


This resource was developed as part of the HyAcademy.eu project.

Hydrogen production by the electrolysis of water



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 Schweizerische Eidgenossenschaft
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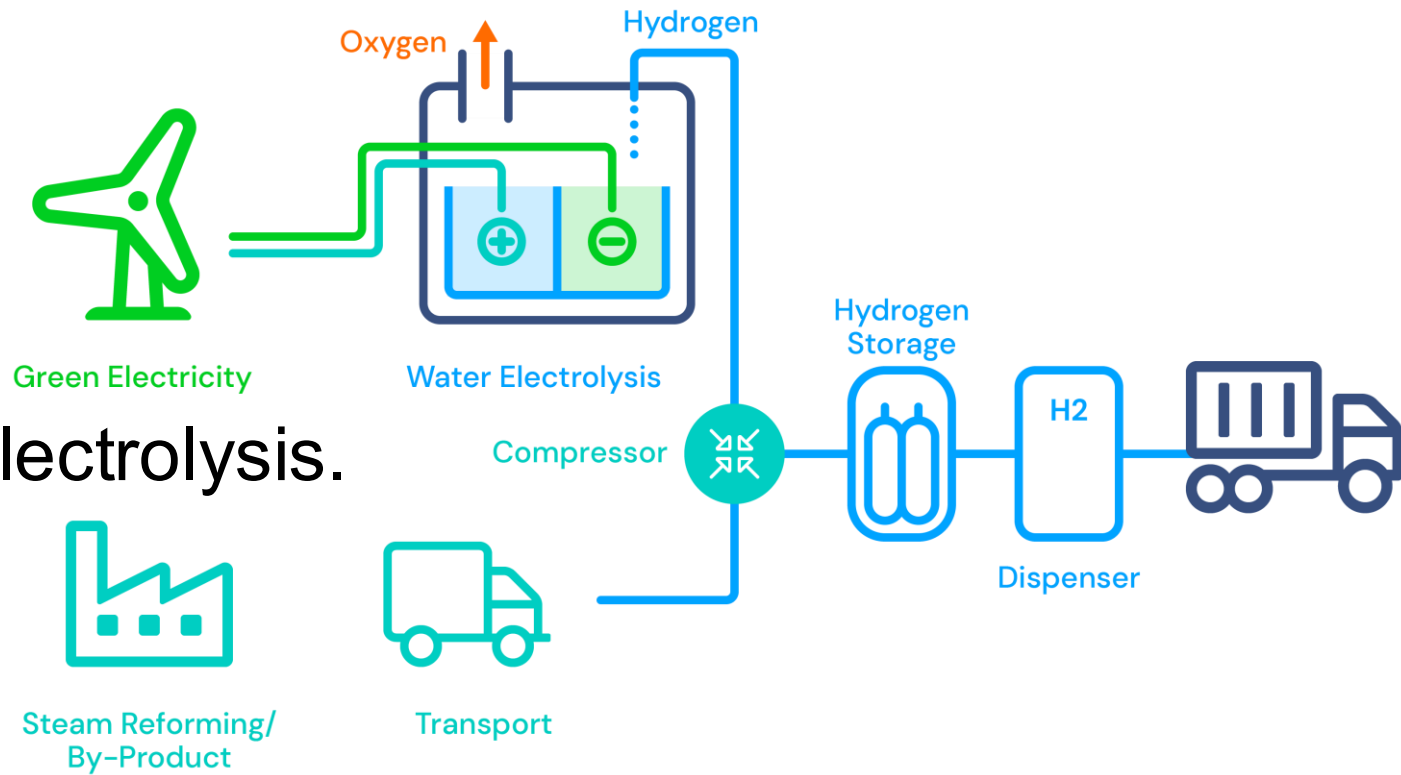
Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER
State Secretariat for Education,
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1. Introduction

