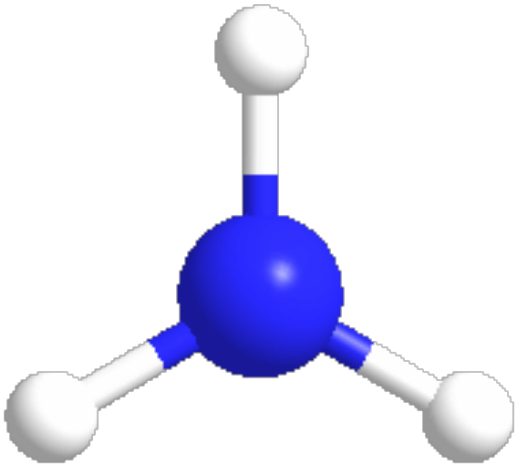
Safety of Ammonia As Hydrogen and Energy Carriers



Wednesday, November 13, 2019 10:20-10:38

Hyatt Regency Orlando - Regency Ballroom P

Ammonia Energy Conference 2019 at 19 AIChE Annual Meeting in Orlando, FL, November 12-14, 2019

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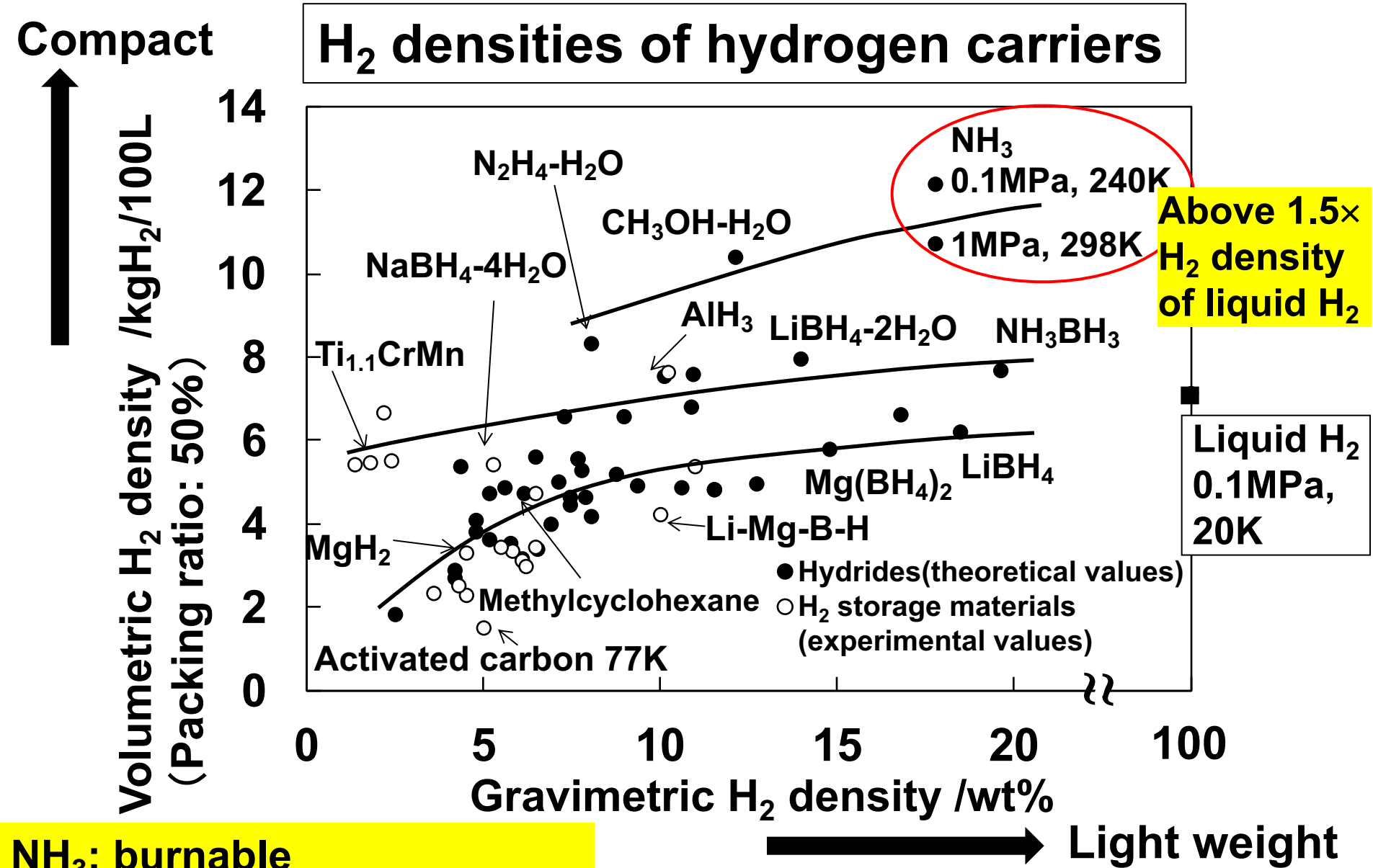
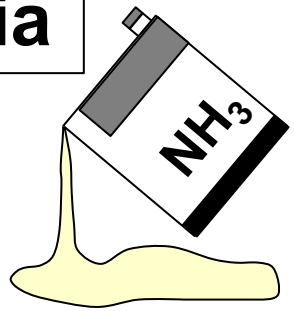
1. Introduction



