High-Resolution Calorimetry for Probing Reactions of Nanopowders with D_2

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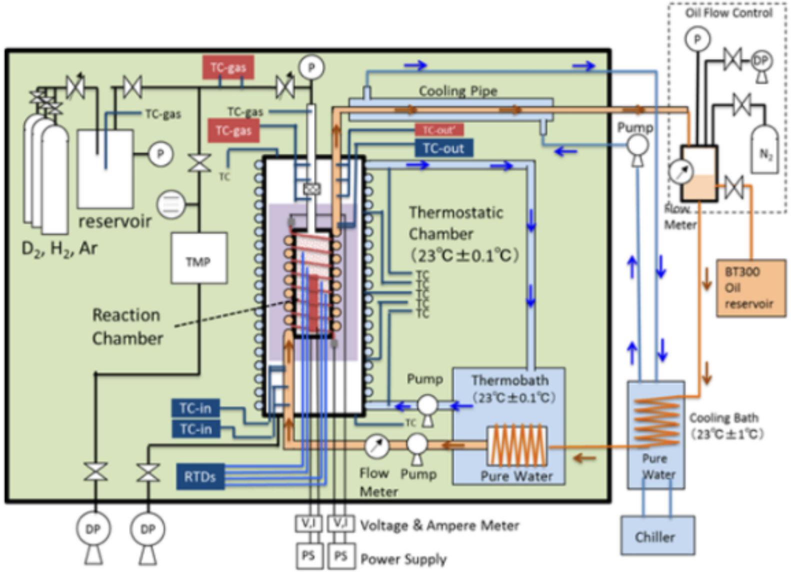
Agenda

