Material development for low-temperature latent heat storage

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ZUSE-GEMEINSCHAFT
FVEE ForschungsVerbund Erneuerbare Energien
Renewable Energy Research Association
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Material development for low-temperature latent heat storage

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- Latent heat storage and salt hydrates
- Development of salt hydrate mixtures as heat storage materials
- Application example
- Summary

Latent heat storage with phase change materials (PCM)

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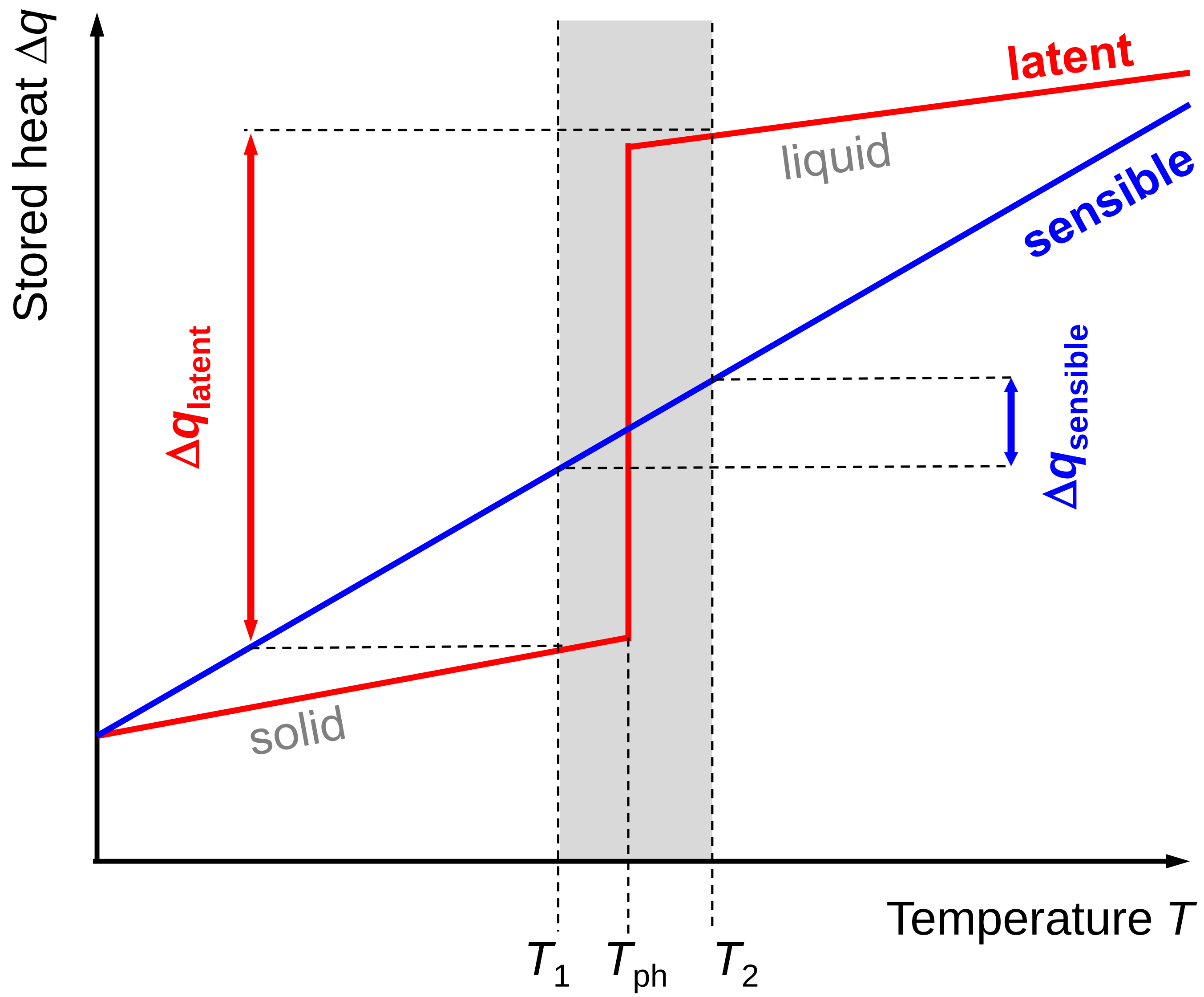
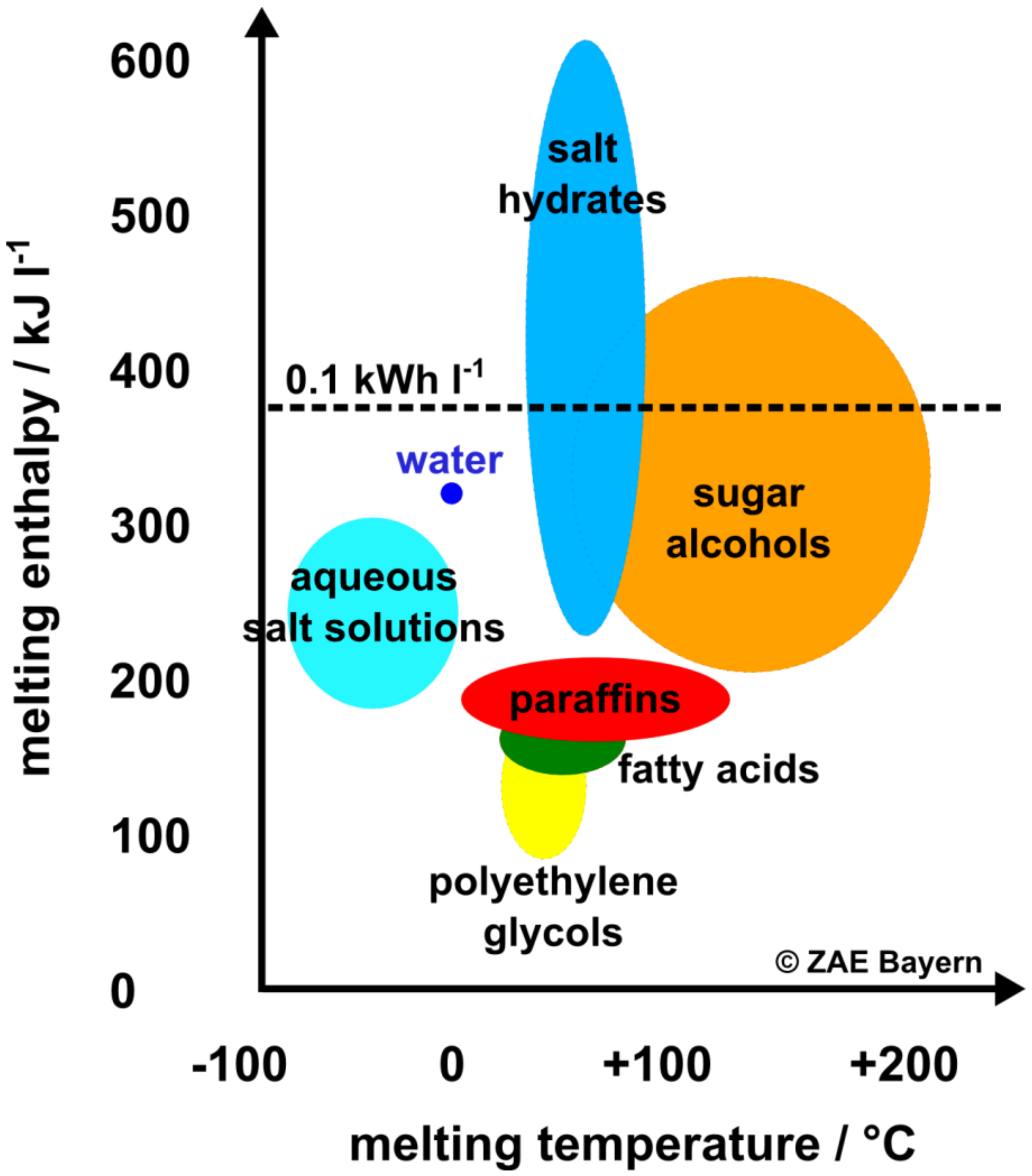


