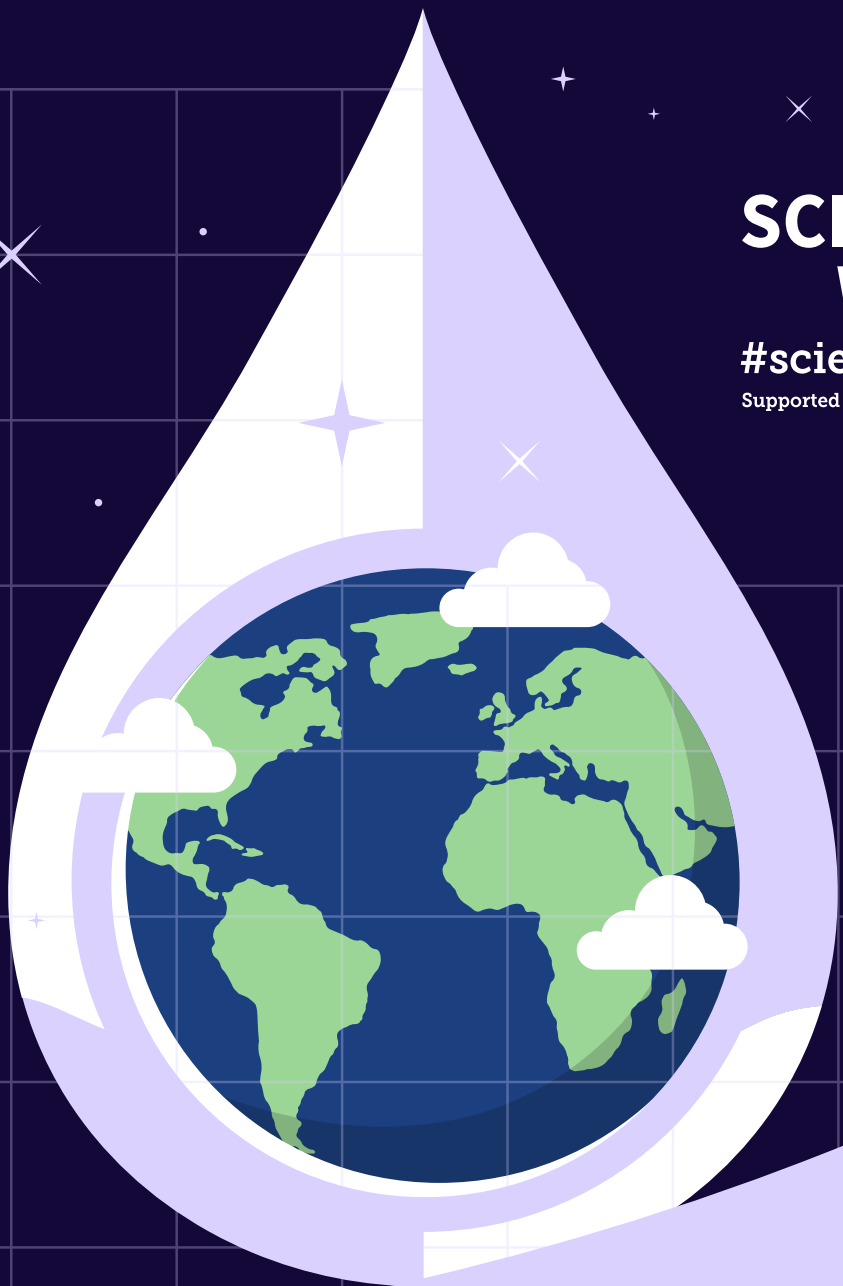
Post-Primary Activity Pack

Activities for learners
at a post-primary school level

Ireland esero

Water: From Molecule to Ocean

SCIENCE WEEK
#scienceweek
Supported by Research Ireland



esa
EUROPEAN SPACE AGENCY

Taighde Éireann
Research Ireland

8th-15th November 2026

What is Science Week?

Science Week is a week-long event in Ireland each November, celebrating science in our everyday lives. It features nationwide events and regional festivals, connecting the public with STEM through a wide variety of activities. This year it's November 8th to November 15th.

The theme for 2026 is **Water - From Molecule to Ocean**. Water is essential for all life on Earth, and it plays an important role in our environment, communities and future. From rivers, lakes and oceans to the water that comes out of our taps, there is so much to discover!

This year, Science Week encourages us to explore the science behind water, learn about new ideas and inventions, and discover how we can protect our water supplies and use water sustainably.

Science Week takes place across Ireland, with festivals, workshops, school activities, community events and much more. It brings together scientists, researchers, teachers, students and communities to explore how science can help us understand and solve challenges in the world around us. There are lots of opportunities to ask questions, try new things and discover something new.

Science Week would not be possible without the many partners and organisations that organise events and activities across the country. Their work helps make science exciting, accessible and enjoyable for everyone.

For more information, exciting events and activities, and the latest Science Week 2026 updates, visit the official Science Week website at **www.scienceweek.ie**!

Are you ready to dive into Science Week 2026? Get curious, explore the theme of Water and discover the science all around you!



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What's on for Science Week 2026?

SCIENCE WEEK

#scienceweek

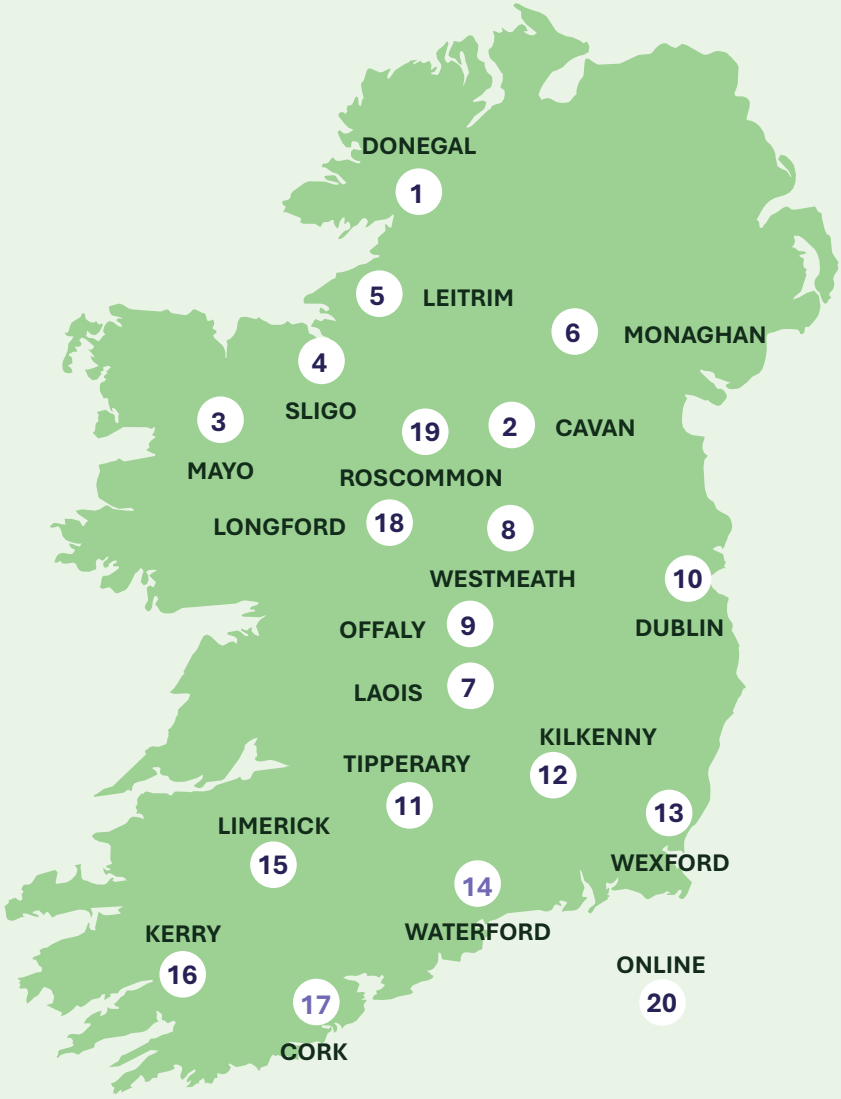
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Science Week Events and Festivals

Discover what's happening near you this Science Week with the Festival Map, your guide to STEM events taking place across Ireland.

For second level school events, select second level student audience on the **Science Week Events page.**

Find out more at **ScienceWeek.ie**



1. **DONEGAL**
   - Finn Valley Science Festival
   - Sligo Science festival
2. **CAVAN**
   Cavan Monaghan Science Festival
3. **MAYO**
   Circus Science By The Sea Festival 2026
4. **SLIGO**
   Sligo Science Festival
5. **LEITRIM**
   - Ripple Effect: Leitrim & Roscommon Science Festival
   - Sligo Science festival
6. **MONAGHAN**
   Cavan Monaghan Science Festival
7. **LAOIS**
   Midlands Science Festival
8. **WESTMEATH**
   Midlands Science Festival
9. **OFFALY**
   Midlands Science Festival
10. **DUBLIN**
    - C'mere Til I Tell Ye
    - North Dublin Science Festival
11. **TIPPERARY**
    Tipperary Festival of Science
12. **KILKENNY**
    Kilkenny Science Festival
13. **WEXFORD**
    Wexford Science Festival
14. **WATERFORD**
    South East Science Festival
15. **LIMERICK**
    Limerick Festival of Science
16. **KERRY**
    Kerry Science Festival
17. **CORK**
    SpaceFest 2025 - 2027
18. **LONGFORD**
    Midlands Science Festival
19. **ROSCOMMON**
    Ripple Effect: Leitrim & Roscommon Science Festival
20. **ONLINE**
    North Dublin Science Festival

A selection of Science Week events across the country...

