Unprecedented xenon collection and separation from air on silver-exchanged zeolites

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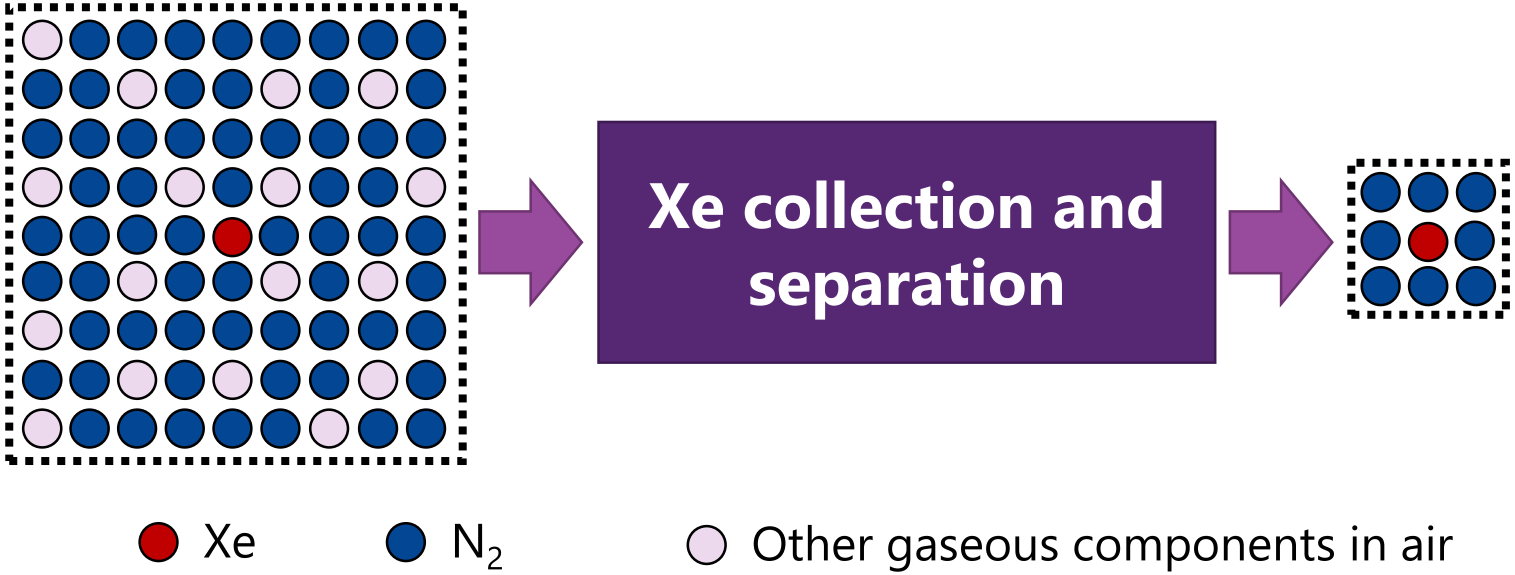
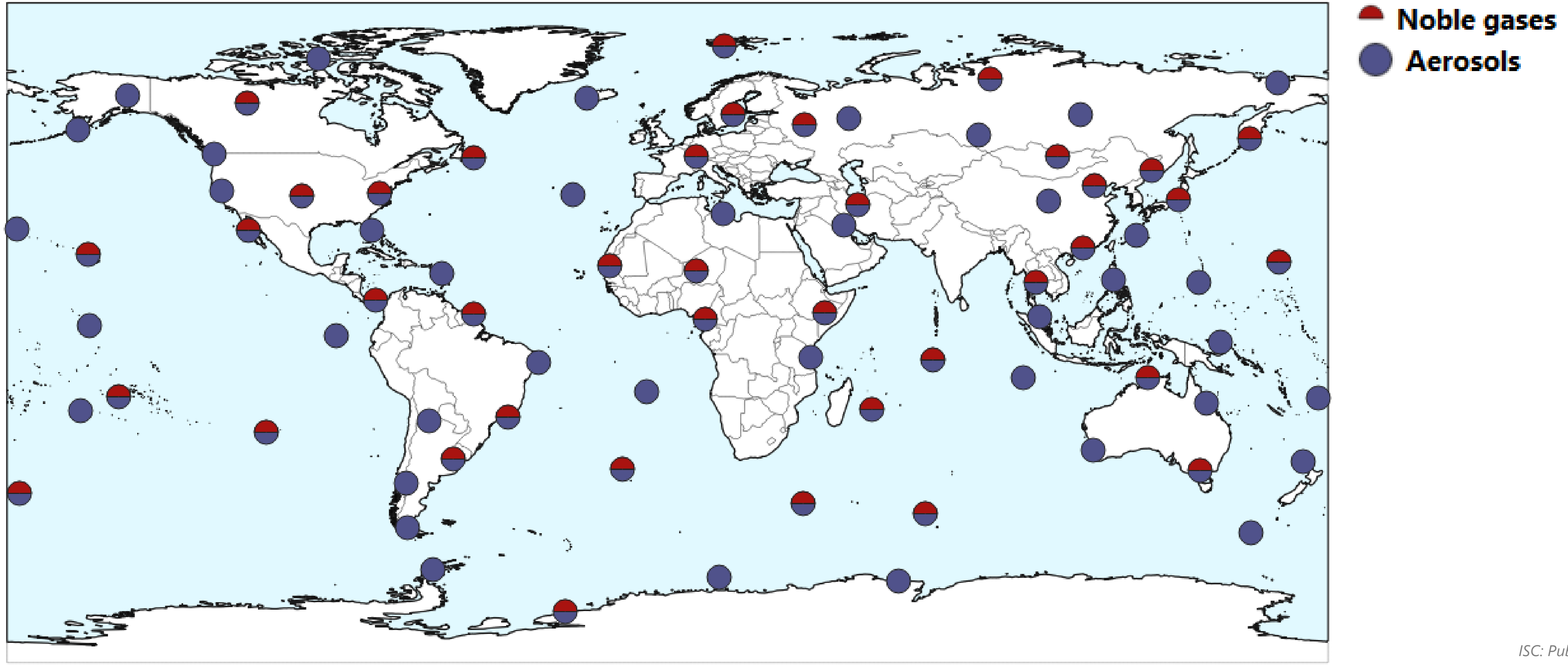


