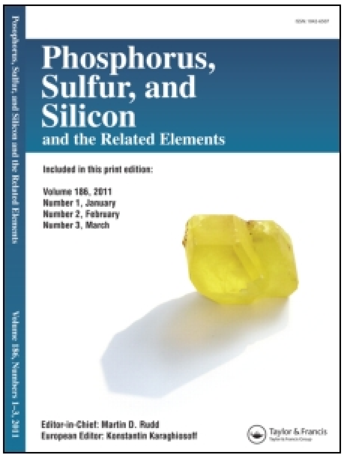

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REACTION OF CARBOHYDRATES AND PENTACOORDINATE OXAPHOSPHORANE AND THEIR BIOMIMETIC MECHANISM

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The reaction of D-hexoses, D-pentose and organic pentacoordinate 1, 3, 2-dioxaphospholene were investigated. The observation showed that there were obvious differences of reaction ratio, intermediate, and final products in the reactions between hexoses and pentose *via* pentacoordinate phosphorus compound. The results should give significant clue to the metabolic mechanism of carbohydrate phosphate in nature.

Keywords: Carbohydrate; phosphorylation; pentacoordinate phosphorus intermediate; biomimetic mechanism

Glycosyl phosphates are of considerable interest as intermediates for the synthesis of nucleotides, which in turn are substrates for glycosyl transferases and participate in the synthesis of oligosaccharides in glycoproteins and glycolipids. For the investigation on glycogen phosphorylase, many synthesises of glycosyl phosphonates have been reported[1–5].

However, there is no such report in the phosphorus chemistry to explain why only pentose D-ribose is used as the central block in nucleic acids and in ATP as the energy carrier, but not the hexose D-glucose [6–8]. Although, there are very rich source of D-glucose and they were served as the cell wall structural components and energy storage. Therefore, it is necessary to investigate the possible reaction mechanism of saccharide and phosphorylation.

The pentacoordinate phosphorus intermediate was proposed to participate in biological process [6, 8–10]. In order to obtain confirmative informa-

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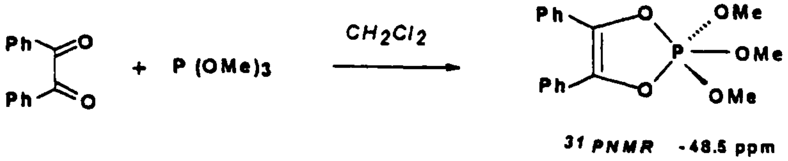
tion about the reaction mechanism of carbohydrate, we investigated the phosphorylation reaction of carbohydrates by directly ester exchange reaction of pentacoordinate phosphorus compounds and try to search for some clue to the mechanism of glycosyl phosphate in life chemistry.

RESULT AND DISCUSSION

In order to understand the chemistry of the carbohydrate phosphorylation, the reactions of different monosaccharides with 2, 2, 2 – trimethoxy – 4, 5-diphenyl – 2, 2- dihydro – 1, 3, 2 – dioxaphospholene [Scheme I and named P (5)] were studied by using ^{31}P NMR technique.

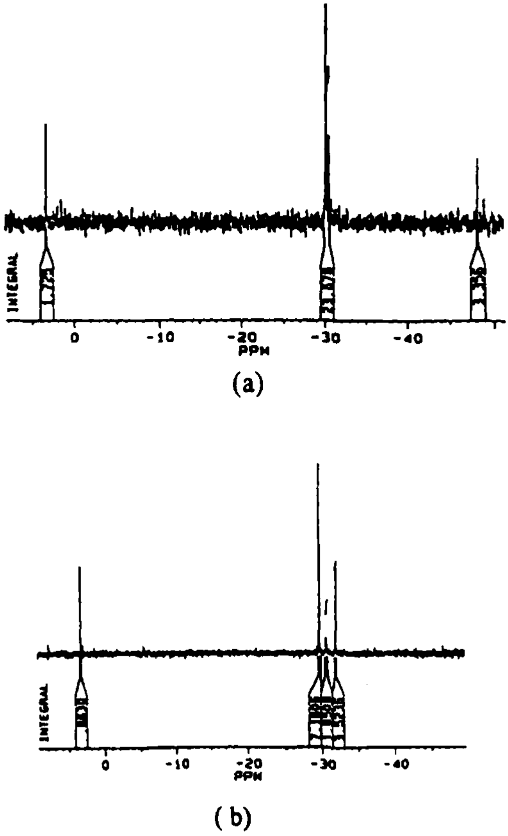


SCHEME I The synthesis reaction and ^{31}PNMR of P (5)

The reactions of D-ribose and D-hexoses and P (5) were investigated by tracing the ^{31}P NMR spectra, the results shown that there were two different types of intermediate in the processing of reaction and several different types of products were finally confirmed by FAB mass spectra and ^{31}P NMR spectra[11].