High Δq in narrow ΔT around the phase change

→ Each application requires a PCM with a suitable transition temperature

Salt hydrate mixtures as PCM



- Salt hydrates: high melting enthalpies, low costs (e.g. $CaCl_2 \cdot 6H_2O$)
- Several temperature ranges without cost-effective PCM
- Pure substances known

→ Salt hydrate mixtures

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Development of PCM based on salt hydrate mixtures

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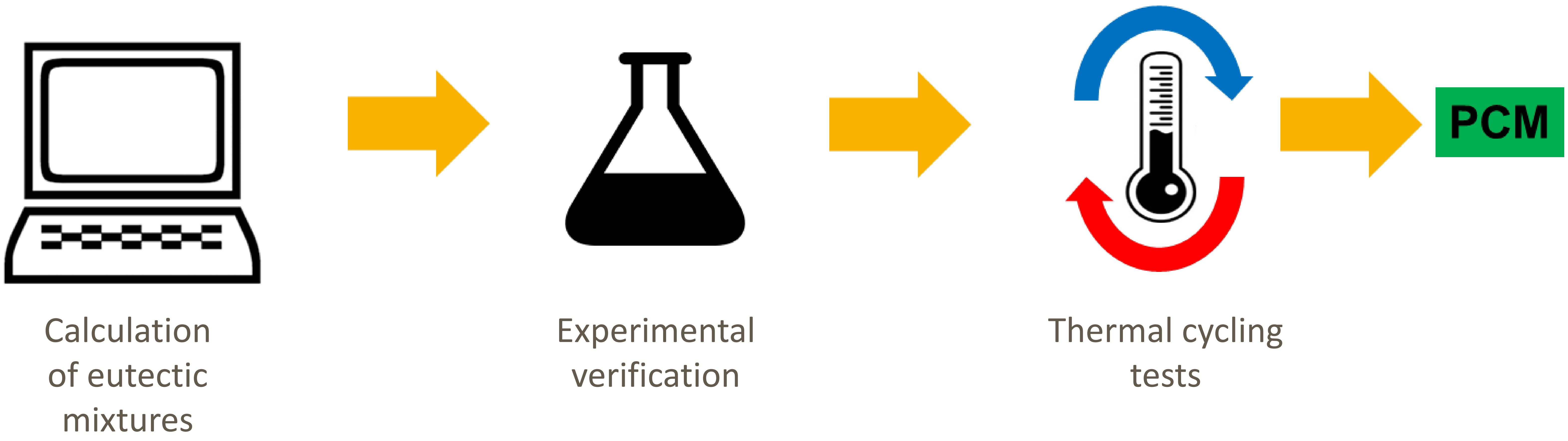

Calculation of eutectic mixtures

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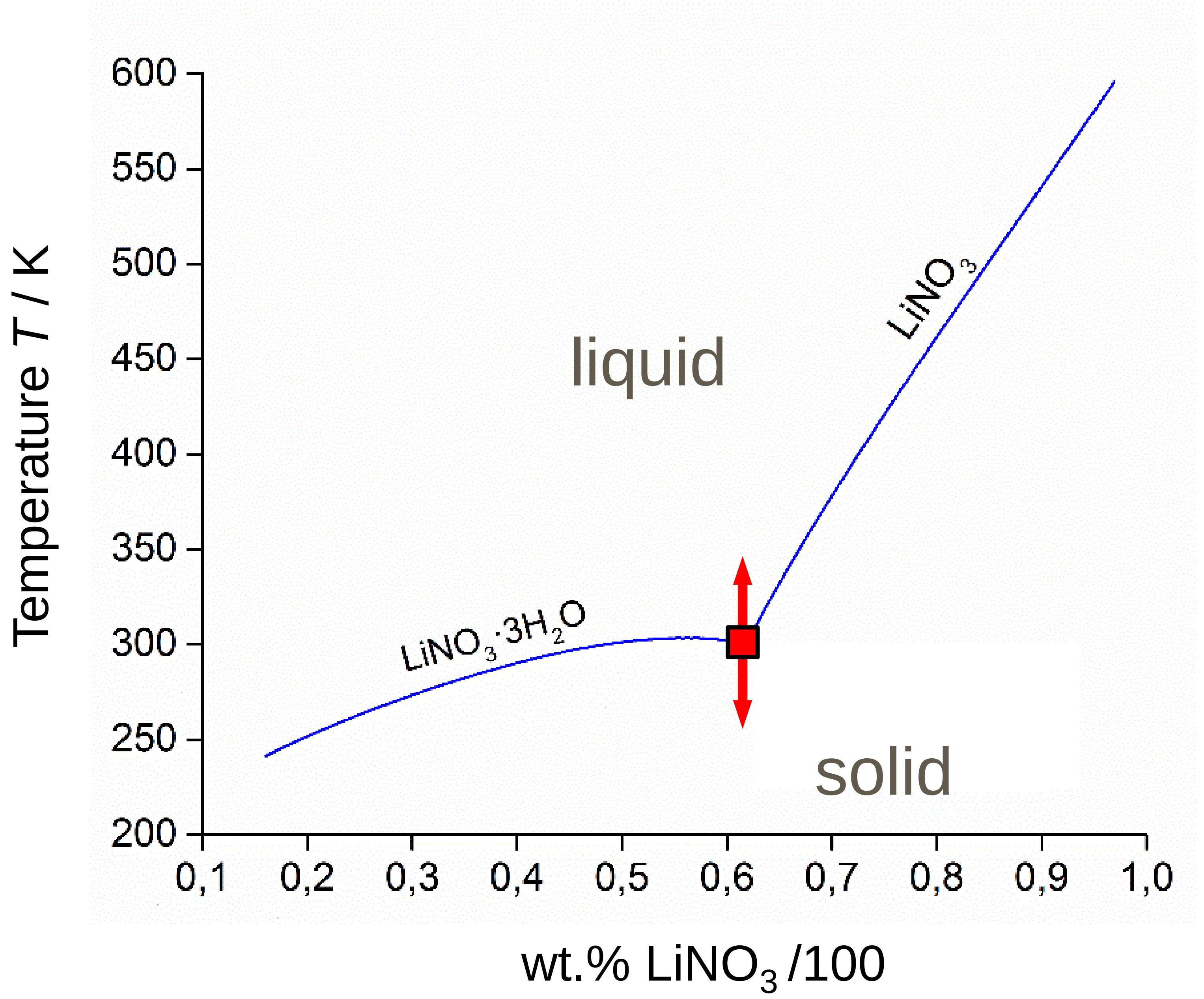


