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Materials Science

Determination of Thermodynamic Function Parameters of Tedzami Clinoptilolite

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(Presented by Academy Member Ramaz Khurodze)

Abstract. The thermodynamic function parameters of the Tedzami clinophthilolite, including its dehydration and carbonation by CO_2 sorption, as well as rehydrolime pozzolanization of cement have not yet been sufficiently studied. This lack of data limits its application in industrial and environmental projects aimed at reducing the amount and footprint of CO_2 emitted into the atmosphere during cement production. The study involved predicting the thermodynamic function parameters of raw and dehydrated Tedzami clinophthilolite and the possibility of calcium hydroaluminosilicate formation and during cement hardening using approximate methods of calculation. The research findings revealed the following properties of Tedzami clinophthylolite: transition from a hydrated to an anhydrous state; physicochemical sorption of CO_2 generated during technological process; participation in rehydrogenation pozzolanization and carbonization of cement to reduce or eliminate the CO_2 footprint and contribution to solving environmental issues through ecologization of cement technology. *© 2026 Bull. Natl. Acad. Sci. Georg.*

Keywords: aluminosilicate, capture, enthalpy, modification, portlandite

Introduction

At the beginning of the 21st century, more than 40 natural zeolites (ZEO_{nat}), were known, differing from each other in crystal structure, cation content, and Si/Al ratio. Among them, tuffs (TF) containing the mineral clinophtilolite (CPT) are characterized by their stable composition and particularly high CPT content (70-95%) (Tsitsishvili et al., 1992).

Dehydrated CPT exists in a metastable, nonequilibrium state, which contributes to its physicochemical, especially sorption activity (Smith, 1999; Navrotsky and Tian, 2001). The temperature at which dehydration begins, in addition to the rate and duration of heating, is reflected in the thermodynamic (THD) function parameters (Wendlandt, 2024). Due to the gas separation ability of CPT, it is widely used as gas/water filters and in environmental technologies (Skhvitaridze et al., 2024).

With the flue gases of the clinker kiln of a cement plant, ≤ 890 kg of CO_2 is emitted into the atmosphere per 1 ton of clinker produced, which represents the corresponding carbon footprint =(CFP). CO_2 is

considered the main greenhouse gas responsible for climate change. Accordingly, numerous technological methods have been developed to prevent it. In projects such as Carbon Capture, Utilization and Storage (CCUS), CO_2 is captured in a FF containing the zeolite mineral – CPT. In this direction, positive results have been obtained using the CPT-TF of the Khekordzula deposit in Georgia (Skhvitaridze et al., 2024). The "green technology" for cement production "CO_2 ZEOCEM" was developed, and selected as one of the 19 finalists out of 101 participants in the global competition for innovative technologies of the "Global Cement and Concrete Association" (GCCA).

Studies have substantiated the use of natural hydrous aluminosilicates modified by calcination as effective mineral additives to cement, as well as the possibility of using CPT-TF as a sorbent to reduce emissions and traces of CO_2 into the environment (Skhvitaridze et al., 2024). For the adsorption of CO_2 in CPT-TF, it is practically necessary to dehydrate it to a temperature of ≤ 400°C, while thermodynamically (as THD) the onset of dehydration is expected at $t = 79.75$°C and $P = 684$ mm Hg Torr. It is assumed that during the cyclic process of CO_2 sorption-regeneration, CO_2 forms "adduct compounds" with alkaline (Na^{1+}, K^{1+}) and alkaline earth (Ca^{2+}, Mg^{2+}) me1tals CPT (Davarpanah et al., 2020).

Using the above-mentioned assumptions, adding mineral additives into cement contributes to the reduction of CO_2 emissions into the atmosphere and carbon footprint formed by flue gases.

Materials and Methods

Research materials are as follows: 1. TZCPT mineral in quantity ≤ 95mass% in 0-30 mm clastic tuff of Tedzami deposit, located in Georgia, where the remaining 5 mass% is quartz and traces of other minerals. TZCPT together with Khekordzula CPT-TF (Skhvitaridze et al., 2024) has been periodically utilized in Georgian cement production since 2000.

