Surface Measurement Systems
World Leader in Sorption Science

BTA Frontier

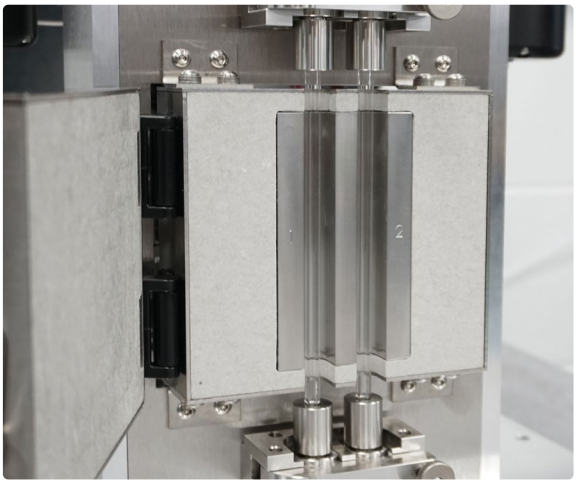
Self-Contained Multi-Component Breakthrough Analyzer

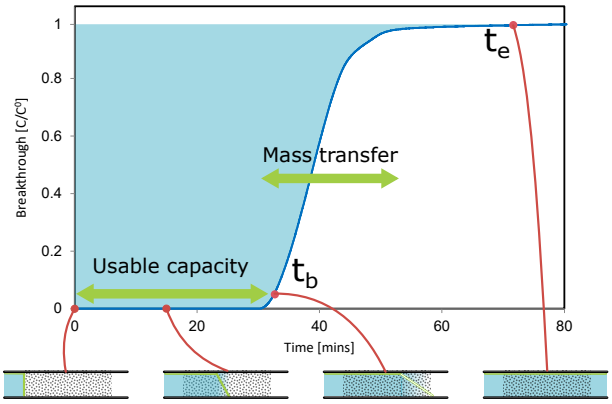
Single & multi-component sorption analysis for direct insights into breakthrough and equilibration times

BTA Frontier

The **BTA Frontier** revolutionizes sorbent testing with its cutting-edge packed bed breakthrough analysis, delivering unmatched precision in real-world process conditions. Engineered for versatility, it accurately measures competitive adsorption with a wide range of gases and vapors across multiple sample types. By seamlessly mixing single or multi-component adsorbate streams and passing them through a packed sample column, the BTA Frontier quantifies retention of the component. This allows crucial sample properties and process-relevant key performance indicators to be determined.

User-friendly and efficient, it features advanced sensors for CO_2, H_2O, organic vapors, and a thermal conductivity detector (TCD) with an optional mass spectrometer. Purpose-built for precise gas-phase mixing, adsorbate detection, temperature, and flow control, the BTA Frontier ensures unmatched accuracy and confidence in your results.

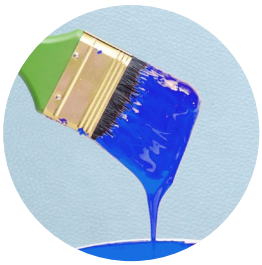




Industry Applications:

Carbon Capture, Utilization, & Storage

Material Characterization



VOC Capture & Remediation

Adsorbent Process Scale-up

What is BTA?

Breakthrough Analysis (BTA) is a sorption technique for determining breakthrough curves, tracking how a sorbent material interacts and captures vapors/gases over time. It reveals key adsorption insights, including breakthrough times, saturations points, and equilibrium data.

