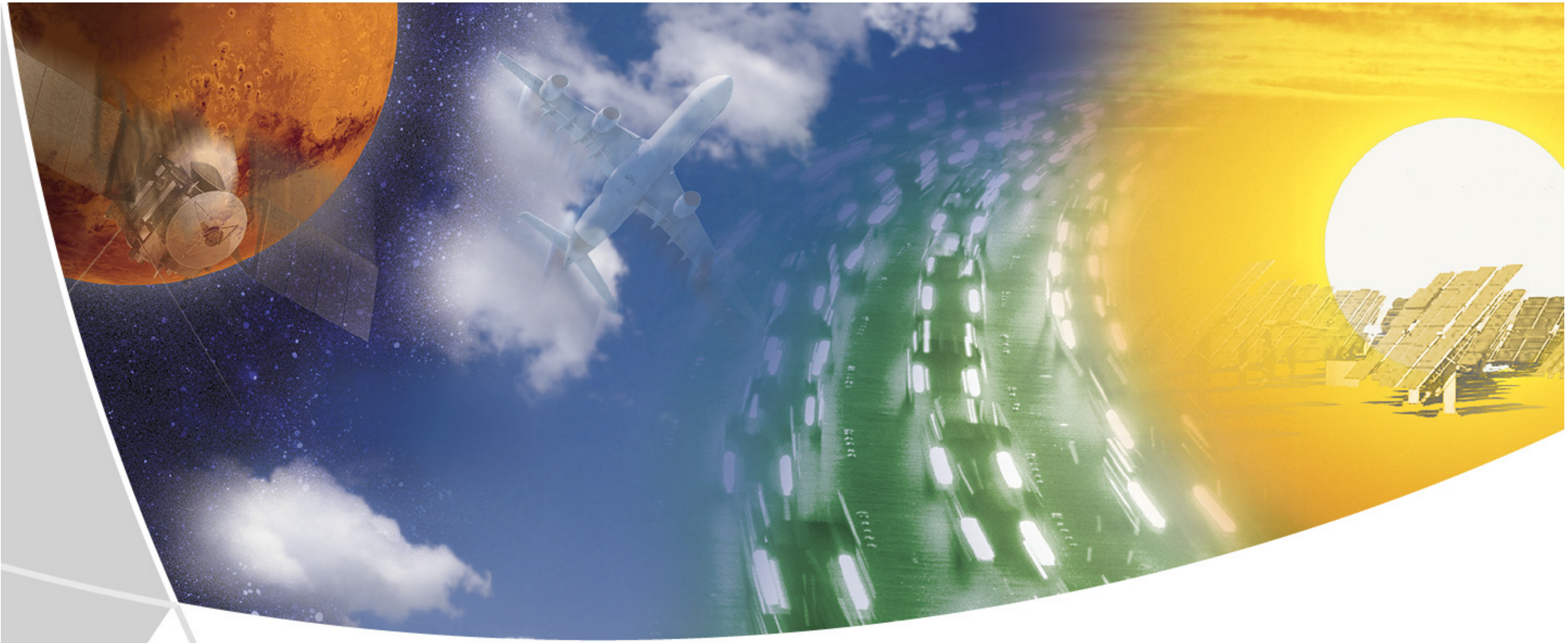

OVERVIEW OF MOLTEN SALT STORAGE –

MATERIAL DEVELOPMENT FOR SOLAR THERMAL POWER PLANTS

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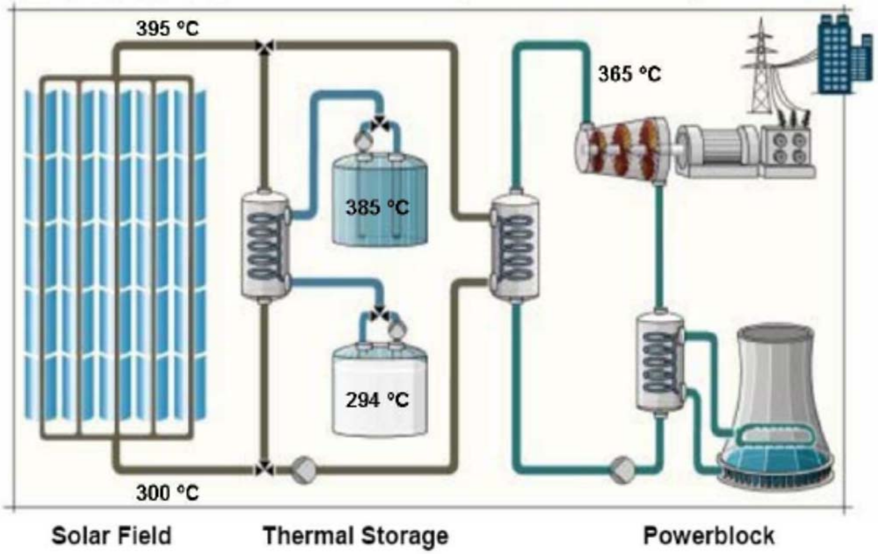
Outline

- Introduction to Solar Energy and Thermal Energy Storage (TES)
- Data on state of the art storage material
- Development of new salts for higher storage capacity

Exploitation of solar energy



Availability of solar energy ⟷ Demand for electrical power

⇒ impact of Thermal Energy Storage (TES)

Requirements on storage material

Storage capacity = $C_p * \Delta T$

- For large storage capacity ΔT of usage should be large:
  → Low melting temperature
  → High thermal stability (additionally important for high sefficiency)

- The heat capacity should be large

State of the art storage material: „solar salt“

- Definition: mixture of $NaNO_3$ and KNO_3 (60:40 wt%)

- Properties: ratio of $NaNO_3$/ KNO_3 is close to the eutectic mixture (→ low melting temperature

- Thermophysical values are available:
  - Heat capacity
  - Thermal conductivity
  - Thermal diffusivity
  - Density

Research on temperature stability

thermal decomposition reaction:

(1) $2\ NaNO_3 \Leftrightarrow 2\ NaNO_2 + O_2$

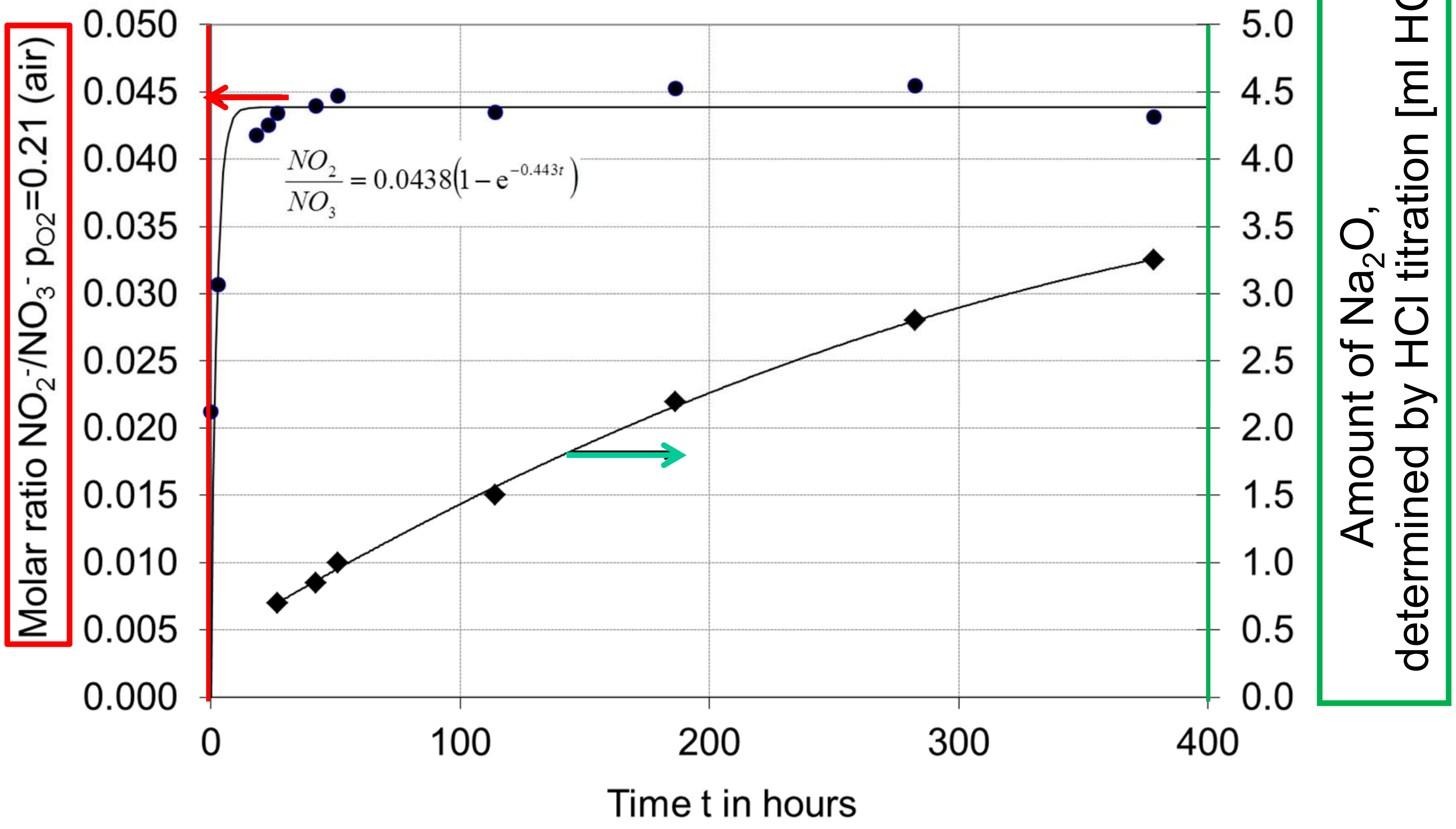
(2) $2\ NaNO_2 \rightarrow Na_2O + NO + NO_2$