Different reaction rate in different glycose with P (5)

D-Glucose, D-mannose, and D-ribose, as models for hexose and pentose respectively, were reacted with P (5). The proceeding of reaction could be monitored by the integral area of signal of P (5) in the ^{31}PNMR spectra. The results showed that D-hexose and D-pentose exhibited a different reaction rate with P (5). The reaction of D-ribose was about six times faster than that of D-glucose, D-mannose, and the reaction rate constants were $k_{Glu} = 1.3 \times 10^{-4}$ / mol.sec, $k_{Man} = 1.0 \times 10^{-4}$ / mol.sec, and $k_{Rib} = 6.2 \times 10^{-4}$ / mol.sec, respectively. The ^{31}PNMR spectra in the reactions of D-glucose and D-mannose with P (5) were showed in Fig. 1. The different ^{31}P NMR chemical shifts were due to the C-2 hydroxy configuration of glucose and mannose in (a) and (b).



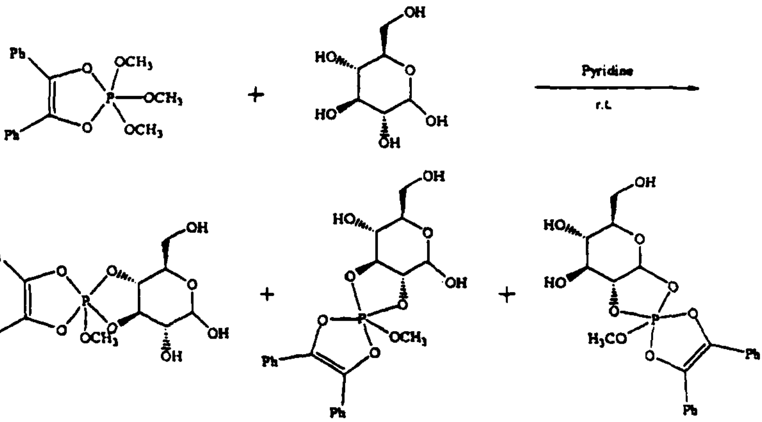
(a)

(b)

FIGURE 1 ^{31}PNMR spectra of D-glucose(a, 4hrs) and D-mannose (b, 6hrs) reacted with P (5)

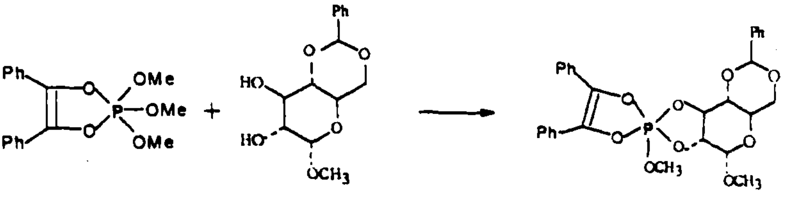
Different intermediates in the reactions of glycoses with P (5)

Generally, the reaction of carbohydrate with P (5) might first go through a pentacoordinate phosphorus compound to give a spiro-oxyphosphorane (Scheme II, multipeak signals appeared at δ: −29.0 ~ − 31.5 ppm in the ^{31}PNMR due to the mixtures of pentacoordinate oxyphosphorane of glucose, see Scheme II, and all of them gave the same molecular ion M^+ at m/z = 450 in the FAB-MS)[11-12]. The reaction products of D-mannose and D-ribose and P (5) were also determined in the same way.



SCHEME II The products of ester exchange reaction of D-Glucose and P (5)

The protected D-glucoside reacted with P (5) was used to further confirmed the above result (Scheme III). The signal at $\delta = -31.5$ ppm in the ^{31}PNMR belonged to the only pentacoordinate spiro-oxyphosphorane product, and the structure was determined on the basis of EI mass spectrum (M^+ m/z: 552 and the other characteristic fragment ions).



SCHEME III The reaction of protected D-glucoside with P (5)

When the reactions were kept for over two hours, the D-glucose, D-mannose and D-ribose showed that there were very different intermediates by trapping with ^{31}PNMR (the modals were showed in Fig. 2).

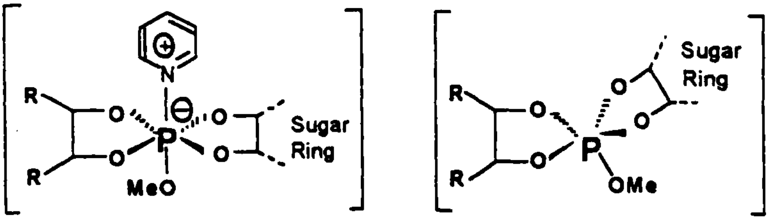


FIGURE 2 Hexacoordinate phosphorus intermediate of D-ribose and pentacoordinate phosphorus intermediate of reaction of glycose with P (5)

In the reaction of D-ribose, except pentacoordinate phosphorus intermediate (δ about – 24.0 ppm in the ^{31}PNMR) like in the reaction of D-hexoses, the hexacoordinate spiro-oxaphosphorane intermediate also appeared the signal at δ – 91.0 ppm in the ^{31}PNMR (Fig 3) [12] and the signal disappeared in four hours.

