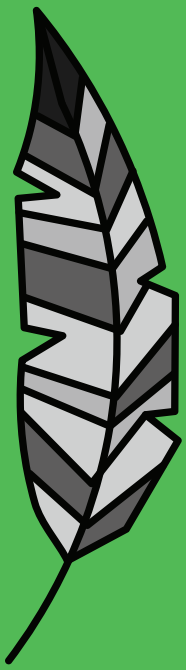
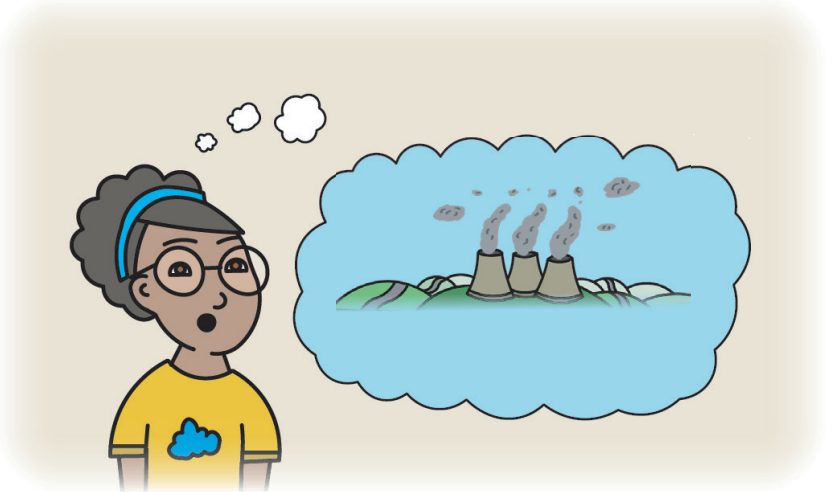
KATY AND THE HYDROGEN PIGEON FLY TOWARDS A BETTER FUTURE

CHIARA PUECHER



Katy is a 12-year-old girl. Since she was little, she has been passionate about different means of transport. Her dream is to become an aeroplane pilot, to soar through the skies and travel around the world.

One day at school Miss Green, her teacher, explains to her and the whole class that cars and other vehicles work by burning fossil fuels, such as petrol or diesel. The burning of fuels releases energy that allows vehicles to run. This releases tiny particles called exhaust gases into the air. They are harmful to our health and to the environment. One of these exhaust gases, the teacher explains, is carbon dioxide.



"**Carbon dioxide**", explains Miss Green, "forms a shield around the Earth that protects us and keeps the temperature to allow life on Earth. This shield is called the atmosphere, it traps part of the heat sent by the sun on Earth, like a greenhouse in your garden. That is why it is called the **greenhouse effect**."

"If it's like a shield that protects us, why do they say on the news that the greenhouse effect is harmful?" asks Mark, one of Katy's classmates.

"Power plants, factories, heating, cars and aeroplanes produce carbon dioxide. When the amount of carbon dioxide is too high, the greenhouse effect becomes more intense. The atmosphere traps more heat on Earth and the **climate changes**. This is called global warming, it is as if the Earth has a fever. When you have a fever, you feel ill, and the same is happening to our Earth. Sea levels are rising, glaciers are melting, and the weather is becoming more extreme with more floods and heat waves causing damage," concludes Miss Green.

Katy looks out of the window at a tiny aeroplane crossing the sky. Flying does not sound so attractive anymore.

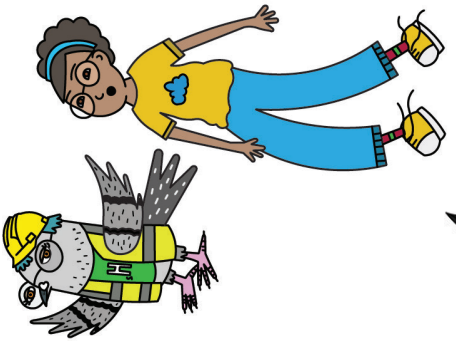
A few days later…

It's a summer day, one of those slow days when time seems to stretch. Katy is lying under the beech tree in her grandmother's garden, watching the leaves move and aeroplanes fly in the sky. She feels sad thinking about all the carbon dioxide that aeroplanes emit and remembers what she learned at school in the past year. The sound of the leaves is so relaxing that she falls asleep…

Suddenly, Katy hears some strange noises. She looks up and sees a funny bird in front of her.

"Hydrogen Pigeon!" the bird introduces itself. "Explorer. Time traveller. Occasional crumb thief. Katy, will you fly with me **to explore hydrogen?**"

JOURNEY INTO THE PAST ...



The Hydrogen Pigeon flaps its wings three times and they find themselves flying over London at the end of the 1700s. In front of Katy's eyes, a crowded city spreads out under them. She sees large factories with long chimneys spewing black smoke, fleets of ships on the River Thames ready to set sail on their next voyage. Horse-drawn carriages carry aristocrats in extravagant clothes and children dressed in rags steal loaves of bread from the market. They land and the Hydrogen Pigeon starts explaining:

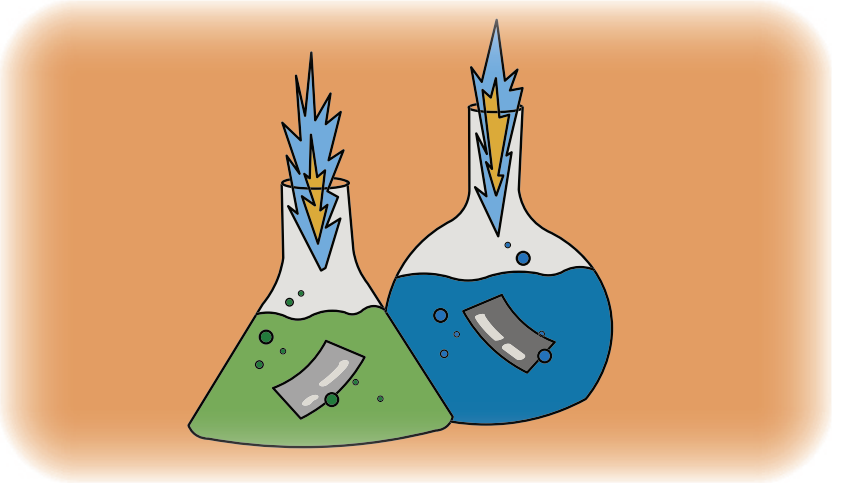
"Dear Katy, we are in London in the year 1766, when London was the beating heart of the British Empire and the largest city in the world! This is during the Industrial Revolution. New machines, new technologies and more factories and jobs are causing people to move from the countryside to the city to find work, with the hope for a better life.

