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STUDYING THE COMPOSITION AND PROPERTIES OF USTYURT GYPSUM MINERALS OF THE REPUBLIC OF KARAKALPAKSTAN

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Abstract
This article is dedicated to the study of the chemical and physicochemical properties of gypsum minerals obtained from the gypsum deposits of the Ustyurt Plateau in the Republic of Karakalpakstan. The research focuses on exploring the potential applications of these gypsum minerals as high-quality raw materials in the industrial and construction sectors. During the study, energy dispersive X-ray fluorescence (EDRF) spectrometry, infrared (IR) spectroscopy, and thermal analysis techniques were employed to thoroughly investigate the composition and properties of the samples. The results demonstrate the purity and chemical stability of the gypsum, providing scientific insights into its dehydration and decomposition processes.2

Keywords: Ustyurt gypsum minerals, dehydration, thermal properties, chemical composition, phase transitions.

Introduction

In recent years, extensive scientific research has been conducted in Karakalpakstan to study local mineral raw material resources and their applications across various industrial sectors. To date, nine gypsum mineral deposits have been identified in Karakalpakstan. The gypsum and anhydrite reserves on the Ustyurt Plateau are situated in layers up to 4 meters thick and are widely exploited [1].

Gypsum ($CaSO_4 \cdot 2H_2O$) is a calcium sulfate dihydrate and is a widely occurring mineral in nature. Its theoretical composition by mass is as follows: CaO - 32.56%, SO_3 - 46.51%, and H_2O-20.93%. Gypsum has a compressive strength of approximately 80 MPa, a true density of 2.2-2.4 g/cm³, and an average bulk density of gypsum gravel between 1300-1600 kg/m³. On the Mohs scale, its hardness is rated as 2. The solubility of gypsum in water at 20°C is 0.2% as calcium sulfate, and at 100°C, it is 0.17%. The highest solubility is observed within the temperature range of 32°C to 41°C. Gypsum readily undergoes dehydration when heated to 100-105°C, partially or fully losing its crystalline water, a process linked to the positioning of water molecules between the lattice sites in the crystal structure, involving layers of Ca^{2+} ions and sulfate tetrahedra SO_4^{-2} [2].

According to regulatory documents, gypsum stone used for the production of binding materials must meet the following criteria: the first-grade raw material must contain at least 95% dihydrate gypsum, the second grade at least 90%, the third grade at least 80%, and the fourth grade at least 70% dihydrate gypsum [3].

Pure gypsum is white, but impurities can impart various colors. Iron oxides give the gypsum a yellow-brown hue, organic impurities a gray color, and so forth. Based on appearance and structure, gypsum is classified into several types: "gypsum spar," with large, transparent crystals; fine, silky, fibrous gypsum known as selenite; and granular gypsum; the purest form is referred to as alabaster [2].

Research is being conducted to develop binding materials for various purposes, capable of replacing imports, based on the local raw materials of Karakalpakstan. For these purposes, samples of gypsum minerals from the Ustyurt deposits were selected and studied.

Methods and Materials

To analyze the chemical and physicochemical properties of gypsum minerals from the Ustyurt Plateau, samples were collected from the Ustyurt gypsum deposits. The chemical composition of the samples was determined using the NEX DE (Japan) energy dispersive X-ray fluorescence (EDRF) spectrometer. This advanced analytical technique is highly suitable for analyzing the chemical composition of substances. Measurements were conducted in an air atmosphere without sample rotation, using a DE-10 mm diaphragm to focus the X-rays.

Infrared (IR) spectroscopy was conducted to determine the molecular composition and structural characteristics of the samples. The IR spectra were measured using a Fourier Transform Infrared spectrometer. Samples were mixed with KBr and compressed into pellets, with measurements carried out in the wavenumber range of 400-4000 cm^{-1}.