1. Description of a new microwatt resolution calorimeter

2. Results from two sample runs involving D_2 and a nanopowder

Past reports of anomalous heat outputs



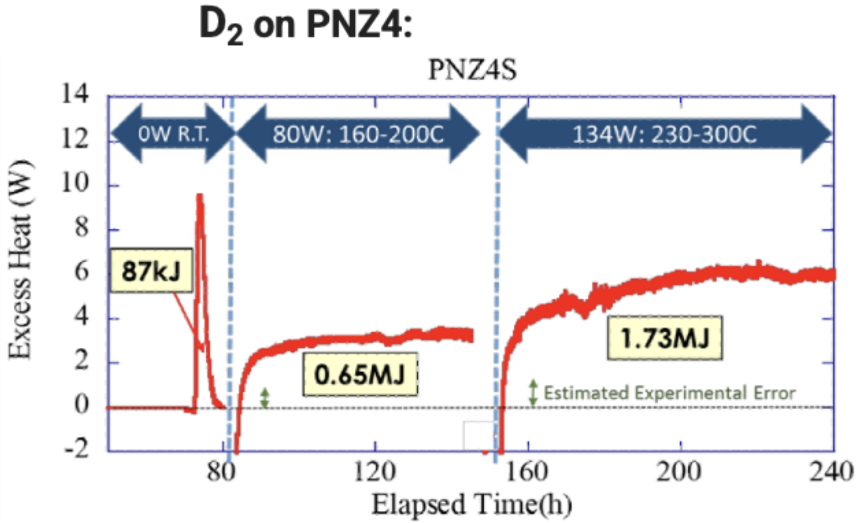


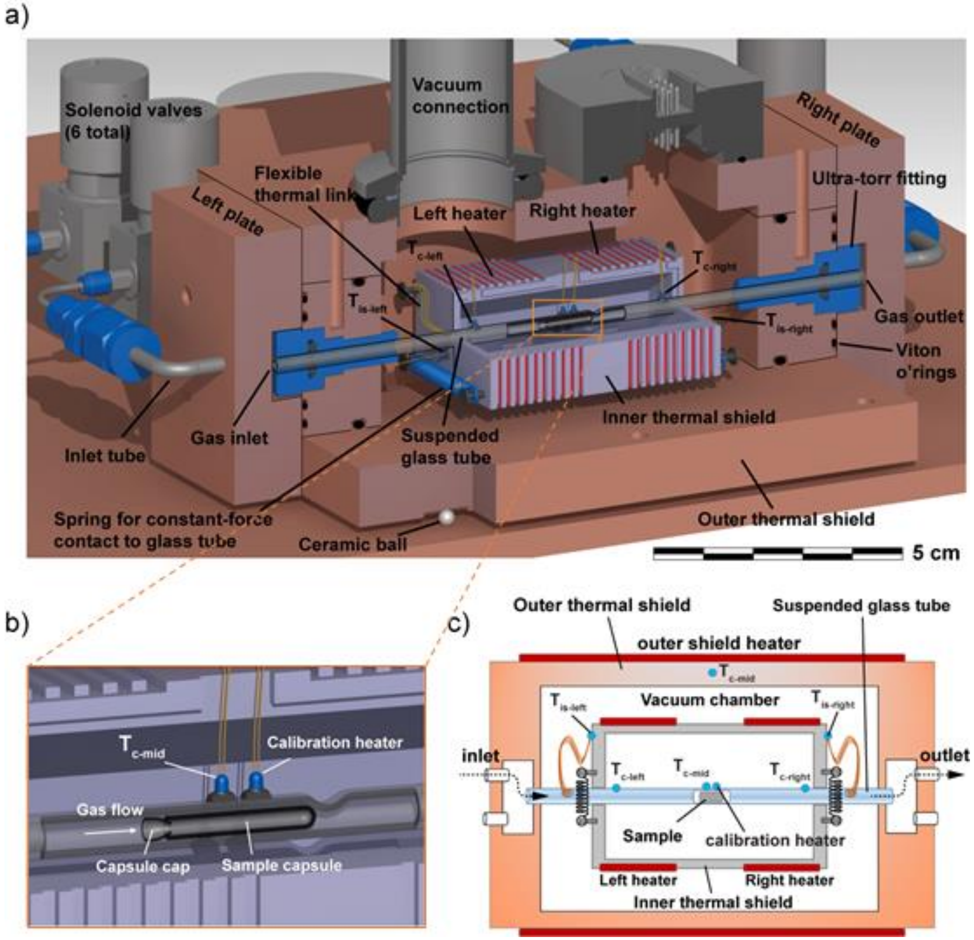
Table 1. Sample composition.

Sample name	Tested at	Weight (g)	Molar fraction (%)				
			Cu	Pd	Ni	Zr	O
PNZ4s	Tohoku University	109.4	---	3.6	25.2	53.4	17.8
PNZ4	Kobe University	109.4					

14.9 eV per D atom
Assuming all introduced Deuterium results in energy generation

Iwamura, Yasuhiro, et al. *J. Condensed Matter Nucl. Sci* 24 (2017): 191-201

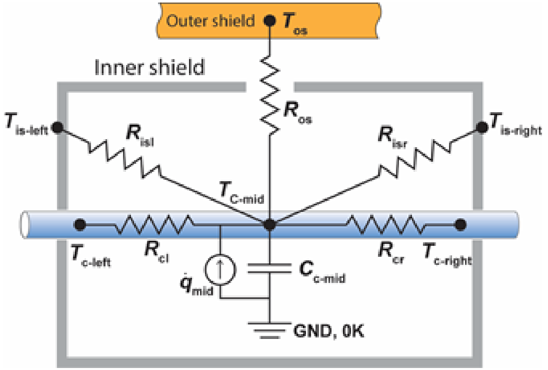
Microwatt resolution calorimetric reactor



Specifications

- Temperature range: R.T. – 300 °C
- Pressure range: 10 mbar - 30 bar
- Heat flow resolution: < 3 μW/√Hz
- long-term stability <4 μW/hour
- Mass balance resolution: 0.1 μmol

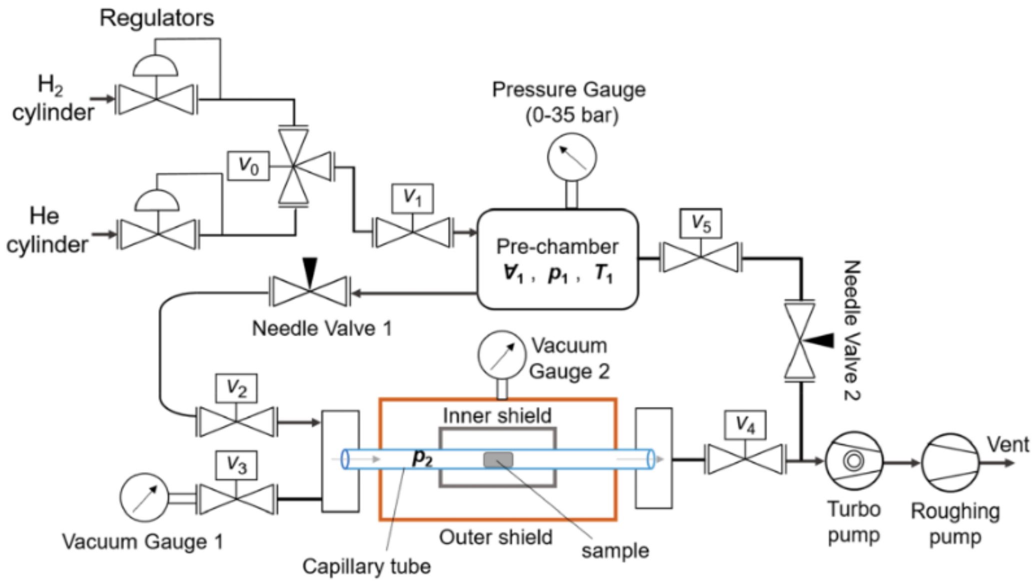
Lumped-thermal capacity model:

