Study of 8AgFER-B zeolite performance for Radon-222 removal in Carbon Dioxide

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Motivation

Rn-222 is a radioactive noble gas that creates background signals in underground experiments and poses health risks. CO_2 produced as a byproduct of geothermal power generation may contain Rn-222 and is often reused for industrial or food applications, requiring radon removal. Because adsorption performance depends strongly on the carrier gas, the behavior of adsorbents must be evaluated in CO_2. While 8Ag-FER-B shows excellent performance in air, its adsorption characteristics in CO_2 remain insufficiently studied. This study investigates the Rn-222 adsorption performance of 8Ag-FER-B in CO_2.

What is 8AgFER-B

8Ag-FER-B is a silver-exchanged ferrierite (FER) zeolite developed as a high-performance radon adsorbent.

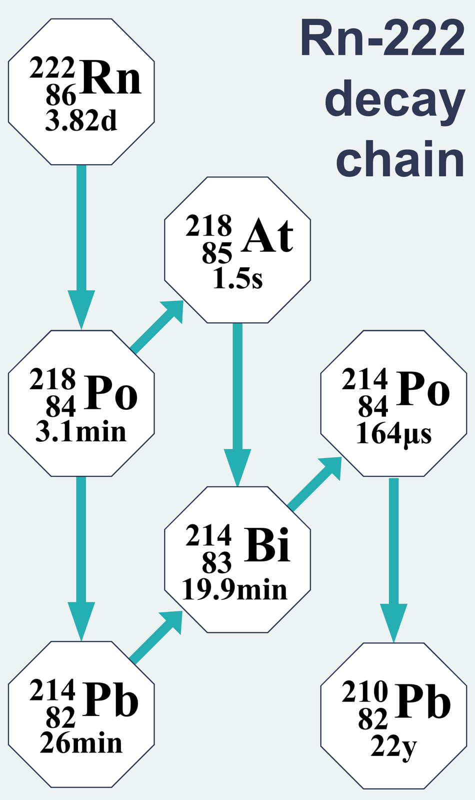
8AgFER-B that is used is produced by Sinanen Zeomic Co., Ltd. with 8.4% silver amount using special ion exchange process.

FER zeolite provides a microporous framework suitable for trapping noble gases.

What is Radon-222

Rn-222 is a radioactive noble gas from natural uranium decay chains. Its α-emitting progeny pose serious health risks and create background events in underground detectors, motivating the need for efficient radon removal.

Rn-222 decay chain



Rn-222 can be carried by gases such as CO_2. Since adsorption depends on the carrier gas, absorber performance must be tested under different gas environments.

Performance Evaluation

The adsorption performance is quantified using the adsorption coefficient (K), calculated in the following steps

$$Rn_{ratio} = \frac{\text{Rn count/day via}}{\text{Rn count/day bypassing}}$$

$$\text{Retention Time}, RT = \frac{\text{Detector volume}}{\text{Flow rate} \times Rn_{ratio}} + \frac{\text{Detector volume}}{\text{Flow rate}}$$

