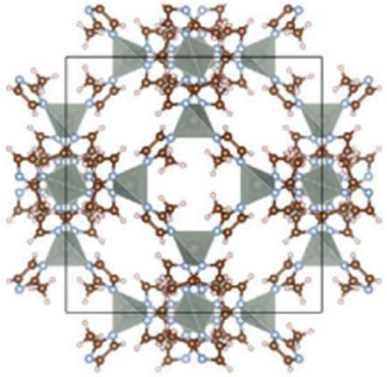
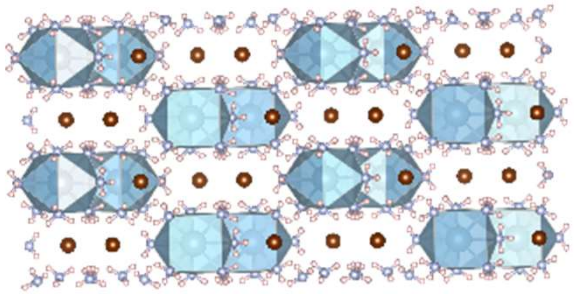
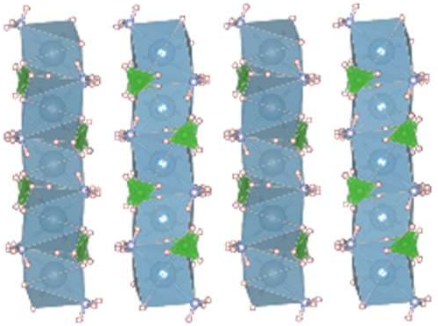
Towards Safer, Cheaper Ammonia Storage

MariNH3
Clean, green ammonia engines for maritime







Sorbents can enable storage at room temperature and atmospheric pressure

Require heating to release ammonia

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Metal Halides and Borohydrides