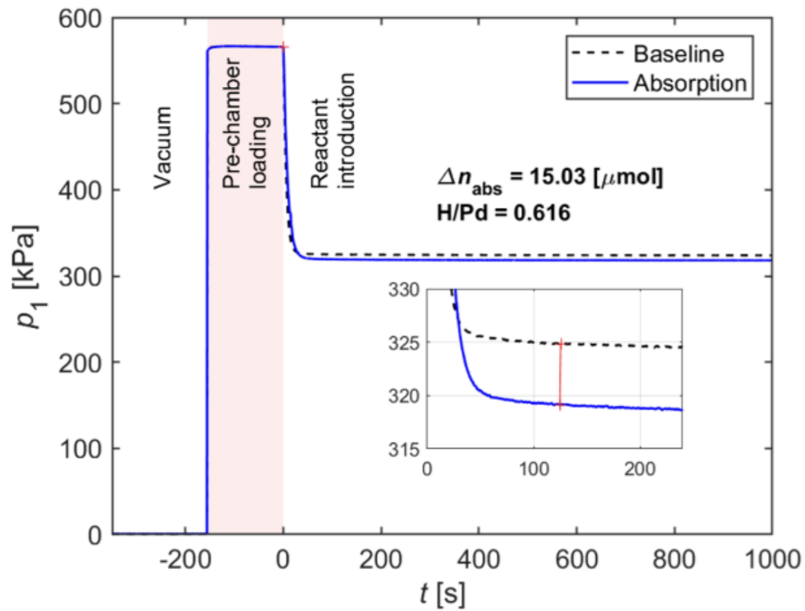


$$\dot{q}_{\mathrm{mid}} = \sum_i (T_{\text{c-mid}} - T_i)/R_i + C_{\text{c-mid}} \frac{dT_{\text{c-mid}}}{dt}$$

