Enhancing Oxidation Stability of Amine-containing CO_2 Adsorbents using Hydroxyethyl Starch

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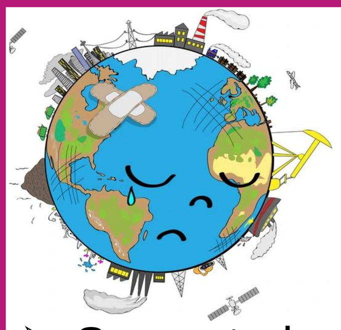
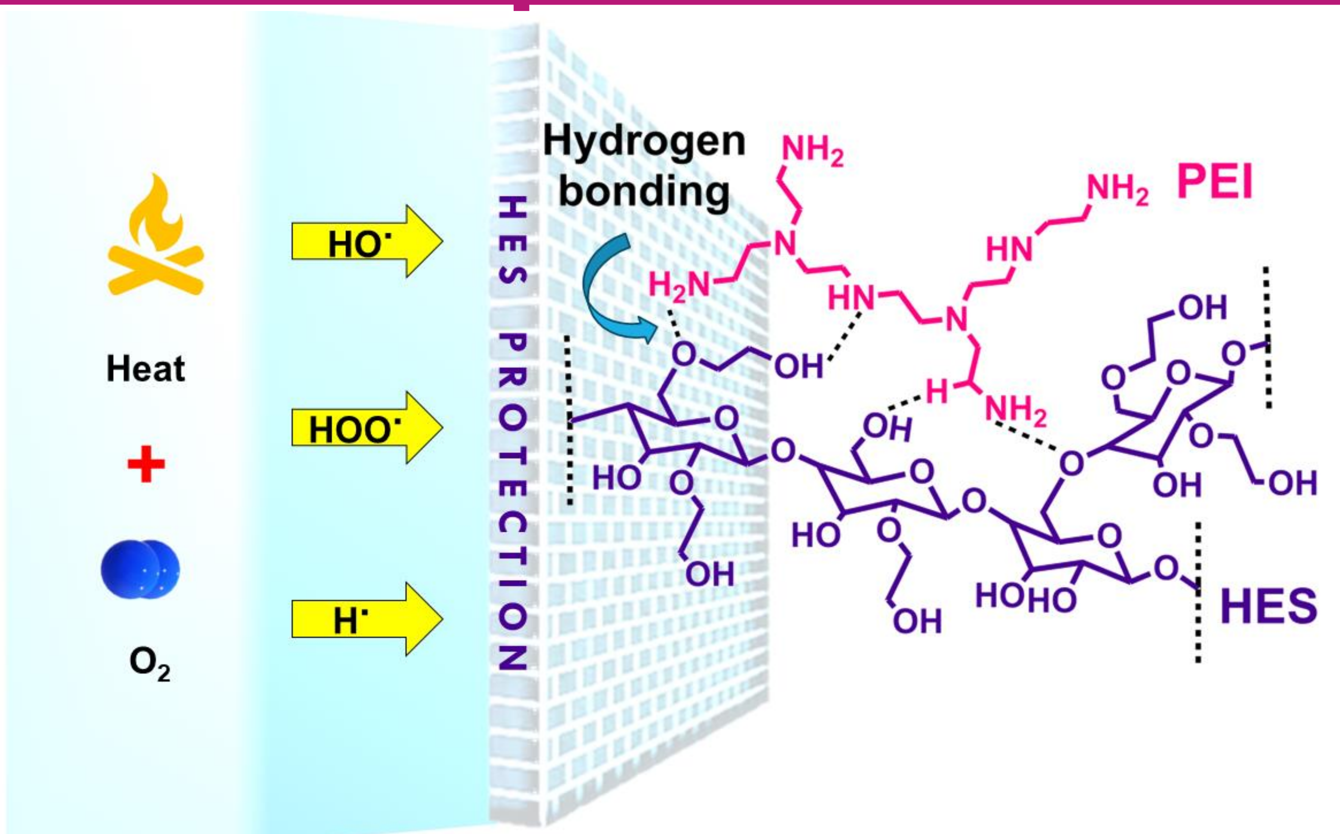
1 INTRODUCTION



