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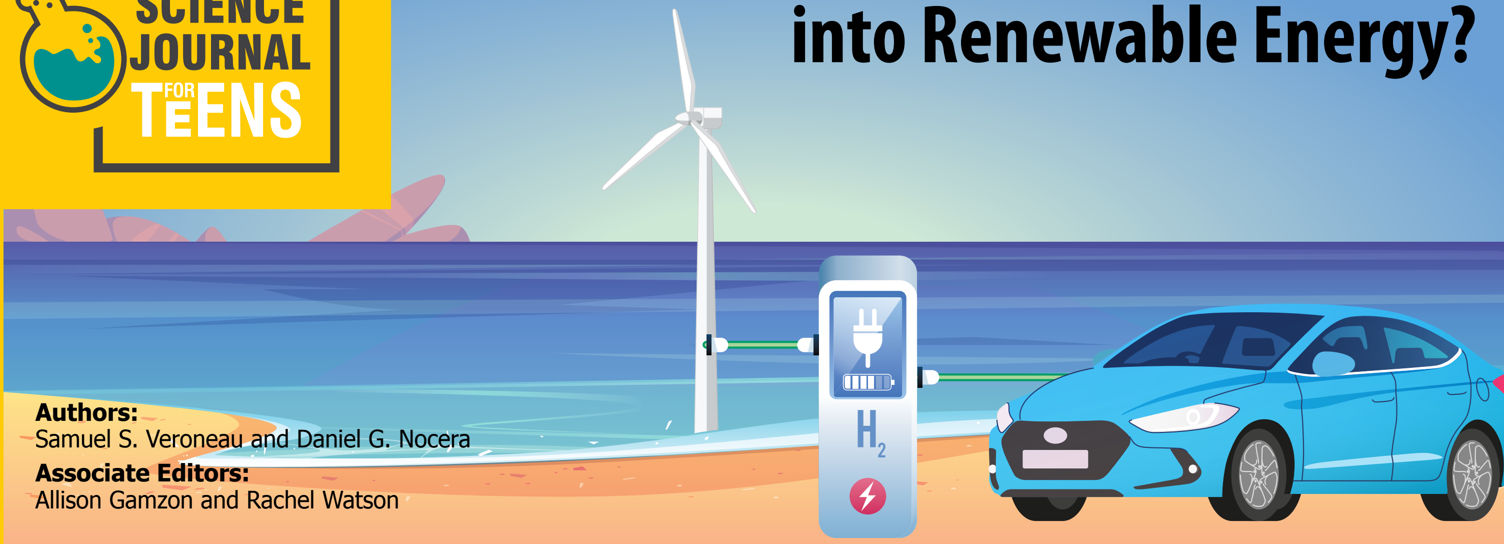
How Can We Turn Ocean Water into Renewable Energy?



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Abstract

Think about what life would be like without energy. No refrigerators, no computers, no cars, and no cellphones! Today, most of the world's energy comes from fossil fuels, which are nonrenewable resources (resources that take a long time for the Earth to make) that pollute our air and land. That is why we are trying to find cleaner, renewable energy resources that can power our planet.

Hydrogen is a great renewable fuel that can be made from water. Most of the water on Earth is saltwater, so we created a device that can make hydrogen from it at a low cost. It combines the process of osmosis with the reaction of water splitting. Our data show that this device is effective and efficient, which means hydrogen could become more available in the future.

Introduction

When you think of renewable energy, you probably think of solar and wind. These resources can definitely give us energy, but not always and not everywhere. Some places are not sunny or windy enough – and nowhere is sunny and windy *all* of the time. That's why scientists think hydrogen is an exciting type of renewable energy. We can make it using solar and wind energy, store it, and use it anywhere and anytime!