The research methods include the prediction of the potential formation of calcium hydrosilicate and aluminosilicate. Determination of the functions Thermodynamic (THD) function parameters of TZTCPT were determined, including the enthalpy of formation $\Delta_f H^0_{298}$, Gibbs free energy ($\Delta_f G^0_{298}$), and entropy $\Delta_f S^0_{298}$. In addition, key parameters such as the temperature of the onset of dehydration and partial pressure according to the guidelines set out in**].** In the context of participation in **CCUS** processes, the physicochemical (CO_2) sorption parameters and $Ca(OH)_2$ sorption parameters in TZCPT were determined.

The research objects are as follows:a) dehydration of TZCPT and absorption of CO_2 – processes of capture of T (K) or t (°C)] and P; b) $TZCPT_{deh}$, with CO_2 (ad)sorption into carbonate pozzolan (CARP) and $Ca(OH)_2$ (ab)sorption into rehydro-lime pozzolan (Rehydro-liming Pozzolna=RHLP), respectively, the possibility of modifying TZCPTcarp and $TZCPT_{RHLP}$.

The research employed thermal (DTA) and X-ray diffraction (XRD) methods of solid, powdery materials. Mathematical analysis, including a thermodynamic approach was applied for the evaluation of cement testing methods. Laboratory dryers and muffle furnaces were used for sample preparation.

Table 1. Coefficients a, b, c CPT_{nat} and $TZCPT_{deh}$, $\Delta_f Cp = f$ (T)J · K^{-1} ·mol^{-1}

Title	*a*	*b*	*c*
Σ (*a,b,c*) TZCPTnat (a,b,c) =	290.90	135.26	- 53.03
Σ (*a,b,c*) TZCPTdeh (a,b,c) =	228.58	134.64	- 57.42

First of all, a search was conducted for chemical and THD constants of the materials used in the studies. These data, previously reported in Skhvitaridze et al., (2024)., are summarized in Table 1. The Table

presents the designations of the compounds participating and formed in the process of hydration and hardening of cement, the CCN process, as well as their data $\Delta_f G°_{298}$ kj/mol.

The X-ray phase analysis was performed on a DRON 4.0 diffractometer (scanning speed 10/20 = 1 g/s. Anode - Cu, radiation - K¥, I = 12 ml, filter - Ni, V = 30 kV), natural, 300°C and 700°C after heating for 1 hour. The characteristic peaks of the TZCPT according to the X-ray phase analysis data: [(2.97; 3.34; 3.95; 7.97; 8.792) (Fig. 1 and (Skhvitaridze et al., 2024)], 300°C and 700°C after 1 hour of calcination are repeated and do not change in magnitude. Thermal properties of TZCPT were determined on a NETZSCH derivatograph [STA-2500 analyzer, REGULUS thermogravimetric (TG), differential thermogravimetric (DTG) and differential thermal analyzer (DTA). TZCPT was heated to 1000°C at a rate of 10°C/min (Fig. 2).

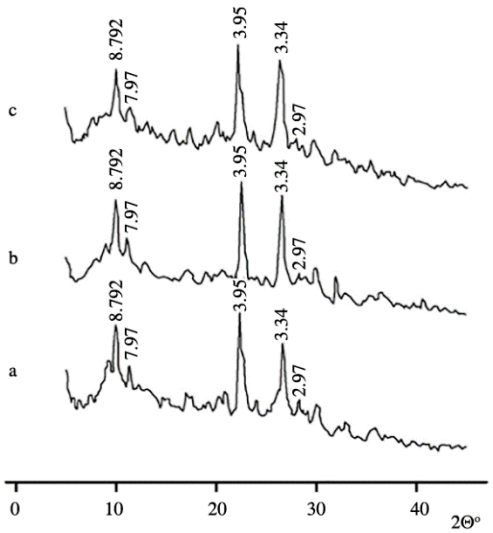

Fig. 1. Difractogram of of CPT-TF.

