COMPLEX DI-HYDRATE CALCIUM PHOSPHATE - GLUTARALDEHYDE: FORMULATION MECHANISM

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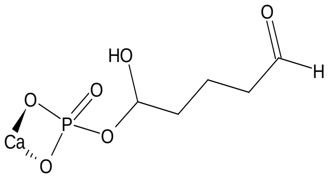
Abstract

The di-hydrate calcium phosphate $CaHPO_4$, H_2O (DCPD) reacts with glutaraldehyde $OCH – (CH_2)_3 – CHO$ (GL) in an aqueous solution to give the complex $OCH – (CH_2)_3 – CH(OH) – O – PO_3Ca$ (DCPD-GL). In the solution, the complex appears in the form of hydrates (enolic stabilized by intramolecular isomery d, e, f and as the corresponding carboxylic acid g). In the solid state it is the enolic form wich dominates (cis and trans).



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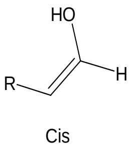

Cis

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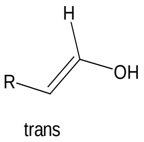

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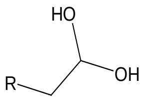

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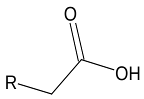

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Keywords: Complex di-hydrate calcium phosphate, Glutaraldehyde, Mechanism

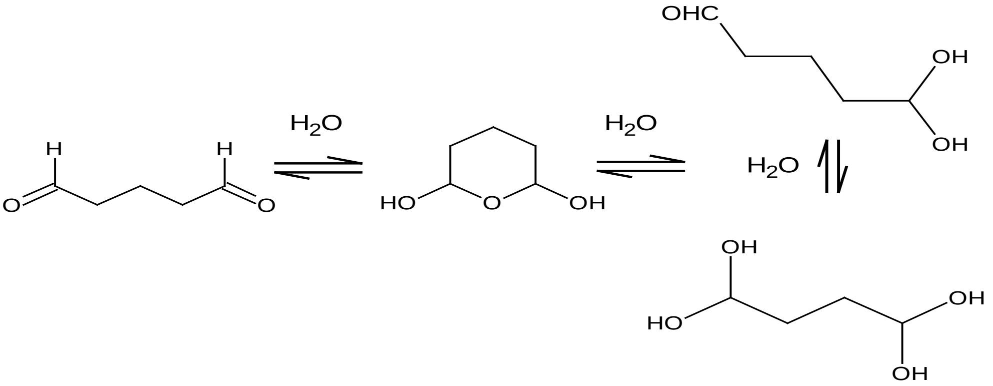
Introduction

The 1.5-dipentanal is a compound of great importance in cytochemistry, immunochemistry, microscopy, RX, as a fixer of protein, glycogen and phospholipid (Hopwood D, 1972 ; Sabatini D D et al 1963 ; Rechards F M et al 1968 ; Hopwood D., 1967). The glutaraldehyde reacts with the calcium phosphate to give the complex DCPD – Gl (Schéma 1) (Bouzid M et al 2013) with good yield.

$$\underset{\text{DCPD}}{CaHPO_4, 2H_2O} + \underset{\text{GL}}{OHC - (CH_2)_3 - CHO} \longrightarrow \underset{\text{Complexe DCPD - GL}}{OHC - (CH_2)_3 - CH(OH) - O - PO_3Ca}$$

