

# The Dicalcium Phosphate Dihydrate Fixator and Stabilizer of Glutaraldehyde

Bouزيد Mohammed<sup>1</sup>, Djadi Amina<sup>2</sup> and Guechtoulli Samira<sup>2</sup>

1. *Research Unit: Materials, Processes and Environment, University M'Hamed Bougara, Frantz Fanon City, Boumerdes 35000, Algeria*

2. *Department of Research and Development, Health Technology of Algeria, Tipaza 42000, Algeria*

Received: March 27, 2013 / Accepted: May 02, 2013 / Published: September 25, 2013.

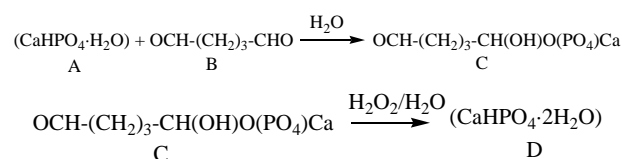
**Abstract:** The dicalcium phosphate dihydrate (A) reacts with glutaraldehyde (B) in aqueous solution with a yield of 95%. The resulting product (C) is chemically stable. The obtained purity is checked by UV-Visible and the structure is discussed on the basis of the Infrared absorption FTIR. The reaction mechanism is explained by the approach of the hydroxyl group (-OH) of one of the aldehyde functions (-CO) of 1.5 dipentanal with the enolic form, which stabilizes the product (C). The reversible reaction is performed by mild oxidation of the compound (C) in aqueous medium at ambient temperature. The compound (A) is generated with high efficiency. The comparative spectral and thermography study confirms this result.

**Key words:** Dicalcium phosphate dihydrate, glutaraldehyde, oxidation, thermography.

## 1. Introduction

The Glutaraldehyde is a product used in the field of cold disinfection of surfaces and medical surgical instrumentation in large quantities [1-3]. In the light of studies on the bactericidal properties, the Glutaraldehyde destroys vegetative forms of bacterial species (lacking waxy wall) in at least five minutes and *Microbacterium tuberculosis* in ten minutes [3, 4]. Other important applications are stressed in various textile, paper, photography, tanning industries... [5, 6]. The physicochemical properties of the glutaraldehyde (volatility, miscibility, reactivity, etc.) [7, 8] show that it is harmful both to the health and the environment [9-13]. The risk of pollution is increased by the risk of explosion or fire [14]. Faced with such a dilemma (Production/pollution), the dicalcium phosphate dihydrate ( $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$ ) offers an easy way to stabilize the molecule by chemical fixation of

glutaraldehyde  $\text{OCH}(\text{CH}_2)_3\text{CHO}$ . In fact, the role of fixator/stabilizer  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$  compound (A) is based on the approach of the hydroxyl group (-OH) of one of the aldehyde functions -CHO of  $\text{CH}_2\text{-CH}_2\text{-OCH-CH}_2\text{-CHO}$  (B) in solution, with a yield of 98. The resulting product of this connection is stable, the product (C). In addition, the mild oxidation with  $\text{H}_2\text{O}_2/\text{H}_2\text{O}$  of the compound (C) regenerates the compound (A) with an excellent yield (99%).

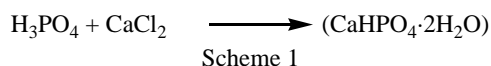


## 2. Materials and Methods

The dicalcium phosphate dihydrated  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$  compound (A) is obtained by double decomposition of phosphoric acid  $\text{H}_3\text{PO}_4$  (Merck) and the salt of calcium chloride  $\text{CaCl}_2$  (Merck) in aqueous solution. After filtration, washing with distilled water followed by drying under hot air [15].

---

**Corresponding author:** Bouزيد Mohammed, doctor research fields: physical chemistry of bioproducts. E-mail: technosante@hotmail.fr.



