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Molten salt chemistry in nitrate salt storage systems: Linking experiments and modeling

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Abstract

Sensible heat storage in molten nitrate salts is a key technology when it comes to thermal energy storage in combination with concentrating solar power (CSP) plants. Currently, a mixture of sodium and potassium nitrate called Solar Salt is used at temperatures between 280 and 560 °C. Our research approaches comprise an improvement of Solar Salt stability at temperatures above 560 °C, which comes along with a broadening of the operating temperature range. In this way, a higher storage capacity and efficiency, as well as economic advances can be achieved. Numerous publications about the chemistry of molten nitrate salt mixtures reveal the formation of chemical species such as nitrite ions, nitrous gases and oxide ions and carbonate ions. Among these, the reversible reaction of nitrate to nitrite with release of oxygen is the predominant reaction at temperatures below 560 °C. So far, there is a lack of literature that pays particular attention on the contributions of reaction kinetics and mass transport effects on the reaction velocity of the nitrate/nitrite-reaction. However, understanding of these physico-chemical phenomena is essential, because further decomposition reactions build on the nitrate/nitrite-reaction. In this study, experiments at different scales (50 mg to 100 g) are compared with regard to the reduction reaction velocity at 500 °C. A data treatment procedure for thermogravimetric analysis experiments successfully eliminates effects of salt evaporation on the measured mass changes. The chemical equilibrium of the salt samples turned out to be reasonable, when compared to literature values. It was found, that the surface-to-volume ratio of the salt melt samples significantly affects the evaporation rates and the reaction velocity. The time period that is needed until chemical equilibrium is reached at 500 °C clearly increases when the surface-to-volume ratio decreases. The thermogravimetric analysis apparatus enables experiments, which measure reaction kinetics without mass transport limitations. It is demonstrated that a simulation model adapted from literature displays a reaction velocity that incorporates both reaction kinetics and mass transport without differentiation of the two phenomena.

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