SOCRATCES

Use of steam during calcination in the CaL-CSP process: Kinetics and cyclability

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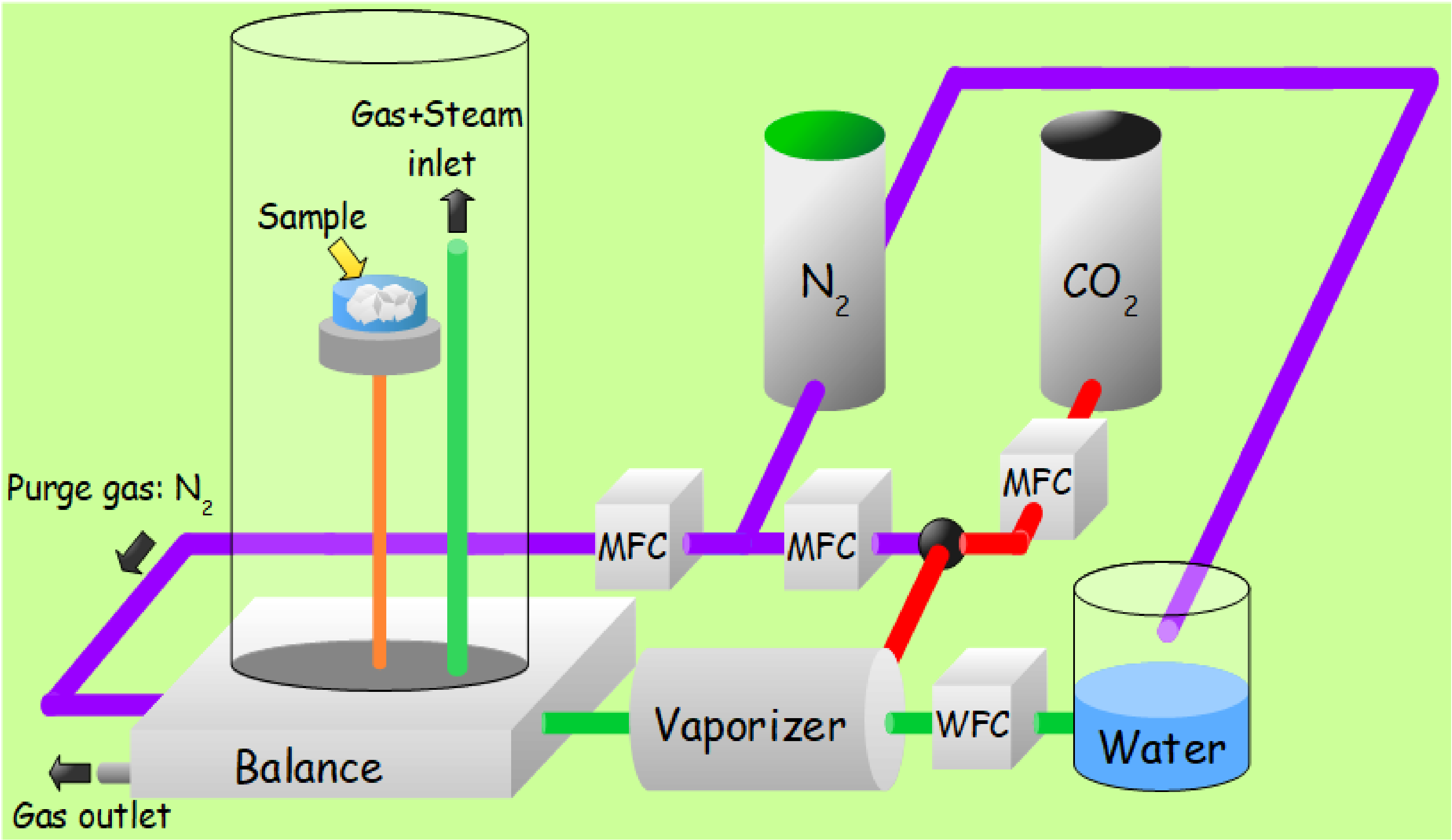
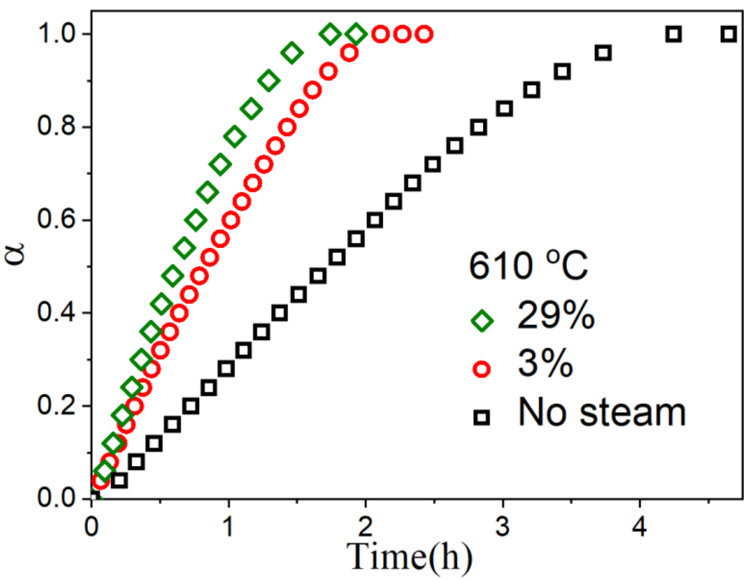
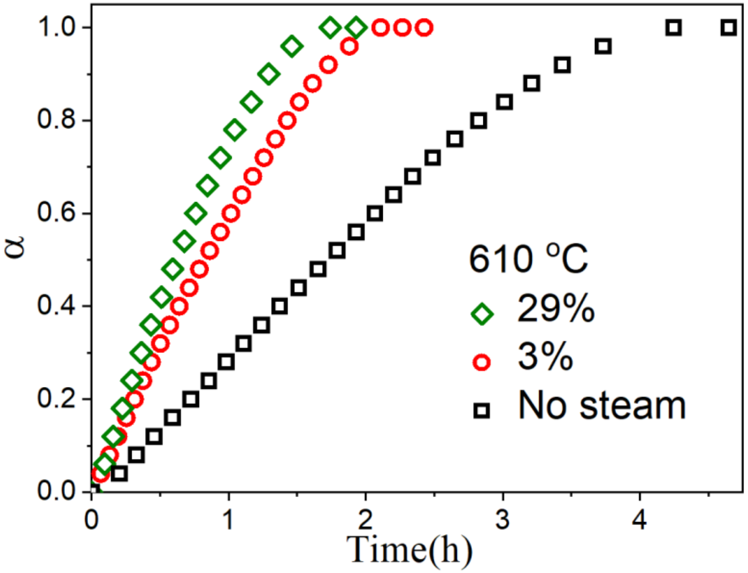


