Co-Adsorption of Carbon Dioxide on Zeolite 13X in the Presence of Preloaded Water

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Background

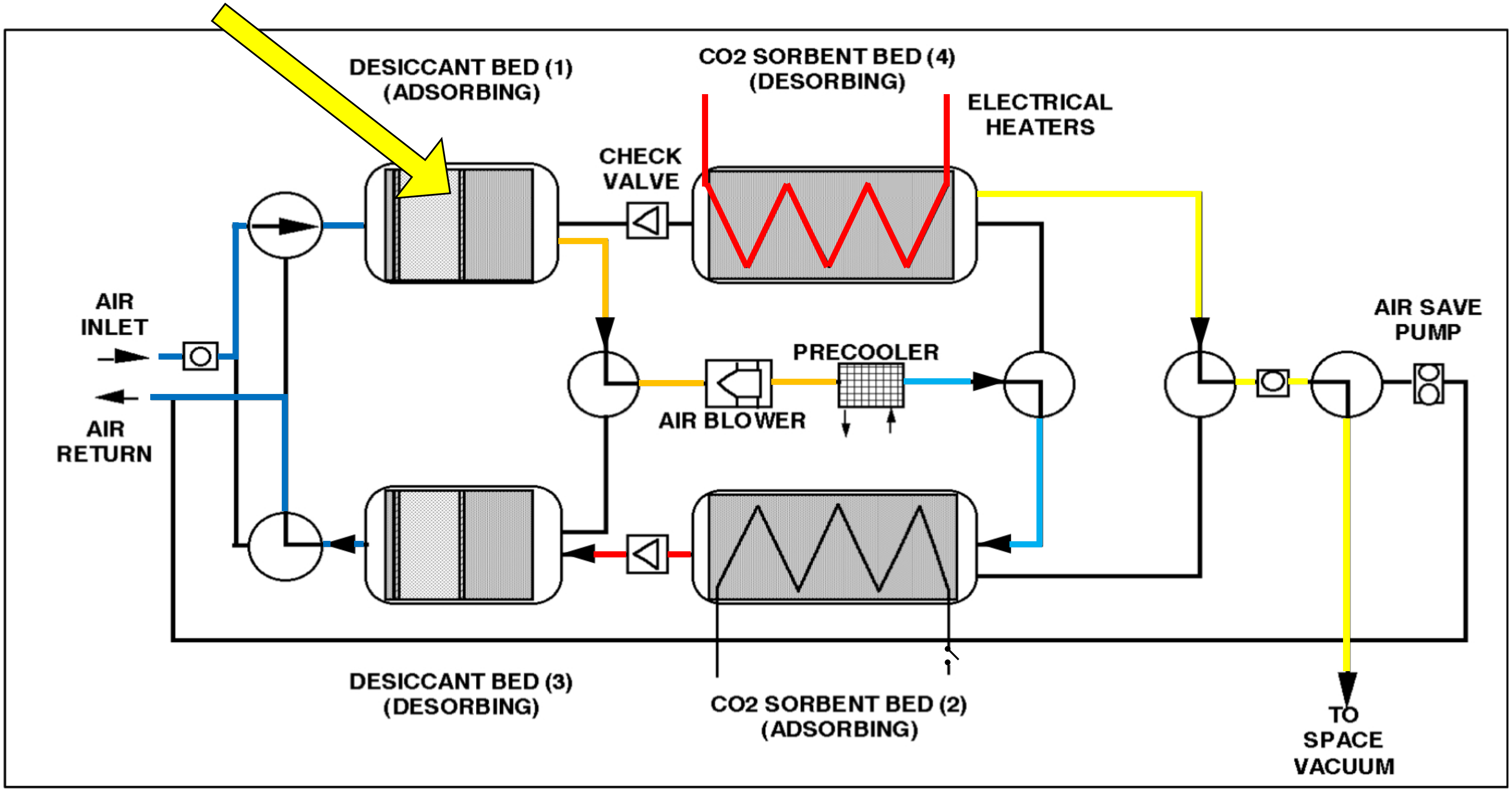
- Carbon Dioxide removal is a key aspect of Life Support for long-duration missions
  - Need to improve Mass, Power, and Volume of systems

- Cabin air has three major constituents:
  - Oxygen and Nitrogen
  - Carbon dioxide (CO_2)
  - Water Vapor