This is where our friend, the chemist and physicist **Henry Cavendish**, lives. When it comes to experiments and discoveries, he is unbeatable! Today we are going to visit him in his laboratory."

The Hydrogen Pigeon flaps its wings three times and they land in a scientific laboratory. There is a bookshelf full of scientific texts covering an entire wall. The rest of the room is filled with shelves holding scales, candles, glass containers, burners, flasks, containig different chemical substances. In the centre of the room a man wearing a powdered wig (typical of all important people of the time) is studying a text written by the famous scientist Boyle from the 1600s. Henry is carrying out an experiment shown in the book.

A glass bottle in front of him is bubbling and hissing. Katy and the Hydrogen Pigeon watch as Henry experiments with different substances, discovers that **by placing metals such as zinc, iron or tin into acid, a gas is produced**, bubbling away in the bottle. Henry is thrilled. With this experiment, he confirms what his colleague Boyle proposed—the discovery of a new element known today as **hydrogen**.

Fascinated by this new element, Henry continues to explore it and discovers that, when in contact with air, hydrogen burns very quickly. ***Whoosh!* - a very pale, almost invisible, blue flame dances in the laboratory.** Before Katy's astonished eyes, Henry exclaims "This is flammable air!"



Henry also notices that tiny droplets of water appear near the flame. Henry has a lightbulb moment: **water is made of hydrogen and oxygen!**

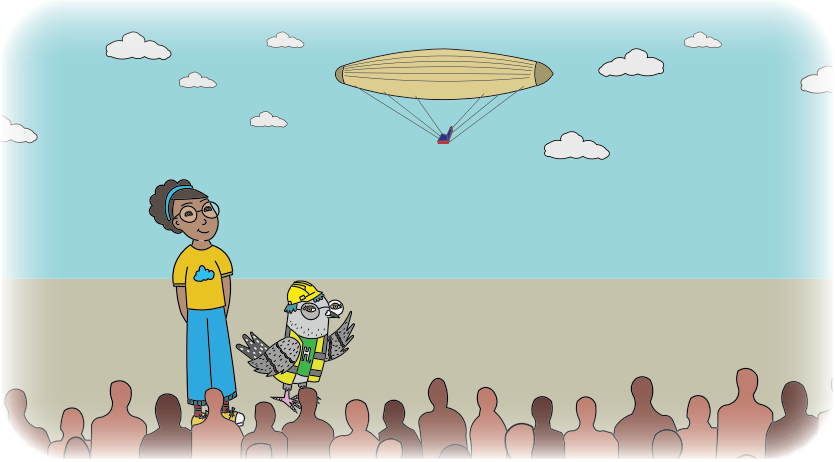
Katy gasps "Fire has produced water!" She realises that when a reaction happens, two substances meet and change into something new. Katy thinks about the pizza she usually makes with her parents at the weekend - when different ingredients are mixed together and cooked, they become something new, which is much more fun than just the simple sum of the ingredients.

After this sensational discovery, Katy and the Hydrogen Pigeon notice Henry run out of his laboratory in a hurry. Is he perhaps going to inform the scientists of the Royal Society in London?

Katy doesn't have time to find out. The Hydrogen Pigeon flaps its wings again and the two of them land in the Royal Garden of the Tuileries in Paris. They are surrounded by a crowd of people who are looking up at the sky.

The crowd is following the movements of a huge **balloon** floating above with a wicker basket hanging beneath it that is carrying two men. The Hydrogen Pigeon explains that they have reached the year 1783. They are watching the very first hydrogen-filled balloon, called Le Globe. Katy and the Hydrogen Pigeon gaze in wonder as Le Globe slowly rises into the sky. **It is filled with hydrogen which is lighter than air.** It lifts the two aeronauts high into the skies, the physicist Jacques Charles and his assistant Nicolas-Louis Robert, peeking out from the basket.

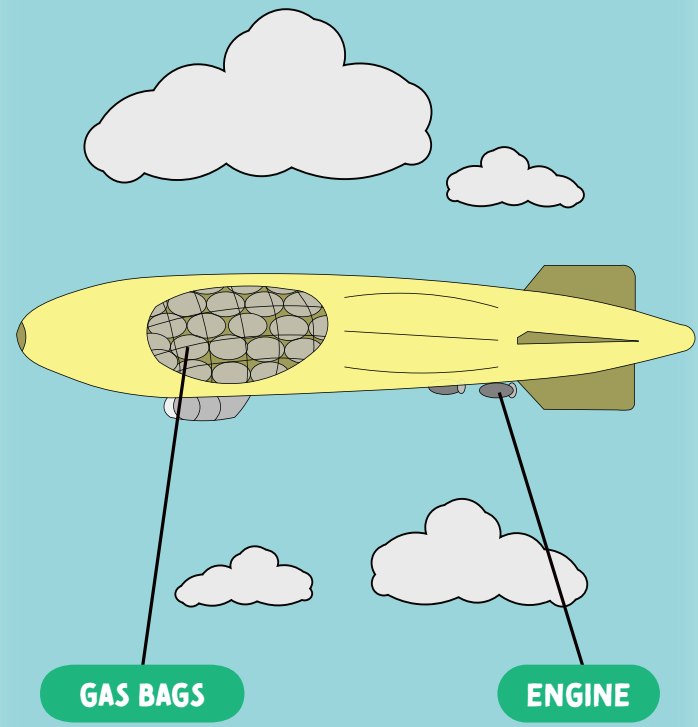
Just a flap of wings and Katy and the Hydrogen Pigeon fly through time once again. They are still in Paris, but 69 years later, in 1852. They end up in a crowd gazing upwards at the flight of an airship. It is the airship invented by the French engineer Henri Giffard. "What does an airship have to do with hydrogen?" Katy is puzzled. The Hydrogen Pigeon points at a large cloud of mist.