Key Features

Single-Component Breakthrough Curve

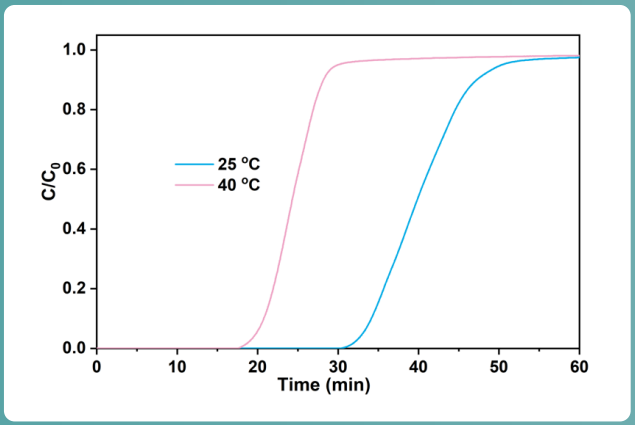


Figure 1. Water (50%RH) adsorption on 13X zeolite

Single-Component Breakthrough Curve

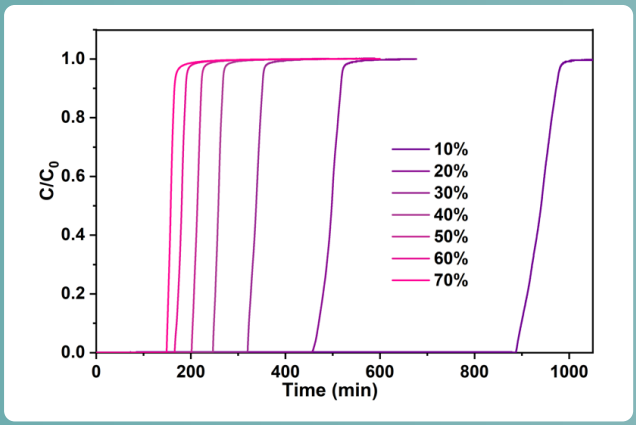


Figure 2. Water adsorption on 13X zeolite at 25 °C

Thermal Desorption

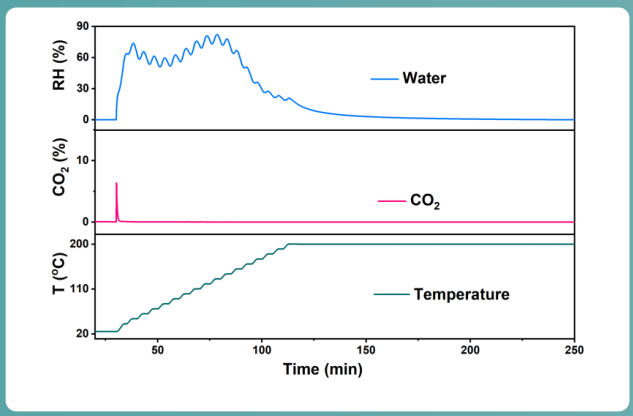


Figure 3. Desorption of CO_2 and water after adsorption on zeolite 13X

Sorbate Cycling

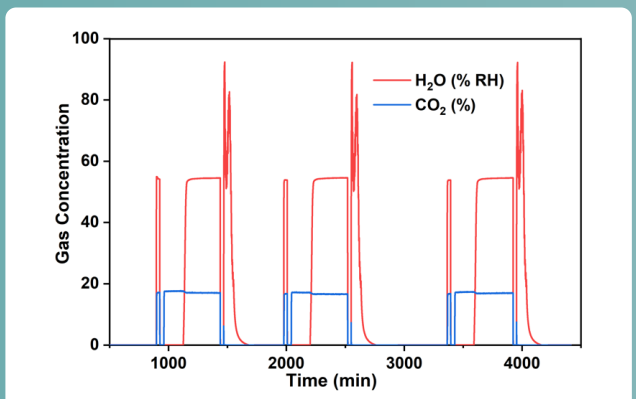


Figure 4. Cyclic adsorption

Comprehensive Gas and Vapor Breakthrough Measurements:

- Conduct single (Fig 1 & 2) or multi-component sorption (Fig. 3), sample regeneration, and cycling (Fig. 4) experiments.
- Analyze true multi-component sorption, assessing the uptake of one gas/vapor (e.g., CO_2, VOCs) in the presence of another (e.g., water, N_2).
- Utilize independent control over a wide range of gas/vapor concentrations.

Self-Contained, Scalable System:

- Generate uniform gas mixtures for accurate testing across different materials.
- Simultaneously perform multiple measurements using a standard sensor array.
- Measure VOCs from ppb to high %, and CO_2 from ppm to high %, with fast sample loading and changing.

Unmatched Flexibility and Accuracy:

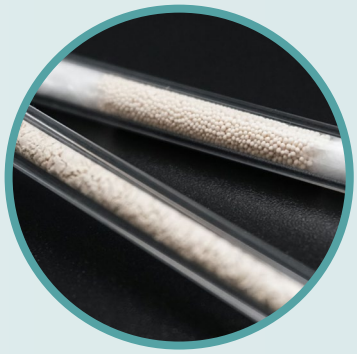
- Parallel activation in two columns for increased throughput. Accommodate samples masses from 30 to 3000 mg and a range of sample morphologies (e.g., pellets, monoliths).
- Utilize up to six gas inlets, two heated liquid reservoirs, and a temperature-controlled incubator.
- Optimized flow path with automatic dead volume determination, dedicated mass flow meter for outlet flow measurement, and pressure transducers at the columns end pressure indicators before and after columns.
- Optional mass spectrometer is available for analyzing complex gas mixtures.

Hardware

Versatile Sample Set-up

The BTA Frontier's innovative two-column design allows for sequential experiments, enabling simultaneous sample activation while significantly increasing throughput to optimize your analysis schedule. Whether you're conducting small-scale studies or large-scale projects, the BTA Frontier adapts seamlessly to your research needs.

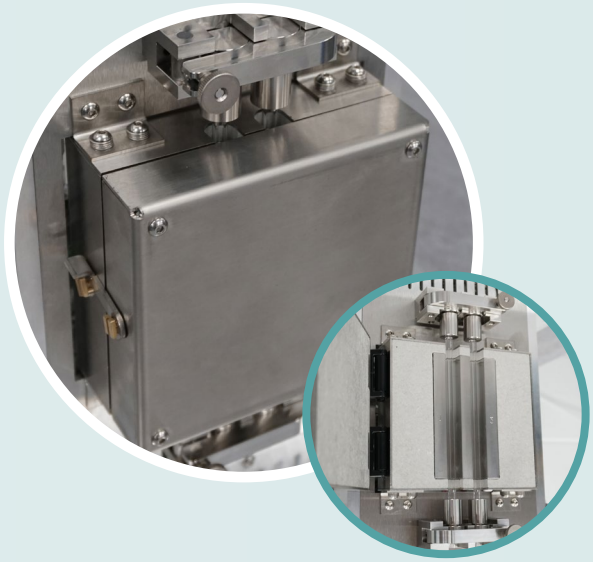
Engineered for consistency, it delivers precise, repeatable results, making it an ideal choice for advancing gas separation research and material characterization.