A. Reihani *et al.*, ACS Sensors (2020)

Gas handling system





A. Reihani *et al.*, ACS Sensors (2020)

Demonstration of calorimetric capabilities: hydrogenation of Pd nanoparticles

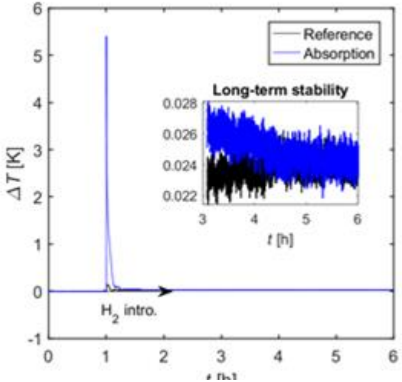
Absorption and baseline

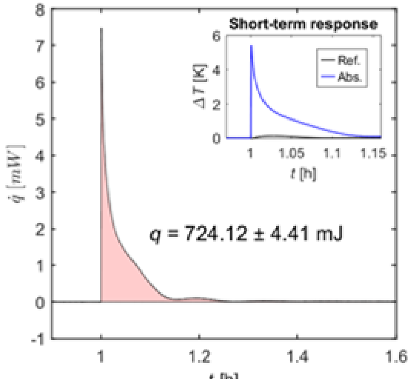
Heat of reaction

P_{H2} = 7 bar abs

T_{RXN}= 30 °C

m_{Pd} = 5.10 mg

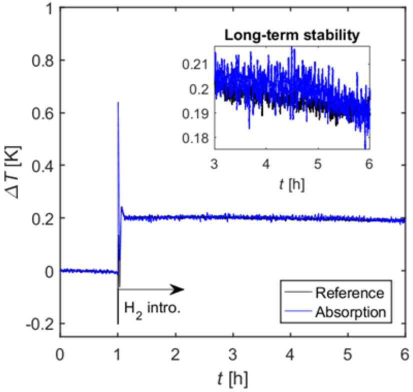


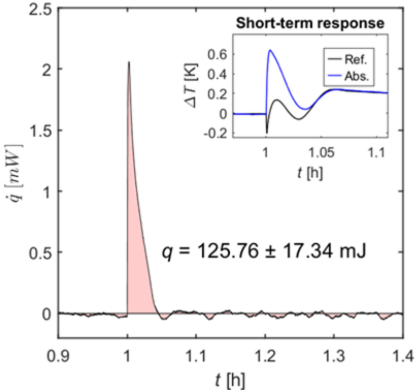


P_{H2} = 7 bar abs

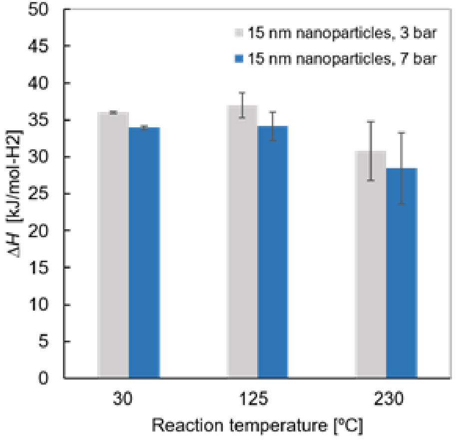
T_{RXN}= 230 °C

m_{Pd} = 3.77 mg





Enthalpy of hydrogenation



A. Reihani *et al.*, ACS Sensors (2020)

Preliminary work exploring heat outputs from metal nanopowders in D_2 environments

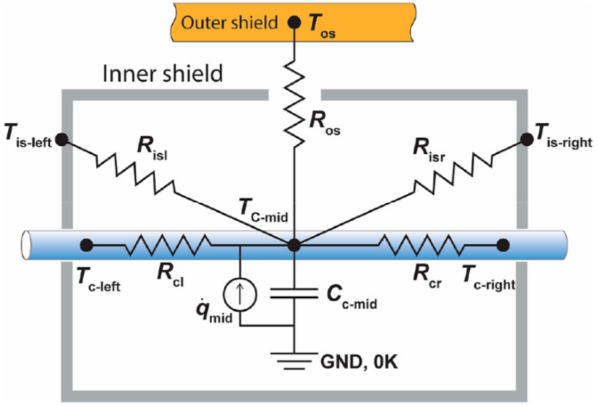
First run: Measurement from a nanopowder

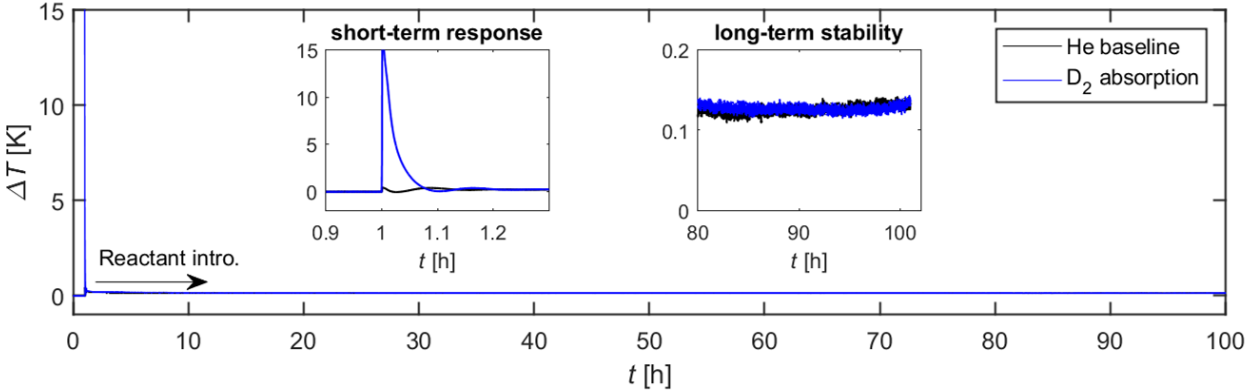
Temperature difference signal is obtained using the thermal network model:

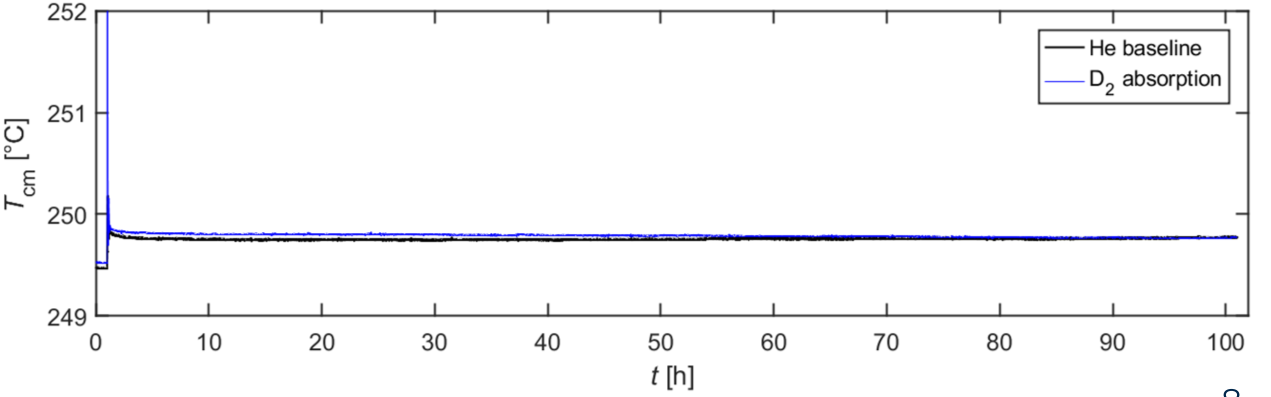
ΔT = Tc-mid – Tc-mid,expected, where

$$T_{\text{c-mid,expected}} = R_{\text{tot}} \sum_i T_i / R_i$$

$$R_{\text{tot}} = \left(\sum_i