Simulations and Experimental Results of a Lab-Scale Hydrogen Storage Tank based on $NaAlH_4$

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Introduction

- Experimental study of Cerium-doped $NaAlH_4$ (provided by KIT, Karlsruhe)
- 26 experiments of a lab-scale tank (300 g $NaAlH_4$)

2-step reaction:

$$NaAlH_4 \leftrightarrow \frac{1}{3} Na_3AlH_6 + \frac{2}{3} Al + H_2$$

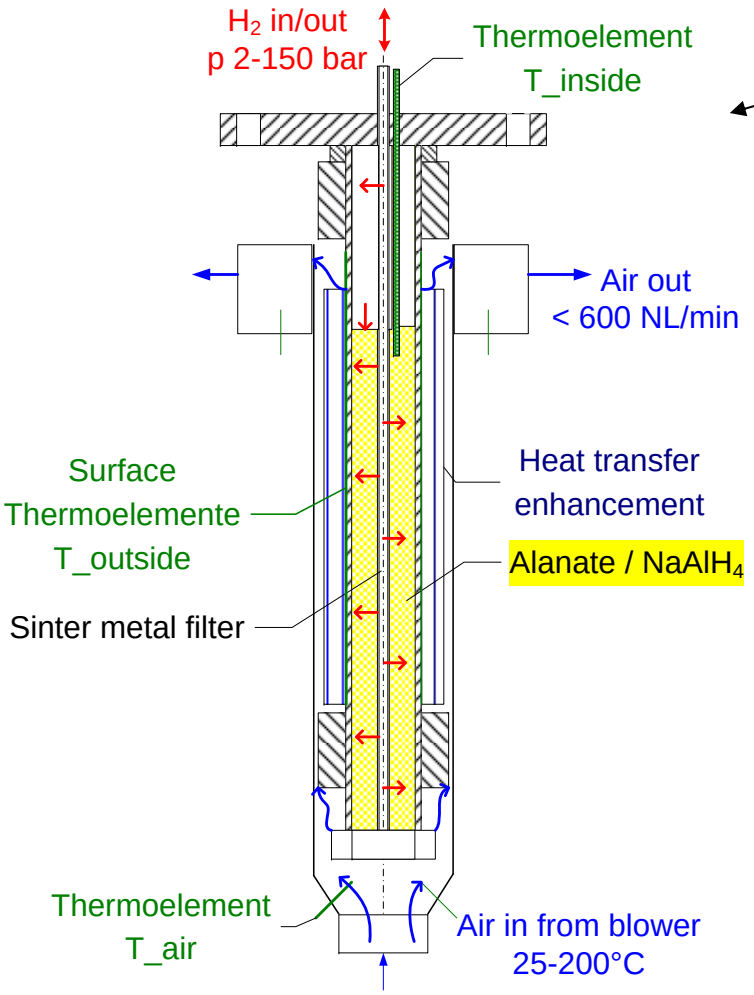
$$\frac{1}{3} Na_3AlH_6 \leftrightarrow NaH + \frac{1}{3} Al + \frac{1}{2} H_2$$