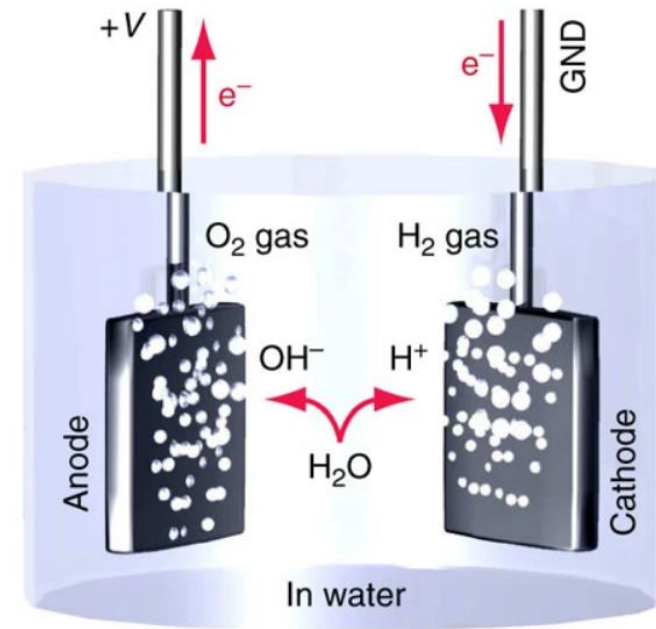
2. Theory of water electrolysis.



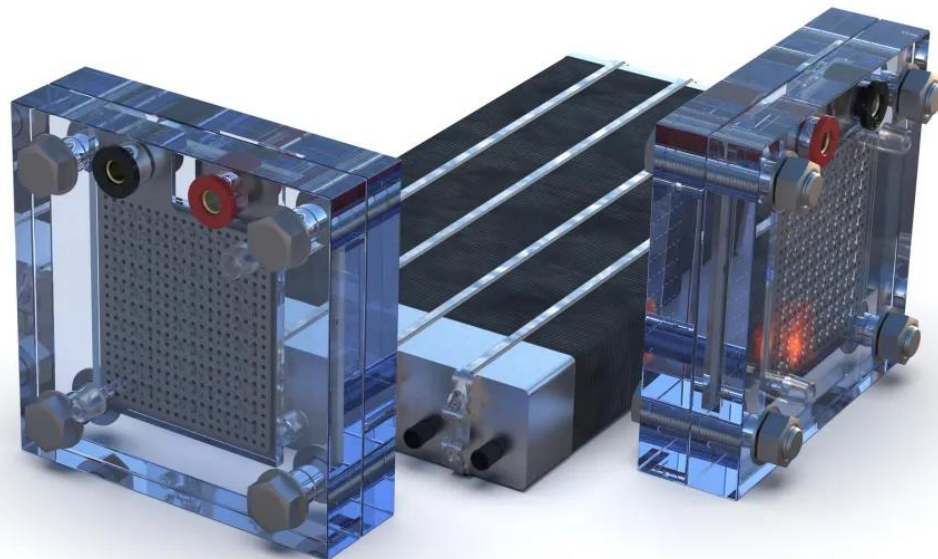
<https://www.h2haul.eu/hydrogen-infrastructure/>

1. Introduction

- **Water electrolysis** is the process of using electricity to split water (H_2O) into **oxygen** (O_2) and **hydrogen** (H_2) gases.