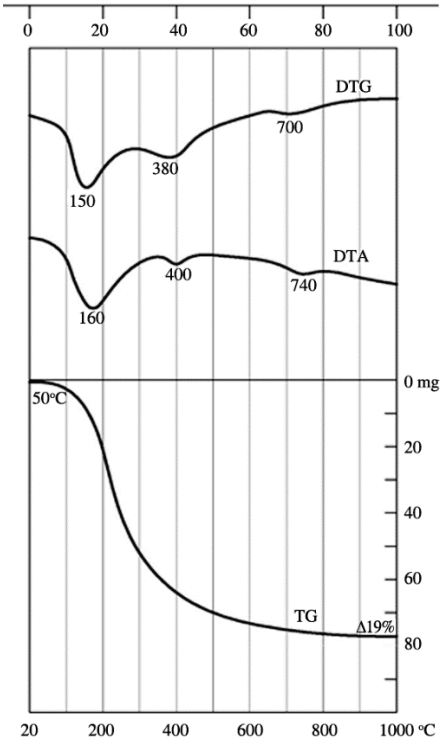

Fig. 2. Derivatogram of CPT-TF.

Table 2. Complete chemical analysis of TZCPT

Name	Chemical composition		Name	Chemical composition	
	Mass. %	EU of ion		Mass. %	EU of ion
Na_2O	4.23	Na 3.71	Fe_2O_3	1.63	Fe 0,55
K_2O	1.52	K 0.88	SiO_2	60.10	Si 28.02
CaO	3.90	Ca 1.89	TiO_2	0.28	Ti 0.11
MgO	0.90	Mg 0.61	O(g)	-	Og 72.00
Al_2O_3	13.95	Al 7.88	H_2 (l)	13.49	H_2O.20.27

Using the method of chemical-oxidative analysis (Table 2) and according to Tsitsishvili et al. (1992), the summation method, the generalized stoichiometric composition of the unit cell (UC) of zeolites was determined:

$$\zeta = (M', M''_{0.5})x(H_2O)_n[Al_xSi_{1-x}O_2], x \in (0;1). \quad (1)$$

Here M', M" (non-framework compounds) are cations of alkali and alkaline earth metals (sometimes Fe+2, etc.). Aluminosilicate frame elements are enclosed in square brackets "; x ∈ (0;1) – degree of aluminization of the silicate framework, where ∈ – membership index within the range TZTCPT $x = Al/(Al+Si)\,(0;1) = 0.22$.

$$\zeta = Na_{3,71}K_{0,88}Ca_{1,89}Mg_{0,61}[(Al_{7,88}Fe_{0,55})(Si_{28,02}Ti_{0,11})O_{72}]\cdot 20{,}27 = 1{,}855Na_2O\cdot 0{,}44K_2O\cdot 189CaO\cdot 0.61$$
$$MgO\cdot 3.94Al_2O_3\cdot 0.275Fe_2O_3\cdot 28{,}02\beta SiO_2\cdot 0{,}11TiO_2\cdot 1.725\cdot O_{(g)}\cdot 20{,}27H_2O\,(1) \quad (2)$$

The determination of the THD function parameters of the TZCPT is problematic due to their experimental complexity, therefore the enthalpy of the TZCPT $\Delta_f H^0$, the Gibbs free energy $\Delta_f G^0$, the entropy S^0_{298}, as in (Skhvitaridze et al., 2024), were determined by an approximate method: according to the principle of structural analogy of the constituent compounds and summing up the values:

$$\Delta_f TC(\zeta) = \Sigma_i y_i t_i\,, \quad (3)$$

where TC of any THD (H, G, S) is constant; ζ is the stoichiometric composition; *i* is the number of compounds in the zeolite; y_i is the component of the chemical compound in the zeolite; t_i is the constant:

$$\Delta_f C_{Pi} = (\Delta a_i + \Delta b_i + \Delta c_i)\,. \quad (4)$$

The molecular mass of TZCPT was calculated using empirical stoichiometry, formulas (2) and (4) and the data in Table 1:

$$M_{ZTCPT} = \Sigma_i y_i m_i\,. \quad (5)$$

In the formula (Skhvitaridze et al., 2024), m_i is the molecular mass of the chemical compound, M_{TZCPT}= 2819.08 g mol^{-1}; This mass of 20.27 water molecules – M_{H2O}= 365.27 g mol^{-1}.