To determine the thermal properties of the samples, differential thermal analysis (DTA) and thermogravimetric analysis (TGA) were performed. These methods are essential for understanding the thermal behavior, phase transitions, and stability of substances under varying temperatures. DTA and TG measurements were conducted using the STA PT 1600 synchronous thermal analyzer manufactured by Linksys, Germany. The results of the analyses were presented in tables and graphical illustrations.

Results and Discussion:

The chemical analysis results of gypsum samples collected from the Ustyurt 1 and Ustyurt 2 gypsum deposits on the Ustyurt Plateau have revealed significant scientific insights. The analysis indicated that the primary components in the samples are SO_3 and CaO, confirming that these are high-quality gypsum minerals [4]. The mass percentages of SO_3 (Ustyurt 1: 44.92%, Ustyurt 2: 44.85%) and CaO (Ustyurt 1: 32.06%, Ustyurt 2: 31.37%) in the samples confirm the high purity of the gypsum. The presence of oxides such as SiO_2 and Al_2O_3 in the samples also affects the mechanical and chemical properties of the material (Table 1).

Table 1 Chemical Composition of Gypsum Minerals

Location	SO_3	CaO	Al_2O_3	SiO_2	Cl_2	Fe_2O_3	SrO	П.П.П	CO_2
Ustyurt 1	44,92	32,06	2.85	4.32	0.103	0.147	0.026	21.86	1.76
Ustyurt 2	44.85	31,37	2.64	2.44	0.1	0.09	0.03	16.89	3.14

The amount of SiO_3 in the sample from the Ustyurt 1 deposit is significantly higher compared to the sample from the Ustyurt 2 deposit, which may influence the hardness of the gypsum. Similarly, the

Al_2O_3 content is higher in the Ustyurt 1 sample than in the Ustyurt 2 sample, potentially affecting its thermal properties and resistance to chemical factors. Minor components such as Fe_2O_3, Cl_2, and SrO are present in small amounts in both samples. Although Fe_2O_3 is present in small quantities, it can still impact the color variations and strength properties of the gypsum [6].

The IR spectrum of the samples showed several characteristic absorption bands indicative of specific molecular vibrations within the gypsum system. The absorption bands at 1100 cm^{-1} in both samples are associated with sulfate (SO_4^{2-}) vibrations, confirming the presence of gypsum ($CaSO_4 \cdot 2H_2O$). The bands around 595 cm^{-1} and 667 cm^{-1} correspond to the bending vibrations of the sulfate group. The strong absorption bands observed around 3400 cm^{-1} and 3520 cm^{-1} are attributed to the stretching vibrations of hydroxide (OH^{-1}) groups, indicating the presence of water molecules within the gypsum crystal lattice (Figure 1).