To make hydrogen, scientists use a process known as *water splitting*. In this process, electricity transforms water (H_2O) into hydrogen gas (H_2) and oxygen gas (O_2). Water splitting requires pure water without any extra bits like dirt particles that might cause problems. These impurities can *corrode* the materials used to split the water. But pure water is uncommon since 97% of the Earth's natural water is salty. So currently, before it can be split, water needs to be purified using expensive *desalination* techniques. That's why we wondered: could there be a low-cost, *efficient* way to split hydrogen from natural water?

We wanted to use *osmosis* to take the water out of the salty ocean and use it to make hydrogen. Osmosis occurs when a membrane separates two solutions. The membrane acts as a filter. It lets some materials through but not others, so we call it a *semipermeable membrane*.

For osmosis to occur, one of the solutions needs to be saltier than the other. This difference in *salinity* causes water to flow from the less salty solution through the membrane to the saltier solution. That is why if you put a grape in the ocean, it will shrivel up – the water leaves the grape because the ocean is saltier. We combined this process with water splitting to make hydrogen from saltwater.

A car filling up at a hydrogen fuel station in California

Source: https://www.energy.gov/eere/articles/h2usa-accomplishments-push-hydrogen-infrastructure-forward

Methods

We created a device (Figure 1) that can perform water splitting and osmosis at the same time. We placed a semipermeable membrane at the bottom of a tube and made sure it was held tight. Outside the tube we put a solution made with water and table salt (NaCl). When you dissolve NaCl in water, it turns into Na^+ and Cl^- , which are known as *ions*. This solution represents seawater.

Then we put a solution of another salt, sodium phosphate (Na_3PO_4), inside the tube. We made the solution inside the tube saltier so water could flow into the tube through the membrane. Most importantly, sodium phosphate doesn't react with anything, so it can make our solution saltier without any undesirable side effects.

At the top of the tube, we placed two wires made out of platinum. We connected the metal strips with wires and a power source. We wanted to keep the volume of the solution inside the tube constant. We determined how fast the osmosis could make water flow in and how fast the water splitting would "eat" it up. Then we set them up to be equal to determine how much electricity we needed to make the device work.

We ran the device for two days. During this time, we measured how much phosphate escaped our device and how much Cl^- got inside. We also measured the amount of hydrogen gas created. For comparison, we ran a water-splitting device directly in saltwater without osmosis.

