

Synthesis and Dissolution Kinetics in a Simulated Bone Resorption Medium of Amorphous Carbonated Calcium Phosphates

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Abstract

Amorphous carbonated calcium phosphates (ACCPs) with different carbonate contents and Ca/P ratios were reproducibly synthesized by the reaction parameters as low temperature, high pH value, using initial solutions of calcium and phosphate at low concentrations, and various amounts of carbonate, as well as freeze drying of the precipitates. The addition of carbonate to the solutions led to form precipitates with higher Ca/P ratios with respect to the initial solutions. Heat treatment of freeze-dried ACCPs at 500 °C had no influence on their amorphous structure. The results of elemental carbon and thermal analysis showed that the carbonate may be eliminated in a wide range of temperature (500–1150 °C). Dissolution rate of ACCPs in the simulated bone resorption medium was dependent to the contents of carbonate and remaining water. Dissolution rate of the specimens with higher carbonate contents was controlled by the carbonate content, but the amount of remaining water had major influence on the dissolution rate of the precipitates with lower carbonate contents. The dissolution kinetics was found to follow a shrinking-core model, with product layer as the rate-determining step. Formation of an amorphous calcium phosphate and/or thermodynamically desirable dicalcium phosphate dihydrate as possible product layer prevents complete resorption of ACCPs under bone resorption conditions, and promotes osteoblastic activation process through nucleation and growth of biological apatite.

Keywords: Amorphous carbonated calcium phosphates; Osteoclasts; Dissolution kinetics; Bone substitutes; Bone tissue engineering

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pH

Ca/P

Ca/P

°C

(pH / /)

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/

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asmesgar@yahoo.com :

-

:

-

:

[] pH

CO₃²⁻ Cl⁻ F⁻ HPO₄²⁻ Fe²⁺ Na⁺ Mg²⁺

[]
(Ca,X)₁₀(PO₄,CO₃,Y)₆(OH,Z)₂
Z Y X
[]

[]

[]

[]

pH

:

Ca/P

[]

mM [PO₄]³⁻ /

°C

(HA)

[]

B

A

pH

B

A

/

[]

B

)

[]

(Rugger Vaccum Pump, Reax 2000

cmHg

() °C

[]

(Biotol, Plasma Biotol Limited, England) HA

°C

* Torr

EDWARDS

°C / h

ARL 3410 ICP-AES

PW 3710 (XRD)

pH

(ELTRA 80S) /

[]

°C

pH

Netzsch (TG DTA)

°C/min

STA 1640

°C

T= °C

[]

[]

pH / mM

(HANNA Instruments, pH 211 Microprocessor) pH

Ca/P

mM

mL (+) μm

pH /

Ca/P

[]

rpm

°C

/ Ca/P CO₃

/ pH / mol/L

Ca/P

(CO₂)

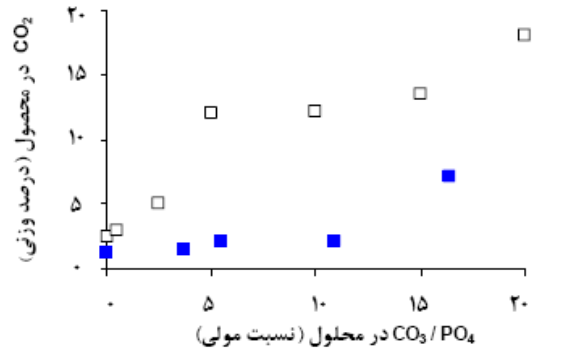
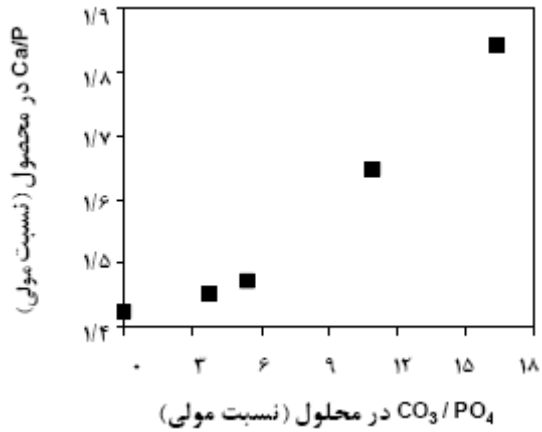
pH

)

(CO₃/PO₄

/

pH



Ca/P = / (CO₃/PO₄)

[]

°C [] Tadic []

Tadic .