NH_3: burnable substance → Energy carrier

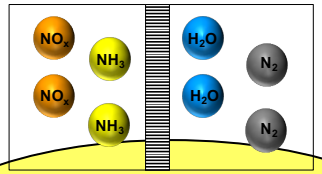
Y. Kojima, Hydrogen storage materials for hydrogen and energy carriers, International Journal of Hydrogen Energy, 44, 18179-18192 (2019)

Application of anhydrous ammonia

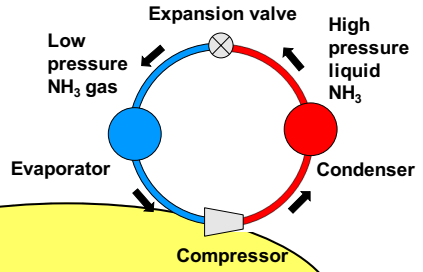


Fertilizer

Hydrogen and energy carriers



NOx reducing agent



Refrigerant

NH_3

Material for polymers

$+[NH(CH_2)_5CO]_n$

Material for nitrides, gunpowder

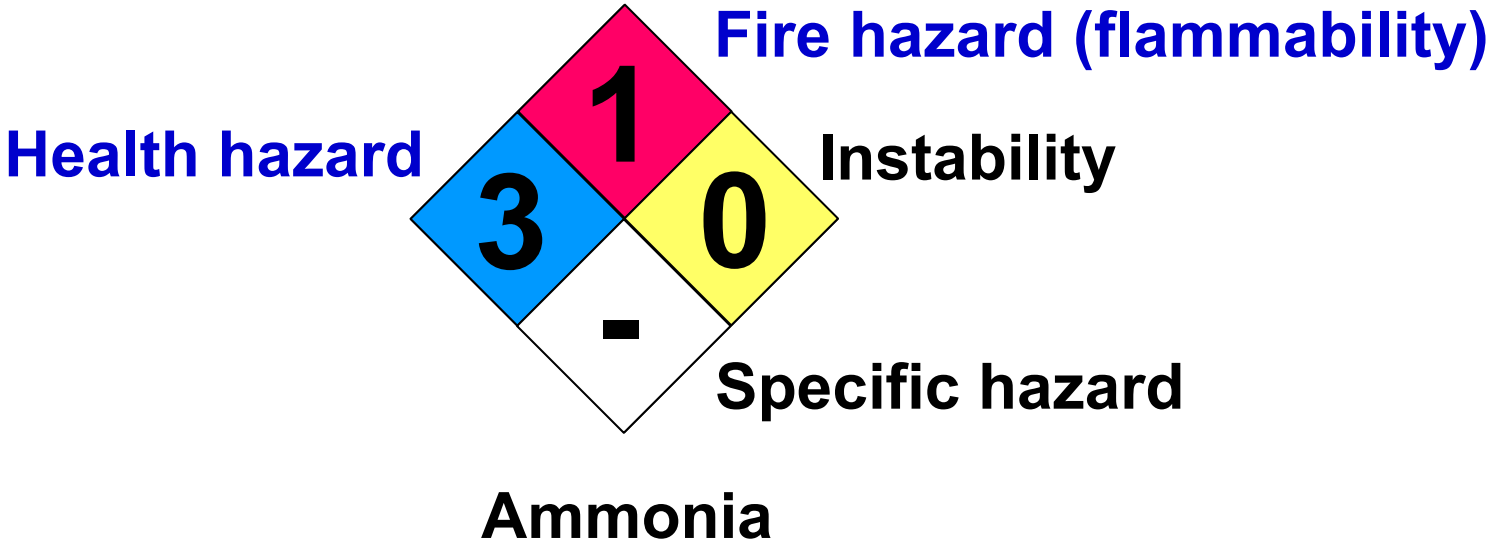
Ammonia: deleterious substance

Purpose: To figure out regulations for safety of NH_3, survey NH_3 accident and propose new concept of ammonia removal system