- Sample columns available in multiple internal diameter sizes: 2mm, 3mm, 4mm, and 1 cm and in both stainless steel & silanized glass.
- Accommodates a variety of samples, including powders, granules, pellets, fibers, and more.

- Used with or without a temperature probe embedded in the bed

Precise Temperature Control for Optimal Performance



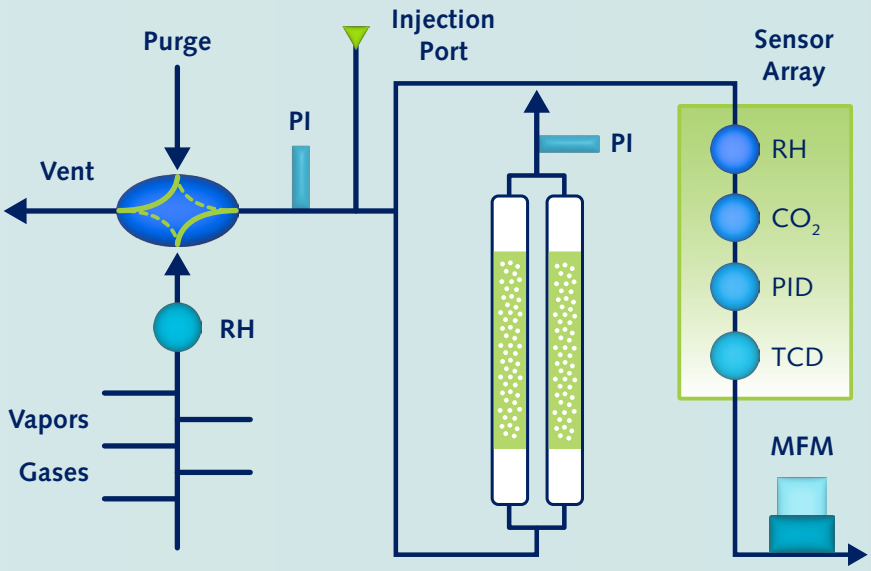
The BTA Frontier's column oven and dynamic control features provide precise, stable temperature regulation throughout automated experiments, offering several key advantages:

- Delivering reproducible and reliable outcomes
- Ensuring stable organic and water vapor generation
- Preventing unwanted condensation
- Studying temperature-dependent reactions
- Enhancing sensitivity for detecting low-abundance analytes

Gas Generation/Mixing System Available

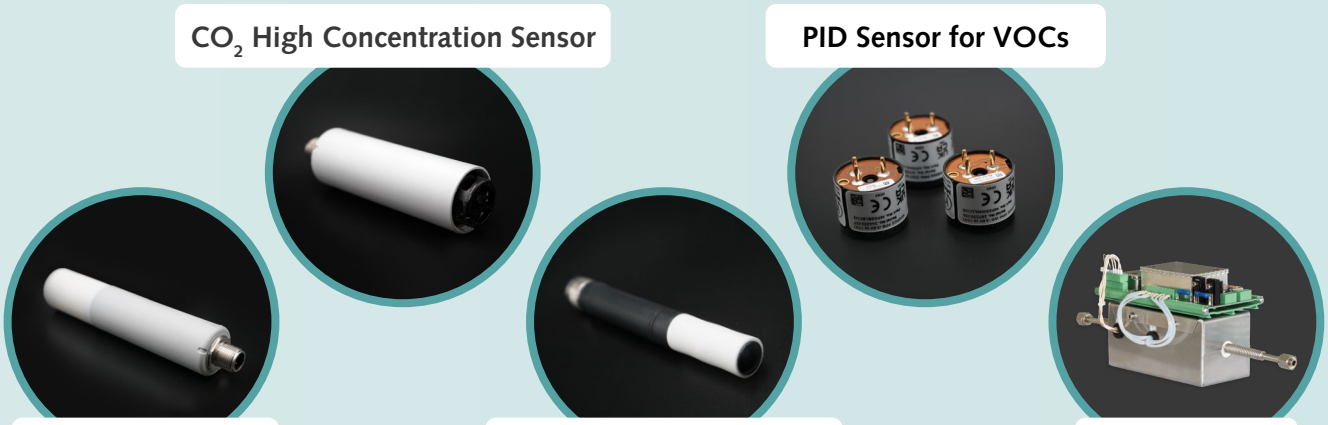
The BTA Frontier features precise gas generation and mixing with multiple inlets for flexible vapor or gas assignment. Its integrated sensor and purging system ensure uniform gas distribution, delivering reliable data across various applications.