Theoretical capacity:
3.6 wt.% H_2 and 1.9 wt%. H_2

Real capacity (after doping):
~4.6 wt.% H_2 total

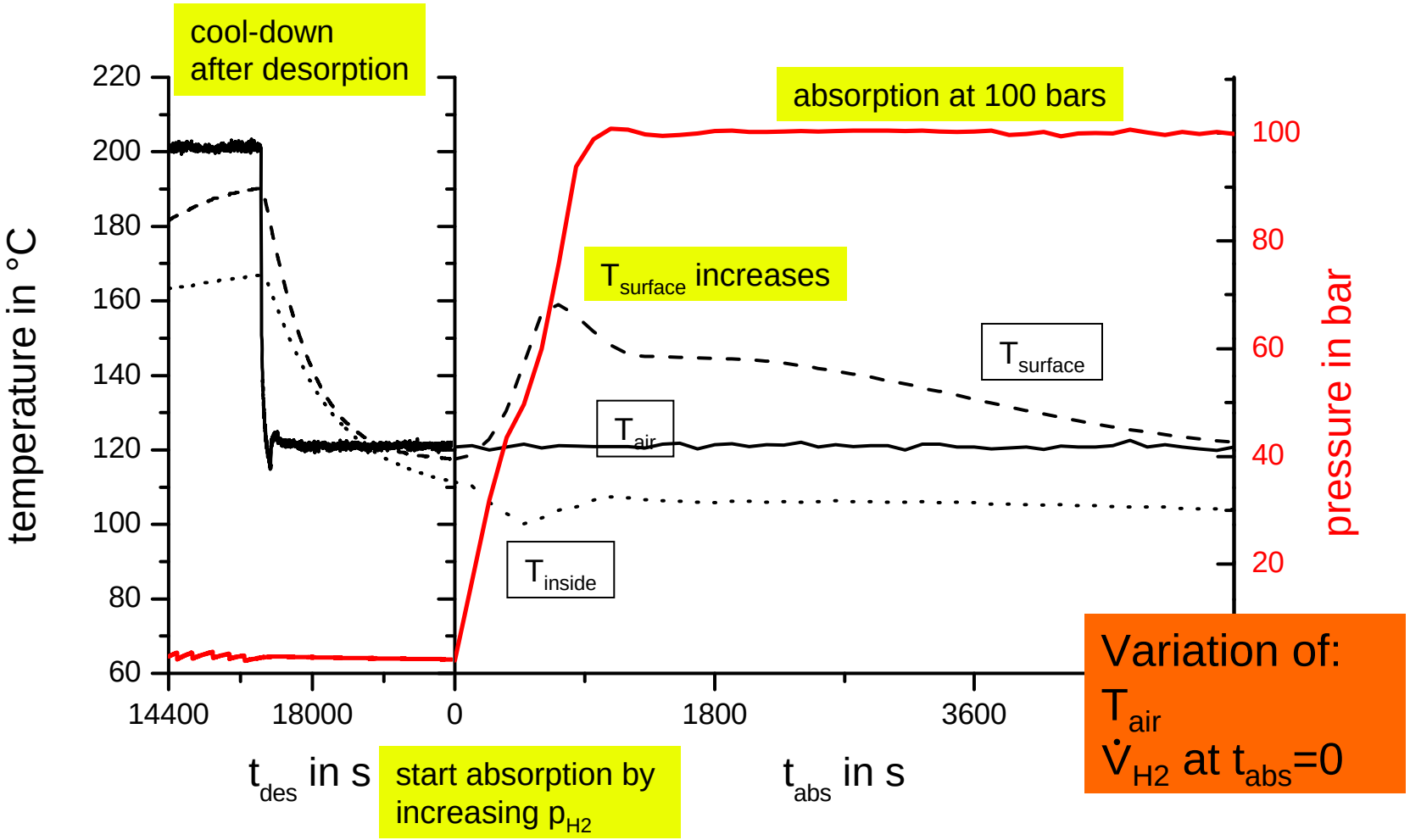
Enthalpy of reaction:
~ -40 kJ/molH_2 (exothermal absorption)

