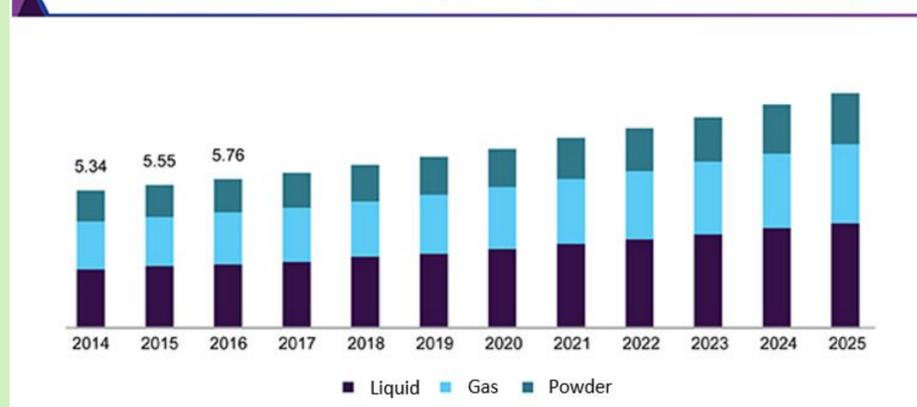


A Greener Future by Electrochemical Synthesis of Ammonia

Introduction: What is ammonia?

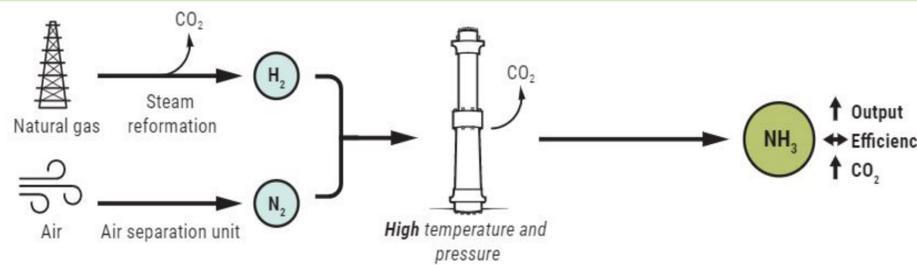
- ❑ Inorganic compound composed of a nitrogen atom covalently bonded to three hydrogen atoms.
- ❑ Manufactured and produced naturally from bacterial processes and the breakdown of organic matter.
- ❑ Characterized as a colorless gas or compressed liquid with a pungent odor.
- ❑ The global ammonia market size is worth 72.82 billion USD in 2020 is expected to reach 78.69 billion USD by the end of 2026 due to the rising demand for ammonia in the fertilizer industry and ammonia being the building block for the world nitrogen industry.

U.S. ammonia market revenue by product form, 2014 - 2025 (USD Billion)



What are the problems we faced in using the traditional method to synthesize ammonia?

- ❑ The Haber-Bosch process is the tradition and most widely used method to synthesize ammonia commercially.

