Density Measurements of Molten Salts using Two-Electrode System

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Table of Contents

- Measurements and estimation of densities for molten salt
- Two-electrode system
- Volume-height calibration curves construction
- Density measurements of multi-component fluorides
- Possible uncertainties from this methodology

Estimation of Densities for Molten Salts

- Density is a fundamental thermophysical property of matter.
  - Factor of dimensionless numbers in fluid mechanics
  - The Archimedean method has been actively used for density measurements.
- Theoretical calculation for densities of ideal mixtures

$$\frac{1}{\rho_{mixture}} = \sum_i \left(\frac{w_i}{\rho_i}\right)$$

where w_i: weight fraction and ρ_i: supercooled density of each component.

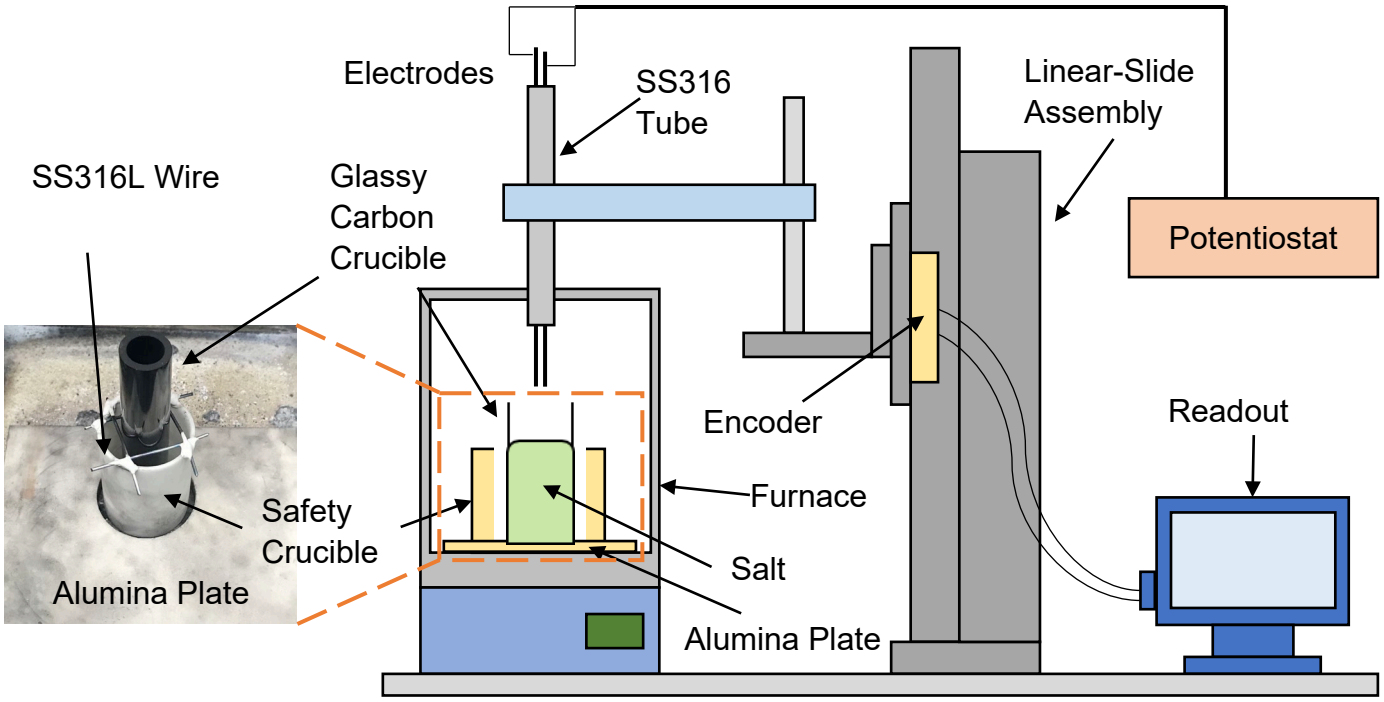
- Components of mixtures have higher melting points than the mixtures [1]:
  - LiF: 1121 K, NaF: 1266 K, KF: 1131 K
  - LiF-NaF-KF (FLiNaK): 727 K
- Previous studies revealed that the theoretical calculation showed 2% deviation or less from actual measurements [2], [3].

[1] Janz, G., Tomkins, R., Physical Properties Data Compliations Relevant to Energy Storage, the Secretary of Commerce (1981)
[2] Gallagher, R. et al., J. Chem. Eng. Data, vol. 67 (2022)
[3] Mariani, R, Vaden, D., J. Nucl. Mater., Vol. 404 no. 1 (2010)

Two-Electrode System for Density Measurements

- A two-electrode system with a linear slide was developed to calculate densities of fuel salts by measuring heights of the salt samples.
- This system was inspired by the two-electrode system developed by Zhang and Simpson [4].

