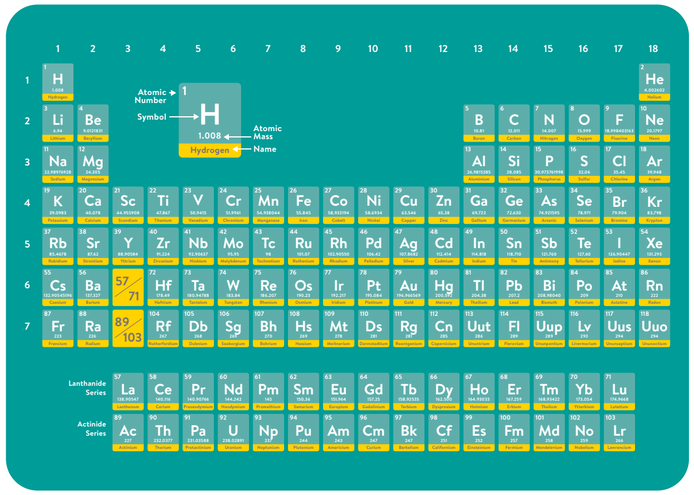
Materials & Hydrogen

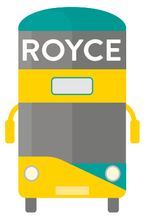
HENRY ROYCE INSTITUTE

WHAT IS HYDROGEN?

Hydrogen is the most common element in the universe. It is **the first element of the periodic table** with the chemical symbol **H**. A hydrogen molecule is formed by combining two hydrogen atoms and is written with the formula **H_2**.



Hydrogen has many uses in our society, for example as a fuel for cars, buses, trucks, and even space rockets!



Future challenges for **materials scientists** include **reducing our reliance on rare metal materials** and **investigating how materials interact with hydrogen**, for example in the gas distribution network or aircraft fuel tanks. Addressing these challenges with materials science will help to **improve hydrogen production** and **contribute to a more sustainable society.**

WHERE DOES IT COME FROM?

Hydrogen prefers to bond with other molecules, so very little 'pure hydrogen' is available on Earth. To produce hydrogen for commercial uses, it first needs to be extracted from other sources such as water, natural gas, or oil.

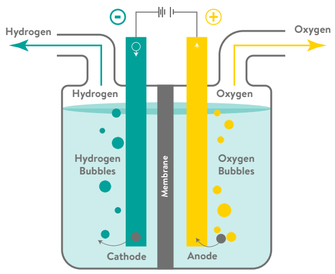
Conventionally, most hydrogen is produced from coal and gas (or other fossil fuels) which emit carbon dioxide (CO_2) into the atmosphere contributing to global carbon emissions. However, another method produces hydrogen by splitting water molecules (H_2O) into hydrogen and oxygen using electricity. This chemical process is called **electrolysis**.

HOW DOES MATERIALS SCIENCE HELP?

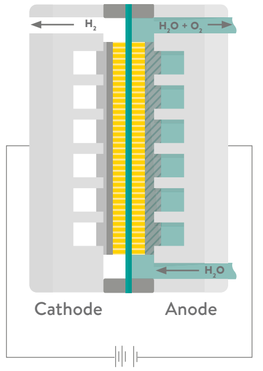
Water electrolysis involves the separation of hydrogen and oxygen molecules by applying electrical energy to the water.

When a direct current is passed through the water, oxygen ions **(O^{2-})** accumulate in the positive electrodes, called cathodes, while hydrogen **(H^+)** accumulates in the negative electrodes which are called anodes.

ELECTROLYSIS



PEM ELECTROLYSER



PEM electrolysers produce two times more hydrogen than oxygen by volume, and the process can be made even cheaper and more efficient by using electricity from renewable energy sources (such as wind and solar power) to split the water.

A range of materials are used in PEM systems. **Titanium plates** and **platinum metal coatings** form parts of the electrolyser as they can withstand the harsh conditions inside the fuel cell. New solid **silicone-based polymers** have also been developed using materials science to seal the electrolyser's cell and make them much more durable.

To make hydrogen production free of carbon emissions, materials scientists have developed an innovative method of electrolysis that uses a new type of membrane, called a **Proton Exchange Membrane (PEM)**, generating hydrogen using renewable electricity and tap water. These PEM fuel cells are currently the leading technology option for generating so called 'green hydrogen'.

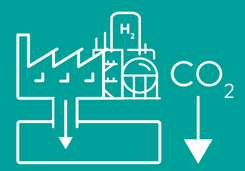
Materials science is also providing new coatings for more durable blades and generators in wind turbines, which will contribute to a reduction in the cost of renewable energy used to generate green hydrogen.

TYPES OF HYDROGEN

GREY
from fossil fuels

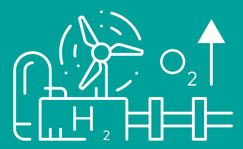
CO_2 released into atomosphere

BLUE
from fossil fuels



CO_2 stored underground

GREEN
from renewable energy



O_2 released into atmosphere

Hydrogen produced from fossil fuels (like coal, natural gas or methane) is called **grey hydrogen**, as it releases CO_2 into the atmosphere contributing to climate-changing emissions.

However, if the CO_2 from these fossil fuels is captured during the process and then stored safely, the impact of the process on the environment is much lower. Hydrogen produced in this manner is called **blue hydrogen**.

These CO_2 emissions can be eliminated entirely from the production if the electricity used to produce hydrogen with electrolysis is supplied from renewable resources (such as solar or wind power). This type of hydrogen is called **green hydrogen**.

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