**Decarbonising AMMONIA production. Revolutionary new process**

**About a year ago I made a video looking at ways to convert hydrogen into ammonia without using the massively CO2 emitting processes that are currently required by the global industries that use these two products.**

**And one of the questions I get asked the most in the comments sections of this channel is whether I can do some follow up videos on the technologies I’ve talked about, to see if any of them actually make any progress as we hurtle through arguably the most important decade of our lifetimes.**

**And, in this case, it looks as though some decent progress has indeed been made by one of the teams that I featured in last year’s program.**

**So, I figured now was as good a time as any to see what they’ve been up to.**

**Hello and welcome to Just Have a Think.**

**The team in question is based at Monash University in Australia and they reckon they’ve made a pretty useful breakthrough that could finally eradicate the existing method of making ammonia – a process called Haber-Bosch - which is currently responsible for about two percent of global greenhouse gas emissions.**

**So, why should we be interested in ammonia anyway?**

**Well, although it’s one of those chemicals that everyday consumers like you and I probably don’t think about too much, and very rarely come into direct contact with, it’s actually a very widely produced industrial product used predominantly to make agricultural fertilizers, but also for numerous other industries including plastics and pharmaceuticals.**

**According to this article in New Atlas, more than two hundred and thirty million tonnes of ammonia is produced annually in a global market worth the best part of a hundred billion dollars a year. And demand looks set to rise as research teams look for ways to use it as a replacement for fossil fuels.**

**The way to get ammonia is to derive it from hydrogen. Now, as you probably know, hydrogen is already a very good energy carrier, so why not just use that as a fuel source?**

**Well…currently there are a few reasons. The vast majority of hydrogen made today is produced via a process known as Steam Methane Reformation or SMR, - not to be confused with the other SMR technology : Small Modular Reactors. They’re a completely different kettle of fish, which we looked at in this video.**

**The methane reformation process pumps high pressure steam into methane gas to liberate the hydrogen atoms. But the by product is a shed load of Carbon Dioxide. About six tonnes of CO2 for every one-point one tonnes of hydrogen produced. Which we don’t want. The fossil fuel industry bods are promising they’ll start capturing all that CO2 in a process they call Blue Hydrogen, and that’s something I had another little rant about in this video.**

**Anyway, once it’s been liberated, hydrogen does carry a very high level of energy per unit mass, but it also has very low density at normal room temperature - about a third the density of natural gas for example. So, in order to store it and transport it, it has to be cooled right down to about minus two hundred and fifty degrees Celsius to make it into a liquid, or it has to be pressurised. That reduces the process efficiency by about thirty percent.**

**Once it’s in that form though, it carries about forty-thousand watt-hours of energy per kilogram. Compare that to the two hundred and eighty or so watt-hours per kilogram that the best lithium-ion batteries can produce, and you start to see why the energy industry is keen on developing it.**

**But hydrogen atoms are extremely small compared to other elements, so they have a nasty habit of leaking through the walls of whatever container they’re being stored in. And it’s a very reactive element as well, so it can corrode the steel walls of pressurised cylinders and pipelines…which is not ideal!**

**And that’s where ammonia comes into the picture. This might sound a bit weird, but Ammonia is actually a better hydrogen carrier than hydrogen itself. For the same volume, ammonia contains fifty percent more hydrogen than hydrogen does. It liquifies at only minus thirty-three degrees Celsius compared to minus two hundred and fifty odd degrees for hydrogen and it only needs to be compressed to ten times atmospheric pressure to make it practically transportable. Plus, it doesn’t corrode steel or leak out of containers. So, it has great potential as a high-density green fuel for very large and very hard to decarbonise transport systems like shipping and aviation.**

**The Haber-Bosch cycle that I mentioned earlier compresses nitrogen and hydrogen at about two-hundred and fifty times atmospheric pressure, and temperatures of about four hundred degrees Celsius in tall, narrow steel reactors where an iron catalyst helps to liberate the individual nitrogen atoms so that they’ll react with the hydrogen atoms in the right proportions to produce ammonia. The process uses a huge amount of energy, and** **because the reactors are typically operated continuously to prevent damaging the catalyst, they can’t easily be powered by intermittent renewables like wind and solar, which means they’re invariably run on fossil fuels, which of course means more CO2 released into the atmosphere. The process is also responsible for nitrate pollution of ground water and it emits large quantities of another greenhouse gas, nitrous oxide, into the atmosphere.**

