Preprint

Short communication

Exploring Novel Combinations of Quaternary and Ternary Salts

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Abstract

The advancement of heat transfer fluids (HTFs) is crucial for improving the efficiency of solar thermal energy systems, particularly in concentrated solar power (CSP) plants. This short communication highlights recent research focused on novel quaternary and ternary nitrate-based salt mixtures as HTFs. These mixtures, characterized by enhanced thermophysical properties such as higher thermal conductivity, lower melting points, and increased specific heat capacity, represent a promising solution to the limitations of traditional binary salt systems. Experimental and comparative analyses reveal significant potential for these innovative HTFs to boost CSP system performance, aligning with sustainable energy goals and the UN's SDGs.

Introduction

The global shift toward renewable energy solutions has intensified the demand for efficient HTFs capable of storing and transferring heat effectively in CSP plants. Conventional binary nitrate salts, such as a mixture of sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3), are commonly used but exhibit limitations like relatively high melting points and moderate thermal conductivity. Recent advancements have turned attention to quaternary and ternary salt mixtures, which can provide superior properties for CSP applications [1-11].

The purpose of this communication is to present an overview of these recent innovations and their potential to revolutionize HTF technology, thereby enhancing CSP system performance and contributing to a more sustainable energy infrastructure.

Methodology

A review of experimental studies involving novel quaternary and ternary salt mixtures was conducted. The focus was on the thermophysical properties that directly impact the efficiency of CSP operations, including melting point, thermal stability, and specific heat capacity. Data was gathered from key research, such as [1-4] among others.

Key Findings

1. **Improved Melting Characteristics**: Quaternary nitrate salt mixtures (e.g., $NaNO_3$-KNO_3-$LiNO_3$-$Ca(NO_3)_2$) have demonstrated lower melting points compared to traditional binary salts. This property allows CSP systems to operate at lower startup temperatures, improving energy efficiency.

2. **Enhanced Thermal Conductivity**: The incorporation of nanoparticles such as Al_2O_3 and TiO_2 has been shown to significantly boost the thermal conductivity of these salt mixtures. Yasinskiy et al. (2018) highlighted that TiO_2-based nanofluids, when added to HTFs, enhanced heat transfer properties by up to 20%.

3. **Stability and Specific Heat Capacity**: Research into ternary salt systems, such as those containing sodium nitrate, potassium nitrate, and calcium nitrate, has shown promising results in terms of high specific heat capacity and stability at elevated temperatures. This is vital for maintaining efficient thermal storage over prolonged operational periods.

Discussion

The advantages of using quaternary and ternary salt mixtures as HTFs are numerous. Lower melting points and higher thermal conductivities reduce energy consumption during system startup and operation, while improved heat capacity enhances the energy storage potential of CSP systems. These advancements also align with the UN's Sustainable Development Goal 7 (affordable and clean energy), as they promote a shift to more efficient and sustainable energy sources.

However, while these innovative HTFs show promise, challenges remain. Long-term stability under repeated thermal cycling, potential corrosion issues with storage tanks and pipelines, and the cost of incorporating nanoparticles must be addressed through continued research and development. Life cycle analyses and cost-benefit assessments are essential to determine the commercial viability of these advanced HTFs.

Conclusion

Quaternary and ternary salt-based HTFs, particularly those enhanced with nanoparticles, represent a significant advancement in the field of renewable energy technology. By offering improved thermal properties, these innovative mixtures can support the development of more efficient CSP plants, thereby contributing to global efforts to achieve sustainable energy solutions. Further research into long-term stability and economic feasibility will be crucial for transitioning these innovations from the laboratory to large-scale applications.

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