- The mechanism for strong CO_2 adsorption in zeolites (and many sorbents) is also the same mechanism for H_2O
  - Water vapor is selectively adsorbed over CO_2

4-Bed Molecular Sieve

Opportunity to optimize CO2 removal by shrinking the 13X desiccant layer 'just enough'



Desiccant Beds

- Zeolites have a very strong affinity for water
    - Enables a nearly complete scrubbing of water vapor from air
        - Key factor for protecting downstream systems:
            - CO_2 sorbent beds
            - CO_2 reduction systems
    - Small amounts of water inhibit CO_2 adsorption

- In the CDRA and 4-Bed Desiccant Beds, the zeolite layer is dried each cycle
    - Ideal for ensuring complete water scrubbing
    - Also re-enables CO_2 removal
        - This CO_2 never reaches the sorbent bed -> Inefficiency!

Measurement of CO_2 and H_2O

- The challenge:

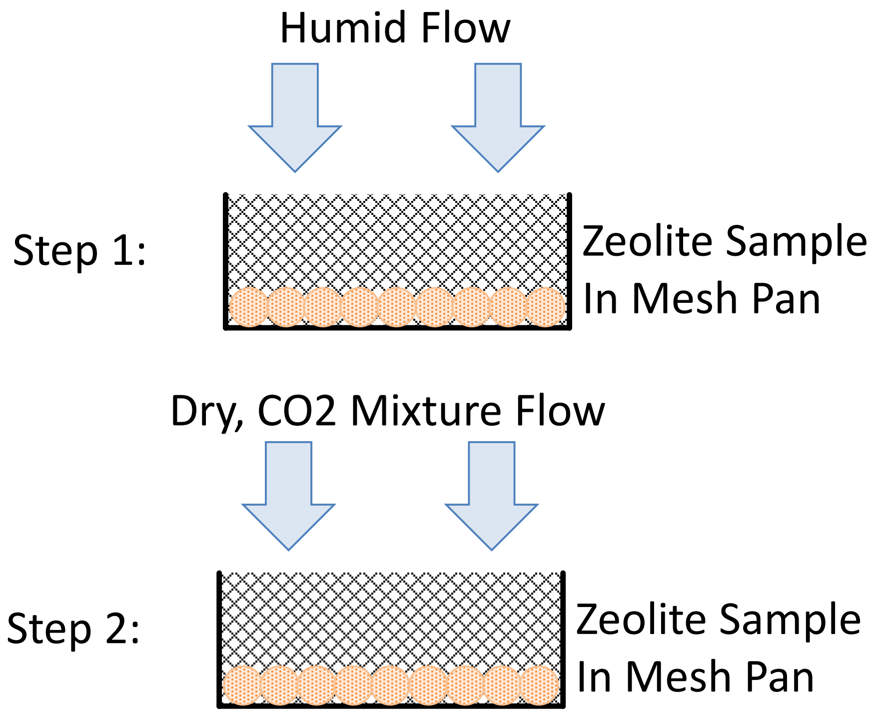
  Orders of magnitude

- To adsorb ~5 mol/kg at room temperature on 13X
  - Water vapor at 1 Pa
  - Carbon Dioxide at 10 kPa