Scheme of the Experimental Testing Setup

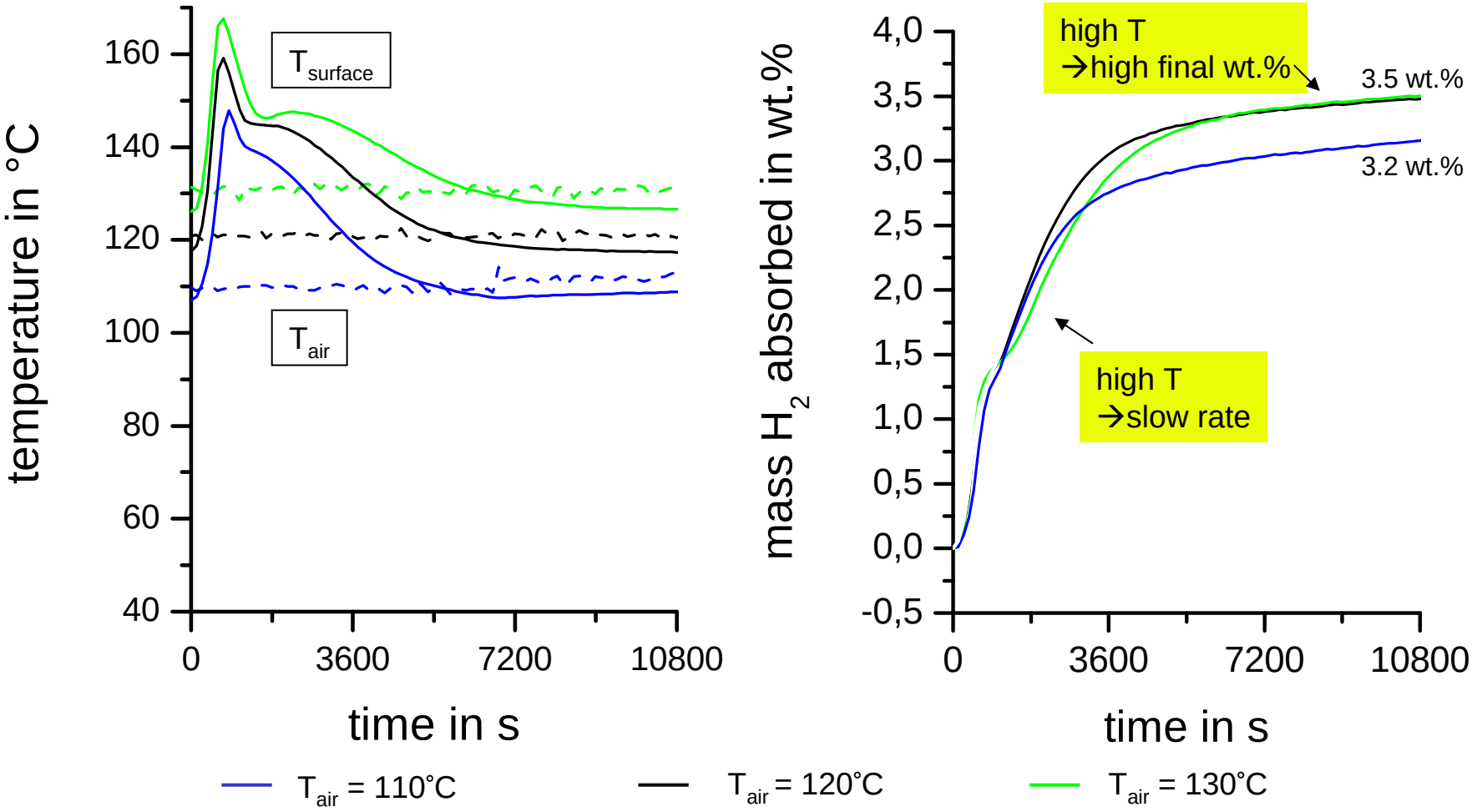


Tank &
Testing setup

Absorption Experiments: Procedure



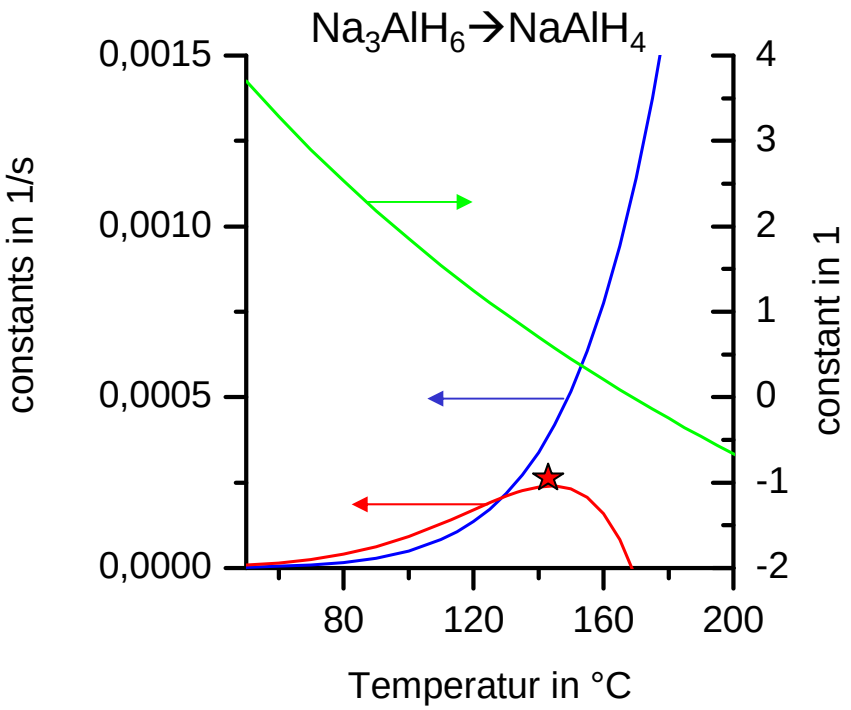
Absorption Experiments: Variation of T_{air}



Absorption with $\dot{V}_{H2}$=10 NL/min

Rate of Reaction of the Absorption:

