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Synthesis and Structural Characterization of Sodium Aluminate Prepared via Combustion Method

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Abstract: ***In this study, sodium aluminate (NaA_5lO_8) was synthesized using a combustion method, a rapid and energy-efficient route for producing crystalline materials. The structural properties were analyzed using X-ray diffraction (XRD) techniques. The XRD pattern revealed sharp and intense diffraction peaks corresponding to the monoclinic phase of sodium aluminate, indicating high crystallinity and phase purity. The combustion method proved effective in achieving a homogenous product with well-defined crystalline structure. This study highlights the potential of combustion synthesis as a viable approach for producing high-purity sodium aluminate for applications in catalysis, wastewater treatment, and ceramics.***

Keywords: Sodium aluminate, Combustion synthesis, X-ray diffraction, Crystal structure, Phase analysis

1. Introduction

Sodium aluminate ($NaAl_5O_8$) is a prominent industrial compound used in a variety of applications such as water treatment, paper manufacturing, catalysis, and ceramics. Its utility is largely attributed to its basic nature and high reactivity in aqueous environments. Conventional methods for synthesizing sodium aluminate typically involve high-temperature solid-state reactions, which are often energy-intensive and time-consuming.

Combustion synthesis, also known as solution combustion or self-propagating high-temperature synthesis (SHS), has emerged as a cost-effective and rapid alternative for producing oxide materials. This method involves an exothermic redox reaction between a fuel and an oxidizer in an aqueous solution, resulting in the formation of the desired product within minutes. The high temperature generated during combustion promotes crystallization and phase formation, often eliminating the need for further calcination.

This work explores the synthesis of sodium aluminate via the combustion method and investigates its structural characteristics using X-ray diffraction (XRD). The study aims to demonstrate the effectiveness of this synthesis route and provide insight into the crystalline phase and purity of the product.

2. Experimental Procedure

2.1 Materials

All chemicals used in this study were of analytical grade and used without further purification. The precursors used for the synthesis of sodium aluminate were sodium nitrate ($NaNO_3$), aluminum nitrate nonahydrate ($Al(NO_3)_3 \cdot 9H_2O$), and urea ($CO(NH_2)_2$) as a fuel.

2.2 Synthesis via Combustion Method

Stoichiometric amounts of sodium nitrate and aluminum nitrate were dissolved in distilled water to form a clear solution. Urea was then added as a fuel to facilitate the combustion process. The homogeneous solution was heated in furnace at approximately 300°C in a ceramic crucible. Upon reaching the ignition temperature, a self-sustaining exothermic reaction took place, producing a voluminous white solid. The resulting product was allowed to cool naturally, then grind into a fine powder for characterization.

2.3 Characterization (XRD Analysis)

The crystalline phase of the synthesized sodium aluminate was examined using X-ray diffraction (XRD). The XRD analysis was conducted using Cu Kα radiation (λ = 1.5406 Å) over a 2θ range of 10° to 80° at a step size of 0.02°. The obtained diffraction pattern was analyzed to identify peak positions and match them to standard JCPDS data for sodium aluminate.

3. Results and Discussion

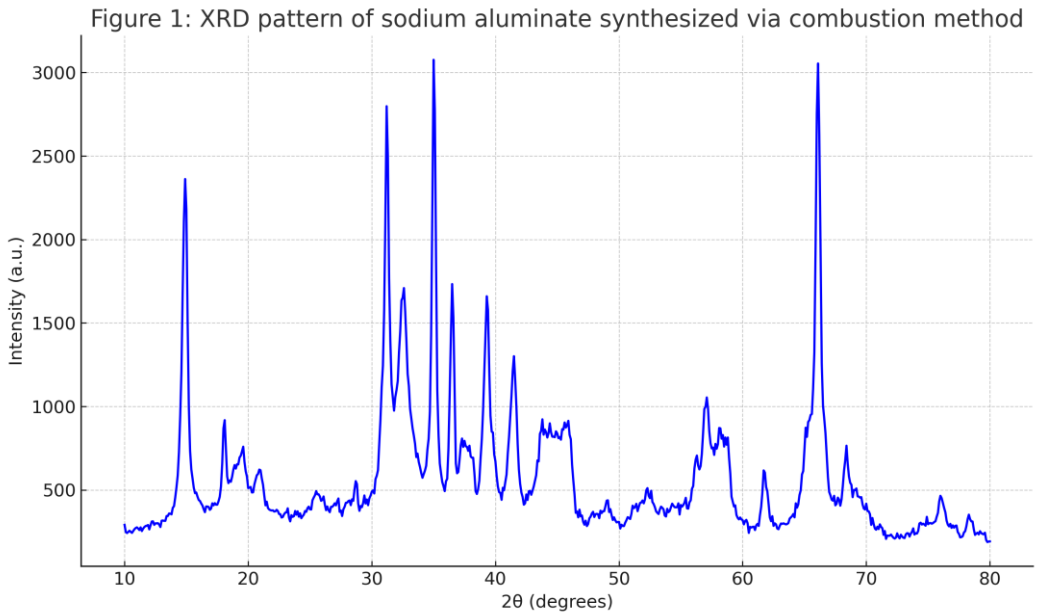

Figure 1: XRD pattern of sodium aluminate synthesized via combustion method.