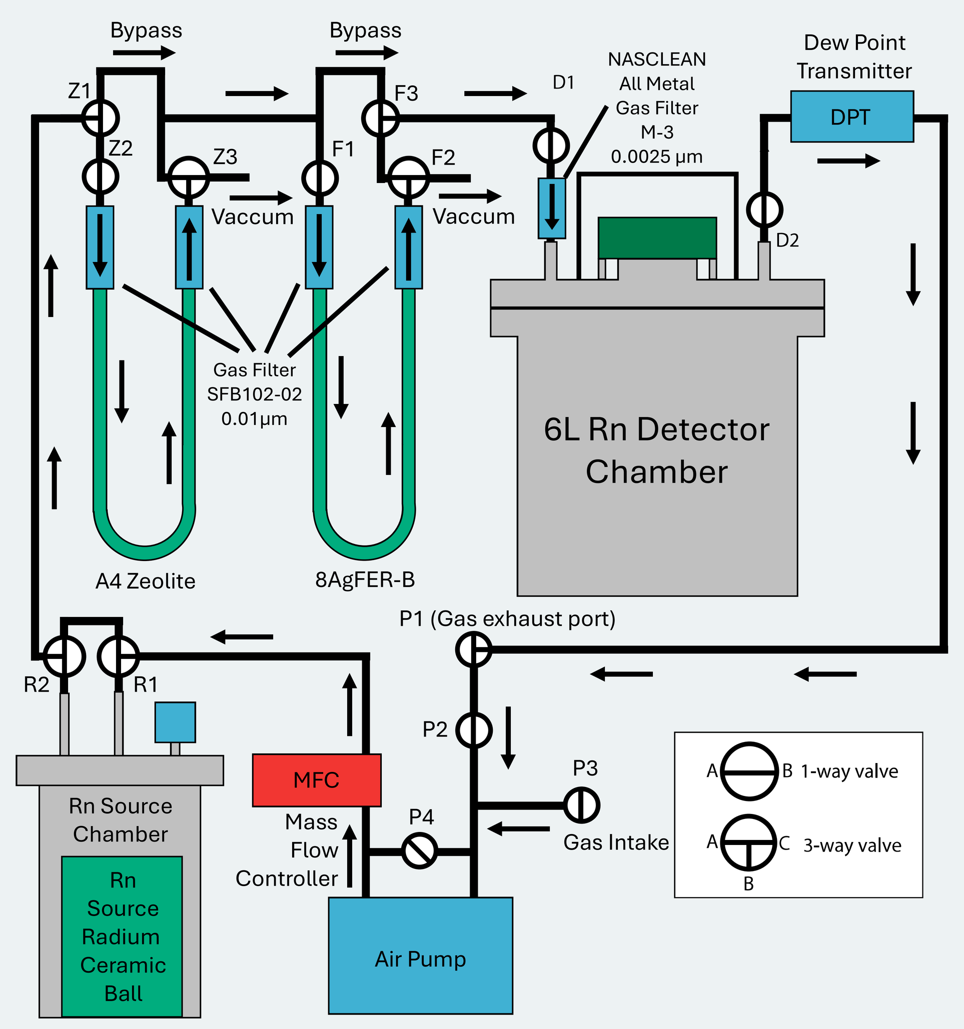
$$\text{Adsorption Coefficient}, K = \frac{\text{Flow rate} \times RT}{\text{Mass of adsorber}}$$

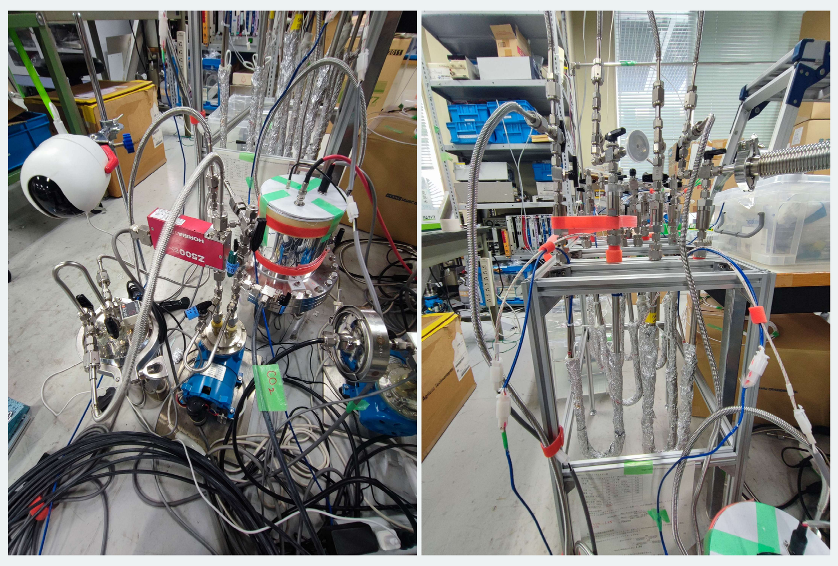
Future Plans

Verification of measurement reproducibility

Repeated adsorption tests under identical conditions

Setup - Isolated gas system





Rn Source

Radon is generated using 1 kg radium ceramic balls, producing both Rn-222 and Rn-220. An air pump drives the gas through the system. The chamber includes a pressure gauge and bypass line for flow control.

Adsorber

A4 zeolite (27.54 g) — removes moisture to protect adsorbent performance
8Ag-FER-B (20.00 g) — primary Rn adsorbent

