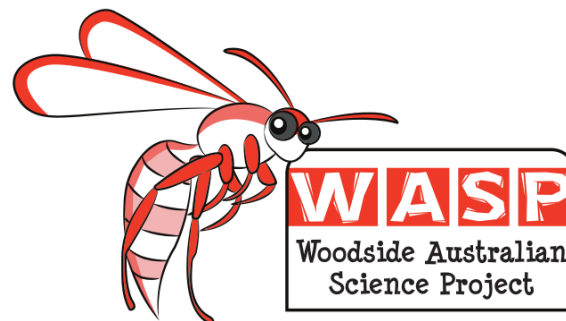


Hydrogen

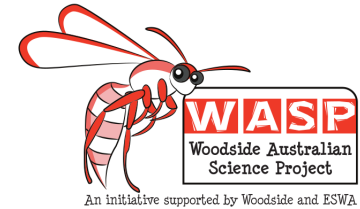
A Modern Energy Source?



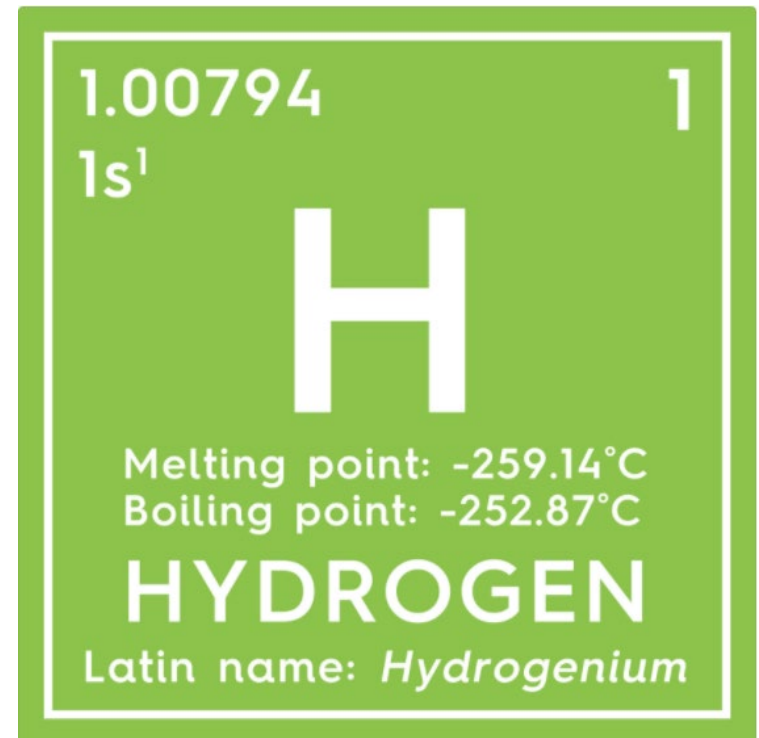
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What is hydrogen?



- Most abundant element in the universe
- Very effective energy carrier



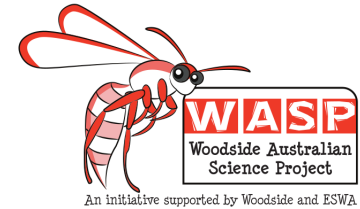
History of hydrogen



- 1776 – formally identified
- 1839 – first hydrogen-powered fuel cell
- 1920s to 1930s – used in airships crossing the Atlantic
- 1960+ – used for spacecraft



How do we use hydrogen today?



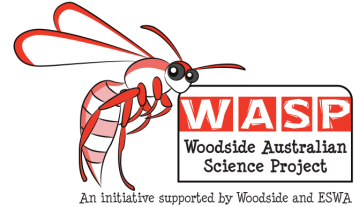
Hydrogen is produced from fossil fuels

- 50% to make ammonia
- 40% to 'crack' petroleum
- Remainder: glass production, electronics manufacture, etc.