- Achieve unmatched accuracy with uniform gas generation.
- Gain flexibility with multiple purging options before or during gas preparation.
- Prepare gas mixtures while performing other functions like simultaneous cooling and activation.



Advanced Sensors for Enhanced Application Potential

The secret to the self-contained nature of the BTA Frontier is its internal series of top-range sensors, enabling the instrument to engage in precise gas and vapor detection, giving the instrument its varied application potential.



CO_2 High Concentration Sensor

PID Sensor for VOCs

CO_2 PPM Sensor

Relative Humidity Sensor

TCD Detector

Hardware Setup

Pressure Transducers

Located before and after the columns to accurately evaluate pressure drop.

Relative Humidity Sensor

Capacitive detector for relative humidity measurement (0-100% RH)

PID Sensors for VOCs

Detection of wide range of VOCs from ppb to % level (upper limit: 10,000 ppm)

CO_2 Sensor

- NDIR sensor capable of detecting CO_2 at concentrations relevant for PCC and DAC applications
- Two options targeted for High Concentration (%) and low concentrations (ppm) level

Two Heated Reservoirs

- The built-in reservoirs are located in the temperature-controlled incubator (5-60°C)
- Thoughtfully designed for generating water and organic vapors

TCD Sensor

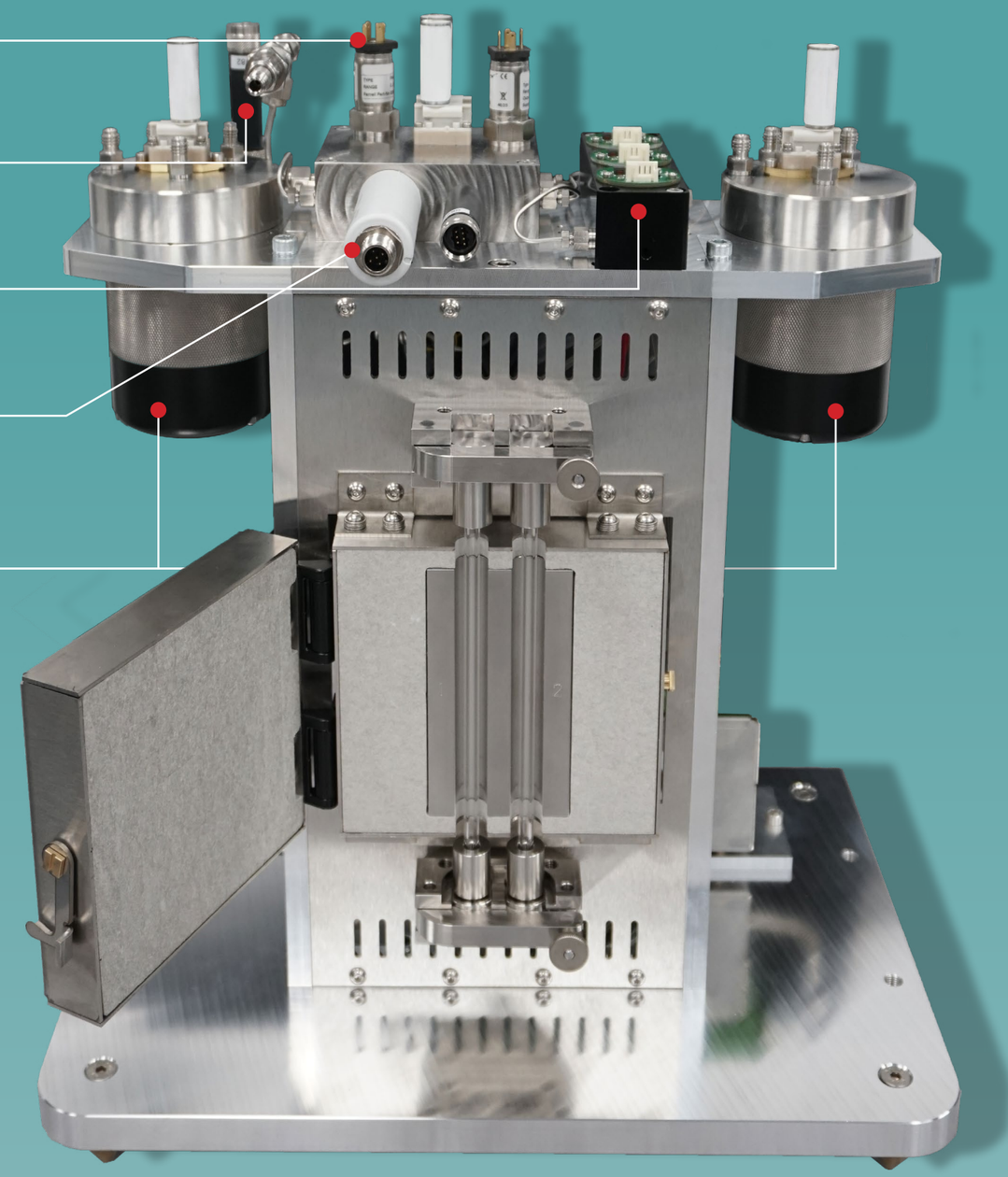
- General purpose, universal sensor for measuring concentration changes through thermal conductivity variations
- Self-contained heated unit with quick response time (T90 < 3s) and tunable ranges

Gas Inlets

- Equipped with five high-precision MFCs for seamless control of solvents, humidity, and gases on the feed side
- Dedicated purge gas MFC ensures system purity
- Effortless, software-driven gas calibration for all MFCs

Flow Path

- Advanced two-path bypass system with purge for both column and sensor train
- Minimizes dead volume while ensuring stable and complete feed gas mixing



Case Study 1 : Carbon Capture with Zeolite 13X

Zeolite 13X, an aluminosilicate zeolite, is a promising material for carbon capture, particularly in Post-Combustion Capture (PCC) and Direct Air Capture (DAC).