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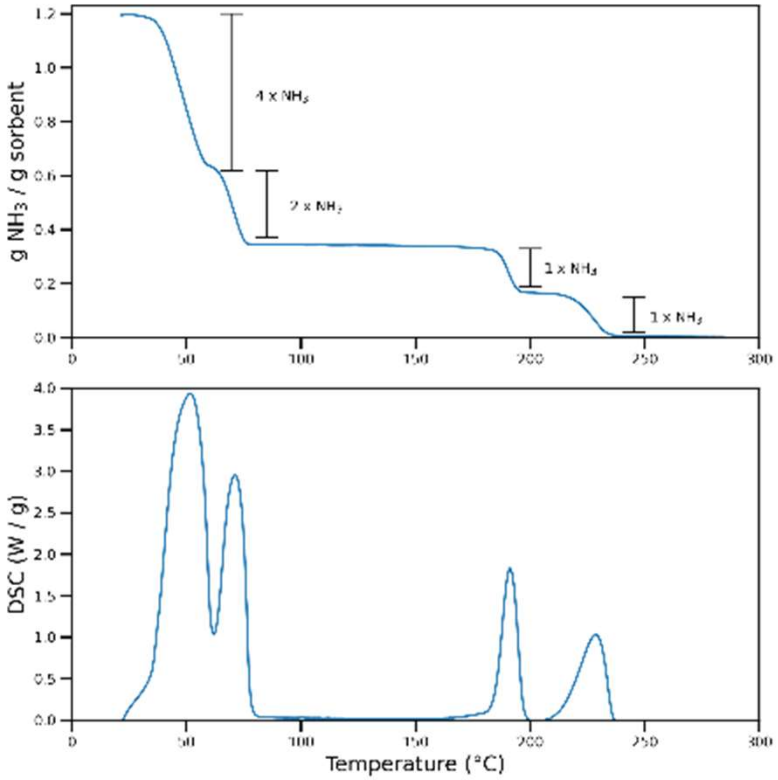
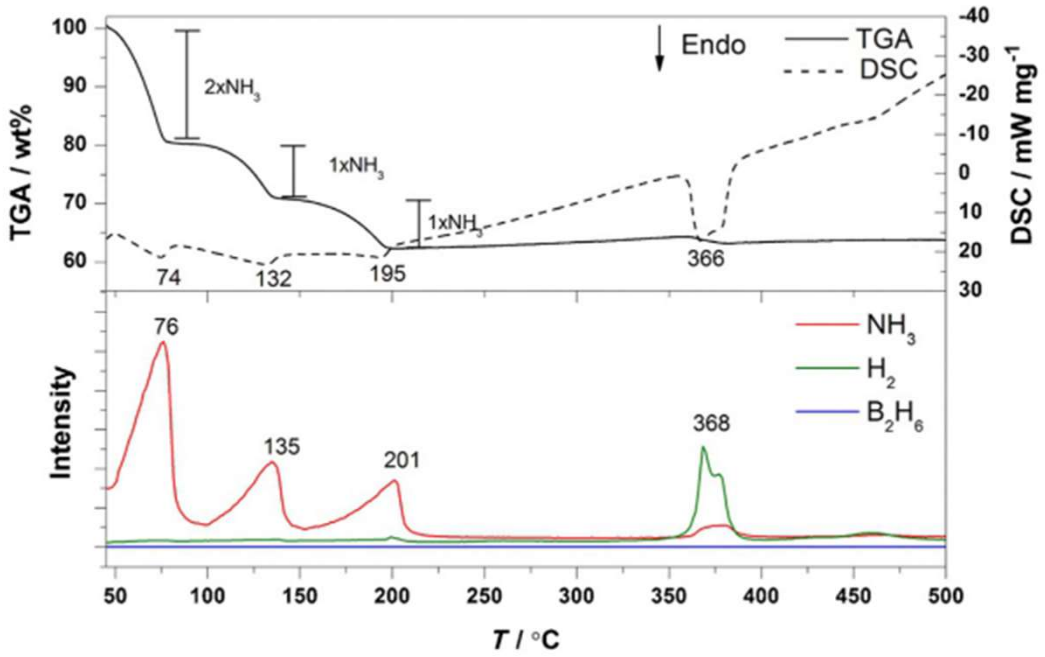
Clean, green ammonia engines for maritime



$CaCl_2(NH_3)_8$
Calcium chloride



$Ca(BH_4)_2(NH_3)_4$
Calcium borohydride

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Metal Halides and Borohydrides