Katy discovers that the airship flying above them has a steam engine! But the surprises are not over! **The large envelope of the airship is filled with hydrogen.** Hydrogen is lighter than air, so that the airship rises into the sky.

"After Henri Giffard's balloon invention, engineers in Italy and Germany began building their own airships. Wealthy people used them for commercial trips and explorers were eager to discover new distant lands with them," explained the Pigeon. "Giant floating ships, imagine sleeping in the skies" it whispered. The Norwegian explorer Roald Amundsen travelled to the North Pole on the airship Norge in 1926 with Umberto Nobile, the Italian engineer who had designed it. It was the first time in history that humans had flown over the North Pole.

RIGID AIRSHIP



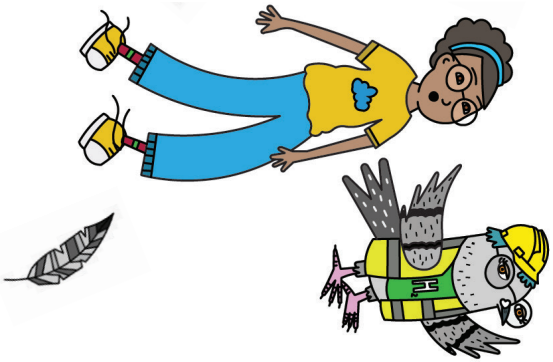
Unfortunately, in 1937, an airship that departed from Frankfurt, Germany, was landing in New Jersey, USA, when it caught fire during landing. **Most of the passengers on board survived.** After this '**Hindenburg Disaster**', though, companies reduced their use of hydrogen for many years and the production of airships was stopped.

Hydrogen is a flammable gas like many other fuels, but those working with it did not yet know how to handle it safely."

"Was that the end of hydrogen?" Katy asks the Hydrogen Pigeon anxiously. She wonders about the future of hydrogen. It fascinates her so much.

The Hydrogen Pigeon smiles. "I will tell you more secrets of hydrogen. Over time, scientists have learnt to handle hydrogen safely. The power of hydrogen is no more dangerous than the petrol we use daily. It can be either beneficial or destructive like fire, which warms us in winter and cooks our food but can also destroy an entire forest. Dear Katy, you need to know that everything depends on how this power is handled by the people who use it. To manage such a great power, a lot of knowledge and study are needed."

JOURNEY INTO THE PRESENT ...



HYDROGEN PRODUCTION

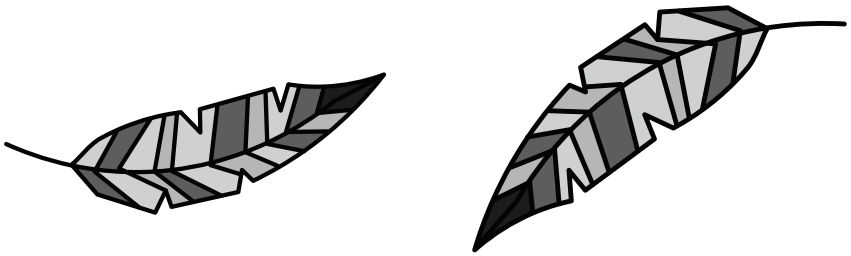
The Hydrogen Pigeon flaps its wings and immediately the two of them return to the present. This time they land at a hydrogen production site.

Outside the factory windows, Katy sees huge wind turbines. Through their large blades, the wind transfers its energy to electricity, becoming a strong electric current. This electric current is used to produce hydrogen.

Katy and the Hydrogen Pigeon are welcomed by Ray, a young scientist responsible for the operation of the electrolysis cells, the machines that make hydrogen out of water.

Ray explains to the two friends, "**Hydrogen on Earth is only found bonded in other substances. For example, hydrogen atoms bonded to oxygen atoms form water, H_2O.** To separate the hydrogen and oxygen molecules, energy is needed. Instead of burning fossil fuels, we can use the sun, the wind, geothermal heat, or water, which, with their energy, allow electricity to flow. This is environmentally friendly electricity.

Electrolysers split water molecules by electric current. **Two metal bars called electrodes are immersed in a water solution.** The electric current from the wind turbines passes through the metal bars and the water, splitting it into hydrogen and oxygen."