■ Binary eutectic

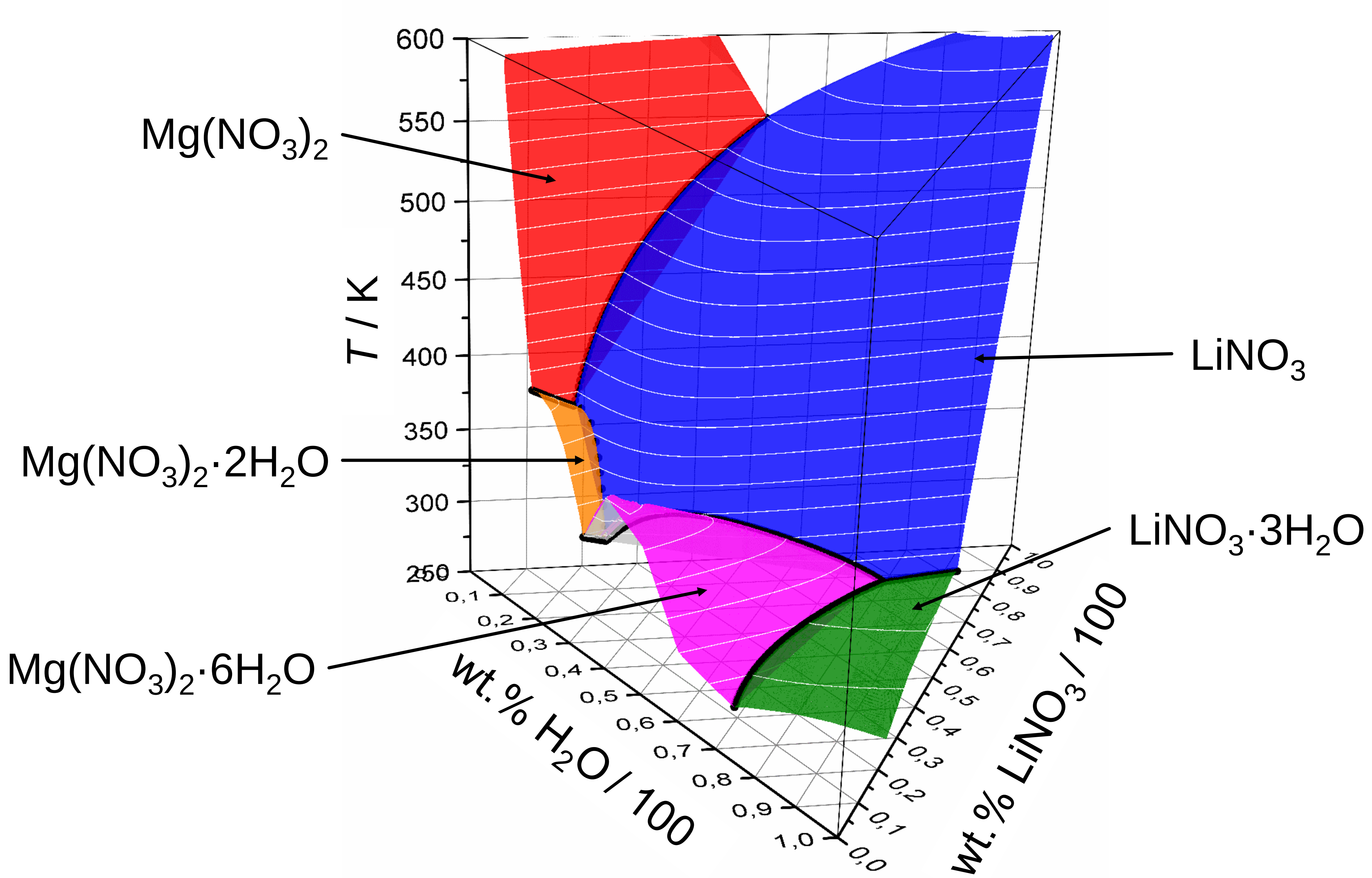
↕ ΔT

- Eutectics: reproducible phase transition
- Binary eutectics known

→ Calculation of ternary systems (salt A + salt B + H_2O)

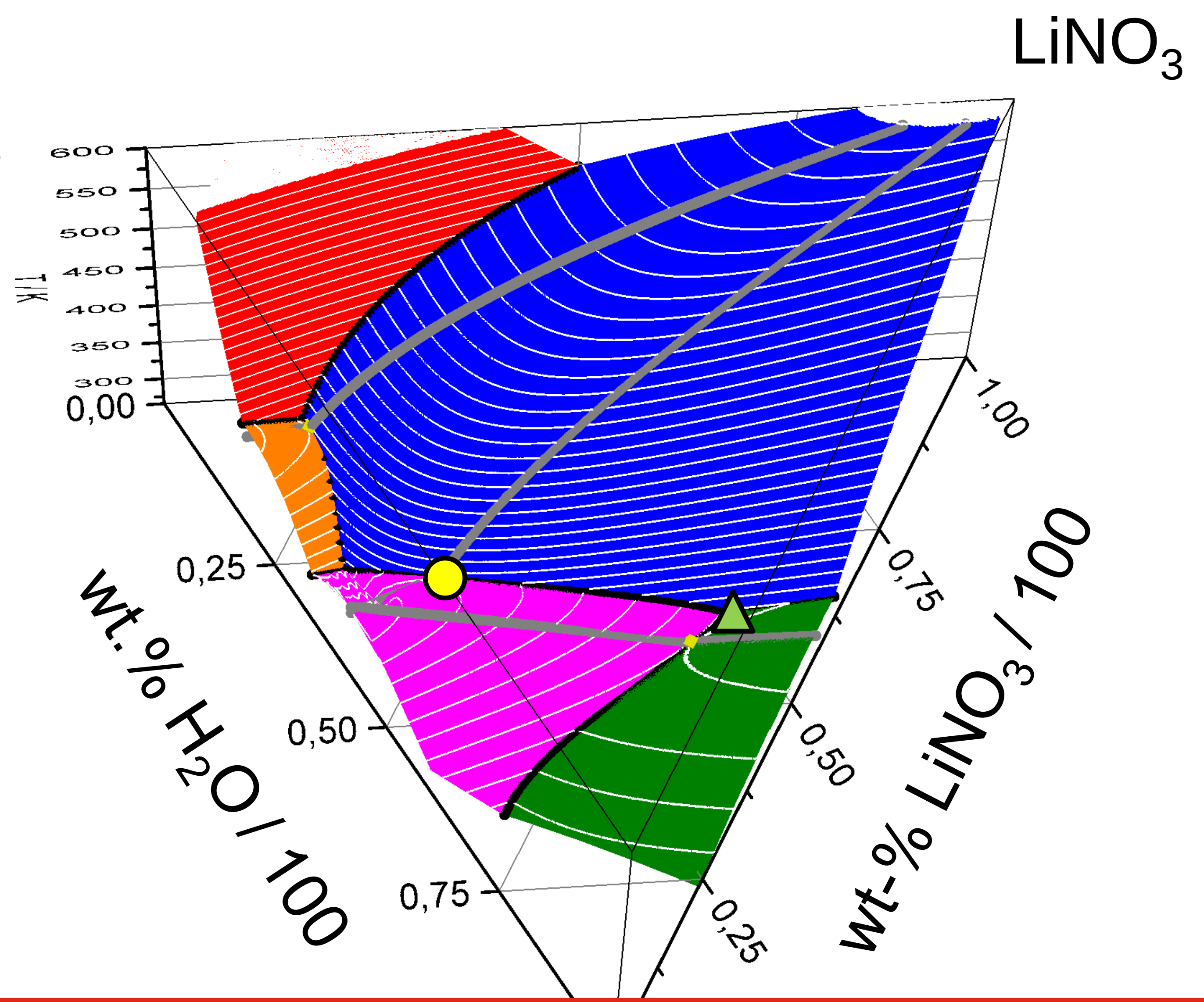
Calculation of ternary systems

$LiNO_3 + Mg(NO_3)_2 + H_2O$



$LiNO_3 + Mg(NO_3)_2 + H_2O$

Eutectics



△ Ternary eutectic

○ Pseudo-binary eutectic

	wt% $LiNO_3$	wt% $Mg(NO_3)_2$	wt% H_2O	*T* /°C	Solid phases
○	14.2	49.6	36.2	73.2	$Mg(NO_3)_2 \cdot 6H_2O + LiNO_3$
△	48.1	12.8	39.1	25.1	$Mg(NO_3)_2 \cdot 6H_2O + LiNO_3 + LiNO_3 \cdot 3H_2O$