Gas+Steam
inlet
Sample
N2
CO2
Purge gas: N2
MFC
MFC
MFC
Vaporizer
WFC
Water
Balance
Gas outlet



1.0
0.8
0.6
0.4
0.2
0.0
α
0
1
2
3
4
Time(h)
610 °C
29%
3%
No steam

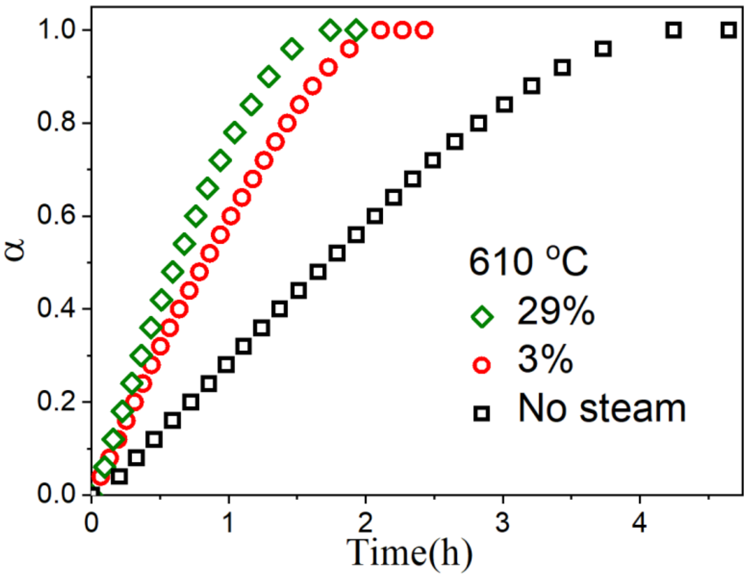
Non-parametric kinetic method



J. Sempere, R. Nomen, R. Serra, J. Soravilla. *The NPK method an innovative approach for kinetic analysis of data from thermal analysis and calorimetry. Thermochim. Acta.* ***2002****. 388: 407-414.*

Non-parametric kinetic method

For isothermal conditions: $t = g(\alpha) \cdot (k(T))^{-1}$



Non-parametric kinetic method

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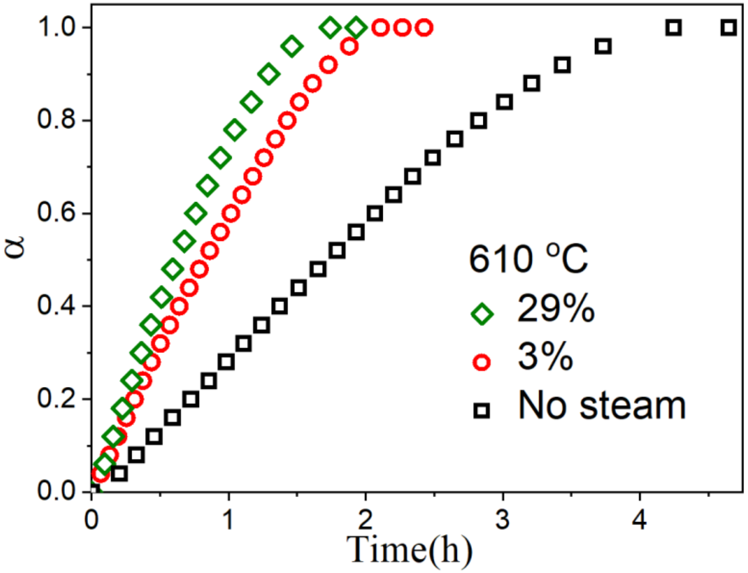

$$\begin{array}{cc} & \begin{array}{ccc} T_1 & T_2 & T_3 \\ \downarrow & \downarrow & \downarrow \end{array} \\ \boldsymbol{t} = & \begin{pmatrix} t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \end{pmatrix} \begin{array}{l} \leftarrow \alpha_1 \\ \leftarrow \alpha_2 \\ \leftarrow \alpha_3 \end{array} \end{array} \Rightarrow \boldsymbol{t} = \boldsymbol{u} \cdot \boldsymbol{w} \cdot \boldsymbol{v}^{\boldsymbol{T}}$$