[]
pH / (°C)

()

Ca/P

Tadic

[]

)
Ca/P (CO₃/PO₄)

CO₂

Ca/P

CO₂

Ca/P

[]

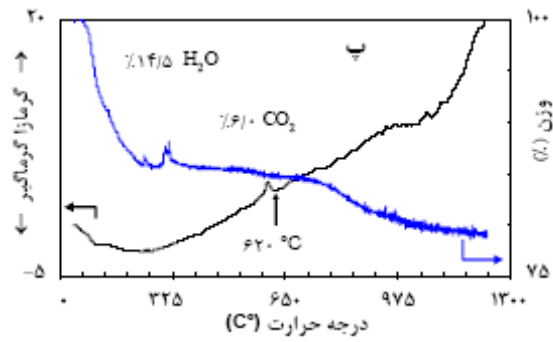
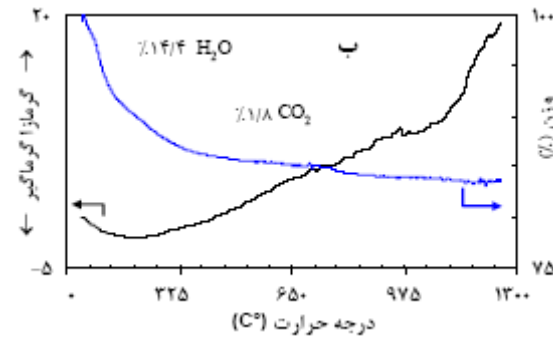
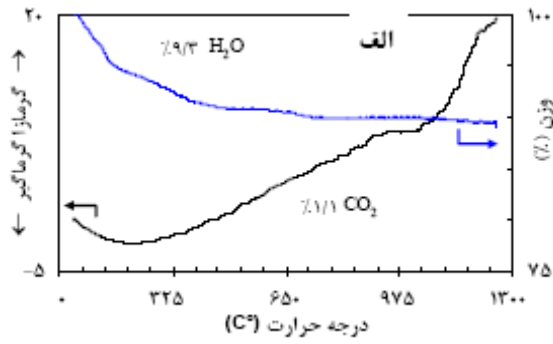
(HA) /

CO₂

N₂

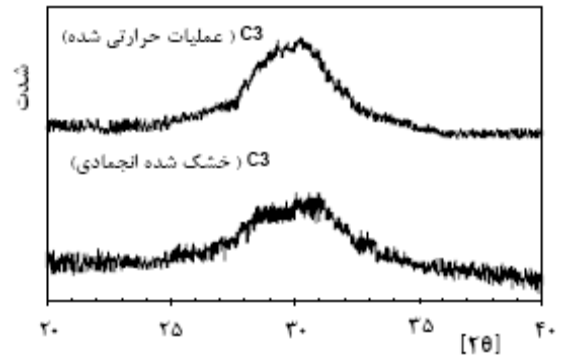
) Ca₉(PO₄)₆

([])



TG DTA

:(CO₃/PO₄)
/ /



C3

°C

°C

CO₂

[]

) C1

) C2 (

C3 (CO₃/PO₄ = /

)

(CO₃/PO₄ = /

C3 C2 C1

°C

.(/)

C3 C2 C1

°C

°C

C2 C1

°C

C3

C3 C2 C1

TG

°C

(DTA TG)

C3 C2 C1

/)

°C

C1

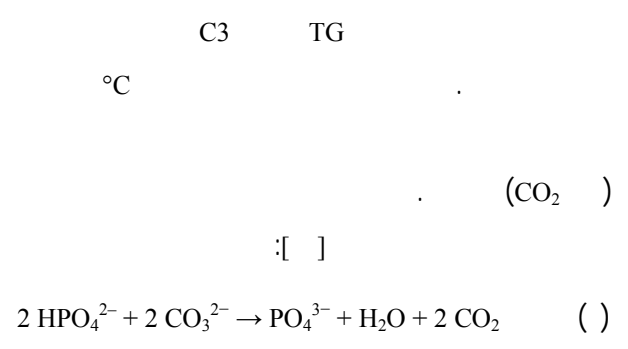
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/