During dehydration, voids are formed in the TZCPT, the total volume of which is equal to the water content:

$$V_{ZTCPT} = MH_2O/\,pH_2O = 365.27/0.99705 = 366.35cm^3\,. \quad (6)$$

The density of CO_2 under normal conditions at 25°C (298 K) = 1.8083 g/cm^3, the volume of 1 mole of CO_2 will be: $V_{CO_2} = M/P = 44.01/1.8089 = 24.34cm^3/mol$. Accordingly,the voids formed in the TZCPT can absorb: $V_{TZCPT}/V_{CO_2} = 366.35/24.34 = 15.01mol$ CO_2. The density of $Ca(OH)_2$ under *p* normal conditions (25^0C) = 2.211 g/cm^3. Then: Vm = 74.093 g mol-1 / 2.211 g/cm^3 = 33.51108 cm^3 mol^{-1}; In the void of 366.35 cm^3 volume, formed during dehydration in Tezami zeolite, not water is (absorbed), but an "aqueous solution of lime": 366.35 cm^3 / 33.51108 cm^3 = 10.93 = 11.0 mol $Ca(OH)_2$.

The enthalpy of formation of TZCPTnat, $\Delta_f H^0_{298}$ was calculated using formula (2) and the data from (Skhvitaridze et al., 2024):

$$\Delta_f H^0{}_{298TZCPTnat} = -40740.454kj\cdot mol^{-1}\,. \quad (7)$$

Gibbs free energy of formation of TZCPTnat. $\Delta_f G^0_{298}$ TZCPTnat under standard conditions is calculated using formula (4) and the data in Table 1:

$$\Delta_f G^0{}_{298TZCPTnat} = -37643.783kj\cdot mol^{-1}\,. \quad (8)$$

The entropy of TZCPT. From the Gibbs-Helmholtz equation $\Delta_f G^0{}_{298} = \Delta_f H^0_{298} - T\Delta S^0_{298}$ obtained entropy value is: $T\Delta S^0{}_{298} = \Delta_f H^0_{298} - \Delta_f G^0_{298} = -3096.671kj\cdot mol^{-1}$.

The quantities calculated above in TZCPTdeh will be as follows:
$\Delta_f H^0_{298} TZCPT_{deh} = \Delta_f H^0_{298TZCPTnat} - 20.27\Delta_f H^0_{298} H_2O_L = -34946.68kjmol^{-1}2199858J/mol$.

$\Delta fG^0T = f(T)$ from the Gibbs-Helmholts equation to obtain the physicochemical values at any desired temperature it is necessary to integrate it:

$$\Delta_f G^0T = \Delta_f H_f^0 - \Delta aTInT - 1/2\Delta bT^2 - 1/2\Delta cT^{-1} + yT \ . \tag{9}$$

In the range of 25-100°C (298-373 K) of heating of TZCPT, dehydration will begin, i.e.: TZCPTnat – 20.27 H_2O. In fact, the right part of equation (2) represents zeolite water release. The temperature of the onset of dehydration of the TZCPT (Fig. 2) and the pressure were determined using the calculation method as follows:

$$\Delta_f G^0{}_T = -707738 - 596.78 \cdot T \cdot InT - 107.675 \cdot 10^{-3} \cdot T^2 - 5.16 \cdot 10^5 \cdot T^{-1} + 1645{,}1011T\,, \tag{10}$$

$$\Delta_f G^0_{298} = +2199858J/mol\,;\ \Delta G_f{}^0{}_{368} = -352J/mol\,;\ \Delta_f G^0_{367.85} = 0\,, \tag{11}$$

$$\Delta_f G^0_{367.85} = 0\,;\ T = 367.85(K) = 94.7^\circ C\,, \tag{12}$$

$$LgK = -\Delta_f G^0T/4.576 = -0.2185;\ K = 0.6046atm\,;\ P = 459.5mm\ Hg\,, Torr\,.$$

The possibility of physical sorption in the dispersion system "TZCPT– $CO_2$was evaluated.