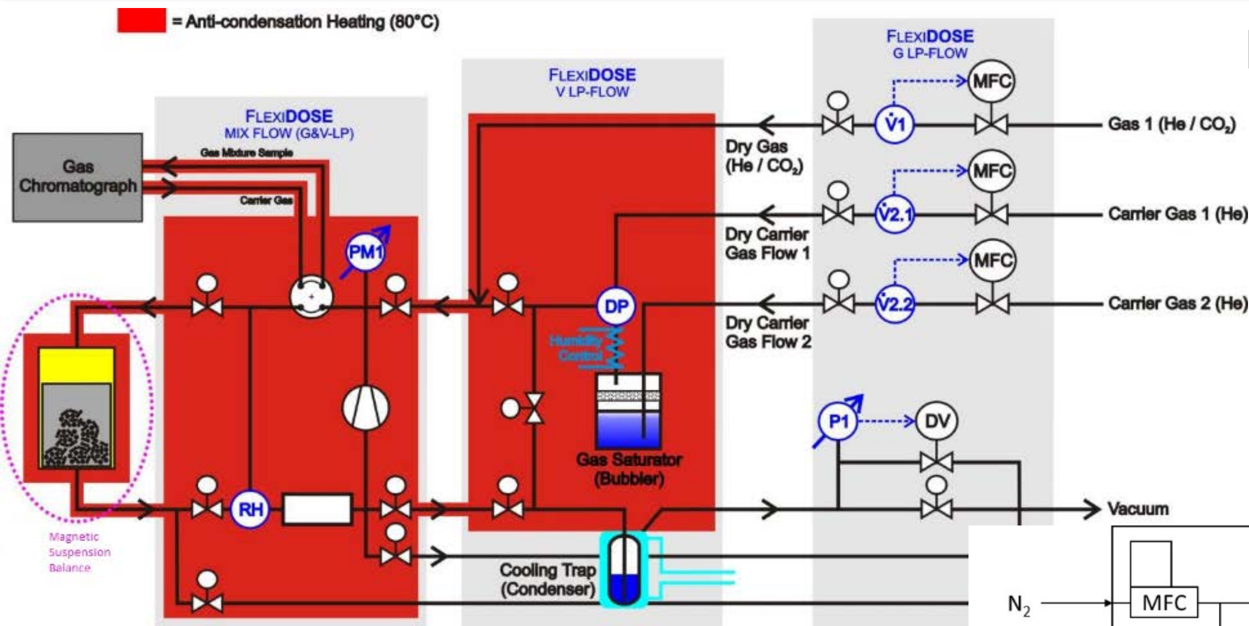
  - Essentially this requires 10,000x more gas mixture volumes to reach equilibrium for water than CO_2.
    - More time leads to build-up of errors, a new approach is needed

Methodology

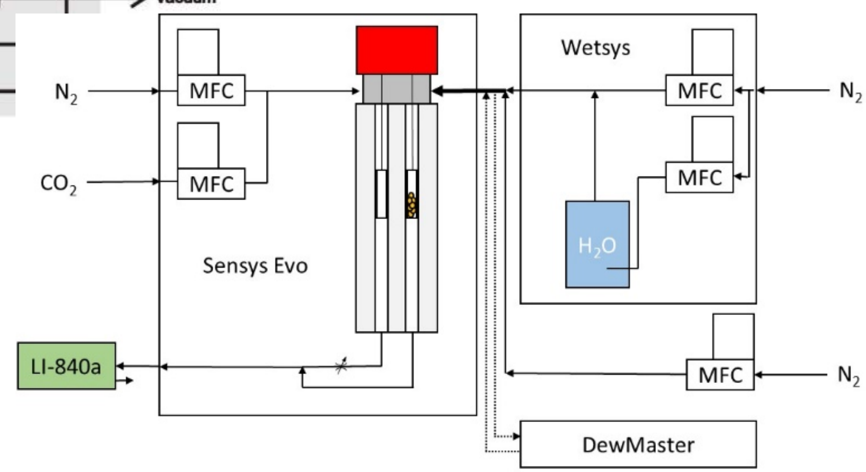
- Adopt previously proven method:
  - Pre-load a thin layer of zeolite beads with water vapor