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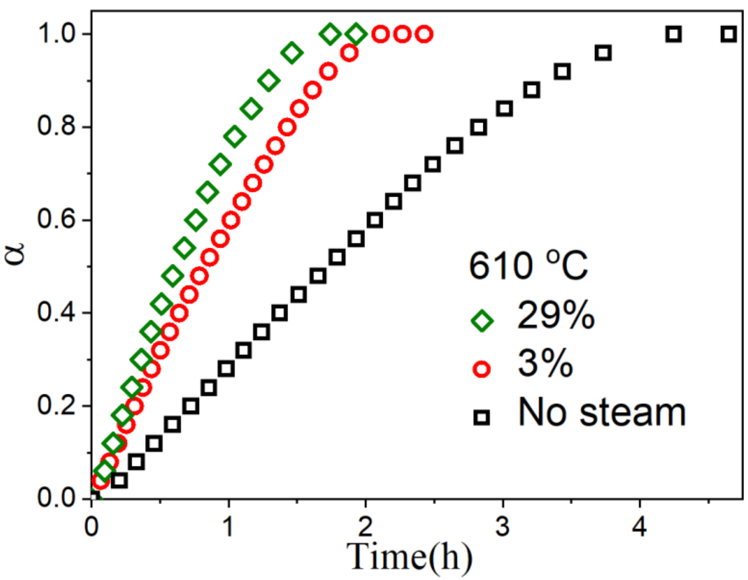

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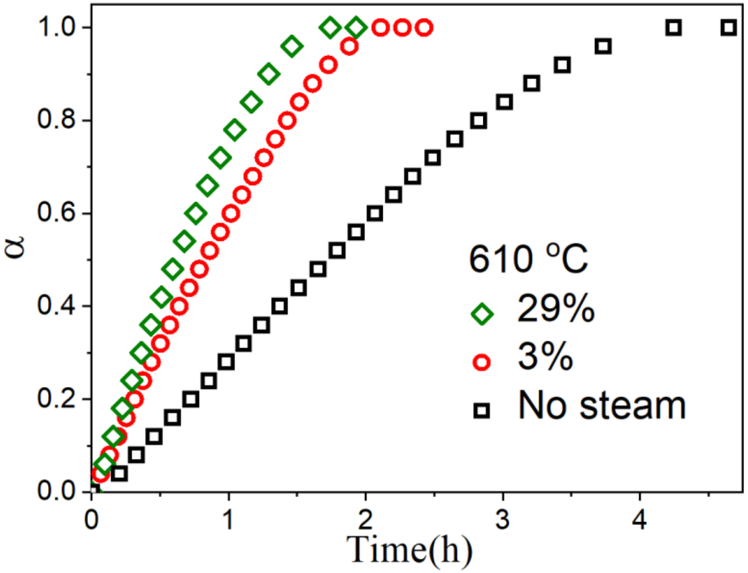
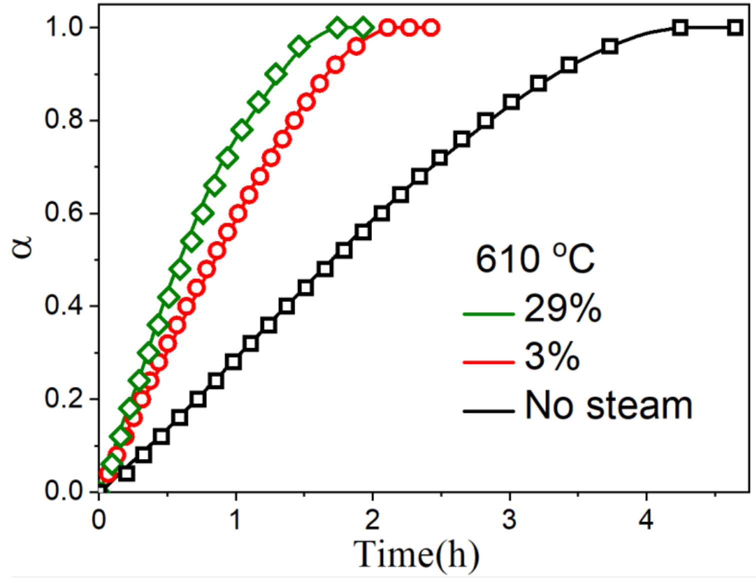
$u(\mathrm{i}, 1) \propto g(\alpha_i)$ with $\mathrm{i} = 1:3$