**The team at Monash University have been running their Ammonia Project for some time now, looking for ways to produce ammonia using the abundantly available renewable wind and solar energy that Australia has to offer, combined with electrolysis of water. In fact I referenced an article on the subject in last year’s video, written by Professor Doug MacFarlane OF Monash University.**

**Their latest breakthrough is a process involving an electrolyte that’s very familiar in lithium-ion batteries. The team dissolved nitrogen gas into that electrolytic solution so that when a current was applied across the cell, a compound called lithium-nitride was produced at the cathode.**

**But, the team also added a hydrogen ion carrier to the solution in the form of phosphonium salts. More specifically, for those of you with a hankering for complicated scientific nomenclature, it was a solution of Tetraethyl Phosphonium Cations.**

**The phosphonium cations are attracted to the cathode, which is covered with the highly reactive lithium nitride. As each one arrives it releases a hydrogen ion which displaces one of the lithium atoms in the lithium nitride molecule before diffusing away, leaving the coast clear for another phosphonium cation to come in and displace another lithium atom. Once all three lithium atoms has been displaced the lithium nitride is transformed into an ammonia molecule which then diffuses away from the cathode, leaving the lithium ions in place ready to form new lithium nitride molecules.**

**The depleted phosphonium cations are now neutral compounds which, for reasons that I’m sure are perfectly rational in the world of science, are called Ylides. The Ylide compounds moves back across to the anode where they pick up new hydrogen ions to replenish themselves back into tetraethyl phosphonium cations to start the reaction all over again in a process that, so far, the team have been able to run continuously for up to four days.**

**As long as it’s powered by renewable energy, which is eminently achievable in Australia, then the whole thing has a negligible carbon footprint.**

**Producing ammonia via direct electrolysis at ambient temperature has been something of an elusive holy grail for some years now. According to the most recent paper submitted by the Monash team to the online journal Science, previous attempts have yielded ammonia production rates of less than one nanomole per second per square centimetre, which no doubt means very little to the majority of us layfolk, but which is apparently at least two orders of magnitude lower than current industrial targets.**

**This new process has apparently achieved production rates of around fifty-three nanomoles of ammonia per second per square centimetre, which while still not on a par with Haber Bosch, is certainly a big step in the right direction. And the process has the major advantage of not requiring any hydrogen to be produced beforehand, either by steam methane reformation or by electrolysis. That means an entire step has been removed from the supply chain, which of course brings the overall energy consumption and costs down significantly.**

**Professor McFarlane explains that their system is massively scalable right up to an industrial level or could be produced by something the size of an iPad to provide small amounts of ammonia to run things like commercial greenhouses or hydroponics operations. And if ammonia can be produced in this kind of distributed way, where local production meets local demand then of course you’d do away with a lot of the expense and emissions of the transport system currently carting the product all over the world.**

**The Monash team has now patented their technology and even reached the stage of creating a start-up business called Jupiter Ionics which has already attracted one point eight million US dollars of seed investment to get them going.**

**Now, for completeness, I should say that there are several other research teams around the world working on potential alternative ways to generate ammonia without using the Haber-Bosch method, and although the Monash team’s latest development is very promising and clearly one that they believe can be commercialised, there’s no guarantee that they’ll be first to market or have the most cost-effective process. All of that remains to be seen as the concept gets properly scaled up to production levels, which as many of you good folks point out to me on a regular basis, is usually the part of the process where many great ideas come unstuck. So, I’ll keep my eye on progress down under and keep you posted with any further developments.**

**In the meantime, if you’re one of those people working in this development field and you’ve got some useful insights you can share, or if you have views on these technologies in general then why not dive down to the comments section below and leave your thoughts there.**

**That’s it for this week though.**

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**As always, thanks very much for watching, have a great week, and remember to Just Have a Think.
See you next week**