Density-measurement system developed by this study



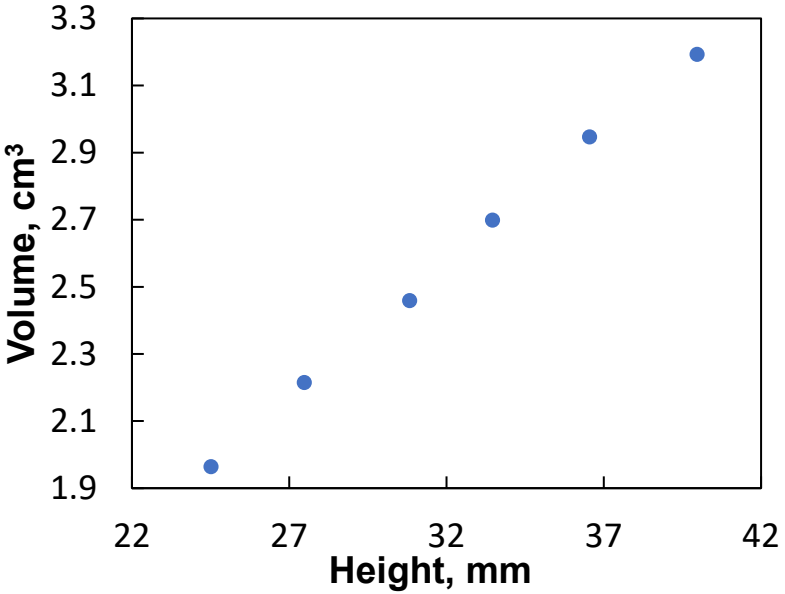
[4] Zhang, C., Simpson, M., Journal of Nuclear Fuel Cycle Waste Technology, 15, 2 (2017)

Volume-Height Calibration Curves

- Volume-Height calibration curves were constructed by measuring heights of FLiNaK samples with different masses at selected temperatures.
- Corresponding volumes of samples for each temperature were calculated using a $\rho - T$ correlation of FLiNaK (Chrenkova et al., 2003)

$$\rho = 2.4089 - 6.24 \times 10^{-4} T$$

- Measured volumes and heights were plotted on coordinate planes.



Volumes and heights of FLiNaK obtained at 873 K

[5] Chrenkova, M. et al., Journal of Molecular Liquid, 102/1-3 (2003)

