ASSOCIATION OF POLYHYDROXY COMPOUNDS WITH CATIONS IN SOLUTION

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Paper ionophoresis has provided evidence for the existence, in dilute aqueous solution, of complexes of neutral polyhydroxy compounds with cations of the alkali and alkaline earth metals. The compounds were submitted to precision ionophoresis in supporting electrolytes containing metal acetate, under the conditions stated in Table 1. Many showed definite, reproducible movement towards the cathode, and some typical results are tabulated.

cis-Inositol was outstanding in showing measurable movement in solutions of all metal acetates tested, and migrated rapidly in Ca^{++}, Sr^{++} and Ba^{++} even when the concentration was much reduced; e.g. its relative migrations in 0.1, 0.05 and 0.025-M strontium acetate were 82, 61 and 45, respectively. Movement of the other compounds showed a nearly linear dependance on concentration of metal ion. epi- And allo-inositol and cis-quercitol also showed considerable movement

Table 1

Relative Migrations of Polyhydroxy Compounds in the Presence of Metallic Ions

Compound	Ba^{++}	Mg^{++}	Na^{+}	K^{+}
cis-Inositol	82	20	10	6
epi-Inositol	25	2	3	3
L-Iditol	13	1	1	1
Allitol	5	1	1	1
D-Talose	18	0	2	2

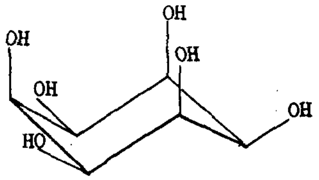
Cationic movements are given as percentages of the anionic movement (about 10 cm.) of nitrobenzene-p-sulphonic acid (Frahn and Mills, 1959) on the same strip, with 2,3,6-tri-O-methyl-D-glucose as marker for zero migration. The electrolyte was a 0.1-M solution of metal acetate in 0.2-M aqueous acetic acid. Ionophoresis was performed for 1 hr. at a potential gradient of about 20 V/cm. on Whatman no. 4 paper under a uniform pressure of 0.4 atm., cooled by tap-water. Compounds were applied as 0.1-M aqueous solutions.

in these three electrolytes; other cyclitols were less reactive. Most reducing sugars showed only slight or zero movement in all electrolytes, but D-talose and D-ribose migrated in Ca^{++}, Sr^{++} and Ba^{++}. Alditols showed only slight movement in sodium acetate; in Ca^{++}, Sr^{++} and Ba^{++} their migration was moderate, being greater for isomers with the larger numbers of αT-diol groups (defined by Barker and Bourne, 1952). The general trend was for much greater movement in the presence of Ca^{++}, Sr^{++} or Ba^{++} than in solutions of other metals; for the others, the order of decreasing effectiveness was Mg^{++}, Na^{+}, K^{+}, Li^{+}, NH_4^{+}. No compound migrated in tetramethylammonium acetate. The method cannot be satisfactorily applied to solutions of heavy metals that are adsorbed by cellulose.

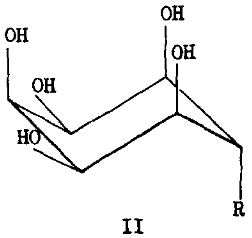
Several carbohydrates are known to form crystalline addition compounds with sodium and calcium salts, but there has been no clear evidence that simple, neutral polyhydroxy compounds can remain associated with the ions of the metals in dilute solution. The present results may be interpreted as a partial, reversible combination of hydroxy compound with metal ion in solution, probably effected by several hydroxyl groups replacing water molecules in the hydration sphere of the ion.

The degree of association will be determined by the configuration of the hydroxy compound and the ionic radius and preferred co-ordination geometry of the metal. For _cis_-inositol in the presence of Ca^{++}, Sr^{++} or Ba^{++}, the equilibrium evidently lies far in favour of the complex. The outstanding complexing power of _cis_-inositol is probably due to the presence of three axial hydroxyl groups in its two equivalent stable conformations (I) (Angyal and McHugh, 1957), which are suitably placed for simultaneous close approach to a cation. _epi_-Inositol (II; R = OH) and _cis_-quercitol (II; R = H) also have this configuration of groups in less favoured conformations. Alternative arrangements of three hydroxyl groups that are close enough together to be associated with a cation can be discerned in the other compounds showing cationic migration. Several hydroxyl groups are closely adjacent in the β-pyranose form (III) of D-talose.

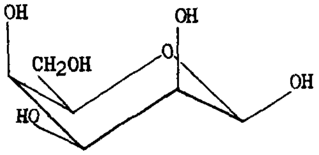
Sodium and potassium ions combine far more weakly with hydroxy compounds, even _cis_-inositol, than do the divalent ions, but to a degree that could be



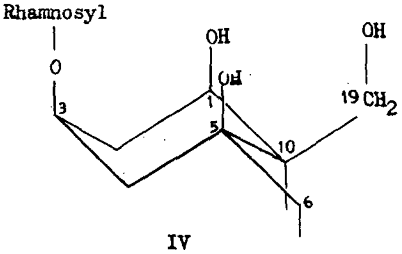
I



II



III



IV

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biologically significant. Since a more closely ordered arrangement of groups is possible for cell membranes and other organised systems than for simple molecules free in solution, the selectivity for these metals observed in active transport (reviewed by Christensen, 1960, and by Kruhøffer, 1961) could be effected by precise steric control of a few simple complexing sites. Ouabain, which is physiologically very active and selectively influences the transport of sodium and potassium, has a conformation (partial structure IV) in which the three hydroxyl groups at positions 1, 5 and 19 have the same spatial separation as the axial groups in cis-inositol (Tschesche and Snatzke, 1955).

A number of cyclitols and alditols gave evidence for weak complexes with sulphate ion when run in tetramethylammonium sulphate. No complexes could be detected with nitrate or perchlorate ions. Frahn and Mills (1959) found that the migration of alditols (as anions) in sodium hydroxide varied widely for stereoisomers, but here the movement may have been due to true ionisation, rather than to complexing with hydroxyl ions; the mobility tended to decrease as the number of αT-diol groups increased. In non-aqueous media, complexing of polyhydroxy compounds with alkali-metal hydroxides and acetates is a fairly general phenomenon (Rendleman and Hodge, 1961).

Selective complexing of polyhydroxy compounds with salts of metals occurs in column and paper chromatography. The order of increasing adsorption of various carbohydrates on the barium salt of Dowex 50 resin (Jones and Wall, 1960) roughly agrees with the order of mobilities in barium acetate. The strong retention of D-talose is noteworthy. We have found that the presence of barium salts markedly changes the R_F values of complex-forming carbohydrates in paper chromatography. On untreated Whatman no. 1 paper, the R_F values of D-glucose, D-talose, D-ribose and cis-inositol in acetone-water (4:1 by vol.) were 0.29, 0.47, 0.50 and 0.12, respectively; on paper dipped in 0.2-M barium chloride and dried before use, the values were 0.24, 0.23, 0.28, 0.04; similar pretreatment with 0.2-M barium acetate gave the values 0.16, 0.13, 0.20, 0.02.

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