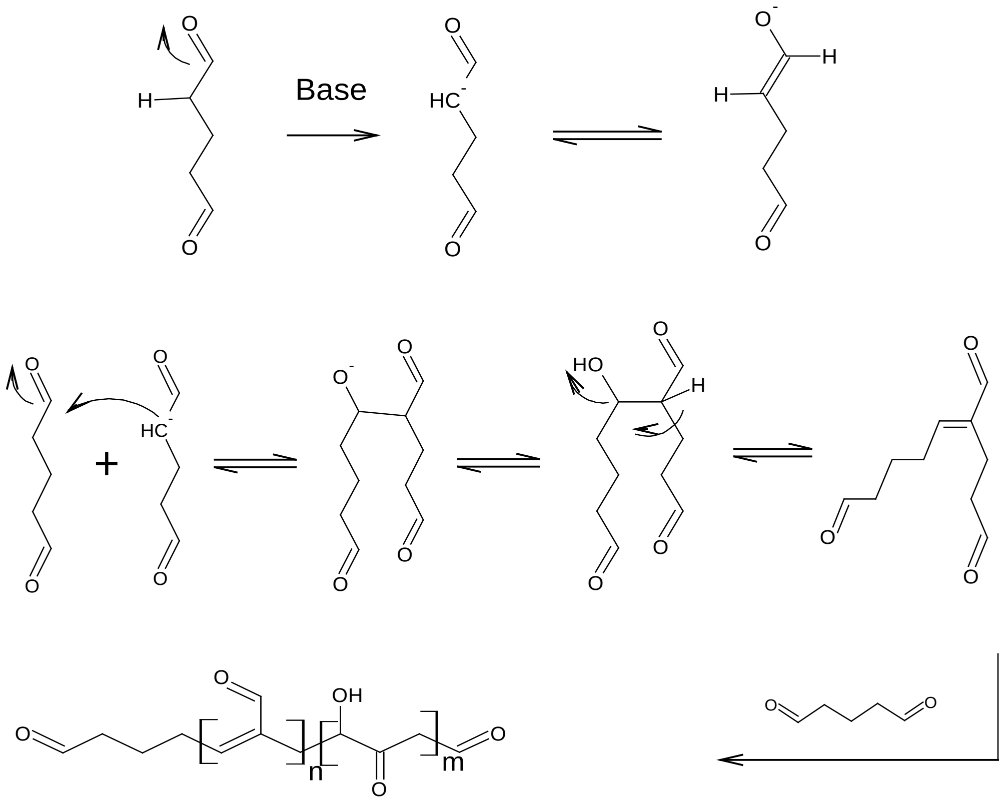
Schema 1: Complexation reaction DCPD-GL

The spectral study of 1,5-dipentanal in solution should enable to elucidate the behavior of the molecule in an aqueous solution in order to suggest the mechanism of this reaction. The literature does not solve the problem. The 1,5-pentanal behaves in an acidic medium as an equilibrium with linear and cyclic hydrates (P. M. Hardy et al., 1969) (schema 2).



Schema 2: GL in acidic aqueous solution (P. M. Hardy et al., 1969)

In a basic medium, the literature (N. R. Kildeeva et al., 2009) reports the condensation of the aldehyde according to schema 3.



Schema 3: Mechanism of the aldol condensation reaction in a basic medium (N. R. Kildeeva et al., 2009)

Based on a spectral literature magazine, we propose a mechanistic configuration of the reaction (schema 4).