R_i^{-1} \right)^{-1}.$$

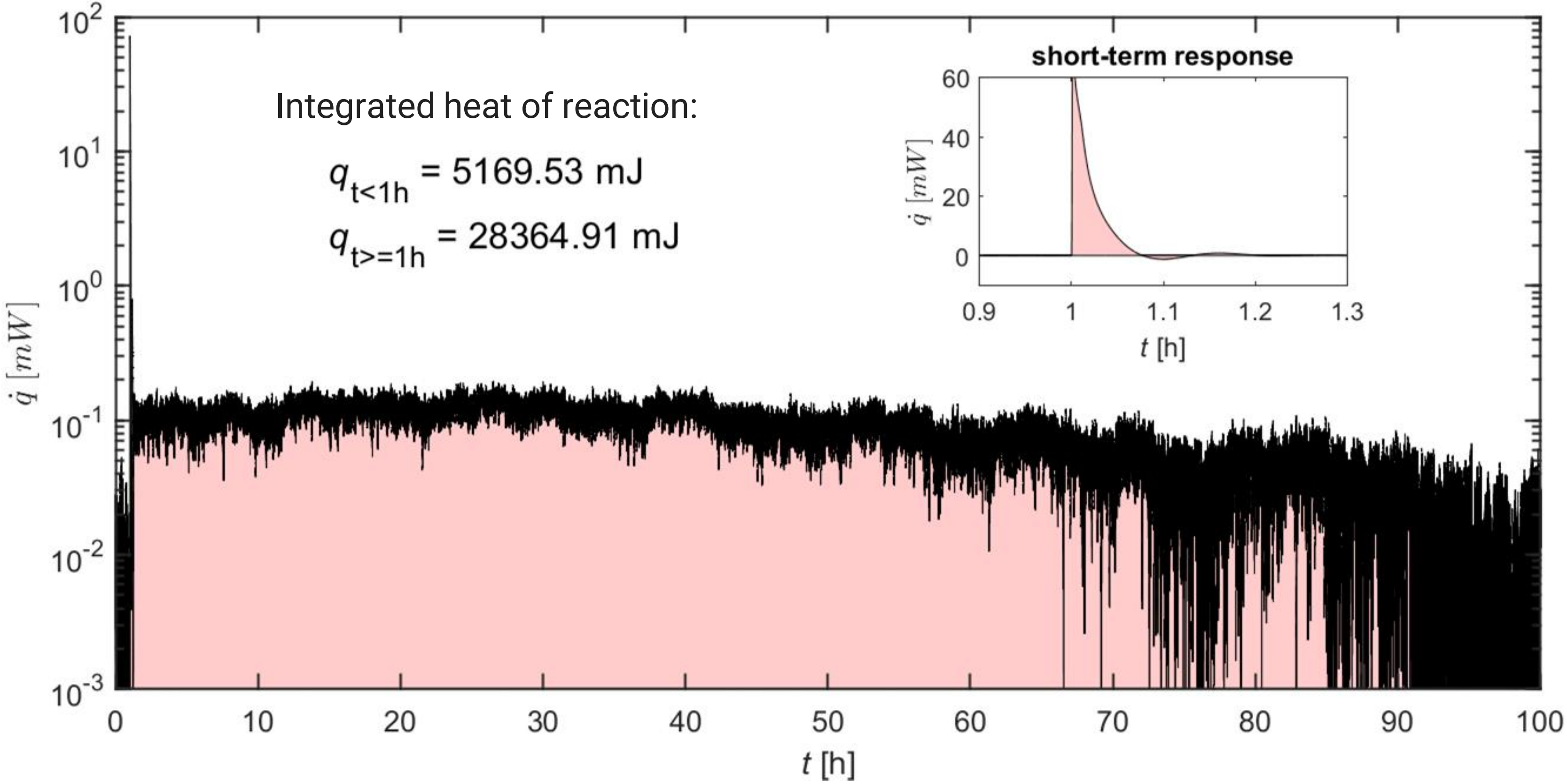






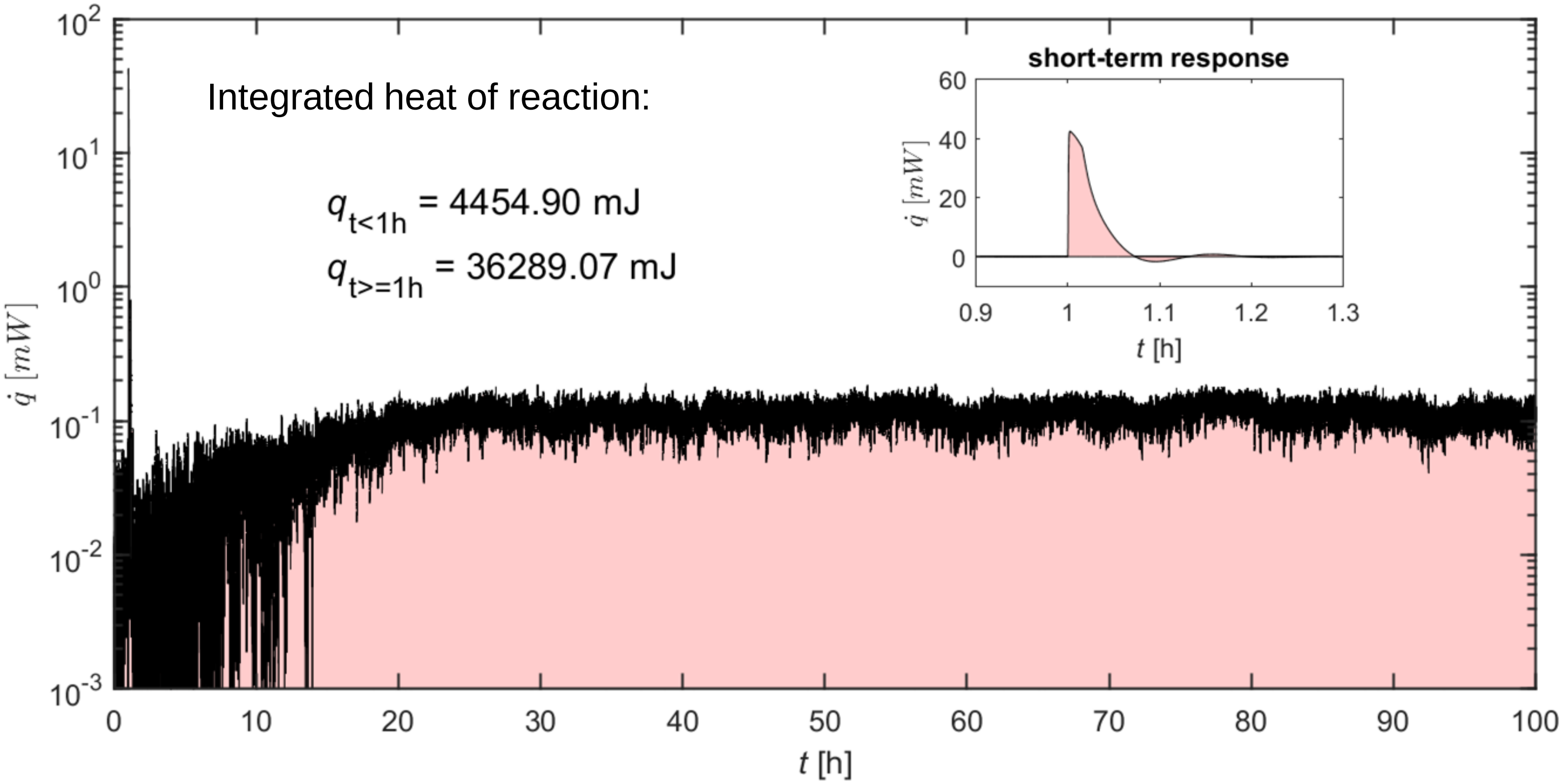
First run: Heat release rate (nanopowder + D_2)