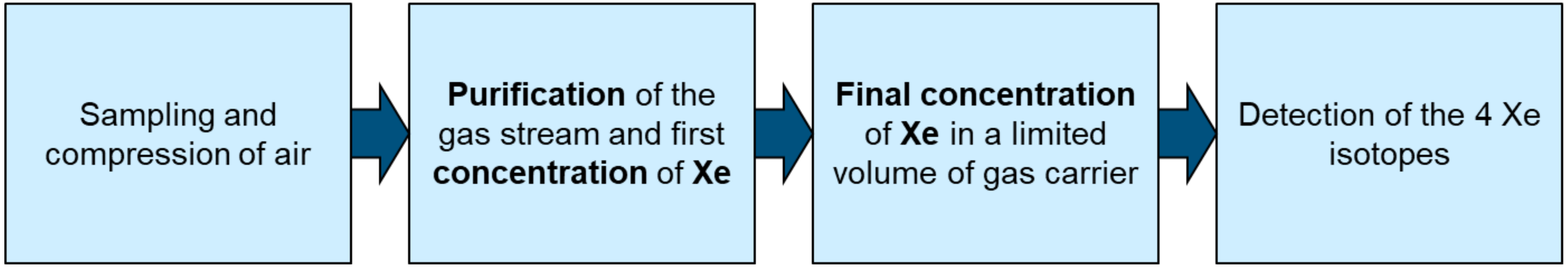
Introduction

- Radioxenon in the atmosphere is continuously monitored in the International Monitoring System for the verification of the CTBT