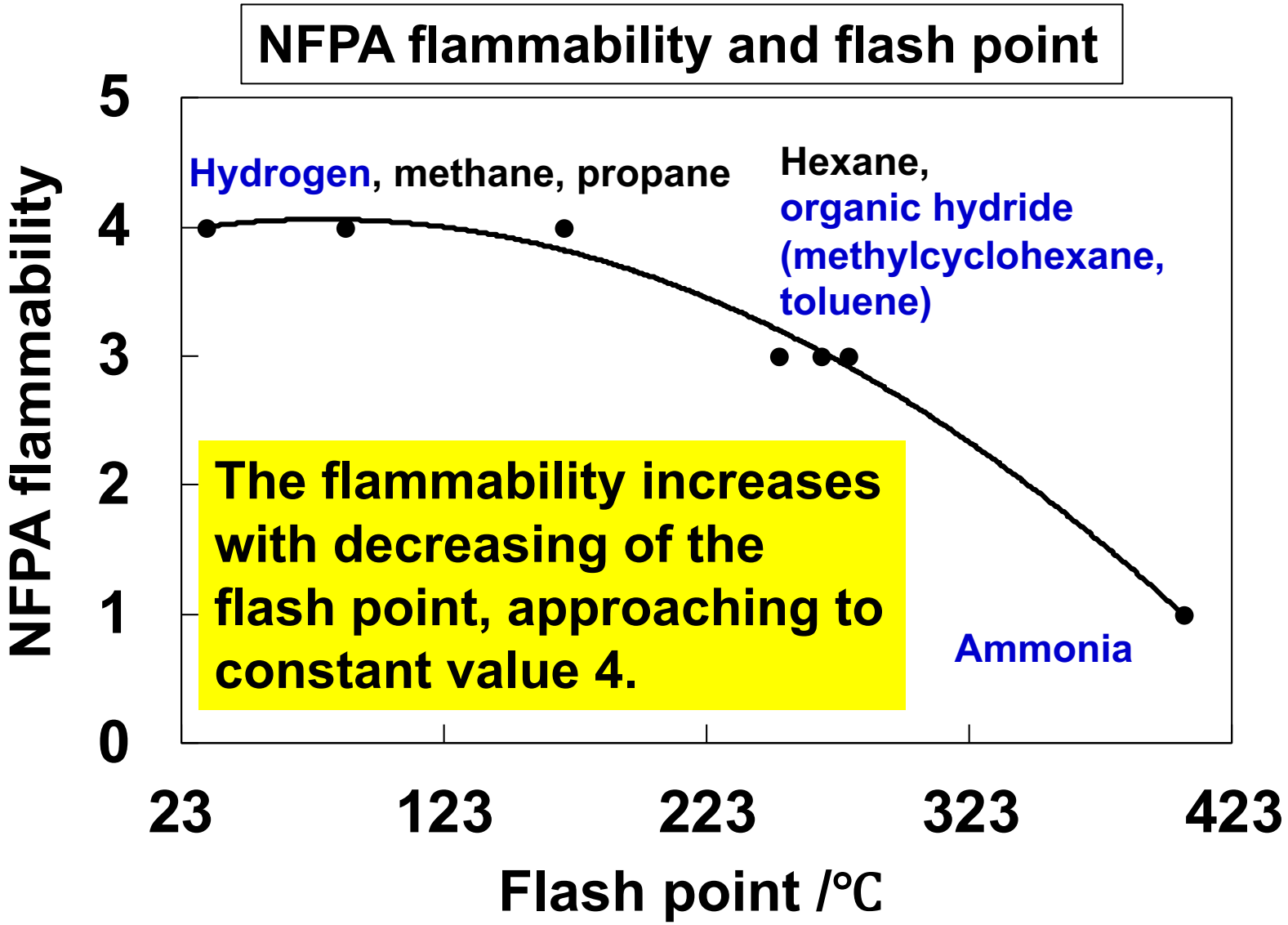
2. Regulations for safety of NH_3

(1)USA: NFPA(National Fire Protection Association) 704

Fire diamond of ammonia



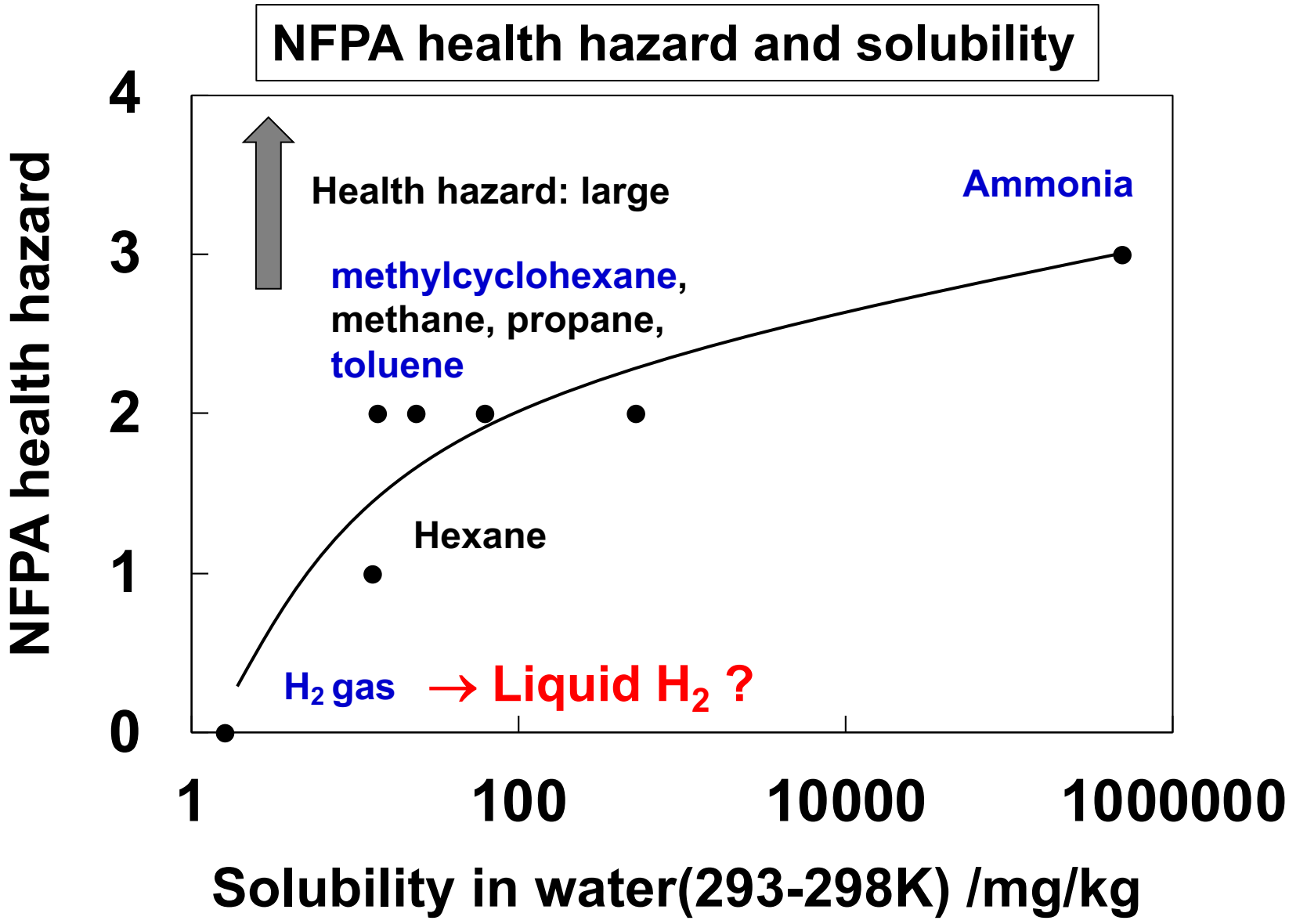
(2)Japan: GHS (The Globally Harmonized System of Classification and Labelling of Chemicals)
(3)EU: CLP regulation (Regulation on Classification, Labelling and Packaging of substances mixtures