Instruments



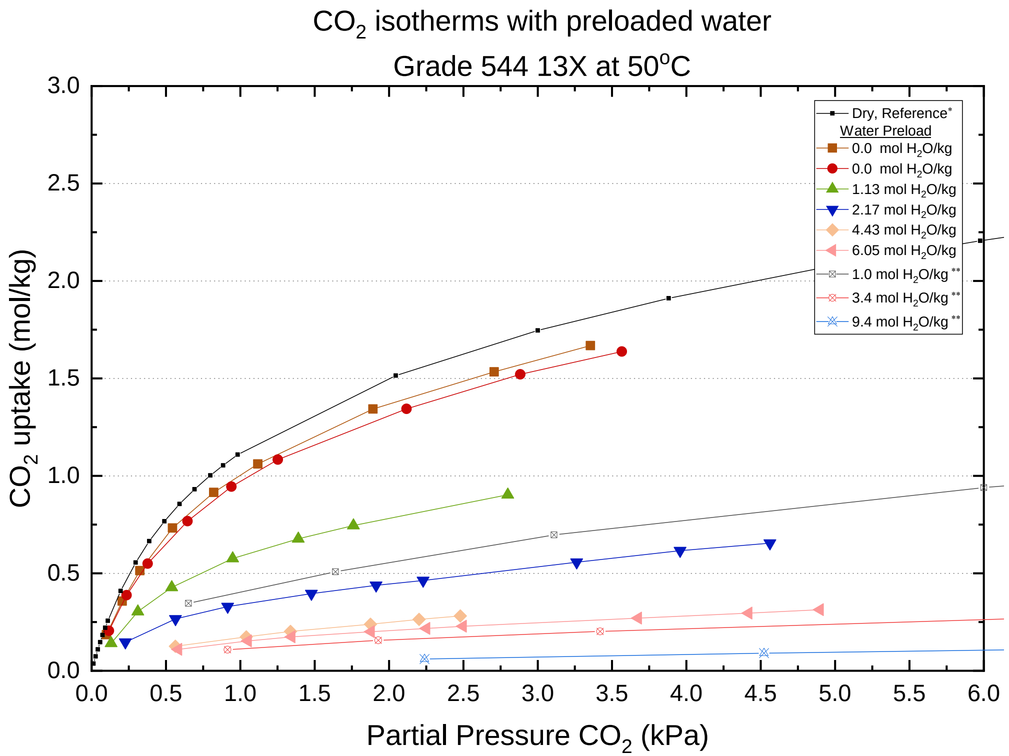
Rubotherm G&V LP



SETARAM Sensys Evo TGA

Results

- Isotherms measured at 25, 50, 75, and 100°C.
- Higher capacity than previously published data
- Roughly 1 mol H2O/kg unaccounted



Analysis

- A simple model is needed
  - Small number of data points
- A good fit was achieved by applying a factor to the existing pure component CO2 isotherm model

$$n^*_{CO_2} = \sum_{i=1}^{3} n_{sat,i} * \frac{b_i * P_{CO_2}}{(1 + b_i * P_{CO_2})}$$

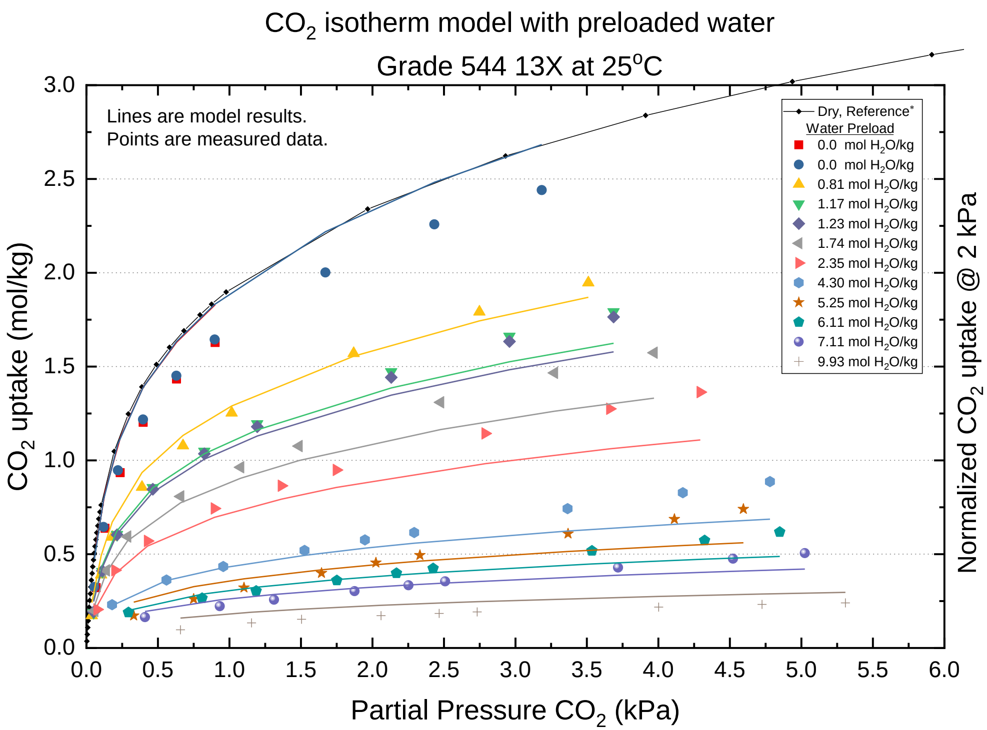
$$n_{CO_2} = n^*_{CO_2} * (1 - f_{H_2O})$$