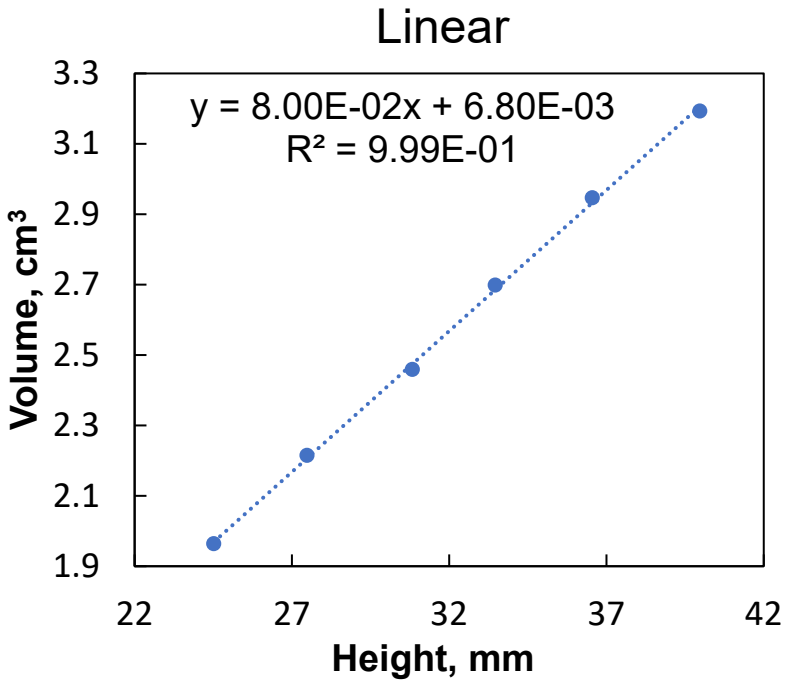
Selection of the Best Model

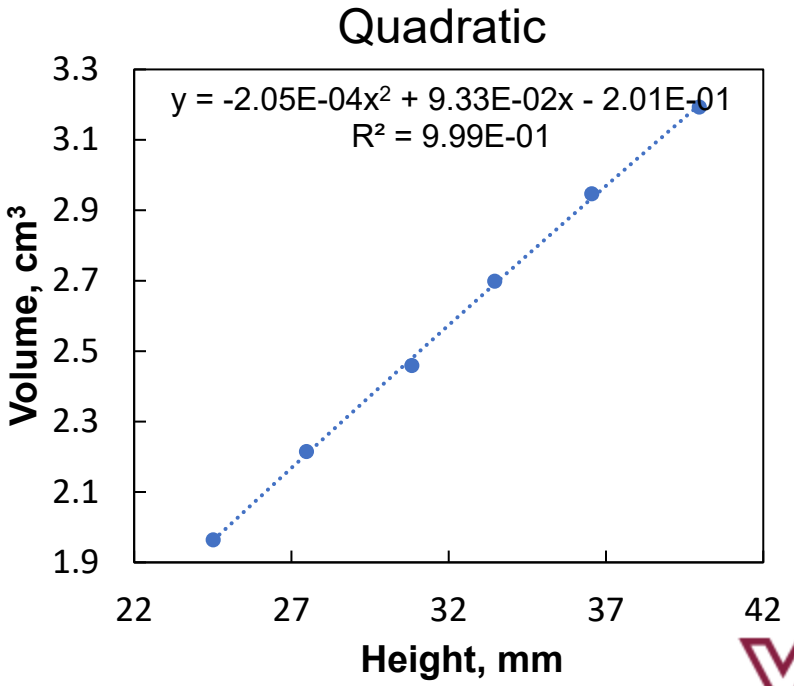
- Corrected Akaike's Information Criterion (AICc) Analysis

$$\mathrm{AICc} = n \ln \frac{SSE}{n} + 2K + \frac{2K(K+1)}{n-K-1}$$

where SSE : sum of squared error, n: size of samples, K: total number of estimated regression parameter

- Linear correlations were selected for all temperatures.