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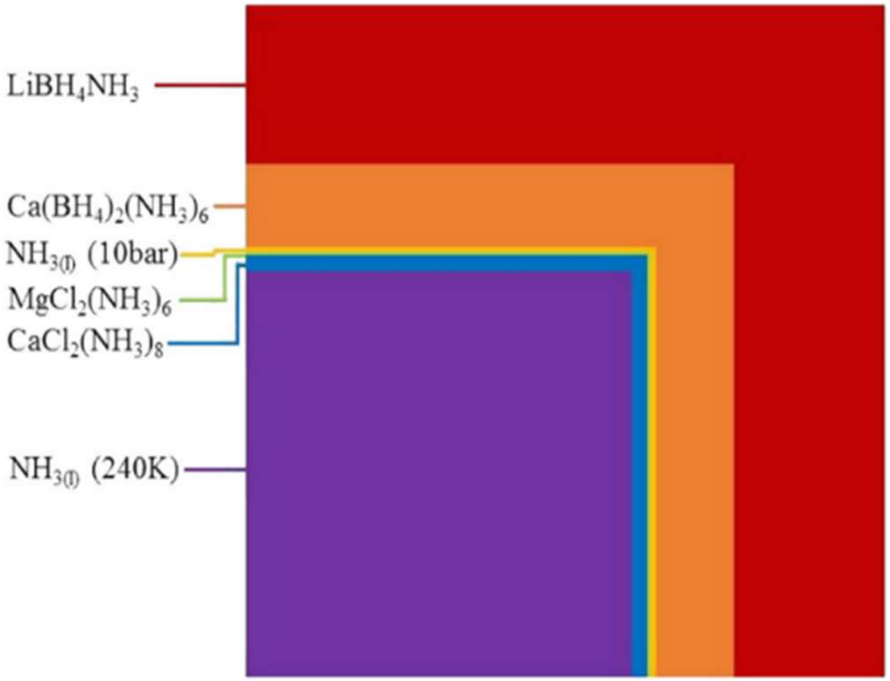
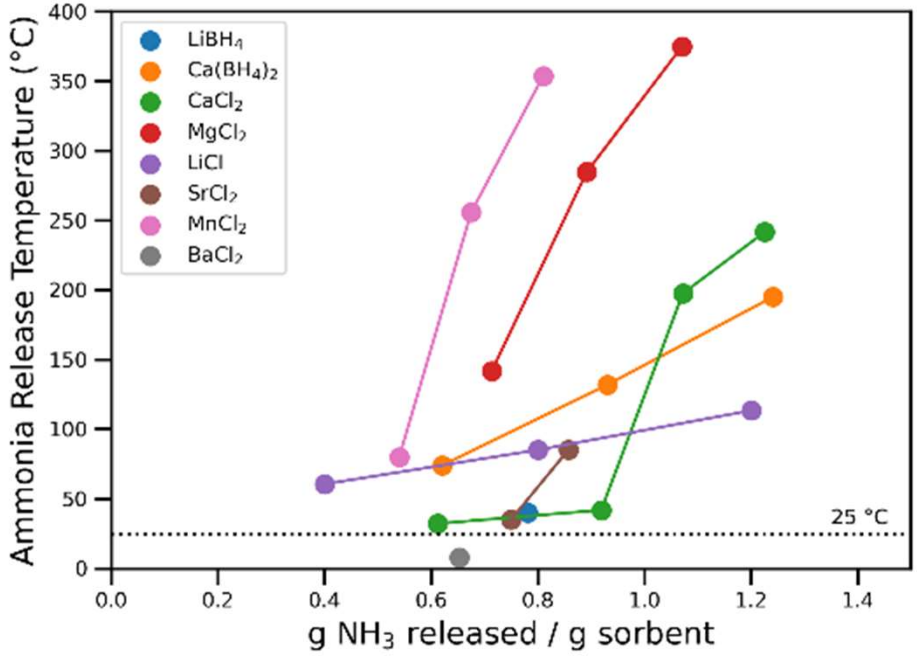