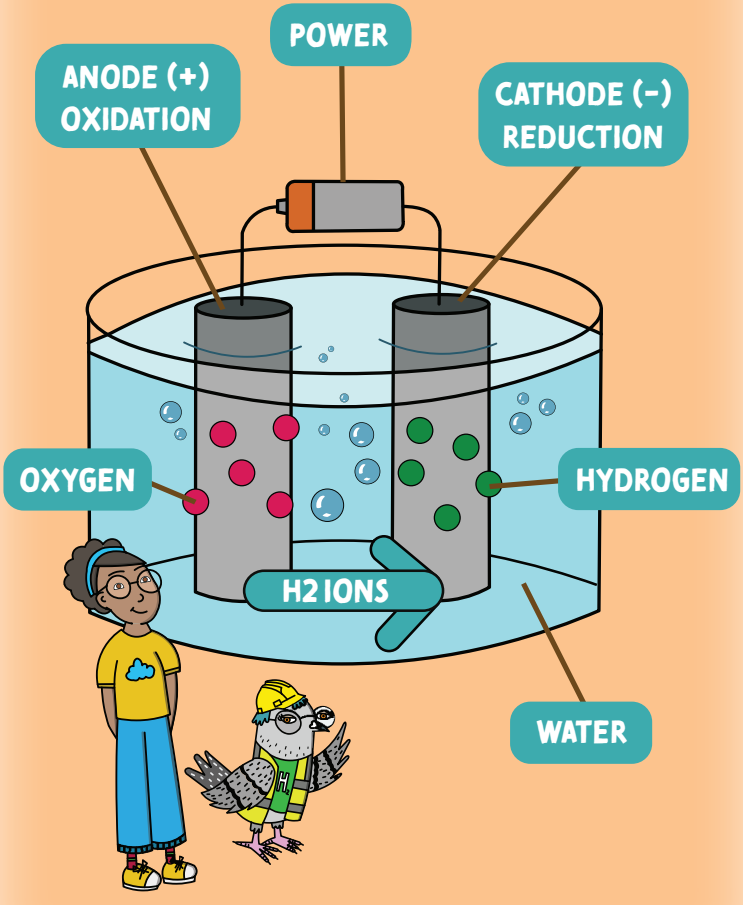
“Look!” exclaims Katy, “bubbles are rising in the water!”

“The bubbles you see rising around the electrodes are hydrogen and oxygen,” says Ray, “the electric current splits water molecules to form oxygen around one metal bar, the positive side. Hydrogen bubbles are formed around the other metal bar, the negative side. As the water is split into hydrogen and oxygen, some heat is also produced,” Ray continues.

“Wow!” exclaims Katy, “**electricity splits water into hydrogen and oxygen!**”

“Exactly,” says Ray, “and the best part is that all this happens without polluting! The hydrogen we produce here is called ‘**green hydrogen**’ because it **is produced using electricity powered from renewable, clean sources** like the sun, wind, and water. Unfortunately, many industrial plants still produce hydrogen using fossil fuels. Finding a solution that does not harm the Earth is not easy, but it’s worth it!” concludes Ray.

ELECTROLYSIS

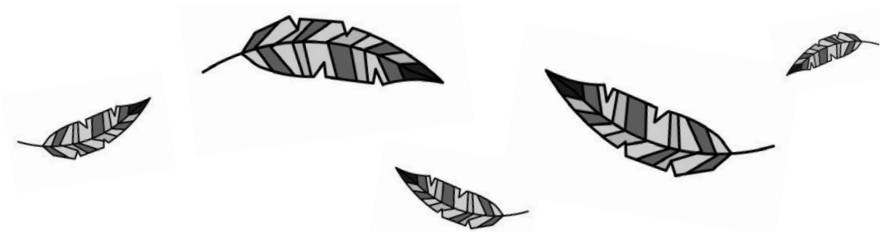


HYDROGEN STORAGE AND TRANSPORT

On their tour of the factory, Katy and the Hydrogen Pigeon come across a woman in a lab coat.

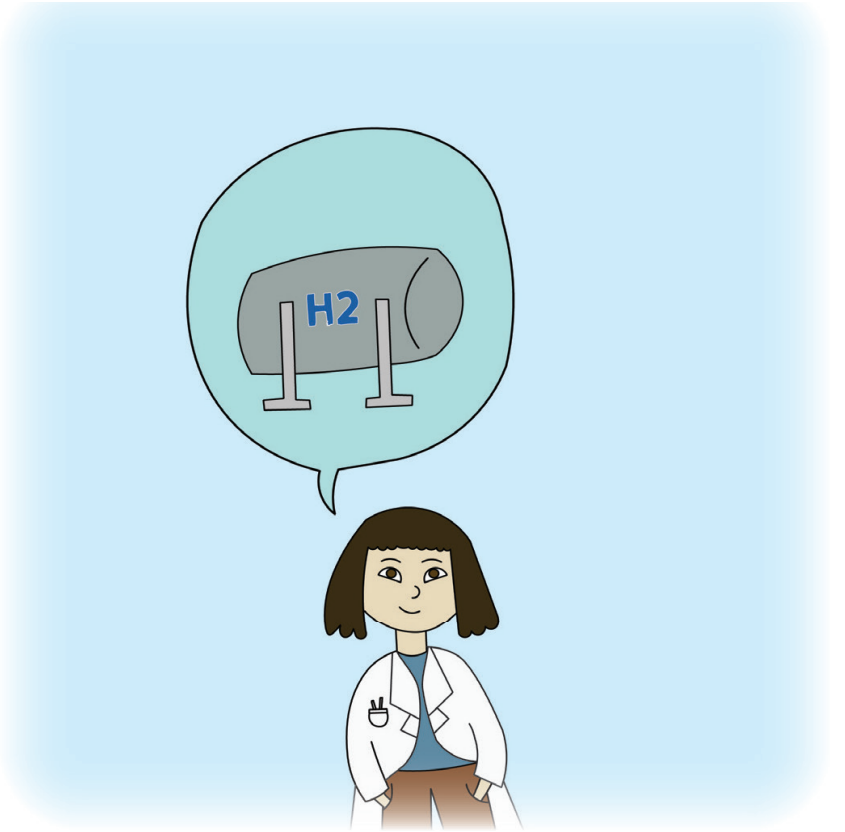
"Hello!" smiles Mei. She is a young hydrogen expert at the factory. "Hydrogen is a very light gas and tends to escape, just like the helium balloons that float away into the sky. That's why **hydrogen is safely stored in sturdy cylinders**. They are made of metal or combinations of different materials and are super strong. They look like big bottles!" She laughs.

"Scientists," Mei continues, "are also planning to store hydrogen in underground caverns." She grins and describes a big space with her arms. "These reservoirs are made of salt, and hydrogen can be trapped in cavities dug in these salt rocks. This way, we can go and get it whenever we need it."



