Electrochemical Properties and Analyses of CeCl₃ in LiCl-KCl Eutectic Salt
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Thermodynamic and electrochemical properties of cerium in LiCl-KCl eutectic salt have been measured and studied at different concentrations (0.5 – 4 wt%) and temperatures (698 K – 798 K) via both cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) techniques as a part of developing a fundamental understanding and methodology in materials detection and accountability for pyroprocessing technology. CV experiments were performed to determine the diffusion coefficient and apparent standard potential of CeCl₃ on the tungsten working electrode. The diffusion coefficient was calculated by using Delahay equation, and ranging from 0.48 × 10⁻³ to 1.01 × 10⁻³ cm² s⁻¹. Results reveal that the calculated diffusion coefficient of CeCl₃ in the salt follows the Arrhenius temperature relationship and it is weakly affected by the changes in concentration of CeCl₃. The apparent standard potentials were calculated from peak potentials showing linear relationship with temperature. Exchange current density values of Ce⁺/Ce couple in the salt were obtained from EIS experiments, ranging from 0.0076 A cm⁻² to 0.18 A cm⁻². The results indicate that these values follow Arrhenius temperature dependence and increase when CeCl₃ concentration increases.

Pyroprocessing technology has been proposed as another promising method for the recovery and recycle of uranium and actinide elements from the used nuclear fuel. An essential step in this technology is the electrorefining process in which uranium is selectively recovered by using solid cathodes in chloride-based molten salt at high temperature. The co-recovery of uranium and transuranic elements can be accomplished by replacing the solid cathodes with a liquid cadmium cathode because the reduction potentials of the elements become close when the liquid cadmium is used as a cathode electrode. Since uranium is the major element in most nuclear fuel cycle paths as well as pyroprocessing technology, the assessment of accurate thermochromical data for the element in the molten salt is extremely important.

Many studies on the thermochemical properties of uranium have been done in LiCl-KCl molten eutectic salt in different temperature ranges. Masset et al. investigated diffusion coefficients of actinides and lanthanides in LiCl-KCl via cyclic voltammetry (CV) and chronopotentiometry (CP). Kuznetsov et al. studied the electrochemical behaviors of actinides and rare-earth metals in LiCl-KCl salt. They performed CP and chronoamperometry (CA), and linear sweep voltammetry to determine the diffusion coefficients. Hoover et al. in 2014 extended the uranium concentration in LiCl-KCl molten salt up to 10 wt% and observed the electrochemical and thermodynamic behaviors of uranium using CV, CP, and anodic striping voltammetry. These data are valuable to a development of kinetic models, which can be useful for understanding the main features of actinide electrodeposition at the electrode surface, and also for prediction of material distribution in an electrorefiner of a safeguarding aspect. Zhan developed a kinetic model for electrorefining system showing that the model is capable of predicting the kinetic features and material fluxes of nuclear materials in the electrorefiner.

However, an exchange current density of uranium, which is essential to the physic-based model, has not been well measured and understood due to challenges of the measurement. Only few studies on the exchange current densities of uranium in LiCl-KCl have been published. Choi et al. in 2009 performed a linear polarization method in LiCl-KCl at 773 K and reported the exchange current density of uranium ranging from 0.3 to 0.5 A cm⁻². Later, Ghosh and co-workers reported that the exchange current density of uranium is 8 ± 2 mA cm⁻², by measurements of Tafel plot. Rose et al. in 2015 measured the exchange current density of uranium from Tafel plot, ranging from 69.5 ± 9 to 220 ± 32 mA cm⁻². These literature results, a meaningful comparison of the reported data is not possible owing to the dispersed values of the exchange current density of uranium. This may be due to challenges of measuring reliable slope on Tafel plot and electrode surface area where uranium deposition occurs. Therefore, further studies must be conducted on measurement of the exchange current densities of uranium.

These aforementioned challenges provide a motivation for this study to investigate another element that may exhibit similar uranium characteristic and to establish proper electrochemical techniques that can be applied toward uranium. Cerium is one of the common elements to be used as a surrogate material for uranium. The main reason is that cerium has similar ionic size with uranium, and its reduction potential is closer to uranium than other lanthanide materials. Therefore, cerium was selected for the purpose of developing methods to evaluate the electrochemical and thermodynamic properties of uranium in the molten salt. Several studies on the electrochemical behaviors of cerium in the molten salt at high temperatures have been conducted. In 1998, Iizuka conducted CP to determine diffusion coefficient of CeCl₃ at different temperatures. Marsden and Pesic in 2011 measured apparent standard potentials and diffusion coefficients of CeCl₃ by CV. They also determined the exchange current densities of CeCl₃ using the linear polarization method.