Rate of reaction can be described as function of T,p and x:*



E_{a1}	61600	J/mol	k_{a1}	20833	1/s

*W.Luo,J.Gross; J.Alloys Comp. 385 (2004) 224-231

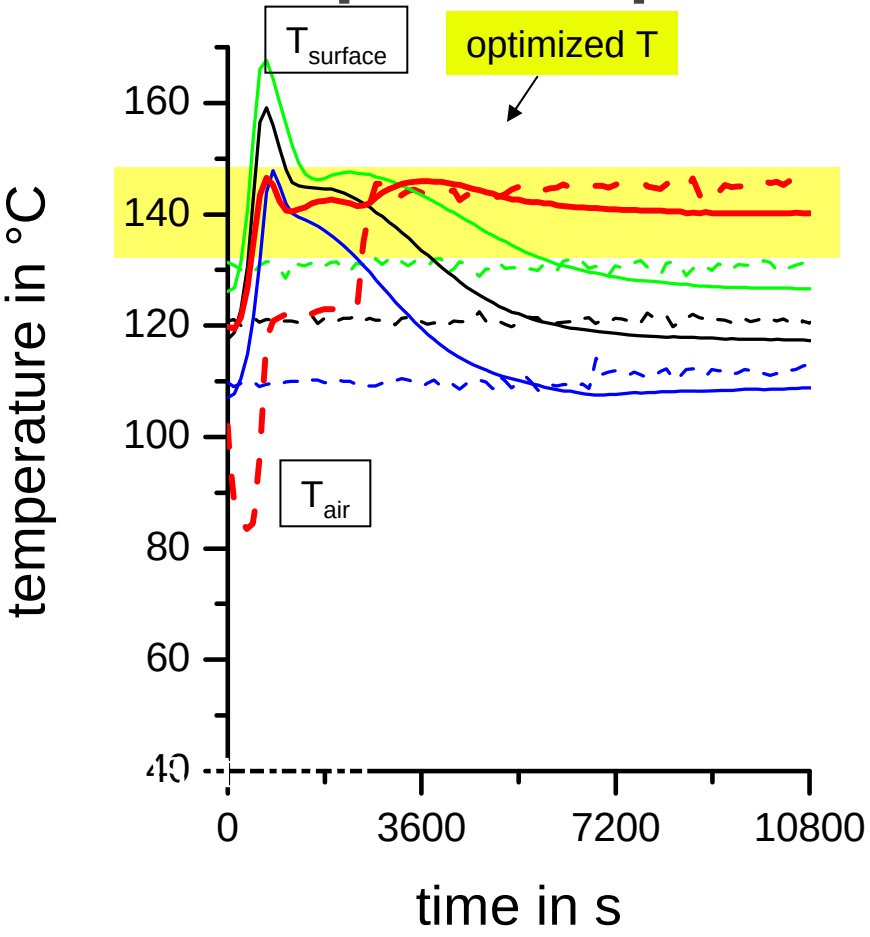
- $f_1(T)$ $\quad k_{a1} \cdot \exp(-\frac{E_{a1}}{RT})$
- $f_2(p,p_{eq}(T))$ $\quad \ln(\frac{p}{p_{eq1}})$
- $f_3(x)$ $\quad (5{,}6 - Hwt\%)^2$