$v(\mathrm{j}, 1) \propto (k(T_j))^{-1})$ with $\mathrm{j} = 1:3$

Non-parametric kinetic method

$$t_{ij} = u(\mathrm{i},1) \cdot w(1{,}1) \cdot v(\mathrm{j},1)$$

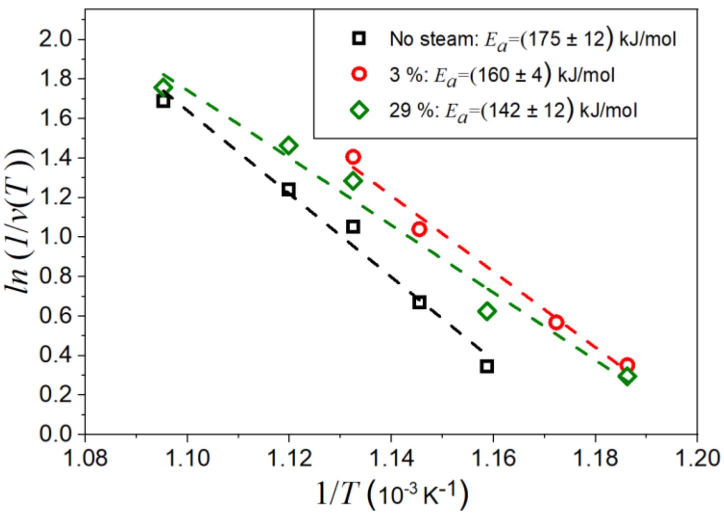




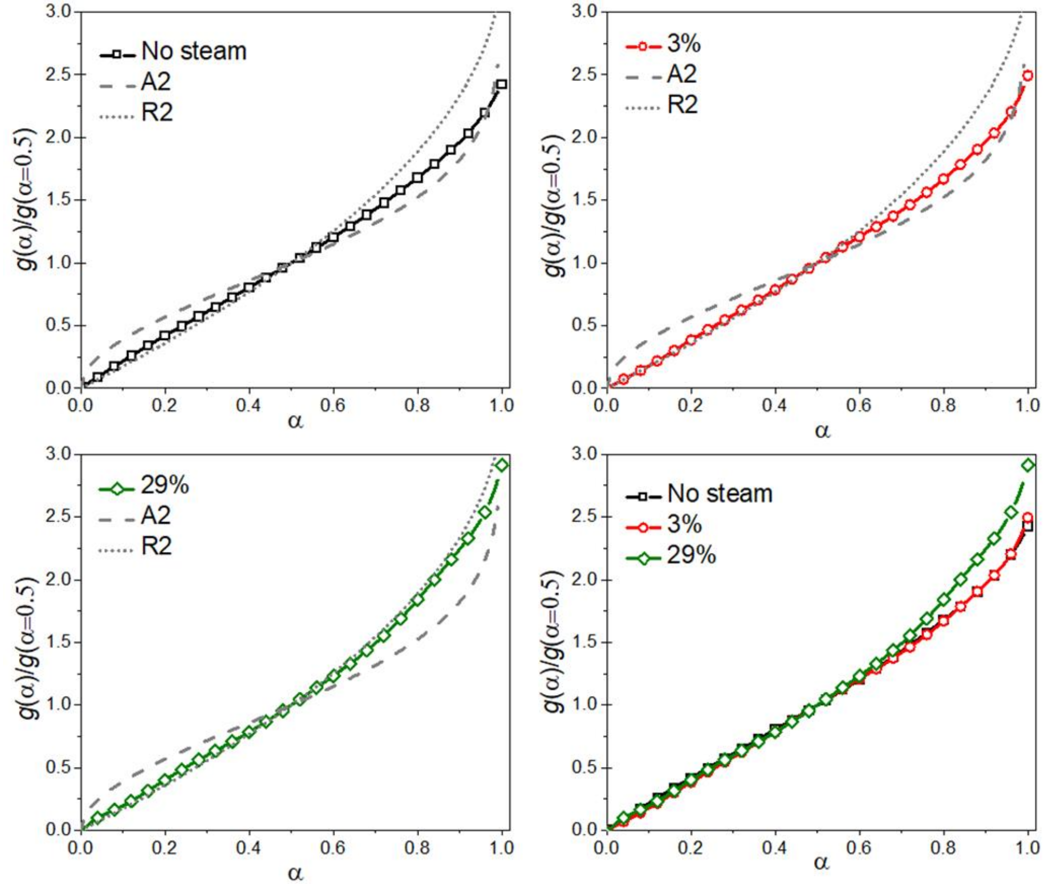
Non-parametric kinetic method

$$k(T) = A \cdot e^{-E_a/RT}$$

$$v(\mathrm{j},1) \propto \left(k(T_j)\right)^{-1}$$



$$u(\mathrm{i},1) \propto g(\alpha_i)$$



Non-parametric kinetic method

Kinetic parameters		
Partial pressure of steam	E_a(kJ·mol^{-1})	A^*(s^{-1})
No steam	175 ± 12	$(3.4 \pm 0.1)\cdot 10^6$
3 %	160 ± 4	$(9.2 \pm 0.2)\cdot 10^5$
29 %	142 ± 12	$(1.1 \pm 0.4)\cdot 10^5$