Materials and methods

Absorption spectroscopy Ultra-Violet Visible

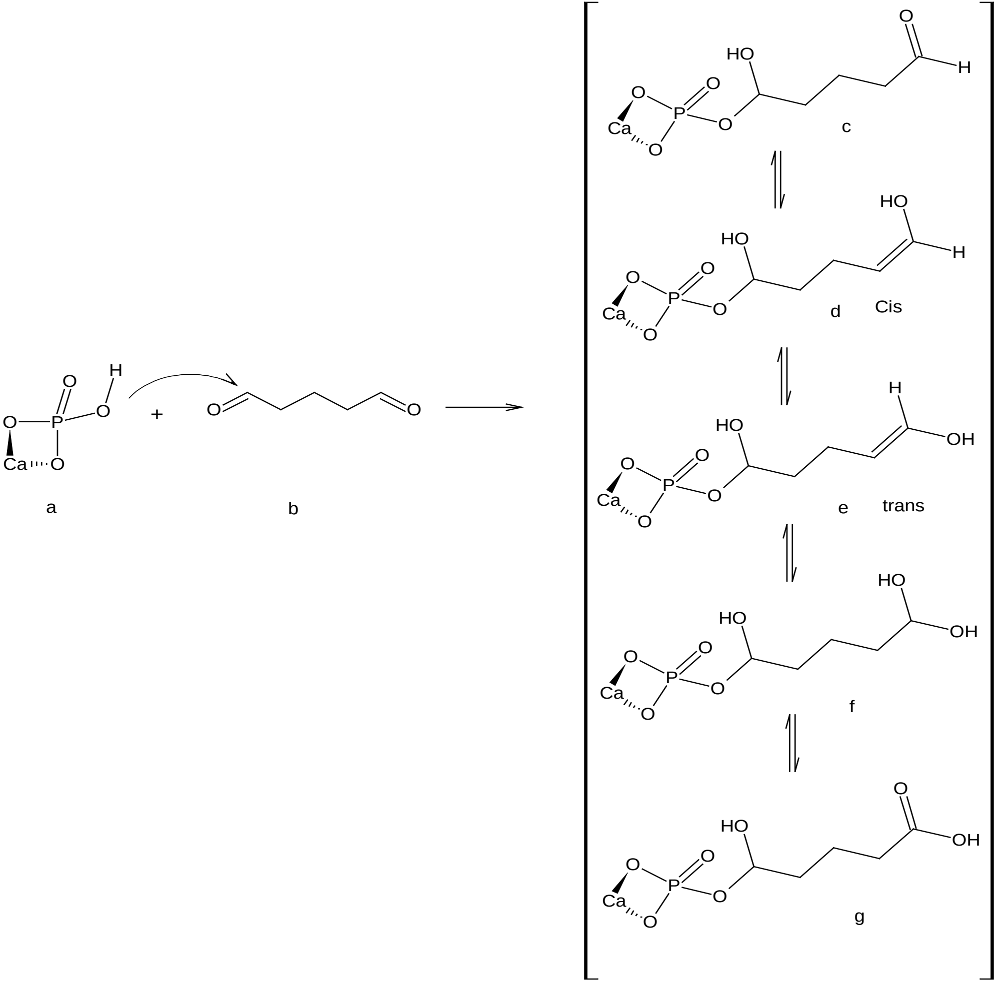
The UV-visible analysis is performed with a spectrophotometer (Lambda EZ210). The scanning between 190 and 1100 nm of infinitely dilute solutions used to determine the absorption band of the products.

Infrared Absorption Spectroscopy

The infrared absorption spectrophotometry is carried out using a spectrometer Nicolet Type 5700 series on pellets formed of 1 mg of product dispersed in 300 mg of KBr.

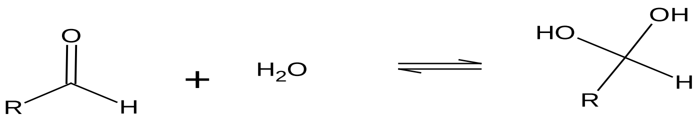
Results and discussion

The di-hydrate calcium phosphate reacts with glutaraldehyde in an aqueous solution to give the complex DCPD-GL with a good yield. The brick-red compound is stable under normal conditions of temperature and pressure (M. Bouzid et al., 2013) (schema 4).



Schema 4: Reaction of DCPD with GL

Studies conducted by Hardy et al (P. M. Hardy et al., 1969) and confirmed by (E.B. Whipple et al., 1974), (P. Monsan et al., 1975) based on NMR study, UV-Visible consider that the unsaturated forms other than dialdehydes present only a minor constituent. They attribute the spectra obtained to the presence of linear and cyclic hydrates in solution. The UV-Visible spectrum of glutaraldehyde reveals two responses at 235 nm and 285 nm (Figure 1). The intense band at 235 nm corresponds to the residue of GL with a polymeric nature and double bonds designated by (S.Margel 1980), the poly-glutaraldehyde (PGL). The band at 285 nm corresponds to the monomer GL. It has been noted that the peak at 235 nm varies according to pH (Maximum at 12.3) (S.Margel 1980). These data are in contrast with the batochrome effect. The absorbance at 285 nm is due to aldehyde groups, the concentration of which should decrease during the aldol condensation reaction. However, the experience shows that this is not the case. The peak at 285 nm increases during the polymerization. This situation can be explained by the displacement of equilibrium between hydrated and non-hydrated forms of GL (Schema 5). On the basis of UV-Visible spectral studies, the author considers the equilibrium of the reaction as a cause of spectral changes.



