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The Hydrogen Economy

Potential benefits and difficulties

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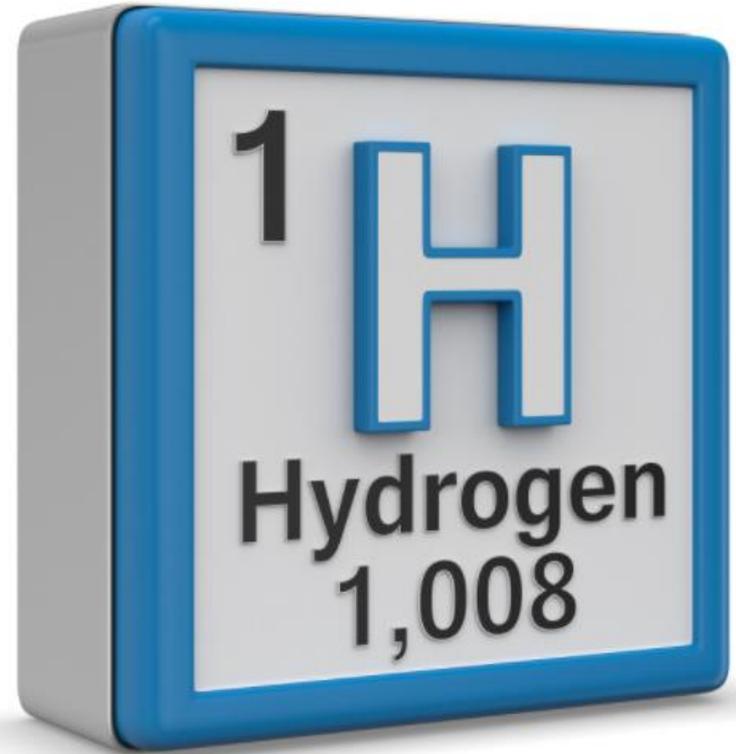


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Why hydrogen?

- Most abundant element in the universe
- High energy content
 - 140 MJ/kg for H₂
 - 44 MJ/kg for petrol
- Emission = water



Brief history of hydrogen

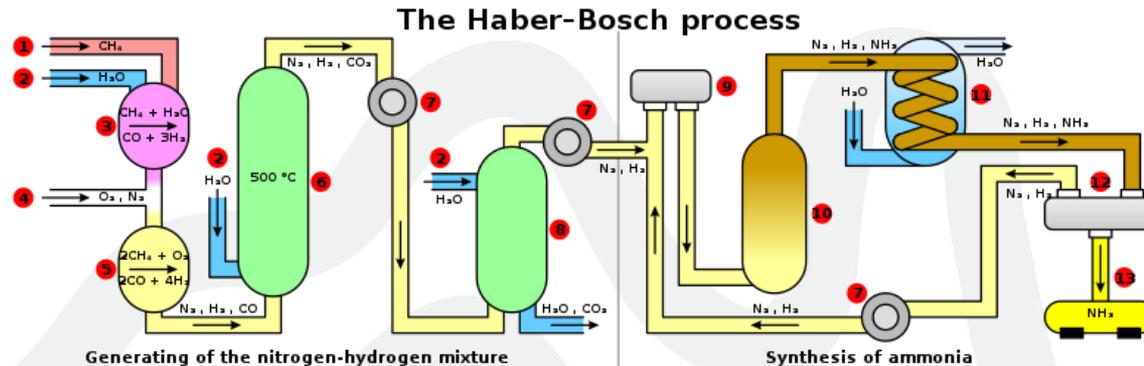
- 1776 – formally identified
- 1800 – produced from electrolysis of water
- 1839 – first hydrogen-powered fuel cell
- 1920s to 1930s – used in airships crossing the Atlantic
- 1960+ – used extensively for spacecraft
- 1970s – GM proposes term “hydrogen economy”



How do we use hydrogen today?

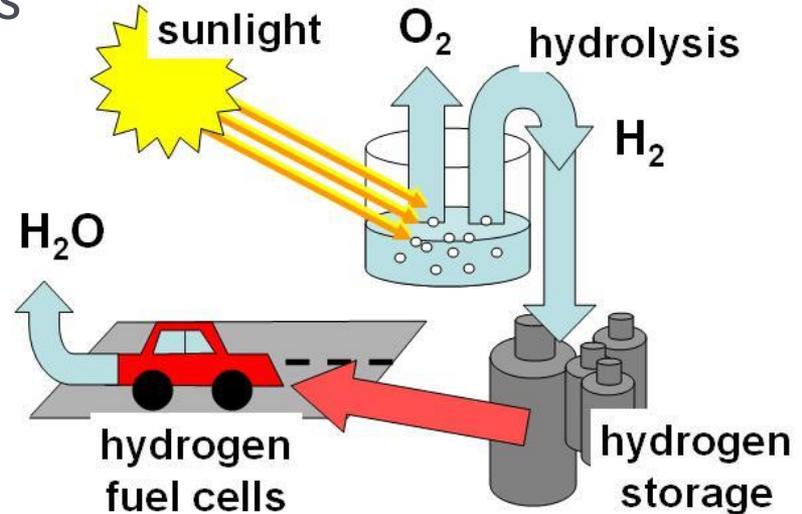
Hydrogen is typically produced from fossil fuels

- 50% in Haber process to make ammonia
- 40% to hydrogenate petroleum products
- Remainder: glass production, electronics manufacture, coolants