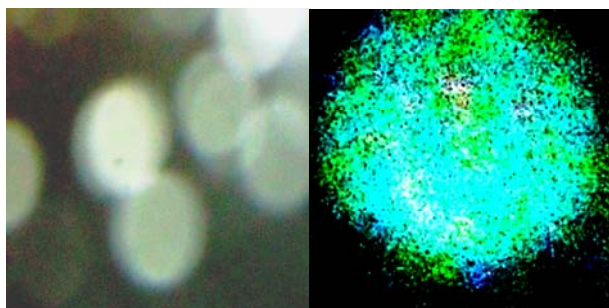
**Scheme 1** Synthesis reaction of the product A.

The  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$  (A) appears in the form of white powder of spherical particles of 8 mm diameter (Fig. 1), on average with a variable porosity (Fig. 2).

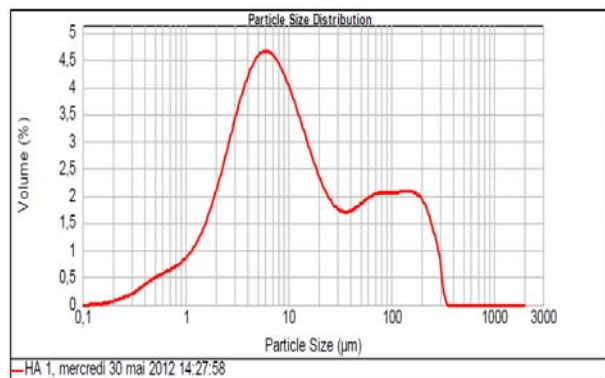
The purity of the compound (A) is verified by UV-Visible (Fig. 3), the structural characterization is based on analysis by FTIR and confirmed by thermogravimetric study.

The fixation/stabilization reaction of the glutaraldehyde solution 20% (Anios, France) controlled by UV-Visible (Fig. 4). In a flask containing 250 ml of one mole of  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$  was added 50 ml of  $\text{OCH}(\text{CH}_2)_3\text{CHO}$  (B) in aqueous solution under magnetic stirring. The reaction takes place at ambient temperature. The purity of the product (C) of red brick color is controlled by UV-Visible (Fig. 5), the yield of this reaction is 98%.

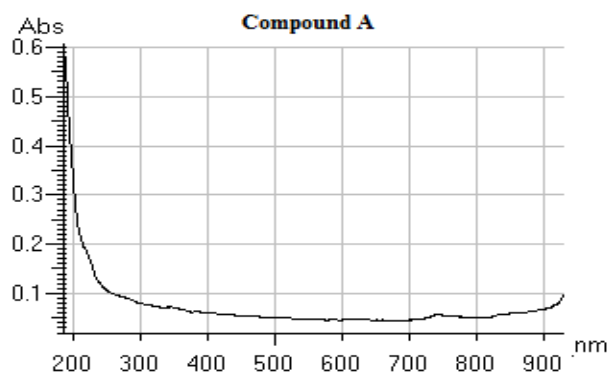
The reaction of  $\text{H}_2\text{O}_2/\text{H}_2\text{O}$  with the compound (C) under the same conditions allows to regenerate the compound (D) with an excellent performance (99%).



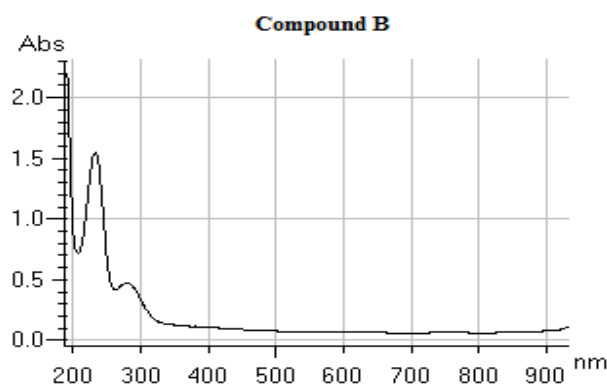
**Fig. 1** Microscope observation compound A.