→ Determination of decomposition temperature can be reported by mass loss

→ Equilibrium constant of reaction (1) is given by:
$(NaNO_2 / NaNO_3) * pO_2$

→ Reaction (2) can be followed by determination of Na_2O

Long term stability of solar salt



Solar Salt in synthetic air atmosphere in an open type system at 550 °C

Development of new salts

Aim: Increase of the storage capacity, given by: C_p* ΔT

(1) Increase of C_p

(2) Increase of ΔT (by lowering temperature of liquid-solid transition)

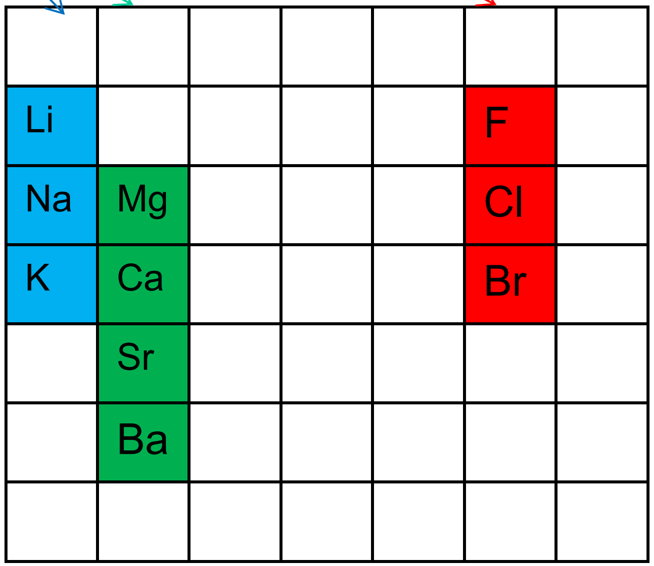
(1) Increase C_p per volume (voluminetric heat capacity):

→ can be estimated due to correlation of: atomic radi ↔ C_{p_vol}

Atomic radii of salt components

Salt: Cations and anions

Periodic table:



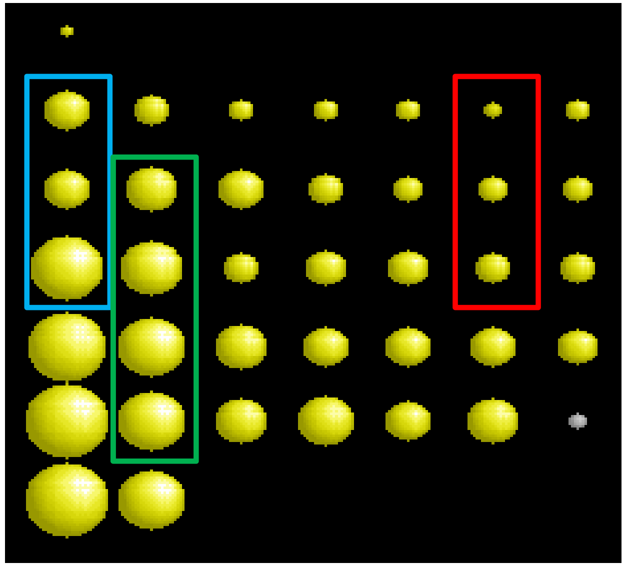
alkali element

alkaline earth element

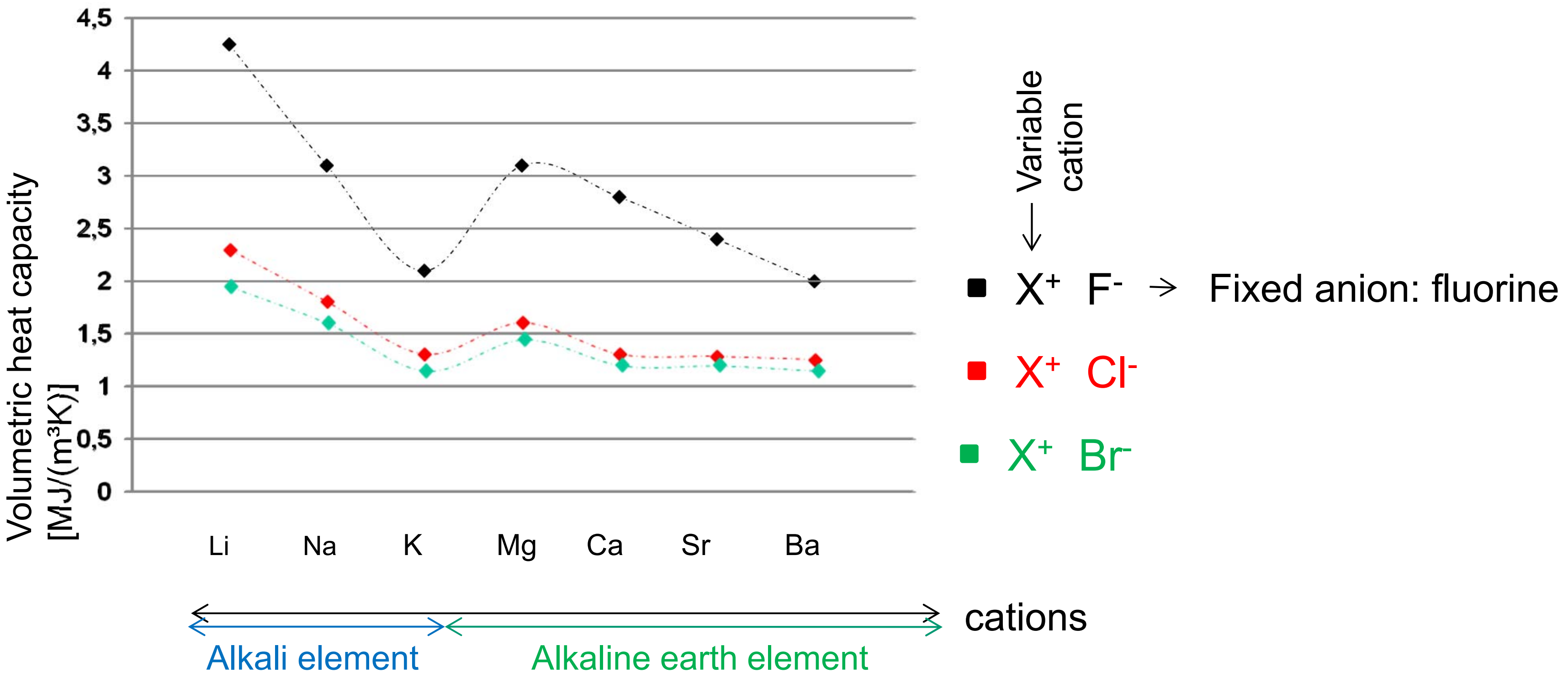
halogenes

Correlation

elements
↕
atomic radii:



Systematic change of heat capacity



Development of new salts

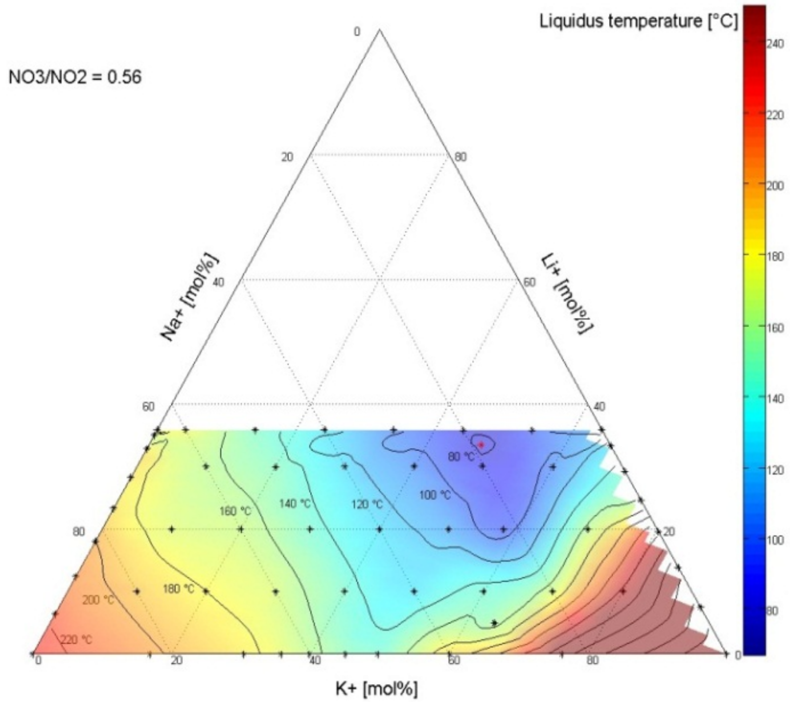
Increase of the storage capacity, given by: $C_p * \Delta T$

(1) Increase C_p

(2) Increase ΔT (by lowering temperature of liquid-solid transition)

→systematic screening/ creation of phase diagrams

	NO_2	NO_3	NO_2, NO_3
Single salts and binary systems with common cation			
Ca	398 °C[#]	561 °C[#]	393 °C
K	440 °C	334 °C	316-323°C
Li	220 °C	254 °C	196 °C
Na	275 °C	306 °C	226-233 °C
Binary systems with common anion and ternary reciprocal			
Ca,K	185 °C	145-174 °C	130 °C
Ca,Li	205-235 °C	235 °C	178 °C
Ca,Na	200-223 °C	226-230 °C	154 °C
K,Li	98 °C	126 °C	94 °C
K,Na	225 °C	222 °C	142 °C
Li,Na	151 °C	196 °C	126 °C
Ternary additive common anion and quaternary reciprocal			
Ca,K,Li	N/A	117 °C	N/A
Ca,K,Na	N/A	130 °C	N/A
Ca,Li,Na	N/A	170 °C	N/A
K,Li,Na	N/A	119 °C	75 °C
Quaternary additive common anion and quinary reciprocal			
Ca,K,Li,Na	N/A	109 °C	N/A



Summary

- Overview of a commercial molten salt TES (thermal energy storage) system
- Examination of the thermal stability of nitrate salts
- Identification and characterisation of salt formulations with a high storage capacity/ low liquidus temperature