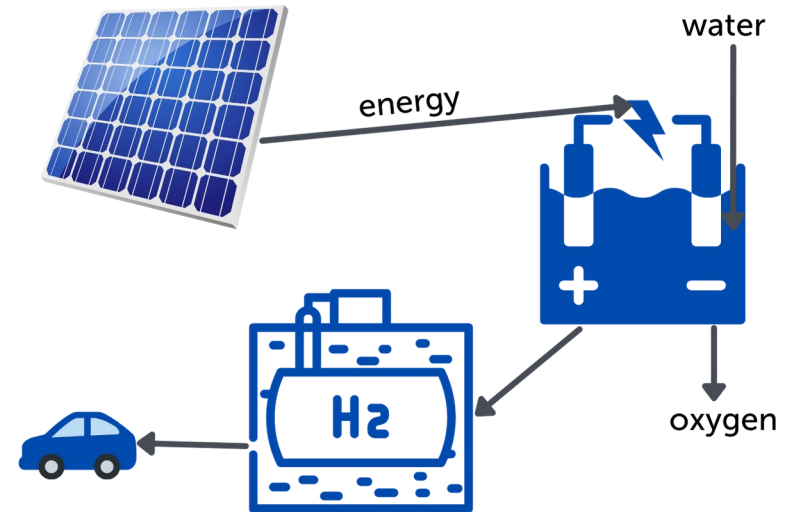


Chemical plant that produces ammonia and fertilisers

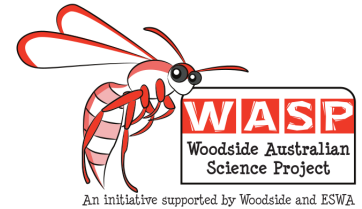
Hydrogen fuels



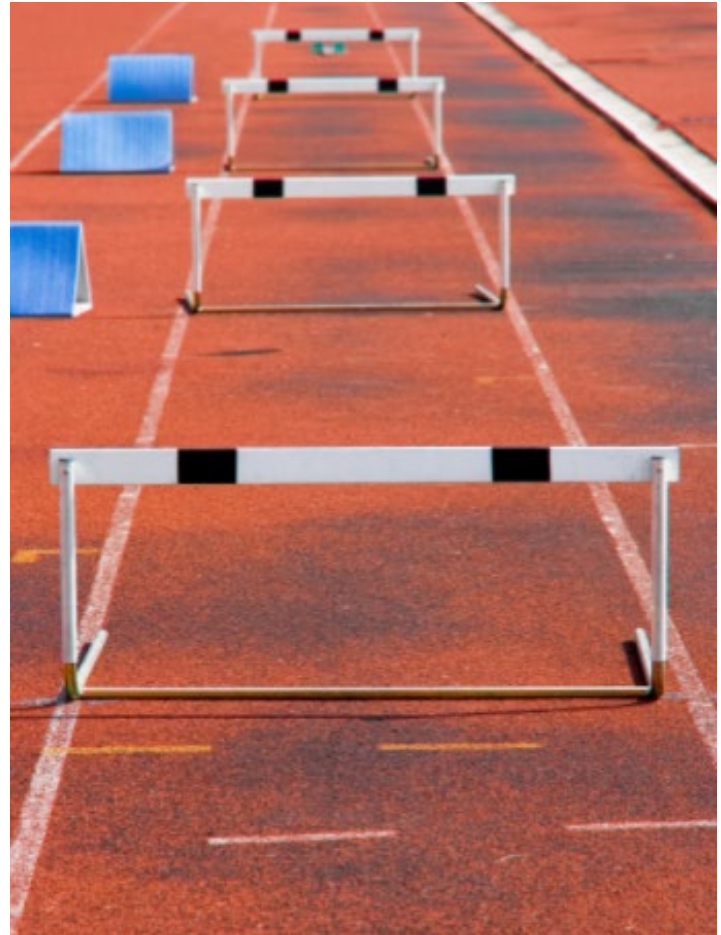
- Another way to produce hydrogen is by electrolysis of water
- The hydrogen is then stored until needed
- Hydrogen fuel cells can power transport and utilities
- Combustion emission is water



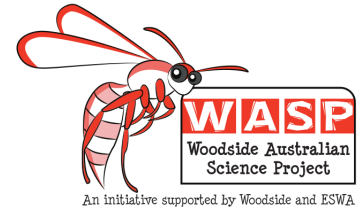
What difficulties must be overcome?



- Safety
- Production
- Storage
- Setting standards



Safety



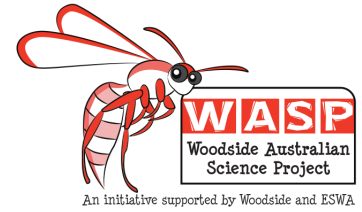
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- Hydrogen and oxygen combine explosively
- Makes metal brittle
- Safety procedures needed if the general public is going to handle hydrogen (e.g. refuelling cars)



