Educational Initiative “Green Hydrogen”
Fossil fuels contribute to climate change through increased CO2 emissions. The use of renewable energies (wind, solar, hydropower) enables a CO2-free, climate-friendly energy supply based on a hydrogen concept.
Electrolysis of water
Conversion of hydrogen in a PEM fuel cell into electricity
Explosion of an H2/O2 mixture in a syringe rocket
Operating a PEM fuel cell car
Fossil fuels contribute to climate change through the increase in CO2 emissions. The use of renewable energies (wind, sun, water) enables a CO2-free, climate-friendly energy supply based on a hydrogen concept.

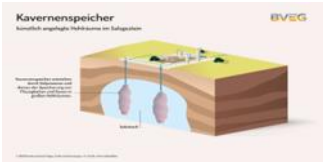
	First, dissolve the enclosed sodium carbonate (20 g) in 100 ml of tap water. This creates a saturated sodium carbonate solution, which we will use as electrolyte. The freely moving ions in the solution can transport charges without adversely affecting the desired reaction.
	Hang the two electrodes on the rim of the beaker and place the two 10 ml syringes with open stopcocks over the electrodes. When using the electrolysis cell for the first time, use regular tap water instead of sodium carbonate solution to practice the following technique! Pour the prepared sodium carbonate solution into the electrolysis beaker. Air will escape from the syringes. Use another 10 ml syringe to remove any remaining air from the lower syringes and close the stopcocks (turn them sideways).

Instead of a solar cell (e.g., 5V/1A) or a power bank charged with green energy, we are using a 9V battery as the energy source here for cost reasons.
Immediately after connecting the battery, gas bubbles can be seen rising in the positive and negative terminals.
Using the PP-tubes included (6 ml), the two gases can be identified as oxygen (positive terminal) or hydrogen (negative terminal).
Note: Oxygen has a higher density and hydrogen a lower density than air. Adjust the opening of the tube accordingly when filling it with oxygen or hydrogen.

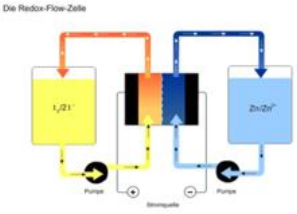
After a short time, different volumes of the two gases produced become apparent:
Negative electrode: Hydrogen → 2 Vol
Positive electrode: Oxygen → 1 Vol

The ignition of different volumes of hydrogen and oxygen mixtures in a PP tube, known as an "oxyhydrogen reaction," can be used to support a hypothesis related to the formula H_2O.

Negative electrode: $4\ H_2O + 4\ e \rightarrow 2\ H_2 + 4\ OH^-$
Positive electrode: $2\ H_2O \rightarrow 4\ H^+ + O_2 + 4\ e$
Overall reaction: $2\ H_2O$ + energy → $2\ H_2 + O_2$



Zinc iodide cell

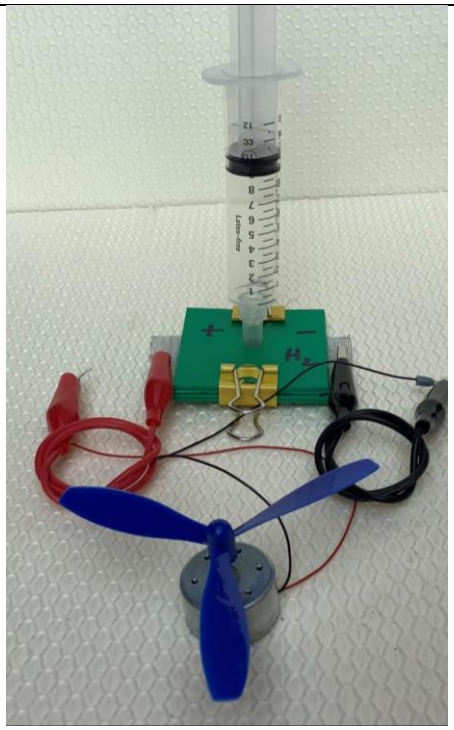


Hydrogen can be used as an energy storage medium when there is a surplus of wind and solar power (utilizing excess capacity).
The hydrogen produced can be stored for later use:
Physical storage: In Pressure vessels at 350-700 bar https://hexagonpurus.com/our-solutions/mobility/fuel-storage-systems

- In Caverns, e.g., Gronau-Epe (Germany), 38 million m^3 https://www.youtube.com/watch?v=nY7NygMchs4&t=35s

Chemical storage: e.g. in a Redox flow cell
Charging (energy absorption):
(-) $Zn^{2+} + 2e \rightarrow Zn$
(+) $2\ I^- \rightarrow I^2 + 2e^-$