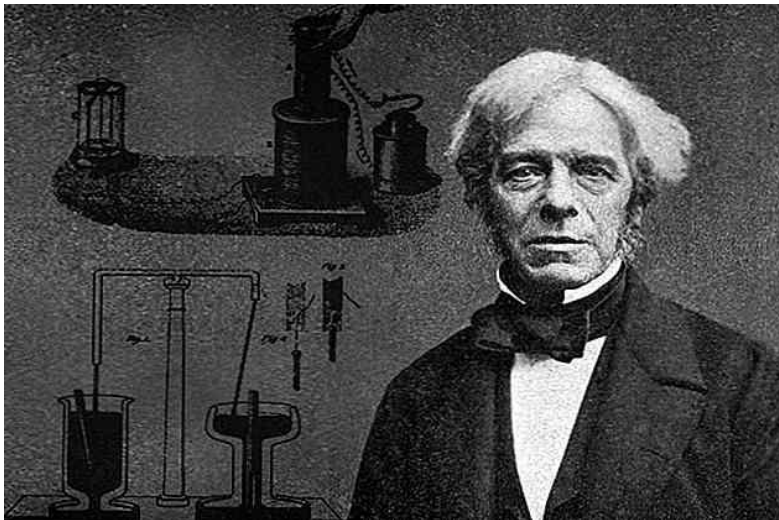
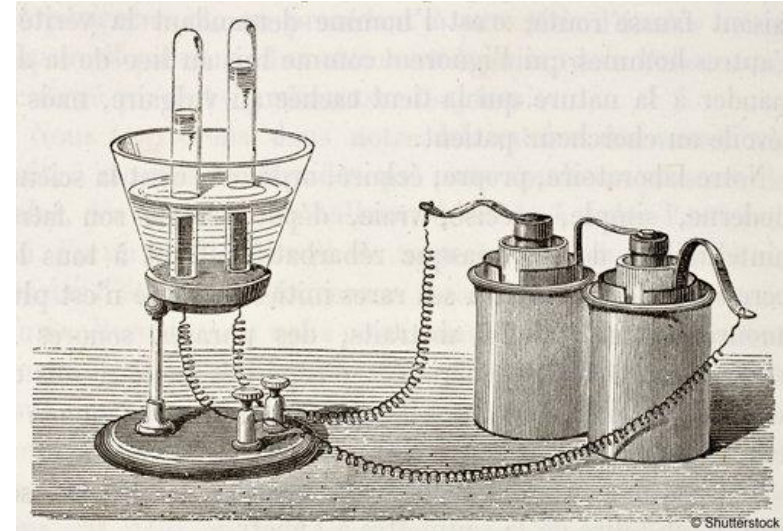
<https://doi.org/10.1038/ncomms1112>



<https://www.exponent.com/artide/electrolyzer-boom>

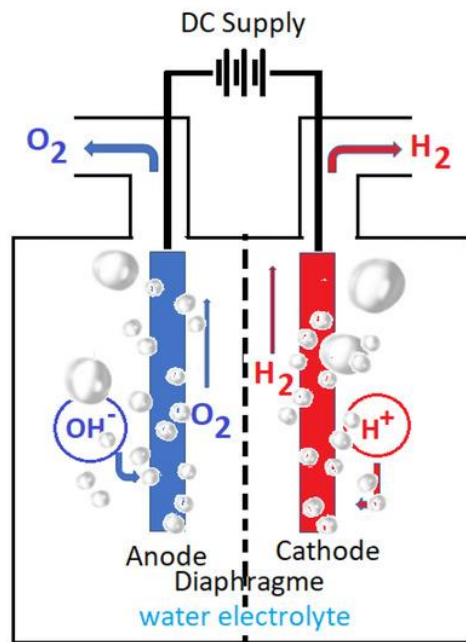
- The reaction takes place in a unit called **electrolyzer**.

- The **water electrolysis** was performed for the first time in **1800** by the English scientists William Nicholson and Anthony Carlisle.



- The English scientist Michael Faraday discovered the **laws of electrolysis** and reported them in **1833-34**, it is a law of mass conservation and is therefore strictly verified.

