Physico-Chemical Investigation and Modeling of Nitrate Salt Melts

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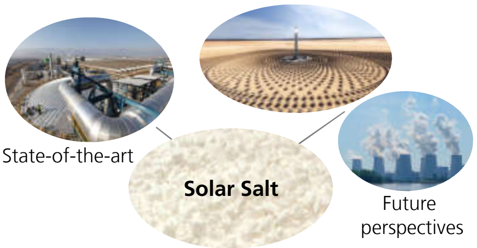
Motivation

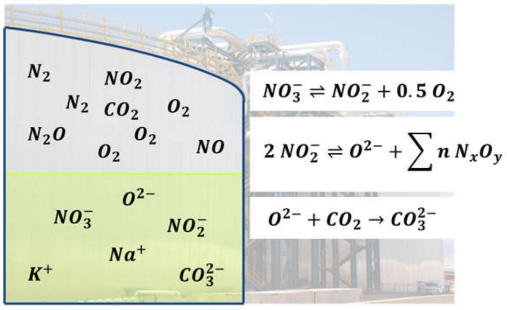


Potential
- more economic
- increased lifetime

Objectives

- Enhance the storage capacity Q, Q ~ ΔT
- Increase the efficiency of the conversion heat to power, ~T_{max} ↑
- Raise upper operating temperature above the present limit of ~565 °C (T_{max})
- Increase salt stability and reduce corrosivity at high temperatures (>560 °C)

→ Identify the ongoing reactions, corresponding chemical equilibria and reaction kinetics



Approach & Methods

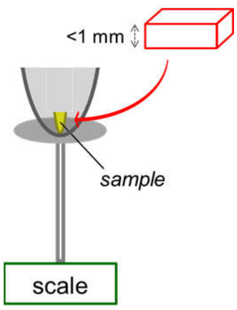
Experimental Set-Ups

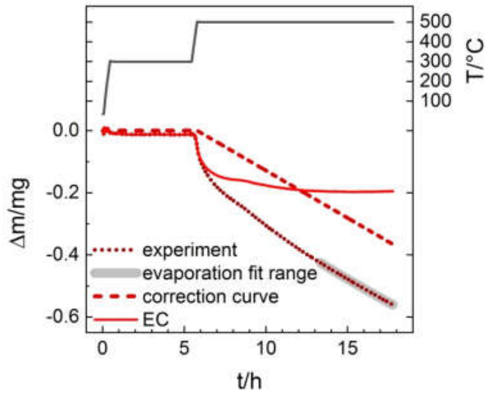
- mg-scale: Thermogravimetric analysis (TGA)
- 100 g-scale: Autoclave test rig

- Temperature- and atmosphere-controlled experiments
- Post-analysis of salt samples:
  - Ion chromatography: NO_3^-, NO_2^-
  - Acid-base titration: O^{2-}

Measurements

- TGA experiments
- 50 mg Solar Salt
- Isothermal segments at 450, 475, 500, 525, 550 °C
- Correction with regard to salt evaporation [1]



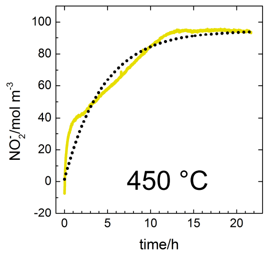


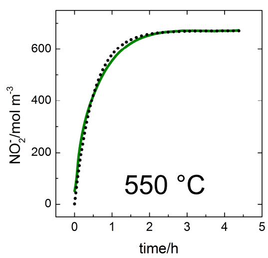
- Measured mass change ↔ Reaction progress
- Fit of the experimental curves with a kinetic rate law equation

$$\frac{dc_{NO_2^-}}{dt} = k_{Red}(T)\cdot c_{NO_3^-} - k_{Ox}(T)\cdot c_{NO_2^-}\,p_{O_2}^{0.5}$$

Results

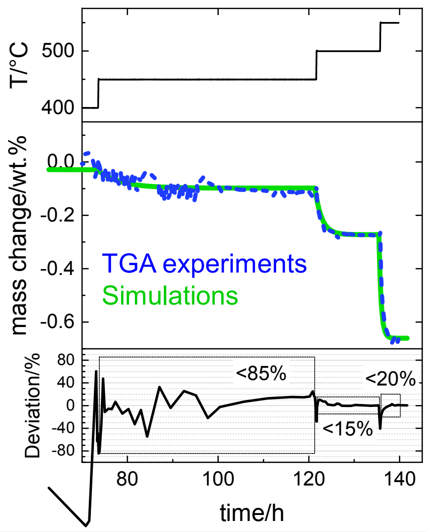
- TGA results and kinetic fits [2]





$k_{Red}(T)$ and $k_{Ox}(T)$

- Comparison of experiments and simulation results



Summary & Outlook

- Thermogravimetric analysis method for nitrate salts that eliminates salt evaporation effects
- Experimental investigation and mathematical description of the intrinsic kinetics of the nitrite forming reaction in Solar Salt
- Validation of the rate law and its parameters
- Towards macrokinetics: Combination of the intrinsic kinetics and mass transport phenomena
- Towards the entire reaction network: Thermodynamics and kinetics of oxide and carbonate formation

References

[1] Sötz V. A., Bonk A., Forstner J., Bauer T. Molten salt chemistry in nitrate salt storage systems: Linking experiments and modeling. *Energy Procedia,* 155, 503-513 (2018).
[2] Sötz V. A., Bonk A., Bauer T. Microkinetics of the reaction $NO_3^- \rightleftharpoons NO_2^- + 0.5\,O_2$ in molten sodium nitrate and potassium nitrate salt. Submitted to *Thermochimica Acta* (2019).

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