Negative values are not shown in log plot



Second run: Heat release rate (nanopowder + D_2)

Negative values are not shown in log plot



Instrument stability across baseline measurements with He

Temperature difference signal is obtained using the thermal network model:

ΔT = Tc-mid – Tc-mid,expected, where

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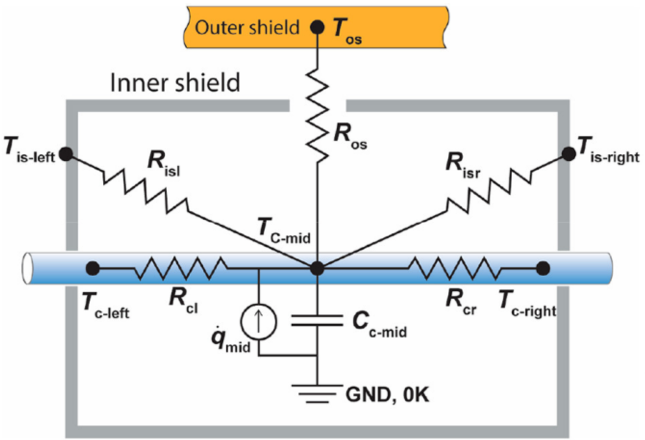
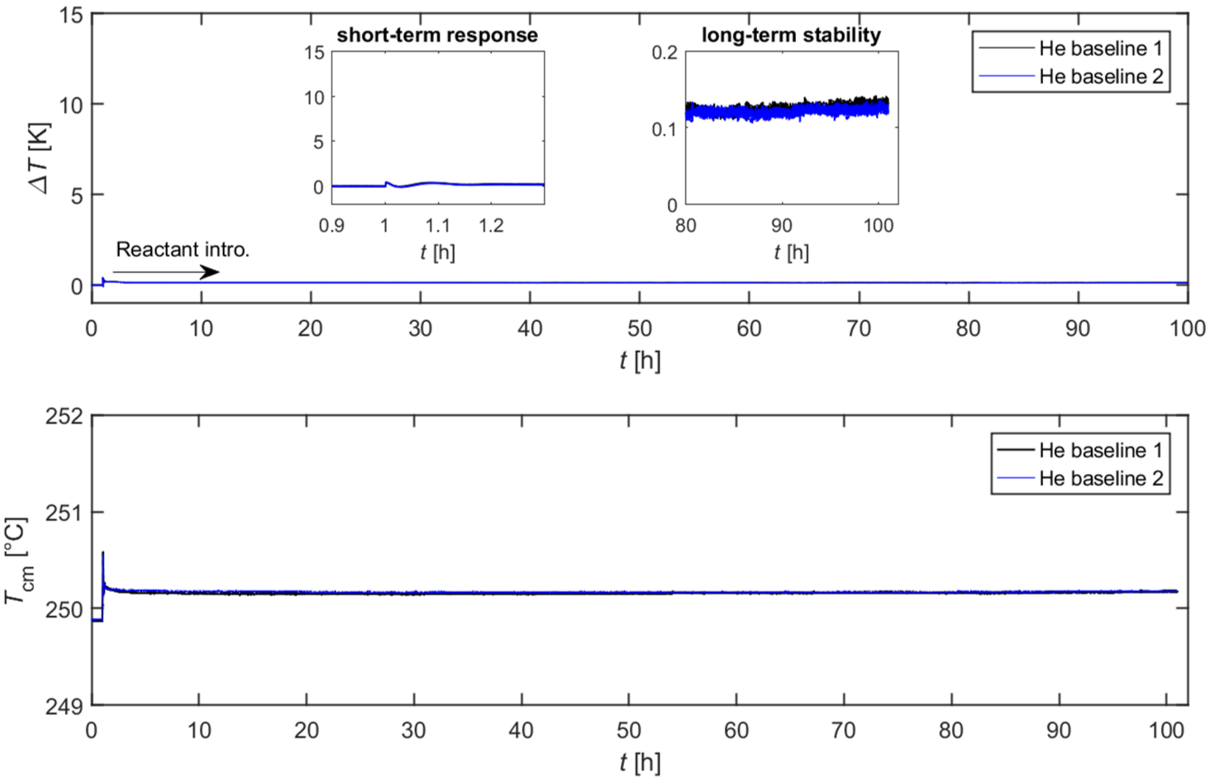