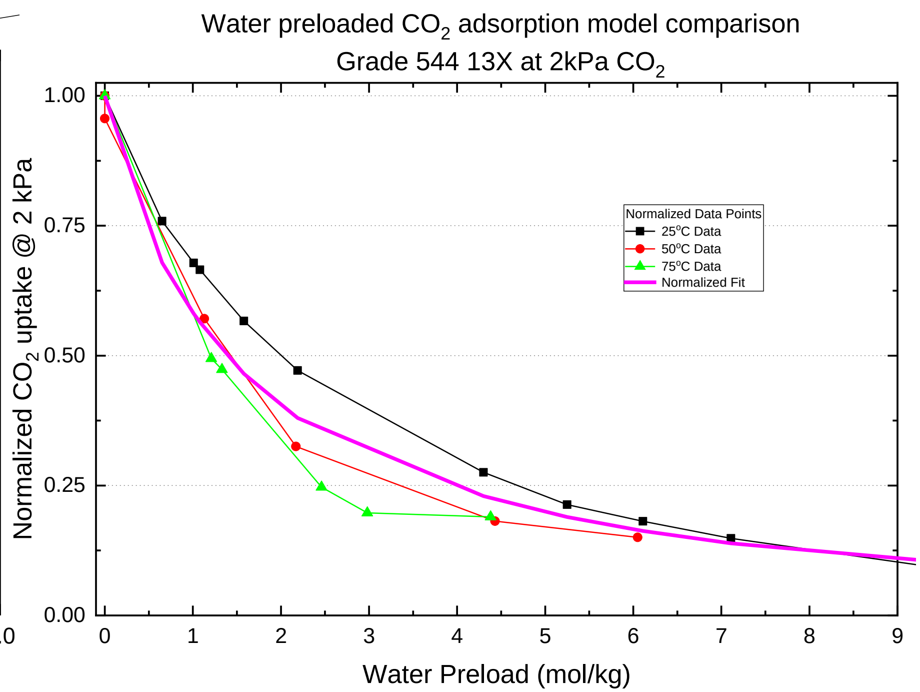
$$f_{H_2O} = \frac{b_{H_2O} * n_{H_2O}}{\left(1 + (b_{H_2O} * n_{H_2O})^{t_{H_2O}}\right)^{1/t_{H_2O}}}$$

Fitting Parameter	Value	Units
b_{H_2O}	0.500	(mol H_2O/kg)$^{-1}$
t_{H_2O}	1.251	[-]

