Exploring the use of Hydrogen and Superconductivity in the Healthcare Industry

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Abstract

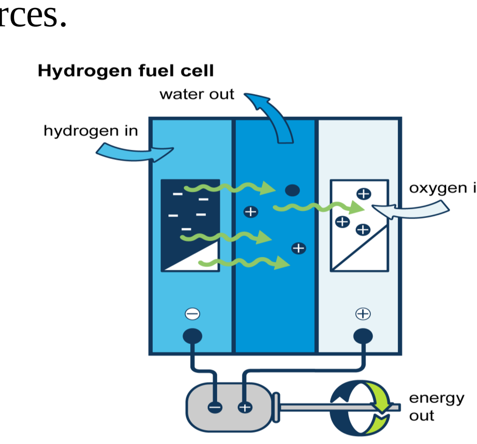
As people across the world are becoming more aware of the consequences of their carbon footprint, we are seeing a major shift to more sustainable energy sources to support our needs. Hydrogen as an energy carrier is gaining traction.

- The use of liquid hydrogen (boiling point 20 K) has gained traction. The healthcare sector is considering hydrogen to support its technology.
- Through the process of combining hydrogen and oxygen to produce electricity, hydrogen fuel leaves water and heat as by-products, rather than carbon dioxide.
- Engineers have been studying the use of liquid hydrogen to cool superconducting devices of MRI and other medical machines; hydrogen is a cost-effective and abundant cooling agent, rather than the expensive and scarce liquid helium that is currently used.
- In the pharmaceutical side of healthcare, NMR spectroscopy is also beginning to explore new superconductors and higher temperature operation supported by liquid hydrogen to expand the accessibility and lower cost technologies for drug discovery and studying protein structures.

While hydrogen is not a panacea when it comes to sustainable fuel, it is certainly a step in the right direction to kick off this conversation on fueling our world to continue its productivity in the right way.

Hydrogen

As the most abundant element in our universe, hydrogen has been used for many industrial sectors for nearly 100 years. The healthcare industry is one of several industries leaning towards hydrogen as fuel for generating electricity and as cryogenic liquid to support superconducting technologies. Much of the advanced technology used in diagnosing and treating disease through heavy ion radiation therapy and producing pharmaceuticals, uses liquid helium as a cryogenic agent or cooling agent for superconducting technology (MRI, NMR, and Particle Therapy). As the price of liquid helium rises due to its short supply, researchers are looking to liquid hydrogen as a replacement. Liquid hydrogen is 20 Kelvin (approximately -400°F, -250°C), which makes it an optimal cooling agent for new kind superconductors, High Temperature Superconductors.. With its cost-effectiveness and abundance, hydrogen is slowly climbing the ranks in the world of sustainability energy sources.



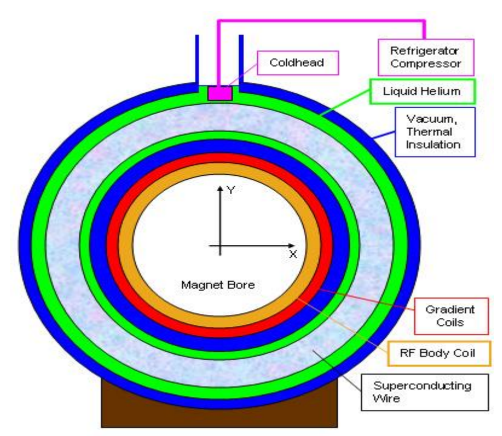
Source: Adapted from the National Energy Education Project (public domain); https://www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php

Superconductivity in Healthcare

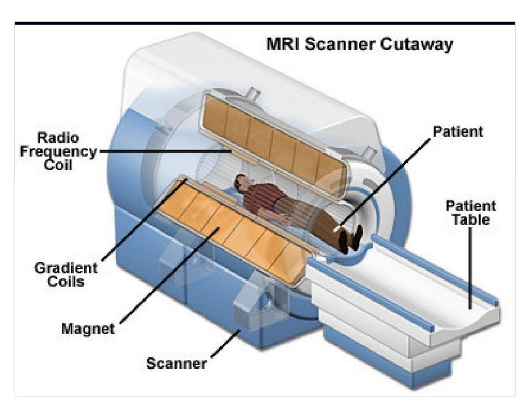
Superconductivity exists in certain materials, giving them the ability to carry and transport electrical currents with as little disruption or loss as possible. Nearly 100 years ago, this phenomenon was observed in mercury, cooled with liquid helium to 4 K.

- As technology advanced and more research was done, scientists discovered materials, beyond mercury, that exhibit superconductivity, when cooled to below their respective critical temperatures. Many superconducting materials, including high temperature superconductors that show superconductivity at much higher temperatures of 90 K and higher.
- Since 1970s, superconducting wires were used in Nuclear Magnetic Resonance spectrometers and medical imaging machines, MRI machines. Superconducting wires have been used to generate very strong magnetic fields that are essential for MRI and NMR. High magnetic field is essential for high resolution MRFI images and NMR spectra.
- The use of liquid hydrogen rather than liquid helium in MRI machines reduces their overall cost to operate, in turn also reducing the financial burden on patients and increasing their accessibility to those who need them.

The use of superconductors in magnetic imaging revolutionized diagnostics and treatment in healthcare. They are far less invasive than other diagnostic procedures, produce less harm than x-rays, and provide some of the clearest images needed to identify disease and treat patients.