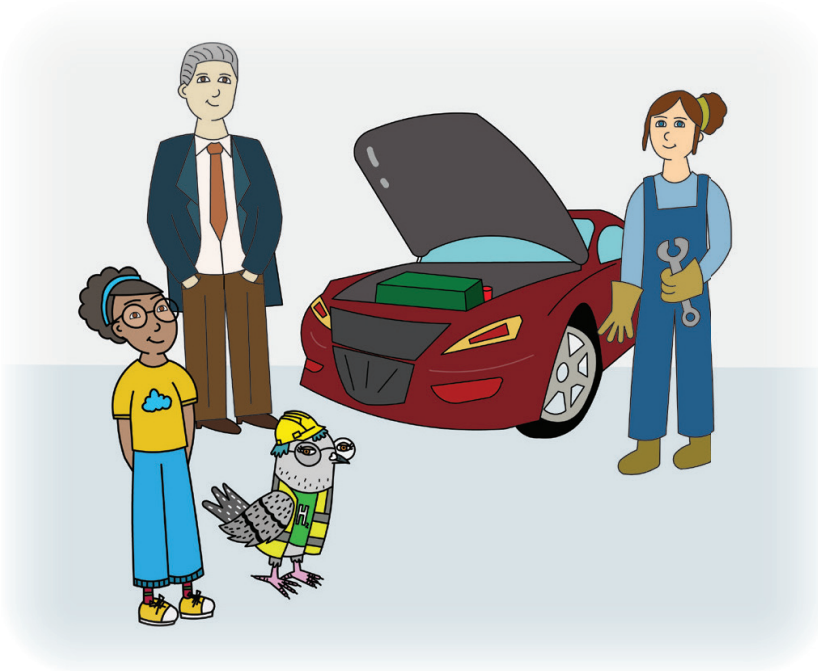
Impressed, Katy asks: “But how is hydrogen then transported?”

“**Hydrogen is squeezed tight to obtain high pressure. It is then filled into cylinders and transported to where it is used via trains, ships or lorries.** In addition, some companies are using underground pipes to transport hydrogen. However, new solutions and ideas are being found all the time,” smiles Mei.



THE USE OF HYDROGEN

Katy takes to the Hydrogen Pigeon's wings and they continue their journey to visit a famous car company that makes **hydrogen-powered vehicles**. They are welcomed by Satoshi, an engineer who works for the company. Katy is excited: she can't wait to find out how such a light gas can power vehicles. Satoshi takes them to the production department where auto mechanic Frida is tinkering with the electric motor of a car.

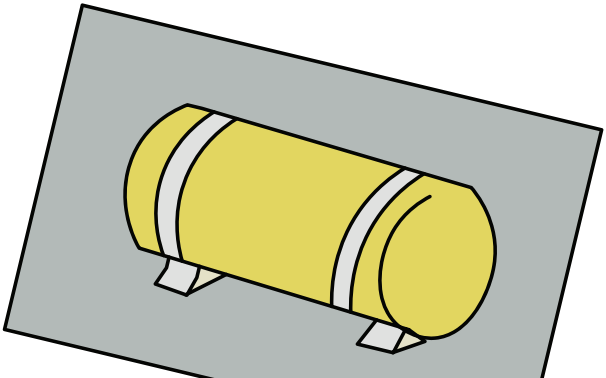


“In our company, we manufacture cars and vans and work with other companies that are developing the first hydrogen-powered boats,” Satoshi explains.

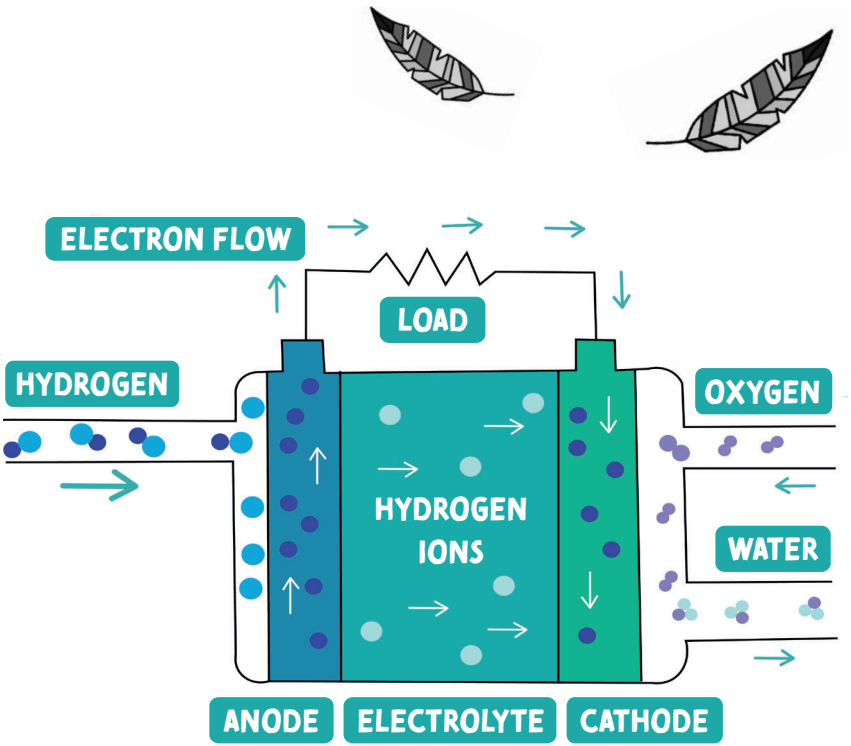
Frida invites Katy and the pigeon to come closer and shows them the car’s components.

“Here are the **hydrogen tanks**,” says Frida pointing to large bottles. “They **are connected to the fuel cell**, the heart of the car. In the fuel cell the hydrogen and oxygen react and power electricity. This allows electricity to flow to the electric motor. The reaction does get a little warm so there is a small cooling system nearby to keep things running smoothly. Any spare energy is stored in a battery ready to be used later. At the back of the car, there is an exhaust which releases **water vapour, the only product of the fuel cell**.”