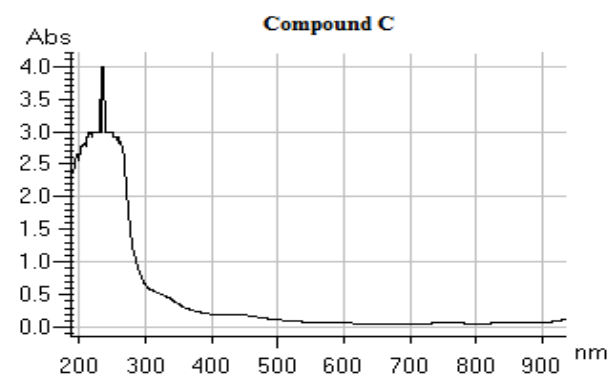
**Fig. 2** Laser granulometry laser spectrum of compound A.



**Fig. 3** UV-Visible spectrum compound A.



**Fig. 4** UV-Visible spectrum compound B.



**Fig. 5** UV-Visible spectrum compound C.

The result is verified by UV-Visible spectral methods (Fig. 6) and infrared (Fig. 9). The confirmation is cemented by thermogravimetric study of the regenerated compound (D)  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$  (Fig. 8).

**Laser Granulometry:** The apparatus used for particle size measurement is a type MALVERN MATERSIZER 2000 with the Scirocco as an accessory of dry dispersion.

**Infrared absorption spectroscopy:** The infrared absorption spectrophotometry: Nicolet 5700 series

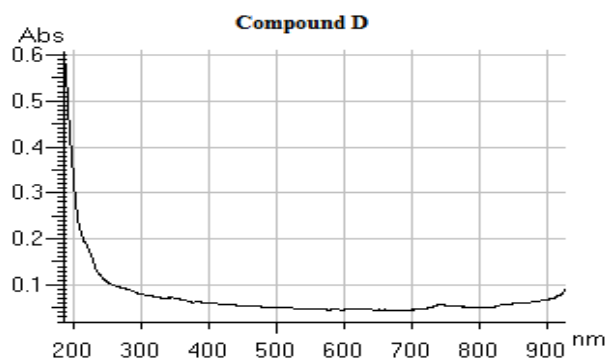


Fig. 6 UV-Visible spectrum compound D.

spectrometer on pellets consisting of 1 mg of product dispersed in 300 mg of KBr. Analyses performed in reflection have been with the same spectrometer team ATR module (for “Attenuated Total Reflection”). In this case, the sample is deposited directly on the crystal.

Ultra violet (visible Absorption Spectroscopy):  
Instrument: Model: Lambda EZ210 Spectrophotometer. ROM Version: 2550 02. Instrument Parameters, Measurement Type: Wavelength Scan, Data Mode: Abs, Starting Wavelength: 1,100.0 nm, Ending Wavelength: 190.0 nm, Scan Speed: 1,200 nm/min, Sampling Interval: 1.0 nm, Slit Width: 2 nm, Lamp Change: 340.0 nm, Baseline Correction: System, Response: Fast, Path Length: 10.0 mm, Peak Integration, Method: Rectangular, Sensitivity: 1 Threshold: 0.0100.

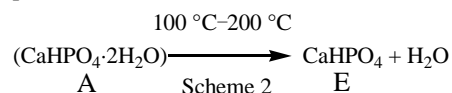
Thermogravimetry: To study the thermal properties, samples of about 10 mg were measured using Seiko SSC 5200 thermoanalyzer (model 220 TG/DTA) with heating rates of 10-50 ° C/min. flow rate of 100 ml/min.

