needles of m. p. 152–153°.

The formaldehyde used was a U. S. P. formalin solution. The other aldehydes were Eastman preparations.

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[1] Abstract of a thesis presented by G. Nathan Reed to the Graduate Council of Kansas State College in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] Presented in part before the Division of Organic Chemistry of the American Chemical Society at the Rochester meeting, September, 1937.

[3] K. Saito, *Bot. Mag. Tokyo*, **21**, No. 249 (1907).

[4] A critical review of the literature upon kojic acid was made by Barham and Smits, *Trans. Kansas Acad. Sci.*, **37**, 91–113 (1934).