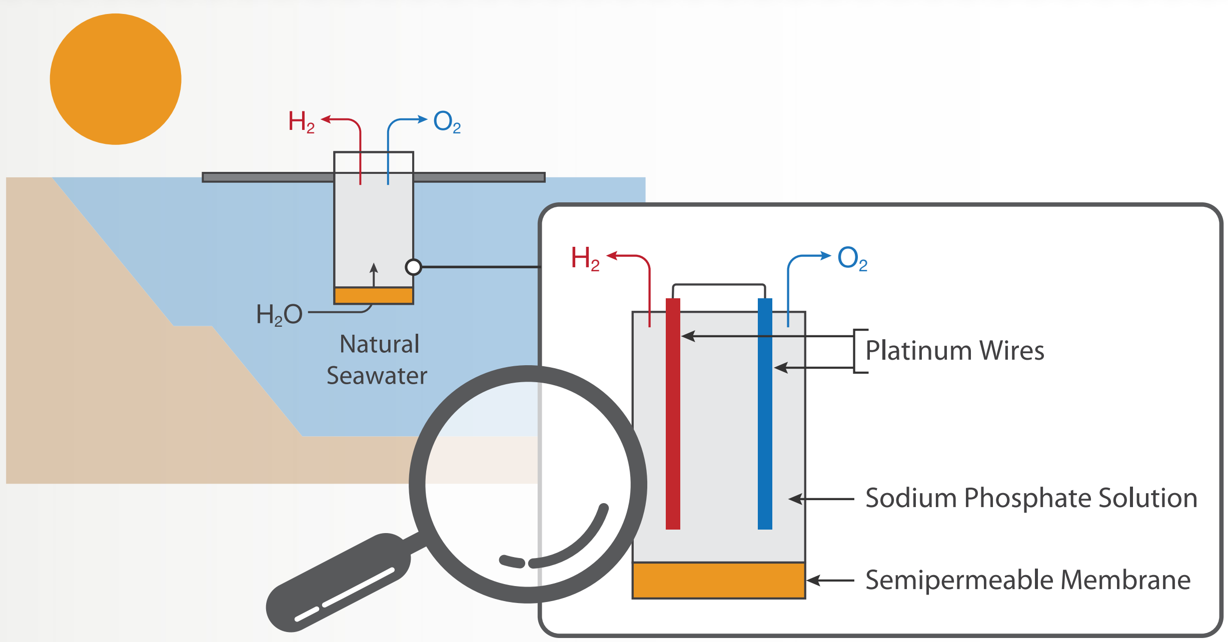

Figure 1:
Our forward osmosis water-splitting device.

Results

Our osmosis water-splitting device worked really well. At the end of the two-day period, we measured the total amount of hydrogen created by the device. We compared this value to the amount of hydrogen we expected the device to make. We call this comparison the *faradaic efficiency*. A high faradaic efficiency tells us that the water-splitting reactions occurred without any unexpected side reactions. The faradaic efficiency for the osmosis water-splitting device was 100% for hydrogen. When we tried to split saltwater without osmosis, the faradaic efficiency for hydrogen dropped down to only 50%.

Discussion

Our research shows that it is possible to create hydrogen from seawater using osmosis – and, better yet, that we can do it efficiently. We know that saltwater cannot be split into hydrogen gas as efficiently as pure water, because we get a much lower faradaic efficiency. Without osmosis, the Cl^- in the saltwater causes side reactions that make water splitting happen less efficiently. The membrane in our device stopped the Cl^- ions from entering the tube. By keeping the Cl^- out, the osmosis water-splitting device made as much hydrogen gas as possible.

Our next step is to improve the design and lower the cost of the device. We already tested new metals and found that nickel and stainless steel work even better. These metals are also much cheaper than platinum. We also want to explore other membrane materials to make our device more efficient.

Conclusion

With a growing population and growing energy demands, renewable energy has become essential. Our osmosis water-splitting device is a new approach to making renewable energy a reality. It will make hydrogen production more affordable by avoiding expensive water purification processes. It will also help make renewable energy a possibility anywhere in the world.

You can also help reduce the use of nonrenewable energy resources by conserving energy at home. You can switch to LED lightbulbs, take shorter showers, and take public transportation or carpool whenever possible. No matter what you choose to do, it will reduce your energy impact on the environment!

Glossary of Key Terms

Corrode – to cause gradual damage by chemical action. Rusting is a type of corrosion.

Desalination – a process to remove salt from water.

Efficient – achieving or creating as much as possible (in our case, hydrogen gas) with the least waste possible.

Faradaic efficiency – for a chemical reaction involving electricity, the percentage of electrons going to make your desired product (in our case, hydrogen gas). It's named for Michael Faraday, a 19th-century scientist who contributed to the field of electrochemistry.

Osmosis – a process that moves water through a semipermeable membrane to filter out unwanted solids, ions, and waste. We used forward osmosis, which relies on the difference in salinity to move the water (from a less salty solution to a saltier one). This is different from reverse osmosis, which requires lots of pressure to move water through the membrane and is often used in desalination.

Ions – atoms that have a positive or a negative charge because they have lost or gained electrons. Na^+ is a positively charged ion because it has lost an electron and Cl^- is a negatively charged ion because it has gained an electron.

Salinity – a measure of how much salt is dissolved in a liquid (usually water).

Semipermeable membrane – a material that allows certain substances through but not others. For example, a material that allows water through but not salt.

Water splitting – a process that uses electricity to break water (H_2O) into hydrogen gas (H_2) and oxygen gas (O_2).

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