Volumes of different ammonia storage methods



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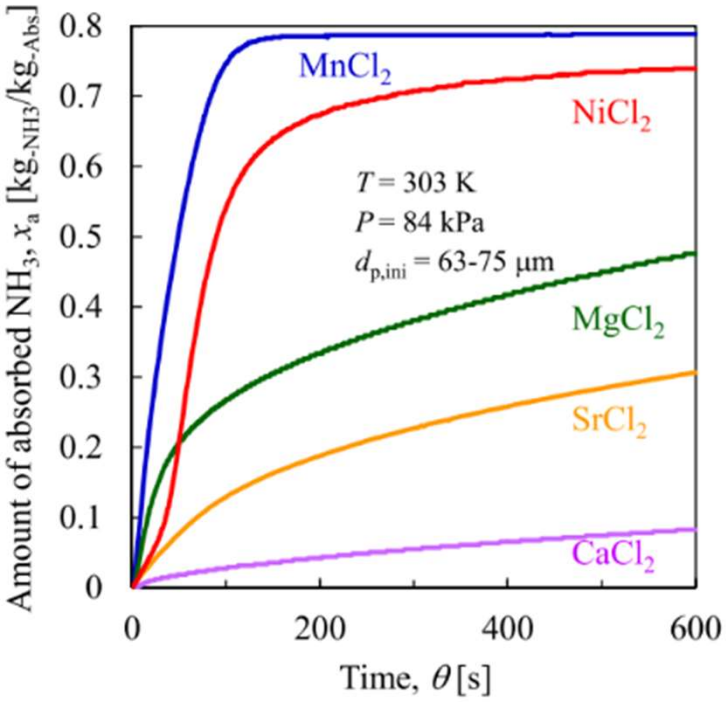
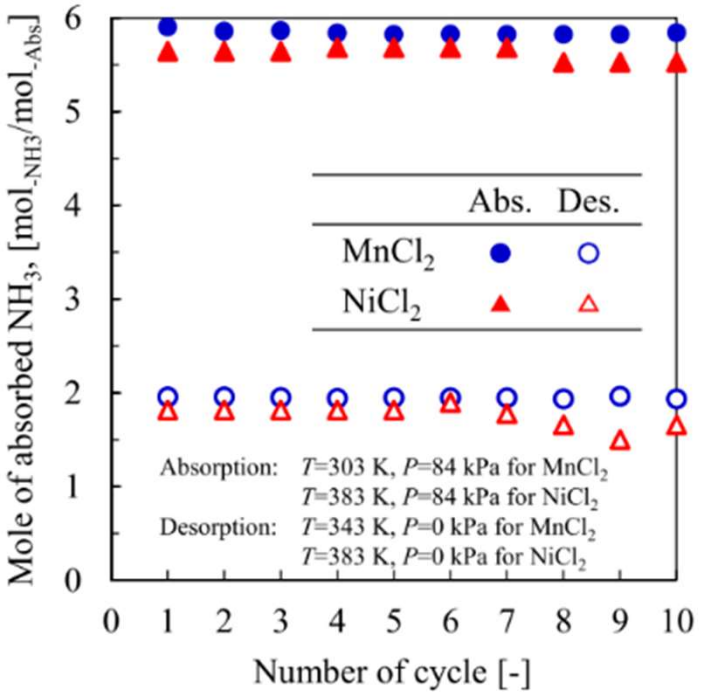


Rates of absorption in metal halides can vary greatly



Stability upon cycling generally good for metal halides

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Metal-Organic Frameworks (MOFs)