Thus, the main goal of this work is to measure and analyze thermodynamic and electrochemical properties of CeCl₃ in LiCl-KCl eutectic salt at different concentrations and temperatures using two methods: 1 CV for measuring the diffusion coefficients and apparent standard potentials and 2 electrochemical impedance spectroscopy (EIS) for determining the exchange current densities. This study will provide useful insight into these properties with a unique feature of EIS technique by reducing uncertainty of electrode area measurement because very small current is applied at around an open circuit potential.

**Experimental**

The electrochemical experiments were performed in an argon-atmosphere glove box, as shown in Figure 1a. The oxygen and water concentrations were monitored and maintained below 0.5 ppm (Figure 1b) for all the experiments. Within the glove box, a Kerrlab melting furnace (Figure 1c) was used to melt and maintain the electrolyte at the desired temperatures. The electrochemical measurements were performed using a VSP-300 potentiostat/galvanostat from Biologic Science Instrument (Figure 1d) at five different temperatures (698, 723, 748, 773, and 798 K). Figure 2 shows the experimental setup within the furnace. The LiCl-KCl-CeCl₃ electrolyte was loaded in a tapered alumina crucible (Coorstek, 99.8% Al₂O₃). This alumina...
crucible was placed in a secondary crucible designed to contain any molten salt upon possible failure of the primary crucible. Once the salt was melted, the cathode, anode, and reference electrodes were lowered into the salt through the alumina oxide sheaths. The salt temperature was monitored via an inserted thermocouple (see Figure 2).

Anhydrous lithium chloride (LiCl) and potassium chloride (KCl) (99.995%) were purchased from Alfa Aesar, and then mixed to prepare a LiCl-KCl (58.2:41.8 in mol%) eutectic salt. The amount of cerium chloride (0.102, 0.42, and 0.84 g) was added into 20 g mol% CeCl$_3$ (equivalent to 0.5, 2, and 4 wt% of CeCl$_3$ in LiCl-KCl salt), respectively. Silver chloride (Alfa Aesar, 99.998%) and cerium metal chips (Sigma-Aldrich 99.9%) were used as reference and counter electrode, respectively.

Tungsten rod (1.5 mm and 2 mm in diameter) was used as the working electrode. The length of the working electrode submerged into the salt was measured, and the measured surface areas were ranging from 0.32 cm$^2$ to 0.63 cm$^2$ depending on experimental runs. Prior to using the counter electrode, an oxide layer on the cerium chips was eliminated using sand paper under argon environment. The cerium chips were then loaded in a molybdenum basket and lowered into the prepared salt. Silver-silver chloride (Ag/AgCl) reference electrode was prepared by contacting a 1 mm Ag wire with LiCl-KCl-5 mol% AgCl in a 7 mm diameter Pyrex tube. At the tip of the Pyrex tube, the thickness of the wall was made thin enough (less than 0.5 mm in thickness) allowing ionic conduction between the solution and electrolyte. Prior to each experiment, the working electrode was anodically cleaned by stripping at a potential of −0.1 V versus the reference electrode for 3 minutes. Then, an open circuit potential (OCP) was checked to ensure the equilibrium condition has reached in the system. It should be noted that all salts were dried at around 523 K for 5 hours to remove possible moisture despite having the salt in sealed glass ampoules under argon prior the melting processes. The furnace was heated at 5 K/min to avoid thermal shock on the alumina crucible.

Figure 1. Experimental setup and instruments. (a) Innovative Technology argon atmosphere glove box, (b) Oxygen and moisture display by sensor in the glove box, (c) Kerrlab furnace, (d) VSP-300 potentiostat/galvanostat, Biologic Science Instrument.