- Level of CO_2 has risen to 422 ppm in 2024 and is associated with extreme weather conditions.
- Supported polyethylenimine (PEI) is most popular among solid amine adsorbents for CO_2 capture.[1]
  - ✓ Affordable
  - ✓ Selective
  - ✓ High amine content
  - ✓ Readily available in different molecular weights
  - ✖ Oxidation Stability
- One of the biggest hurdles for their further development is their limited oxidation stability.[2]
- Methods developed to improve the oxidation stability often lead to significant decrease in their CO_2 uptake.[3]



2 OBJECTIVES

- Use a highly stable polymer with abundant hydroxyl and ether groups, like hydroxyethyl starch (HES), to enhance oxidation stability of PEI.
- Prepare adsorbent using straightforward impregnation method.
- Evaluate performance of HES-PEI co-impregnated materials under different oxidation conditions using CO_2 uptake measurements, and mass spectrometry.
- Compare oxidation stability of HES-PEI with other hydroxyl-containing additives.
- Minimize decrease in CO_2 uptake.

3 EXPERIMENTAL

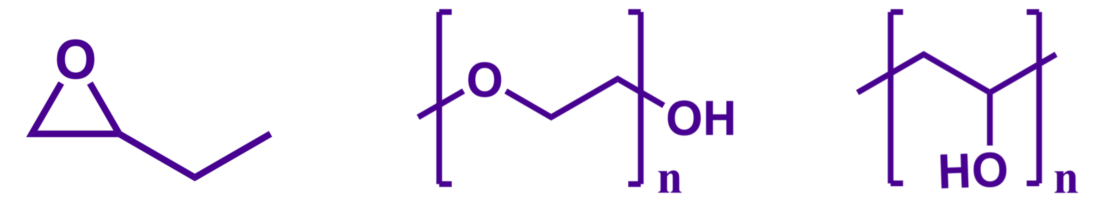
Materials and Methods

Material: PEI, epoxy-butane (EB), hydroxyl containing polymers (HCPs). HCPs include HES, polyvinyl alcohol (PVA) and polyethylene glycol (PEG).

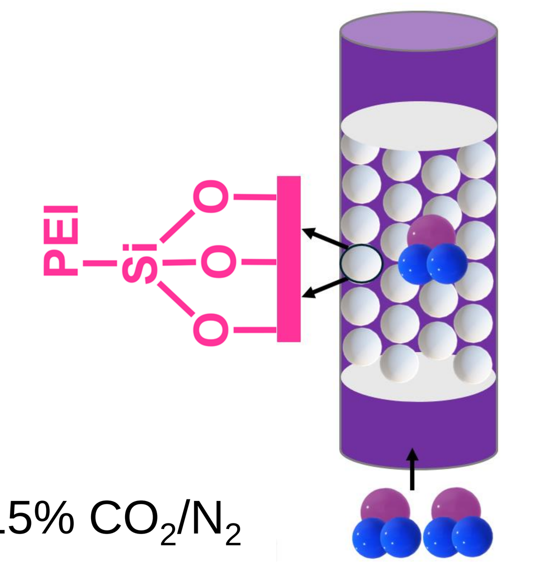
Support: Pore-expanded aluminosilica (PE-AlSiO$_2$).

Method: Impregnation or co-impregnation

Solvent: Methanol or water.