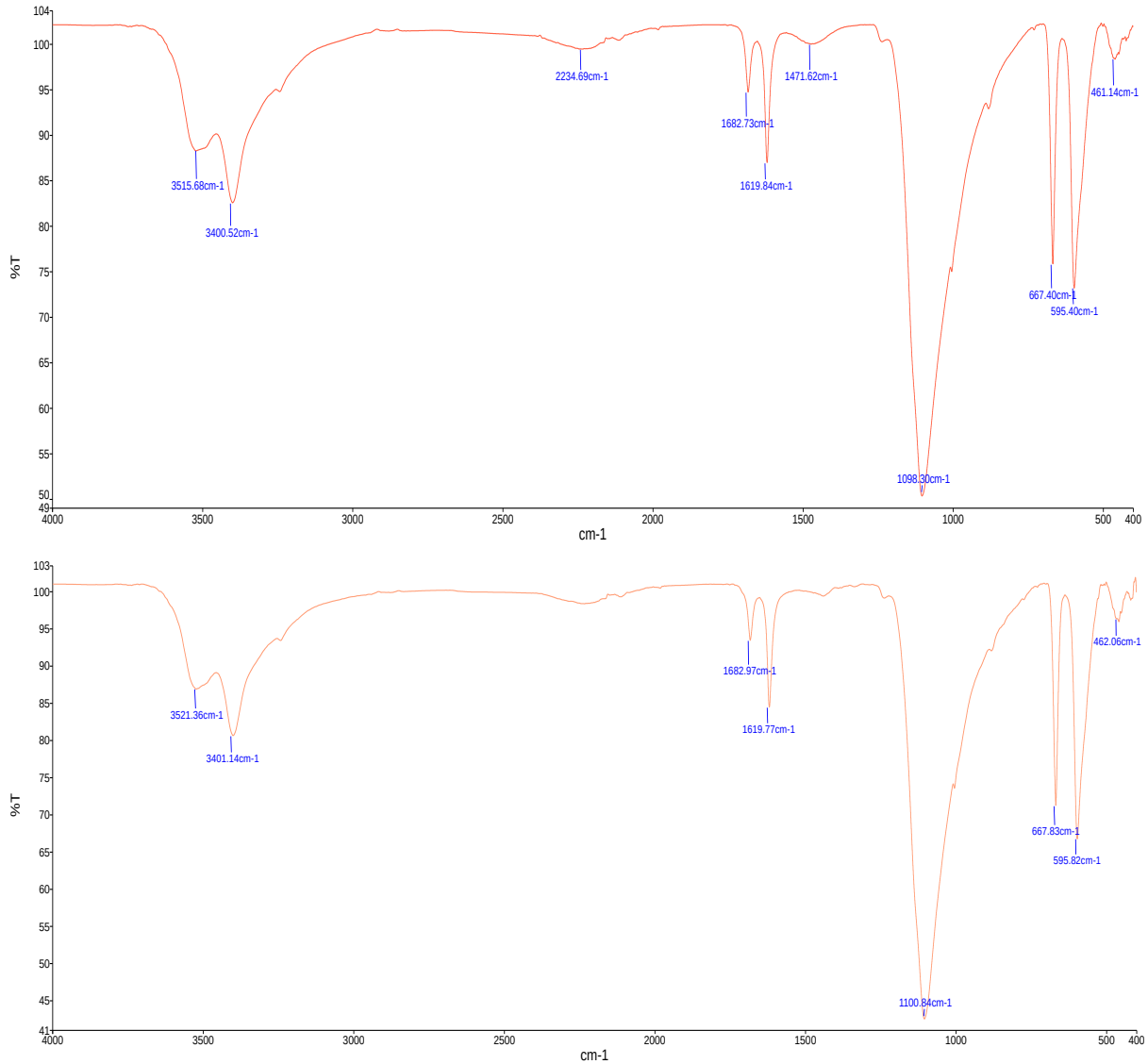

Figure 1. IR Spectrum of Ustyurt Gypsum Minerals
a) Ustyurt 1 b) Ustyurt 2

Spectral analysis identified slight differences between the two deposits. The Ustyurt 1 gypsum showed slightly higher absorption intensity at 1100.84 cm^{-1} compared to the Ustyurt 2 gypsum at 1098.30 cm^{-1}, indicating minor variations in the orientation or bonding environment of the sulfate

group. The observed absorption bands correspond to specific vibrational modes of gypsum and its impurities [5].

Differential thermal analyses (TGA and DTA) of the gypsum samples were conducted. The TGA and DTA results for the Ustyurt 1 gypsum sample are illustrated in Figure 2.