Introduction

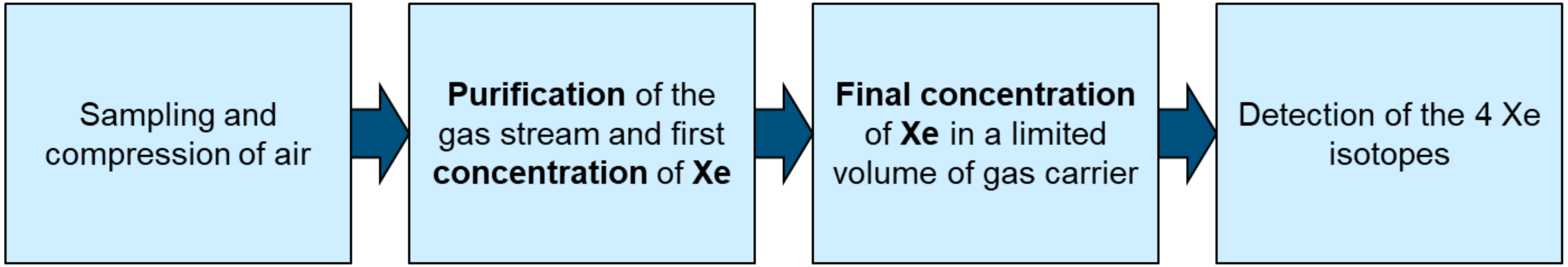
- Noble gas (radioxenon) monitoring systems
  - Requirements
    - 1 mBq/m^3 (Xe-133), 10 m^3 of air, 24h collection/measurement time, 95% data availability
  - 4 stages: air sampling, separation, concentration and detection
  - Quite complex and energy demanding separation systems



  - < 2020
    - 2^{nd} stage: remove H_2O and CO_2 using zeolites/molecular sieves/permeation membranes
    - 3^{rd} stage: concentrate Xe on activated carbon (AC) at 100-150 K or room temperature

Introduction

- Noble gas (radioxenon) monitoring systems
  - 4 stages: air sampling, separation, concentration and detection



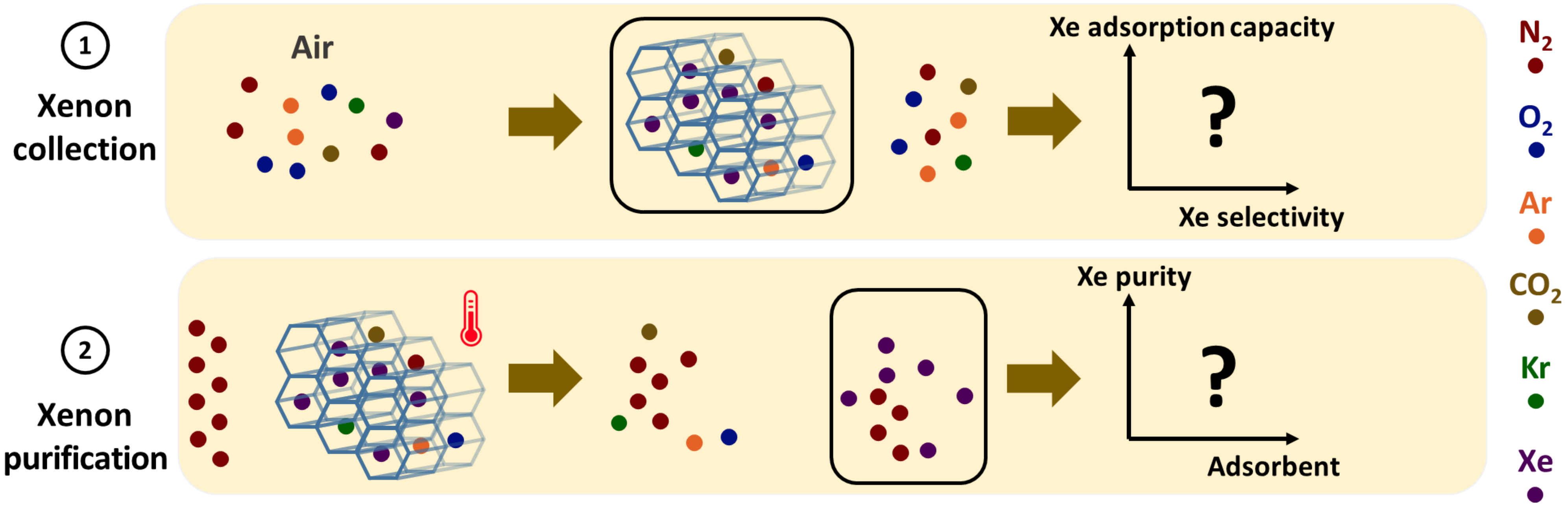
- Some new systems > 2020
  - 3rd stage: silver-exchanged zeolites (AgZs) at room temperature
    - Decreased energy consumption during desorption (smaller columns)

AgZs both for the 2nd and 3rd stage ?
Metal-Organic Frameworks (MOFs) ?