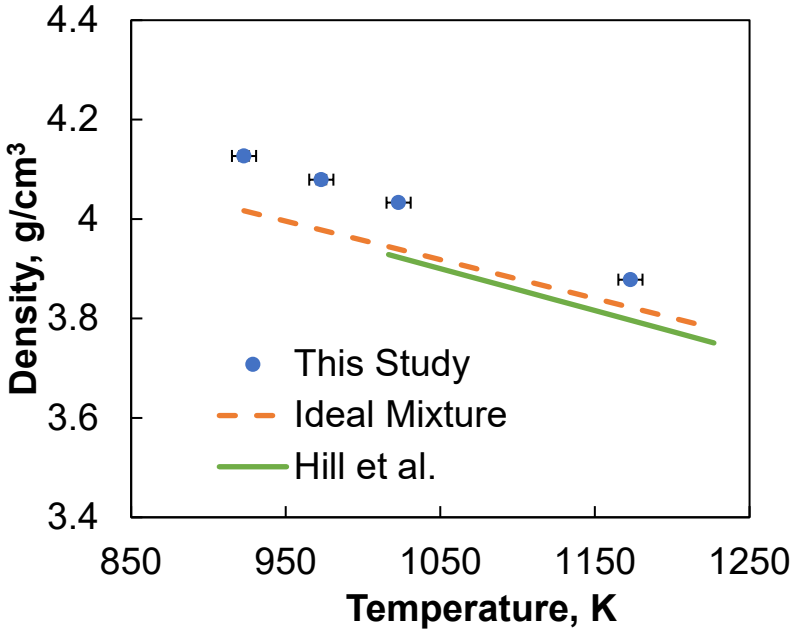




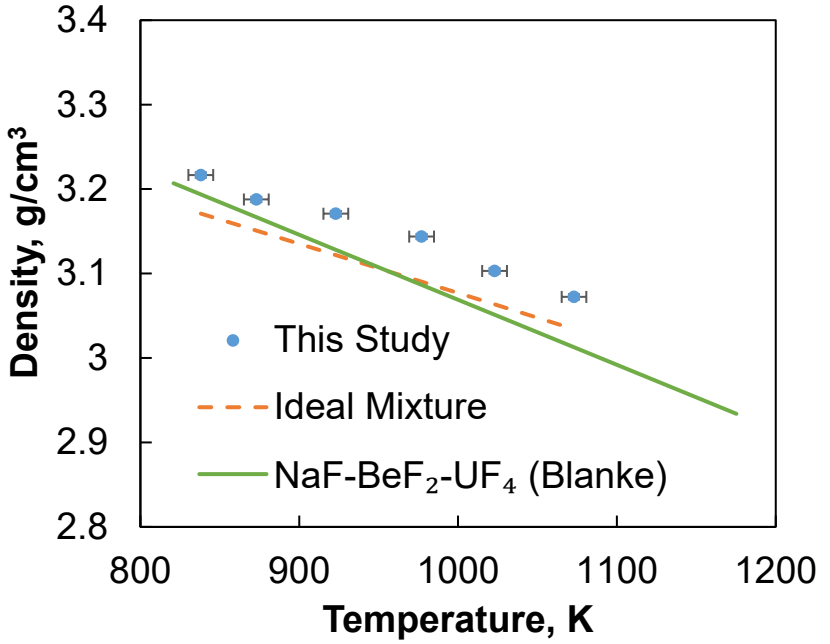
Densities of Multi-Component Fluorides

- Different systems of molten salts were used to measured their densities including LiF-ThF_4, LiF-ThF_4-UF_4, NaF-KF-UF_4, NaF-BeF_2 and NaF-BeF_2-UF_4-ZrF_4.
- Measured densities of those salts were comparable to ideal-mixture values, showing deviations around 2% or less.
- The measured densities were also comparable to data from previous studies.

LiF-ThF_4 [6]



NaF-BeF_2-UF_4-ZrF_4 [7]



[6] Hill et al., J. Inorg. Nucl. Chem., 29 (1966)
[7] Blanke, B., Comments on Viscosity and Density Measurements ORNL CF 55-11-14 (1955)

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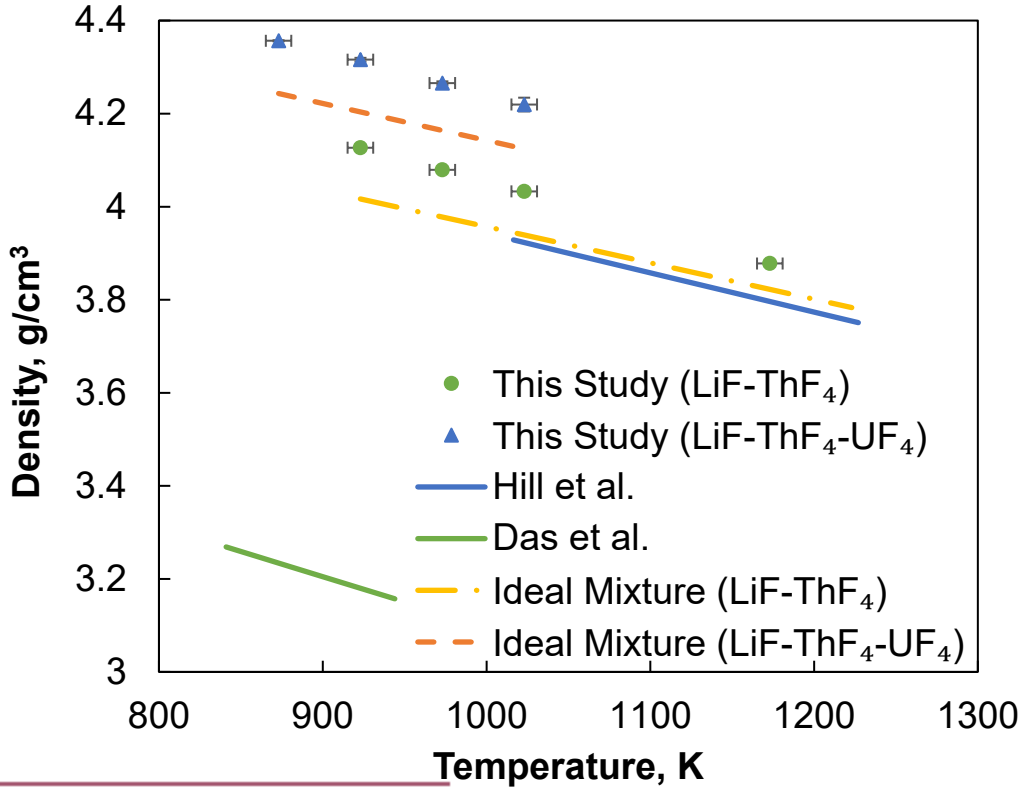
Densities of Multi-Component Fluorides

- Measured densities of LiF-ThF_4, (80-20 mol%) were comparable to data reported by Hill et al. [6].
- Measured densities of LiF-ThF_4-UF_4 (77.50-19.95-2.55 mol%) were deviated from data reported by Das et al. [8].
- Considering comparable LiF/ThF_4 ratios of those two salts, data from this study might be more reliable.