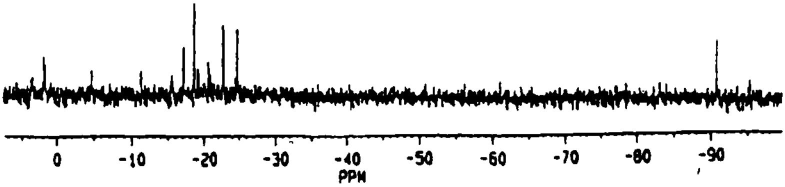


FIGURE 3 The ^{31}PNMR spectrum of the reaction of D-ribose and P (5) in 2 hours

Different kind products in the reaction of hexoses and pentose with P (5)

Finally, the D-hexoses usually gave only monophosphate of glycose. The ^{31}PNMR spectrum of final glucose product was shown in Fig. 4. The FAB-MS gave M^+ at m/z 468. The quasi-molecular weight was given at m/z 467.1107 ($C_{21}H_{24}O_{10}P$, calculated: 467.1127) in the high-resolution negative ion FAB-MS. Meanwhile, the formed disaccharides were also obtained in the reaction [13].

On the contrary, the product of D-ribose gave pyrophosphate of ribose (Fig. 5, the signals at δ – 0 ppm and – 9.10 ppm in the ^{31}PNMR and M^+ at m/z 310 in FAB-MS for the pyrophosphate) in addition to the monophos-

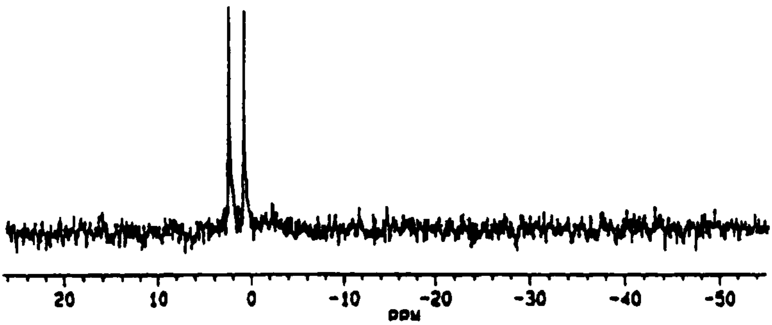


FIGURE 4 The final product ^{31}PNMR spectrum of the reaction of glucose and P (5)

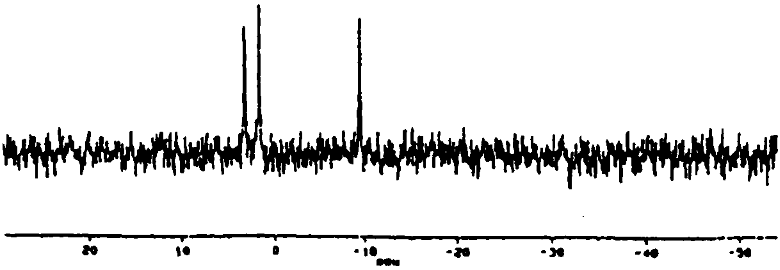


FIGURE 5 The final product ^{31}PNMR spectrum of the reaction of ribose and P (5)

phate (psedomolecular ion $[M+H]^+$ at m/z 439 in positive ion FAB-mass spectrum due to linking a methyl and a benzoin group in the phosphate). The possible structures were shown in Scheme IV.

Monophosphate of D-glucose and D-ribose

Pyrophosphate of D-ribose

SCHEME IV The final products of saccharide phosphate

The phenomena might reflect the difference between D-hexoses and D-ribose metabolism *via* phosphate in nature. The further studies are in progress.

CONCLUSION

The investigation results indicated that there were two different types of intermediates exhibited in the reactions of D-ribose and D-hexoses with P (5) and resulted in different kinds of products. Therefore, the differentiation of D-hexoses and D-ribose in nature might be due to the pentacoordinate phosphorus participation. It should give some significant clue that phosphorus plays an important role in life chemistry.

EXPERIMENTAL

^{31}PNMR were recorded on a Bruker ACP-200 200MHz NMR spectrometer. Chemical shifts of ^{31}PNMR are referenced to external 85% H_3PO_4. Positive and negative ions FAB-MS data were obtained on a KYKY Zhp-5 double focusing mass spectrometer from the Scientific Instrument Factory, Beijing, China and glycerol as the matrix.

General Methods

Under the protecting of dried N_2 gas, 0.1 mmol D-ribose, D-glucose, D-mannose and 0.1 mmol 2, 2, 2 – trimethoxy – 4, 5 – diphenyl – 2, 2 – dihydro – 1, 3, 2 – dioxaphospholene [P (5)] were respectively put into NMR tube with 0.5 ml pyridine, and then by using ^{31}PNMR technique traced the procedure of the reaction at different time. When the sign at δ –30 ppm appeared, the products were sent for FAB-MS. After the reaction products were kept one week in room temperature, their ^{31}PNMR spectra were recorded. The solvent (pyridine) was removed under reduced pressure and then the residues were analyzed by the FAB-MS for determining the final products.

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