Physical sorption of gaseous CO_2 in solid, fragmented TZCPT can be conditionally carried out according to the following equation:

$$TZCPT_{deh} + \underline{15{,}01CO_2} = TZCPT_{deh} + 15.01CO_2\,; \tag{13}$$

CO_2 is physically sorbed (and modified)TZCPT- CO_{2PHSOR} :

$$\text{Enthalpy}\ \ \Delta_f G^0_{298TZCPTdeh} + 15{,}01\Delta_f H^0_{298}CO_2 = -40853.28kjmol^{-1}\,, \tag{14}$$

$$\text{Gibbs free energy-}\ \Delta_f G^0_{298TZCPTdeh} + 15{,}01\Delta_f G^0_{298}CO_2 = -38756.25kjmol^{-1}\,, \tag{15}$$

$$\Delta_f G^0_T = 961406 + 171.885TInT - 33.851510^{-3}T^2 - 32.05510^5T^{-1} - 3577.004T\,, \tag{16}$$

$$\Delta_f G^0_{370.29} = 0\,;\ T = 370.29K = 97.15^\circ C\,;\ P = 293mmHg, Torr\,.$$

Possibility of chemical sorption of CO_2 in the dispersion system "TZCPT – CO_2".

Studies on CCUS processes have confirmed the sorption of CO_2 molecules on the surface of TZCPT, as well as in the structural and anhydrous pores of its framework (Skhvitaridze et al., 2024). TZCPT contains alkali (Na^+, K^+) and alkaline earth (Ca^{2+}, Mg^{2+}) metals, which are likely to undergo carbonization through chemical sorption forming carbonates:

Alkaline oxides:

$$1.855Na_2O + 1.855CO_2 = 1.855Na_2CO_3\ \Delta_f G^0_{298} = -513.35kjmol^{-1}\,, \tag{17}$$

$$0.44K_2O + 0.44CO_2 = 0.44K_2CO_3\ ,\ \Delta_f G^0_{298} = -151.46kjmol^{-1}\,. \tag{18}$$

Alkaline earth oxides

$$1.89CaO + 1.89CO_2 = 1.89CaCO_3\,,\ \Delta_f G^0_{298} = -246.29kjmol^{-1} \tag{19}$$

$$0.61MgO + 0.61CO_2 = 0.61MgCO_3\ \ \Delta_f G^0_{298} = -29.41kjmol^{-1}\,.$$

According to the report, 4.785 mol CO_2 can be chemically sorbed from the 15.01 mol CO_2 physically sorbed in TZCPT. The corresponding activities are as follows: $Na^+ > Ca^{+2} > K^+ > Mg^{+2}$.

Chemical sorption of CO_2 in the TZCPT can occur according to the following conditional equation:

$$TZCPTnat. - 20.27H_2Og + 15.01CO_2 = [TZCPTdeh + 4.785CO_2] + 10.225CO_2\,. \tag{20}$$