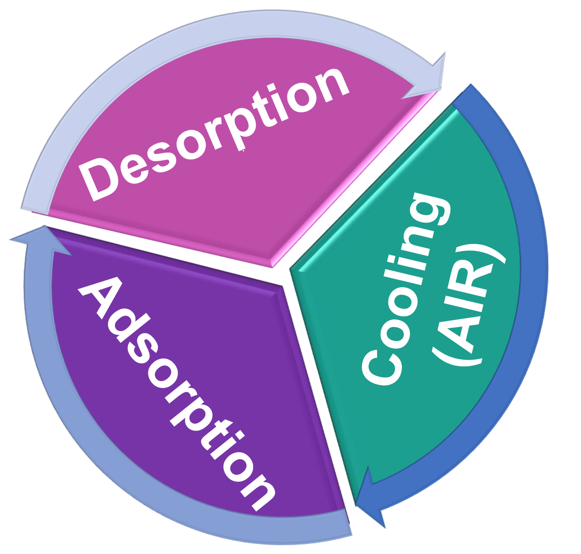


EB PEG PVA



Adsorbent bed

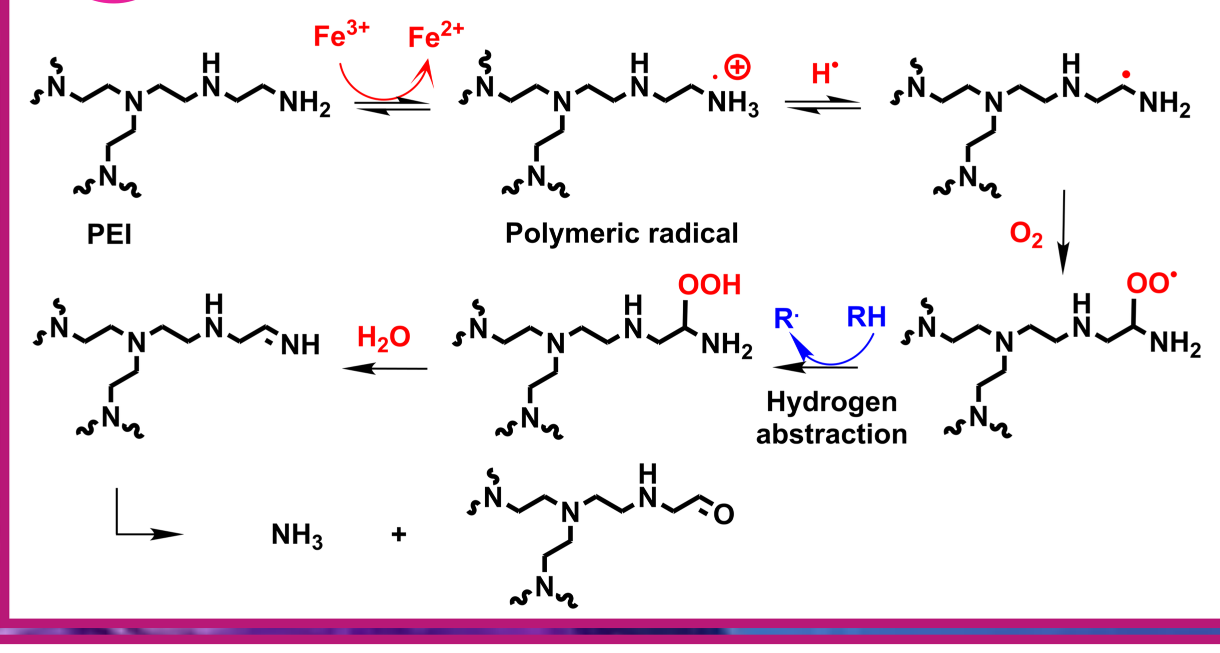
Testing Conditions



Temperature swing adsorption-desorption cycle

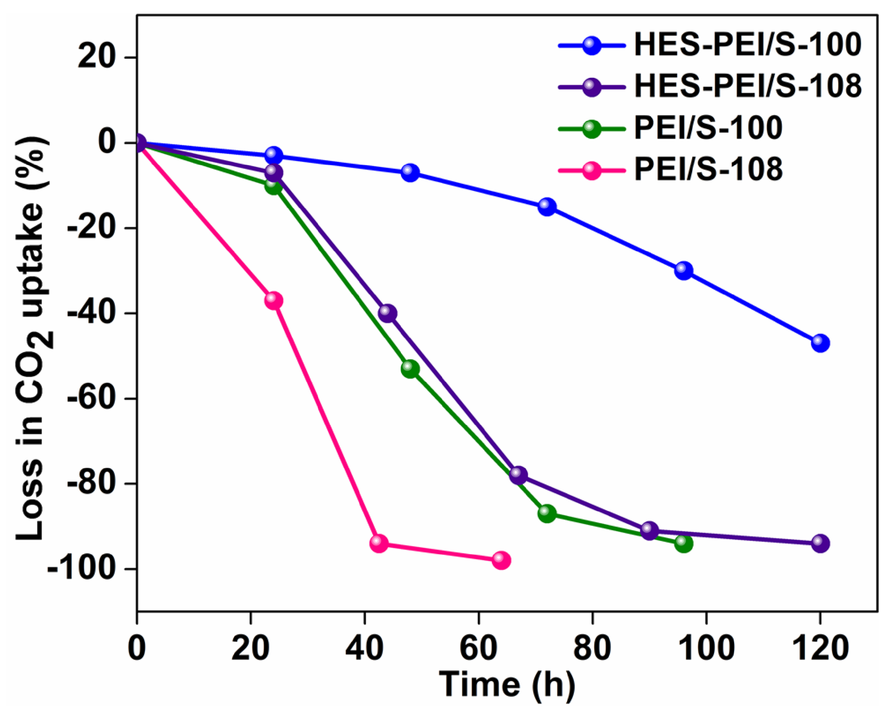
PEI is most susceptible to oxidation during the cooling stage.[4] Therefore, the oxidation stability of adsorbents was investigated at 100/108 °C under flowing air for different time intervals.