Fire hazard: Ammonia<Organic hydrides <Hydrogen

Japanese GHS

Fire hazard: Organic hydrides <Hydrogen, Ammonia



The health hazard increases with the solubility in water.

Health hazard: Hydrogen gas <Organic hydrides <Ammonia

Fire diamond of hydrogen and energy carriers

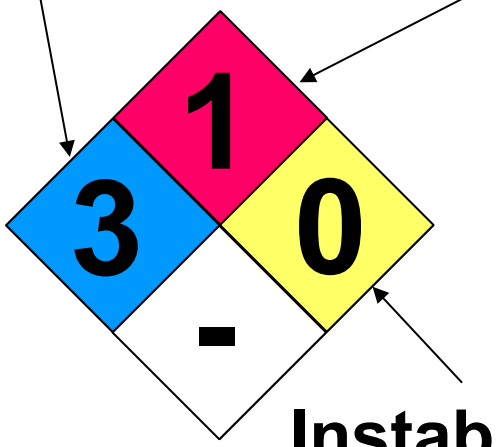
Ammonia (NH_3)

Liquid hydrogen

Organic hydrides
(Methylcyclohexane, Toluene)

Health hazard

Fire hazard (flammability)



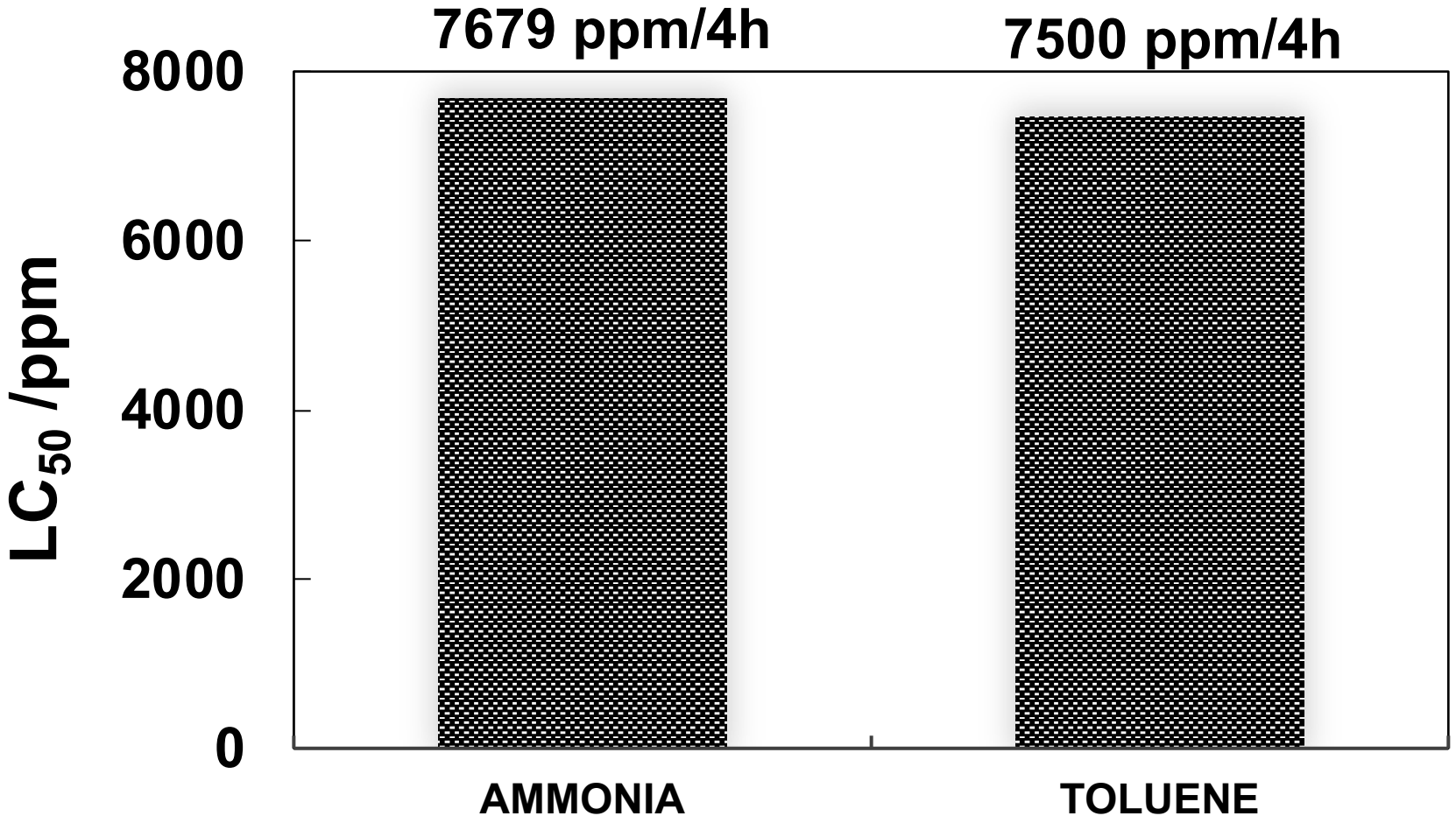
Instability

Ammonia and liquid H_2 have same health hazard.