Experimental verification of calculated eutectics

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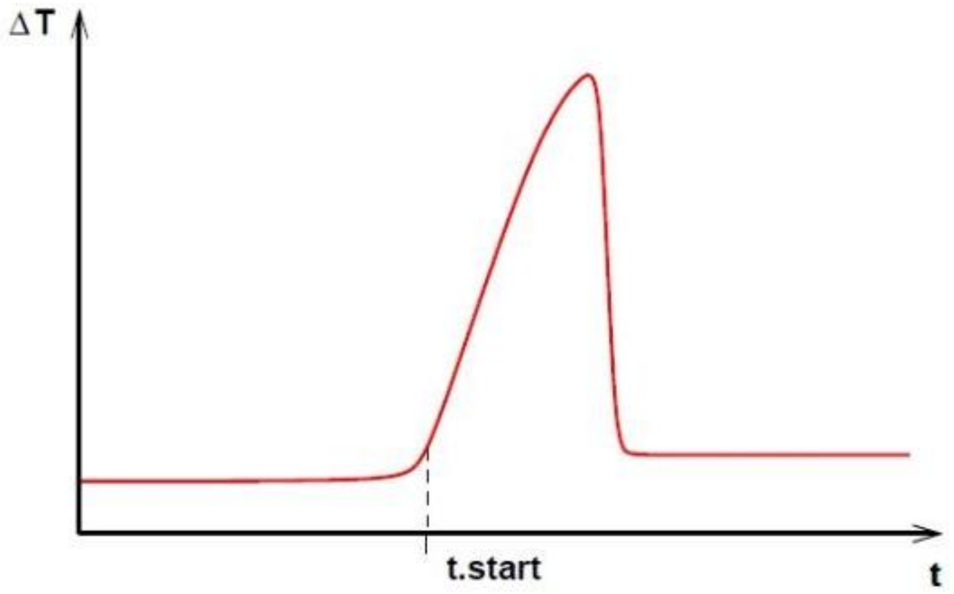
1. Concentration determination

Moisture analyzer

Titration

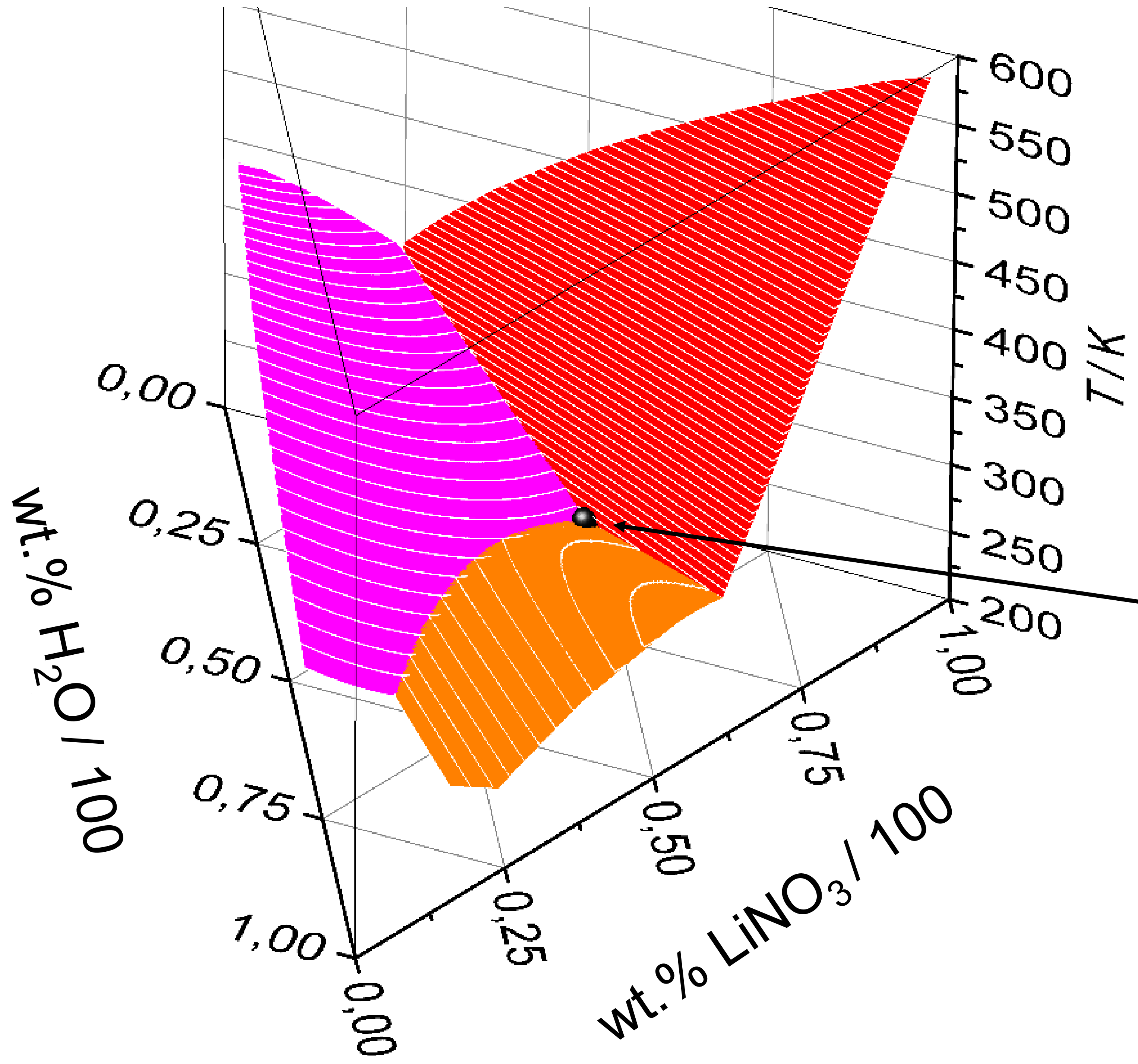
Pictures: ZAE Bayern

2. Calorimetry (DSC)



Prediction

Ternary eutectic in the system NH_4NO_3 + $LiNO_3$ + H_2O



3 solid phases in equilibrium with aqueous salt solution:

NH_4NO_3 + $LiNO_3$ + $LiNO_3 \cdot 3H_2O$

Composition:

27.97 wt% NH_4NO_3
44.80 wt% $LiNO_3$
27.22 wt% H_2O

Eutectic temperature:

17.6 °C

Verification

Measurement of enthalpy-temperature curves via DSC

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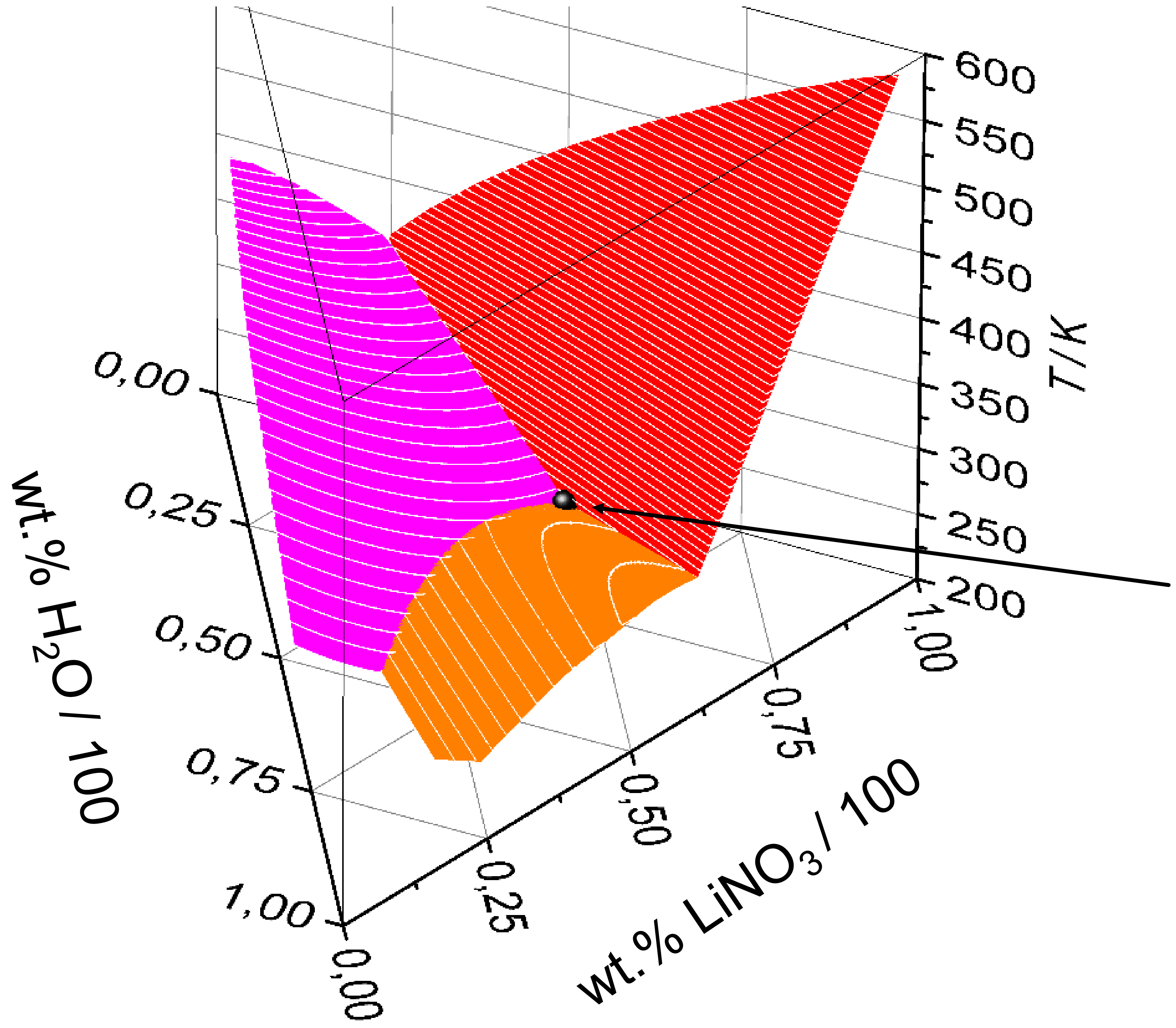
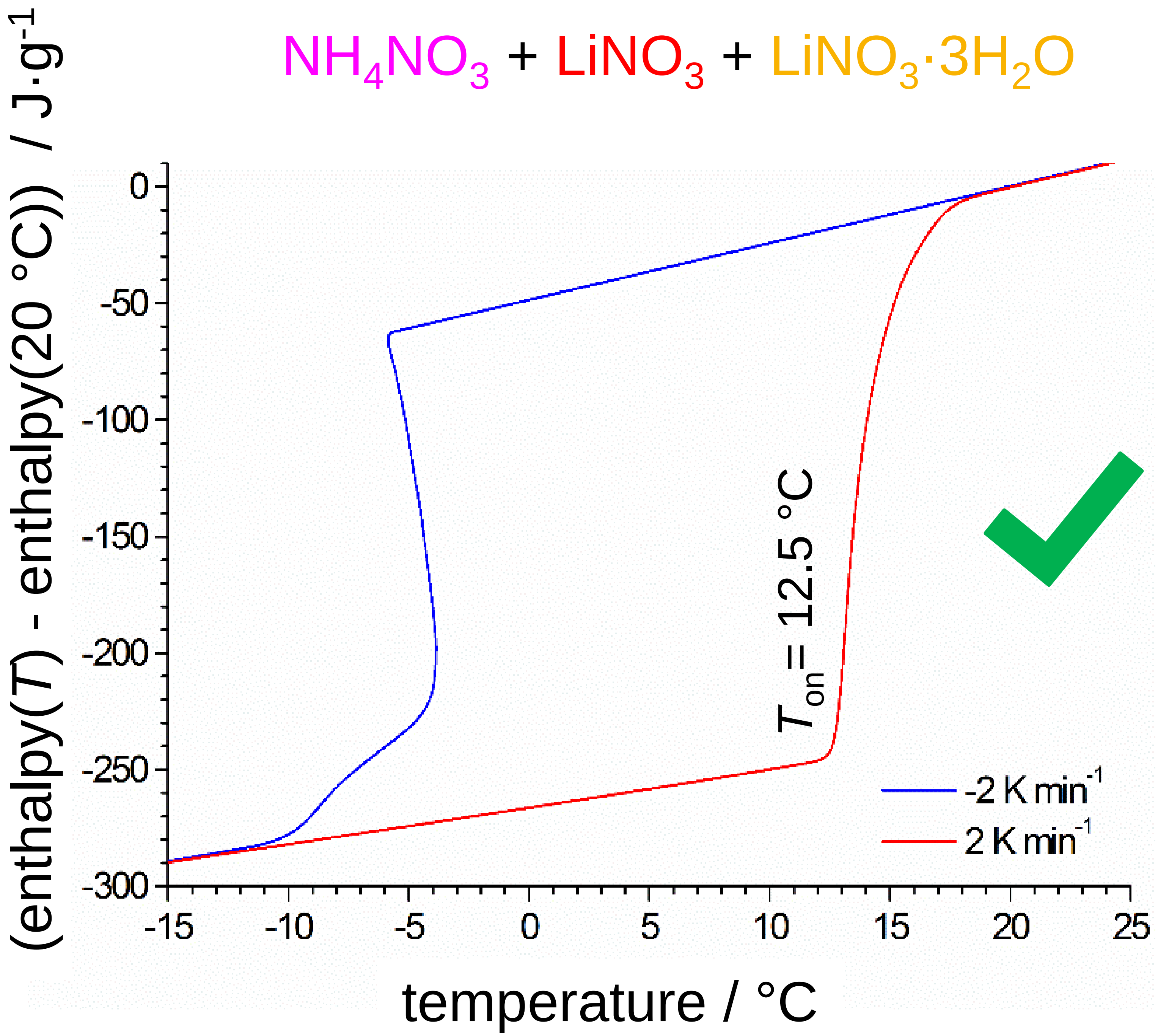
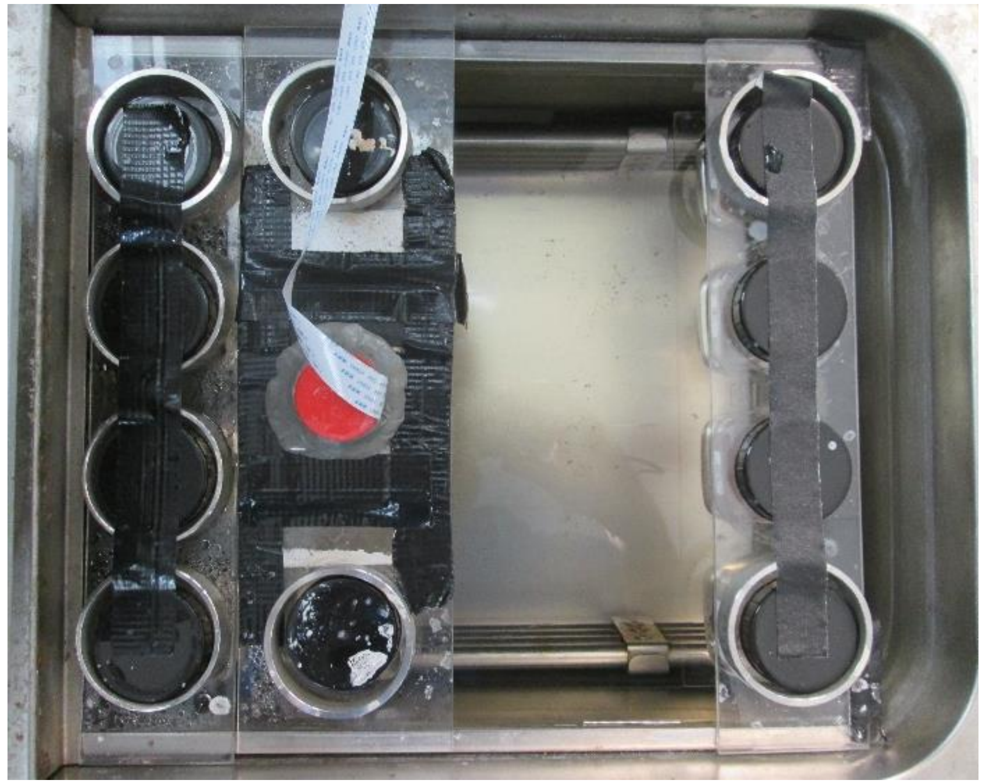