Objectives

1. How efficient and selective are AgZs and MOFs, compared to AC, in collecting Xe from atmospheric air ?

2. How easy and in which purity can we thermally recover the collected Xe from AgZs and MOFs compared to AC ?



Selected adsorbents

- Reference adsorbent
  - Activated carbon: Nusorb GXK

- Silver-exchanged zeolites used in new systems
  - Ag-ETS-10 & Ag-ZSM-5

- MOFs – Selection criteria (end 2018)
  - Only commercially available MOFs
    - > 10 g
  - Hydrothermal stability
  - Xe adsorption properties (from Xe/Kr separation literature)

➔ **HKUST-1**, **Ni-DOBDC**, UiO-66 and ZIF-8

Activated Carbon (AC)

Nusorb GXK

Silver-exchanged Zeolite (AgZ)

Ag-ETS-10 (SAUNA III)

Ag-ZSM-5 (SPALAX-NG)

Metal-Organic Framework (MOF)

Ni-DOBDC

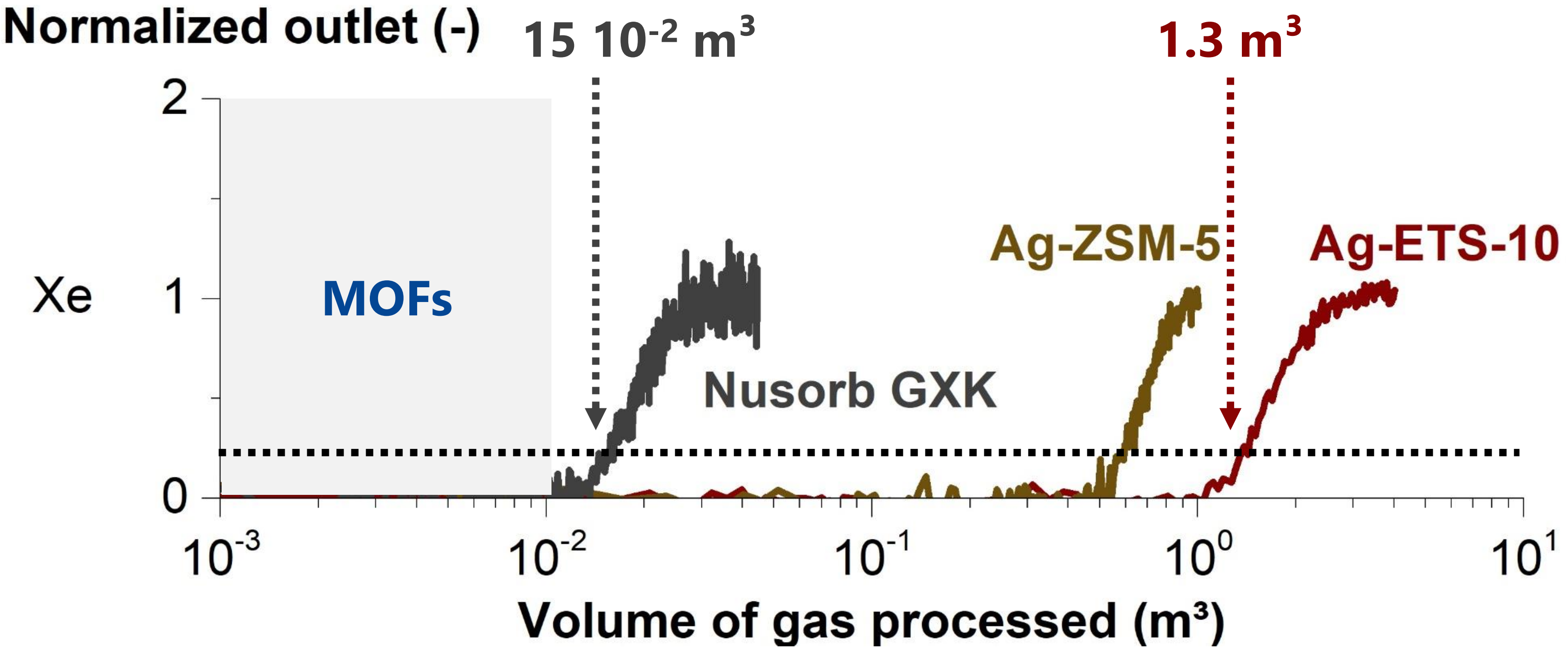
HKUST-1

1

How efficient and selective are AgZs and MOFs, compared to AC, in collecting Xe from atmospheric air ?