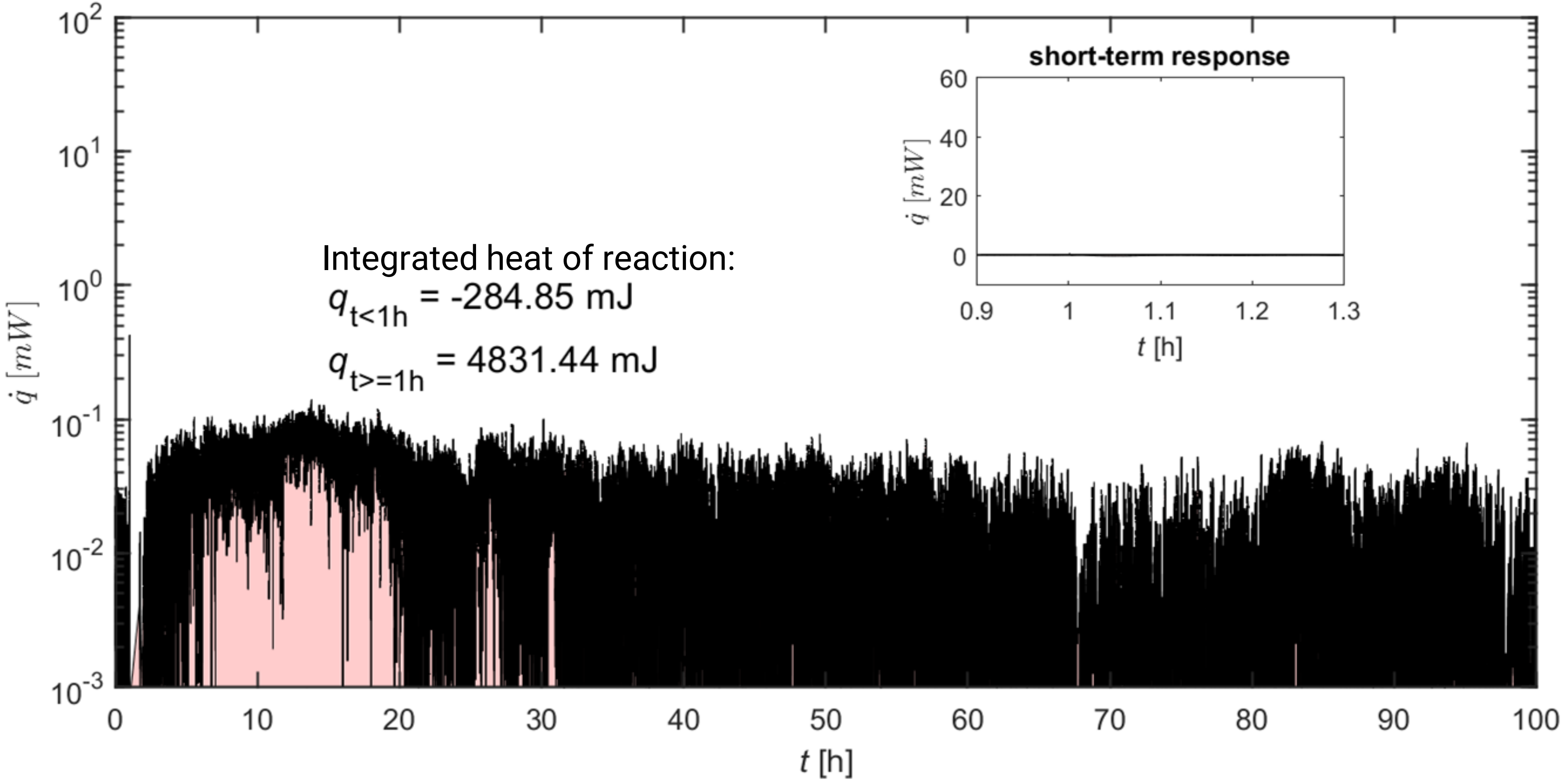




Heat release rate in He based control experiments is small



Necessary next steps

- Repeat measurements with a blank sample for both D_2 and He to eliminate the possibility of reactions with adsorbed Oxygen or due to possible leaks into the calorimeter
- Characterize reaction products using mass spectrometry
- Explore the possibility of oxidation of metals as source of exothermic reactions