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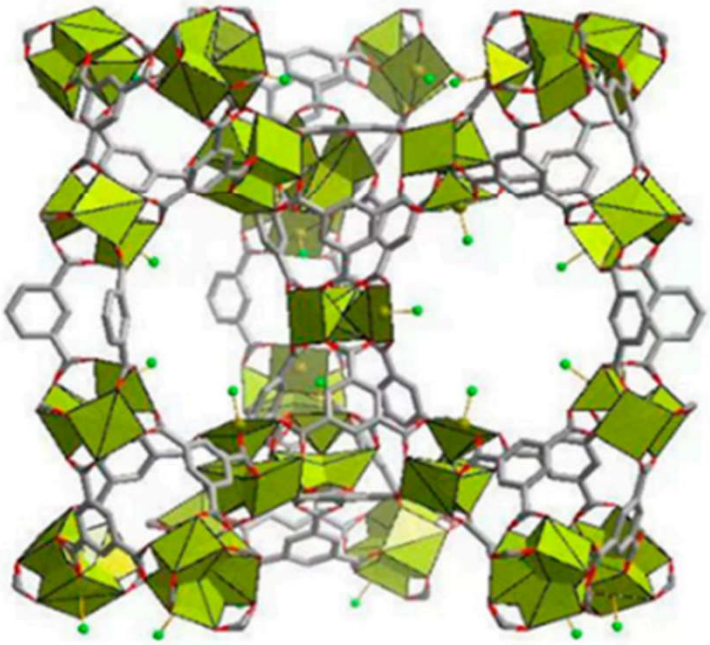
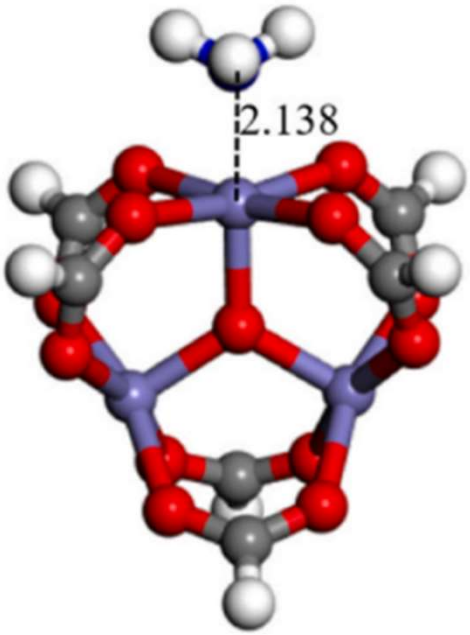
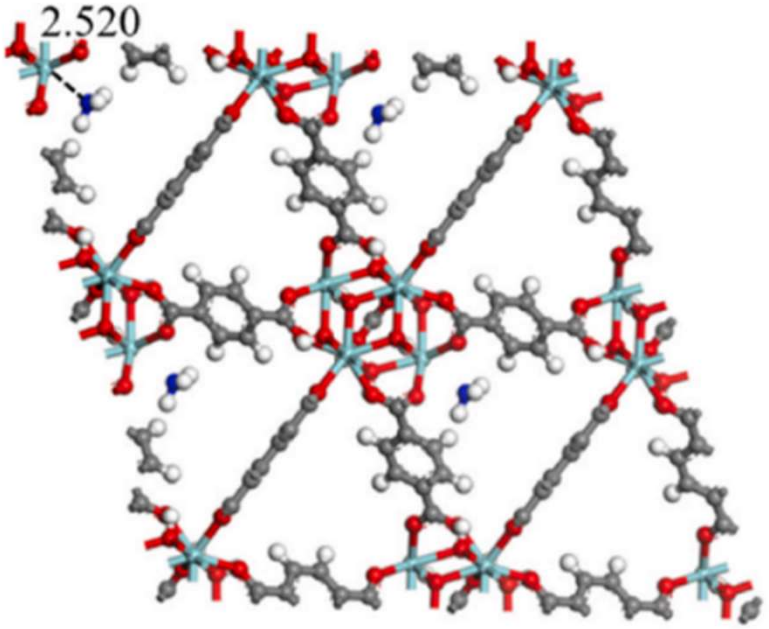
Clean, green ammonia engines for maritime







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Metal-Organic Frameworks (MOFs)