There are hundreds of events taking place as part of Science Week 2026 all over Ireland. Check out the Science Week website to find one near you. Here are some events suitable for second level students which we think you may find interesting – check these out and explore more for yourself at **scienceweek.ie/whats-on**

Who Do THEY Think You Are? What Does Your Data Say About You? @ Dublin City University

Monday 9 - Friday 13 November, 09:00 – 17:00

Every day, you leave digital breadcrumbs across your devices. Who Do THEY Think You Are? is an interactive free exhibition demystifying data tracking, digital profiling, and data brokering. Scan a QR code on your phone to see what inferences data brokers make, map your digital day, test your Privacy IQ, and unlock resources to take control of your footprint.



Find out more - Who Do THEY Think You Are? What Does Your Data Say About You? - Science Week

Let's Talk Science Festival 2026 @ Rediscovery Centre, Dublin

Saturday 7 November, 11:00 – 16:00

Join us on Saturday 7th November 2026 for a spectacular day of discovery. It's an all-day, family-friendly event packed with exciting STEM activities for all ages. From hands-on experiments to mind-blowing demonstrations, there's something for every budding scientist to enjoy. Come explore everything from technology and ecosystems to the special science week theme of water and its vital role in our world.



Find out more and book - Let's Talk Science Festival 2026 - Science Week

Fuel, Feel, Flourish @ The Island Theatre, Ballinamore, Leitrim

Thursday 12 November, 20:00 – 21:00



Fuel, Feel, Flourish is an engaging and informative evening created especially for teenage girls, bringing together experts in nutrition, psychology, skin health and sport for practical conversations about growing up, confidence and wellbeing.

Dr Tara Treacy, GP and founder of ClearDerm, will tackle teenage skin and acne, Dr Sharon Madigan, Head of Performance Nutrition at the Sport Ireland Institute, who will talk about how teenage girls can properly fuel their bodies, Charlene Tyrrell, All-Ireland-winning Leitrim footballer, will bring a real-life perspective.

Find out more and book - **Fuel, Feel, Flourish - Science Week**

Mind Waves @ Gaiety School of Acting, Dublin

Friday 13 - Saturday 14 November, 19:30



This Science Week, themed Water: From Molecule to Ocean, students from the Gaiety School of Acting, The National Theatre School of Ireland, bring two journeys to life through theatre, inspired by research at UCD Conway Institute.

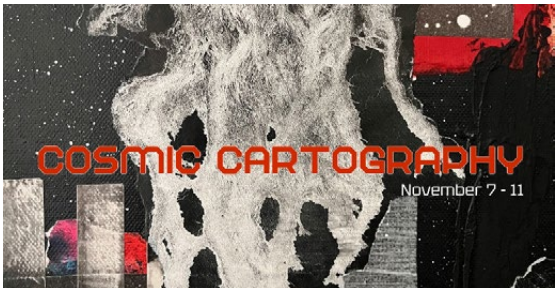
The first explores micro- and nanoplastics and cardiovascular health. Tiny plastic particles are found in the environment and are increasingly detected in the human body. UCD researchers are investigating whether they can accumulate in blood-vessel plaques and contribute to heart disease.
The second explores zebrafish, a freshwater fish helping scientists understand human disease, from inherited blindness to eye cancer, and investigate treatments.

Following each performance, audiences can join a Q&A with UCD scientists and the cast.

Find out more - Mind Waves - Science Week

Cosmic Cartography Exhibition @ Marina Market, Cork

Saturday 7 - Wednesday 11 November, 11:00 – 18:00



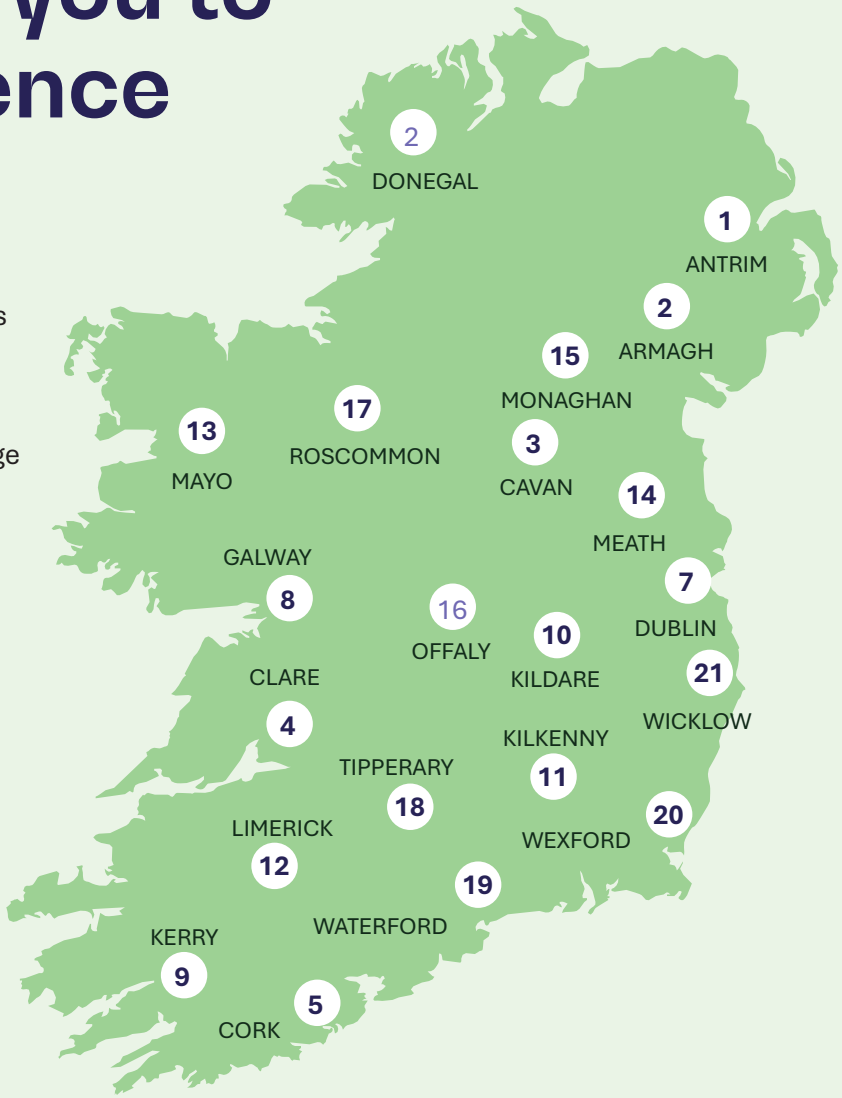
How do we map a universe too vast to fully comprehend? How have people across cultures made sense of the stars, and how do we find our place in the cosmos? From marking time, tracking the seasons and crossing the seas, the night sky has been a source of scientific observation and artistic inspiration. *Cosmic Cartography* invites you to look up, look closer and get curious about our universe.

Find out more - **Cosmic Cartography Exhibition - Science Week**

Places near you to explore Science

Across Ireland there many are amazing **Research Ireland Discover Centres** to go and explore science and the world around us. These centres support schools to engage learners in science education outside of the classroom in an inquiry-based way and provide opportunities to meet scientists and engineers from a range of disciplines.

Find one near you below and contact them to plan a trip!



1. **ANTRIM**
   - W5
2. **ARMAGH**
   - Armagh Observatory Planetarium
3. **CAVAN**
   - Cavan County Museum
4. **CLARE**
   - Aillwee Burren Experience
   - Shannon Aviation Museum
5. **CORK**
   - Fota Wildlife Park
   - Lifetime Lab
   - Mitchelstown Cave
   - MTU Blackrock Castle Observatory
   - The Hollies Centre for Practical Sustainability
6. **DONEGAL**
   - Glenveagh National Park
7. **DUBLIN**
   - Airfield Estate
   - NSPCA Rathfarnham
   - Dublin Zoo
   - EPIC: The Irish Emigration Museum
   - DIAS Dunsink Observatory
   - Global Action Plan Ireland
   - Irish National Sailing and Powerboat School
   - The Rediscovery Centre
   - Think Big Space
   - Explorium
8. **GALWAY**
   - An Gáirdín
   - Brigit's Garden
   - Galway Atlantaquaria
9. **KERRY**
   - Crag Cave
   - Dingle Ocean World Aquarium
   - Tralee Bay Wetlands Centre
10. **KILDARE**
    - Irish National Stud & Gardens
    - Irish Peatland Conservation Council
    - Lullymore Heritage & Discovery Park
11. **KILKENNY**
    - Castlecomer Discovery Park
    - National Reptile Zoo
12. **LIMERICK**
    - Craft Maker Space
13. **MAYO**
    - Ballycroy Visitor Center - Wild Nephin National Park
    - National Museum of Ireland - Turlough Park
14. **MEATH**
    - Emerald Park
15. **MONAGHAN**
    - Knocknagrave Environmental Centre
16. **OFFALY**
    - Birr Castle Demesne and Historic Science Centre
    - Clara Bog
17. **ROSCOMMON**
    - Arigna Mining Experience
18. **TIPPERARY**
    - Cabragh Wetlands
    - Cloncannon Biofarm
19. **WATERFORD**
    - Lismore Heritage Centre
    - Oceanics Surf School and Marine Education Centre
    - Waterford Nature Park
20. **WEXFORD**
    - Wexford Wildfowl Reserve
21. **WICKLOW**
    - Kippure Estate Education Centre

Dublin Zoo

www.dublinzoo.ie



Located in Phoenix Park, Dublin Zoo is an exciting place to explore the science of animals, wildlife and the natural world. Students can discover how different species live, learn about animal behaviour and explore the importance of biodiversity and conservation. A visit to the zoo also highlights how habitats, food chains and ecosystems work together, and why protecting endangered species is so important. From understanding how animals adapt to their environments to discovering how we can protect wildlife for the future, Dublin Zoo brings science to life!