Hindenburg disaster. May 6 1937 in Lakehurst, New Jersey

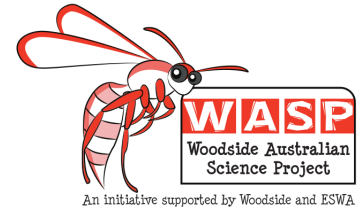
Safety solution: fuel cells



- Produce electricity by combining oxygen and hydrogen without combustion



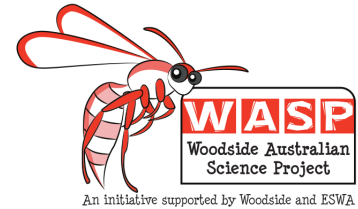
Production



- More than 90% is from fossil fuels
- Electrolysis of water is more expensive and less efficient
- Bioproduction is currently being researched



Storage

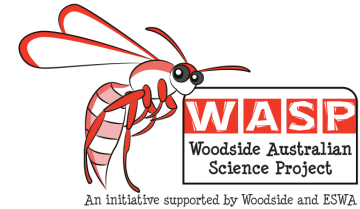


- Low density ($11 \text{ m}^3 = 1 \text{ kg}$)
- Storage options:
 - Pure gas or liquid
 - Chemically bonded



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

Setting standards

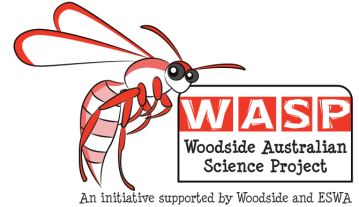


- International standards being developed for:

- Use
- Production
- Storage
- Transport
- Refuelling
- Measurement
- Purity



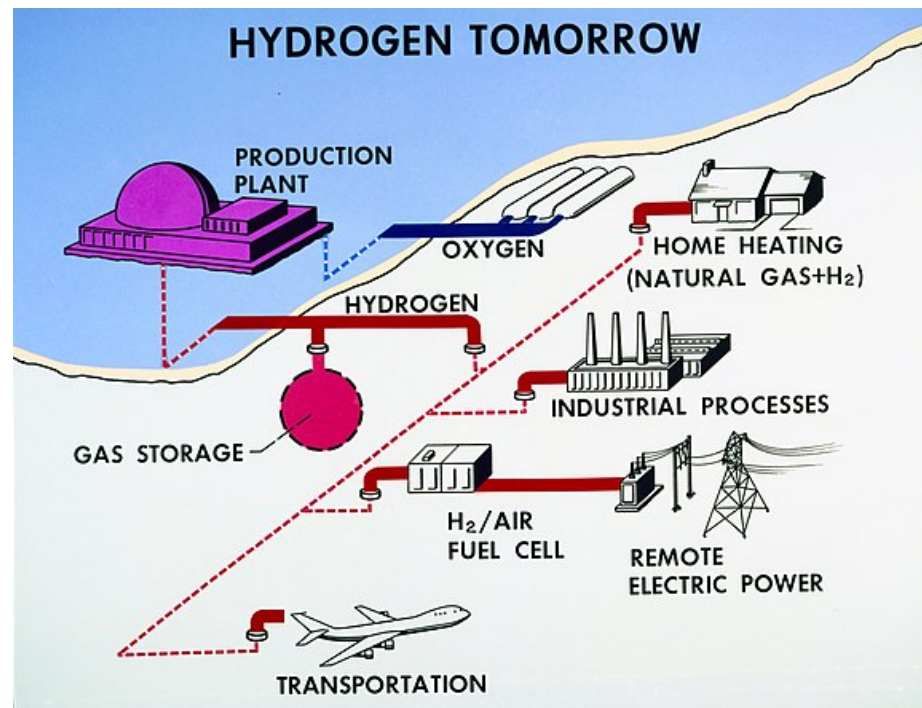
The future of hydrogen?

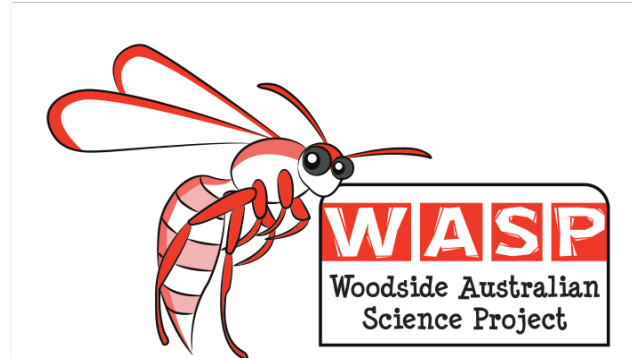


- Hydrogen cars: Toyota Mirai, Hyundai Nexo
- Hydrogen buses and trucks
- Advantages:
 - Short refuelling time
 - Suitable for longer distances
 - Trucks can pull heavier loads uphill
- Disadvantages:
 - New infrastructure required
 - Efficiency

The future of hydrogen?

- Home heating
- Industry
- Power generation
- Transportation





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