Viscosities of UCl_3-LiCl-KCl Molten Salts

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1. INTRODUCTION

Physical properties of high-temperature molten salt such as the viscosity, electrical conductivity, and density are very critical in designing and operating a pyroprocess. Such properties also provide important information with regard to the process operation and nuclear material accountancy. Among the many valuable physical properties, viscosity is one of the most important physical properties providing information regarding the transport properties of molten salts comprising various actinide and lanthanide elements in the pyroprocess.

However, not all commercially available measurement systems are adequate for measuring the viscosity of high-temperature corrosive molten salts [1]. Recently, we developed a new viscosity measurement system installed inside a glove box, and controlled using custom-made software based on the C# program [2].

2. EXPERIMENTAL

To develop a rotational viscometer system capable of operating on a high-temperature molten salt in a glove box under an argon atmosphere, a specially-designed viscosity measurement system is constructed using a low-viscosity LVDV-II+ Brookfield viscometer, an electric furnace capable of heating up to 900 K and keeping the temperature constant, and a special one-touch quick connector in order to mount a spindle onto the viscometer.

Software for instrument control and data acquisition was installed in a computer system for high-temperature operation after customization. The control program is capable of controlling the temperature of the electric furnace, and the torque value is displayed in real time allowing the device to be stabilized. This was designed to automatically conduct ten measurements repeatedly, and confirm the results in real time; it can therefore detect the influence of fine particles.

3. RESULTS & DISCUSSION

If a rotational Brookfield viscometer is used, the device constant values corresponding to the specific type of device and a spindle must first be determined before measuring the viscosity of the molten salt sample. Because a custom-manufactured spindle is used for corrosive and high-temperature molten salts, the spindle constant must be determined using a viscosity standard solution.

First, torque (τ_q) values in percent between 0 and 100 were measured at a specific rpm using a viscosity standard at room temperature, and the spindle constant value (C_{sm}) can then be obtained using Eq. (1) because the spring torque constant (C_t) of an LVDV-II+ Brookfield viscometer is given by the manufacturer.

$$\eta = \frac{100}{rpm} \times C_t \times C_{sm} \times \tau_q \qquad (1)$$

Once the value of C_{sm} is known, the viscosity for an unknown sample can be determined by measuring τ_q using the identical Eq. (1).

$$T_c = -0.0032 \times T_m^2 + 4.9499 \times T_m - 123.1 \qquad (2)$$

However, because the effect of the axial temperature gradient inside the vessel in a hot furnace on the viscosity measurement system cannot be elucidated accurately, a temperature correction equation (2) was obtained from the calibration curve with pure KNO_3 molten salt, whose viscosity at each temperature is well known.

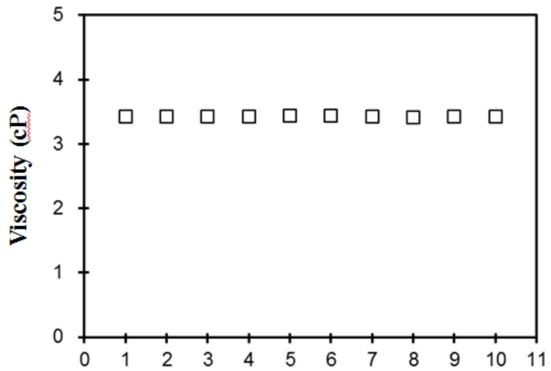

Fig. 1. Viscosities of 3 wt% UCl_3 dissolved in LiCl-KCl eutectic melt at 773 K for ten repetitive measurements.

Fig. 1 shows the results of measuring the viscosity of high-temperature eutectic LiCl-KCl molten salt containing 3wt% of UCl_3. The average and standard deviations for ten repetitive measurements were 3.43±0.02 cP at 773 K.

4. CONCLUSIONS

A rotational high-temperature viscosity measurement system was developed for the corrosive molten salts at or above 700 K. The pure KNO_3 molten salt was used as a calibration standard for the temperature correction for the accurate measurement at high temperatures. The average viscosity of uranium in a high-temperature molten salt was 3.43 cP ±0.02 cP at 773 K for 3wt% UCl_3. In a future study, various compositions of LiCl-KCl molten salt containing uranium and other lanthanide elements such as lanthanum, cerium, and neodymium will be examined to understand the viscous behavior of a multi-component molten salt system.

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