$$t = (1/A^*) \cdot (u(\alpha)/u(\alpha = 0.5)) \cdot e^{E_a/RT}$$

$$A^* = A/u(\alpha = 0.5)$$

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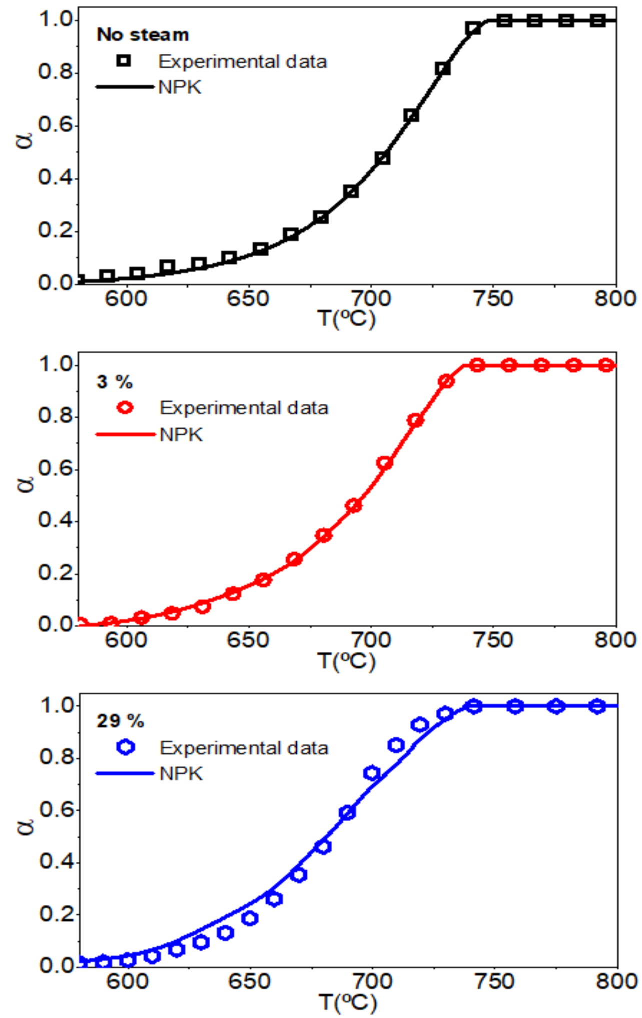
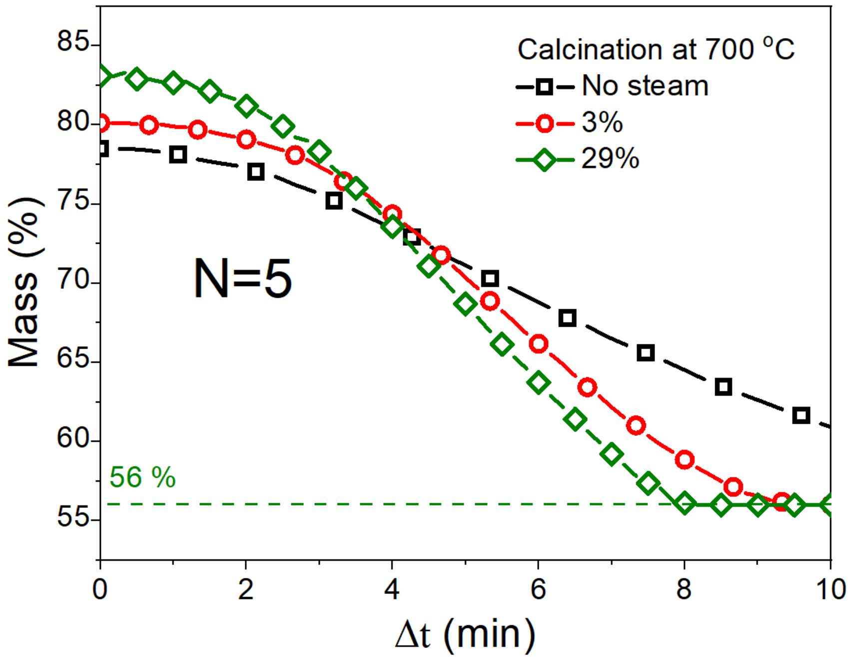
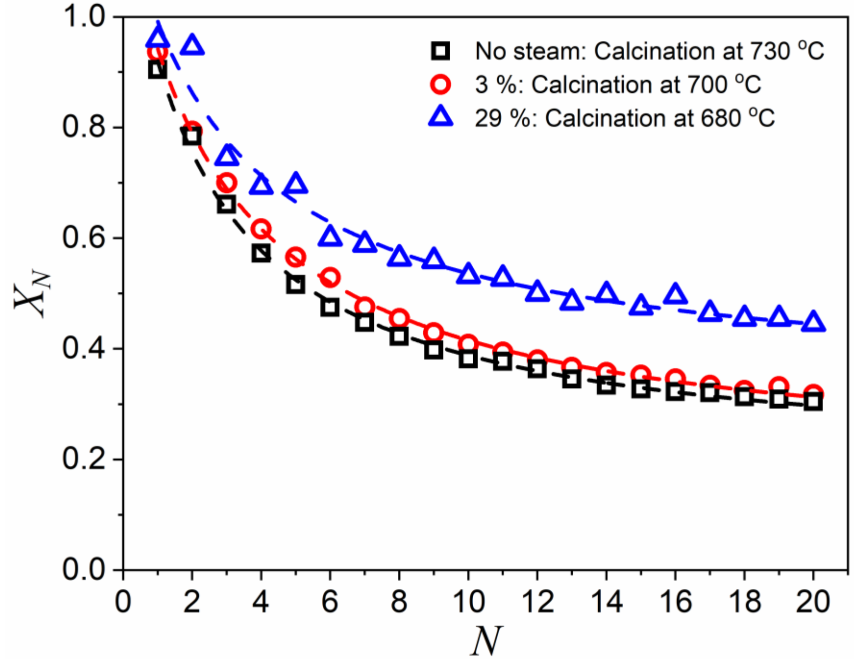


