Mechanisms for heat generated during deuterium loading of alumina-based Pd nanoparticle material

O. Dmitriyeva[1,2] R. Cantwell[1], M. McConnell[1], G. Moddel[2]

Recent studies on gas-loading of Pd nanoparticle materials have demonstrated consistent and repeatable anomalous heat production in the presence of deuterium gas [1-4]. Our group has confirmed anomalous heat production in zeolite and alumina powders containing Pd nanoparticles and found additional features. Investigations at low pressure and slow loading showed a clear association between exothermic and endothermic features and the presence of specific chemical species. These provide insight into the underlying mechanisms and the crucial question as to the origins of the anomalous heat.

1 . David A.Kidwell, Allison E.Rogers, Kenneth Grabowski, and David Knies, ICCF-15, 2009, Rome, Italy
2 . Y.Arata, Y.Zhang, X.Wang, ICCF-15, 2009, Rome, Italy
3 . Y.Sasaki, A.Kitamura, A.Takahashi, ICCF-15, 2009, Rome, Italy
4 . T.Hioki et al., ICCF-15, 2009, Rome, Italy

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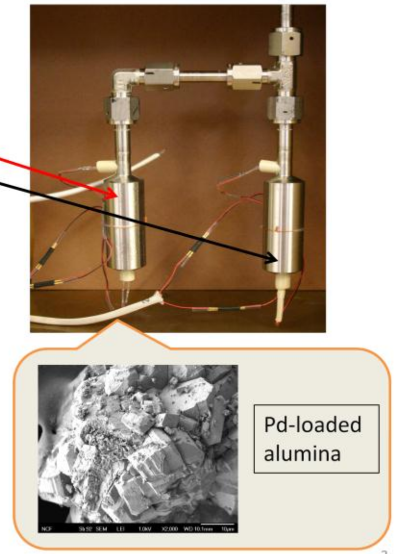
Objectives

- At what point in the gas loading process is excess heat generated?
- What is the mechanism for excess heat generation?
- If source is depleted, can it be recharged?

Material

- 2% Pd in alumina by wet impregnation
- Vessel1-> 6 g of material
- Vessel2-> empty for reference



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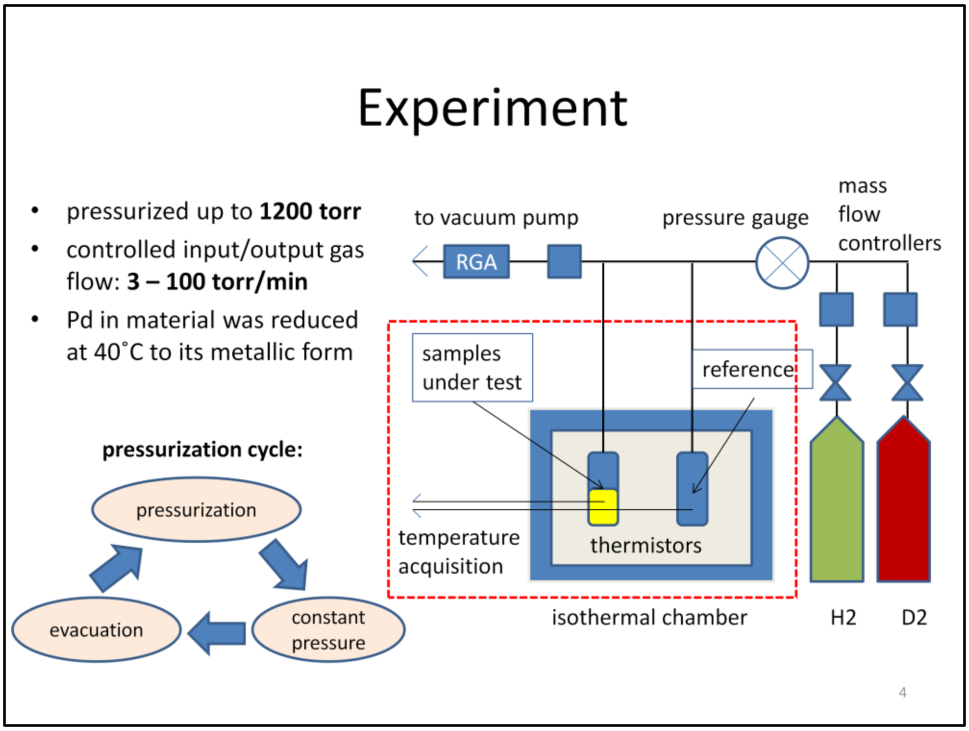
6 g of 2% Pd loaded alumina powder is loaded inside the stainless steel vessel. Another vessel remains empty and is used as a reference.