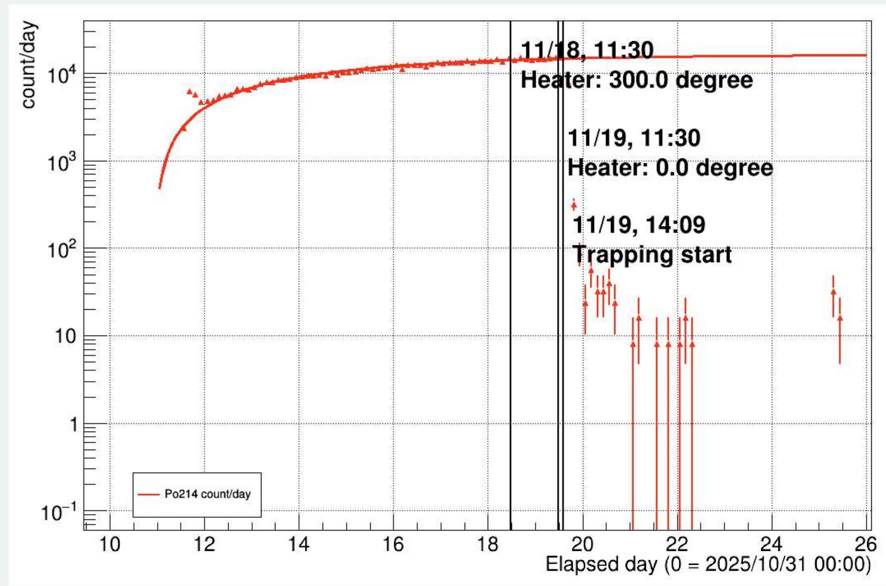
6L Rn

Radon daughters (Po-218, Po-214) are collected using a −500 V high-voltage feedthrough (4 mm) and detected by a Hamamatsu S3204-09 PIN photodiode.
Signals are processed via:
Charge preamplifier → shaping amplifier → DAQ.

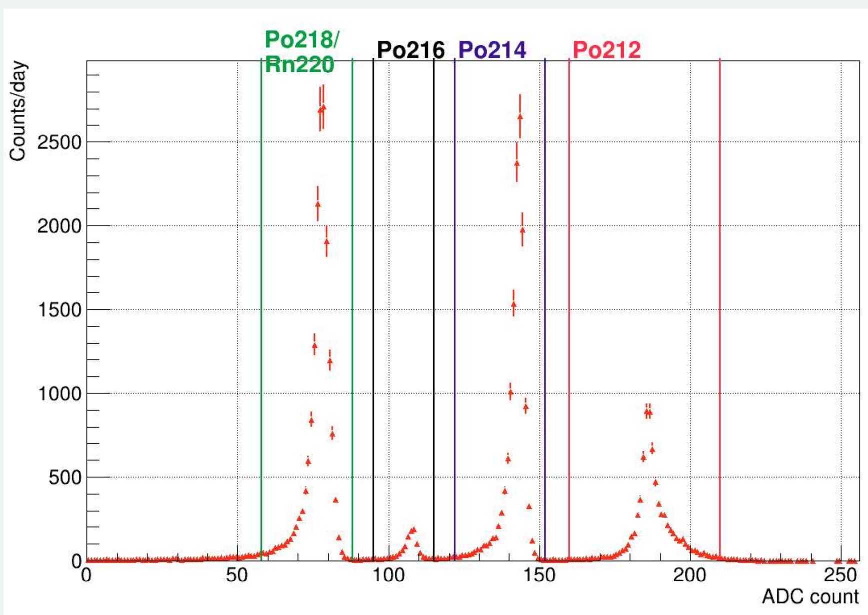
Flow & Humidity

Gas flow is regulated by a mass flow controller (MFC).
A dew-point meter monitors moisture to prevent degradation of adsorption performance.