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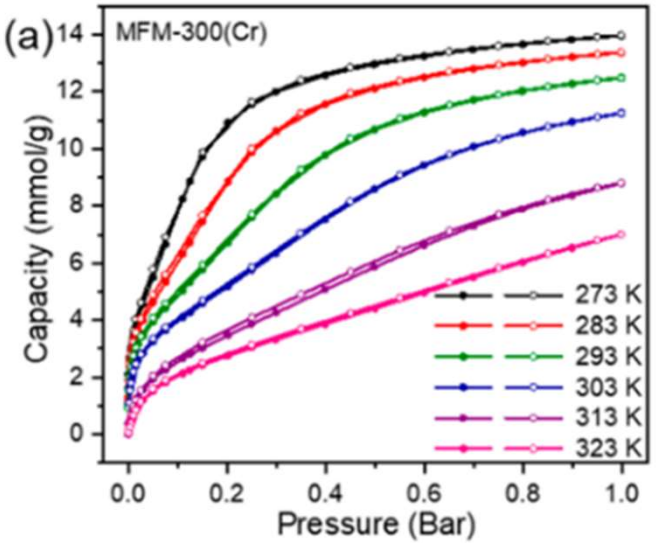
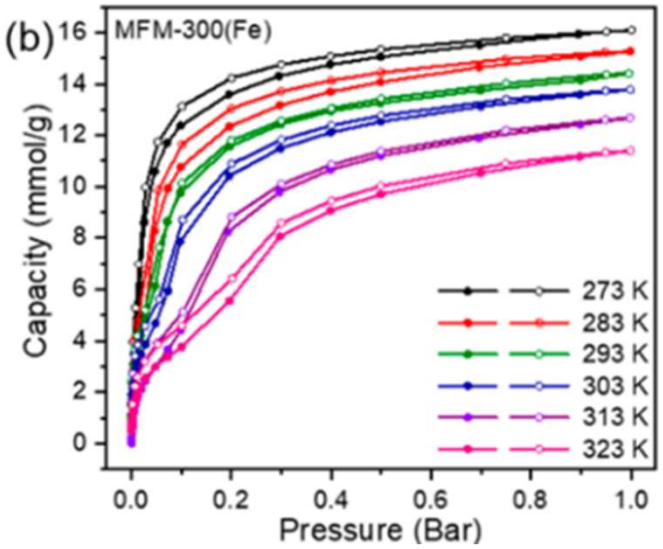
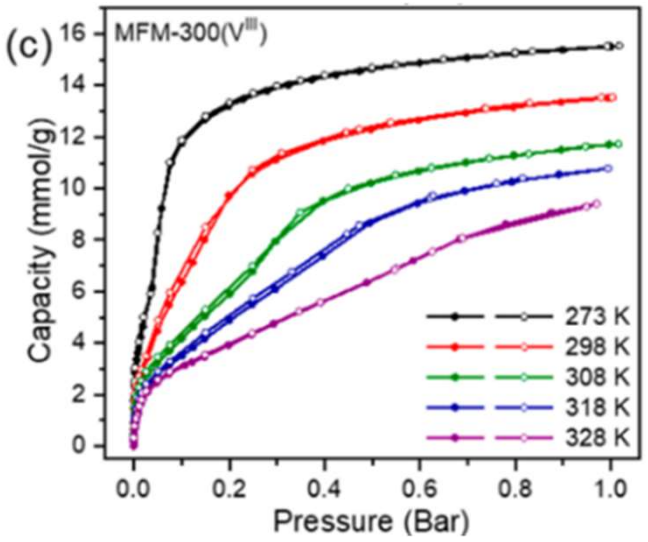


10 mmol/g = 0.17 g NH_3 / g sorbent

Capacities much lower than metal halides and borohydrides



Ammonia content is a continuous function of temperature and pressure, due to the lack of discrete phase transitions



Fast rates due to large pores for gas diffusion

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Deep Eutectic Solvents (DESs)