Stainless steel vessels are placed inside the isothermal chamber (oven) and connected to the gas lines. H_2 and D_2 are supplied to the vessels.

Temperature change is registered by thermistors, glued to the bottom of the vessels. System control, temperature and data acquisition is done by LabView. The calculations on exothermic and endothermic heat are done by integrating the temperature data from the thermistors over a period of time when the temperature is changing in respect to the baseline.

Pressurization cycle:
Gas flow in is regulated by the mass flow controller. After the system is pressurized up to 1200 torr it stays under that pressure for 5 hours. Depressurization is done in controlled manner using another mass flow controller.

Previous findings*

- Excess exothermic heat
  - replicated in Pd loaded alumina and zeolite (Pd nanostructures**)
  - tapers off with repeated load/unload cycles due to Pd nanoparticle agglomeration or "fuel" exhaust
  - exists at low Pd-D loading ratios
  - depends linearly on pressure (quantity of deuterium provided)

*
1. O.Dmitriyeva, R. Cantwell, M. McConnell, G.Moddel, 9th Workshop on Anomalies, Sienna, Italy 2010
2. O.Dmitriyeva, R. Cantwell, M. McConnell, G.Moddel, ICCF-16, 2011, Chennai, India

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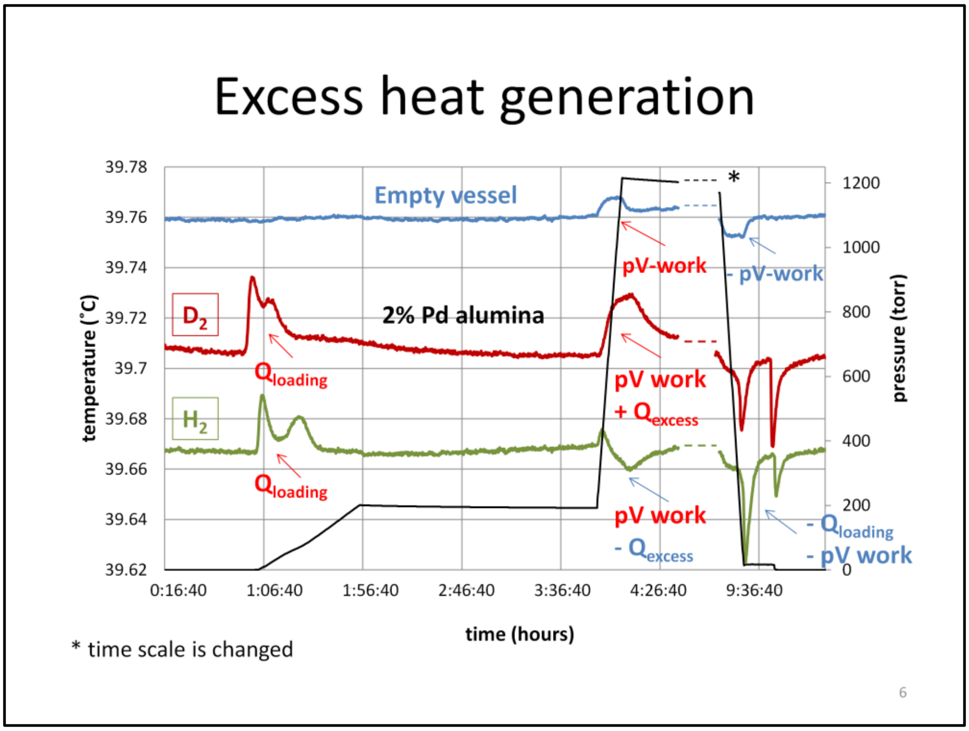
3. D. Kidwell, A. Rogers, K. Grabowski, and D. Knies, ICCF-15, 2009, Rome, Italy
4. Y. Arata, Y. Zhang, X. Wang, ICCF-15, 2009, Rome, Italy
5. Y. Sasaki, A. Kitamura, A. Takahashi, ICCF-15, 2009, Rome, Italy
6. T. Hioki et al., ICCF-15, 2009, Rome, Italy



Typical run done on 2% Pd loaded alumina powder.
2 step pressurization: (1) slow pressurization up to 200 torr, system stays at the constant pressure for 2 hours, (2) fast pressurization up to 1200 torr, system stays at the constant pressure for 5 hours.

Empty vessel shows temperature change associated with the work of pressurization (pV work) during fast pressurization step.
pV work is recovered during evacuation step. Areas under the curve are equal and have opposite sign. No excess heat is generated.