Safety:

Liquid hydrogen(7) <Organic hydrides(5) < Ammonia(4)

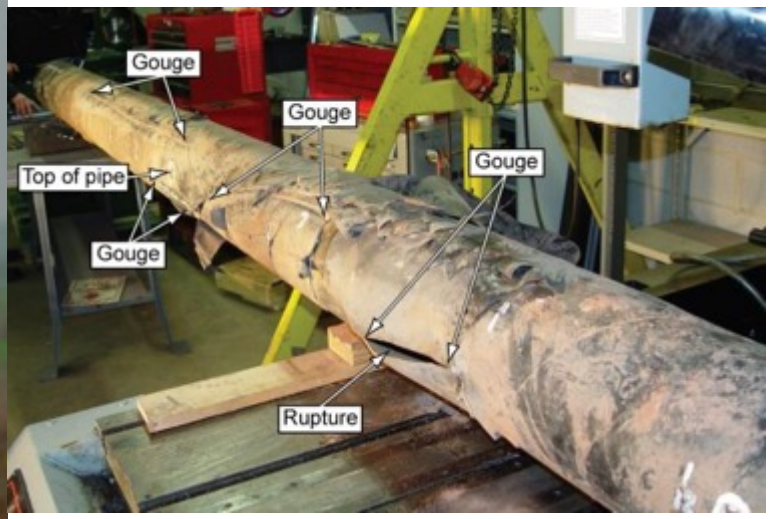
LC_{50} (50% lethal concentration, 4h rat inhalation) of ammonia and toluene



Ammonia and toluene have same health hazard.