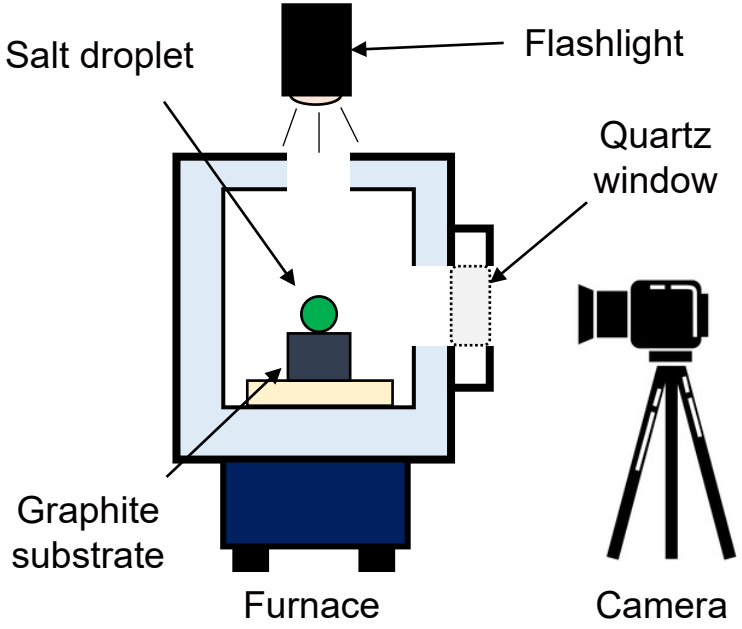
Densities of LiF-ThF_4 and LiF-ThF_4-UF_4

[8] Das, P. et al., J. Fluor. Chem., 226 (2019)

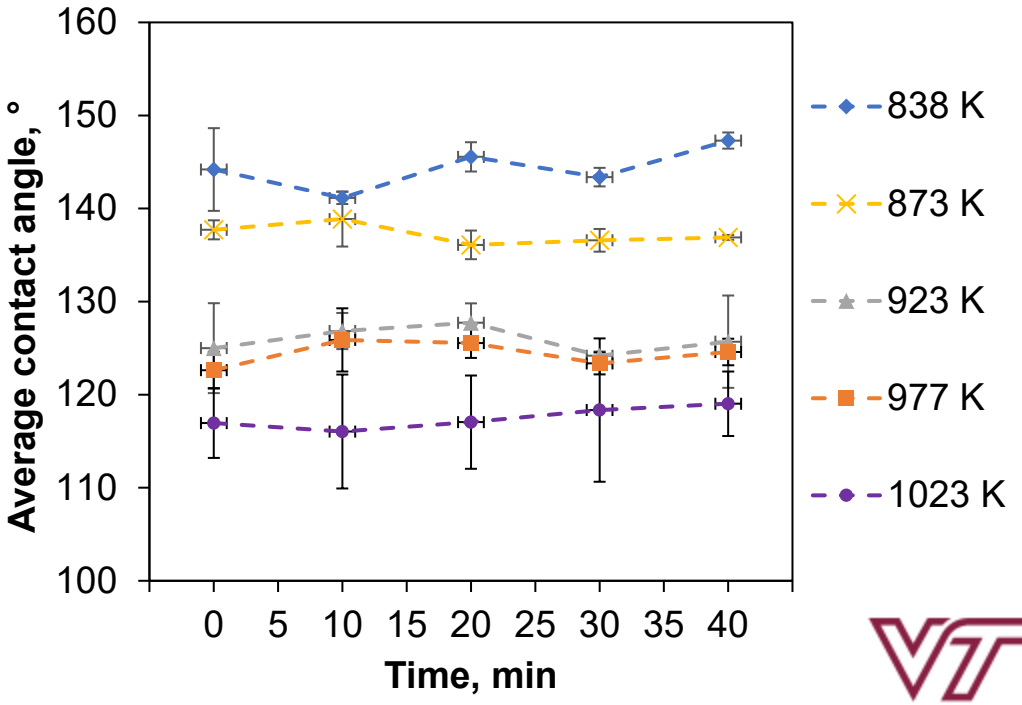
Uncertainties from Surface Convexity

- FLiNaK can have different surface convexity in the glassy carbon crucible from other fluoride salts, which might cause uncertainties of measurements.
- He et al. reported that the contact angle of FLiNaK on graphite at 923 K was 135° [9] which was comparable to that of NaF-BeF_2-UF_4-ZrF_4 measured in this study.

Contact-Angle Measurement Setup



Contact Angles of NaF-BeF_2-UF_4-ZrF_4



[9] He, Z. et al., Carbon 84 (2015) 511-518

Thank you!

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