Using formula (2), we calculated the chemisorbed (modified) ZTCPT- $CO_{2CHEMISOR}$:

$$\text{Enthalpy} - \Delta_f H^0_{298TZCPTdeh} + 4.785CO_2 = \Delta_f H^0_{298TZCPTchem.\text{mod}} = -33682.9625kjmol^{-1} \tag{21}$$

$$\text{Gibbs free energy} - \Delta_f G^0_{298TZCPTdeh} + 4.785CO_2 = \Delta_f G^0_{298TZCPTchem.\text{mod}} = -34723.853kjmol^{-1} \tag{22}$$

$$\Delta_f G^0_T: \Delta_f G^0_T = 837684 - 343.4 \cdot TlnT - 78.3 \cdot 10^{-3} T^{-1} - 22.7 \cdot 10^5 T^{-1} - 168.4 \cdot T, \quad (23)$$

$$\Delta_f G^0_{372.5} = +720 kjmol^{-1};\ \Delta_f G^0 372.8 = 0;\ 99.65°C;\ K = 0.929 atm = 706 mm\ Hg,\ Torr.$$

THD forecast of possibilities for reducing CO_2 emissions into the environment in cement production using TZCPT is highly relevant. Therefore, it is important to study the THD abilities of calcium hydrosilicates/aluminosilicates by rehydrosintering in the reaction of TZCPT with CH during hydrate hardening of TZCPT-containing cement using approximate methods.

To simplify the calculations of the THD interactions with TZCPT and CH, we identified, as a first approximation, the primary compounds reactive with CH in the composition of TZCPT, as a result of which the values given in formulas (1) and (2) were modified as follows: $TZCPT \bmod = 2CaO + 4Al_2O_3 + 28SiO_2 \cdot$

$$[2CaO + 4Al_2O_3 + 28SiO_2] + 11Ca(OH)_2 = 2[CaO \cdot Al_2O_3 \cdot 2SiO_2] + 2[2CaO \cdot Al_2O_3 \cdot SiO_2 \cdot 8H_2O] + \\ + 9[CaO \cdot 2SiO_2 \cdot 2H_2O] + 6[SiO_2 H_2 O], \quad (24)$$

with abbreviated designations of compounds obtained in cement chemistry

$$[C_2 + A_4 + S_{28}] + 11CH = 2[CAS_2] + 2[C_2 ASH_8] + 9[CS_2 H_2] + 6[SH] \quad (25)$$

$$\Delta_f G^0_{298} = -8717.00 kj / mol.$$

$$[(C_2 + A_4 + S_{28}) + 15C] \bmod CO_2 + 20CH + 52H = CAS_2 + CS_2 H_2 + C_6 AcH_{32} + 2[C_2 ASH_8] + 22[SH] + 12Cc \quad (26)$$

$$\Delta_f G^0_{298} = -870.00 kj / mol.$$

Results

Determination of the thermodynamic function parameters of natural and dehydrated TZCPT, as well as the ability to carbonize with CO_2 and pozzolanize with rehydrogenation with CH, allows planning and implementing a reduction in the footprint of 890 kg of CO_2 emitted into the atmosphere by producing 1 ton of cement clinker.

According to TZCPTnat, CEM II/B-Q,32.5 cement (grade 32.5) can be added as an additive in an amount of ≤ 35 mass %, and the mechanical strength when tested according to standard procedures, the resulting mechanical strength should be (≤32.5MPa). As a result of pozzolanic, rehydrogenation CO_2 – footprint decreases from 890 kg to 578.5 kg, i.e. by 311.5 kg = 35mass %;

The calculations indicate that in TZCPT, during the (ad) sorptive capture of CO_2 from flue gases, the CO_2 capture – regeneration cycle is repeatable. In this process, 15.01 mol of CO_2 is physically (ad)sorbed-captured in the void of 366.35 cm^3 created by the evaporation of H_2O. The process begins at t = 97.15°C and P = 293 mm Hg Torr. 4.785 mol of the captured 15.01 mol of CO_2 are chemisorbed in TZCPT with alkali/alkaline earth metals at t = 99.65°C and P = 706 mm Hg Torr with the formation of carbonates.

By mixing TZCPTmod$_{CO2}$ into CEM II/B-Q,32.5 type cement while maintaining strength (≤ 32.5 Mpa), 1 mol TZCPT (M = 2819.08 g/mol) in the CCUS process (ad)sorptionally captures 15.01 mol (660.59 g) CO_2 and is modified into TZCPTmodCO_2.