In this case study, shaped zeolite 13X pellets (0.4 mm diameter) were packed into a 4 mm ID column. The sample was activated at 300 °C for 10 hours under a 200 sccm nitrogen flow, followed by cooling to ambient conditions (25 °C). Using the BTA Frontier, its gas adsorption properties were thoroughly analyzed. The system's precise control and multicomponent analysis provided valuable insights into zeolite 13X's gas adsorption efficiency under real-world conditions.

Post-Combustion Capture

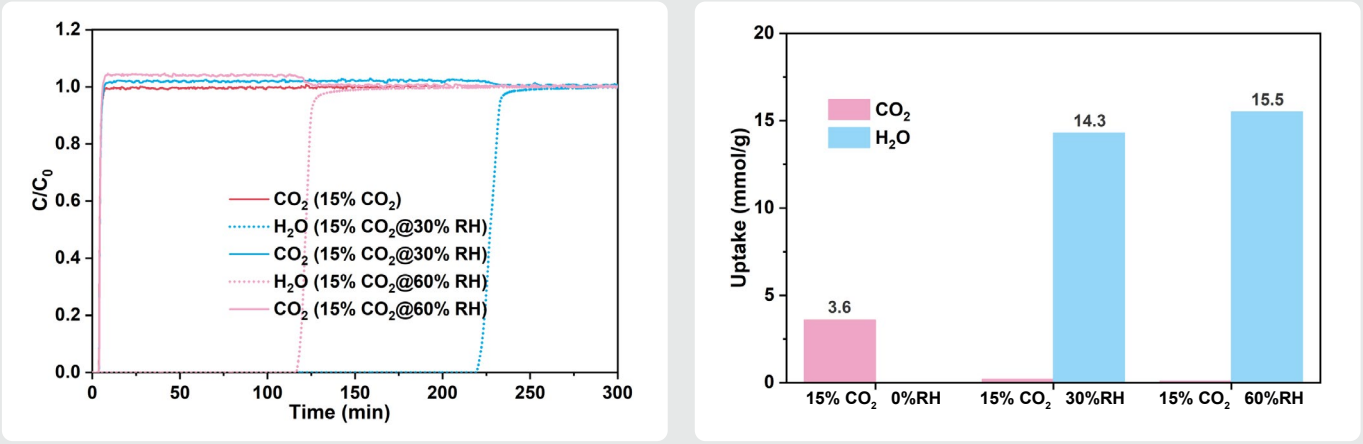


Fig 5 & 6. 15% CO_2 breakthrough (left) and uptake (right) at different relative humidity (0%, 30% and 60%) on zeolite 13X at 25 °C

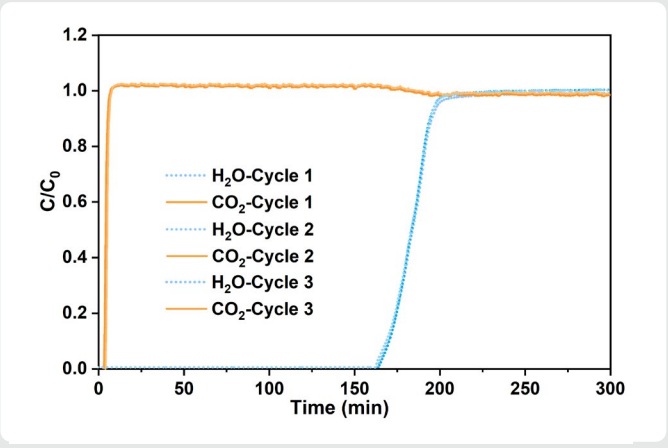


Figure 7. Cyclic CO_2 adsorption on 13x zeolite at 25°C (15% CO_2 @ 60 %RH)

Post-Combustion Capture (PCC):

For point-source conditions a 15 vol% CO_2 flue gas analogue was selected. After activation, inlet conditions of 15% CO_2 at 0% (dry), 30%, and 60% RH were prepared using the BTA Frontier's gas generation and mixing system. Water vapor concentration was precisely controlled by bubbling nitrogen through deionized water via a heated reservoir, ensuring accurate and consistent humidity levels.

Case Study 1 : Carbon Capture with Zeolite 13X

Direct Air Capture (DAC)

Under DAC conditions, CO_2 concentration is as low as 400 ppm—four orders of magnitude lower than in typical PCC scenarios, making CO_2 capture measurements more challenging. After sample activation, the system was switched to dry or wet 400 ppm CO_2 for testing.