4 MECHANISM OF OXIDATION

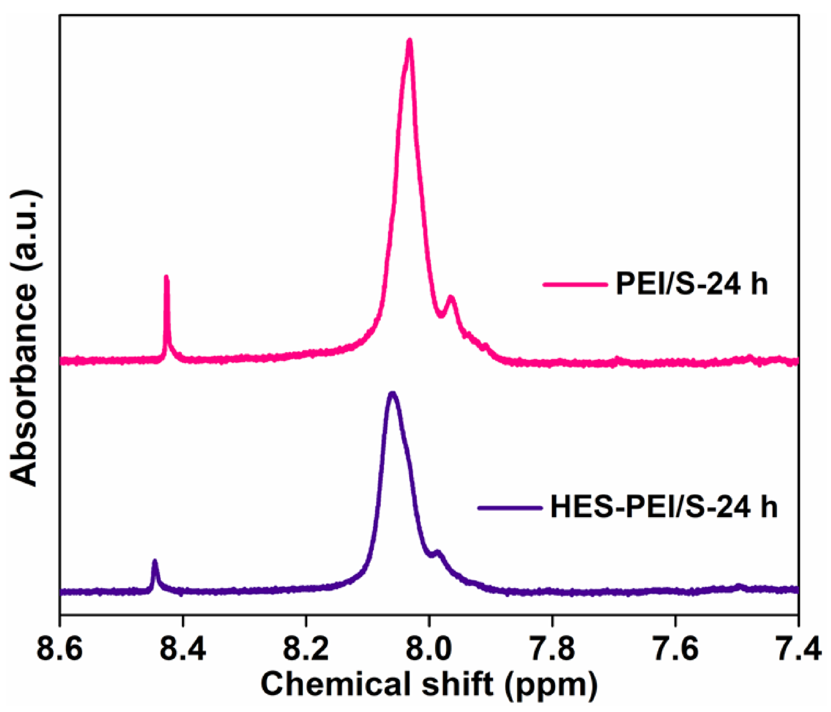


5 OXIDATION AND THERMAL STABILITY

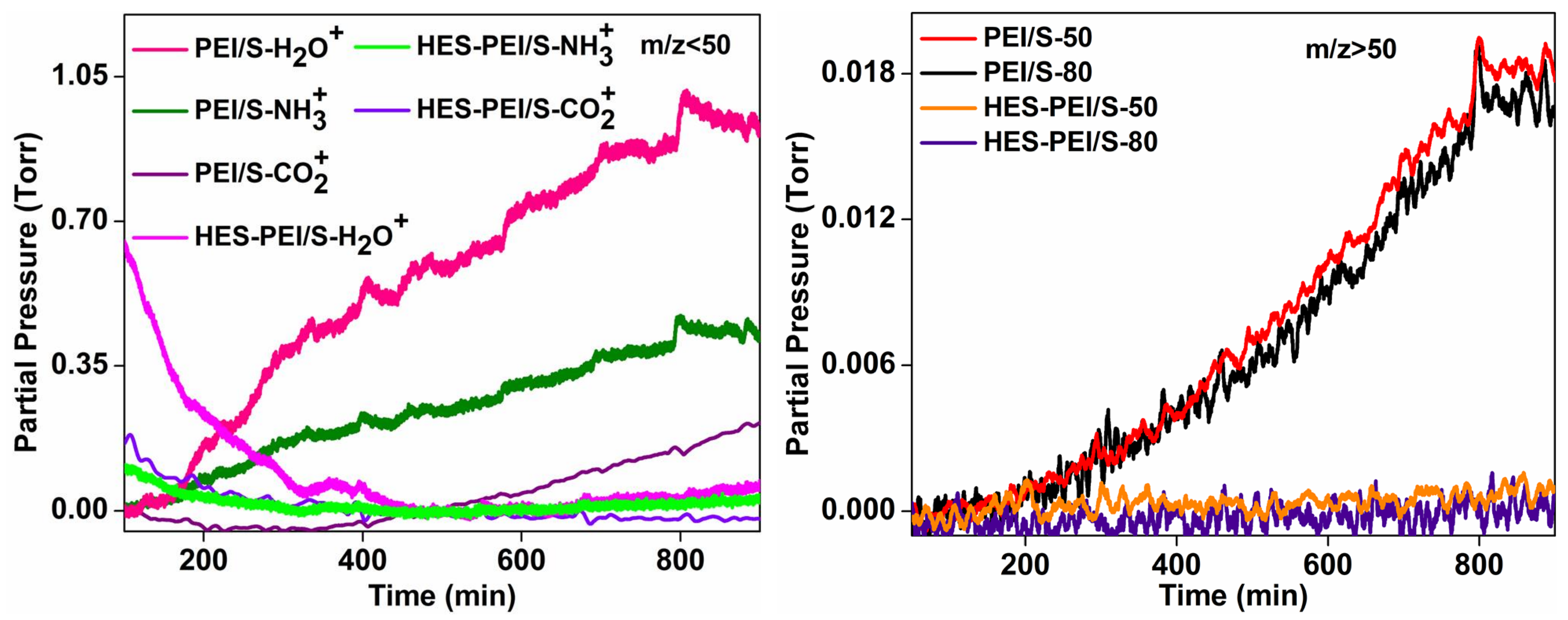
Oxidation Stability