### 3. Results and Discussion

There are two forms of dicalcium phosphate dihydrate with a ratio Ca/P = 1: [15]. Dicalcium phosphate dihydrate (DCPD or brushite) formula  $\text{CaHPO}_4 \cdot \text{H}_2\text{O}$  and its anhydrous salt of formula  $\text{CaHPO}_4$ . The thermal behavior of the product (E) regenerated by mild oxidation with hydrogen peroxide solution (10%) confirms the  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$ . Indeed,

the decomposition curve shown in (Fig. 7) shows an endothermic peak at 113.18 °C which corresponds to the end of the dehydration of the powder  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$ . Whereas the endothermic peak at 200 °C corresponds to the removal of water taken into the crystal lattice [16].

This phase is interpreted in the reaction (Scheme 2), the confirmation is made by measuring the weight loss [17].



Scheme 2 Evolution of the structure of compound A between 100 °C and 200 °C.

Two levels are distinguished on the path of the TG: Respectively, 7.30% and -12.37% of the total mass. The

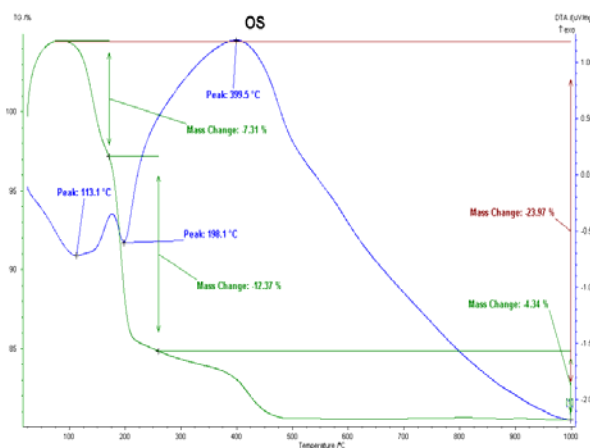


Fig. 7 Thermogravimetry spectrum compound A.

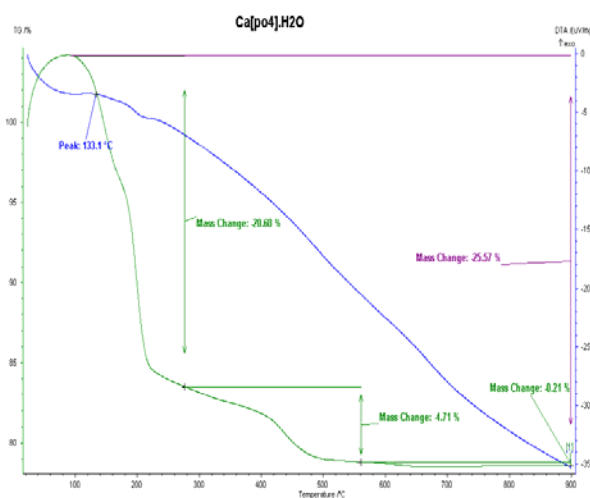
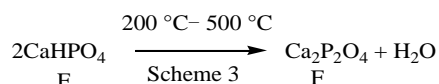


Fig. 8 Thermogravimetry spectrum compound D.

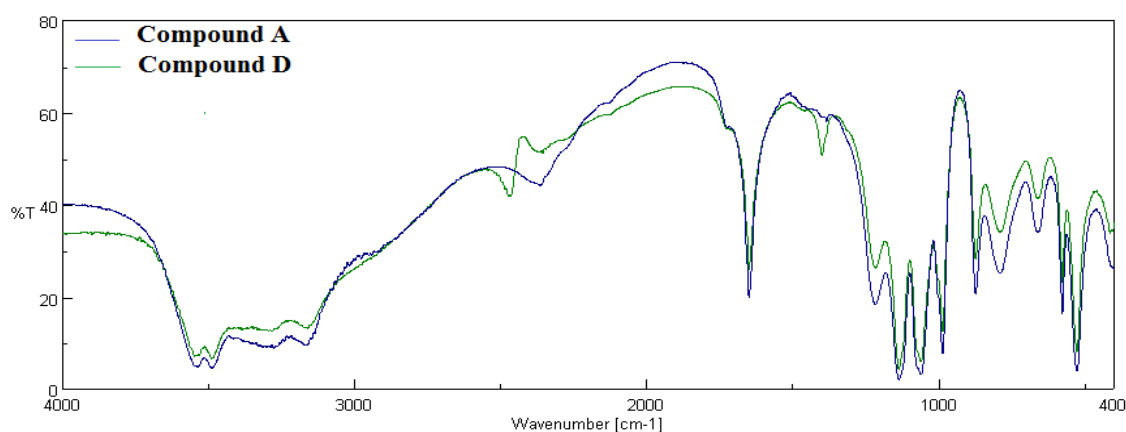
retention of water in our product  $\text{CaHPO}_4 \cdot \text{H}_2\text{O}$  is of 19.67% in agreement with the theory [16], the percentage of the theoretical weight loss of  $\text{CaHPO}_4$  is 20.92% at 300 °C. Between 300 °C and 500 °C is 4.34% with a peak at 399.5 °C on the curve of the TD. This change is explained by the evolution of  $\text{CaHPO}_4$ .