To ensure accuracy, a secondary blank test was performed, demonstrating the rapid response of the sensors and minimal dead volume, which highlights the BTA Frontier's precision in detecting low-

Direct Air Capture

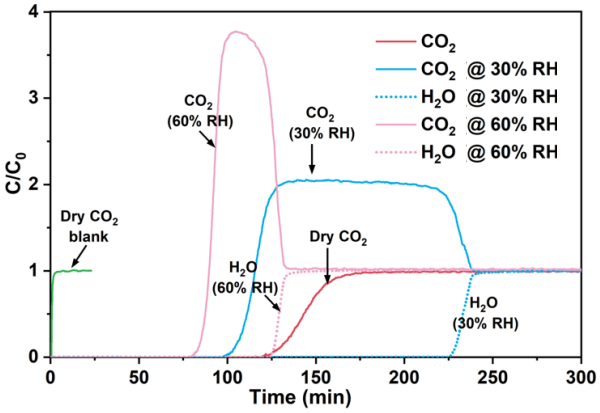


Figure 8. 400ppm CO_2 adsorption at different relative humidities on 13X zeolite at 25°C

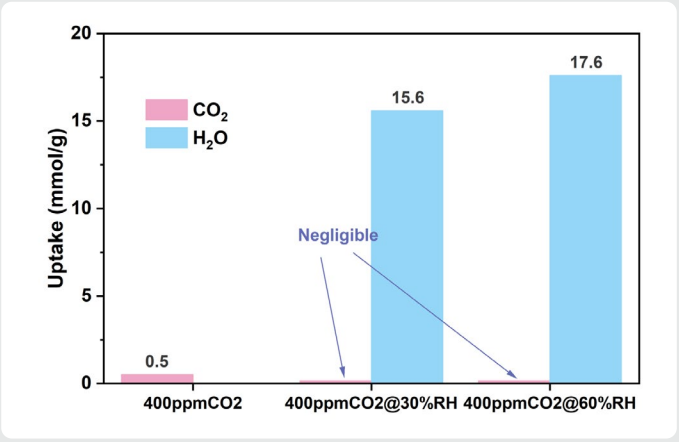


Fig. 9. Toluene (815ppm) adsorption on zeolite 13X under humid conditions (30 % RH) at 25 °C

Key Discoveries:

- **High CO_2 adsorption:** Zeolite 13X demonstrates strong CO_2 adsorption under dry conditions, achieving a capacity of 3.6 mmol/g for PCC and 0.5 mmol/g for DAC experiments.
- **Co-adsorption with water:** In both PCC and DAC scenarios, CO_2 is nearly (PCC) or fully (DAC) displaced by H_2O during co-adsorption on zeolite 13X.
- **Limitation in wet conditions:** The hydrophilic nature of zeolite 13X limits its effectiveness for CO_2 capture in humid environments.

Overall, while zeolite 13X performs well in dry conditions, its water sensitivity highlights the need for alternative materials for effective carbon capture in humid environments.

Case Study 2 : VOCs removal by Zeolite 13X

Volatile Organic Compounds (VOCs) are significant contributors to air pollution, making their removal a pressing concern. The efficiency of porous material filters in remediating VOCs from ambient air is often influenced by ambient humidity.

In this case study, we utilized the BTA Frontier to evaluate the adsorption efficiency of a common VOC, toluene, on a packed column of zeolite 13X. By leveraging the system's multicomponent capabilities, we further explored the effects of humidity on adsorption performance.

The zeolite 13X pellets were packed into a column and placed in the system. The sample was activated *in-situ* at 300°C for 10 hours under 200 sccm of N_2 before conducting adsorption experiments at a constant flow of 815 ppm toluene in N_2 at 25°C, under both dry (Fig. 10) and wet (Fig. 11) conditions.