Percentage loss in CO_2 uptake for PEI/S and HES-PEI/S after exposure to air at 100 and 108 °C.

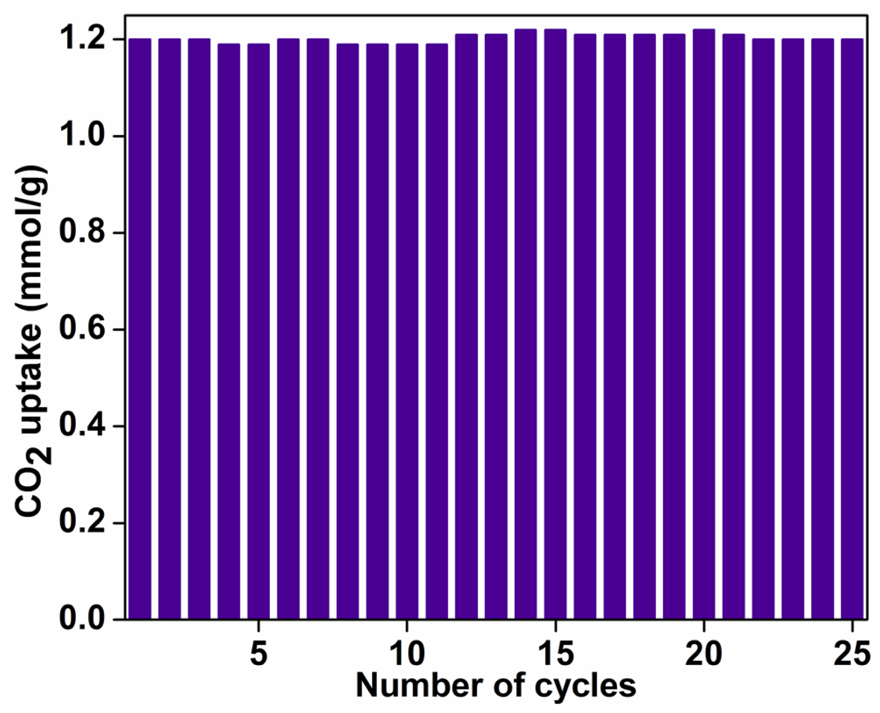


^1H NMR spectra of PEI/S and HES-PEI/S after 24 h oxidation.