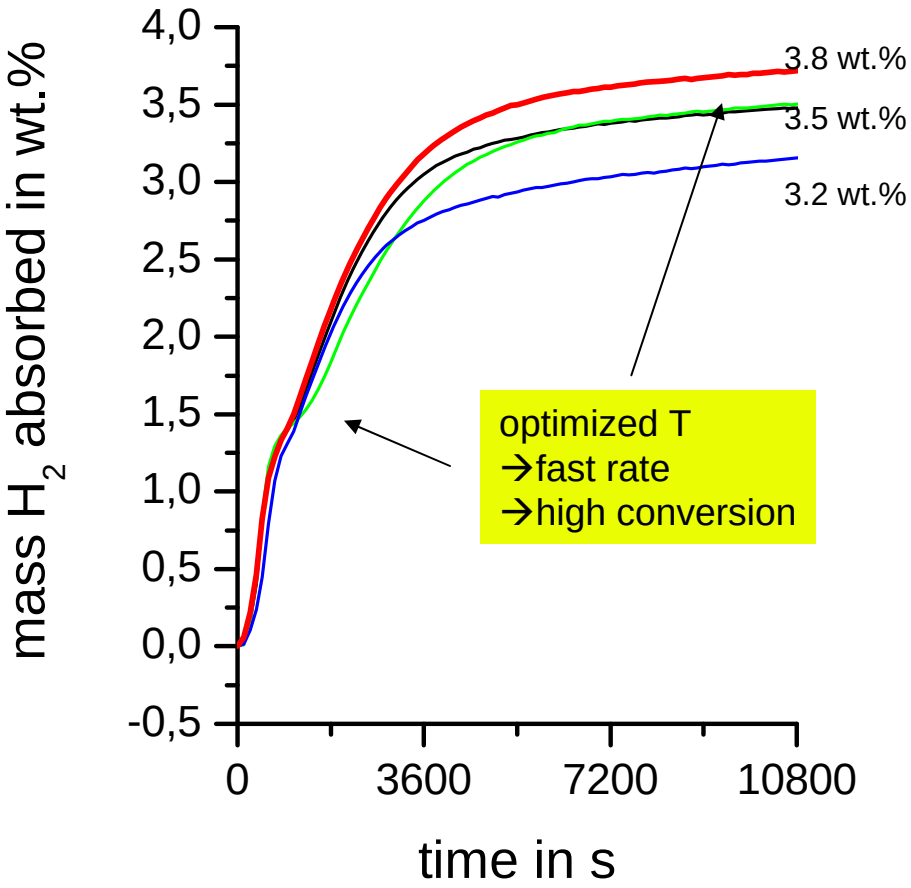
rate ~ $f_1 \cdot f_2 \cdot f_3$

Total rate of 2nd absorption step shows maximum at ~140°C

Heat management is important for exothermal reaction

Absorption Experiments: Optimized T_{air}