(HC) °C	ICP				(FC)	/ / /	C3 C2 C1	TG
	Ca	P	H ₂ O	CO ₃				
FC1	/	/	/	/				
FC2	/	/	/	/				
FC3	/	/	/	/				
HC1	/	/	-	/				
HC2	/		-	/				
HC3	/	/	-	/				

°C
OH
pH
Ca²⁺

OH
" (FC) "
(HC) " °C



[] [] °C

² Bone substitutes

³ Bioactive materials

()

[]

()

[]

pH /

°C

pH

/

pH

[]

pH

[]

pH

[]

/ /

/

[]

%

(FC)

(HC)

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FC3 HC3)

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(FC2 HC2

[]

()

)

C2 C1

(

HC1 FC1

[]

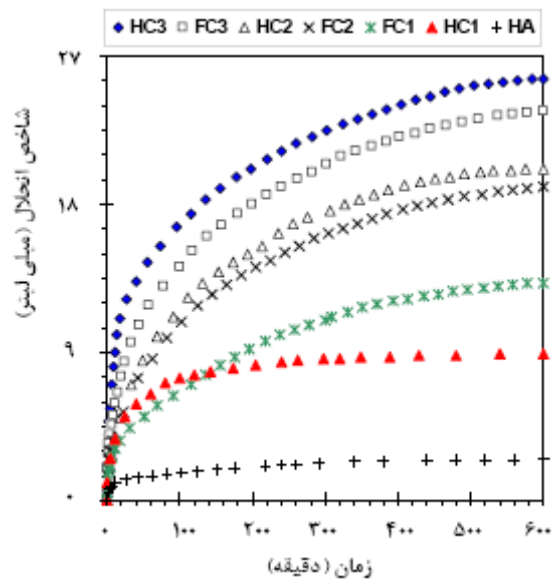
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⁴ Osteoclasts

⁵ Ruffled border

⁶ Phagocytose

⁷ Carbonic anhydrase

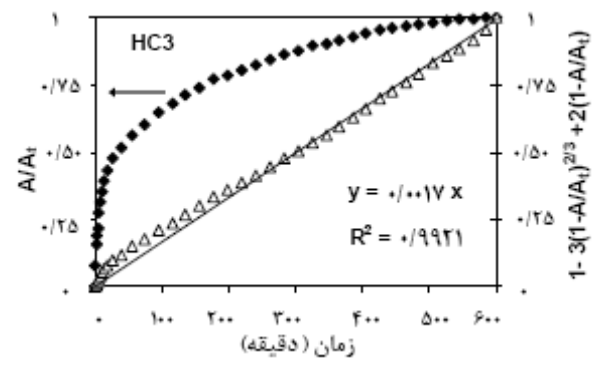
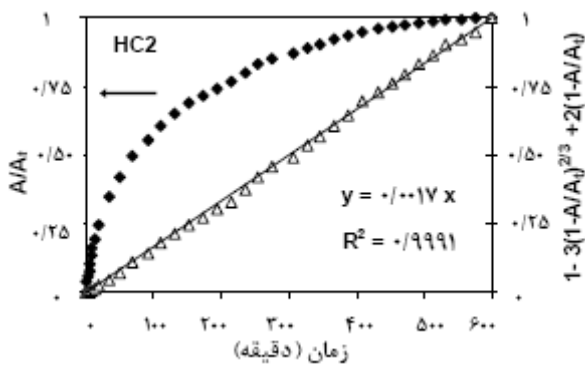
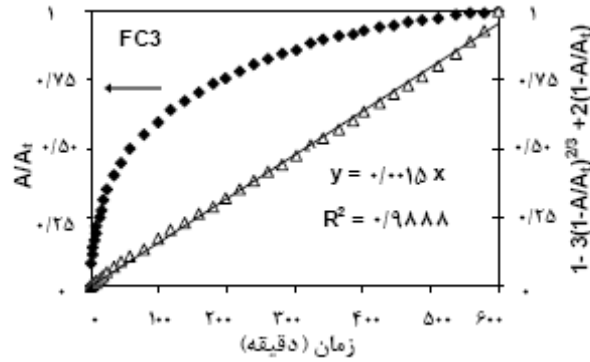
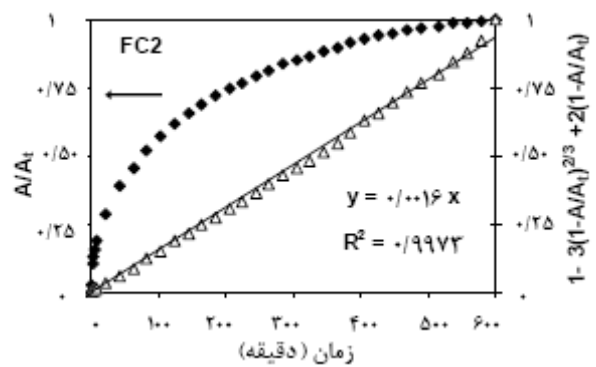
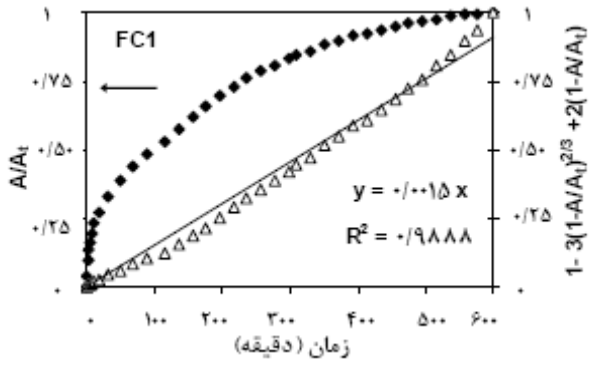