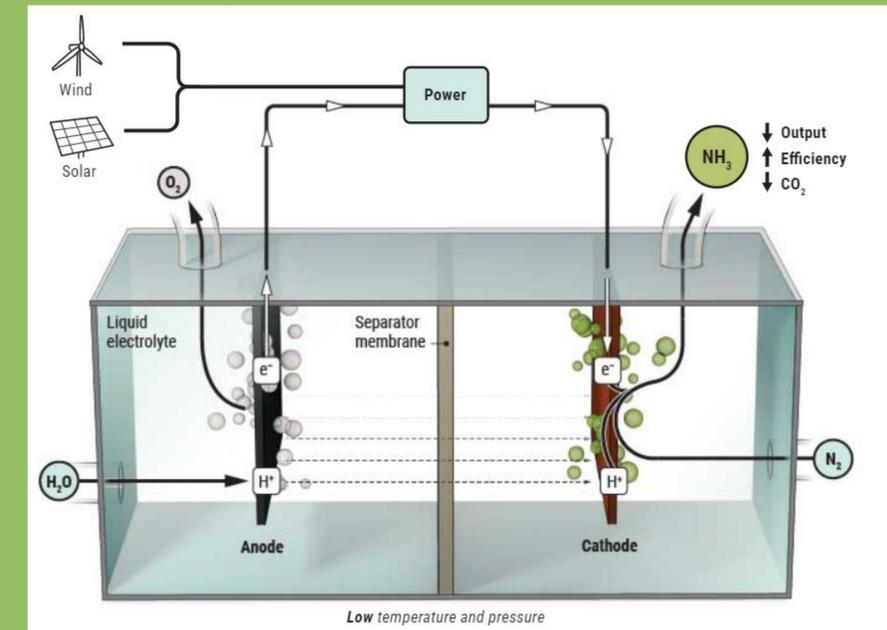


- ❑ Due to the rising demand in the ammonia market, it is predicted that more ammonia would be synthesized in the near future. However, using the traditional method would produce a large amount of greenhouse gas which will worsen the global warming problem.

- 👍 - Fast and efficient
- 👎 - Emit vast amounts of CO₂
- 👎 - Use a lot of energy

Could ammonia be synthesized in a greener way?

- ❑ New and greener method: Electrochemical process
- ❑ Developed by Douglas MacFarlane, a chemist at Monash University in suburban Melbourne.



Anode:



Cathode:



- ❑ At anode: H⁺ produced flows through an electrolyte and a proton-permeable membrane to the cathode and e⁻ produced passes through a wire to cathode.
- ❑ At cathode: H⁺ and e⁻ react with N₂ to form NH₃.
- ❑ The facility still relies on the Haber-Bosch reaction to combine the H₂ with N₂ to make NH₃. But the solar-powered hydrogen source greatly reduces total CO₂ emissions.
- ❑ At present, at room temperature and pressure, it generally has efficiency of between 1% and 15%.
- ❑ H₂O sometimes reacts with e⁻ at cathode, stealing e⁻ that would otherwise go into making NH₃.
- ❑ Using ionic liquid electrolyte allows more N₂ and less H₂O to sit near the catalysts, boosting the NH₃ production.
- ➔ Efficiency of the fuel cell increased greatly from below 15% to 70%.
- ➔ But the drawback is that the ionic liquid in the fuel cell is 10 times more viscous than water. H⁺ have to slog their way to the cathode, slowing the rate of NH₃ production.
- ➔ The use of ionic liquids that are rich in fluorine are investigated, which helps protons pass more easily and speeds NH₃ production by a factor of 10.

What are the advantages and drawbacks?

- 👍 - Far more environmentally friendly technique than the industrial Haber-Bosch process, which emits vast amounts of CO₂. This method cuts total CO₂ emissions roughly in half.
- Can produce ammonia under very mild conditions of temperature and pressure and at a lower cost compared with the Haber-Bosch process of ammonia production.
- The ammonia produced has a wide range of applications, such as fertilizers, explosives and synthetic fibres.
- 👎 - This technology is at an early stage of development which requires considerable work on the development of cell materials and ammonia production catalysts.
- The ammonia production rates achieved by this method are in the 10⁻¹³ to 10⁻⁸ mol.cm⁻².s⁻¹ now and are too low for the process to be economically viable.
- Ammonia gas is highly toxic. Ammonia leaks lead to a significant danger in urban environments. But such disasters are rare.

Conclusion:

- ❑ NH₃ has a rising demand due to its wide range of uses.
- ❑ However, the traditional Haber-Bosch process will produce large amounts of carbon dioxide.
- ❑ So a greener method which can synthesize NH₃ from water, nitrogen and renewable energy, should be used.
- ❑ Main drawback is the low efficiency of the green synthetic method, which can be overcome by research over time.

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