Galway Atlantaquaria

www.nationalaquarium.ie



Located in Salthill, Galway Atlantaquaria is Ireland's largest native species aquarium and a fantastic place to explore the science of water and marine life. Students can discover the amazing creatures that live in Ireland's rivers, lakes and seas, learn how aquatic animals survive in their environments, and explore the importance of healthy marine ecosystems. From understanding food chains and ocean habitats to discovering how pollution affects marine life, a visit to the aquarium shows why protecting our waterways and oceans is so important. It's a great way to dive into the science of water and discover the incredible life beneath the surface!

Explorium

www.explorium.ie



Located in Sandyford, Dublin, Explorium – Ireland's National Sport and Science Centre is an interactive science centre where students can explore science, technology, engineering and maths (STEM) through hands-on exhibits and exciting challenges. Discover how the human body works, experiment with forces and motion, and explore the science behind sport, movement and technology. With opportunities to test ideas, solve problems and learn by doing, Explorium makes science fun, engaging and relevant to everyday life. It's a great place to get curious, challenge yourself and discover the science all around you!

Oceanics Surf School and Marine Education Centre

www.oceanics.ie



Located in Tramore, County Waterford, Oceanics Surf School & Marine Education Centre helps students explore marine science and discover the importance of protecting our oceans. Through educational activities, seashore safaris and rockpool explorations, students can learn about marine wildlife, coastal habitats, tides and ocean conservation. The centre also offers school programmes through the Marine Institute's Explorers Education Programme, bringing science to life through hands-on learning and outdoor discovery.

Discover Dingle Oceanworld Aquarium

www.dingle-oceanworld.ie



Located in Dingle, County Kerry, Dingle Oceanworld Aquarium is a great place for students to explore marine science and discover the amazing diversity of life in our oceans. Students can learn about sharks, penguins, otters and other aquatic animals while exploring their habitats, behaviours and adaptations. School groups can also take part in guided, aquarist-led tours to learn more about marine ecosystems, biodiversity and ocean conservation. It's an exciting opportunity to discover how science helps us understand and protect marine life!

Space as a Tool for Teaching STEM



Bring STEM learning to life in your classroom with these exciting, hands-on projects from the European Space Agency (ESA) that inspire curiosity, problem-solving, and innovation. Each project offers students the opportunity to engage with real-world science and technology challenges, fostering inquiry-based learning and developing 21st-century skills. Whether it's coding for the International Space Station, designing a lunar habitat, investigating local climate issues, or building a mini satellite, these projects will captivate learners and provide valuable cross-curricular learning experiences.

Below are details on each project, complete with resources and instructions on how to get your students involved.

To find out more and register for the projects, go to esero.ie/projects/

Astro Pi Challenge

Engage Your Students with Real Coding in Space!

The European Astro Pi Challenge, created by ESA and the Raspberry Pi Foundation, offers an incredible opportunity for your students to send their code to the International Space Station (ISS). This project helps students gain hands-on experience with scientific experimentation in space and practise logical thinking and computing skills, using Python programming language

This project is ideal for introducing coding, data analysis, and space science in an engaging and practical way. Teachers can access lesson plans and activity guides to integrate the challenge into their classroom.

For registration and additional information, visit esero.ie/astro-pi



CanSat

Let Your Students Build and Launch Their Own Satellite.

Introduce your students to the exciting world of aerospace engineering with the CanSat project. This ESA competition challenges students to design, build, and launch a mini-satellite—a CanSat—that fits into the size of a drinks can. It's a hands-on experience that brings space technology and engineering to life. Students will

- **Design and Build a CanSat**
- **Launch and Collect Data**
- **Analyse and Present Data**

This is a perfect project for students in TY and senior cycle or equivalent in schools, Youthreaches, and youth clubs interested in electronics, coding, and engineering, providing a practical introduction to space missions.

For registration and additional information, visit esero.ie/cansat



Climate Detectives

Investigate Climate Change with Your Students!

Empower your students to tackle real-world climate issues with the Climate Detectives project by ESA. This initiative allows students to become young climate scientists. They can complete Earth related activities, collect evidence and earn Detectives badges.

For registration and additional information, visit esero.ie/climate-detectives



Moon Camp Challenge

Help Your Students Design Space Habitats!

Get your students thinking about space exploration with the Moon Camp Challenge, a project run by ESA and the Airbus Foundation. In this challenge, students will design a lunar base capable of sustaining human life on the Moon, or a space base further afield in our Solar System. They will explore the challenges of living in extreme environments and then create a model of their solution.

For registration and additional information, visit esero.ie/moon-camp

Activities

Time to make a splash and get hands-on learning this Science Week 2026!

These activities are suitable for secondary school and Youthreach classrooms and explore a range of water related topics, from water in our environment, to water as an energy source, and using images and data from ESA Earth Observation satellites to understand our oceans.

Let's dive in!

Extracting Water from Lunar Soil

Learn about filtration and distillation, and changes of state of matter while exploring water on the Moon.

Students will interpret data from a pressure vs. temperature graph for water and discuss how changes of state are different on the Moon compared to what we are used to on Earth. They will compare two methods for separating mixtures, simple distillation and filtration, in the context of extracting water from lunar soil and decide which is most efficient on Earth and on the Moon.

Power from Water

Explore how to produce oxygen and hydrogen on the Moon in this set of three activities.

Students will learn about electrochemistry and study electrolysis which uses an electric current to split water into its components: hydrogen and oxygen. These products can be used as propellants for spacecraft and/or to provide oxygen to support a crew.

Highways of the Ocean

Investigate sea currents and the connection to climate in this set of activities.

Students will use a multimedia module to learn about sea currents, the highways of the oceans, and how they are important for understanding local climates. They will investigate what causes ocean currents through hands-on activities and using satellite images to analyse the temperature of the sea surface. Students will gain an understanding of why satellite observations are useful for monitoring sea currents.

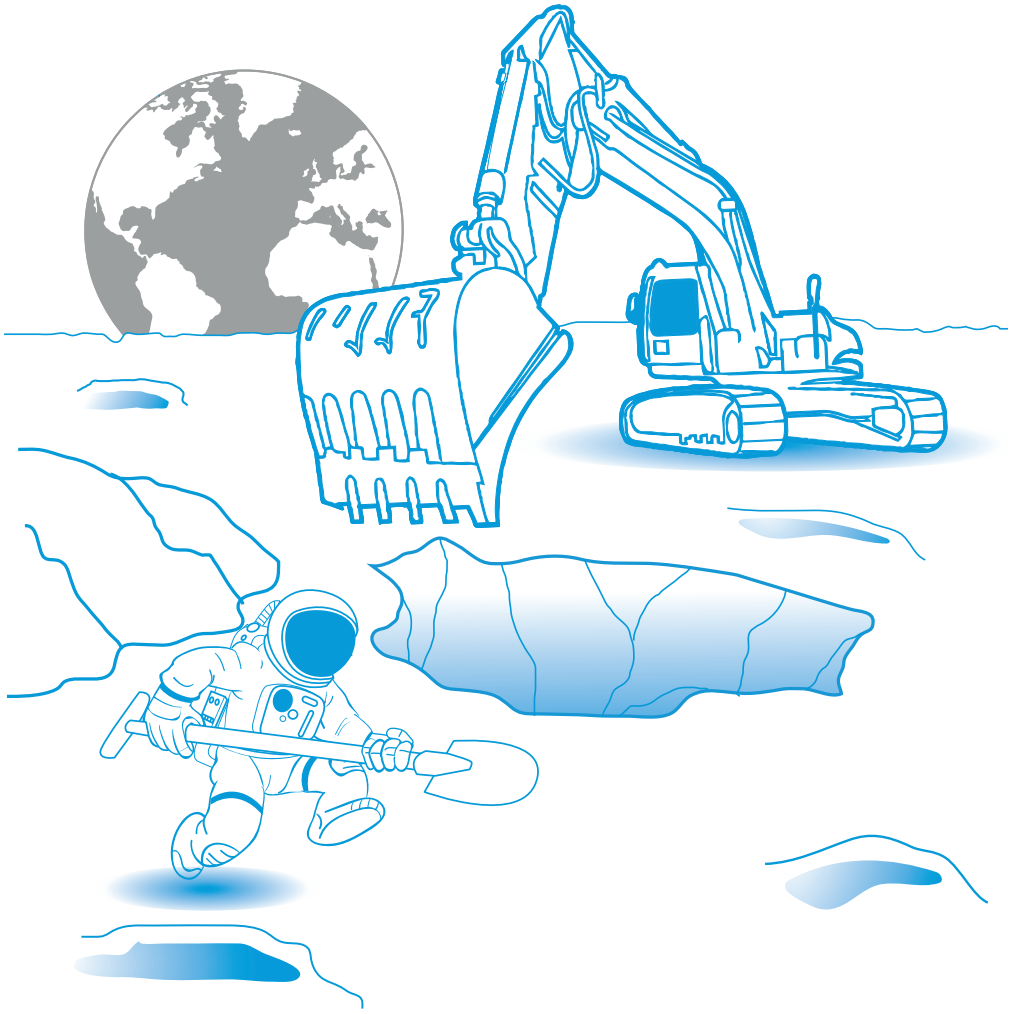
This would be a useful activity to use as part of the Climate Detectives ESA School Project!