D_2 run: Temperature is changing in the vessel with material during slow pressurization step due to PdD formation ($Q_{loading}$)
Temperature is changing during fast pressurization step (pV-work + Q_{excess})
pV-work and $Q_{loading}$ are recovered during evacuation step. D_2 run exhibits excess exothermic heat Q_{excess}

H_2 run after seven D_2 runs: Q_{excess} can be NEGATIVE!
Temperature is changing in the vessel with material during slow pressurization step due to PdH formation ($Q_{loading}$)
Temperature is changing during fast pressurization step (pV-work - Q_{excess})
pV-work and $Q_{loading}$ are recovered during evacuation step. H_2 run exhibits excess endothermic heat Q_{excess}

Mechanisms for heat generation

Pressurization $\rightarrow$ $$Q_{loading} + (pVwork) + Q_{excess}$$

Depressurization $\rightarrow$ $$-Q_{loading} - (pVwork)$$

$$Q_{excess} / time \propto \begin{cases} \Phi_D \cdot \dfrac{dp}{dt} & \text{D}_2\text{ : Excess exothermic heat} \\ \Phi_H \cdot \dfrac{dp}{dt} & \text{H}_2\text{ : Excess endothermic heat} \end{cases}$$

Φ – quantity of remaining fuel

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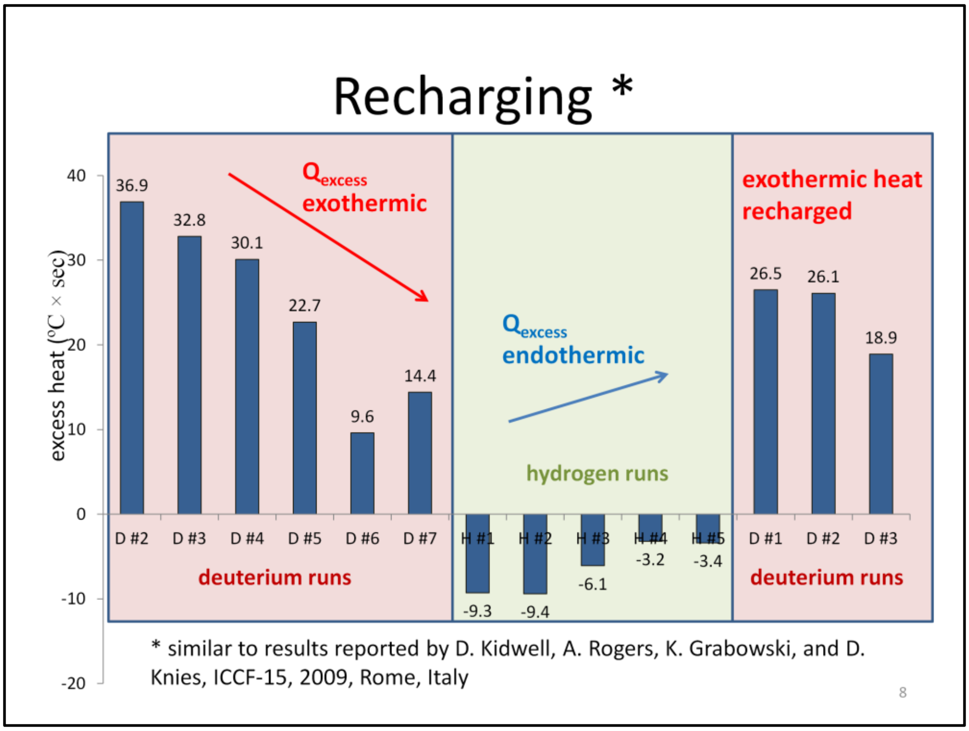
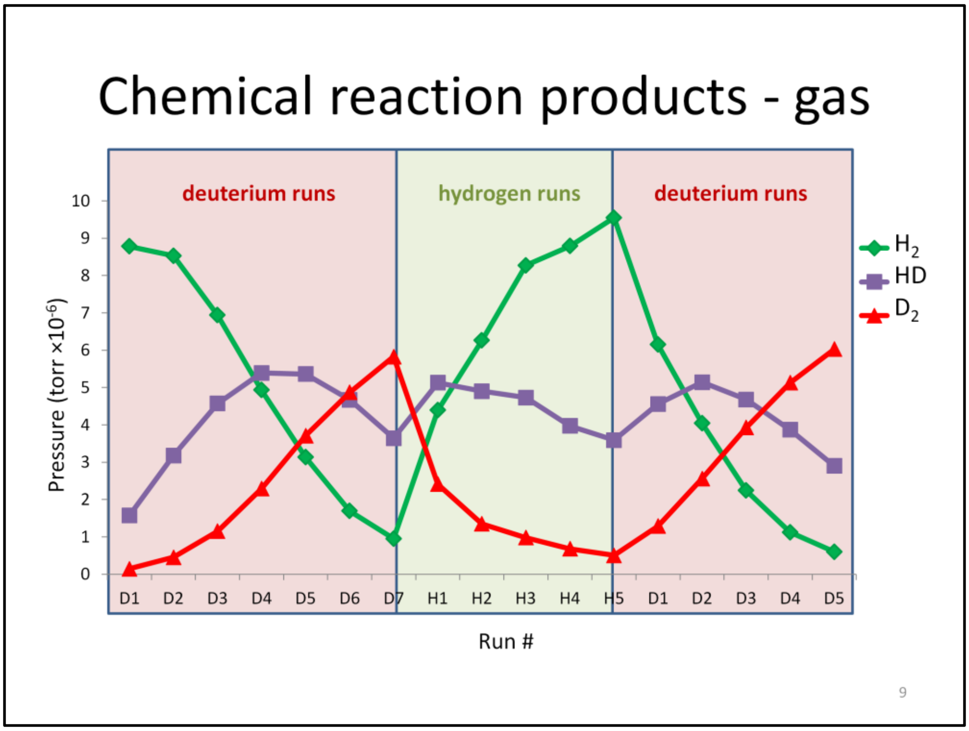