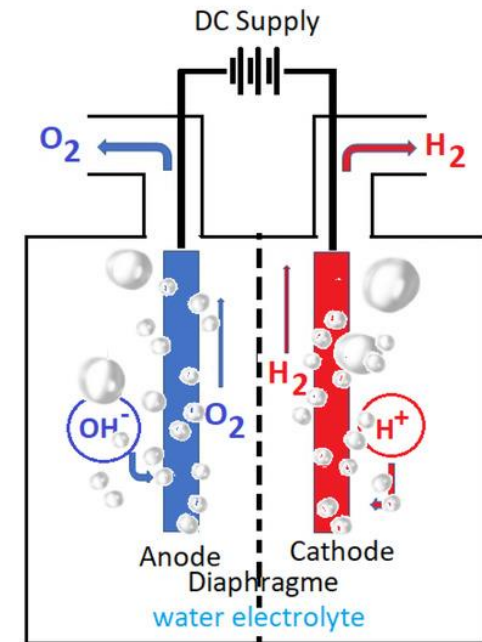
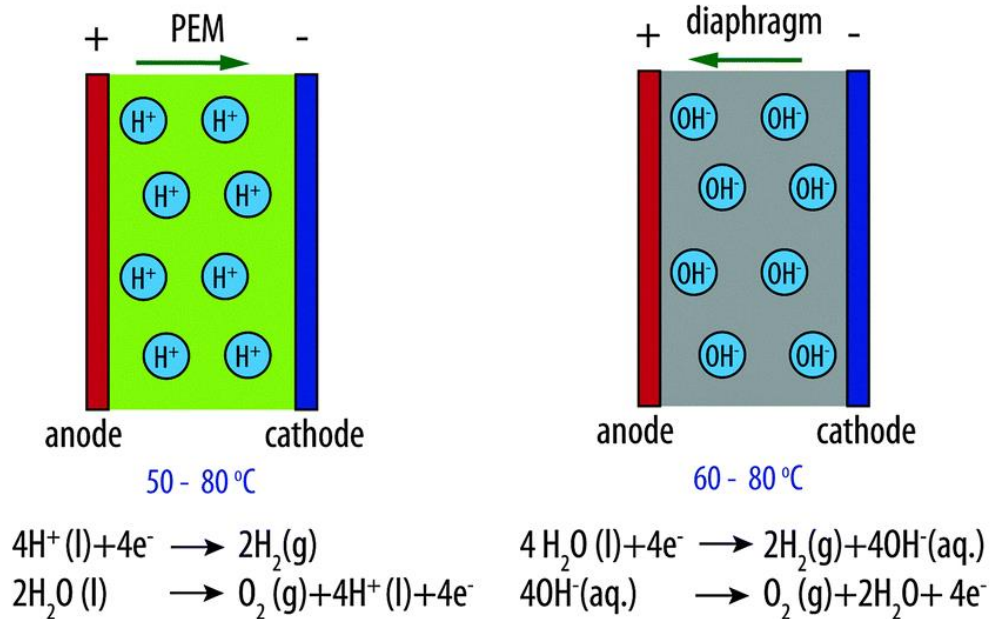
- The **electrolysis** causes the production of oxygen gas to the anode and hydrogen gas to the cathode if there is **sufficient potential difference**.



The electrolysis of water usually involves **dilute, or moderately concentrated, salt solutions in order to reduce the power loss** driving the current through the solution, but the presence of salt is not a requirement for electrolysis.

- The **first electrolysis units were using an acid electrolyte**, but the acidic medium was abandoned due to severe corrosion problems.

- The **polymer electrolyte membrane (PEM)** electrolyzers use a proton-conducting membrane as electrolyte, which presents the advantage of being oxygen impermeable.