Results and Discussion

Cyclic voltammetry (CV) of the LiCl-KCl-CeCl$_3$ system.— The CV technique was first applied to the pure LiCl-KCl system to identify that no other reaction occurs in the range between 0 V and −2.5 V versus Ag/AgCl reference. The voltammogram of pure LiCl-KCl (in Figure 3) shows that Li reduction starts at −2.55 V (vs. 5 mol% Ag/AgCl). No red-ox reaction between 0 to −2.4 V was observed and residual current in that region was less than 2 mA. Therefore, it was safe to perform the CV experiments over that potential range without worry from other reactions. Figure 4 shows the cyclic voltammograms of CeCl$_3$ (0.5 wt%, 2 wt%, and 4 wt%) in LiCl-KCl at 773 K. Cerium reduction and oxidation peaks were observed at around −2.2 and −2.09 V versus Ag/AgCl reference electrode, respectively. For 2 wt% CeCl$_3$, the peak potentials stay at the same potential under different scan rates representing the reversibility of the reaction in the range of the scan rate. However, the peak potentials move slightly in the negative direction according to the scan rate when the concentration of CeCl$_3$ was increased to 4 wt%. This may be considered as a quasi-reversible reaction. The difference between peak potential and half peak potential can be used to calculate the number of electron transferred by the following expression,

\[
E_p - E_{\frac{1}{2}} = -0.77 \frac{RT}{nF}
\]

where $E_p$ is the peak potential (V), $E_{\frac{1}{2}}$ is the half peak potential (V), $R$ is the universal gas constant (J mol$^{-1}$ K$^{-1}$), $T$ is the absolute temperature (K), $F$ is the Faraday constant (C mol$^{-1}$), and $n$ is the number of electrons transferred. The calculated number of electron transferred, $n$, was ranging from 2.5 to 3.1 agreeing with the expected value for the reduction process of Ce$^{4+}$/Ce. The cathodic peak currents were plotted with respect to the square root of the scan rate to avoid thermal shock on the alumina crucible.

Figure 3. Cyclic-voltammogram of pure LiCl-KCl eutectic salt at 773 K at the scan rate of 0.1 V s$^{-1}$. Tungsten rod (2 mm in diameter) was used as cathode electrode, and the surface area was 0.471 cm$^2$. 

Figure 2. Schematic sketch of the experimental setup of all electrochemical experiments.
calculate diffusion coefficient of CeCl$_3$ in LiCl-KCl using Delahay equation which is known for soluble-insoluble process:

$$i_p = 0.611 \times FSC_0 \left( \frac{nFSD}{RT} \right)^{1/2}$$  \[2\]

where $i_p$ is the peak cathodic current (A), $S$ is the electrode area (cm$^2$), $C_0$ is the bulk concentration of CeCl$_3$ (mol cm$^{-3}$), $v$ is the scan rate (V s$^{-1}$), and $D$ is the diffusion coefficient (cm$^2$ s$^{-1}$). Here, the concentration of CeCl$_3$ (mol cm$^{-3}$) is a function of temperature. The diffusion coefficient of CeCl$_3$ was determined at different concentrations, as indicated in Figure 5. Small decrease of the values could be observed by increasing concentration from 0.5 wt% to 2 wt%; however, the diffusion coefficients of CeCl$_3$ in LiCl-KCl salt were approximately the same between the concentration of 2 and 4 wt%. Present study shows smaller values for the diffusion coefficients comparing with those from Marsden and Pesic and Iizuka. But these values possess a similar trend. The diffusivity generally follows Arrhenius temperature relationship, which can be expressed as

$$D = D_0 \exp \left( \frac{-E_a}{RT} \right)$$  \[3\]

where $D_0$ is the pre-exponential factor, and $E_a$ is then an activation energy (kJ mol$^{-1}$) for the diffusion. Therefore, the activation energy can be calculated from the slope when ln(D) is plotted versus 1/T. The values of R-squared between the fitted regression lines and experimental points were all greater than 0.96 indicating a good fit to the data sets. Table I lists the diffusion coefficients of CeCl$_3$ and the average activation energies with different temperatures at three different concentrations.

From the cyclic voltammogram, the apparent standard potential of CeCl$_3$ was calculated from the cathodic peak potentials. For a reversible soluble/insoluble system, the cathodic peak potential can be expressed as

$$E_p = E^0_{Ce^{3+/2+}} \left( \frac{RT}{nF} \right) \ln \left( \frac{X_{CeCl_3}}{X_{CeCl_3}^0} \right) - 0.854 \left( \frac{RT}{nF} \right)$$  \[4\]

where $E_p$ is the peak potential (V) obtained from the cathodic side in this case, $X$ is the mole fraction, and $E^0_{Ce^{3+/2+}}$ is the apparent standard potential. The apparent standard potentials versus Cl$^-$/Cl$_2$ reference electrode were calculated by using the potential difference between Ag/AgCl (5 mol%) and Cl$^-$/Cl$_2$ reference electrode from