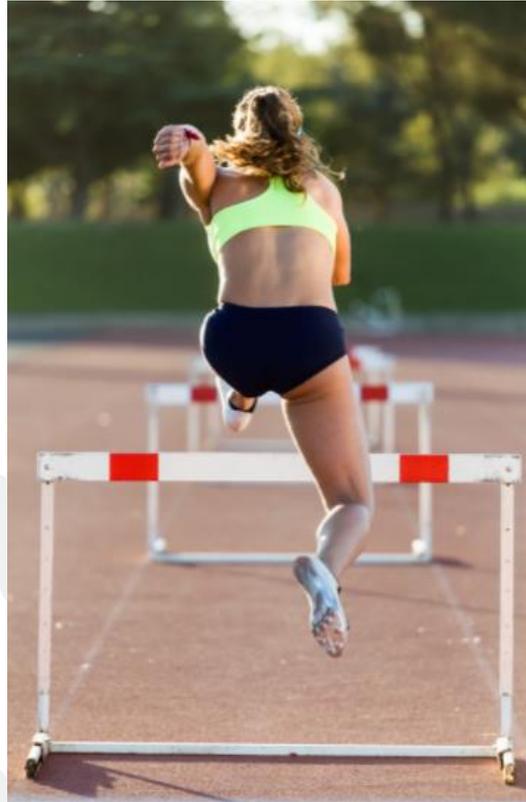
Hydrogen fuel for clean energy

- Renewable energy produces hydrogen by electrolysis of water
- Hydrogen is stored until needed
- Fuel cells power transport and utilities
- Only emission is water



What difficulties must be overcome?

- Safety
- Production
- Storage
- Setting standards



Safety

- Hydrogen and oxygen combine explosively
- Makes metal brittle
- Safety procedures needed if general public is going to handle hydrogen (e.g., refueling cars)

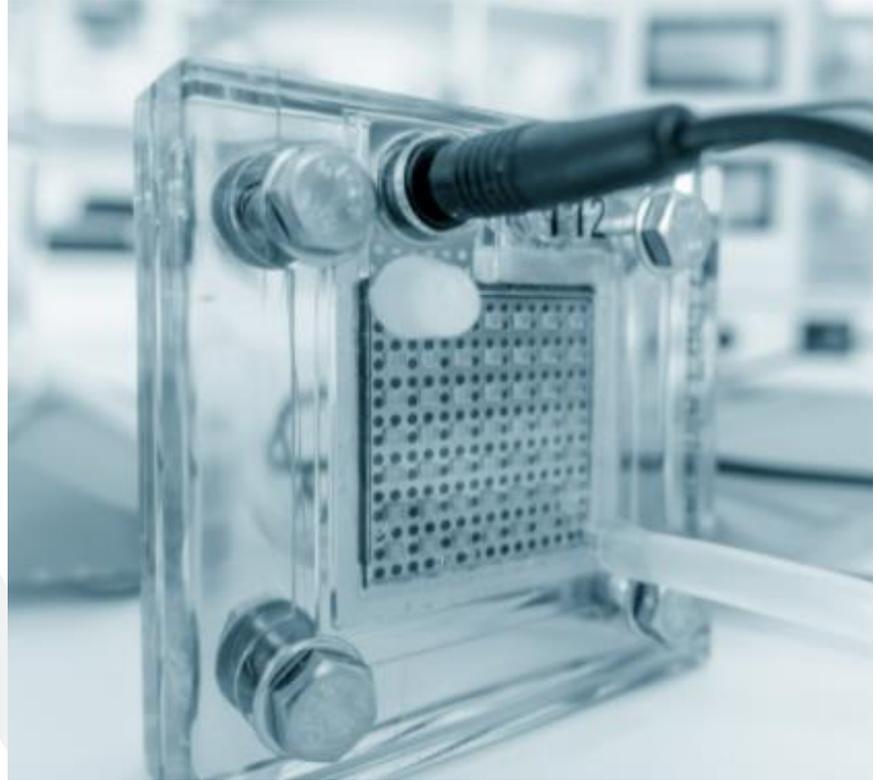


Hindenburg disaster. May 6 1937 in Lakehurst, New Jersey



Safety answer: Fuel cells

- Produce electricity by combining oxygen and hydrogen without combustion



Production

- More than 90% is from fossil fuels
- Electrolysis of water is more expensive and less efficient
- Biological production options



Storage

- Low density ($11 \text{ m}^3 = 1 \text{ kg}$)
- Storage choice depends on use
 - pure gas or liquid
- Compressed
- Liquefied
- Adsorbed onto material
- Chemically bonded



Liquid hydrogen storage tank at Kennedy Space Center was used to fuel the space shuttle. (TomFawls 2013, creative Commons 3.0)



Setting standards

- ISO standards being developed for:
 - Use
 - Production
 - Storage
 - Transport
 - Refuelling
 - Measurement
 - Purity



The future of hydrogen

- Hydrogen cars: Toyota Mirai, Hyundai Nexa
- Advantages:
 - Quick refilling
 - Lighter mass
- Disadvantages:
 - Lack of infrastructure
 - More expensive to run
 - 35-40% efficiency vs 70-80% for battery-powered vehicles



Toyota Mirai (2015, public domain)



The future of hydrogen

- Heating
- Electricity production
- Fuel cell backup power
- Steel refining





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