Xe collection from air at room temperature

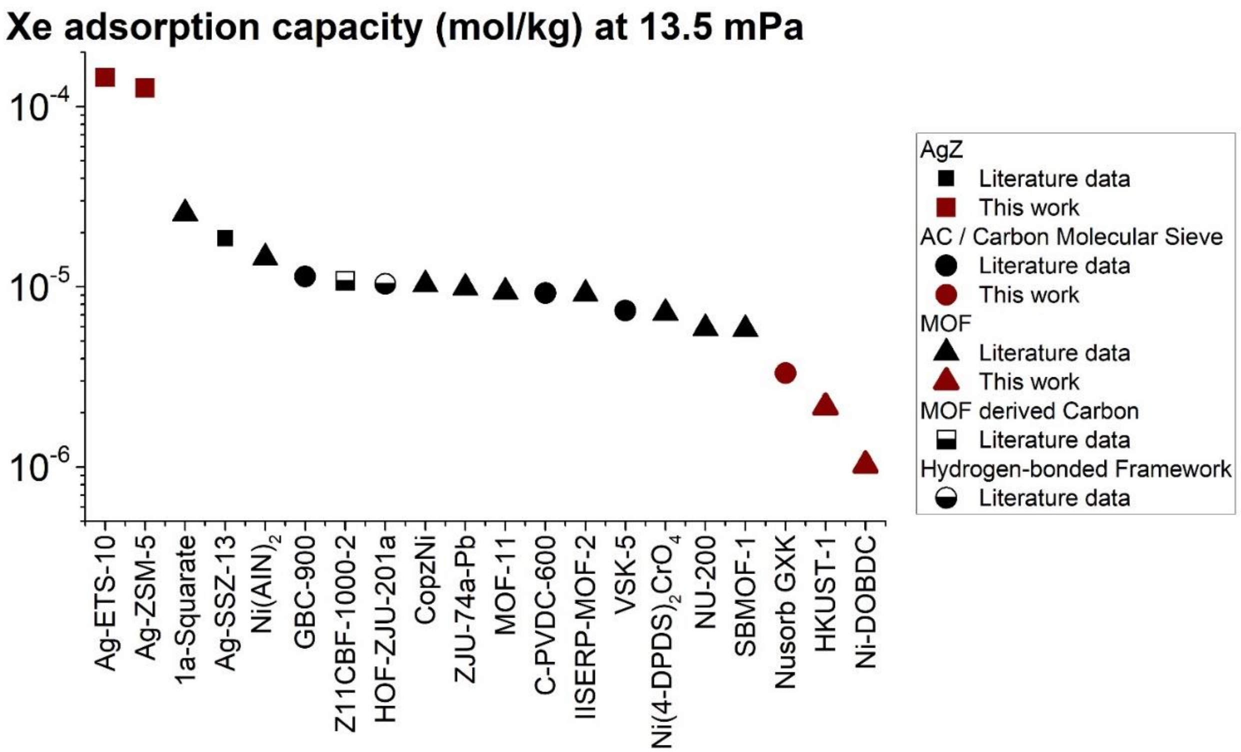
- Breakthrough of Xe in dry air (87 ppb) at 0.12 m^3/h in 50 cm^3 of adsorbent