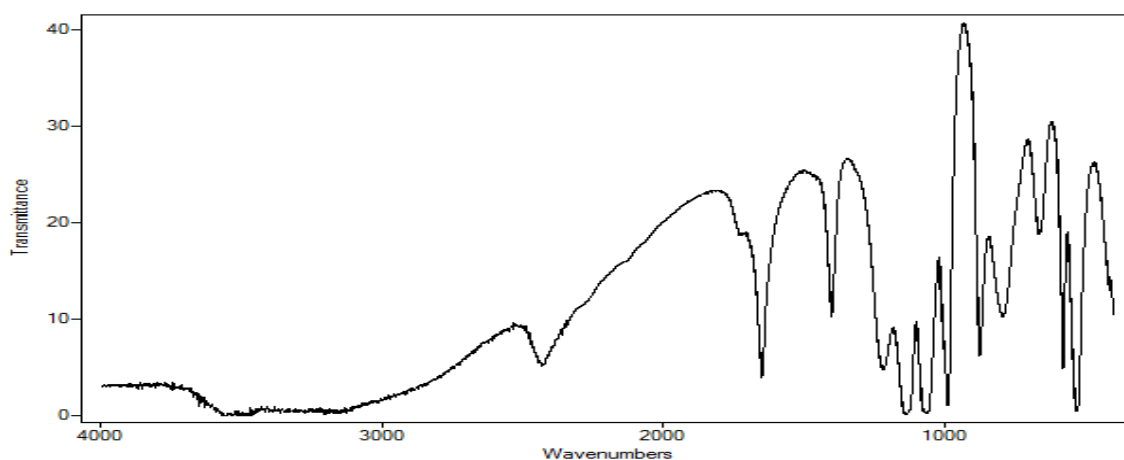
**Scheme 3** Evolution of the structure of compound A between 200 °C and 500 °C.

The similarity of the thermal decomposition of products: the starting (A), regenerated (D) and the levels related to the evolution in terms of mass loss of these two products reinforce the results of spectral analysis. The comparative of the absorption of UV-Visible spectra (Fig. 3) and (Fig. 6) as well as Infrared absorption spectra FTIR of compounds (A)

and (D) appear superimposed (identical) (Fig. 9). The spectral study of the compound (C) shows the chemical nature of the binding. The glutaraldehyde solution (B), controlled by UV-Visible reveals optimal optical density at 233 nm (Fig. 4) a characteristic of dipentanal 1.5. The compound (C) absorbs in the wavelength: 237 nm (Fig. 5) with a peak relatively wide. In addition, the FTIR spectrum of compound (C) indicates significant structural information (Fig. 10).  $\text{PO}_4$  group appears with a good resolution (Fig. 10), compared to the starting spectrum of  $\text{CaHPO}_4 \cdot \text{H}_2\text{O}$  (Fig. 9). The spectrum of the molecule (C) is divided on one hand between the group  $\text{CaPO}_4 \cdot 2\text{H}_2\text{O}$  of the compound (B) and the organic group  $(-\text{CH}_2)_3\text{-CHO}$  introduced by the dialdehyde (B). The FTIR spectrum of  $\text{CaHPO}_4 \cdot \text{H}_2\text{O}$  (A) shows absorption bands at 3,538.7-3,489.6, 3,289.0-3,278.4, 3,164.6-3,018.1  $\text{cm}^{-1}$  which are characteristics of (O-H) stretching water, according