![Figure 4. Cyclic-voltammogram of CeCl$_3$ in LiCl-KCl at 773 K at scan rates of 0.05, 0.1, 0.15, and 0.2V s$^{-1}$: (a) 0.5 wt% CeCl$_3$, with a working electrode (tungsten) area of 0.534 cm$^2$. (b) 2 wt% CeCl$_3$ with a working electrode (tungsten) area of 0.6283 cm$^2$. (c) 4 wt% CeCl$_3$ with a working electrode (tungsten) area of 0.3240 cm$^2$.](image1)

![Figure 5. Plots of diffusion coefficient of Ce$^{3+}$ versus inverse temperature at different CeCl$_3$ concentrations (0.5, 2, and 4 wt%).](image2)
the double-layer capacitance and \( W \) is the diffusion related resistance (Warburg).

A frequency ranging from 50 kHz to 50 mHz was used, and the applied potential amplitude was set at 10 mV. Figure 8 shows impedance spectra for 0.5 wt% of CeCl\(_3\) in which the potential was gradually increased from the equilibrium potential (−2.169 V). In general, an impedance should be measured at an equilibrium potential to properly calculate \( i_0 \). However, at the equilibrium potential, the impedance swiftly increases at the high frequency and downward distortion was observed at low frequency as shown in Figure 8 because no ion transfer can occur between the tungsten electrode and cerium ions. Therefore, minimum overpotentials (\( \eta = 1–5 \) mV) was applied to the cell for the cerium reduction to occur at the electrode surface. For example, in Figure 8, by increasing \( \eta \) from equilibrium potential, a transition point can be observed at −2.172 V (open circles in Figure 8), where also a diffusion related impedance (Warburg impedance) started to be seen at low frequency region. This indicates that electrons transfer and diffusion from the bulk salt to the electrode surface started to occur at that potential. In this case, current density flows through the EIS experiment was only less than 1.5 mA cm\(^{-2}\) at that potential. In this case, current density flows through the EIS experiment was only less than 1.5 mA cm\(^{-2}\) at that potential. Therefore, minimum \( \eta \) for Ce\(^{3+}/\)Ce reduction to occur were confirmed by OCP measured right after the EIS experiments. After performing EIS at the potential of −2.172 V, OCP was maintained at the equilibrium potential for 500 s while OCP was released from the double-layer capacitance and \( W \) is the diffusion related resistance (Warburg).

The measured and fitted impedance spectra of Ce\(^{3+}/\)Ce for the three different concentrations of CeCl\(_3\) at the different temperatures are indicated in Figure 9. Instead of using capacitance and Warburg impedance, constant phase element (CPE) was introduced, which is

\[
Z_{CPE} = \frac{1}{T(j\omega)^\beta}
\]  

[5]

Table I. Diffusion coefficients (D) measured from CV experiments and activation energy (\( E_a \)) at different concentrations and temperatures.

| CeCl\(_3\) | 0.5 wt% | 2 wt% | 4 wt% |
|---|---|---|---|
| T [K] | D \([10^{-9} \text{ cm}^2 \text{ s}^{-1}]\) | \( E_a \) [kJ mol\(^{-1}\)] | D \([10^{-9} \text{ cm}^2 \text{ s}^{-1}]\) | \( E_a \) [kJ mol\(^{-1}\)] | D \([10^{-9} \text{ cm}^2 \text{ s}^{-1}]\) | \( E_a \) [kJ mol\(^{-1}\)] |
| 698 | 0.479 | 0.430 | 0.418 |
| 723 | 0.545 | 0.547 | 0.544 |
| 748 | 0.653 | 0.675 | 0.672 |
| 773 | 0.751 | 0.690 | 0.700 |
| 798 | 1.012 | 0.875 | 0.860 |
| 700 | 720 | 740 | 760 | 780 | 800 | -3.16 | -3.14 | -3.12 | -3.10 | -3.08 | -3.06 |
| Potential [V] | 700 | 720 | 740 | 760 | 780 | 800 | -3.16 | -3.14 | -3.12 | -3.10 | -3.08 | -3.06 |
| Temperature [K] | \( 0.5 \) wt% | \( 2 \) wt% | \( 4 \) wt% | \( 0.5 \) wt% | \( 2 \) wt% | \( 4 \) wt% | \( 0.5 \) wt% | \( 2 \) wt% | \( 4 \) wt% | \( 0.5 \) wt% | \( 2 \) wt% | \( 4 \) wt% |

Figure 6. Plot of apparent standard potentials versus temperature.