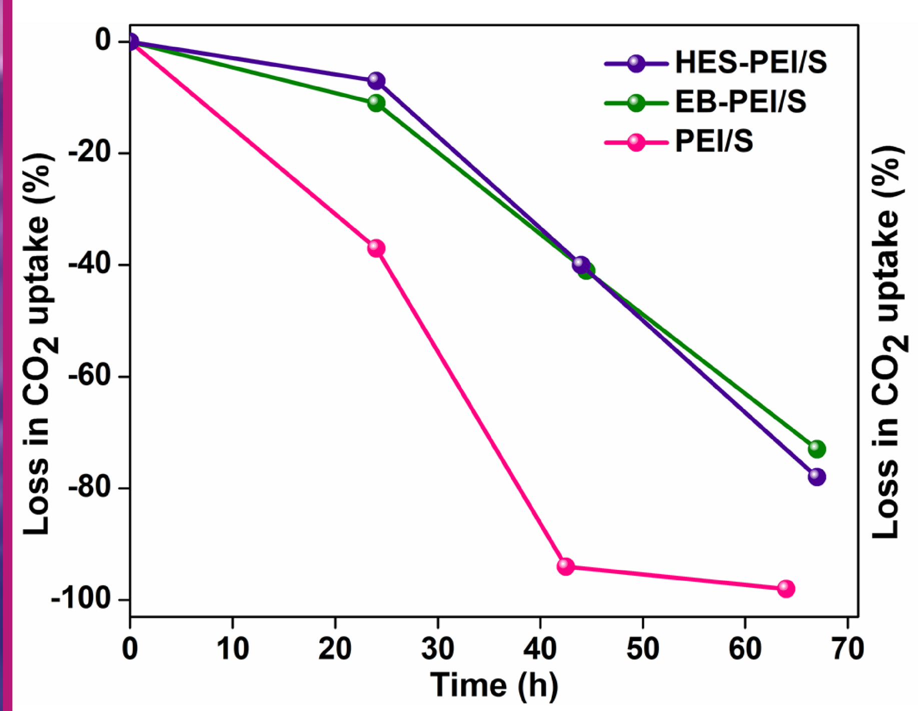
Partial pressure of different degradation fragments of PEI/S and HES-PEI/S with (a) $m/z < 50$ and (b) $m/z > 50$ during exposure to air at 108 °C.