Cyclability

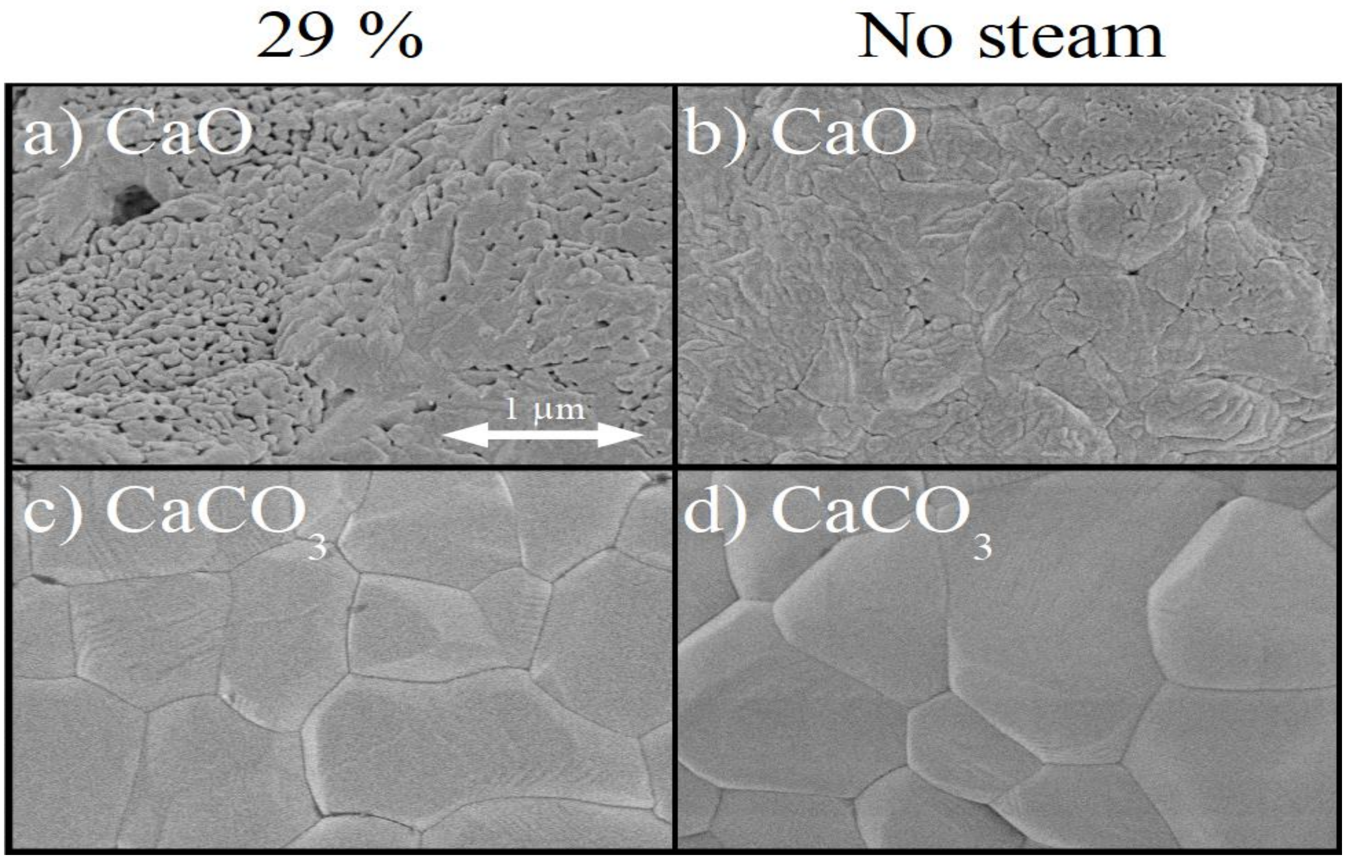




Cyclability

After 20 cyles:

T_{cal} = 680 ºC
T_{carb} = 850 ºC



Conclusions

- Steam addition decreases the apparent activation energy.
- The kinetic model is modified when a large amount of steam is employed.
- The temperature needed to attain full calcination can be decreased.
- Steam helps prevent the loss in reactivity and creates a more open structure resilient to pore plugging.

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Thanks for your attention

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