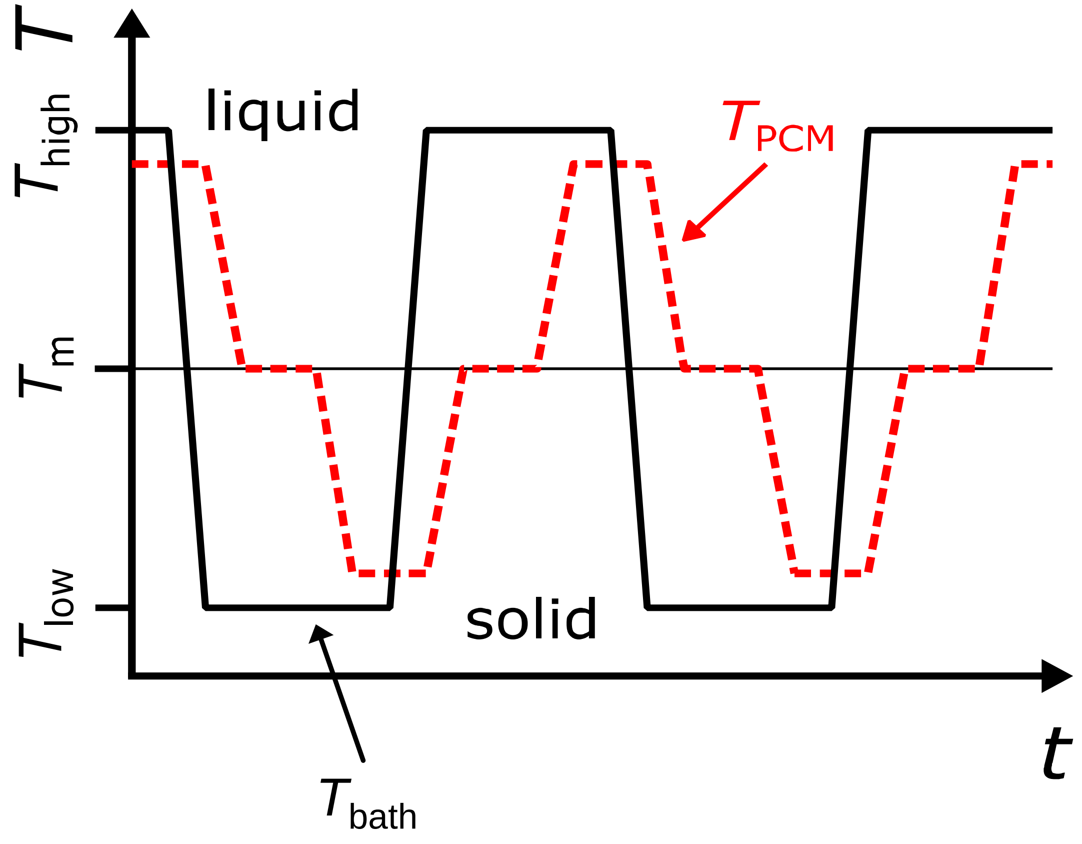
Thermal cycling tests

Visual investigation of phase separation

Experimental setup:



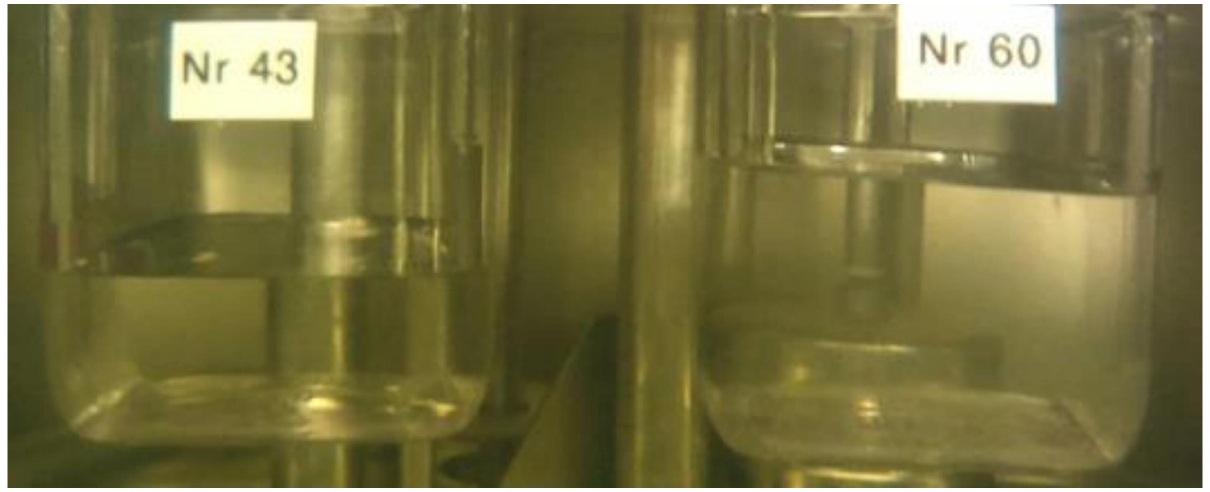
Temperature program:



Thermal cycling tests

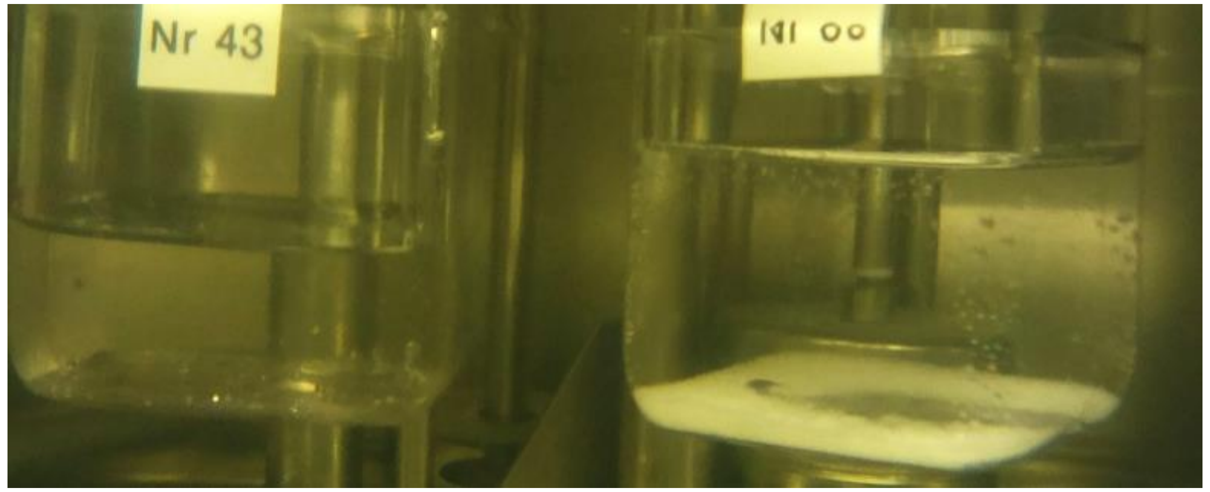
Visual investigation of phase separation