The study confirms that by mixing TZCPTmod$_{CO2}$ into CEM II/B-Q,32.5 type cement at a rate of 35 mass % instead of 45 mass % and maintaining mechanical strength, out of 890 kg of technological CO_2 emitted into the atmosphere, "bound – captured" will be: (890 x 0.45) k g + 105.5 k g = 506 kg CO_2, which reaches 57 mass % of the emitted CO_2 and is an innovative achievement.

Conclusion

The dehydration of TZCPT, its carbonation and the rehydrocarbonation of cement for pozzolanic and carbonate modification, the formation of crystalline hydrates during hydration with cement minerals, demonstrate the capabilities of TZCPT . These include: transition from a hydrated to a dehydrated state; capture of CO_2 generated during production through physicochemical sorption; rehydrogenate, pozzolanic, and carbonate modification of cement; and reduction of the carbon footprint, thereby contributing to the greening of cement technology.

The calculated THD function value for TZCPT, $\Delta fH0298$ = -40740.45 kJ mol^{-1}, is close to the previously reported values, $\Delta fH0\ 298$ = { [- 40232 – (-40452)] – [-41290 –(-41527)]} kJ mol^{-1}, whereas with CPT-TF, studied bySkhvitaridze et al., (2024): $\Delta fH0298$ = - 39825.84, the difference is 626.61 kJ mol^{-1} = 1.57%.

In the TZCPT – CO_2 dispersion system in CCUS processes, the onset of TZCPT dehydration is expected at 94.7°C and a pressure of 459 mmHg Torr, but the temperature is lower than required for CPT (94.85°C), and the pressure is higher (745 mmHg Torr).

In the TZCPT – CO_2 dispersion system during CCUS processes, physical sorption of CO_2 from flue gases in TZCPT will occur at 97.15°C and a pressure of P = 293 mmHg Torr (higher than for CPT at 96.35°C, and a pressure lower than for CPT at 636 mmHg Torr (Skhvitaridze et al., 2024)). Chemisorption occurs at 99.65°C and a pressure of P = 706 mmHg Torr (higher than for CPT at 95°C), and a pressure of P = 706 mmHg Torr, which is higher than the CPT pressure of 534 mmHg Torr). These results confirm that TZCPT exhibits excellent thermodynamic and sorption properties for CO_2 capture and pozzolanic activity, supporting its potential use in environmentally optimized cement production.

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თეძმის კლინოფთილოლითის თერმოდინამიკური ფუნქციები, დეჰიდრატაციისა და CO_2 სორბციით კარბონიზირების, ცემენტის რეჰიდრო-გაკირებითი პუცოლანიზაციის პარამეტრები ჯერ კიდევ არ არის შესწავლილი, რაც აფერხებს მის გამოყენებას ისეთ პროექტებში, რომელთა მიზანია ცემენტის დამზადებისას ატმოსფეროში ემისირებული CO_2-ის რაოდენობისა და კვალის შემცირება. კვლევა ითვალისწინებდა თეძმის ნედლი და დეჰიდრატირებული კლინოფთილოლითის თერმოდინამიკურ ფუნქცია-პარამეტრთა და ცემენტის გამყარებისას კალციუმის ჰიდროალუმოსილიკატთა წარმოქმნის შესაძლებლობათა პროგნოზირებას ანგარიშის მიახლოებითი მეთოდებით. კვლევების შედეგად თეძმის კლინოფთილოლითის უნარებია: წყლიანი მდგომარეობიდან უწყლოში გადასვლა; ფიზიკურ-ქიმიური სორბციით ტექნოლოგიურ პროცესში წარმოქმნილი CO_2-ის შთანთქმა; ცემენტის რეჰიდრო-გაკირებითი პუცოლანიზაცია და კარბონიზაცია; CO_2-ის კვალის შემცირება; ცემენტის ტექნოლოგიის ეკოლოგიზაციით გარემოს დაცვითი პრობლემების ხელშეწყობა.

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