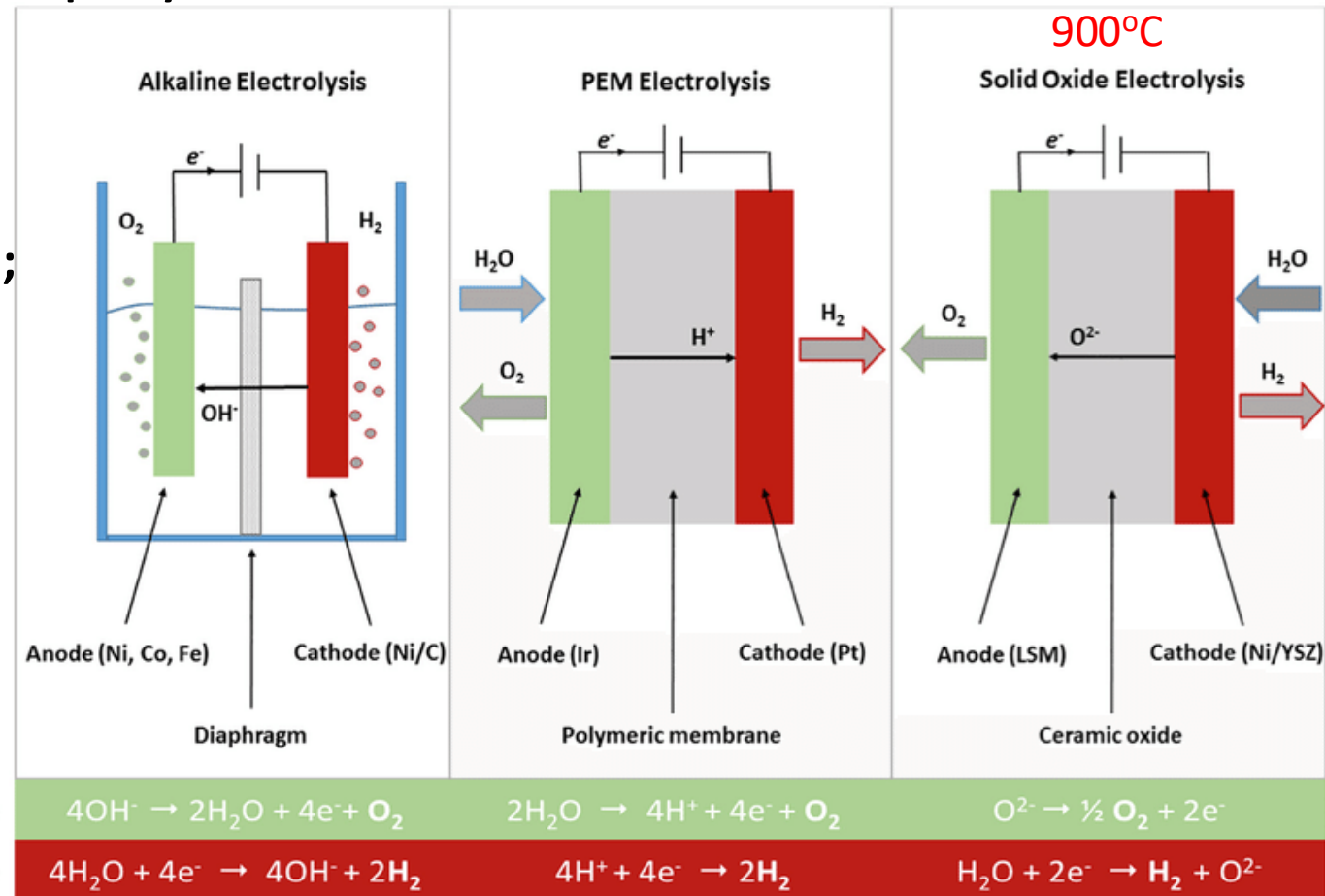


<https://doi.org/10.3390/en15228560>

- Effectively, the **most commercial water electrolyzers use an alkaline electrolyte.**

There are **three main types** of electrolyser technologies, which are named for the electrolyte they employ:

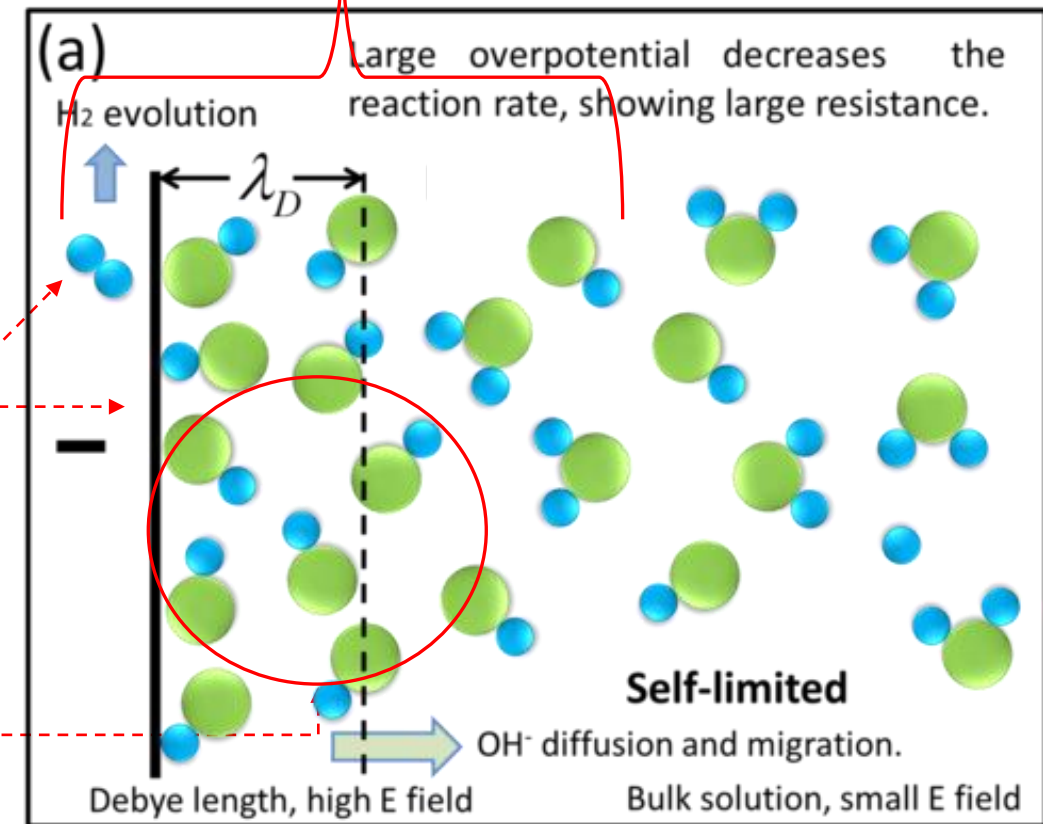
1. **liquid alkaline;**
2. **proton exchange membrane (PEM);**
3. **high temperature solid oxide.**



2. Theory of water electrolysis.

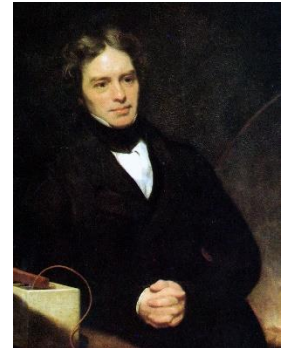
- The water electrolysis reactions are:

- (1) **heterogeneous**,
- (2) taking place at the **boundary between** the electrode and the electrolyte with
- (3) the aqueous boundary layer subject to **concentration and electrical potential gradients** with
- (4) the presence of the **generated gaseous** nanobubbles and microbubbles.



https://en.wikipedia.org/wiki/Virtual_breakdown_mechanism#/media/File:Pure_water_in_macrosystem.png

1. The **quantity of products** formed during electrolysis process can be calculated directly from the **duration and current** flowing, as **96,485 coulombs (one Faraday)** delivers one mole of electrons.
2. **One Faraday** produce, ideally, **0.5 moles of H₂** and 0.25 moles of O₂.
3. The minimum necessary cell voltage to start water electrolysis is the potential **1.229 V**.



- There was established the **quantitative relationship between the amount of electricity (q)** passing through the electrode/electrolyte interface and **the mass (m) of substances** involved in the electrolysis (redox) process:

$$m = k_e q$$

Where:

$k_e = M/nF$ is the electrochemical equivalent in $\text{kg/C} = \text{kg}/(\text{Amperes} \times \text{s})$;

M in kg/mole is the molar mass of substance produced at the interface;

n is the number of electrons involved in the electrochemical reaction;

$F = 96485.3 \text{ C/mole}$ is the Faraday's constant.