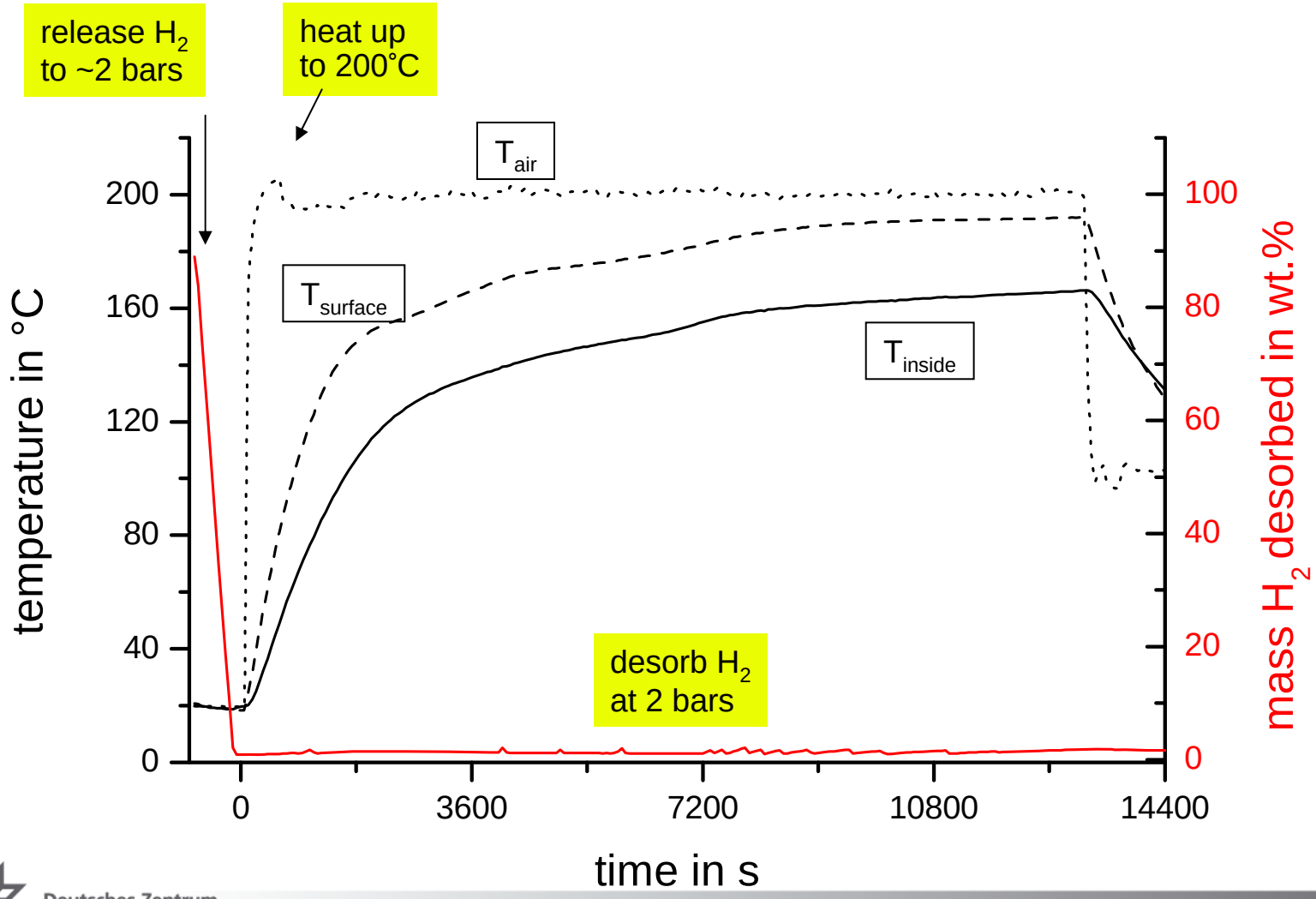




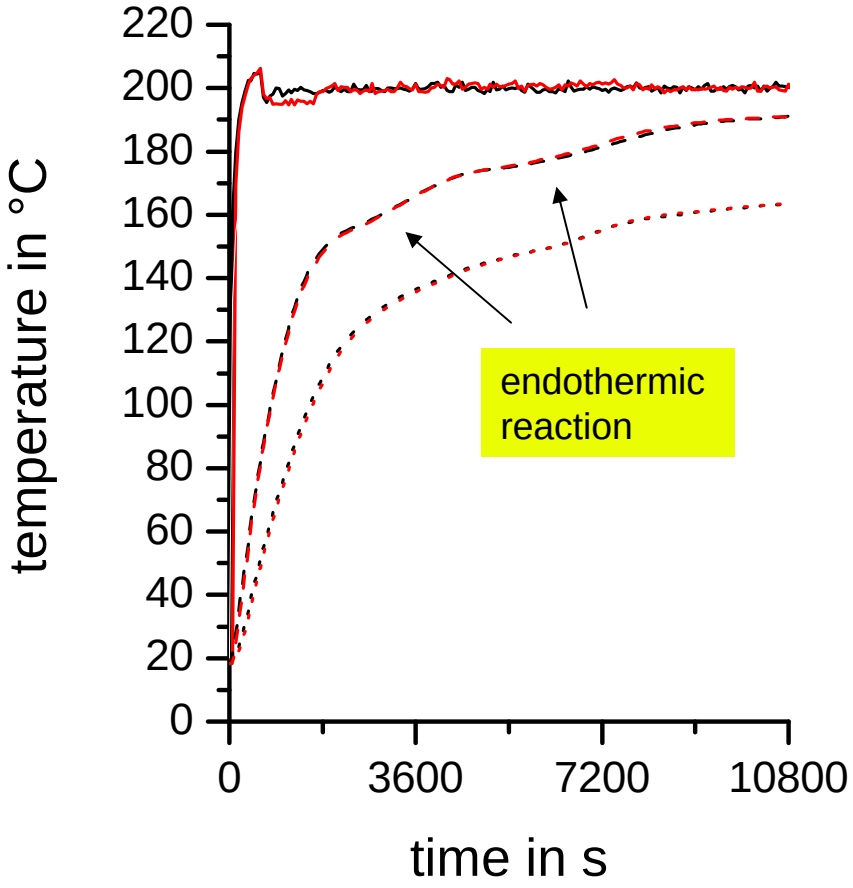
T_{air} = 110°C — T_{air} = 120°C — T_{air} = 130°C — T_{air} = 120-80-120-145°C

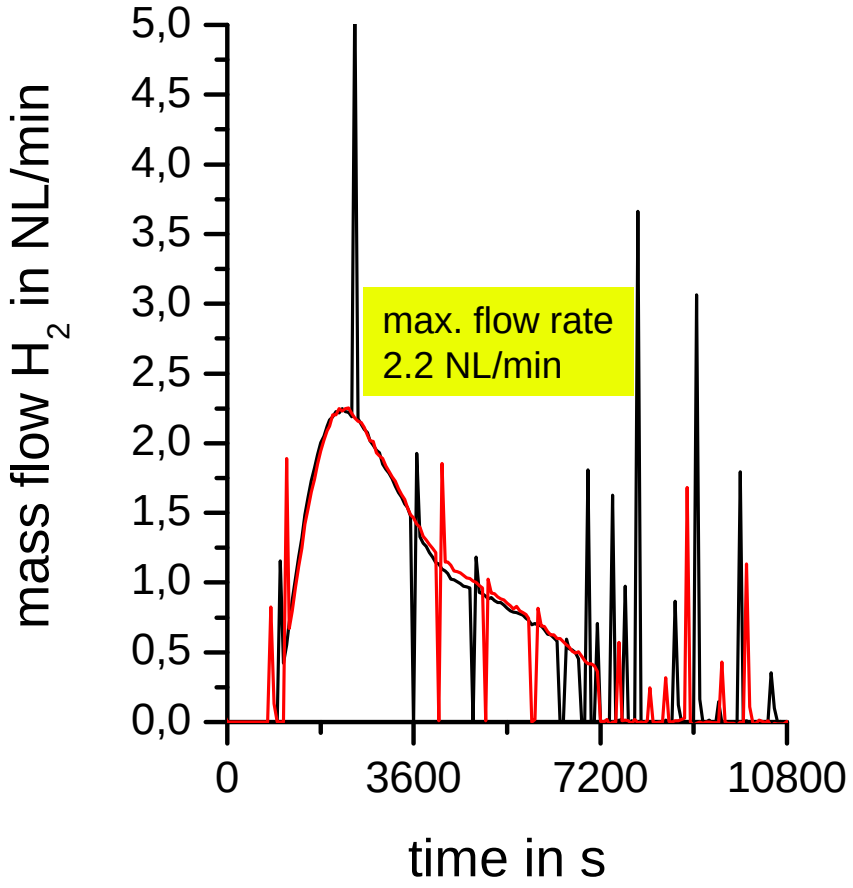
Absorption with $\dot{V}_{H2}$=10 NL/min