Results

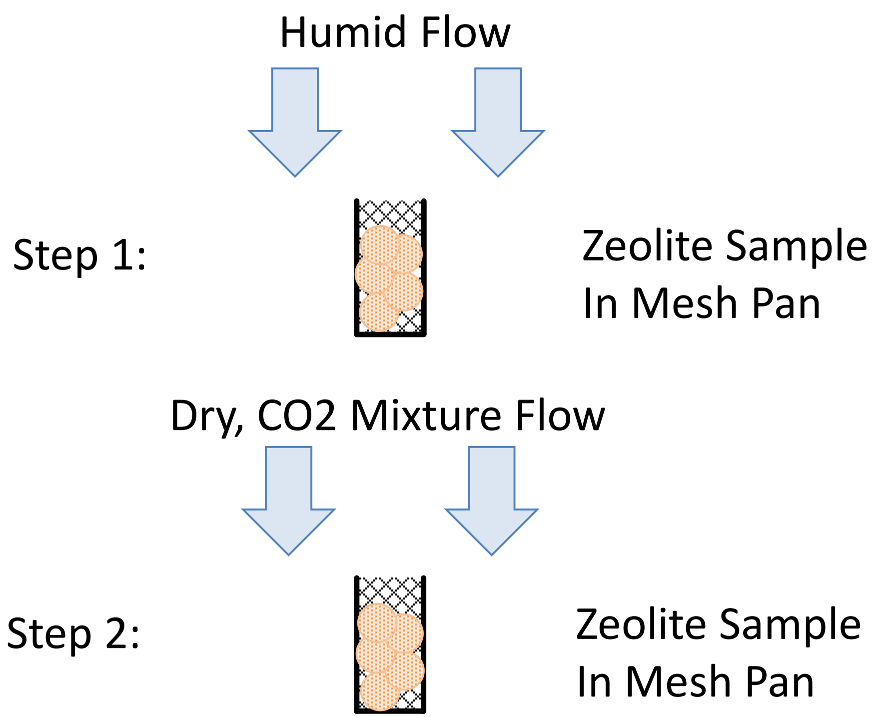
- The model match is fair





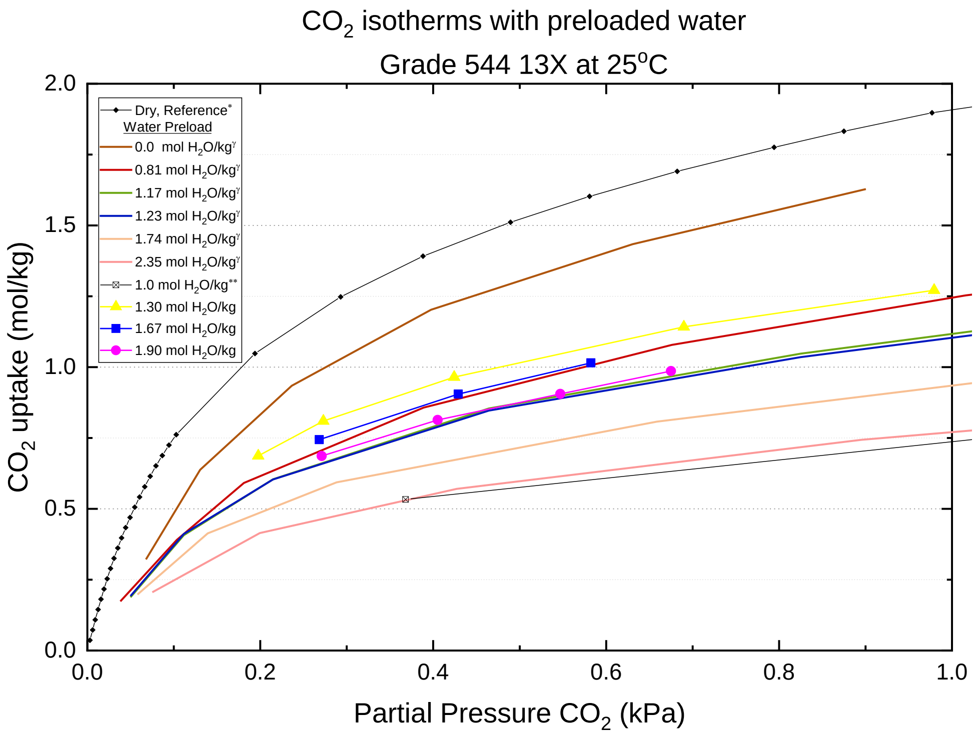
Validation

- Attempt to repeat results in a TGA
  - Slightly different configuration – expected same result



Validation Results

- Results did not show a similar sensitivity to water pre-loading as observed in the Rubotherm
  - Likely due to complete loading on top-most zeolite bead, the rest remaining dry



Conclusions

- Immediate success was obtained with the custom-built Rubotherm instrument
  - Clearly measured the impact of water vapor pre-loading on CO2 capacity in the 13X zeolite
    - This is the material and adsorption system in CDRA and next-gen 4-Bed technology
    - Optimizing this layer has proven performance gains and the results have been used in design of the next-gen 4-Bed
- Attempts to use a second instrument were not as successful
  - TGA is capable for this measurement, but the measurement did not validate the other data
    - Likely due to sample loading and flow path
    - Reveals pitfalls others may encounter and challenges of this system