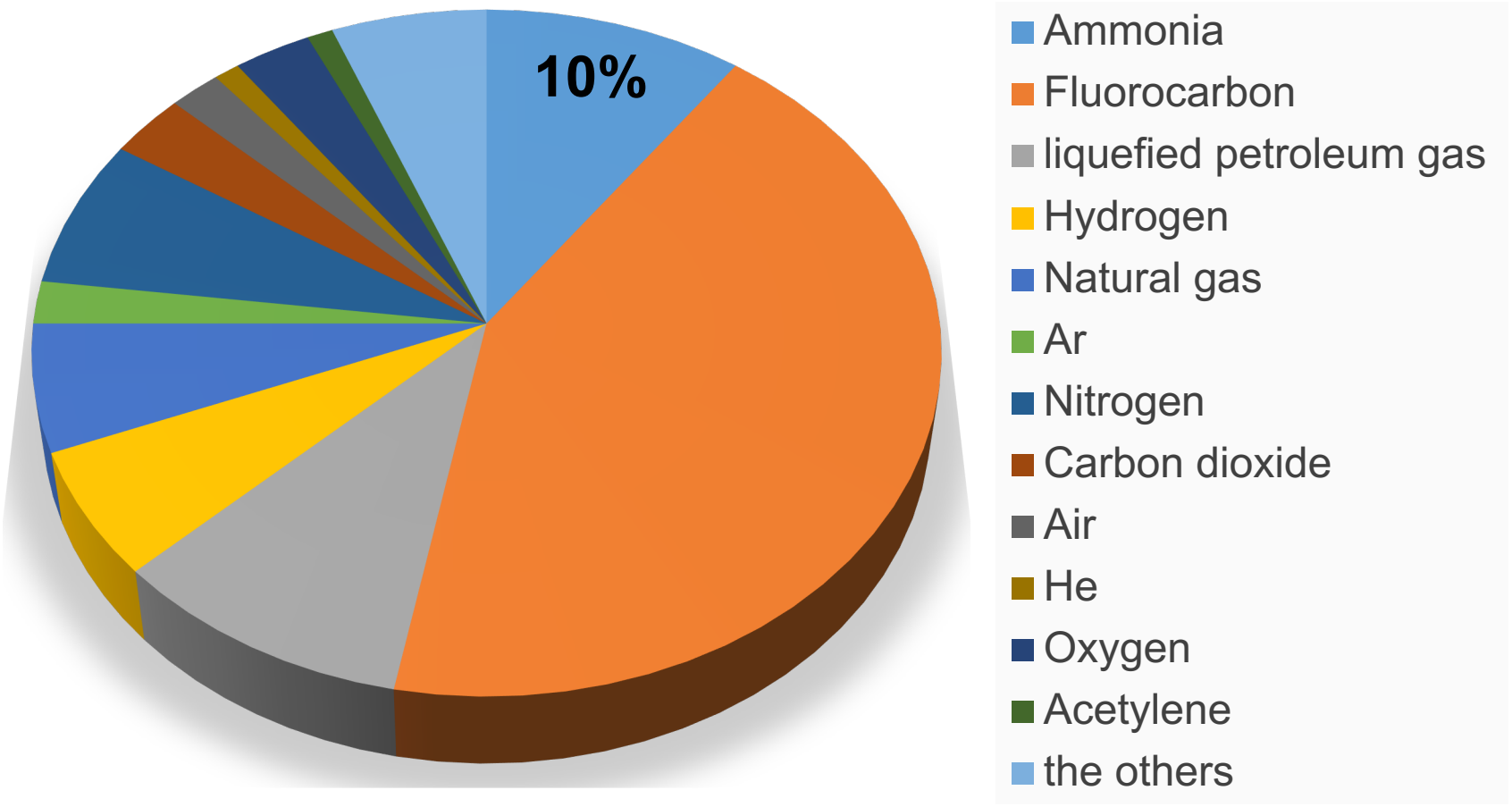
3. Survey of NH_3 accident

Leakage from the ammonia pipeline, Kansas, USA



October 27, 2004

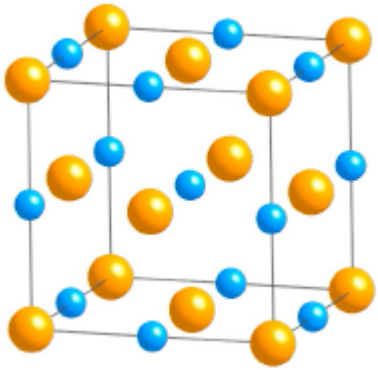
The ratio of the number of ammonia accidents to the number of high pressure gas related accidents in Japan (2014)



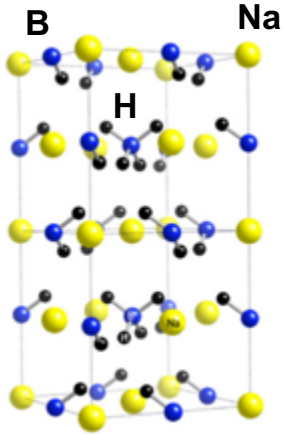
Caused by the leakage from valve, pipe and flange

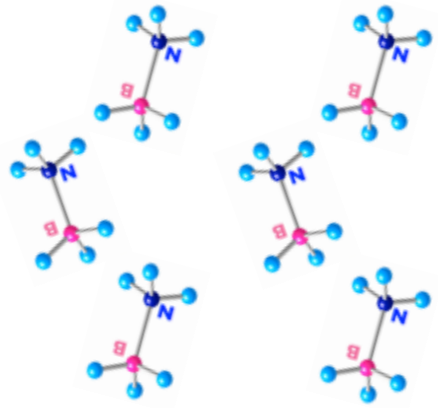
4. New concept of ammonia removal system