Figure 7. Equivalent circuit for the electrochemical cell showing bulk solution resistance, double layer capacitance, charge transfer resistance, and diffusion related resistance.

Figure 8. Nyquist plot for 0.5 wt% of CeCl\(_3\) in LiCl-KCl at 723 K on a tungsten electrode. The frequency was from 50 kHz to 50 mHz, and the applied potential was 10 mV. Applied potentials were ranging from −2.169 to −2.174 V with an equilibrium potential of −2.169 V.
where $T$ is a constant in $F \cdot cm^{-2} \cdot s^{\phi - 1}$, $\phi$ is the number constant between $-1$ and $1$, and $\omega$ is the frequency. CPE is useful in fitting the equivalent circuit because it can represent resistor, inductor, capacitor, Warburg response, and combination of these impedances by changing the value of $\phi$. First, the measured spectra were automatically fitted by using randomize and simplex method in Z-fit software (Bio-Logic), then a manual adjustment was done by changing the values of the equivalent circuit components. As the manual curve fitting was performed, the relative error could be minimized below a fraction of $10^{-1}$. The measured $R_{ct}$ and $\eta$ are summarized in Table II. From the measured $R_{ct}$, $i_0$ can be readily computed by using  

$$R_{ct} = \frac{RT}{nF\phi} = \frac{RT}{n^2F^2Sk^{1-\alpha}_{\text{CeCl}_3}}$$

where $k^0$ is the rate constant for Ce$^{3+}/$Ce, and $\alpha$ is the transfer coefficient of Ce$^{3+}/$Ce. From the measured charge transfer resistance, $k^0$ can be calculated by assuming $\alpha$ is 0.5 based on the observation from CV experiments that Ce$^{3+}/$Ce reaction follows reversible behaviors with a weak diffusion effect (at slow scan rates). Table III summaries $i_0$ and $k^0$ calculated from $R_{ct}$. Figure 10 plots the exchange current densities of Ce$^{3+}/$Ce reaction which can be characterized with concentrations and temperatures. The results indicate that the exchange current densities with 0.5 wt% of CeCl$_3$ are in between 0.0076 A cm$^{-2}$ and 0.016 A cm$^{-2}$, agreeing well with repeated experimental runs. By increasing the concentration of CeCl$_3$ to 4 wt%, the exchange current density appears to increase up to 0.18 A cm$^{-2}$. Marsden and Pesic reported the exchange current density of CeCl$_3$ at 4 wt% concentration using the linear polarization method. The values of $i_0$ from this study are slightly higher, but both studies show similar range of values for the exchange current density of CeCl$_3$ in LiCl-KCl salt.

Based on the given data sets, Arrhenius temperature dependence form can be applied to further looking into temperature effects on the exchange current density using the expressing  

$$i_0 = I_0 \exp(-E_a/RT)$$

where $I_0$ is the pre-exponential factors (often referred to as an exchange current density at an infinite temperature). Figure 11 shows a plot of the logarithm of $i_0$ against the inverse temperature. Here, a straight line can be seen for all three different CeCl$_3$ concentrations. $E_a$ and $I_0$ were calculated from the slope of the straight lines and the intercept of ln $i_0$, respectively. $E_a$ values for Ce$^{3+}/$Ce were 34.5, 30.9, and
Table III. Calculated exchange current density ($i_0$) and rate constant ($k_0$) for the charge transfer at different concentrations and temperatures.

| CeCl$_3$ | 0.5 wt % | 2 wt % | 4 wt % |
|----------|-----------|--------|--------|
| T [K]    | $i_0$ [A cm$^{-2}$] | $k_0$ [$\times 10^5$ cm s$^{-1}$] | $i_0$ [A cm$^{-2}$] | $k_0$ [$\times 10^5$ cm s$^{-1}$] | $i_0$ [A cm$^{-2}$] | $k_0$ [$\times 10^5$ cm s$^{-1}$] |
| 698      | 0.0076    | 0.450  | 0.058  | 1.71   | 0.086  | 1.69   |
| 723      | 0.0091    | 0.536  | 0.068  | 1.99   | 0.107  | 2.20   |
| 748      | 0.0103    | 0.610  | 0.088  | 2.57   | 0.112  | 2.44   |
| 773      | 0.0137    | 0.817  | 0.098  | 2.88   | 0.146  | 3.03   |
| 798      | 0.0158    | 0.944  | 0.113  | 3.33   | 0.177  | 3.69   |