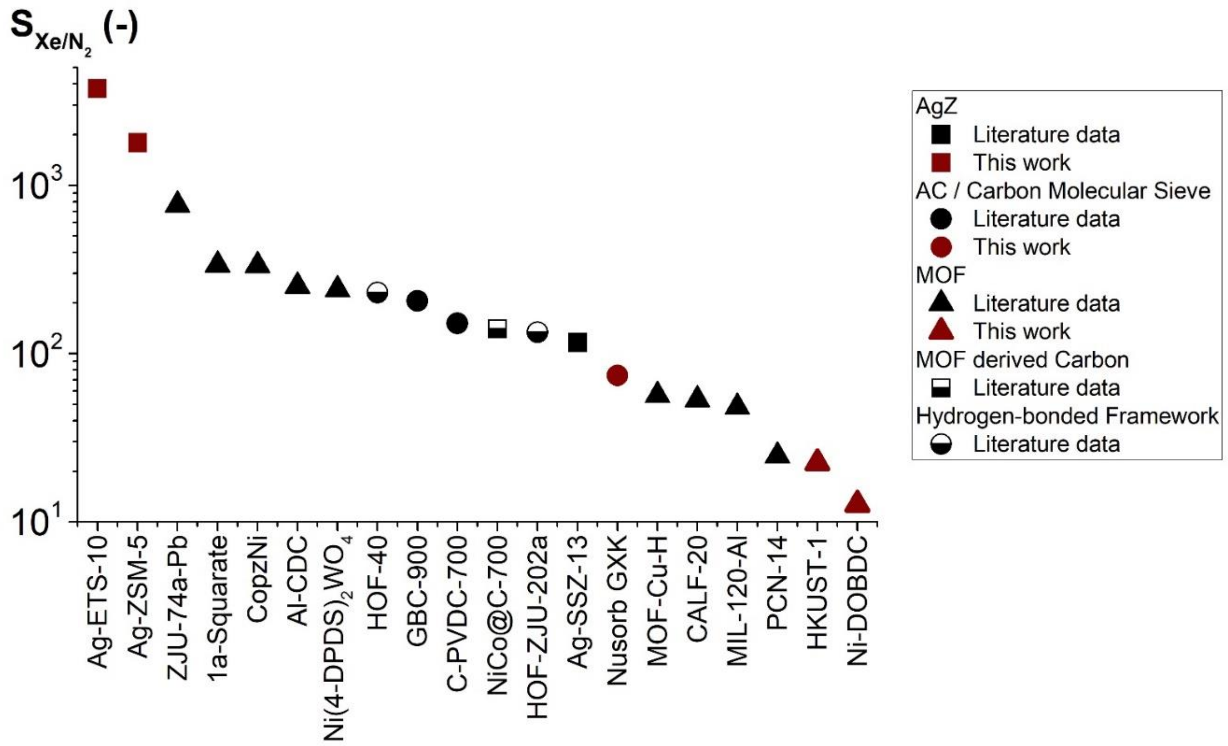


+ Xe selectivity over air on Ag-ETS-10 about 60 times higher than AC (> MOFs)

Xe collection from air at room temperature

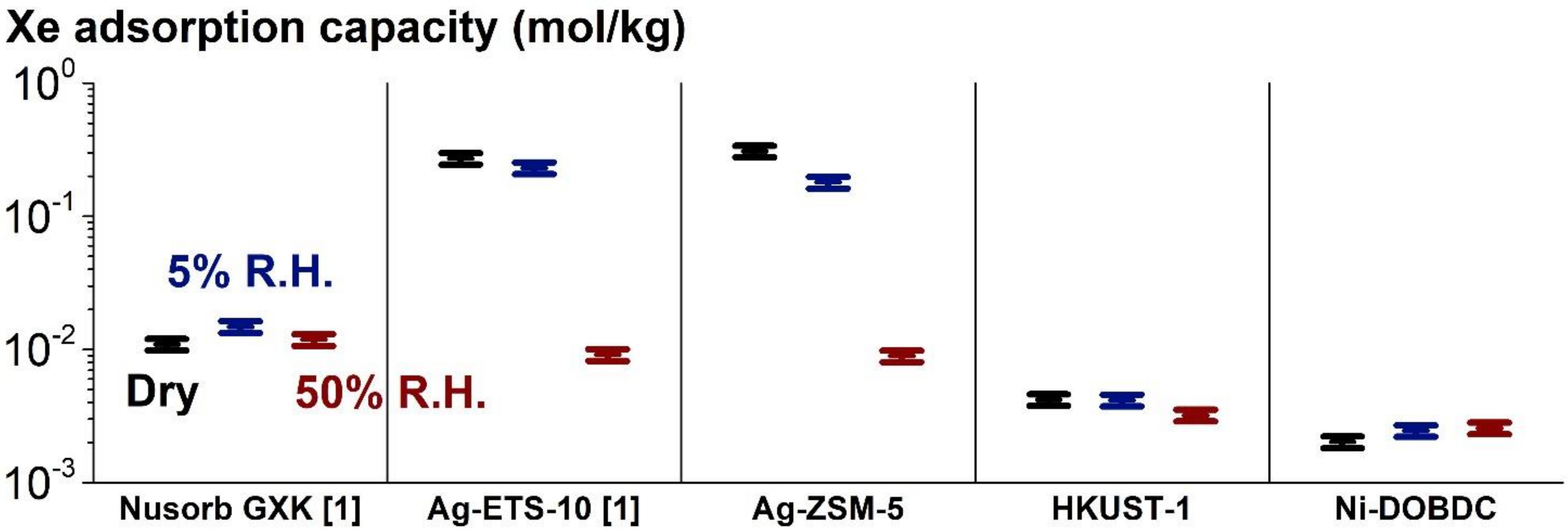
- What about other materials in the literature ?
  - Literature data: use of adsorption isotherm fits