- The water electrolysis, when the steady (stationary) electric current (I) and time period (t) are known, the theoretical (maximum) amount of hydrogen (or oxygen) produced can be calculated using next equation:

$$V_{\text{theoretic}} = k_e I t / q$$

where

$V_{\text{theoretic}}$ in m^3 is the theoretical volume of gas evolved,
 I in A(mperere) is the total current,
 t in s(econds) is time;
 q in kg/m^3 is the gas density.

Due to kinetic processes and competition of ionic reactions at the electrodes, the necessary voltage for electrolysis is considerably higher, generally of the order of **1.7 to 1.9 V***.

**Electrolysis begins at 1.229V*

The **ideal amount of energy** needed per Nm³ H₂ is

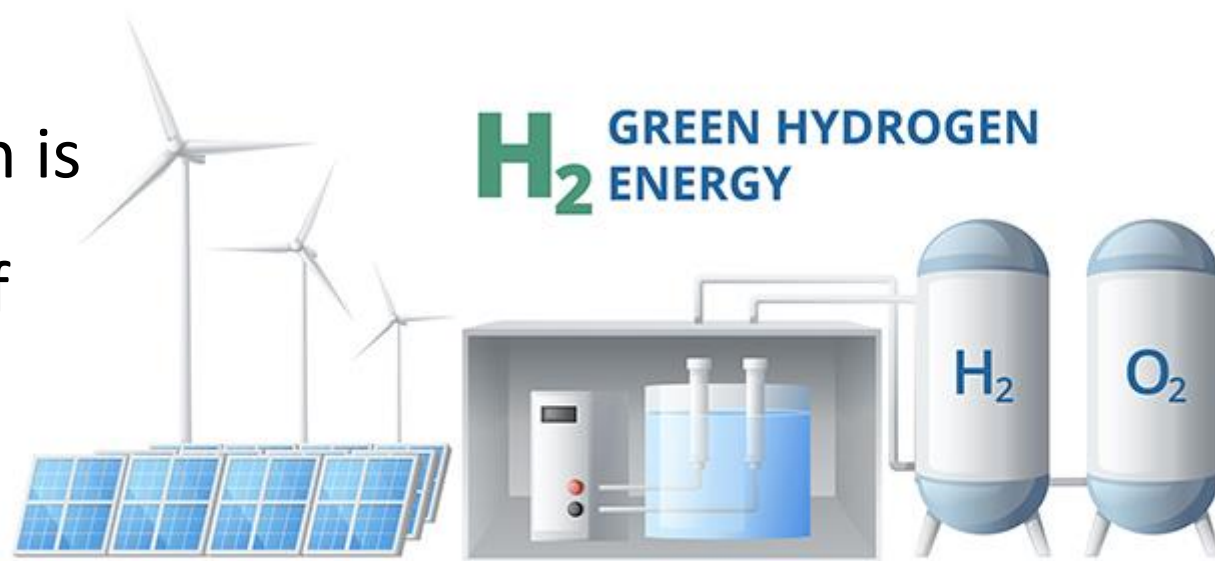
$$\Delta G^{\circ} / V_{\text{N}} = 241 \text{ kJ/mol} / 22.41 \text{ l/mol} = \mathbf{3 \text{ kWh/Nm}^3}$$

N.B. V_{N} = standard molar volume of a gas (22.41 l/mol)

Standard electrolysers require about **4.2 to 4.8 kWh/Nm³**

The electrolysis is a very **promising way to produce** renewable and nonpolluting **hydrogen** if the power input is from renewable energy.

In the transition to global decarbonization, hydrogen is a way to reduce the use of hydrocarbon-based fuels.



Electrolysis


www.ishifuku-kinzoku.co.jp

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Thank You!



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