Rate of LiCl-KCl Salt Vaporization under Vacuum Conditions

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1. Introduction

An electorefining process, a key unit of a pyrochemical process, generates waste eutectic salts containing some radioactive metal chlorides. The most effective method is to separate the radioactive metals from the non-radioactive salts. A promising approach is to precipitate radioactive metals by converting them into salt-insoluble metal compounds by an oxygen sparging[1,2]. Following this, a vacuum distillation process for the removal of LiCl-KCl eutectic salt is available to effectively separate the precipitated particulate metal oxides from the eutectic salt. This study investigated distillation rates of LiCl-KCl eutectic salt under different vacuum conditions. A fundamental study by using a vacuum thermogravimetric (TG) furnace on the distillation rates was performed. The objective of this study was to get understandings of salt vaporization behavior under different vacuums.

2. Experimental

A schematic of the vacuum TGA system used in the first part study is shown in Fig. 1. This vacuum TGA furnace system consists of a cylindrical alumina tube, a load cell, an electric heater, an alumina crucible and a vacuum control unit. This is capable of controlling the temperature to 1200°C and a vacuum of less than 0.1 Torr. Isothermal TG tests were performed at different pressures of 0.5 and 50 Torr. Investigated temperatures were 650°C, 700°C, 750°C and 800°C for 0.5 Torr tests and 750°C, 800°C, 850°C, and 900°C for 5 Torr tests, respectively.

3. Results and discussion

If volatile compounds, such as salts in this study, are measured in the vacuum TGA, a continual loss of mass is expected because those molecules that reach the boundary layer between liquid and gas phase are swept away out of TGA furnace by a vacuum. Under isothermal conditions, this results in a constant rate of weight loss, which depends on the vapor pressure of the salt and mass transfer at the boundary layer as [3]:

$$m_0 - m(t) = AK(P_s - P_g)t \quad \text{(1)}$$

Where m is sample mass, A is vaporizing surface area, K is constant that describe the mass transfer at the boundary layer between the liquid and gas phase, P_s (atm) is vapor pressure of salt and P_g is partial pressure of salt vapor in the gas phase. Eq. (1) describes a steady transfer of molecules from the liquid phase to the gas phase. Vaporized molecules at gas-liquid interface are swept out of TGA furnace in a vacuum TGA system ($P_s >> P_g$). Thus the equation (1) is rewritten as:

$$m_0 - m(t) = AKP_s t \quad \text{(2)}$$

The weight reduction rate of pure KCL-LiCl eutectic salt as a function of time is shown in Fig. 2. As expected by the described theory, see equation (3) and Fig. 2, the evaporation rate is constant at a given temperature and pressure. In Fig. 3, obtained mass reduction rates are plotted logarithmically as a function of the reciprocal temperature in Kelvin. The straight lines expected from the Clausius-Clapeyron equation were obtained by linear regressions. The determined values of mass transfer coefficient, K, are shown in *TABLE I.* Mass transfer coefficient, K, increases as the temperature increases or the pressure decreases.

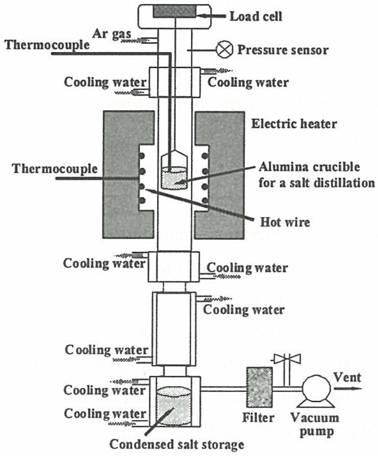

Fig. 1. A Achematics of Vacuum TGA System

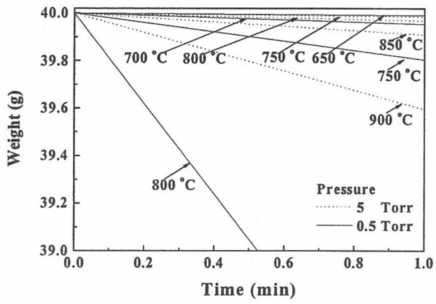

Fig. 2. Weight reduction rates of salt

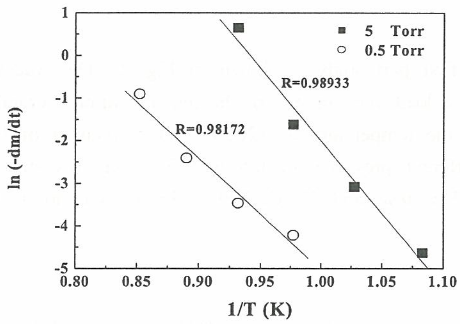

Fig. 3. Arrhenius plot for the vaporization of LiCl-KCl salt under two different vacuum conditions of 5 and 0.5 Torr

Table 1. Mass transfer coefficient, K ($g\ cm^{-2}\ sec^{-1}atm^{-1}$), for LiCl-KCl eutectic salt vaporization

Temperature (K)	*Pressure (Torr)*	
	0.5	5
923	6.07×10^{-3}	
973	5.12×10^{-3}	
1023	7.91×10^{-3}	3.47×10^{-4}
1073	2.20×10^{-2}	4.54×10^{-4}
1123		5.07×10^{-4}
1173		9.78×10^{-4}

4. Conclusion

The determined value of mass transfer coefficient of salt vaporization, K ($g\ cm^{-2}sec^{-1}atm^{-1}$), increases as the temperature increases or the pressure decreases. Obtained vaporization flux equation based on determined mass transfer coefficient, K, was used as a design basis for lab-scale salt distillation test system.

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