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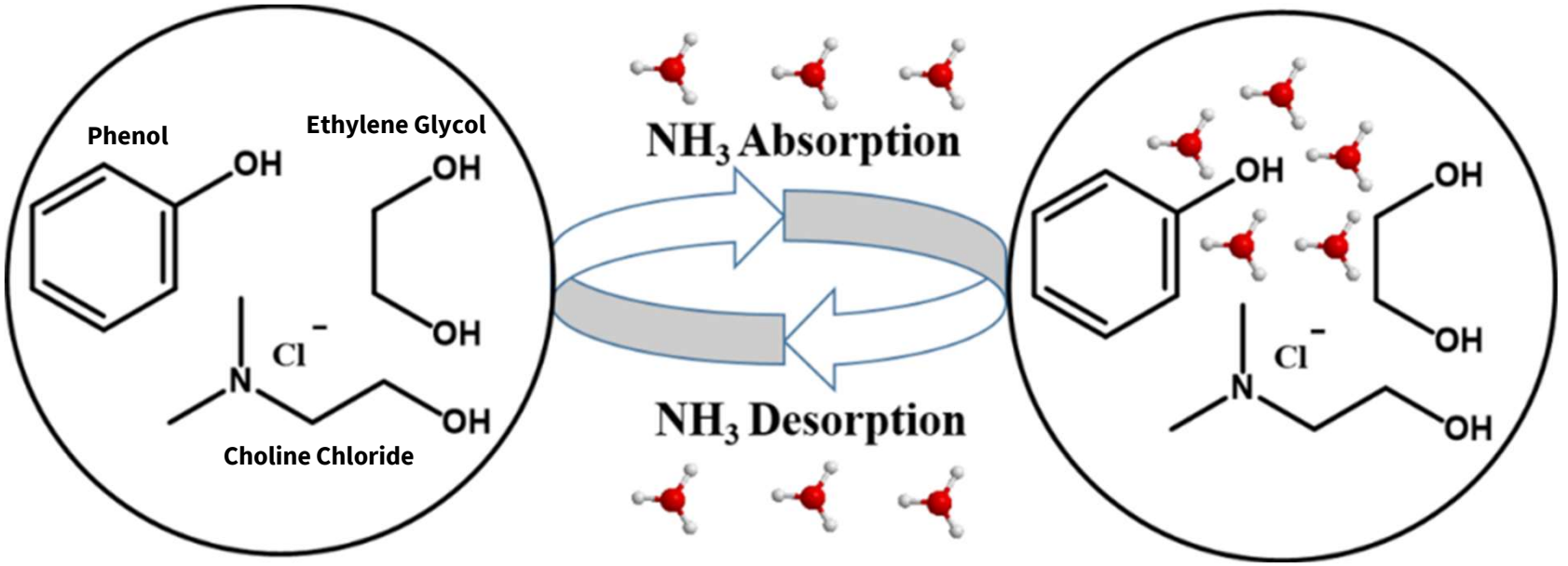

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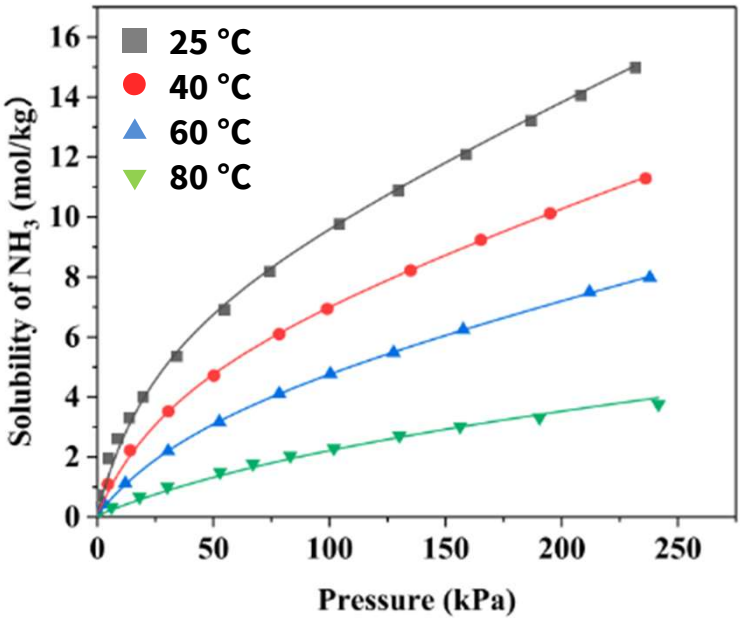
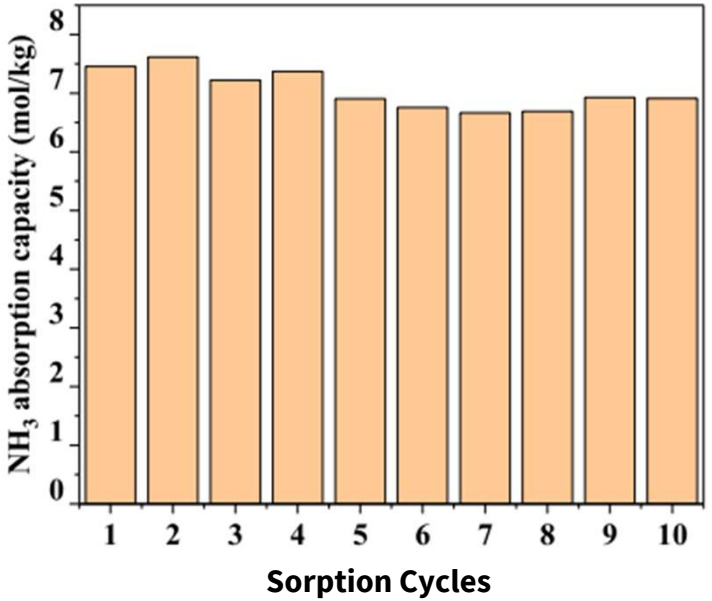