Additionally, Figure 2 presents the Gaussian-fitted peaks which aid in identifying the individual crystalline components and peak broadening behavior.

The XRD pattern of the synthesized sodium aluminate is shown in Figure 1. The diffraction peaks observed at various 2θ values correspond well with the standard diffraction data for monoclinic sodium aluminate (NaA_5lO_8), as per JCPDS card no. 31-1262. The major peaks are observed at approximately 14.9°, 31.20°, 32.6°, 35.0°, 36.5°, 39.3°, 41.4°, and 66.8°, which confirm the formation of the intended phase. Several prominent peaks around 31^0-36^0 and 39-41^0 match closely with reported XRD patern of $NaAl_5O_8$, as indexed from JCPDS card no. 31-1262, which is characteristics of orthorhombic sodium aluminate structure.

The sharpness and intensity of the peaks indicate that the product is highly crystalline. The absence of secondary or unidentified peaks suggests that the synthesized material is phase-pure and free from significant impurities such as residual Al_2O_3 or Na_2CO_3. The high crystallinity can be attributed to the elevated temperatures achieved during the combustion process, which facilitate rapid nucleation and growth of crystal grains.

The broad baseline observed in the lower-angle region may be due to minor amorphous content or nano-sized domains, though the dominant features are consistent with a well-ordered crystalline structure. The combustion synthesis route has proven effective in yielding a single-phase sodium aluminate with strong crystallinity, eliminating the need for prolonged heat treatment.

Additionally, Figure 2 presents the Gaussian-fitted peaks which aid in identifying the individual crystalline components and peak broadening behavior.

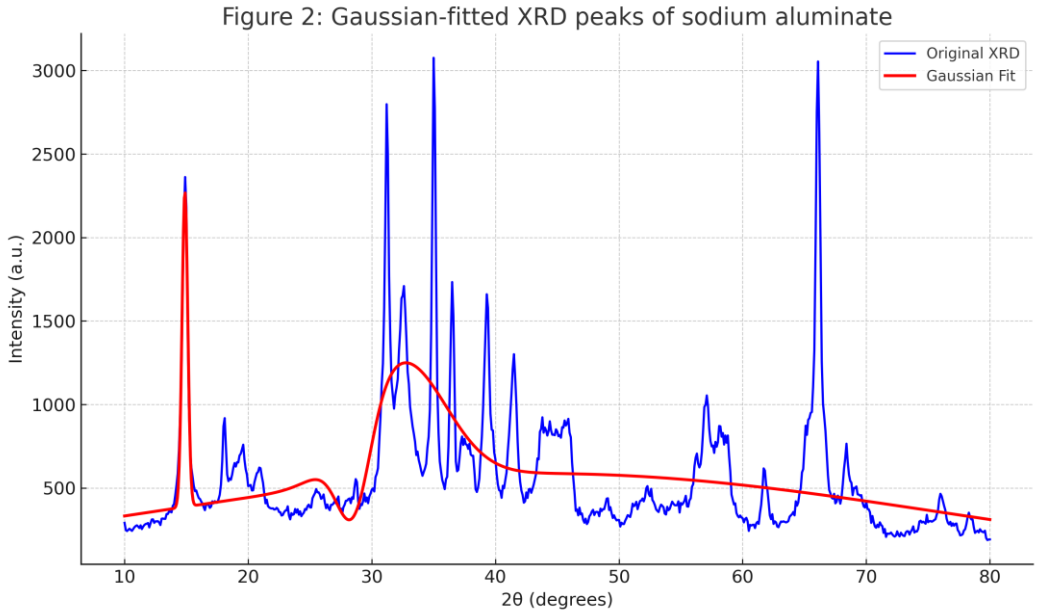

Figure 2: Gaussian-fitted XRD peaks of sodium aluminate.

4. Conclusion

Sodium aluminate ($NaAl_5O_8$) was successfully synthesized using a combustion method, demonstrating the technique's efficiency and simplicity for producing crystalline ceramic materials. The XRD analysis confirmed the formation of a highly crystalline, single-phase monoclinic structure without detectable impurities. The combustion synthesis route, due to its rapid reaction kinetics and self-sustaining nature, provides a cost-effective and energy-efficient alternative to conventional high-temperature solid-state reactions. This method holds promise for scalable production of sodium aluminate, particularly for applications in catalysis, wastewater treatment, and advanced ceramics.

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