Safety first: Ammonia storage in nickel salts for safe and clean vehicles

Hydrogen is what many scientists believe to be the best replacement for fossil fuels in mobile applications such as cars. It contains a lot of energy, it can be used in fuel cells and using hydrogen produces nothing but pure water. The problems, however, lie in the storage of hydrogen: First, it has a very low density (i.e. mass per volume), which makes large storage devices necessary (in terms of mass and/or volume) and second, it is flammable and can combine explosively with oxygen, which poses an inherent potential hazard for users or passengers (or at least is perceived by them as an inherent hazard). One might therefore be persuaded to consider alternative “clean fuels” to hydrogen. One such alternative is ammonia, a gas composed of one atom of nitrogen and three atoms of hydrogen and could therefore be regarded as a chemical hydrogen carrier. By contrast to hydrogen, the flammability of ammonia is low at ambient conditions and it is not explosive. Moreover, it can be stored more conveniently than hydrogen and like its lighter diatomic counterpart, can be used directly in fuel cells releasing nitrogen in addition to water. Both nitrogen and water are clean exhaust products and of course the former constitutes *ca*. 80% of air.

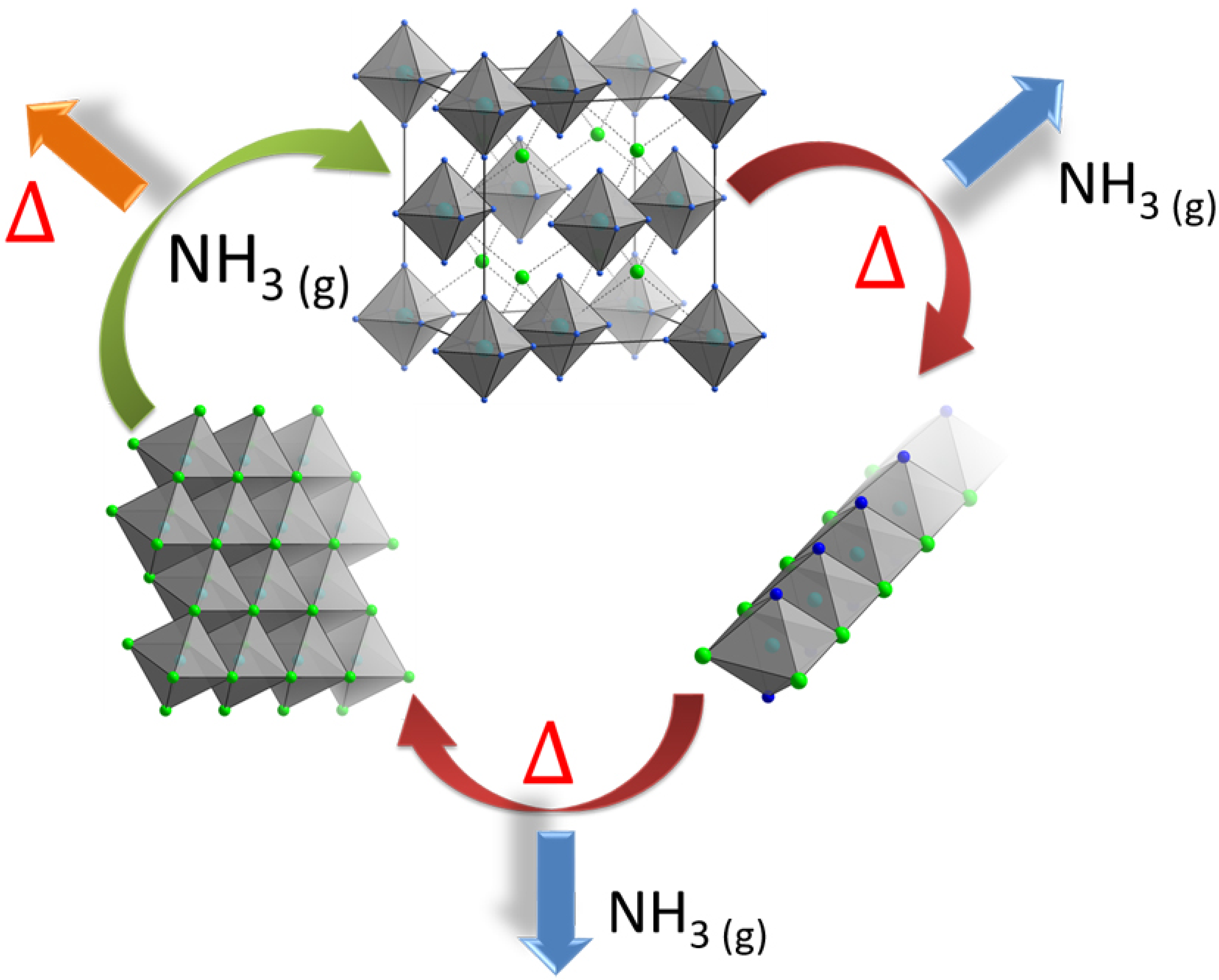

Fig. 1. Ammonia refuelling cycle for nickel halides

Although ammonia can be easily stored in a tank as a liquid, it is not without problems in that not only does it carry a pungent odour, but in large quantities it is also toxic. Therefore, it requires safe containment. Our research is concerned with the development and testing of a solid material that can take up ammonia at ambient conditions and release it when necessary. We have investigated nickel halide salts, i.e. compounds composed of a halogen such as chlorine, bromine or iodine and the transition metal nickel; $NiCl_2$, $NiBr_2$, NiI_2). This work demonstrates that the nickel halides react very quickly with ammonia at ambient conditions to form compounds in which one part of the nickel halide takes up six parts of ammonia. The speed of this ammonia uptake makes the materials very suitable for a quick recharging process at a fuelling station, for example. The captured ammonia is completely released when the material is heated to approximately 300 °C.

One of the key findings in this study was the excellent cyclability of the halide storage materials

(Fig. 1). That is, the material can be re-used (“filled” and “emptied”) many times without losing any of its storage capacity. Importantly, the charged materials also demonstrate very good air stability. Whereas some similar materials lose ammonia fairly quickly when brought into contact with moist air, we discovered that the decomposition of the fully ammoniated nickel chloride compound was very slow, retaining its activity for more than a day. This finding is very important for the safety performance of the material as it could allow the safe recovery of a burst tank without the release of considerable amounts of ammonia gas, for example.

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