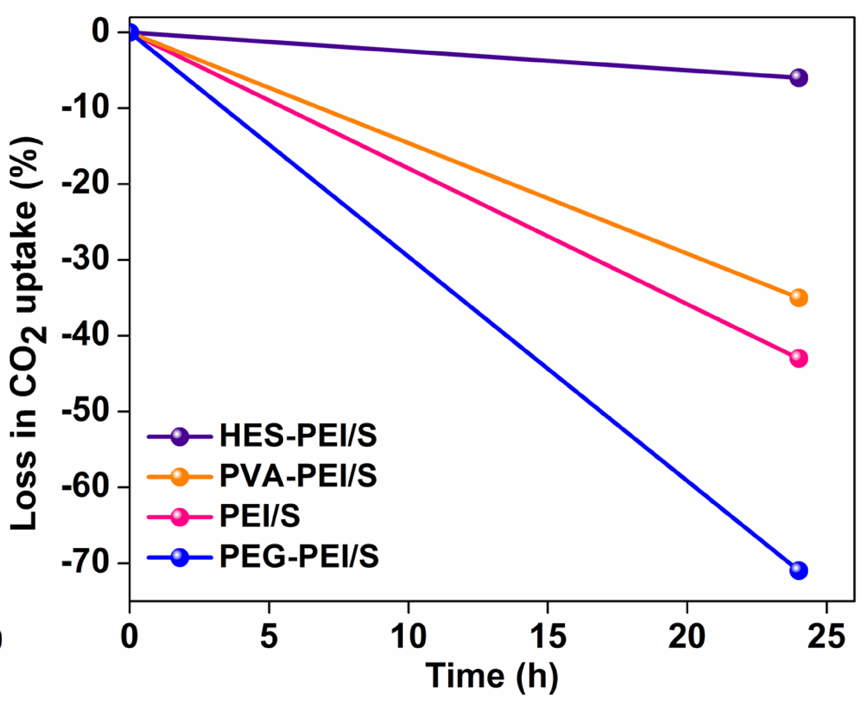
Cycling stability



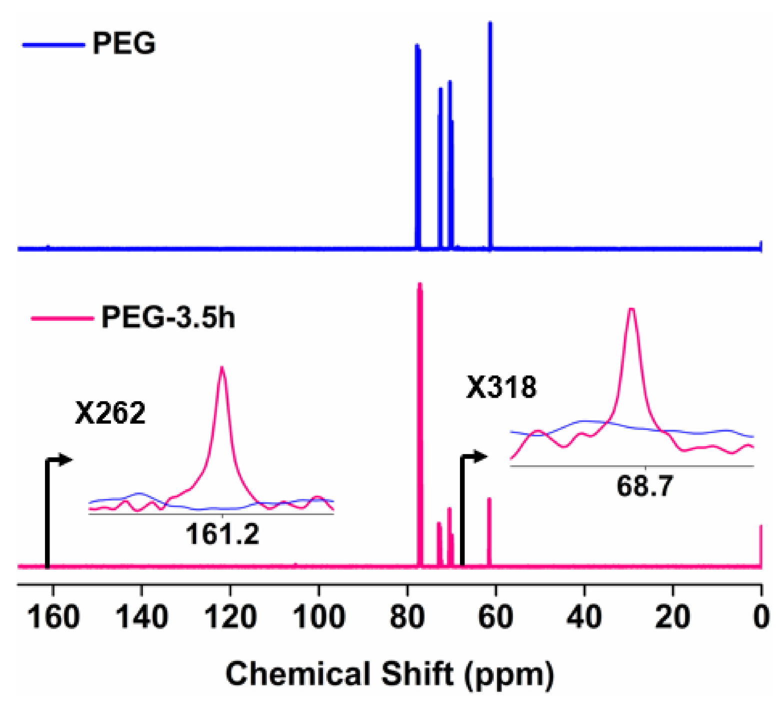
Cyclic CO_2 adsorption–desorption on HES-PEI/S.

COMPARISON WITH OTHER ADDITIVES

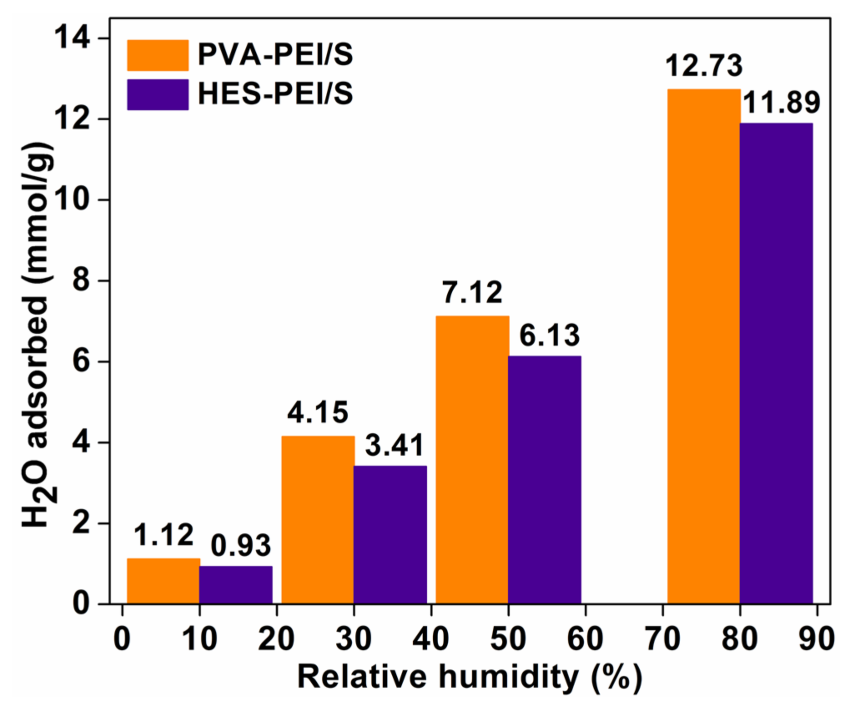




Percentage loss in CO_2 uptake of PEI, EB-PEI/S and HCP-PEI/S after exposure to air at 108 °C for different time intervals.



^{13}C NMR of fresh PEG and PEG oxidized under air.



H_2O uptake of PVA-PEI/S and HES-PEI/S.

6 CONCLUSIONS

- Addition of HES significantly enhanced the oxidation stability of PEI due to efficient hydrogen bonding.
- The oxidation stability of supported PEI in the presence of HES was higher compared to other hydroxyl containing polymers.
- Co-impregnation of supported PEI with HES gave comparable oxidation stability than the epoxide functionalization, but significantly higher CO_2 uptake.

Read the paper

Acknowledgement:

uOttawa CCRI CRIC NSERC CRSNG

Abdel Sayari

References:

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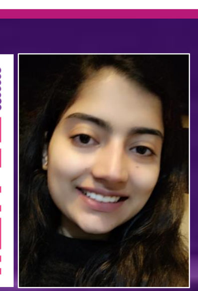
3. K. Min, W. Choi, C. Kim, M. Choi, 2018. Nat. Commun., 9, p. 726.
4. Kaur, C. and Sayari, A., 2024. *Chem. Eng. J.*, 496, p. 153756.



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