Schema 5: Balance aldehyde – hydrate

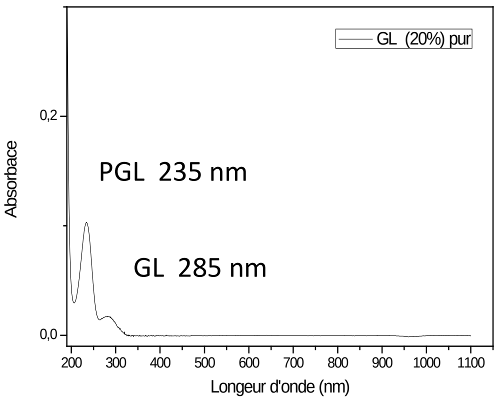


Figure 1: UV-Visible spectrum of GL (2%)

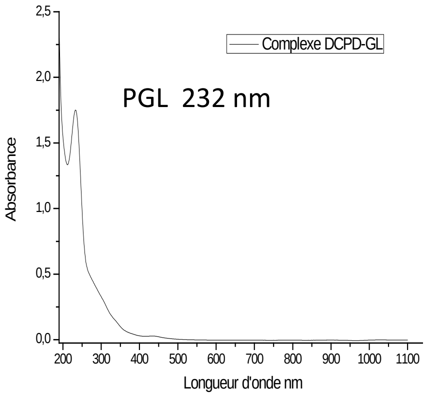
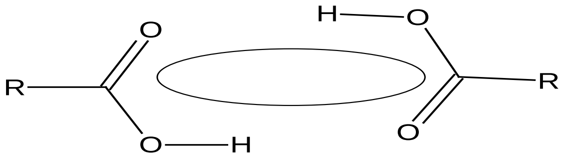


Figure 2: UV-Visible spectrum of DCPD - GL (2%)

Kawahara et al., 1992, resume the study of the structure of 1,5-dipentanal in solution by UV - Visible. They conclude that the GL solution contains up to 70% of polymer entities with semi cyclic acetal structures. The dilution of the solution converts 100% of the polymer into monomer with pH between 3 and 8. The DCPD- GL complex shows a peak at 232 nm, it shows also the peak displacement initially at 285 nm to the low absorbance as a shoulder. It is to be noted that the complexation reaction can be easily followed by UV - Visible. Moreover, the glutaric acid (232 nm) was quoted as a by-product of glutaraldehyde in an aqueous solution (S Margel et al., 1980 ; TAPAS MITRA et al., 2014). H. T.Flakus et al 1999, show the difficulty in interpreting the Infrared spectra. Apparently the phenomenon is governed by the binding (- OH) and the different bridges which may give in solution according to operating conditions (- O - H ... O = C -.). M A Benmalti et al., 2009 report the theoretical study on υ plug (O - H) of the glutaric acid and the cyclic dimer centroid generated system. The study by infrared boils down to the result of the behavior driven by the system (- O - H ... O = C -.) in liquid phase (Figure 3). In the solid phase, the movement of molecules allows only the most stable configurations (Figure 4) with much more explicit spectra.