Discharging (energy loss):
(-) $Zn \rightarrow Zn^{2+} + 2e^-$
(+) $I_2 + 2e \rightarrow 2\ I^-$

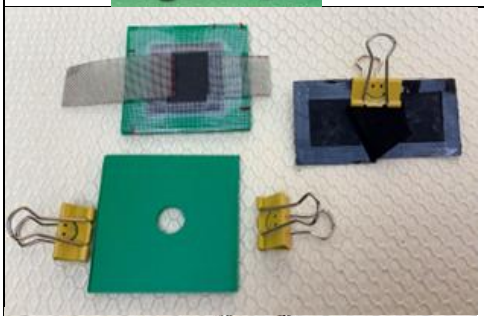


The oxygen produced during electrolysis is released into the environment, as the oxygen in the air (approx. 21%) is sufficient for the subsequent reactions in a PEM fuel cell.

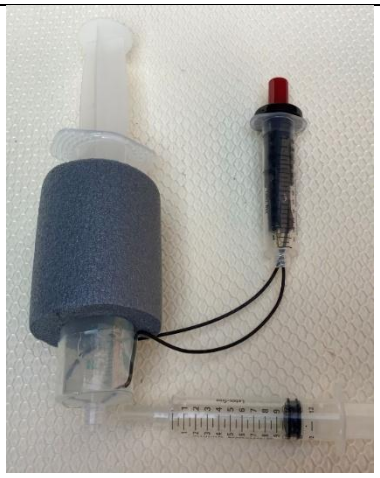
The fuel cell should be humidified by blowing on it with moist air before the hydrogen reacts with oxygen (this improves the function of the PEM membrane).
With a slow supply of H_2 (0.1 ml increments) using the 10 ml syringe, the DC motor (starting at approx. 0.25 V/25 mA) will run for several minutes.

Negative terminal/anode: $2\ H_2 \rightarrow 4\ H^+ + 4\ e^-$
Positive terminal/cathode: $O_2 + 4\ e^- \rightarrow 2\ O_2$
Overall reaction: $2\ H_2 + O_2 \rightarrow 2\ H_2O$ + energy

A PEM fuel cell can also be used to power an electric motor in a car chassis.
To do this, place a syringe filled with approximately 10 ml of hydrogen onto the fuel cell and inject about 2 ml of hydrogen into the fuel cell.
The car will travel a few meters on a smooth surface.
After repeatedly adding 2 ml of hydrogen each time, test how far the car will travel with the available 10 ml of hydrogen (corresponds with 1 mg hydrogen).
What advantages and disadvantages do you see for hydrogen propulsion in the field of mobility?



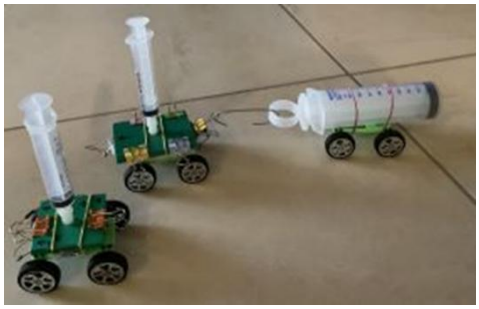
A PEM fuel cell consists of a PEM membrane (PEM = Proton Exchange Membrane), which is permeable only to H+ ions.
Depending on the manufacturer, this membrane is doped with platinum/Pt to varying degrees (spot distribution of Pt, e.g., 1.2 mg Pt per cm^2) and is technically referred to as a Catalyst Coated Membrane (CCM).
The CCM is sandwiched between two gas diffusion layers (GDLs), which are responsible for gas distribution and electrical current transport (they contain graphite).
Nickel electrodes are used as electrical contacts. The power output of the 2 x 2 cm PEM reaction area is approximately 0.135 watts (at 0.9 V/150 mA).



The energy stored in hydrogen can be effectively demonstrated by the explosion of a mixture of 2 Vol H_2 and 1 Vol O_2 in a syringe rocket. Despite the explosion being harmless (please wear safety goggles, use a foam-filled grip, ignite with your arm extended, aim the piston upwards and not at people), only 10 ml of hydrogen and 5 ml of oxygen should be used for ignition. Caution: Loud bang, and the plunger will fly approximately 20 m into the air!

Chemical reaction: $2\ H_2 + O_2 \rightarrow 2\ H_2O$ + Energy

Model cars, trucks, and airplanes with fuel cell propulsion 10 ml of hydrogen (approx. 1 mg H2) is sufficient for a driving distance of approximately 50 to 100 m.



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