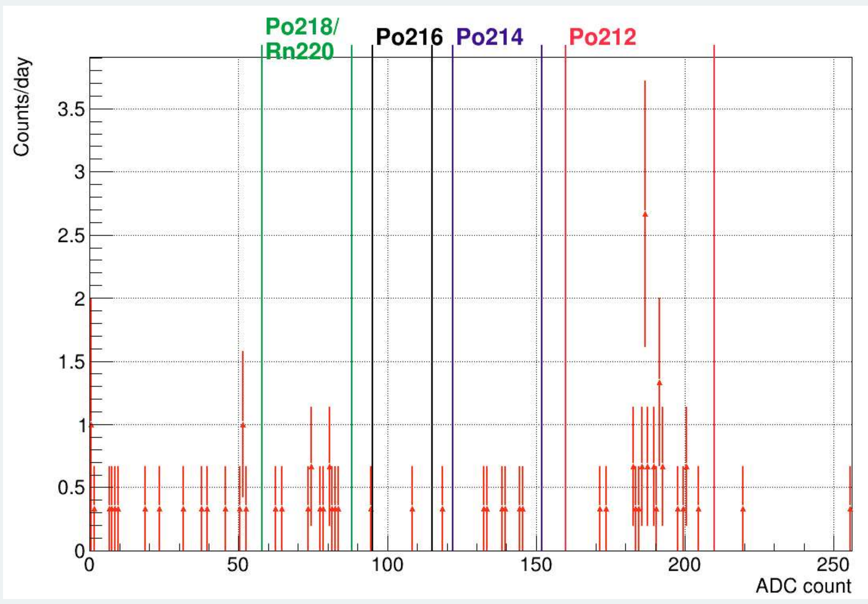
Result



Count/day histogram. 8AgFER-B is baked at 300°C for 24 hour



Spectrum of Polonium isotopes that originate from Rn-222 before the trapping process (16d - 18d)



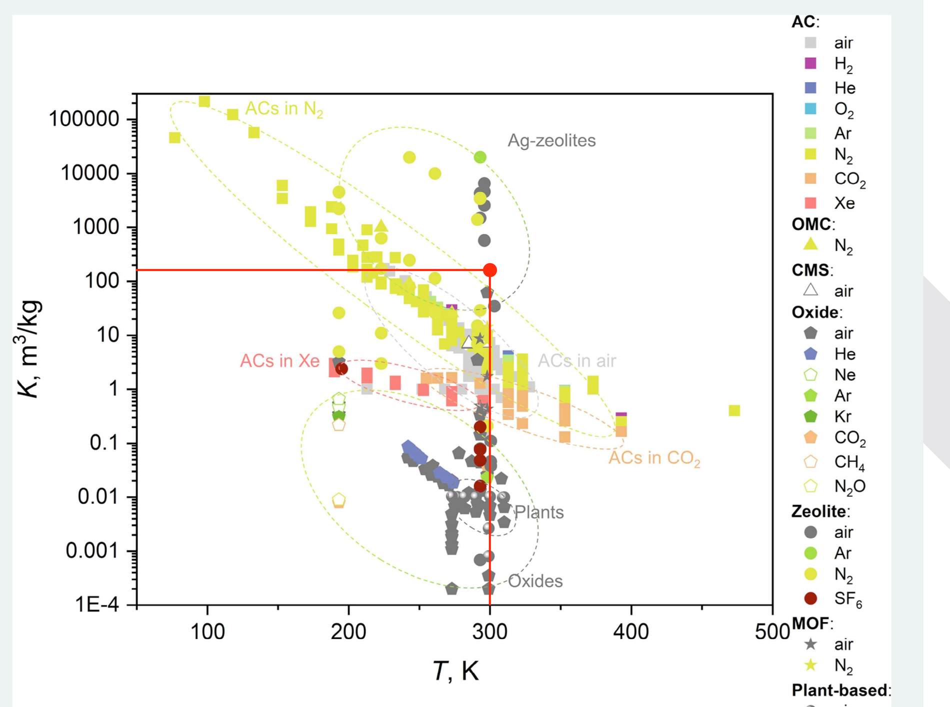
Spectrum of Polonium isotopes that originate from Rn-222 after the trapping process (23d - 25d)

Avg. count/day bypassing column = 13951 ± 200
Avg. count/day via column = 36 ± 3
Adsorption Coefficient, K = 115 ± 22 m^3/kg

Discussion

Compared to previous studies done in G1 grade pure air:
80L detector K = 6560 ± 81 m^3/kg
6L detector K = >4870 ± 12 m^3/kg
K value is only 2% of 6L K value

Comparing count/day before and after trapping process:
Able to remove 99.74% of Rn



The measured value at ~300 K (red point) lies within the Ag-zeolite region and shows significantly higher adsorption performance than activated carbons (ACs) in CO_2. The original figure is taken from [2].

Reference

[1] T Sone, Y Takeuchi, M Matsukura, Y Nakano, H Ogawa, H Sekiya, T Wakihara, S Hirano, A Taniguchi, Study of Radon Removal Performance of Silver-Ion Exchanged Zeolite from Air for Underground Experiments, Progress of Theoretical and Experimental Physics, Volume 2025, Issue 1, January 2025, 013H01, https://doi.org/10.1093/ptep/ptae181

[2] Oleksandra Veselska, Shefali Vaidya, Olivier Llido, Miroslav Macko, Irena Déroche, Sandrine Bourrelly, José Busto, Exploring the science of radon adsorption: Materials, methodologies, and emerging directions, Separation and Purification Technology, Volume 382, Part 1, 2026, 134640, https://doi.org/10.1016/j.seppur.2025.134640.

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