1:5:4 ChCl:PhOH:EG



Absorption: 40 °C, 101.3 kPa
Desorption: 60 °C, 0.1 kPa

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Sorbent Overview

MariNH3
Clean, green ammonia engines for maritime

Metal Halides and Borohydrides	MOFs	DESs
Phase transitions with large, discrete ammonia releases	Ammonia content is a continuous function of temperature and pressure	Ammonia content is a continuous function of temperature and pressure
Ammonia release temperatures can be high for some phase transitions (up to 400 °C)	Low ammonia release temperatures	Low ammonia release temperatures
High gravimetric and volumetric ammonia densities	Low ammonia densities	Low ammonia densities
Slower absorption rates, but very dependent on identity of metal and pressure	Very rapid sorption; virtually no hysteresis	Fast sorption; limited hysteresis
Good cycling stability	Many MOFs show limited stability upon cycling. Research still to be done	Good cycling stability
Solid	Solid	Liquid

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SUNBORNE SYSTEMS

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References

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- Slide 4 - Pressurised NH_3 storage tank: https://tictrucks.en.made-in-china.com/product/QBwJhKXThiYu/China-Pressure-Vessel-Liquid-Ammonia-Storage-Tank-10cbm-100cbm-Anhydrous-Liquid-Ammonia-Liquid-NH3-.html
- Slide 5 – Refrigerated NH_3 storage tank: https://www.geldof.be/?portfolio=double-walled-ammonia-storage-tank-28372
- Slide 7 – ppm values of ammonia https://grontskipsfartsprogram.no/wp-content/uploads/2022/03/Ammonia-as-Marine-Fuel-Safety-Handbook-Rev-01.pdf
- Slide 7 – Ammonia hazard diamond: https://doi.org/10.1021/acs.chas.2c00041
- Slide 8 – Jack Rabbit Tests: https://www.youtube.com/watch?v=poNlA5GpF1I
- Slide 9 – Houston, Texas ammonia spill: https://www.chron.com/news/houston-texas/houston/article/In-1976-an-ammonia-truck-disaster-claimed-the-12906732.php
- Slide 10 – Temperatures of ammonia-air mixtures: https://doi.org/10.1002/jctb.503291102
- Slide 13 – $CaCl_2(NH_3)_8$ desorption: Own PhD work
- Slide 13 – $Ca(BH_4)_2(NH_3)_2$ desorption: https://doi.org/10.1002/cssc.201500713
- Slide 14 – Volumes of ammonia storage: https://doi.org/10.1016/j.ijhydene.2019.01.144
- Slide 15 – Both figures: https://doi.org/10.1252/jcej.13we294
- Slide 16 – Image centre and right: https://doi.org/10.1016/j.buildenv.2021.108421
- Slide 16 – Image left: 10.3390/molecules27227847
- Slide 17 – All figures: https://doi.org/10.1021/jacs.0c11930
- Slide 18 + 19 – All: https://doi.org/10.1021/acssuschemeng.8b05221

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