33870 Molten Chloride Thermophysical Properties, Chemical Optimization, and Purification

A KCl-$MgCl_2$-NaCl ternary molten chloride salt could be purified and optimized to suit Gen3 CSP applications

1. Impact

The project is one of the first to systematically investigate a candidate chloride salt composition that can potentially be used by Gen3 molten chloride CSP. All the scientific knowledge obtained from the project can be translated to the engineering know-hows for the industry to design a molten chloride based CSP plant with key materials properties, corrosion behaviors, etc.

2. Project Goal

The primary goal of the project is to develop a salt handling/preparation/characterization guideline that the domestic and international CSP research community can use to test the Gen3 CSP concept as well as sub-components.

3. Method(s)

The team was first focused on initial understanding of the salt dehydration and purification chemistry and developing the analytical titration method to quantify the key impurity MgOHCl. The team then leveraged the learned knowledge and concentrated the efforts on further optimizing the purification method, understanding corrosion behaviors, and measuring the thermophysical properties with multiple partners to ensure the consistency, reliability and reproducibility of the measured properties.

4. Outcome(s)

With dehydrate carnallite, we were able to achieve major corrosion reduction from >1000 µm/year to < 100 µm/year with addition of elemental Mg. The corrosiveness is found to be directly correlated to the MgOHCl content as measured by analytical titration.

With anhydrous carnallite, the team developed a purification protocol that can consistently produce salt with ≤ 0.1 wt.% of MgOHCl and a melting point of ~400°C.

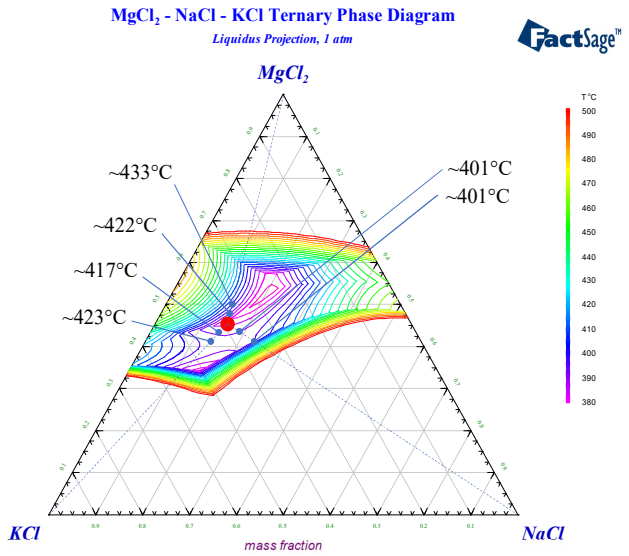
The salt melt's density, heat capacity, viscosity, vapor pressure, thermal diffusivity and conductivity were all measured in the temperature range relevant to Gen3 CSP operation (i.e., 500°-720°C).

5. Conclusion/Risks

Using anhydrous carnallite (AC) as a more premium-grade carnallite from ICL with lower water content is found to be essential in simplifying system and subcomponent design because of lower risks of corrosion damage during salt preparation. Measured thermophysical properties are provided to the Gen3 molten salt pathway community for system and subcomponent design. The key findings are (1) most properties are not very sensitive to a composition shift (within a few wt.%), and (2) vapor pressure is considered a major source of risk because the risk has not been identified before and no more information is available.

6. Team

NREL, University of Arizona, University of Wisconsin-Madison, ICL Innovation ltd., Albemarle, Sandia National Laboratories, Argonne National Laboratory.



NaCl-KCl-MgCl2 phase diagram showing the locations of the baseline salt (red dot) and the six off-baseline compositions (blue dots) with their approximate liquidus temperature based on DSC measurements. The colored contours indicate the liquidus temperatures calculated by FactSage.