32.4 kJ mol$^{-1}$ ($R^2 > 0.98$) for 0.5 wt%, 2 wt% and 4 wt%, respectively. These values are similar to the activation energy for U$^{3+}$/U measured by Roes et al.,$^{13}$ which is 34.5 kJ mol$^{-1}$. As expected, higher activation energy is required for the charge transfer at lower concentration of CeCl$_3$. Interestingly, the activation energy values from the diffusion coefficients shown in Table I are within similar range in comparing to those for the charge transfer, but behave in an opposite trend. That is, the activation energy for the diffusion increases with increasing the concentration of CeCl$_3$, suggesting that it would be due to interaction between particles at high concentration. Dimensionless quantities of $i_0/I_0$ are plotted versus exp(-Ea/RT) in Figure 12. Marsden and Pesic$^{14}$ reported the values of $i_0$ in broad range, so that values were being averaged, calculated, and superimposed onto Figure 12 for comparison.

**Analysis on practical application.**—The results of this work provide the fact that cerium is a good surrogate material for uranium since they show similar electrochemical and thermodynamic behaviors in LiCl-KCl eutectic salt. By comparing the properties of cerium with those of uranium, both are very stable in the trivalent form in LiCl-KCl salt and reduced to metal form by gaining three electrons at certain potentials. However, the standard reduction potential of UCl$_3$ is ranging from -2.4 to -2.6 V versus Cl$_2$/Cl$^-$/reference electrode,$^5$-$^9$ which is about 0.7 V more positive than the standard reduction potential for CeCl$_3$. The diffusion coefficients for UCl$_3$ in LiCl-KCl molten salt have been reported by many researchers,$^4$-$^9$,$^{11}$ which are shown in the Figure 13. Although the values for UCl$_3$ are generally higher than
those for CeCl₃, the diffusion coefficients for both UCl₃ and CeCl₃ are in the same order of magnitude and can be correlated with the temperature. The activation energies for the diffusion of UCl₃ have been reported, ranging from 24.2 to 34.4 kJ mol⁻¹, which is in a good agreement with the activation energy for CeCl₃. The similarity between both the activation energies for the diffusion may be owing to the similar ionic size of uranium and cerium. The exchange currents densities of uranium in the molten salt have been reported with respect to the similar ionic size of uranium and cerium. The exchange current density, the exchange current densities of CeCl₃ are in a similar order, but a meaningful comparison is hard to be made due to the dispersed data for uranium.

Figure 14. Plot of the exchange current densities for U³⁺/U reaction from other research studies comparing with those of Ce³⁺/Ce measured in this study.

Conclusions

Electrochemical properties of CeCl₃ in LiCl-KCl eutectic salt at different concentrations and temperatures have been studied by using CV and EIS techniques. From the CV experiments, it has been shown three-electron exchange for the reduction of Ce⁴⁺/Ce. The diffusion coefficients of CeCl₃ in LiCl-KCl were measured and calculated to be from 0.48 × 10⁻⁵ to 1.01 × 10⁻⁵ cm² s⁻¹, which can be correlated with temperature using Arrhenius expression. The results reveal that the concentration of CeCl₃ has a weak effect on the diffusion coefficients. Comparing with the values for UCl₃, the diffusion coefficients of CeCl₃ are slightly smaller than those of UCl₃. Apparent standard potentials were also computed by using peak potentials from the CV experiments, which were linearly dependent on temperature. EIS experiments were performed to determine exchange current density of Ce⁴⁺/Ce couple in LiCl-KCl molten salt system. Minimum η was applied for Ce reduction to happen and the charge transfer resistance was measured to calculate the exchange current density. The exchange current densities range from 0.0076 A cm⁻² and 0.18 A cm⁻², which can be related to temperature and concentration (see Table III). From Arrhenius temperature dependence, the activation energy for Ce⁴⁺/Ce exchange was determined though EIS data, which is in the same range obtained through CV data sets and in similar range with the activation energy for U⁵⁺/U. By plotting dimensionless quantities of the exchange current density, the exchange current densities of Ce⁴⁺/Ce reaction in this work are in good agreement with those measured by linear polarization method. In comparison with the exchange current densities of U³⁺/U measured by other researchers, the values for Ce⁴⁺/Ce are in a similar order, but a meaningful comparison is hard to be made due to the dispersed data for uranium.

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