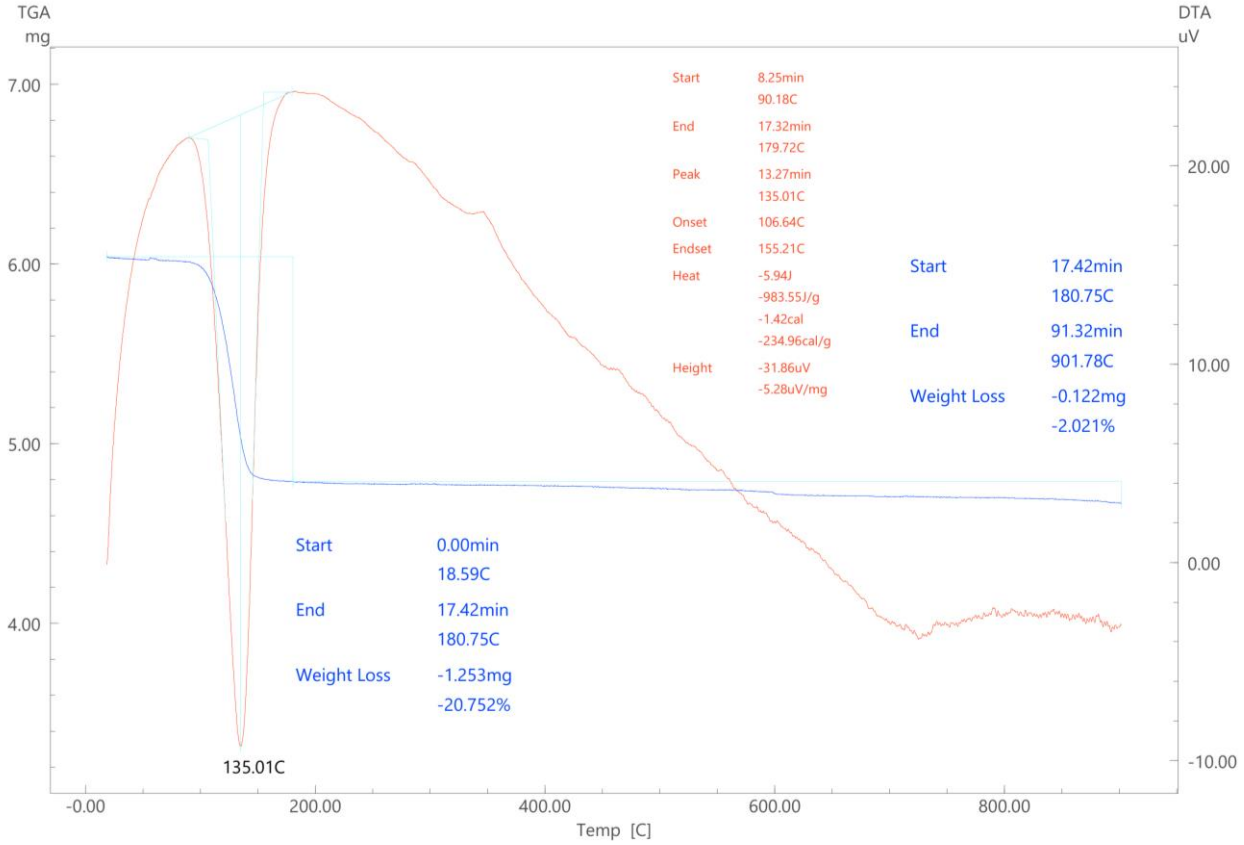

Figure 2. Thermal Analysis Graph of the Ustyurt 1 Gypsum Deposit

The thermal decomposition showed two primary mass loss stages. In the first stage, within the temperature range of 18.59°C to 180.75°C, the mass loss was 20.752%, indicating the dehydration process of gypsum. An endothermic peak was observed at 135.01°C on the DTA curve, associated with the loss of water molecules. This endothermic process absorbs 5.94 J of thermal energy, requiring 983.55 J/g of energy. The second mass loss stage occurred in the range of 180.75°C to 901.78°C, with a mass loss of 2.021%. This stage is related to the decomposition of calcium sulfate dihydrate into anhydrous calcium sulfate. The corresponding endothermic peak at 152.85°C indicates further dehydration processes.

The TGA and DTA results for the Ustyurt 2 gypsum sample also showed two-stage mass loss. The initial mass loss observed in the range of 16.21°C to 180.32°C resulted in a total mass reduction of 20.344% (Figure 3). This dehydration process is represented by an endothermic peak at 152.85°C on the DTA curve, absorbing 18.39 J of heat (980.41 J/g) [7].