**Fig. 9** FTIR spectrum Compound A and D.



**Fig. 10** FTIR spectrum compound C.

**Table 1** Comparison of TFIR compounds (C) and (A).

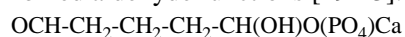
Compound (C) HOCH-CH=CH-CH <sub>2</sub> -CH(OH)O(PO <sub>4</sub> )Ca		Compound (A) CaPO <sub>4</sub> ·2H <sub>2</sub> O	
V (cm <sup>-1</sup> )	T (%)	V (cm <sup>-1</sup> )	T (%)
-	-	414	33.845
527	0.407	527	8.084
577	5.613	576	23.315
632	19.633	661	41.437
792	10.816	790	34.136
873	6.702	873	28.274
987	1.230	986	12.496
1,601	0.210	1,061	5.990
1,136	0.061	1,136	4.327
1,217	4.934	1,217	26.354
1,400	11.292	1,400	50.732
1,650	4.381	1,650	26.049
-	-	2,356	51.136
2,730	-	-	-
2,860	-	-	-
2,950	-	-	-
2,456	6.271	2,467	41.785
3,149	0.358	3,160	13.211
3,285	-	3,285	12.653
3,385	-	3,385	12.897
3,490	-	3,490	6.661
3,530	1.175	3,547	7.179

to (J. Xu et al) [18]. While the bending of water shows 1,649.8 cm<sup>-1</sup>. HPO<sub>4</sub> and PO<sub>4</sub> groups known in the literature [19-23] and our values appear similar with PO stretching observed at 1,136.8-1,060.8 and 986.5 cm<sup>-1</sup> and PO bending observed at 661.5, 576.6 and 527.5 cm<sup>-1</sup>.

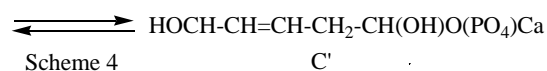
The stretching vibration of -OH appears in the vicinity of 3,400 cm<sup>-1</sup> in our case. This value is a characteristic of -OH stabilized by the environment [17-18], relative to 3,600 cm<sup>-1</sup>: If a (-OH) free. The aliphatic chain -(CH<sub>2</sub>)<sub>3</sub>- provides strong vibration: antisymmetric at 2,920 cm<sup>-1</sup> and symmetric at 2,850 cm<sup>-1</sup> distinctive of the aliphatic chain. However it should be noted in this frequency range lower additional bands which are active in infra red. This is the harmonic bands or combination of internal deformation modes of methylenes. This interpretation explains the broad shoulder starting around 2,700 cm<sup>-1</sup> and appends to the C-(OH) in terms of vibration. The vibrational band of valence (O - H) described since

1,895 appears at 3,300 cm<sup>-1</sup>. This observation has been developed by other studies because of the physical dynamics of the group (O-H) (intramolecular and intermolecular chelate). Two broad bands at 3,530.3 and 3,149.2 cm<sup>-1</sup> in the compound (C) (Fig. 10) correspond to the vibration of water molecules but also the intermolecular behavior (O-H ... O = P), the chelant, and/or enolic forms of groups (-OH) in their molecular configuration [19-23].

The function (-CHO) confirmed by UV-Visible (highly diluted solution) may appear mostly in enolic form. The band at 1,400 cm<sup>-1</sup> characteristic of the double bond (C = C) confirms the proposed mechanism (Scheme 4) reported in the literature in the case of combined aldehyde functions [19-23].