Acknowledgements

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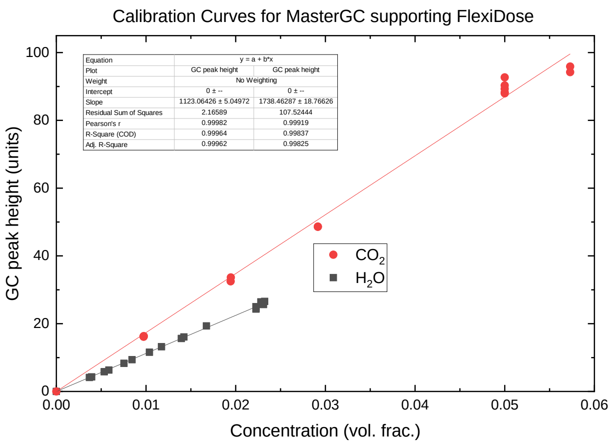
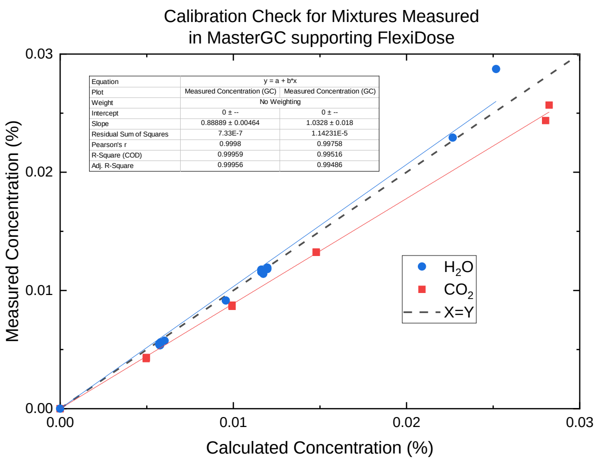
Questions?

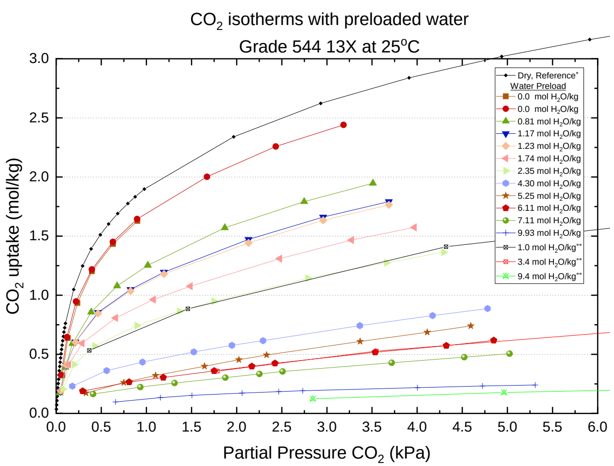
Backup Slides

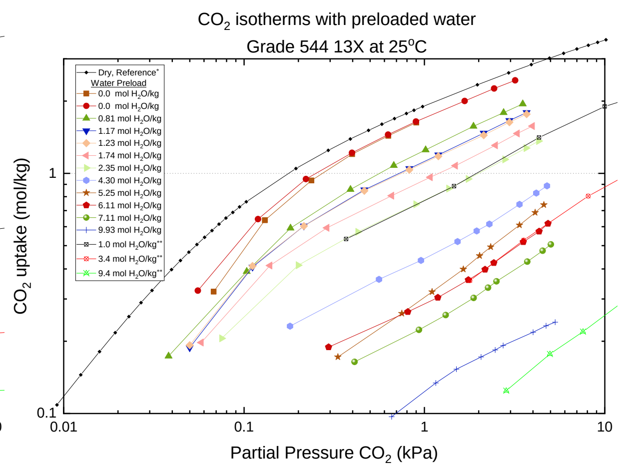
Linearity of calibration

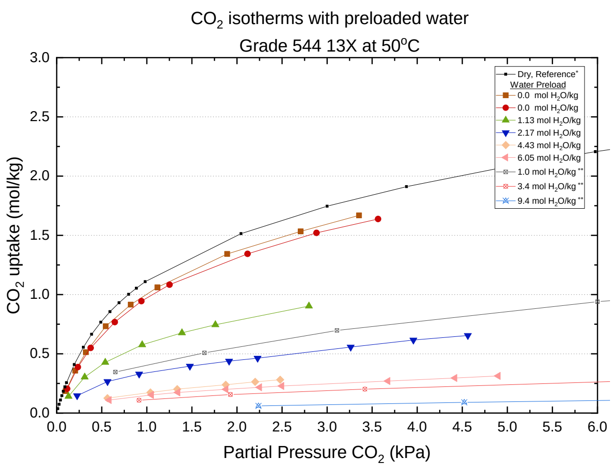




Isotherms 1/2







Isotherms 2/2