“That’s wonderful!” exclaims Katy. “Satoshi, how can all this work?” asks the curious girl.



Satoshi smiles at her eagerness. “The fuel cell is a bit like the electrolyser cell’s twin - except everything runs backwards. Remember how the electrolyser splits water into hydrogen and oxygen with the help of electricity? Well, the fuel cell does the opposite! **Hydrogen and oxygen combine to produce water** and allow electricity to flow to the motor and move the car. You see, while the electrolysis of water requires electricity to produce hydrogen, **bringing hydrogen and oxygen together powers electricity again**.”



Katy is amazed how easy all this sounds. The Hydrogen Pigeon winks at Katy, "When they want to, humans can be really clever!"

Katy and the Hydrogen Pigeon wave goodbye to Satoshi and Frida and soar high into the sky. But the adventure is not over yet! This time, the inquisitive duo meets Haneul. He designs ways to use hydrogen which make life better for people and are kinder to the environment.

Ha-neul tells them "hydrogen isn't just used in cars. It can also provide electricity and heat for buildings. **Fuel cells**, like the ones you've seen in the car, **are essential because they use hydrogen and oxygen from the air to supply electricity**."

"Incredible!" cheers Katy, "But how can hydrogen heat houses?" she asks, curious.

"Another product of the hydrogen-oxygen reaction in fuel cells is heat," Ha-neul explains with a smile, "This heat is gathered and can be used to warm rooms and produce hot water."

"That's great!" says Katy. "I want to live in a hydrogen house."

"You can say that again!" Ha-neul laughs. "**Hydrogen** is essential for us. **When combined with nitrogen**, a part of the air, it **makes ammonia**, a substance that helps plants grow and is the base of fertilizers. Without it, it would be impossible to grow corn, wheat, rice, barley, vegetables or sugarcane - foods we eat every day. Hydrogen is also used to make other chemicals," continues Ha-neul.

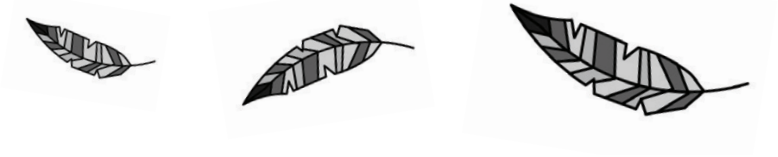
"Wow, hydrogen really is everywhere!" remarks Katy, while the pigeon nods, proudly rustling its feathers.

"Exactly! It's even essential for making plastics," Ha-neul adds.

"So, if we went looking for things made with hydrogen inside or outside our homes, we'd find loads of them!" says Katy.

"Yes! But now I must rush back to the lab. Come visit me again soon!" says Ha-neul.

Katy waves goodbye to Ha-neul, and the Hydrogen Pigeon offers its wing in thanks.



JOURNEY INTO THE FUTURE ...

The Hydrogen Pigeon flaps its wings again. Katy is now at the controls of an aeroplane. She can't believe it. She is now a fully-fledged pilot, exactly what she has always dreamed of!

Katy knows all the flight manoeuvres. She steers the plane to go upwards and uses the pedals to turn right or left. She speeds up and slows down, dancing in the sky. Below her, the clouds glow gold in the sunset. She talks to air traffic control to get information about her route.

Katy is piloting the Pigeon 2.0. It has **large tanks for liquid hydrogen** and fuel cells to power electricity, releasing long trails of water vapour into the air, but no smoke. Katy is excited: she is piloting a clean aeroplane! The Hydrogen Pigeon, now in its co-pilot uniform, smiles at her.

Pling! Katy wakes up and finds herself still under the beech tree in her grandmother's garden. She realises that it has all only been a beautiful dream. She stretches and notices a bird feather - or rather, a pigeon feather - on the grass nearby. Katy looks up at the sky and smiles, thinking of a brighter future.

EXPLORE

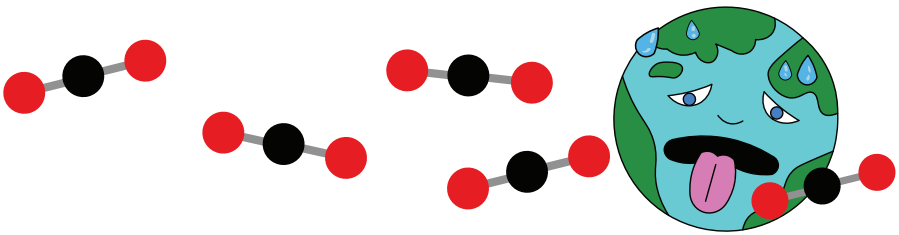
BIG IDEAS MADE SIMPLE

THE GOOD POWER AND THE DESTRUCTIVE POWER OF CARBON DIOXIDE

Carbon dioxide's superpower is to keep the Earth warm, just like a blanket. When it is present in the right amount, carbon dioxide is like a superhero that stops the Earth from becoming too cold.