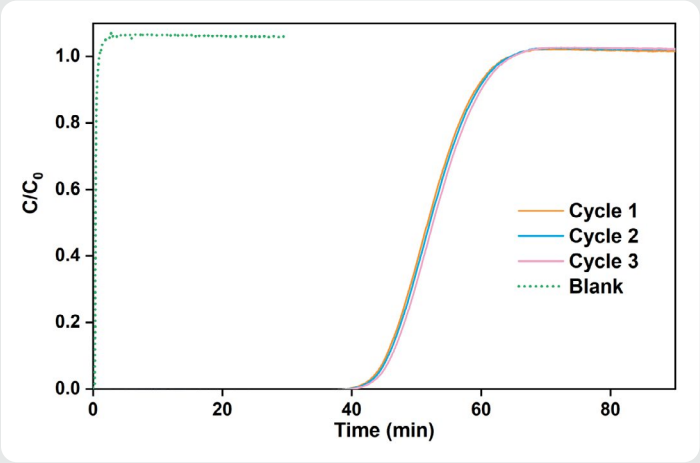


Fig. 10 Toluene (815ppm) adsorption on Zeolite 13X under dry condition at 25 °C

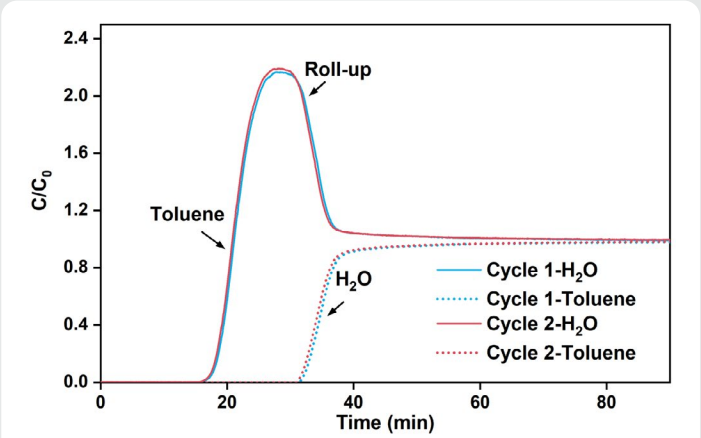


Fig. 11. Toluene (815ppm) adsorption on zeolite 13X under humid conditions (30 %RH) at 25 °C

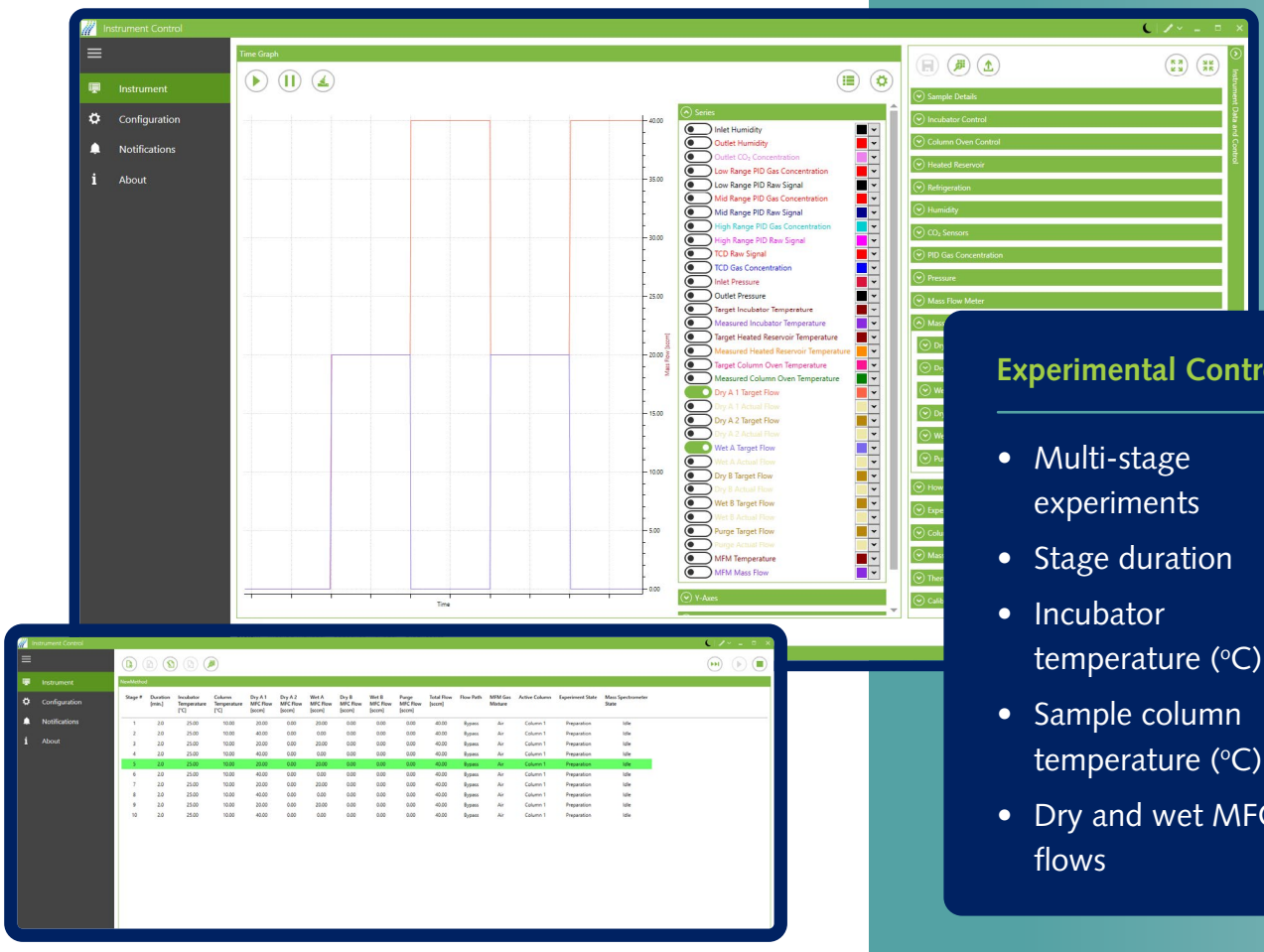
Key Discoveries:

- **Dry conditions:** Zeolite 13X maintains a stable toluene adsorption capacity of 1.95–1.98 mmol/g over three cycles.
- **Wet conditions:** (30 %RH), the toluene adsorption capacity drops significantly from 1.95 mmol/g to around 0.17 mmol/g, due to the hydrophilic nature of zeolite 13X, which has a high water uptake of 15.5 mmol/g. The roll-up effect in the co-sorption curves (Fig. 11) shows that water displaces toluene.