chemistry | C10

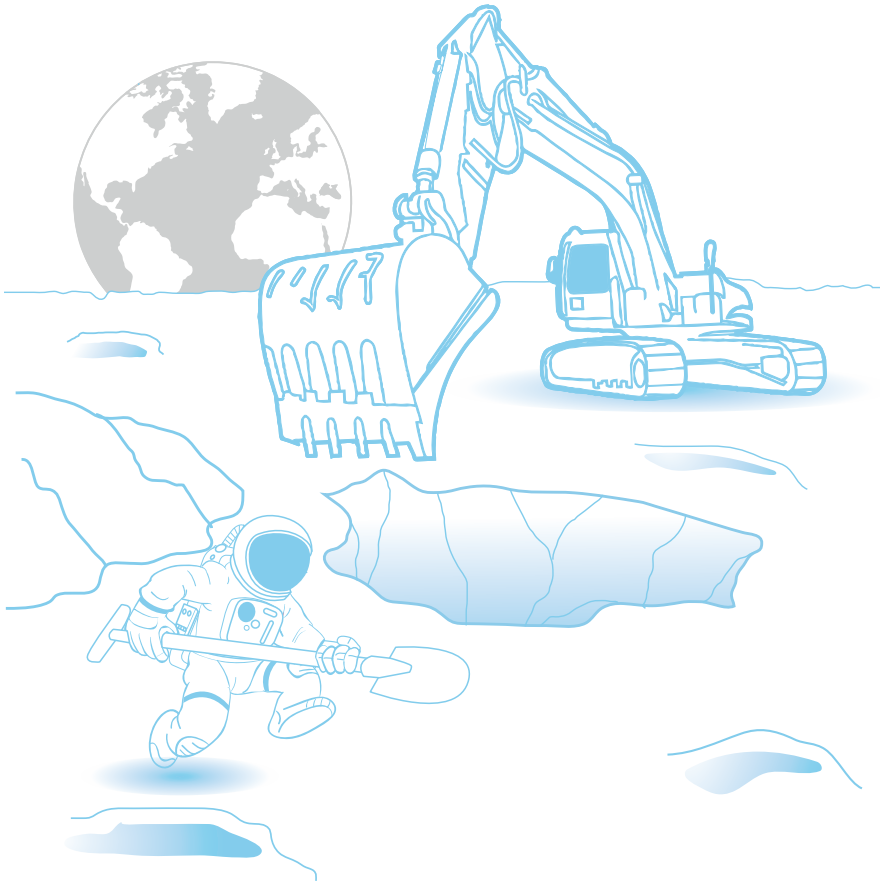
teach with space

→ EXTRACTING WATER FROM LUNAR SOIL

Learning about filtration and distillation



teacher guide & student worksheets



Teacher guide

Fast facts	page 3
Summary of activities	page 4
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Activity 1: Is water different on the Moon?	page 6
Activity 2: Filtration or distillation?	page 9
Student worksheet	page 13
Links	page 22
Annex	page 23

teach with space – extracting water from lunar soil | C10
www.esa.int/education

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teachers@esa.int

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→ EXTRACTING WATER FROM LUNAR SOIL

Learning about filtration and distillation

Fast facts

Subject: Chemistry, Physics
Age range: 12-16 years old
Type: laboratory activity
Complexity: medium
Teacher preparation time: 30 minutes
Lesson time required: 1 hour and 20 minutes
Cost: low – all equipment should be available in a school science laboratory
Location: laboratory
Includes the use of: pre-prepared blocks of ice mixed with sand
Keywords: Moon exploration, Filtration, Distillation, States of matter, Phase transitions.

Brief description

In this resource, students will learn about changes of state of matter using water on the Moon as an example. They will interpret data from a pressure vs. temperature graph for water to enable a discussion about how changes of state are different on the Moon compared to what we are used to on Earth. They will then compare two methods for separating mixtures, in the context of extracting water from lunar soil. They will be given pre-prepared lunar soil analogue blocks and compare simple distillation to filtration and decide which is most efficient on Earth and on the Moon.

Learning objectives

- Learning how changes of state vary depending on pressure and temperature.
- Understanding changes of state in terms of the particle model.
- Learning to use distillation equipment to separate mixtures.
- Using filtration to separate mixtures.
- Carrying out experiments appropriately, having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.
- Evaluating methods and suggesting possible improvements and further investigations.
- Interpreting percentages and percentage changes as a fraction or a decimal.

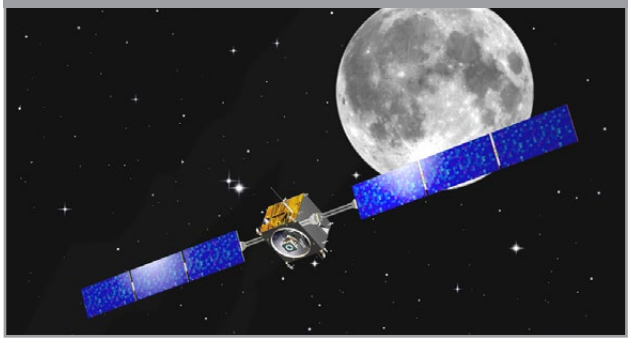
→ Summary of activities

Summary of activities					
	Title	**Description**	**Outcome**	**Requirements**	**Time**
1	Is water different on the Moon ?	Identifying the water phases. Analysing a pressure vs. temperature graph for water in the context of the Moon.	Learn how the extraction of water could be carried out on the Moon.	None	20 minutes
2	Filtration or distillation?	Comparing filtration and distillation processes for “lunar ice cores”.	Plan and carry out an experiment in filtration and distillation.	Completion of activity 1 is advised	1 hour

→ Introduction

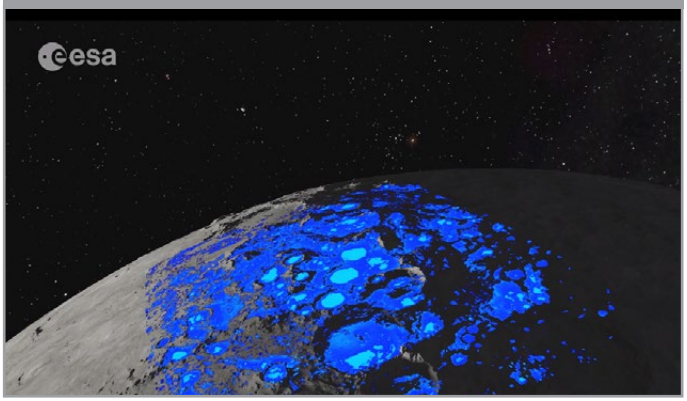
Between 1969 and 1972, twelve astronauts visited the Moon. These lunar missions were the only time humans walked on a world other than Earth. Since then several satellites and robotic missions have studied the Moon. One of those missions was SMART-1, which orbited the Moon between November 2004 and September 2006. SMART-1 took detailed images of the surface and studied what the rocks are made of. The mission ended with a deliberate crash into the lunar surface.

Figure 1



↑ ESA's SMART-1 was Europe's first Moon orbiter

Figure 2



↑ Map of the lunar south pole of where water ice would be stable buried in the top 1 metre (dark blue), and on the surface (light blue).

In 2009, the presence of water on the lunar poles was discovered. However, water only exists on the Moon in the form of ice. The Moon has no atmosphere, so the pressure at the surface is extremely low. At low pressures, water can only exist in the form of a solid (ice) or a gas. In a permanently shadowed crater, where the temperature can be as low as -248°C, the water exists as ice. When the surface of the Moon is heated by the Sun it can reach temperatures of up to 123°C. Because of the low pressure on the Moon, when water ice reaches -40°C it will change state directly from ice (solid) to water vapour (gas). Nowadays ESA, in collaboration with other Space Agencies, is planning to send robotic missions and astronauts to explore the surface of the Moon once more.

In the future, if we wish to build a settlement on the Moon, we will need to consider how to extract the ice from the lunar regolith (soil).

In this set of activities students will have to imagine, they are on a lunar mission and will have to extract water from "lunar" ice cores.

→ Activity 1: Is water different on the Moon?

In this activity, students will investigate the water states and water phase transitions. Students will analyse the phase diagram for water and conduct a simple experiment to learn that pressure and temperature affect the state of water. Lastly, students will relate what they learn to Moon exploration and how water might be extracted from regolith on the Moon.

Equipment

- Syringe
- Hot water
- Printed student worksheets for each student

Exercise

Distribute the student worksheets to each student. Students are first asked to name (identify) the changes of state:

- Sublimation is where a solid changes to a gas (no liquid phase).
- Deposition is where a gas changes to a solid (no liquid phase).
- Freezing is where a liquid changes to a solid.
- Melting is where a solid changes to a liquid.
- Evaporation is where a liquid changes to a gas.
- Condensation is where a gas changes to a liquid.

Students will also have to draw the particle model for the three states of matter.

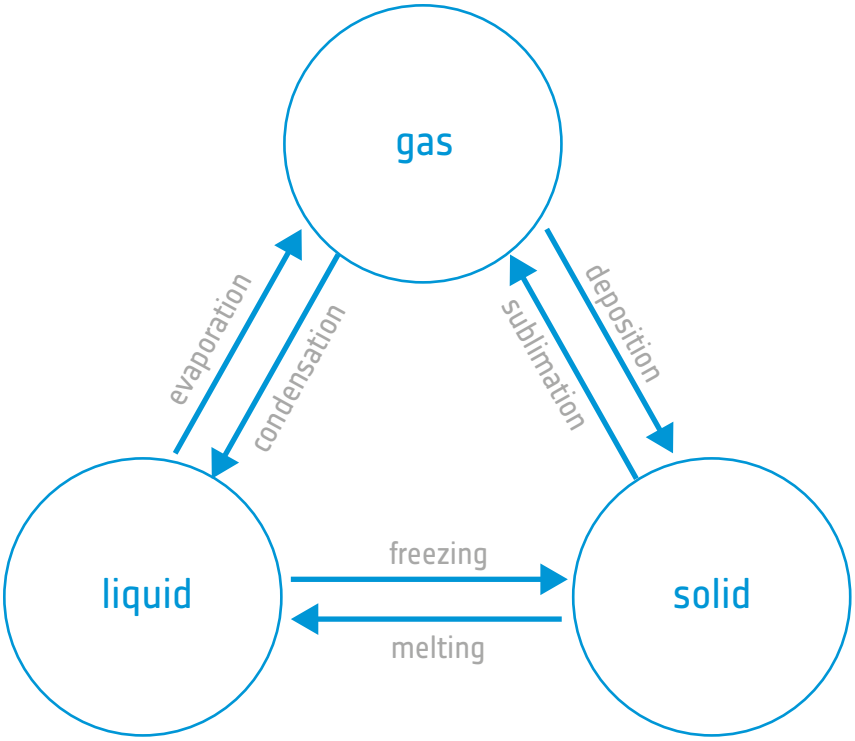
In question 3 students will have to relate the changes of state of water with temperature and pressure. You can provide familiar examples like going diving (pressure increases) and going to the top of a mountain (pressure decreases).