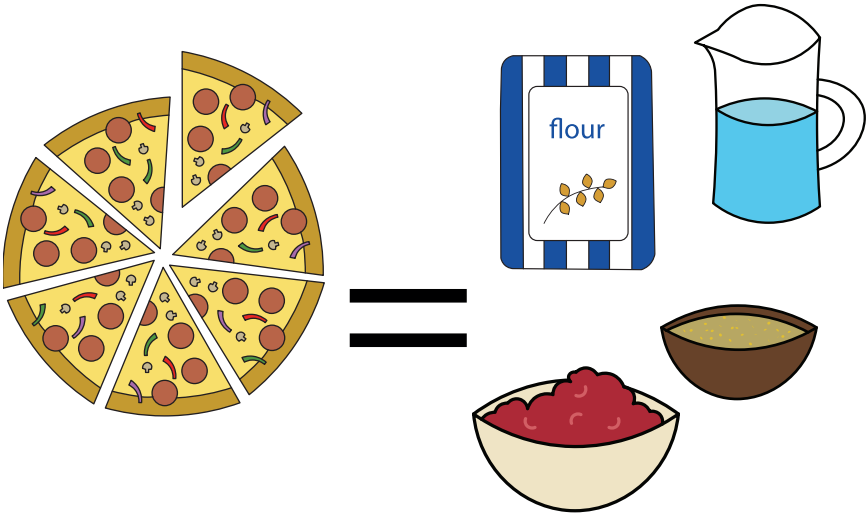
When humans burn coal, oil and gas, they release too much carbon dioxide (indicated with the chemical formula CO_2) into the air.

The blanket then becomes too thick and the Earth starts to get too hot. Because of its high content in the atmosphere, carbon dioxide can no longer control its power and it becomes destructive.



MORE!

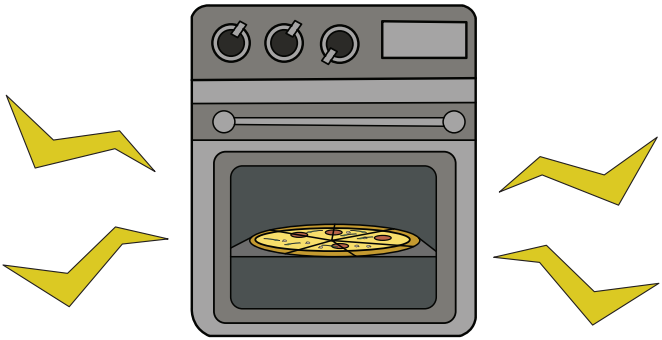
A CHEMICAL REACTION IS LIKE MAKING A PIZZA



A chemical reaction is a bit like making a pizza.

At the beginning, you only have the ingredients: flour, water, yeast, and tomato sauce. On their own, they are just separate things.

When you mix them together and then put them in the oven, something special happens. The heat from the oven releases energy and the ingredients change. Little by little, they stop being just flour and water and become a real pizza.



This is what a chemical reaction is. You start with some ingredients and, thanks to an energy source like heat, in the end you get something new that did not exist before. The pizza is no longer just its ingredients, it has become something different just like a chemical reaction forms something new.

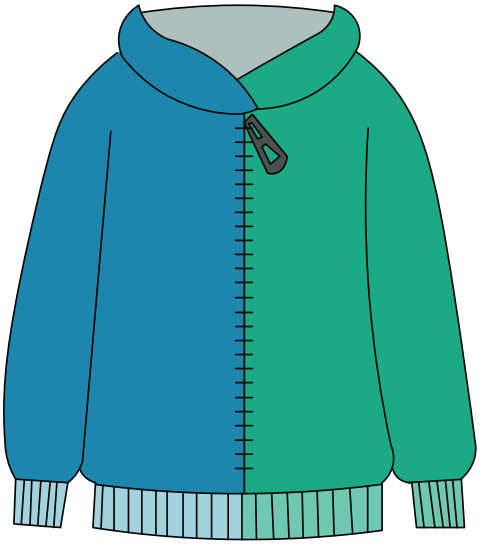
Can you think of other things that turn into something new when you mix them together?

WHAT DO AN ELECTROLYSIS CELL AND A HOODIE WITH A ZIPPER HAVE IN COMMON?

Imagine that an electrolysis cell is like a hoodie with a zipper.

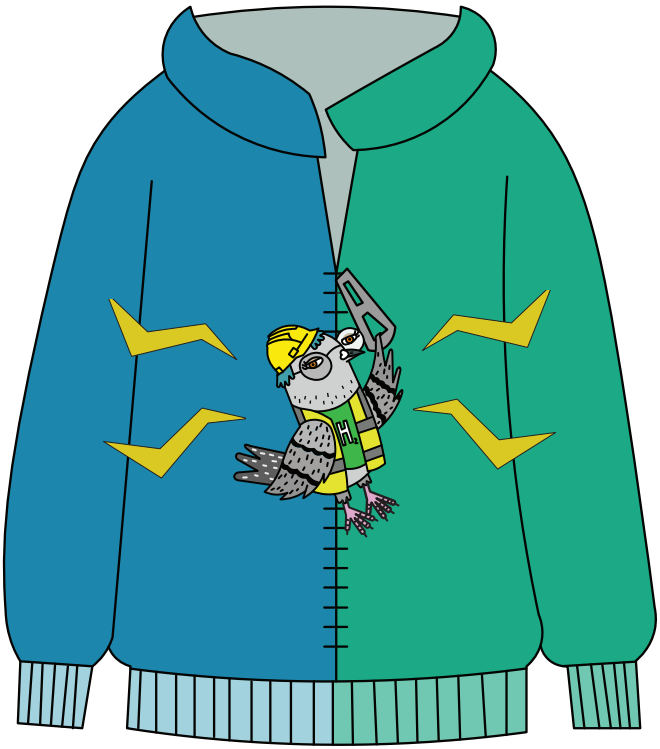
When the hoodie is zipped up, it is like water. Hydrogen and oxygen are together, just like the two sides of the hoodie held together by the zipper.

The zipper is the bond that keeps hydrogen and oxygen together. It does not open by itself, because the two parts like to stay joined.



The two sides of fabric next to the zipper are like the electrodes. They stay in the water and help the electricity move, but they do not change.