Switching between deuterium and hydrogen runs:

1) Excess heat tapers off. Fuel is used up.

2) Excess heat changes from exothermic to endothermic when we go from deuterium to hydrogen. Fuel was produced during deuterium runs and now supports the endothermic reaction in the presence of hydrogen.

3) Excess heat is recharged after switching from hydrogen back to deuterium. Fuel was replenished!



RGA data taken during system evacuation:

H_2 is generated by the system during D_2 runs.
Mass 3 (HD gas) is participating in HD-homoexchange.

Chemical reaction constituents

Deuterium loading		Hydrogen loading	
reactants	products	reactants	products
D_2 H_2O H_2 (residual)	HDO D_2O HD H_2	H_2 D_2O D_2 (residual)	HDO H_2O HD D_2

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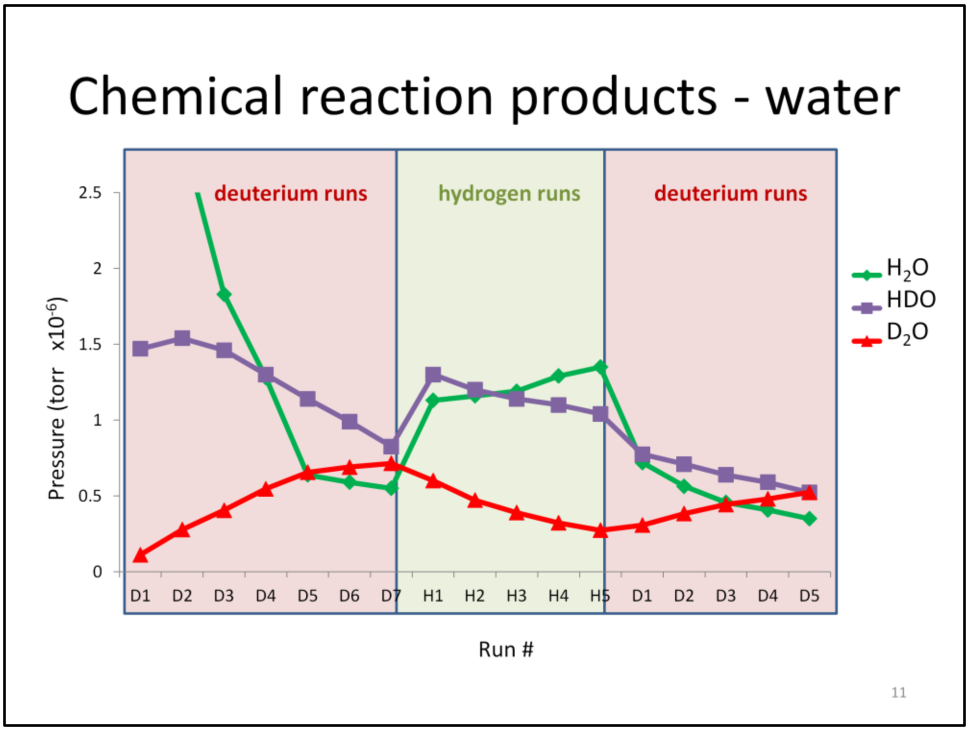

RGA data taken during system evacuation:

H_2O is exhausted and D_2O is generated by the system during D_2 runs.
D_2O is exhausted and H_2O is generated by the system during H_2 runs.
All the above is the evidence of HD-heteroexchange which can be the source of exothermic or endothermic heat.

Conclusions

- **Fuel**:
  - can be used up or replenished to recharge the system
- **HD exchange:**
  - clear evidence from residual gas analysis (RGA) data
- **Some excess heat:**
  - can be exothermic or endothermic, therefore likely of chemical nature