When pressure decreases, water boils at a lower temperature. In question 4 b) students can test the hypothesis they presented in question 4 a), using a syringe to create an environment with lower pressure.

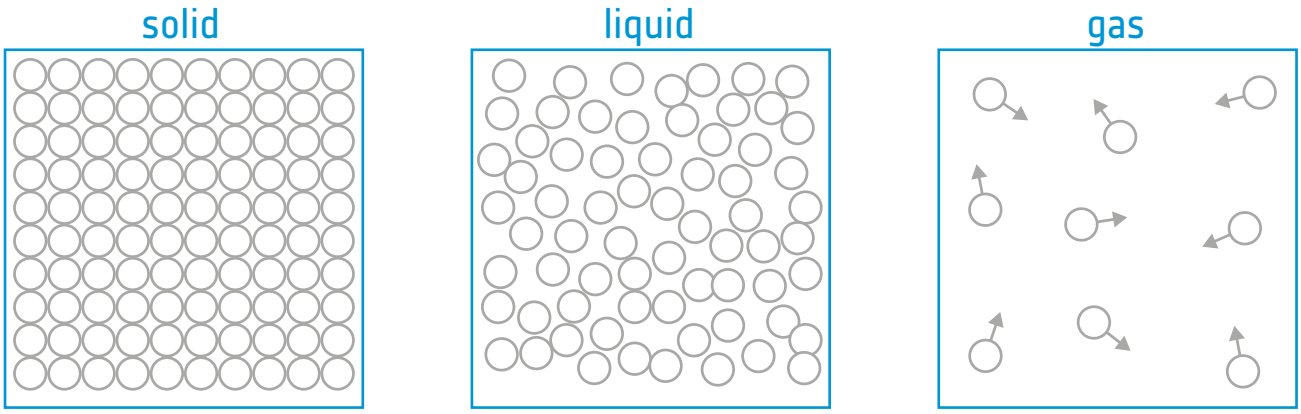
In question 5 we ask the students to apply the concepts they have learned to the Moon environment. You can start by relating some of the previous examples with the Moon: on top of a mountain on Earth air pressure is lower because there is less atmosphere there. On the Moon there is no atmosphere, so the pressure is very low.

Consult the results section for complete answers to the student worksheet questions.

Results



2.



3.

Water state	Temperature range (K)	Pressure (atm)
Solid	<273	1
Liquid	273-373	1
Gas	>373	1

4. a. The boiling point of water decreases as the pressure decreases. At very low pressure (~0.01 atm) water cannot exist in a liquid state.

   b. The pressure in the syringe decreases. Even though the water temperature is below 100°C , the water reaches boiling point and should begin to evaporate.

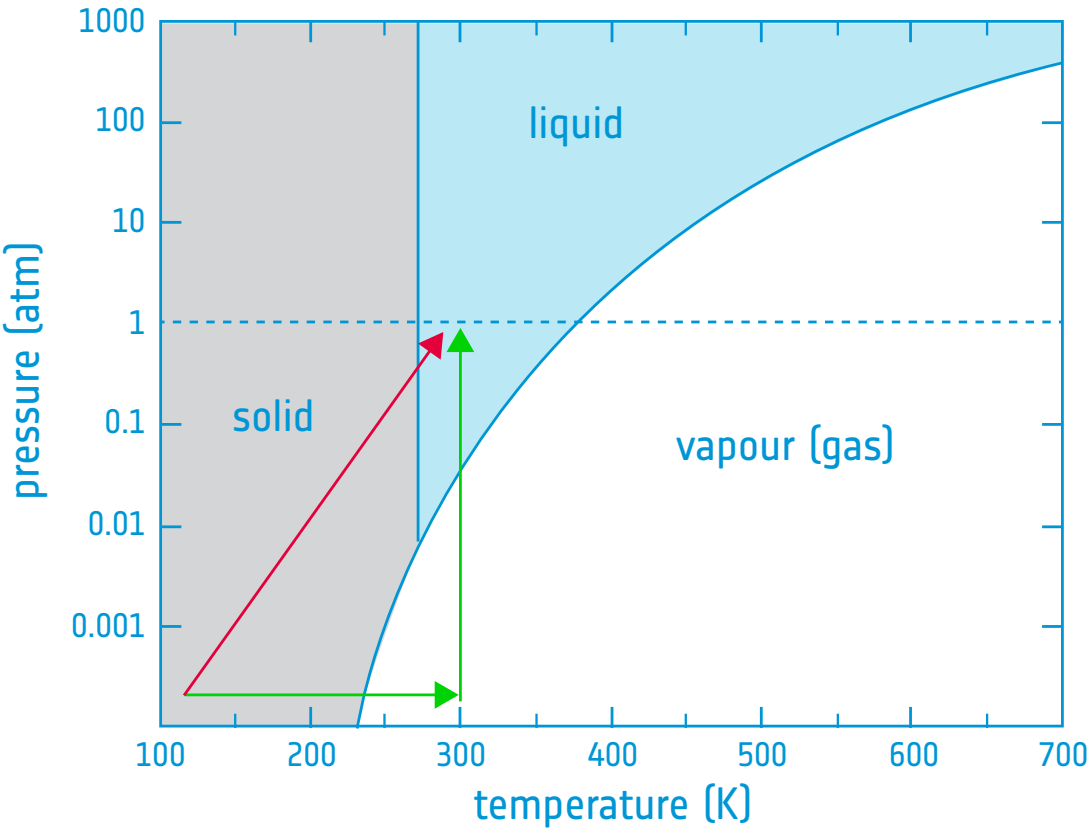
5. a. Figure A2 shows that at very low pressures (close to 0 atm), independent of temperature, water does not have a liquid phase. The Moon has no atmosphere, at the surface the pressure is approximately 0 atm and so the water ice will sublimate, transitioning straight between solid and gas.

   b. Solid (ice)

   c. If you remove the ice from the crater the temperature will increase. When the water ice heats up it will begin to sublimate. If the ice is not kept in a sealed container it will dissipate into a gas and you will lose all the water you collected. This could be counteracted by keeping the ice in a sealed container.

   d. To obtain liquid water you have to increase the temperature and presurre.

   e. Below are a few examples of correct answers.



Example 1 (green) : Heating in sunlight on lunar surface, then pressurising inside Moon base.

Example 2 (red): Pressurising and heating simultaneously. This would occur if the samples were taken directly into a pressurised environment.

→ Activity 2: Filtration or distillation?

In this activity, students will compare two methods of separating water from sand: filtration and distillation. They will be given simulated lunar ice/soil cores to use in their experiment and calculate the percentage mass of water extracted in each case.

Equipment

- Printed student worksheets for each group
- Pre-prepared ice-cores (see Annex)
    - Weighing scales
    - Sand and water
    - Test-tube packaging or similar

Filtration equipment

- Conical flask
- Measuring cylinder
- Filter paper
- Funnel
- Bunsen burner (optional, to melt the ice cores)

Distillation equipment

- Bunsen burner or hotplate/boiling ring
- Conical flask
- Tripod
- Bung with hole for plastic/rubber tubing
- Large tin with a hole in the side
- Ice cubes (for cooling the tubes)
- Small piece of copper tubing (optional – improves cooling)
- Measuring cylinder

Preparation of distillation equipment

The copper tubing (if available) and as much as possible of the plastic/rubber tubing should be inserted into the tin and covered with ice. There should be an air-tight seal between all parts of the tubing.

Health and Safety

Students should wear safety glasses when heating the ice/sand mixture.

If using the bunsen burner: the conical flask used for filtration should be allowed to cool for at least 5 minutes, after removing the heat source, before handling. The flask should then only be held at the top by the neck.

All parts of the distillation equipment, including the measuring cylinder will become hot and could cause burns if handled.

The measuring cylinder used for distillation should be allowed to cool for at least 5 minutes, after removing the heat source, before handling.

If steam or excessive water vapour is coming through the end of the tubing, the Bunsen burner should be moved temporarily away from the conical flask.
If moving the Bunsen burner during the distillation experiment, then it should be held by the base only and changed to a safe flame.

As soon as the mixture inside the conical flask starts bubbling then the heat source must be removed to prevent the glassware from overheating.

Exercise

Divide the students into groups of four. Each group will try both methods: filtration and distillation. The students should plan each investigation before carrying it out. Their plan should be checked and the equipment set up before they are given the ice cores.

The key elements that students should include are as follows:

Filtration

1. Read safety notes and plan accordingly.
2. Set up the filtration equipment, as in the diagram.
3. Measure the mass of the ice cores inside the tray and record the value.
4. Remove the ice cores from the tray and place in conical flask.
5. Measure the mass of the empty tray (take this from the total mass in step 3).
6. Melt the ice cores.
7. Filter mixture.
8. Measure the volume of water recovered.
9. Calculate the percentage mass of water recovered.

Distillation

1. Read safety notes and plan accordingly.
2. Set up distillation equipment, as in the diagram.
3. Measure the mass of the ice cores inside the tray and record the value.
4. Remove the ice cores from the tray and place in conical flask.
5. Measure the mass of the empty tray (take this from the total mass in step 3).
6. Boil mixture until dry.
7. Measure the volume of water recovered.
8. Calculate the percentage mass of water collected.

Students should compare their results and discuss which method recovers the most water, and what they think the reason for this is. They should talk about how water could be lost with both methods. They should conclude that:

- Through the filtration method, water still remains in the sand and in the filter paper.
- With distillation, water can be lost through water vapour, and some will remain in the tubes.

The distillation process is most energy intensive when carried out in the lab. This would not necessarily be the case on the Moon, as distillation (or more precisely sublimation) could take place at low temperatures when in a very low-pressure environment, see Figure A2 of Activity 1, the water vapour will then condense as a liquid in a pressurised environment.

