EFFECTS OF SODIUM NITRITE ON STRUCTURE AND THERMAL PROPERTIES OF $LINO_3$-$NANO_3$-KNO_3 MOLTEN SALT FOR ENERGY STORAGE

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Abstract

The composition of a ternary nitrate containing potassium, sodium and lithium nitrates was investigated in this study, for evaluating its potential as a thermal storage material. Different mass fractions (4%-20%) of sodium nitrite were added into the binary and ternary nitrate elemental compositions. Raman spectroscopy analysis revealed that the ionic bonds between the cation and the nitrate, as well as bonds within the nitrate structure itself were modified by the presence of the sodium nitrite. In fact, for the potassium nitrate, the ionic bonds between the potassium ion, and the nitrate and those within the structure of the nitrate showed a shift towards the blue spectrum. On the other hand, for the sodium nitrate, the ionic bonds between the sodium ion and the nitrate and those within the structure of the nitrate exhibited a shift towards the red spectrum. The starting melting temperature and the thermal stability of the mixed nitrate were affected by the presence of the sodium nitrite. The starting melting temperature decreased from 110 ºC to 104 ºC with the increase of sodium nitrite weight proportion content. Under high temperatures, while increasing the sodium nitrite concentration from 1.87% to3.53%, a decrease in the thermal stability was noted.

Keywords

$NaNO_2$, Energy Storage, Molten salt, Raman spectra, Thermal stability.

Introduction

In the last few years, the public awareness regarding environmental protection issues has been constantly enhanced due to the alarming depletion of the fossil energy resources. Therefore, clean and renewable energy sources relying on natural power, e.g., wind and water power, solar, geothermal and tidal energy, are becoming of increasing importance for the future developments. The wind, water and tidal power sources are restricted by region since they depend on environmental conditions; while the Concentrated Solar Power (CSP) technology is a method of converting the thermal energy received from the sun into electrical power, and it can be applied in sunny regions. One can consider that the CSP is an endless source of clean and free natural energy.The Heat Transfer Fluid (HTF) that is used in the CSP technology is responsible for collecting and transferring the solar energy to the power systems. Therefore, the heat transfer medium directly affects the efficiency of the whole system.

In this work, the Raman spectra of $LiNO_3$-$NaNO_3$-KNO_3 ternary nitrate combined with different $NaNO_2$content proportions were measured to understand the structural changes. Also, thermal studies using differential scanning calorimetry and thermogravimetric analysis of these new mixtures were conducted to obtain their melting points and their maximum stability temperatures.

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Experimental procedure

Four different materials were used in the study: lithium nitrate, sodium nitrate, potassium nitrate and sodium nitrite. All of the experimental materials were analytical reagents.

The nitrates and nitrite were weighed in definite ratios and mixed using a mortar. The mixtures were heated to 300ºC using electrical heating furnace and their temperature was maintained during 30 min. Then the samples were cooled down to room temperature, and ground to powder form. Finally, the samples were stored in the dessicator.

Results and Discussion

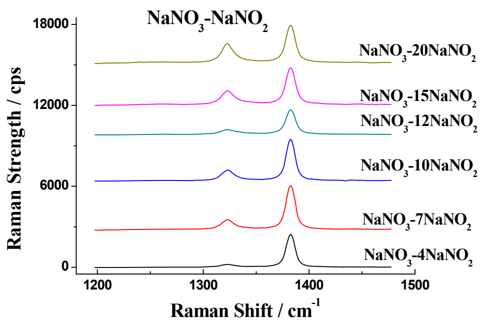

Figure 1. The variation of nitrate elemental Raman spectra for sodium nitrates with different sodium nitrite quantities

The results of the Raman elemental analysis of the nitrate compositions are shown in Figure 1. The characteristics of the spectra reveal the effect of the sodium nitrate on the nitrates that were used in this study.The characteristic peak of sodium nitrite appears on the spectra for sodium and potassium nitrates at amounts exceeding 4%, while in the lithium nitrate spectra, it starts to be detected for sodium nitrite quantities exceeding 15% of the total composition weight. The peak shifts move to lower frequencies for the sodium nitrate, and move to higher frequencies for the potassium nitrates. For the lithium nitrate, the effect of the nitrite is less obvious and requires relatively high quantities to be noticed.

Different mass fractions of 4%, 7%, 10%, 12%, 15% and 20% of sodium nitrite were added to the ternary nitrate. The Raman spectra of these mixed salts with different nitrite proportions are represented in Figure 2. For the wave numbers below 500 cm-1, the Raman shift is likely to be present but not clearly observed. Characteristic peaks of $NaNO_2$at 121 cm^{-1} and 160 cm^{-1} are not observed, probably due to the low concentration of $NaNO_2$ and the weak peak intensity in comparison with the whole spectrum.

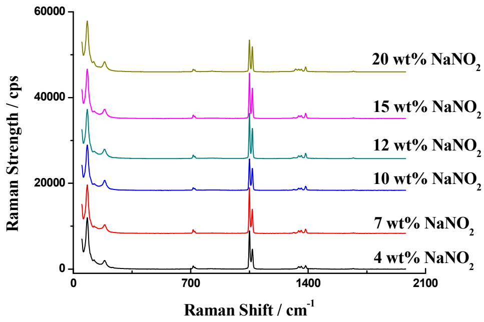

Figure 2. Raman spectra of mixed ternary nitrate salt with different mass proportions of $NaNO_2$nitrite

Conclusion

The Raman spectra and thermal stability were experimentally determined for the $NaNO_3$-KNO_3-$LiNO_3$ ternary system and for the ternary salts combined with sodium nitrite. When the content of sodium nitrite was high (20 wt.%), the corresponding characteristic peaks were observed in the Raman spectra. The typical operating temperature of the $NaNO_3$-KNO_3-$LiNO_3$ ternary system is between 130ºC and 530ºC. The melting temperature of mixed nitrate decreased with the increase in sodium nitrite, however, the weight loss of molten salt increased at high temperatures. Based on the analysis, when the mass fraction of sodium nitrite was 4%, the melting temperature of the molten salt was minimal, and the mass loss as well as the heat absorption capacity were relatively low.

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