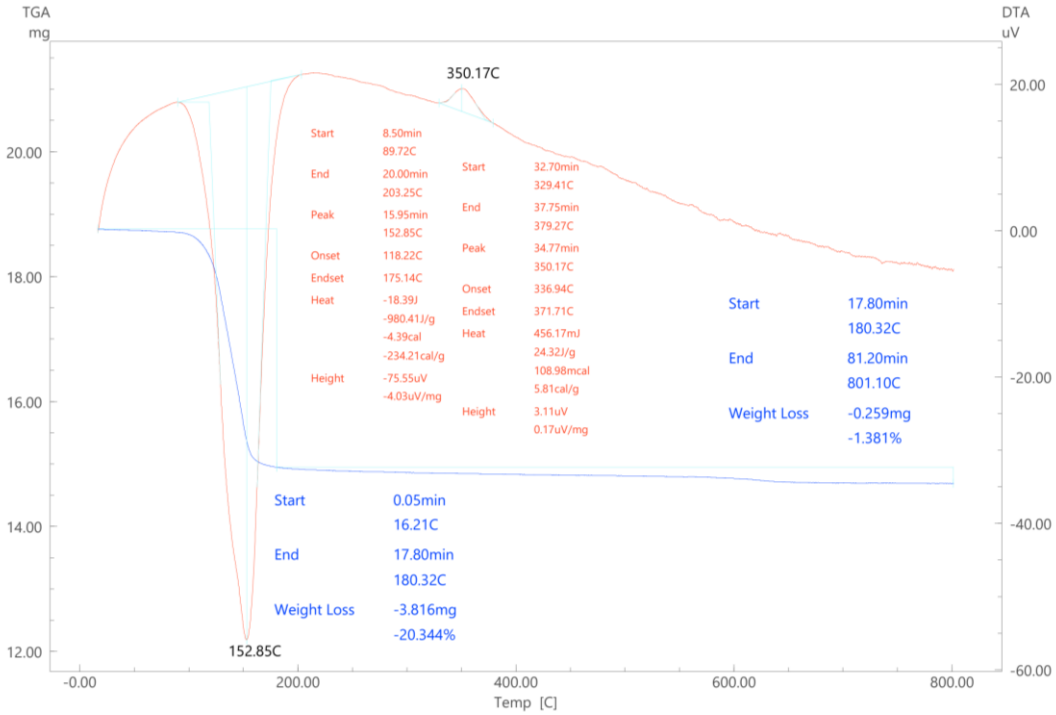

Figure 2. Thermal Analysis Graph of the Ustyurt 1 Gypsum Deposit

The second mass loss stage occurred in the range of 180.32°C to 801.10°C, resulting in a mass loss of 1.381%. The DTA results show a significant endothermic peak at 350.17°C, associated with a substantial phase change. At this peak, calcium sulfate dehydrates (decomposes) and releases heat (24.32 J/g).

The dehydration and thermal decomposition of gypsum samples from the Ustyurt 1 and Ustyurt 2 deposits exhibited similarities. Both samples showed significant mass losses at temperatures corresponding to the loss of water molecules and the transformation of gypsum into anhydrite. The DTA results indicated endothermic peaks associated with these changes, with the main peak observed at 135.01°C for the Ustyurt 1 sample and at 152.85°C for the Ustyurt 2 sample [8]. The slight differences in peak temperatures and heat absorption values suggest minor variations in the purity and crystal structure of the gypsum samples from the two deposits.

Conclusion

The gypsum samples collected from the gypsum deposits of the Ustyurt Plateau were analyzed for their chemical and physicochemical properties. The EDRF spectrometry results confirmed the presence of high amounts of SO_3 and CaO in the gypsum samples, indicating their high quality as gypsum minerals. The IR spectroscopy results identified the molecular vibrations of gypsum within the samples. Thermal analysis (DTA and TGA) results revealed the dehydration and thermal decomposition characteristics of the samples. These findings provide a significant scientific basis for the effective application of gypsum in construction materials technology. Additionally, the high purity and chemical stability of Ustyurt gypsum confirm its potential for widespread use in various industrial sectors.

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