After cycle 1:



After cycle 15:

After cycle 135:



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Application example: Solar heating and cooling with absorption chiller and latent heat storage

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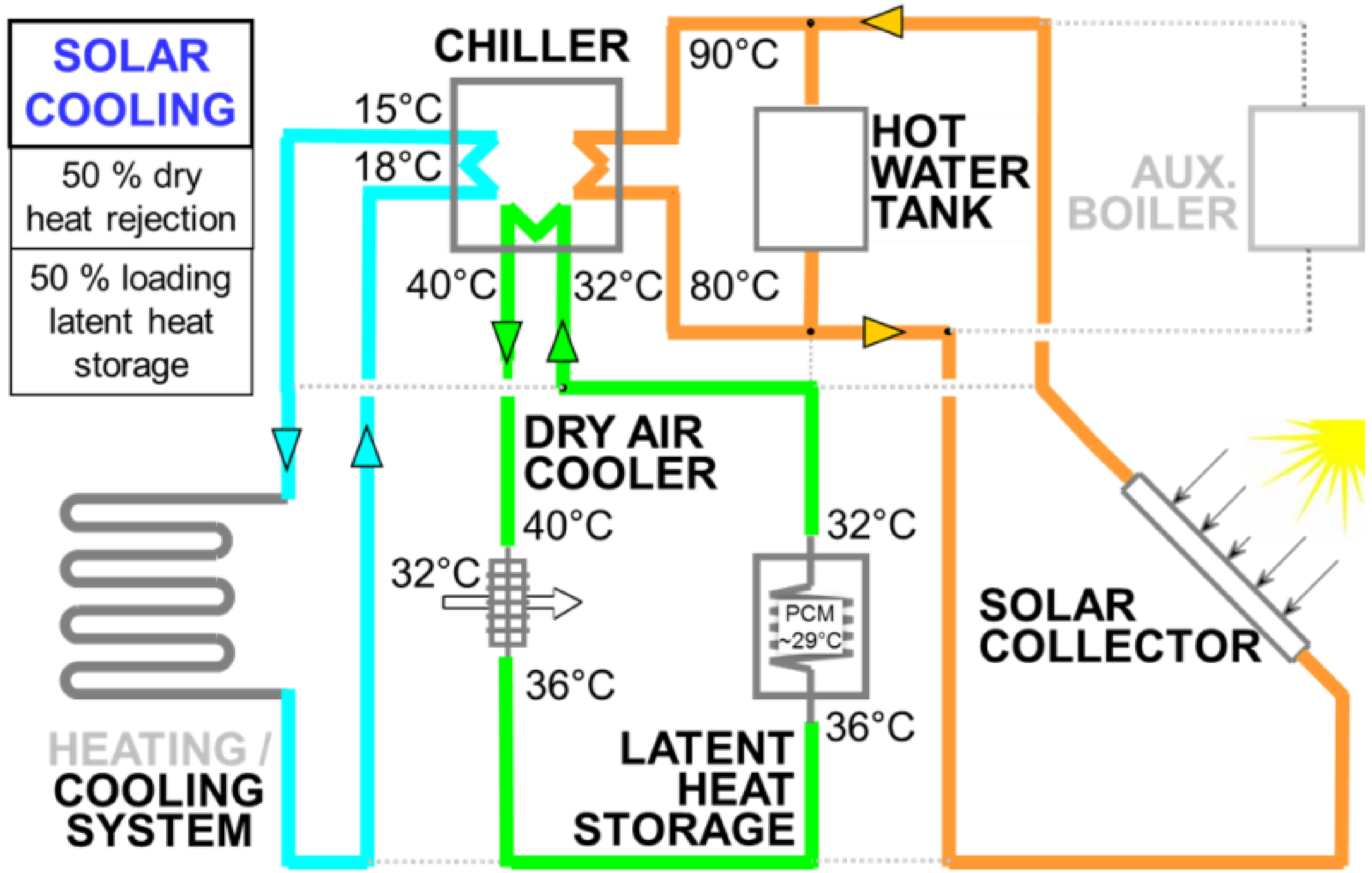
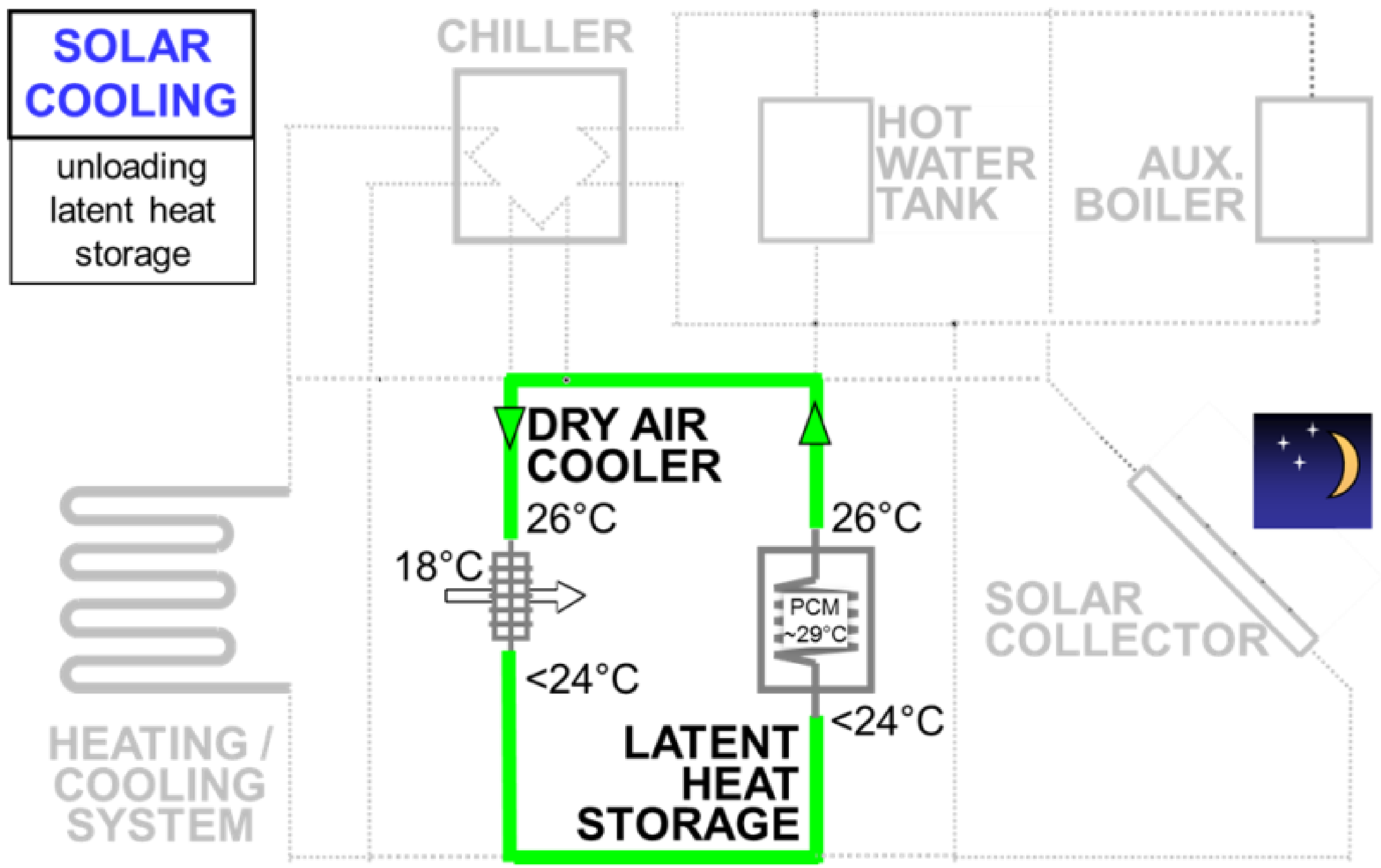
At day:



At night:



Application example: Solar heating and cooling with absorption chiller and latent heat storage

PCM:	$CaCl_2 \cdot 6H_2O$
Melting temperature:	29 °C
Storage volume:	1 / 1.5 m^3
Storage capacity:	80 / 120 kWh (22 – 36 °C)
Power:	10 / 15 kW @ ΔT = 7 K

Pictures: ZAE Bayern

Application example: Solar heating and cooling with absorption chiller and latent heat storage

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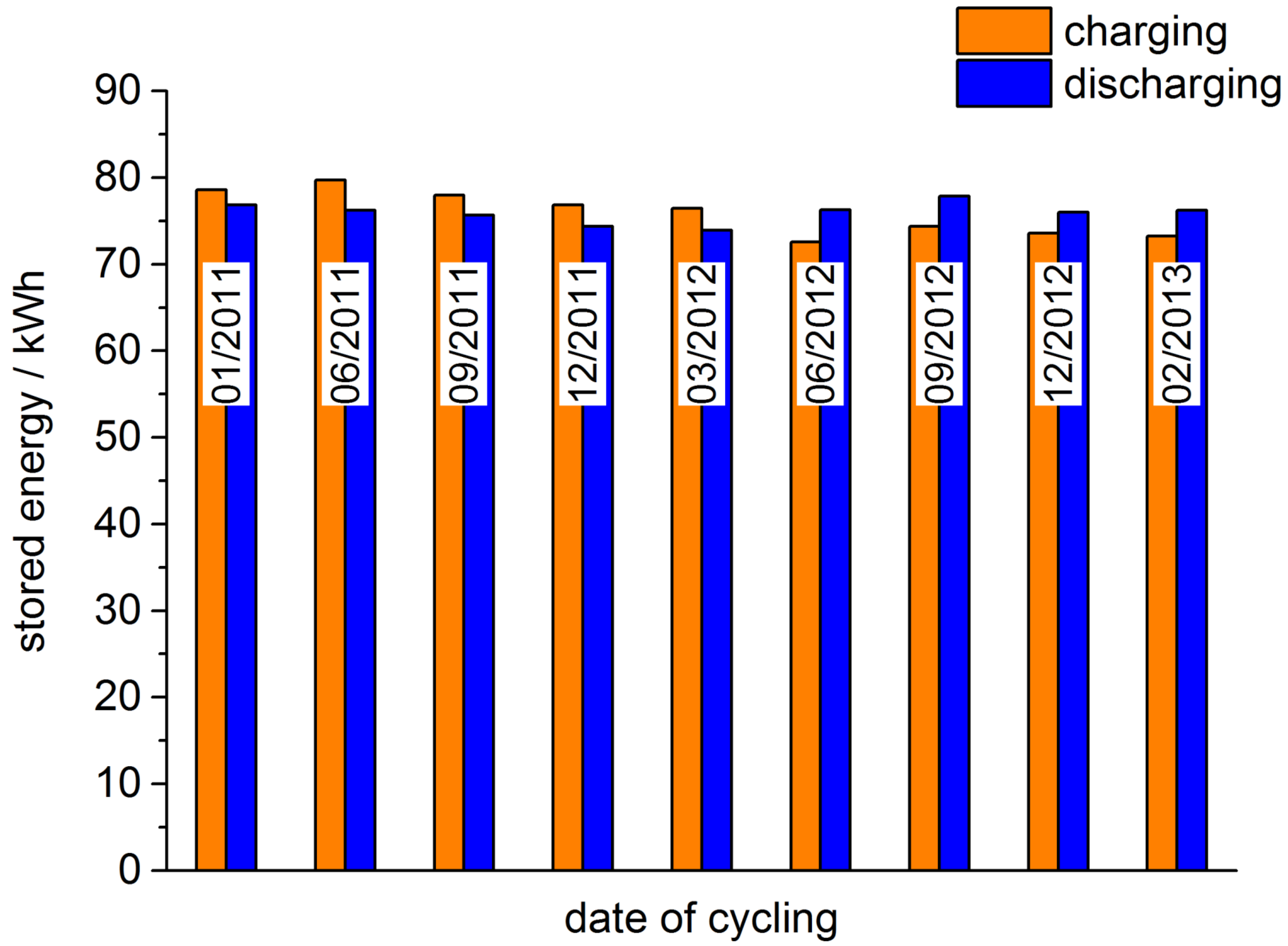

- T_m = 29 °C
- Charging @ 36 °C
- Discharging @ 22 °C

→ Cycling stability validated

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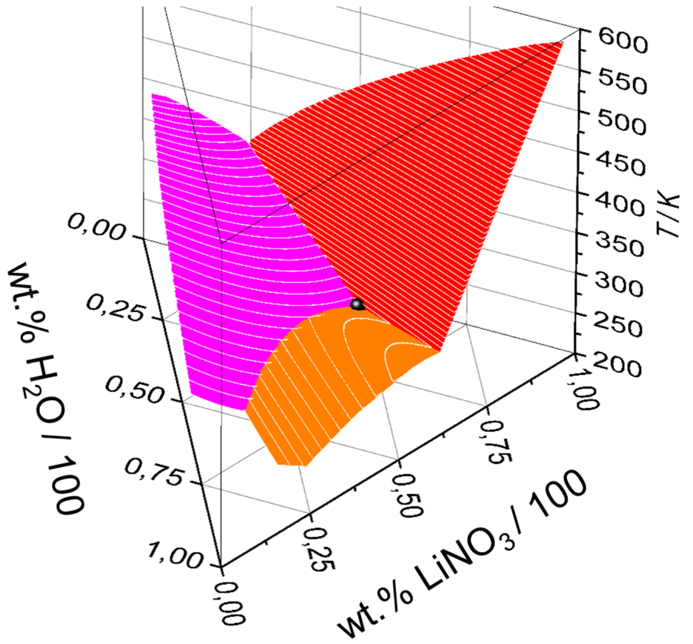
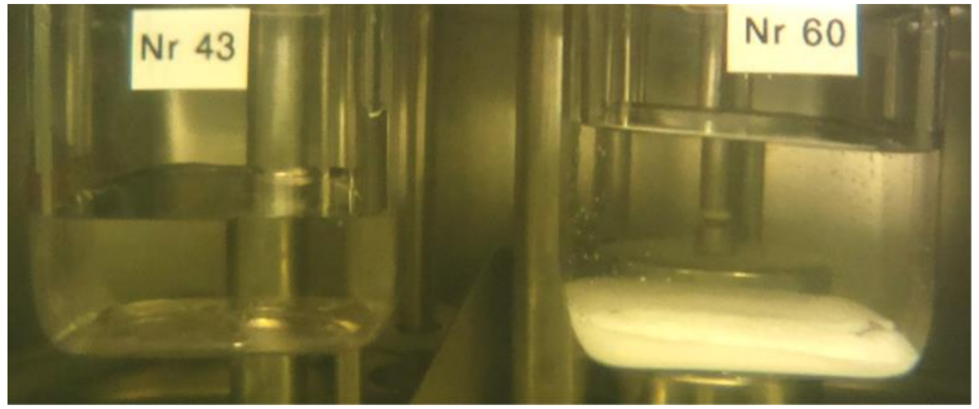


- **Development of PCM based on salt hydrate mixtures**
  - Calculation of phase diagrams
  - Experimental verification via DSC



- **Thermal cycling tests to check long-term performance**
  - Visual investigation of phase separation

- **Low-temperature latent heat storage based on salt hydrates**
  - Immersed capillary tube heat exchanger
  - Testing under application conditions

Thank you for your attention!

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