

High Quality Molten Salt Property Measurements

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Advanced Reactor Technologies Program
Molten Salt Reactors Campaign Program Review
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Objectives

- MSR developers require high quality (NQA-1) data to design, license and operate their reactors
 - Data needed is either unavailable or literature values are conflicting
 - All data available is of insufficient quality
- Performing high-quality measurements to expand the database of relevant binary and ternary mixtures available to developers and modelers
- Systems being measured include:
 - Coolant salts: LiF-NaF-KF and LiF-BeF₂
 - Fuel-bearing salts: NaF-UF₄, NaCl-UCl₃ and NaCl-KCl-UCl₃
 - Round robin salts: LiF-NaF-KF and NaCl-KCl
- Actively engaging with industry, discussing their data needs for MSR development

Thermochemical and thermophysical Property Measurements

- Composition and impurity contents
 - As batched masses and spectroscopic methods
- Phase transition temperatures and specific heat
 - Differential scanning calorimetry
- Density, volume expansion coefficient and surface tension
 - Hydrostatic method
- Viscosity
 - Rotational method
- Thermal diffusivity and thermal conductivity
 - Laser flash analysis

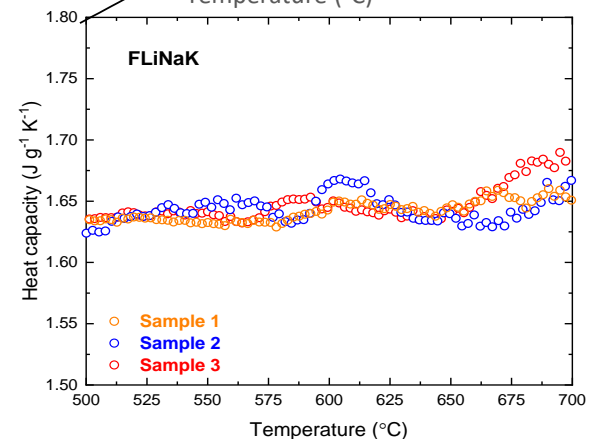
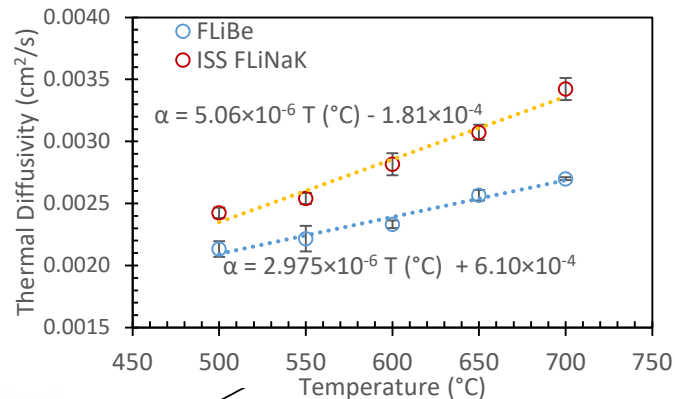
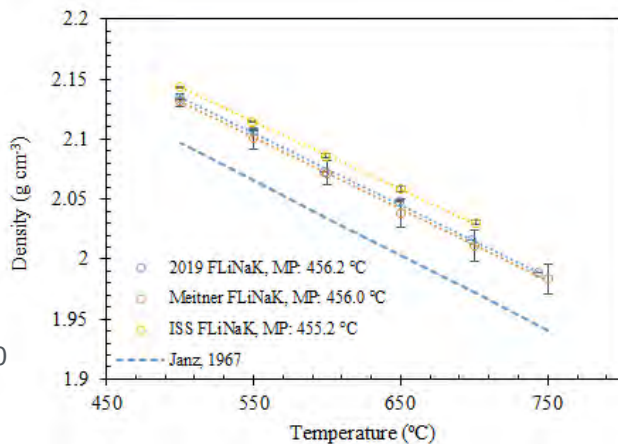
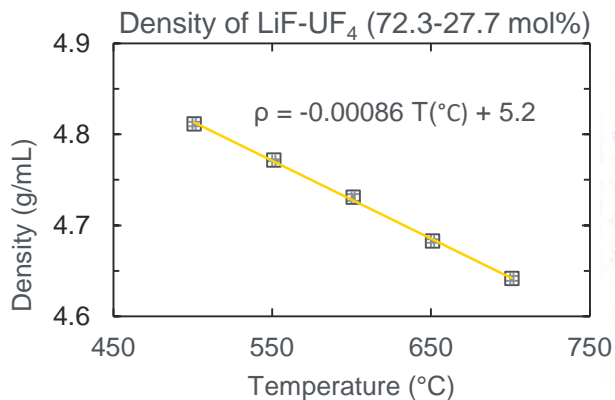
Summary of FY21 Accomplishments

- Measured properties of two coolant salts using improved methods and quality control
- Participated in the MSTPWG Round Robin
- Conducted FactSage™ modeling to determine the compositions in NaCl-KCl-UCl₃ ternary system to be analyzed
- Replicate measurements of same salt batches and across different salt batches made to distinguish effects of variance in salt composition from measurement uncertainty

Sample Measurements

Systematically determined the influence of experimental factors on measured values

- Carefully controlling environmental factors
- Measuring and reporting salt and impurity compositions
- Applying appropriate calculation methods and corrections