Desorption Experiments: Procedure



Desorption Experiments: Max. flow rate H_2 for coupling to HT-PEM

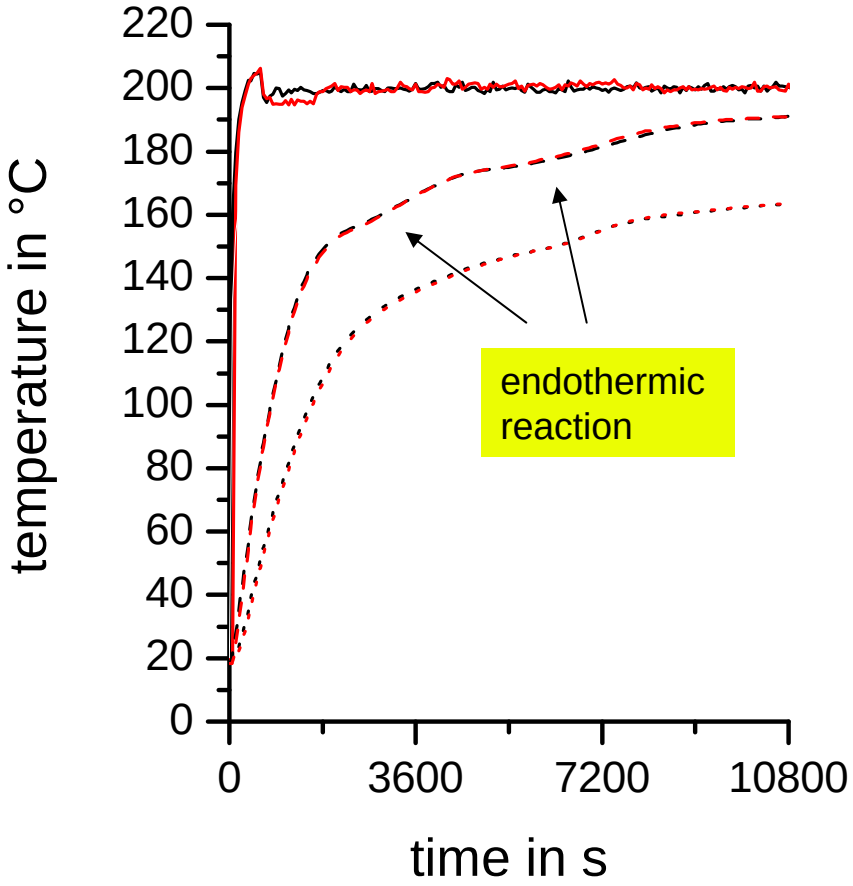


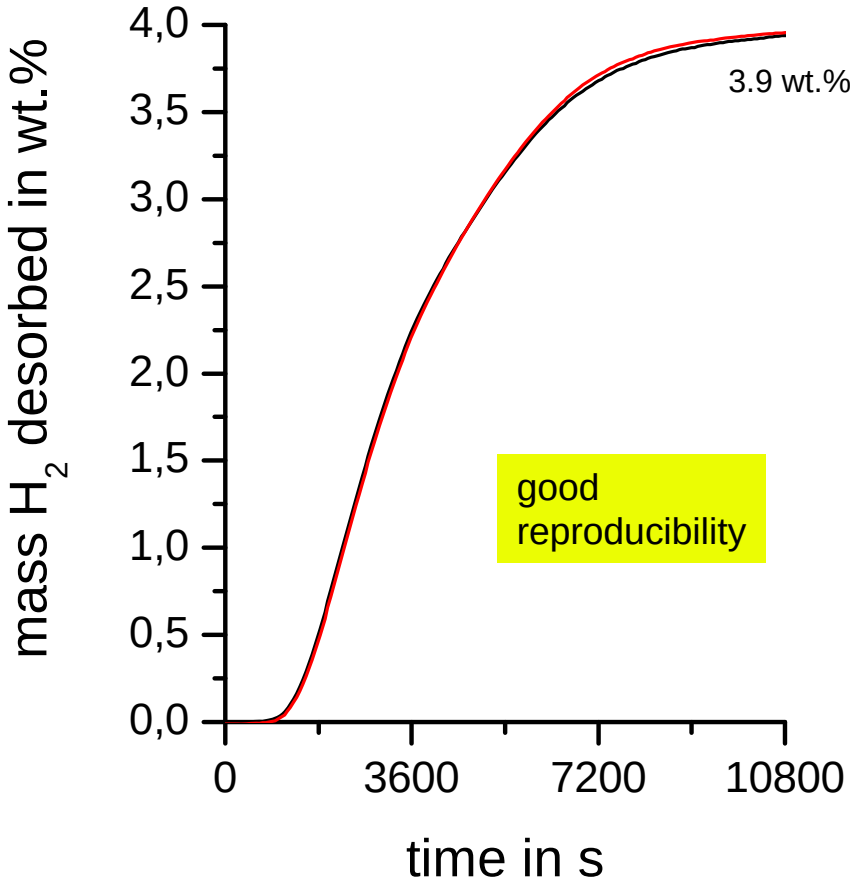


21.05.2010 — 20.05.2010

Desorption at 200˚C and 2 bars

Desorption Experiments: Reproducibility





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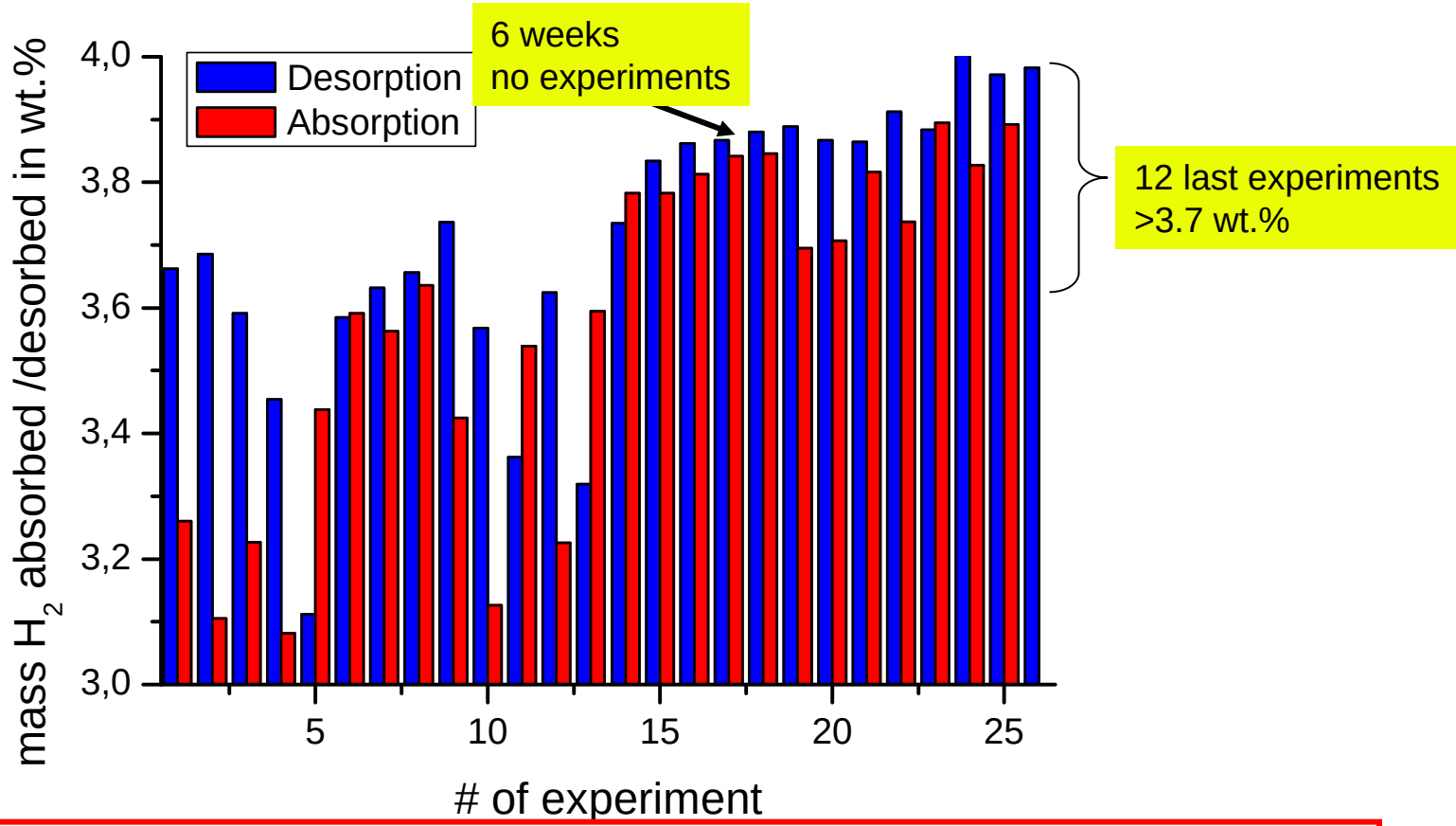
Desorption at 200°C and 2 bars

Experimental Results: Cycling stability



- Good cycling behaviour
- even after 6 weeks break under Ar-atmosphere good results
- >3.7 wt.% H_2 reached in last 12 experiments

Summary

- Cyclibility
- 26 experiments with >3 wt.%; last 10 experiments >3.7 wt.%

- Absorption:
- Reaction rate varies with T_{air}
- T_{opt}=140°C at the surface of the tank
- 140°C can be reached by $T_{air,0}$=80°C and $T_{air,end}$=145°C
- Fastest absorption time: 3.8 wt.% in 3 h (1.5 wt.% in 30 min)

- Desorption:
- After 3 h desorption time at 200 °C and 2 bars, 3.9 wt% H_2 can be released
- Maximal flow rate 2.2 NL/min

Thank you for your attention!

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