Source: Honrak, J. (2012). The Basics of MRI. https://www.cis.rit.edu/htbooks/mri/chap-9/chap-9-h5.htm#9.9. Rochester Institute of Technology. Retrieved from https://www.cis.rit.edu/htbooks/mri/chap-9/chap-9-h5.htm#9.9.



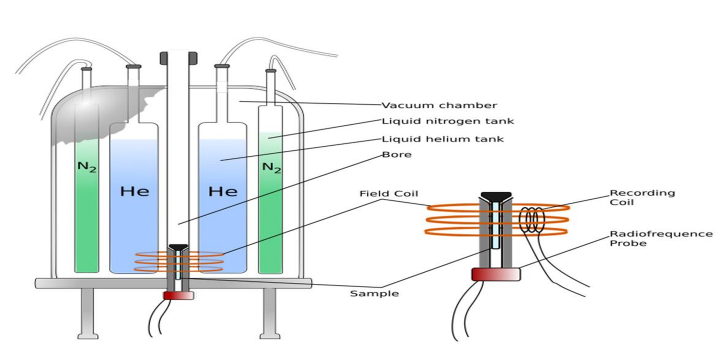
Source: Slideshare.net

Nuclear Magnetic Resonance Spectroscopy in Pharmacy

From early years of simply taking medicines prescribed by nature to finding and developing modern pharmaceuticals that have specific purposes and interactions with the systems of the body, medicine has come a long way in its pharmaceutical industry.

- Drug development is a heavily researched area of medicine with each chemical component highly studied and experimented with, and nuclear magnetic resonance or NMR spectroscopy is one such technique used to do so. NMR uses a strong magnetic field to gather information regarding a chemicals 3D make-up, resolution and purity, and also its intermolecular interactions when present in solution.
- As with MRIs, NMR spectroscopy use liquid helium as a cryogenic agent to cool superconducting magnets used to create strong magnetic field. The process of employing NMR spectroscopy to identify and study pharmaceutical medication is an expensive one, with its expensive instrumentation.
- Researchers are looking to use liquid hydrogen as a replacement for liquid helium to lower cost and complexity of the technology involved.

The checks and balances that come with drug development make it a multifaceted process, with the consequences being far too severe to allow mistakes to occur. As more nations invest in their own pharmaceutical industries, the cost-effective nature of hydrogen has made it a high contender in cryogenics and sustainable fuel.



Source:Carreras, H. Z. (2021). Internal components of an NMR spectrometer. Technology Networks. Retrieved from https://www.technologynetworks.com/analysis/articles/nmr-spectroscopy-principles-interpreting-an-nmr-spectrum-and-common-problems-355891.

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Limitations

Despite the advantages that are associated with hydrogen use, there are challenges that make it difficult for industries to fully commit to its long-term usage and as a replacement fuel to the fossil fuel industry and a cooling agent for superconducting technologies.

- Although hydrogen is the most abundant element in the universe, the only way to harvest it for its use as fuel is to separate hydrogen from water using a process known as electrolysis.
- The infrastructure needed to electrolyze and produce hydrogen in large scale is still a developing area even with incentives put in place by government institutions.
- Storage and transportation of hydrogen is far more complex than fossil fuels due to the cryogenic temperature of 20 K of liquid hydrogen.
- Due to its volatile nature and flammability, hydrogen has an increased risk when it comes to storage. Safety has to be an integral part of liquid hydrogen storage and distribution.

Though these limitations are preventing its widespread use, active research and many monetary incentives have been put in place to encourage the use of hydrogen as a source of clean energy. With the goal of Net Zero Emissions by 2050, hydrogen as fuel will see a greater accessibility and lower costs to complex technology and life-saving treatments in healthcare.

Conclusion

Hydrogen and superconductivity have been long researched and studied. With hydrogen making its roots as fuel for electricity generation and transportation aviation, cryogenic coolant for superconducting technology for healthcare, the future is bright for this emerging industry and for our planet. Its growing popularity in the healthcare field has led to liquid hydrogen becoming more cost effective than its cryogenic agent counterparts, like liquid helium. With that comes greater accessibility to patients and reduced health disparity in disadvantaged communities. Greater incentives provided by nations around the world have expedited the research on hydrogen today, bringing the goal of Net Zero Emissions by 2050 reachable, and a greener future for generations to come.

References

Helium refills in MRI machines - uses, cost, and Challenges - DirectMed imaging. DirectMed Parts & Service. (2021, April 29). https://directmedparts.com/helium-refills-in-mri-machines-uses-cost-and-challenges/

Henderson, M. (2023). *Keeping an eye on the potential shortage of helium for mris*. RSNA. https://www.rsna.org/news/2023/january/helium-shortage-for-mri

International Energy Agency. (2021). *Net zero by 2050 – analysis*. IEA. https://www.iea.org/reports/net-zero-by-2050

National Aeronautics and Space Administration. (2012). *Superconductors enable lower cost MRI systems*. NASA. https://spinoff.nasa.gov/Spinoff2012/hm_6.html

Office of Science. (n.d.). *Doe explains...superconductivity*. Energy.gov. https://www.energy.gov/science/doe-explainssuperconductivity#:~:text=Technologically%2C

Zloh M. (2019). NMR spectroscopy in drug discovery and development: Evaluation of physico-chemical properties. ADMET & DMPK, 7(4), 242–251. https://doi.org/10.5599/admet.737