Ammonia storage (absorption, adsorption)materials

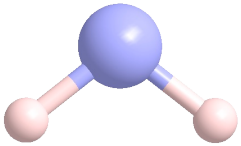


Metal halides



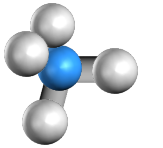


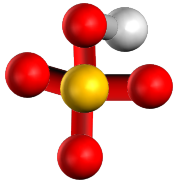
Complex hydrides

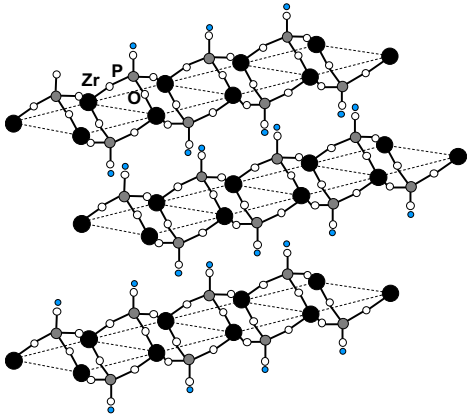


Water

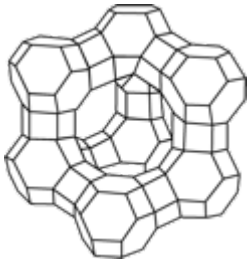
Ammonia remover

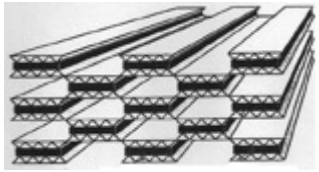






Proton-based materials

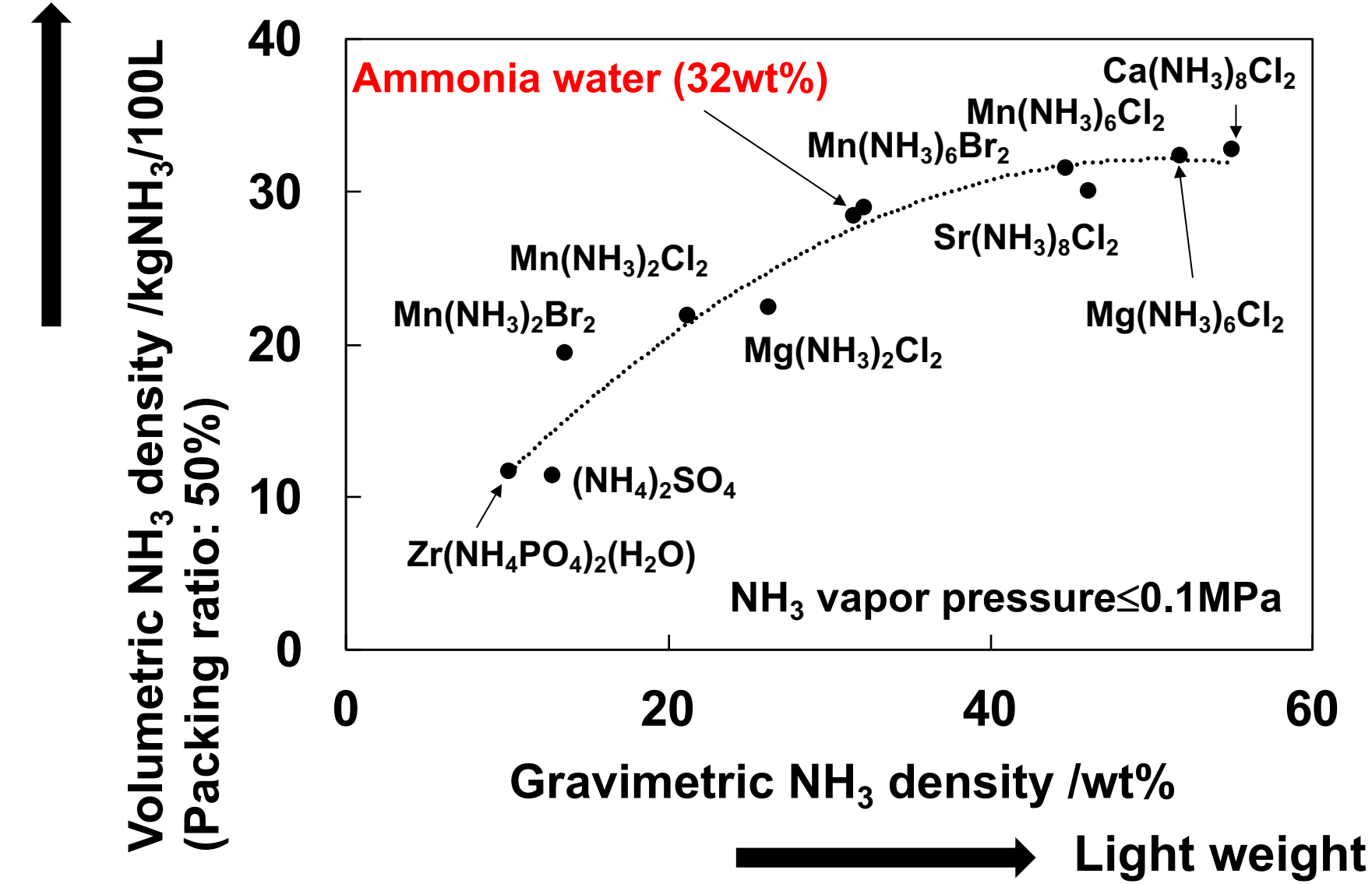




Porous materials

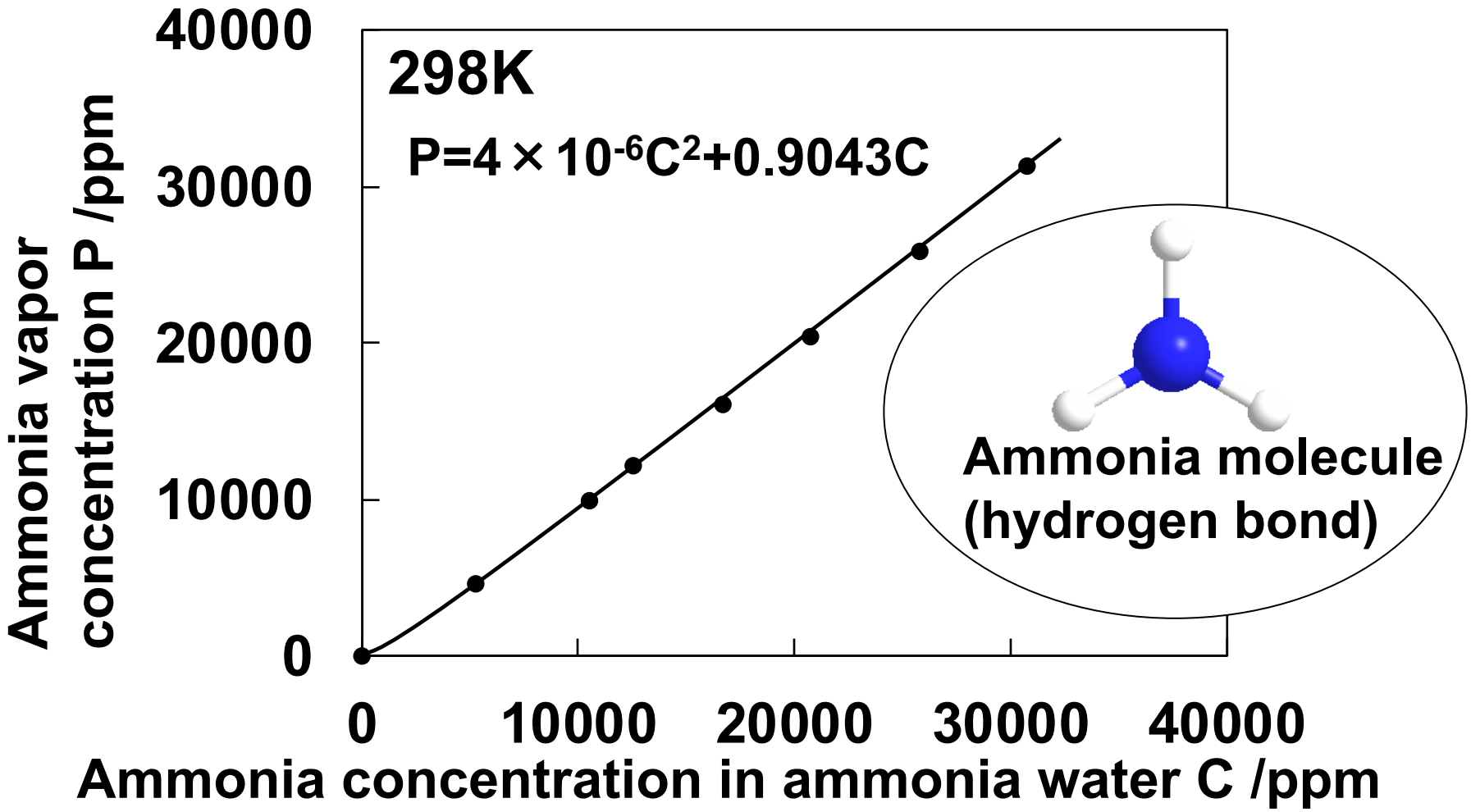
Evaluation and characterization ammonia storage materials