Xe collection from air at room temperature

- What about moisture in the gas stream ?
  - Factor 30 decrease in Xe adsorption capacity on AgZs at 50% R.H.

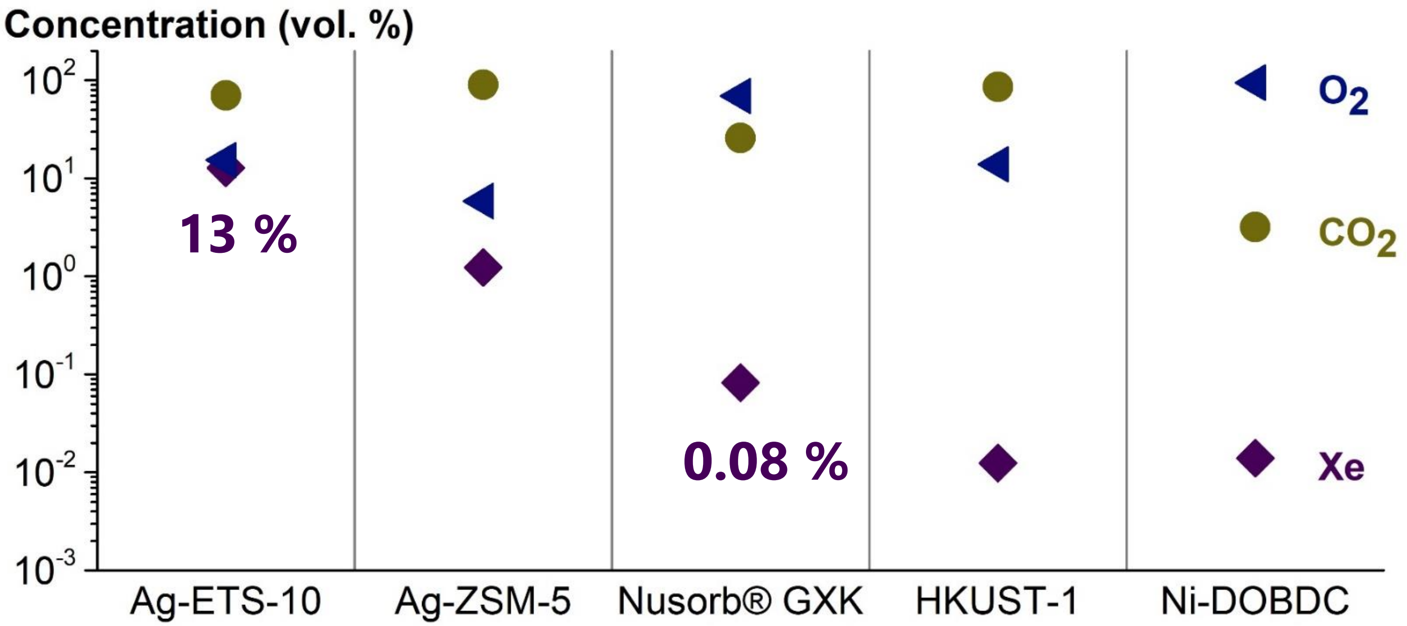


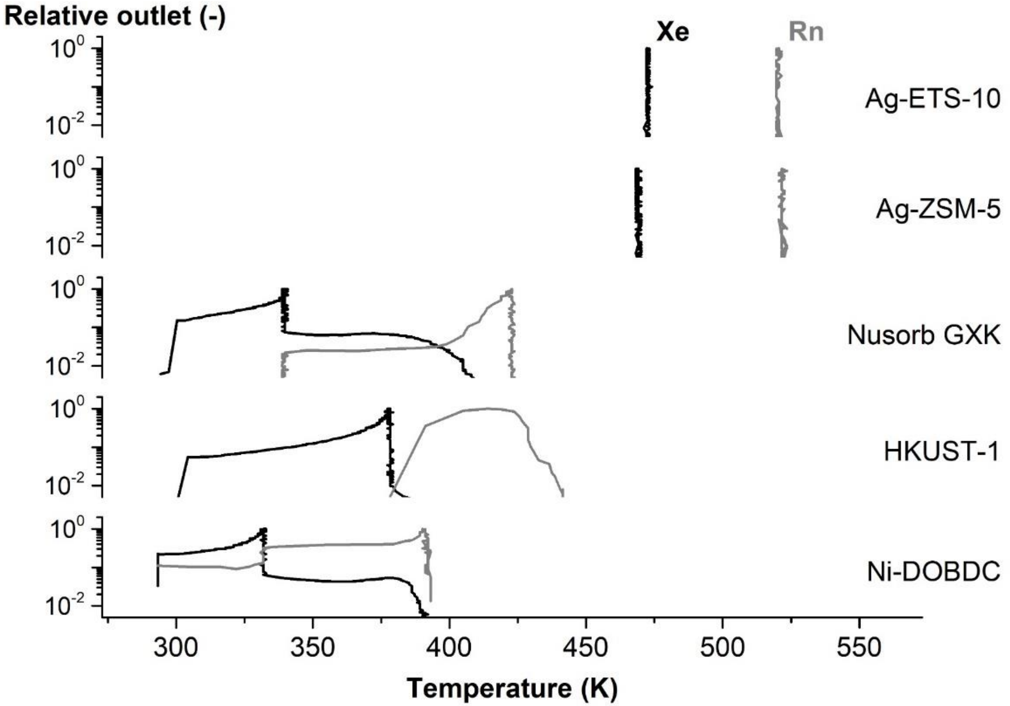
2

How easy and in which purity can we thermally recover the collected Xe from AgZs and MOFs compared to AC ?

Thermal Xe separation from air

- After single thermal cycle
  - 13 vol. % Xe recovered on Ag-ETS-10



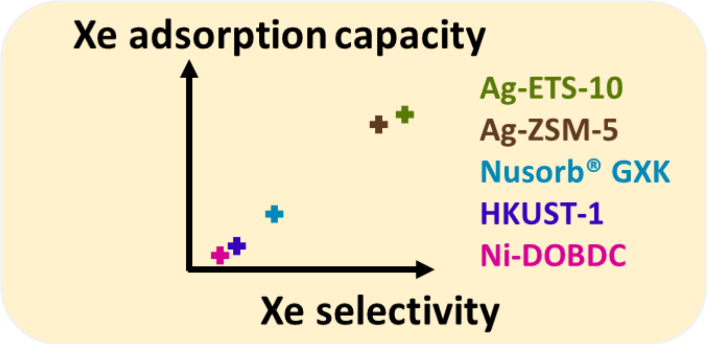


- Impressive Xe/Rn separation on AgZs
  - **BUT** higher temperature required

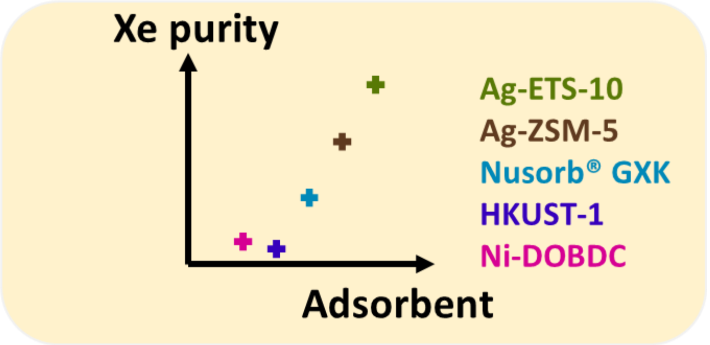
Conclusions & perspectives

1. Xe adsorption & selectivity in air
   - Unprecedented values on AgZs
   - **NOT** in humid conditions
2. Thermal recovery of Xe from dry air
   - Unprecedented values on AgZs
   - **BUT** higher temperature than for MOFs/AC

① Xenon collection



② Xenon purification



- Future work: purity over multiple cycles, durability, other adsorbents ?

- Perspective: simple and low energy demanding systems
  - Use for Xe measurements in emergency situations
  - Use for Xe measurements for atmospheric transport studies

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Silver-exchanged zeolites for collecting and separating xenon directly from atmospheric air

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