C

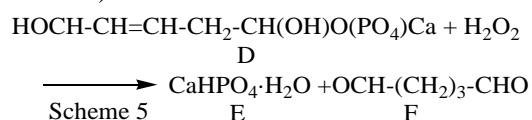


Scheme 4

C'

**Scheme 4** Enolic form of compound C.

The band at  $1,217\text{ cm}^{-1}$  may be characteristic of the skeleton (P-O-C) at the basis of linkage  $\text{CaHPO}_4$ ,  $\text{H}_2\text{O}$  and  $\text{OCH}(\text{CH}_2)_3\text{CHO}$ . This structural part is still poorly understood, preliminary FTIR information in the chemistry of phosphines indicate the range  $1,250\text{--}1,040\text{ cm}^{-1}$  [24, 25]. The treatment of compound (C) with a solution of  $\text{H}_2\text{O}_2$  at 10% generate the compound (A) with a very good performance (Scheme 4).



**Scheme 5** Oxidation reaction of compound D.

The reversibility of the reaction gives the matrix  $\text{CaHPO}_4$ ,  $2\text{H}_2\text{O}$  the property of stabilizer/fixator of the glutaraldehyde. On the basis of the reaction mechanism, the possible scenarios (Scheme 5), highlight the intramolecular bonds.

These bindings contribute to the stabilization of the product (C). They even explain the reversibility of the reaction. The approach of the molecule  $\text{HO}=\text{OH}$  following (Scheme 5) shows the evidence of this step.

#### 4. Conclusions

Glutaraldehyde is a molecule that finds various applications. Consumed in large quantities in the medical and industrial fields. In addition, the molecule appears harmful to both health and environment. The  $\text{CaHPO}_4\cdot 2\text{H}_2\text{O}$  offers an easy and inexpensive way for the fixation and stabilization of glutaraldehyde. The attachment which is a reaction between the group (-OH) of  $\text{CaHPO}_4\cdot 2\text{H}_2\text{O}$  is interpreted in the skeleton (P-O-C) relatively stable. The stability of the molecule is enhanced by the enolic form of the function-free CHO. The mild oxidation by the diluted  $\text{H}_2\text{O}_2$  regenerates the starting molecule.