°C pH / /
 (HNO₃, mM)
 HC
) FC
 HA .(

)
 .
 .[]
 ()
 () ()
 :[]

: ()
 $kt = X$ () C1
 : ()
 $kt = 1 - 3(1 - X)^{\frac{2}{3}} + 2(1 - X)$ ()
 : ()
 $kt = 1 - (1 - X)^{\frac{1}{3}}$ () .[]
 k t X

.[]
 :
 $X = \frac{A}{A_t}$ ()
 A_t A
 .[]



HC2)

(FC3 FC2 FC1)

°C

rpm

pH / /

(HC3

k

HC1

[]

: []

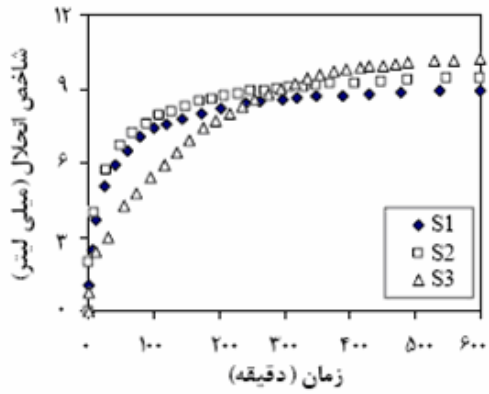
$$-\ln(1 - X) = k t^n$$

()

(FC3 FC2 FC1)

(HC3 HC2)

[]



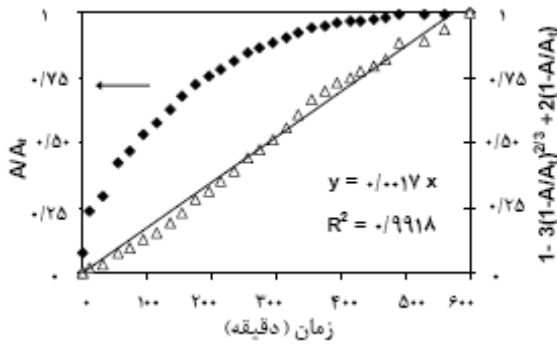
pH / / HCl

HCl

[]

S2 °C rpm S1
°C rpm S3 °C rpm

HCl



°C rpm pH / / HCl

HCl

$$-\ln\left(1 - \frac{A}{A_t}\right) = k t^{0.56} \quad ()$$

°C HCl

°C

°C

°C

°C

()

(XRD)

XRD

[]

)

(XRD

H₃O⁺

(DCPD, CaHPO₄·2H₂O)

" " "

[] Tadic

Ca/P

pH

/

XRD

DCPD

[]

Ca/P

/

°C

DCPD

DCPD

[]

HA

DCPD

/

HA

DCPD

[]

DCPD

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