Sharing our capabilities and data with developers

“Molten Salt Modeling, Thermophysical Measurements, and Database Development” at the 2019 Chemistry and Corrosion Workshop at ORNL

“Viscosity Measurements in a Molten Salt” at the 2020 Molten Salt Thermal Properties Working Group Workshop (held virtually July 2020)

“Argonne’s Molten Salt Property Measurements” at the 2020 MSR Developer Workshop at ORNL (held virtually in October 2020)

“Measuring Thermophysical Properties of Molten Salts” at 2019 GLOBAL Conference in Seattle, WA

Documenting measured data and technique improvements

“Salt Production and Analysis in Support of the MSR Campaign” –submitted in PICs March 2020

“Thermochemical Property Measurements of FLiNaK and FLiBe in FY 2020”- submitted in PICs Nov. 2020

“Thermophysical Property Measurements: Improved Density, Viscosity and Thermal Diffusivity Methods”
– Submitted in PICs Nov. 2020

“Production and Chemical Analysis of NaCl-KCl- UCl_3 Salts” – submitted in PICs Feb 2021

Milestones for FY21

High Quality Molten Salt Property Measurements

Milestone Number	Title	Status
M4AT-21AN0705011	Production and chemical analysis of NaCl-KCl-UCl ₃ salts	Delivered On-Time 2/26/21
M3AT-21AN0705017	Measurement Precision for Reference Salt	8/31/21
M3AT-21AN0705016	Report results of property measurements NaCl-KCl-UCl ₃ salts	10/29/21

All Milestones On Schedule

Future Direction

- Measure properties of priority salt compositions in the MSTDB
- Quantify effects of impurities (oxygen, water, corrosion products) on property values
- Quantify the effects of soluble fuel elements and fission products on property values
- Quantify the solubilities of fuel constituents, fission products, and impurities

Funding Timeline

- FY2019 \$170K MSR to measure properties of salt provided by ORNL and develop database
- FY2020 \$425K MSR to measure properties of FLiNaK, FLiBe, NaCl- UCl_3 and NaF- UF_4
- FY2021 \$340K MSR to measure properties of two compositions of NaCl-KCl- UCl_3 , and measure a reference salt

3 Year Plan and Budget Request

Significance of research: This work provides quality property data for salt mixtures relevant to design and licensing of MSR's.

- FY 2022 \$600K
 - Measure thermophysical and thermochemical properties of Pu-containing chloride and fluoride salts (\$450K)
 - Develop and implement emissivity and vapor pressure methods for molten salts (\$150K)
- FY 2023 \$650K
 - Measure properties of simulated irradiated salts
 - Quantify the effect of ingrowth of impurities including oxygen and water
 - Quantify the effect of soluble fuel elements and fission products on property values
- FY 2024 \$650K
 - Measure solubilities of fuel elements and fission products in standard salts
 - Measure properties of Pu-containing salts of interest to developers

OVERVIEW

Purpose: Provide properties of MSR-relevant salts to support reactor design and safety analyses.

Objectives:

Develop methods to measure property values of actinide-bearing salt mixtures
Measure sensitivities of property values to salt composition, impurities, irradiation, and the ingrowth of fission products
Establish methods to assess quality of property data, precision and bias

Logical Path:

- Develop and implement methods to measure thermal properties of U- and Pu-bearing salt mixtures batched from reagent salts.
- Develop technically sound approaches to analyze measured data and determine property values and uncertainties

Outcomes:

- Documented methods, controls, results, and derived property values in project reports.
- Quantify uncertainties due to composition, measurement, and analysis techniques.
- Promulgate methods through programmatic presentations and reports, and consensus standards.

DETAILS

Principal Investigator: Melissa Rose

Institution: Argonne National Lab

Collaborators:

FY 2022 Total Funding Requested: 600k

3 scenarios

- \$600K measure properties of Pu-bearing salts and develop and implement emissivity and vapor pressure measurements
- \$450K Measure properties of Pu-bearing salts
- \$150K Measure emissivity and vapor pressure of non-rad salts

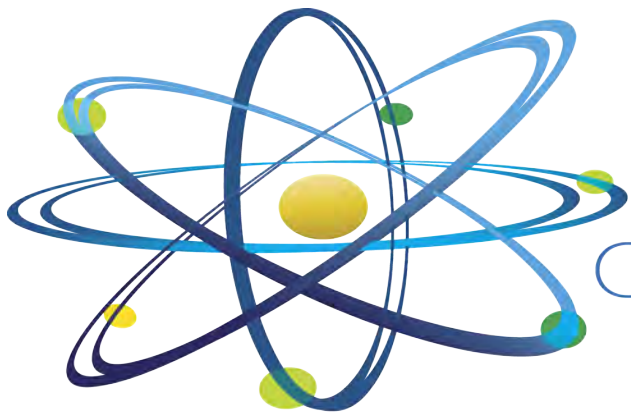
DELIVERABLES

Milestones

M3 Properties of Pu-bearing chloride and fluoride salts

M3 Emissivity and vapor pressure measurement methods and data for molten salts

Journal papers on measurements for molten salts of interest to developers
Present at MSR developer workshop, MSTPWG Workshops, and any additional relevant conferences to engage with MSR developers on data needs



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