The BTA Frontier accurately performs breakthrough curves for both single and multicomponent systems, offering insights into sorption phenomena, equilibration times, and competitive sorption between vapors.

Purpose-built Software

The Instrument control software package provided with the BTA Frontier allows the live plotting of data from all the MFCs, sensors, and heating units and comes with a method and sequence builder for creating complex experiments.



Experimental Controls:

- Multi-stage experiments
- Stage duration
- Incubator temperature (°C)
- Sample column temperature (°C)
- Dry and wet MFC flows

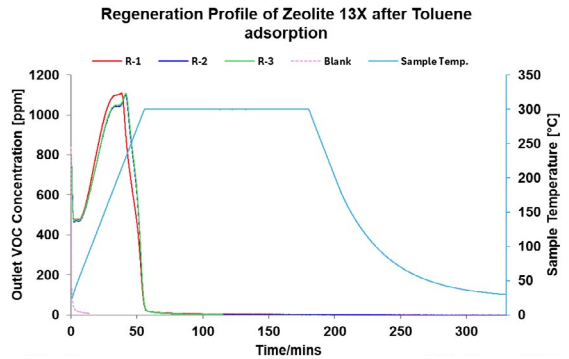


Figure 12: Graph produced from the BTA analysis suite macro

The powerful analysis software automatically compensates for dead volume and calculates uptakes using data from system sensors or any integrated mass spectrometer, ensuring accurate and precise results. With customizable graph options for plotting and data export in text format, this comprehensive analysis suite is ideal for presenting your findings.

Specifications

Construction Materials

Custom-built manifold: 316 stainless steel
Seals: Viton® or equivalent, Kalrez® optional
Tubing: 1/16 or 1/8 inch 316 stainless steel

Inlet Flow Control

Up to six gas inlets
Control Range per MFC: FS up to 200 sccm
Turn-down Ratio up to 1000:1
Calibrated gases include:
N_2, CO_2, He, O_2, Ar, & more

Temperature Control

Incubator Control
Controls entire gas mixing, vapor generation and measurement system
Control Range: 5 °C to 60 °C
Control Accuracy: ±0.1°C

Column Oven
Control Range: Up to 500 °C
Control Accuracy: ±.2 °C

Sample and Configuration

Two-column quick-connect system
Small sample amounts (~30 to 3,000 mg)

Column Sizes:
Length: 165 mm
Glass: 2, 3, 4, 10 mm ID
Stainless Steel: 3- 4 mm ID

Pressure Transducer

Pressure transducers at column inlet and outlets. Full scale 0-2.5 bar
Accuracy better than 1.0 % F.S.
Temperature compensated.

Vapor Generation

Liquid Reservoirs
Up to two 50 mL easy-change reservoirs
Heated to avoid evaporative cooling

Vapor Generation Range
0 – 90% for 5-60 °C [1]
Accuracy: ± 0.5 p/p0 [2]

Gas & Vapor Sensors

Humidity Measurement
Measurement Range 0-100 %RH
Accuracy (5-40 °C) ± 0.8 %RH
Accuracy (40-85 °C) ± 1.5 %RH

CO_2 Measurement
% level 0-20% vol, atmospheric pressure, accuracy down to 0.1 %vol CO_2
Ppm level 0-30,000 ppm, accuracy down to ±40 ppm CO_2

Thermal Conductivity Detector (TCD)
Quick response - T90 ≤ 3 sec
High corrosion resistance
High temperature capability up to 180 °C.

Organics Measurement (PID)
0 – 98% for 5-60 °C
Low-range sensor: 1 ppb-40 ppm [3]
Mid-range sensor: 0-4,000 ppm [3]
High-range sensor: 0-10,000 ppm [3]

System Information

Dimensions: 520 mm (W) x 980 mm (H) x 610 mm (D)
Weight: 80 kg (180 lb)
Electrical: 200 – 240 v, 50/60 Hz, 1,500 VA

System Software

Instrument Control Software

- Live data view and plotting
- Full control over parameters
- Powerful custom methods and sequences
- Multiple component detection
- Multiple concentrations or temperature cycles
- Temperature changes in a single experiment

BTA Analysis Software

- Easy plotting of normalized and molar concentration and other custom plots.
- Dead volume corrected capacities of multiple components.
- User defined control of calculation parameters.
- Software equipped with the calculation of dead volume corrected capacities of multiple components.

Footnotes
*10 – 40 °C
[1] Humidity factory calibrated at 25 °C and 60 °C. Calibrations at other temperatures upon request.
[2] Achievable with humidity – for other liquids depends on vapor pressure
[3] As calibrated with isobutylene