NH_3 densities of NH_3 storage materials



NH_3: large diffusion coefficient in water

Ammonia vapor concentration and ammonia concentration in ammonia water

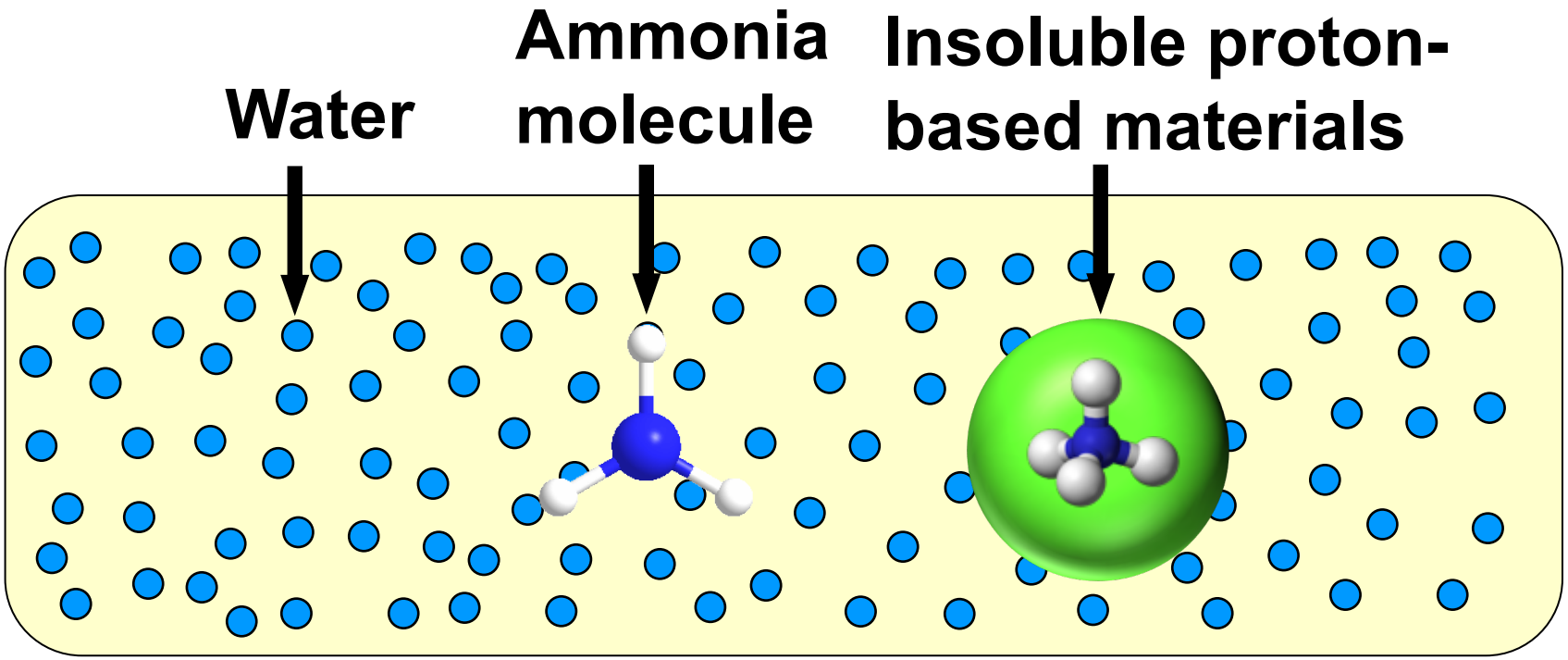


NH_3 concentration: 2500ppm→NH_3 vapor concentration: 2300ppm

(To decrease NH_3 vapor concentration →

Insoluble proton-based materials)

Conceptive picture of ammonia removal system



Insoluble ammonium ion-based materials (coordinate bond) to remove nitrogen

The NH_3 removal system combined water and Insoluble proton-based materials will be candidate to reduce NH_3 concentration in the atmosphere by suppression of water pollution.

5. Summary

(1) NH_3 is safer than liquid hydrogen and organic hydrides by addition of health hazard and fire hazard based on fire diamond.
(2) Water absorbs large amount of NH_3, although the vapor concentration is high.
(3) The NH_3 removal systems combined water and insoluble proton-based materials will be candidate to reduce leaked NH_3 in the atmosphere.

Acknowledgements

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Thank you for your attention.