Results

2. Discuss the health and safety requirements for the activity and ensure all points in the Health and Safety section are covered.
3. Below are some examples of advantages and disadvantages of filtration and distillation.

Discuss with the students how energy is used in each and which requires more. This is a small example of the experiment so you can also have discussions around how easy it would be to scale the experiments up to a practical level.

	Advantages	Disadvantages
Filtration	• Energy efficient • Cost effective • Simple apparatus • Scalable	• Slow • Equipment is dependent on the mixture • Some of the liquid will remain in the residue
Distillation	• Kills harmful bacteria • Adaptable by changing temperature for different mixtures • Scalable	• Uses more energy for heating • More complicated setup

4. The students must measure the mass of the ice cores before carrying out the procedure.
5. The students must measure the mass of water extracted from the ice cores.
6. An example of how much water is recovered for the different methods:

$$\frac{mass\ of\ water}{mass\ of\ ice\ core} * 100$$

Mass of ice cores (g)	Filtration		Distillation	
	Mass of water (g)	% recovered	Mass of water (g)	% recovered
100	19	19%	36	36%

7. Encourage discussions around where water may have been lost during the experiment and the differences between the two processes. This creates a good opportunity to ask how the experiments could be improved in the future.
8. Discuss ways to test cleanliness of the water (inspection by eye is probably the easiest) and where impurities/bacteria/contaminants could be present.

9. a. On Earth, distillation requires more heat energy to boil the cores compared with melting the cores for filtration. Distillation requires two phase changes compared with only one for filtration.

   b. On the Moon, the methods would require approximately an equal amount of energy as they would both require an increase in heat and pressure to obtain liquid water.

10. On the Moon, the pressure is too low for liquid water to exist. If you attempted this investigation on the Moon without being in a pressurised environment you would not retrieve liquid water. As you heat the ice cores the ice would sublimate and the gas would escape leaving you without any water. You would have to use a sealed pressurised container.

11. Any relevant ideas from the students.

12. Example from results above:

Distillation is the most efficient as it recovered 36% compared to 19% by filtration.

$$\frac{36}{100} * 1 \text{ kg} = 0.36 \text{ kg}$$

$$1 \text{ kg} = 1 \text{ l} \quad \text{so} \quad 0.36 \text{ kg} = 0.36 \text{ l} = 360 \text{ ml}$$

13. First, do the calculation to find the mass of water per day for one astronaut:

$$\frac{6}{0.36} = 16.7 \text{ kg}$$

For 6 astronauts:

$$16.7 * 6 = 100.2 \text{ kg}$$

Conclusion

Students should conclude that, on Earth, distillation uses a lot more energy than filtration. However, on the Moon, the low pressure due to the lack of atmosphere means that both methods will require pressurisation and heating to extract liquid water. They should also come to a conclusion about which method they used was the most efficient. Students should realise that we will require a lot of water to survive on the Moon and this presents a big challenge that space agencies are working to overcome.

→ EXTRACTING WATER FROM LUNAR SOIL

Learning about filtration and distillation

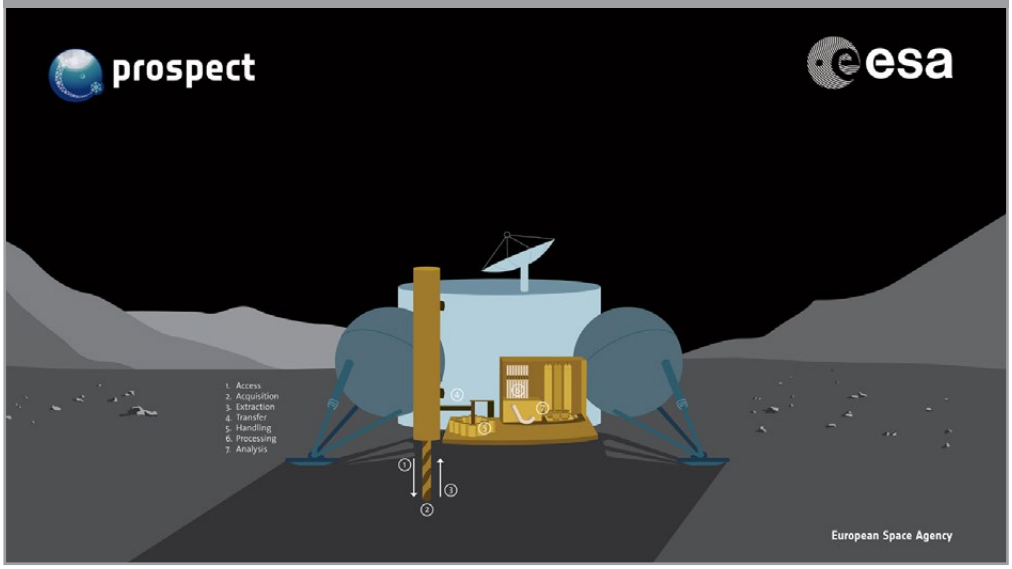
Introduction

Liquid water is an abundant substance on Earth covering 71% of the Earth's surface, but water is actually extraordinary. It is the only common substance known to exist as a solid, liquid, and gas in normal terrestrial conditions and has the ability to dissolve more solid substances than any other liquid. Water is also vital for all known forms of life!

On the Moon, water has been detected in the form of ice. In the future, water ice could be mined to provide liquid water on the Moon for astronauts to drink and for growing plants. The water could also be split into hydrogen and oxygen to provide breathable oxygen and rocket fuel.

ESA is developing the PROSPECT system that will be part of the Luna 27 mission. It will drill into the surface of the Moon to retrieve valuable resources, including water, to support future exploration missions.

Figure A1



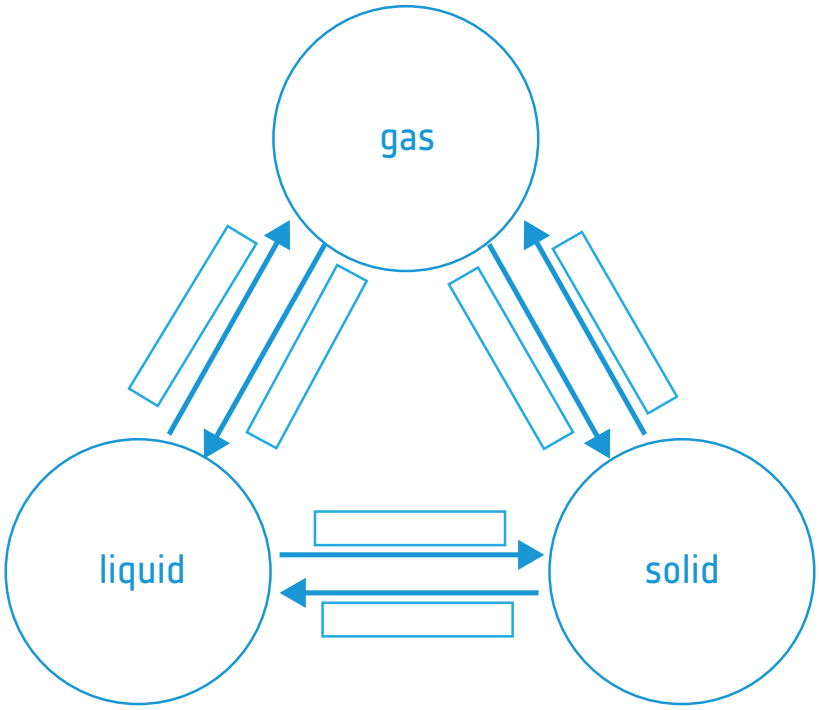
↑ The PROSPECT system concept and its functions.

→ Activity 1: Is water different on the Moon?

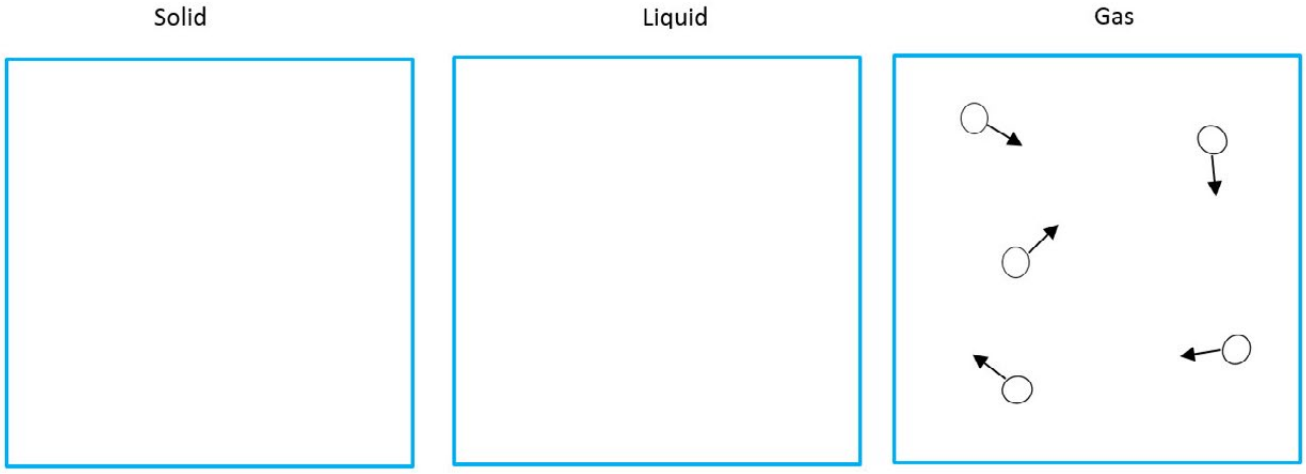
To extract water on the Moon we need to know about states of matter and phase transitions.