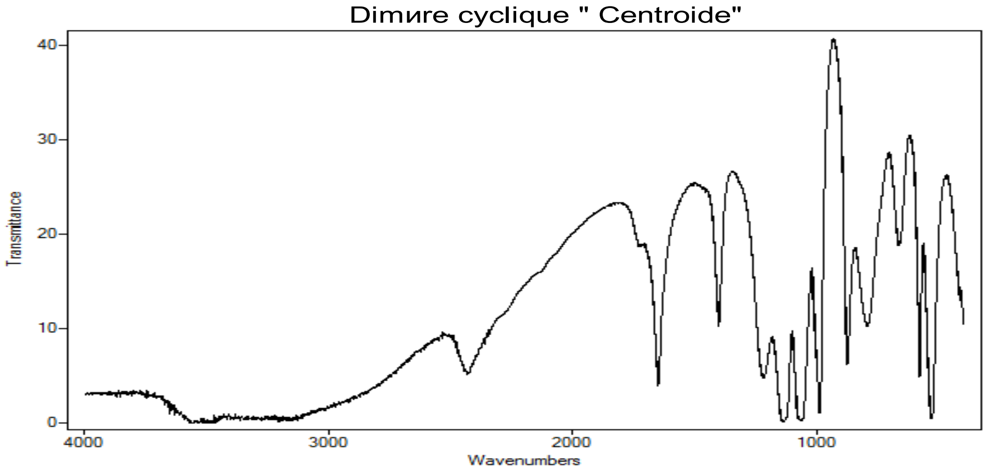


Figure 3: FTIR spectrum DCPD - GL solution H_2O

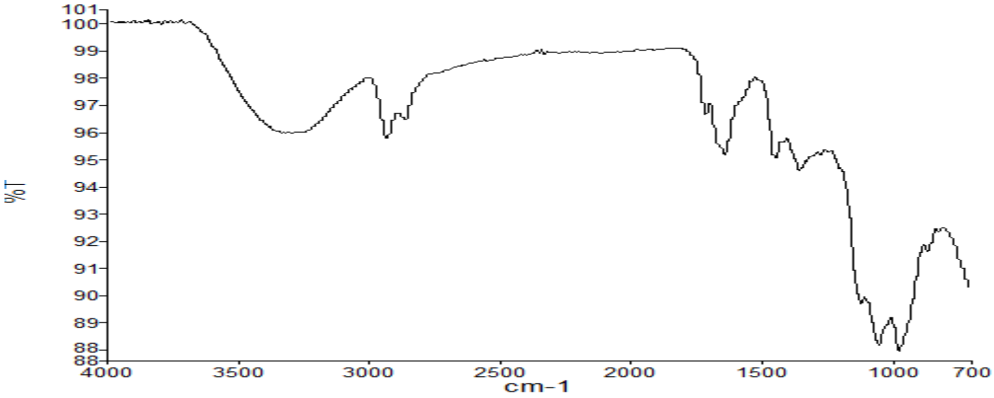


Figure 4: Specter of DCPD IRTF - GL crystal

In the solid phase, the stretching vibration of (- OH) appears near 3400 cm^{-1}. This value is a characteristic of (- OH) stabilized by the environment (RV.J. Mulley et al., 1970 ; JW. Xu et al., 1999), compared to 3600 cm^{-1}: case of free (- OH) (A. Kirmann Monographie). The aliphatic part (- (CH 2) 3 -) offers strong anti-symmetric vibrations at 2920 cm^{-1} and symmetric at 2850 cm^{-1}. The massif between 2850 and 2950 cm^{-1} is a characteristic of the aliphatic chain. In solution, there is a wide shoulder that begins around 2700 cm^{-1} and reaches the vibration group of H_2O around 3500 cm $^{-1}$ and 3600 cm^{-1}. However it should be noted that in this area of 2800 cm^{-1} to 2900 cm^{-1}, there are lower additional bands, active in infrared. This corresponds to harmonic bands or combination of modes of internal deformation of methylenes. It should be noted as well that intramolecular vibrations, (O - H ... O = P) of chilates forms, and / or enol) of groups (OH) in their molecular configuration, exist (Buzon J. et al, 1970 A.. El Hamidi et al., 2012). What is also to be noted is the existence of several equilibrium positions of the hydrogen atom in the system (- O - H ... O = C -.). Several authors agree (Ref A. Kirmann Monographie) to say that at this level, the potential energy curves can then have different unidentical minima. The same authors, interpret the absorption massif between 2700 cm^{-1} and 3500 cm^{-1} as a characteristic of the cyclic dimer of carboxylic acid. In general, in the solid and liquid states, the carboxylic acids do not have the stretching vibration band of the group free (- OH), because of hydrogen bonds established between the (- OH) and the (CO). In our study, it appears clearly on the IR spectra (Figure 4) that the DCPD-GL complex in the solid state, has an alcohol function. The (CHO) function appears mainly in an enolic form. The band at 1400 cm^{-1} characteristic of the double bond (C = C) confirms the proposed mechanism reported in the literature in the case of conjugated aldehyde functions (J. Buzon et al., 1970 ; A. El Hamidi et al 2012). Contrary to the solid state, the band (C = C) splits, which suggests the enol configuration with a mixture of cis and trans.

Conclusion

In solution, DCPD - GL complex can appear in the enol form (cis and trans) and in the carboxylic acid form with the structures of dimer type. In the solid state, the enol form dominates (cis and trans).

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