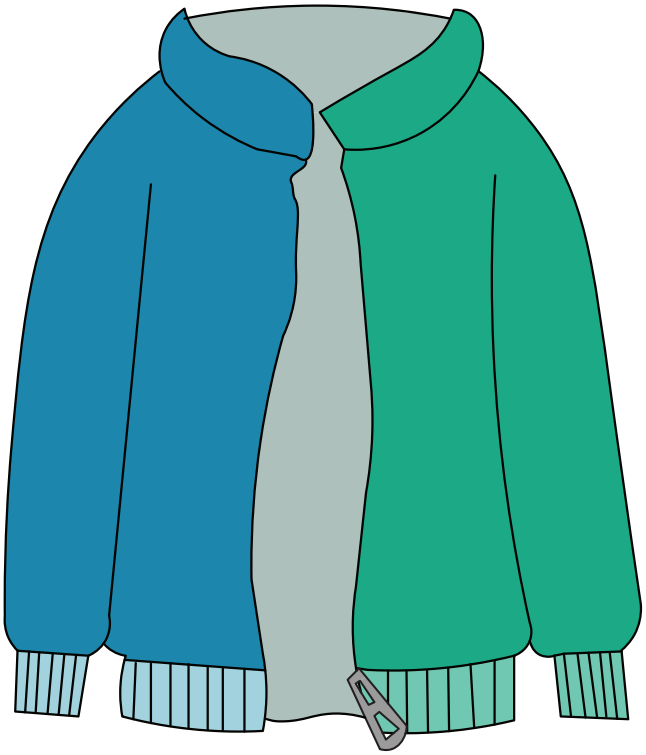
The hand pulling the zipper is the electricity. Electricity, when active, releases energy and does the work, just like a hand moving to pull down a zipper.



When the hand pulls the zipper down, the hoodie opens into two parts.

In the same way, during electrolysis, electricity passes through the electrodes and helps water split into hydrogen on one side and oxygen on the other. That is how electrolysis works, something that was joined is split thanks to electricity.

That is how electrolysis works, something that was joined is split.



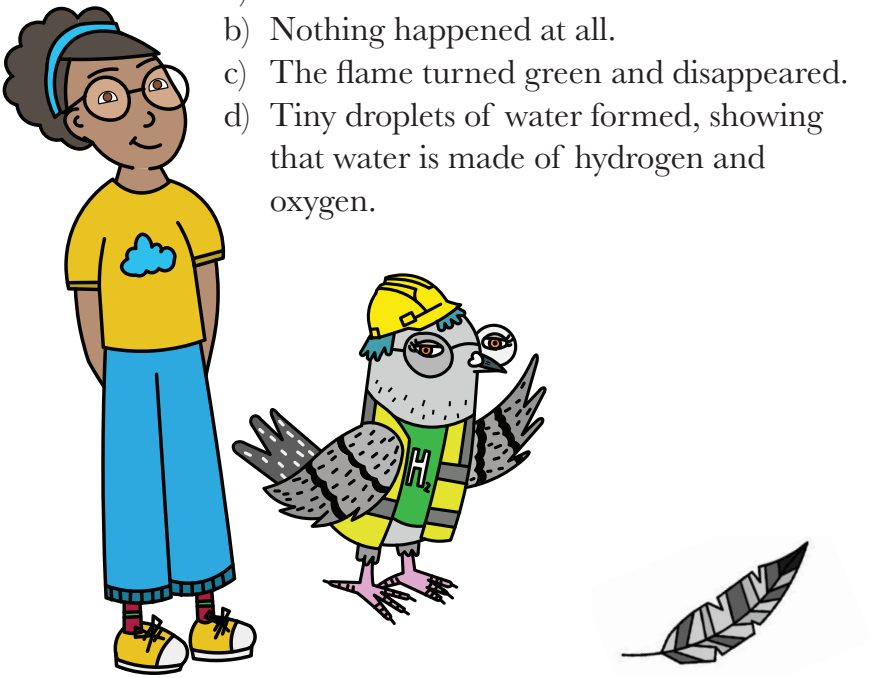
CHOOSE THE CORRECT ANSWER

1) WHAT DID HENRY CAVENDISH DISCOVER WHEN METALS LIKE ZINC, IRON OR TIN WERE PUT INTO ACID?

a) The metals disappeared without leaving any gas.
b) The reaction released hydrogen gas which burns quickly when in contact with oxygen.
c) The acid turned into water without any reaction.
d) The metals started to melt and form gold.

2) WHAT DID HENRY CAVENDISH DISCOVER WHEN HYDROGEN BURNED WITH OXYGEN?

a) It made smoke that smelled sweet.
b) Nothing happened at all.
c) The flame turned green and disappeared.
d) Tiny droplets of water formed, showing that water is made of hydrogen and oxygen.



3) HOW DOES AN AIRSHIP RISE AND MOVE THROUGH THE AIR?

a) The airship uses a steam engine to move while hydrogen in the envelope makes it float.
b) The airship flies because it has giant wings that flap like a bird.
c) The airship rises by burning hydrogen which makes it lighter than air.
d) The airship moves because the steam engine fills the envelope with hot steam.

4) HOW IS HYDROGEN GENERATED FROM WATER IN AN ENVIRONMENTALLY FRIENDLY WAY?

a) By burning fossil fuels to heat the water until hydrogen escapes.
b) By using electricity from renewable energy sources, like sun or wind, to split water in an electrolyser.
c) By mixing water with oil to make hydrogen float to the top.
d) By shaking the water very fast until hydrogen separates.

5) WHY IS HYDROGEN STORED IN SPECIAL CONTAINERS AFTER IT IS PRODUCED?

a) Because hydrogen is very heavy and sinks to the ground.
b) Because hydrogen is very light and can easily escape so it needs strong containers or underground storage.
c) Because hydrogen is dangerous and must be frozen immediately.
d) Because hydrogen turns into water if left in the air.

ARRANGE IN THE CORRECT ORDER

HOW DO FUEL CELLS WORK?

- ☐ This reaction produces water and powers electricity.
- ☐ In a fuel cell, hydrogen reacts with oxygen.
- ☐ The electric motor moves the car.
- ☐ The electricity flows from a fuel cell to power the electric motor.

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Clean Hydrogen Partnership

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