Exercise

1. Fill in the dashed boxes with the different phase transitions:



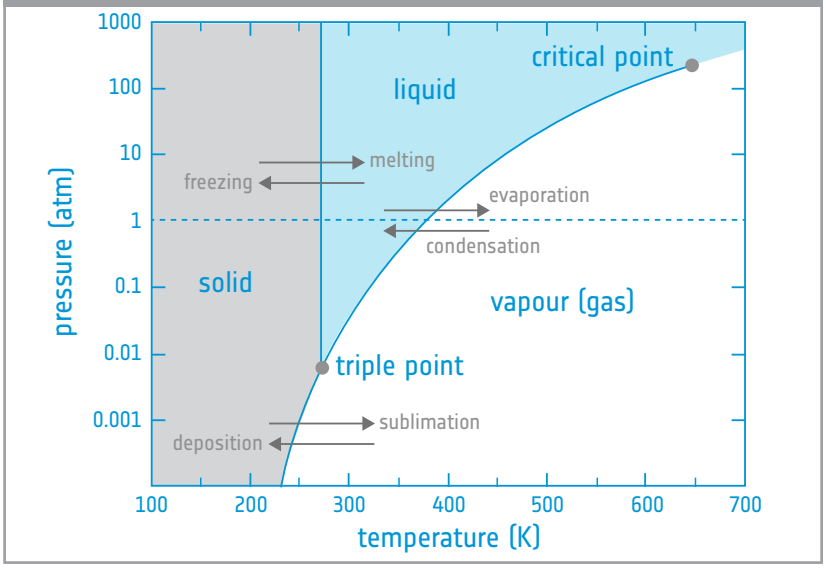
2. Draw the structure of the particles in each of the three states of matter in the boxes below. The particle model for the gaseous state has been done for you.



3. Phase transitions are not only dependant on temperature. They are also dependant on pressure.

The phase diagram below (Figure A2) shows the state of water as a function of both temperature and pressure. It is divided in three regions: solid, liquid and vapour (gas).

Figure A2



↑ Phase diagram for water. The diagram is divided in three regions: solid, liquid and gas. At room temperature (approx. 300 K) and atmospheric pressure (1 atm), we see that water is in its liquid state.

Use Figure A2 to complete the table below:

Water state	Temperature range (K)	Pressure (atm)
Solid		1
Liquid		1
Gas		1

4. a. What happens to the boiling point of water as the pressure decreases? Explain.

b. Test your hypothesis. Use a syringe to suck up approximately 1 ml of hot water (lukewarm or hotter). Place your finger at the tip and pull the syringe back as shown in Figure A3.

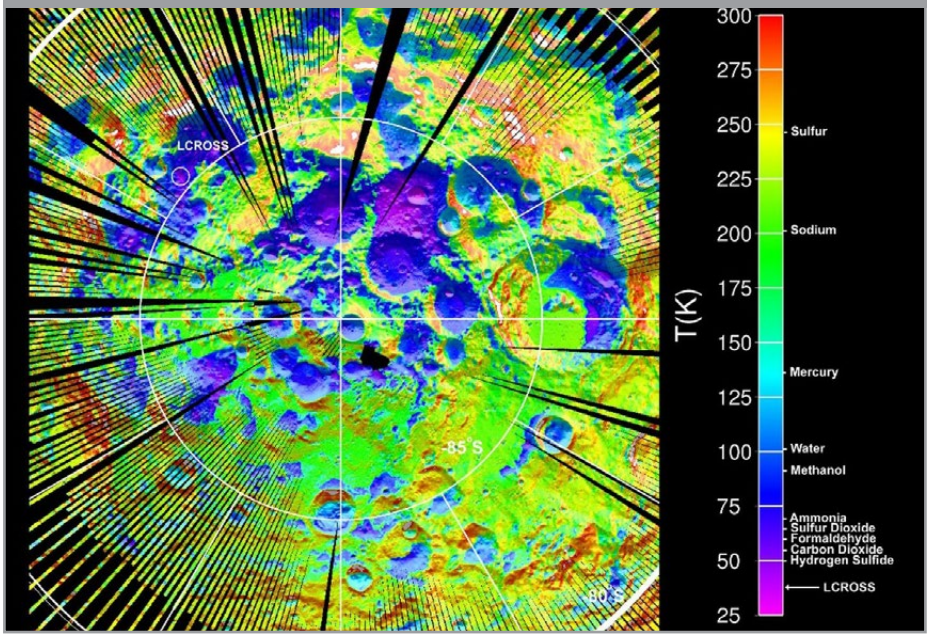
Figure A3



What happens to the water in the syringe?

5. The Moon does not have an atmosphere, so the pressure on the surface is approximately 0 atm. Temperatures on the Moon are extreme, ranging from -248°C to 123°C depending on where you are on the surface and if it is daytime or night time.

Figure A4



↑ LRO Diviner surface temperature map of the south polar region of the Moon during daytime. The map shows the locations of several permanently shadowed craters that are potential locations for water ice.

a. Use Figures A2 and A4 to explain why water is not found in a liquid state on the surface of the Moon.

b. Imagine that you have extracted water from a permanently shadowed crater which has a temperature of 100 K. What state would the water be in in this crater?

c. What would happen to your water sample from question 5 b if you tried to transport it out of the crater?

d. How could you obtain liquid water from ice on the Moon?

e. Draw arrows on the phase diagram to show your solution in question 5 d.

→ Activity 2: Filtration or distillation?

Any water ice extracted from the surface layers of the Moon will be trapped in the lunar regolith (lunar soil). In this activity you will have to find a way of separating the water from the regolith analogue. You will receive frozen "lunar" ice-cores and your task is to compare two ways of extracting the water from the simulated Moon regolith.

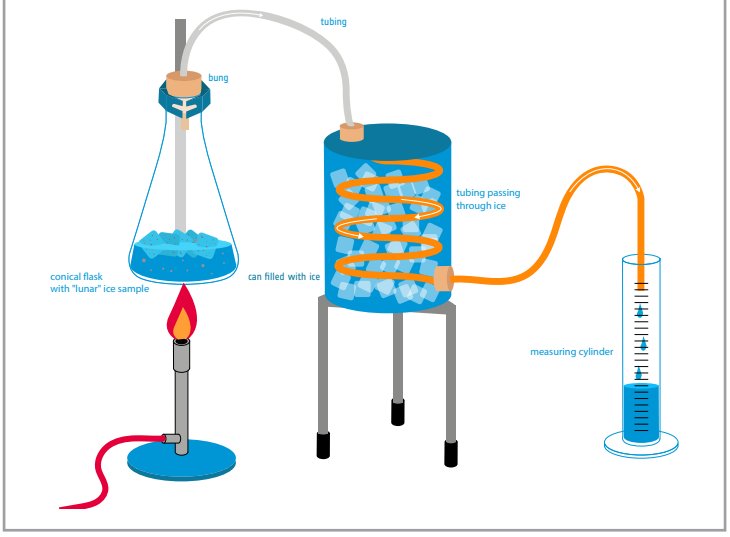
Experiment

Compare two methods for extracting water from lunar regolith: filtration and distillation. **Distillation** is the process of separating substances from a liquid mixture by boiling the liquid and cooling the vapour to form a condensate. **Filtration** separates solids from fluids by adding a medium through which only the fluid can pass.

Distillation equipment

- Bunsen burner or hotplate/boiling ring
- Conical flask
- Tripod
- Bung with hole for plastic/rubber tubing
- Large can with a hole in the side
- Ice cubes (for cooling the tubes)
- Small piece of copper tubing (optional – improves cooling)
- Measuring cylinder

Figure A5

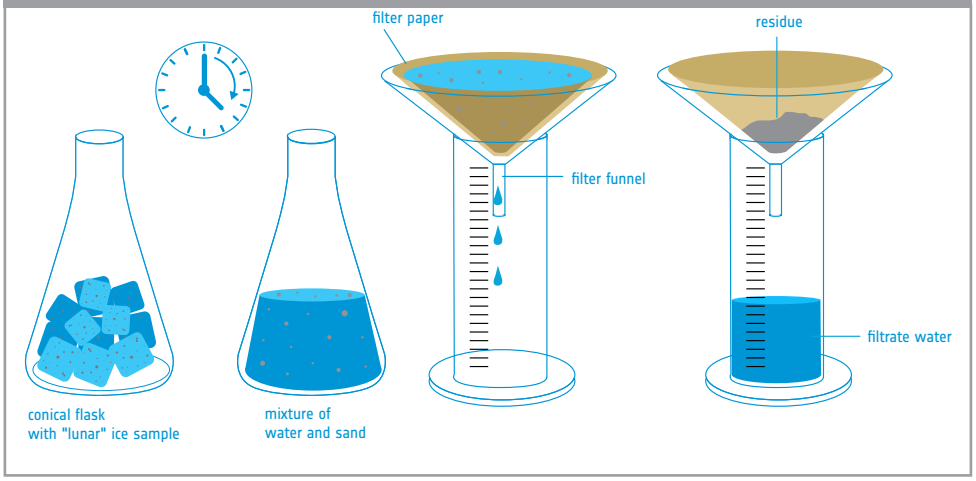


↑ Experimental setup for distillation

Filtration equipment

- Conical flask
- Measuring cylinder
- Filter paper
- Funnel
- Bunsen burner (optional, to melt the ice cores)

Figure A6



↑ Experimental setup for filtration

Your task is to compare the percentage mass of water extracted from the distillation process and the filtration process.

1. Given the information above, and the equipment available, prepare an investigation plan to compare both extraction methods.

2. Which safety concerns should you take into consideration?

3. What do you think the advantages and disadvantages of filtration and distillation are?

4. What will you need to measure **before** carrying out the procedure?

5. What will you need to measure **after** carrying out the procedure?

6. Fill in the table with your results.

Mass of ice cores (g)	Filtration	
	Mass of water (g)	% recovered

Mass of ice cores (g)	Distillation	
	Mass of water (g)	% recovered

7. Which method yields the highest volume of water? Why do you think this is?

8. Which method do you think yields the cleanest water?

9. a. Which method do you think is the most energy intensive on Earth? Explain.

   b. And on the Moon? Explain.

10. What problems would you encounter if you tried to do this investigation on the Moon?

11. Can you think of other ways to extract water from the regolith?

Did you know?