#### References

- [1] D. Zissu, P. Gervais, Glutaraldehyde: Importance and precaution for use in medical services, *Archives of occupational diseases and Occupational Medicine* 55 (6) (1994) 463-466.
- [2] M. Bouzid, A. Djadi, S. Guechtoulli, Global approach and targeted approach in the management of hospital effluents, *Journal of Materials Science and Engineering B* 3 (4) (2013) 214-225.
- [3] R.W. Snyder, E.L. Cheatele, Alkaline glutaraldéhyde: An effective disinfectant, *American Journal of Hospital Pharmacy* 22 (1965) 321- 327.
- [4] A. Djadi, M. Bouzid, S. Guechtoulli, Conception and realization of an endoscope washer-disinfector, 4th Seminar Materials Processes and environment 15 (16) (2012) 195.
- [5] T. Takigawa, Y. Endo, Effects of glutaraldehyde exposure on human health, *Journal of Occupational Health* 48 (2006) 75-87.
- [6] The safe occupational use of glutaraldehyde in the health industries, OSH Occupational Safety and Health Information Series (1992) 1-23.
- [7] N. Bonnard, M.T. Brondeau, D. Jargot, S. Malard, O. Schneider, P. Serre, Glutaraldehyde, Sheet toxicological, FT 171, INRS, Paris, 2010, pp. 1-9.
- [8] Frank W. Kari, Glutaraldehyde (CAS No. 111-30-8), National Toxicology Program, Toxicity Report, Series Number 25, NIH Publication 93-3348 (1993), 1-120.
- [9] S.Yoshika, O. Daisuke, S. Kazunobu, A.Yasuo, Evaluation of passive sampler measurement of glutaraldehyde in occupational indoor air, *Journal of health science* 51 (6) (2005) 629-635.
- [10] N. Binding, U. Witting, Exposure to formaldehyde and glutaraldehyde in operating theatres, *International Archives of Occupational and Environmental Health* 62 (1990) 233-238.
- [11] M.S. Werley, H.D. Burleigh-Flayer, B. Ballantyne, Respiratory peripheral sensory irritation and hypersensitivity studies with glutaraldehyde vapor, *Toxicology and Industrial Health* 11 (5) (1995) 489-501.
- [12] R.O. Beauchamp, M.B.G. St Clair, T.R. Fennell, D.O. Clarke, K.T. Morgan, A critical review of the toxicology of glutaraldehyde, *Critical Reviews in Toxicology* 22 (3,4) (1992) 143-174.
- [13] P. Leinster, J.M. Baum, P.J. Baxter, An assesment of exposure to glutaraldehyde in hospitals: Typical exposure levels and recommended control measures, *British Journal of Industrial Medicine* 50 (1993) 107-111.
- [14] F.W. Kari, Studies of Glutaraldehyde administered by inhalation to F344/N rats and B6C3F1 mice, Research Triangle Park (Etats-Unis), NTP Technical Report on Toxicity Lieu 25 (1993) 1-82.
- [15] A.T. Jensen, J. Rathlev, Calcium hydrogen orthophosphate dihydrate and calcium orthophosphate; *Inorg. Syntheses*, 4 (1953) 19-22.
- [16] Li-Kuo Lin, Jinn-Shing Lee, Chung-King Hsu, Paou-Jang Huang, Hsiao-Tsung Lin, A study on the thermal

- properties of dibasic calcium hydrogen phosphate and monobasic calcium phosphate, *Analytical Sciences* 13 (1997) 413-418.
- [17] V.J. Mulley, C.D. Cavendish, A thermogravimetric method for the analysis of mixtures of brushite and monetite, *Analyst* 95 (1970) 304-307.
- [18] J.W. Xu, I.S. Butler, D.F.R. Gilson, FT-Raman and high-pressure infrared spectroscopic studies of dicalcium phosphate dihydrate ( $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$ ) and anhydrous dicalcium phosphate ( $\text{CaHPO}_4$ ), *Spectrochimica Acta part A-Molecular and Biomolecular spectroscopy* 55 (14) (1999) 2801-2809.
- [19] J. Buzon, G. Chiurdoglu, Molecular structure and property, Hydrocarbon and univalent functions, *Monograph of Organic Chemistry* (7) (1970) 1-942.
- [20] J. Barriol, R. Perron, J. Wiemann, Molecular structure and property, trivalent functions, *Monograph of Organic Chemistry* (9) (1974) 1-302.
- [21] L.J. Bellamy, *The infra-red spectra of complex molecules*, John Wiley & sons (3<sup>rd</sup> ed.), New York, Vol. 1, 1975, 433.
- [22] K.J. Ivin, *Structural studies of macromolecules by spectroscopic methods*, Wiley-Blackwell (ed.), New York (1976).
- [23] A. El Hamidi, M. Halim, S. Arsalane, M. Kacimi, M. Ziyad, Synthesis and characterization of new copper(ii) substituted dicalcium phosphate dihydrate ( $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$ ), *Asian Journal of Chemistry* 24 (6) (2012) 1-5.
- [24] S.B. Zhou, Q.X. Su, X.H. Li, J. Weng, A novel in situ synthesis of dicalcium phosphate dihydrate nanocrystals in biodegradable polymer matrix, *Materials Science and Engineering A* 430 (2006) 341-345.
- [25] V.S. Joshi, M.J. Joshi, FTIR spectroscopic, thermal and growth morphological studies of calcium hydrogen phosphate dihydrate crystals, *Crystal Research and Technology* 38 (9) (2003) 817-821.