Astronauts on the International Space Station recycle most of the water that they use – about 75%. The Water Recovery System can recover water from astronauts' urine and from their breath. This is filtered and cleaned and can be used again. On average, an astronaut on the International Space Station uses 90% less water than that of a person on Earth.



12. For the most efficient method, how many litres of water do you recover per kilogram of lunar ice? (To help with your analysis you can use the fact that 1 litre of water has a mass of 1 kilogram).

13. Assume that we need 6 litres of water per day per astronaut on the Moon. How many kilograms of lunar ice would you have to extract every day to supply a crew of 6 astronauts?

→ Links

ESA resources

Moon Camp Challenge
esa.int/mooncamp

Moon animations about about the basics of living on the Moon.
esa.int/Education/Moon_Camp/The_basics_of_living

ESA classroom resources
esa.int/Education/Classroom_resources

ESA missions

ESA PROSPECT project is studying a lunar drill for sample collection of lunar ice
exploration.esa.int/moon/59102-about-prospect

ESA Smart-1, Europe's first Moon orbiter
sci.esa.int/smart-1

Extra information

The Moon, ESA's interactive guide
lunarexploration.esa.int

Airbus Foundation Discovery Space, water on the Moon
youtube.com/watch?v=wHJ3F7eIxEM

Sample collection of water ice and other icy volatiles
lunarexploration.esa.int/#/library?a=293

Water and volatiles on the Moon
lunarexploration.esa.int/#/library?a=252

→ Annex: Preparation of ice cores



Ice cores should be prepared the day before the practical activity. In this example, packaging material for test-tubes was used but any container that will produce pieces of ice small enough to fit into the conical flasks will do. The total volume of the container should be measured by filling the container with water and pouring into a measuring cylinder. The container should then be filled half with sand by volume, and half with water. The container should then be placed on a level surface in the freezer.

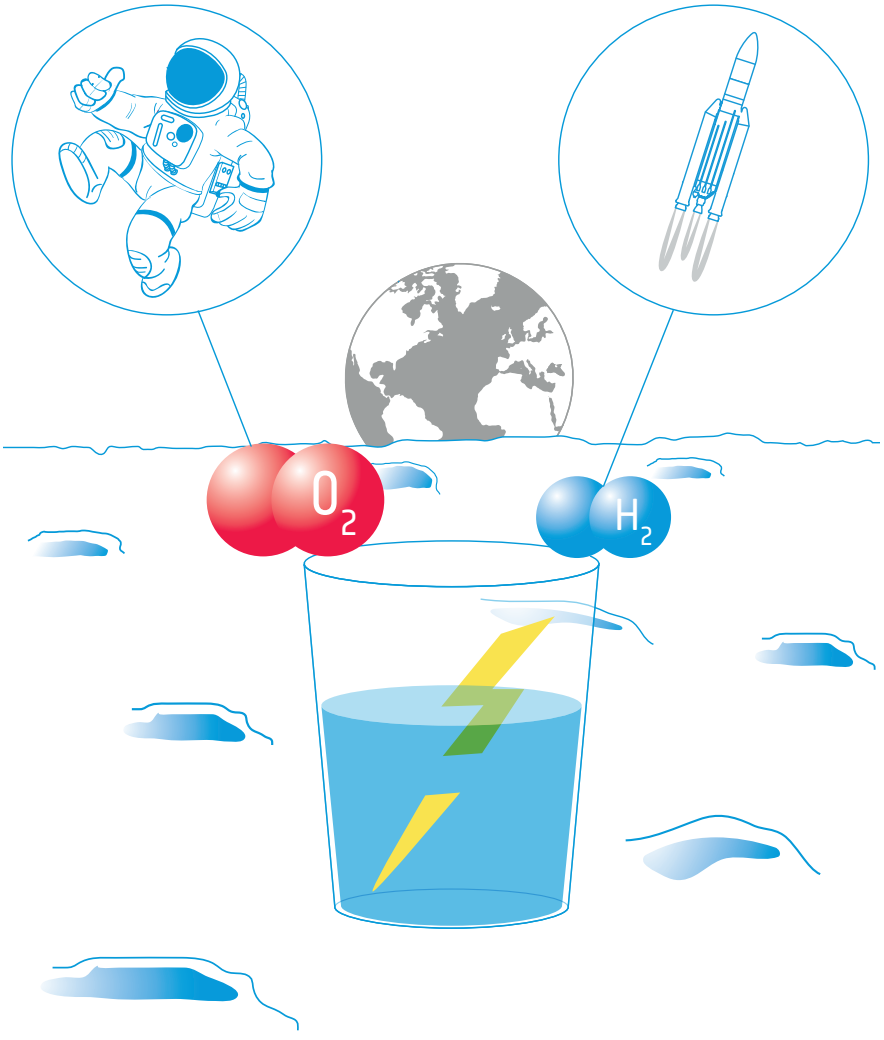
Ice cores should not be taken out of the freezer until immediately before use – this is because the sand side of the mixture can quickly melt and remain in the container.

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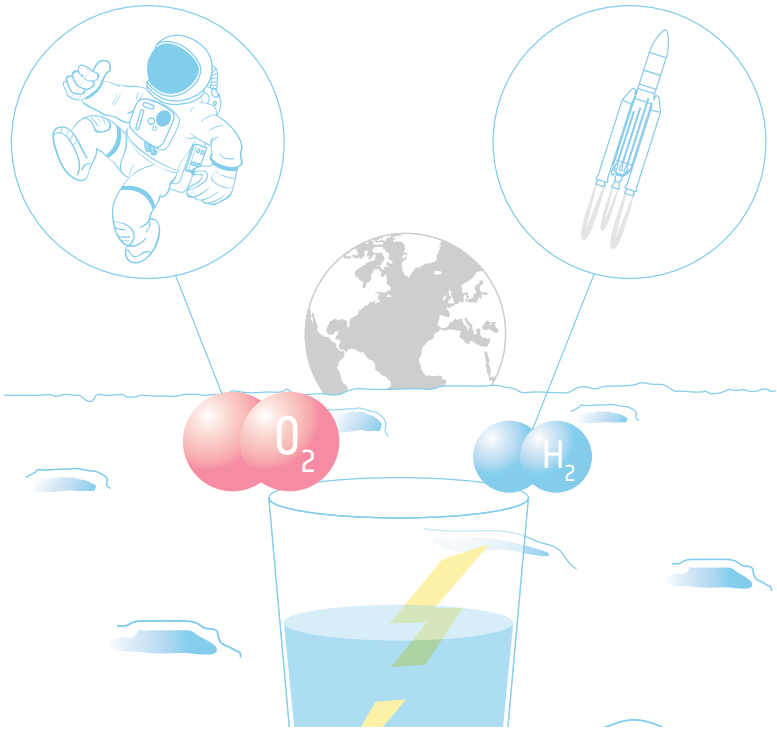
→ POWER FROM WATER

How to produce oxygen and hydrogen on the Moon



teacher guide & student worksheets

European Space Agency



Teacher guide

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→ POWER FROM WATER

How to produce oxygen and hydrogen on the Moon

Fast facts

Subject: Chemistry and Physics
Age range: 14-16 years old
Type: laboratory activity
Complexity: medium
Teacher preparation time: 1 hour
Lesson time required: 2 hours
Cost: medium (5-25) euros for activity 1 and 2 and high (50-100 euros) for activity 3
Location: laboratory
Includes the use of: Zinc and copper plates
Keywords: Chemistry, Physics, Moon, Electro-chemistry, voltaic pile (battery), Electrolysis, Fuel cells

Brief description

In this set of three activities, students will learn about electrochemistry. In the first activity they will build a voltaic pile – a simple battery. This invention marked the beginning of electrochemistry. Students will then study electrolysis. Electrolysis uses electric current to split water into its components: hydrogen and oxygen. These products can be used as propellants for spacecraft and/or to provide oxygen to support a crew. In the last activity, students examine and use a fuel cell.

Learning objectives

- Understanding how a battery works.
- Performing an experimental activity to confirm that certain chemical reactions can create electricity.
- Performing an experimental activity to confirm that electricity can make certain chemical reactions take place.
- Studying water electrolysis and its applications.
- Investigating fuel cells and their applications.
- Writing balanced equations for REDOX chemical reactions.
- Using equipment appropriately to make and record observations.

→ Summary of activities

Summary of activities					
	Title	**Description**	**Outcome**	**Requirements**	**Time**
1	Build your own battery	Building a voltaic pile.	Introduction to electrochemistry; learning how a battery works.	None	45 minutes
2	Water electrolysis	Building an electrolyser and performing water electrolysis.	Learning about water electrolysis and its applications.	Completion of activity 1 is advised.	45 minutes
3	Fuel cell	Investigating a fuel cell.	Learning about fuel cells and their applications.	Completion of activity 2 is advised.	30 minutes

→ Introduction

Human exploration of the Moon requires resources: water, oxygen, food, materials, propellant, etc. Bringing everything from Earth would be very inefficient and expensive, so instead mission designers are investigating how to use resources already available on the Moon. One of the most important resources is water. Scientists found evidence that water may exist in some areas towards the Moon's poles. On a future Moon mission, this water could be used to produce hydrogen and oxygen for propulsion and oxygen for breathable air for the crew.

In this set of activities, we are going to investigate how to store energy in batteries and how to generate oxygen and hydrogen from water. In order to do so we need to learn about electrochemistry!

Electrochemistry is the branch of science that studies the relationship between electricity and chemistry. Certain chemical reactions can create electricity, as is the case in a battery. The opposite is also possible: electricity can make certain chemical reactions happen that wouldn't happen spontaneously.

In this resource students will be guided through the principles and chronology of electrochemistry, from the invention of the first battery (the voltaic pile) to the modern use of fuel cells.

In this resource the students will build the following devices:

1. **Battery:** A device that generates electricity from chemical reactions.

2. **Electrolyser:** A device that uses electricity to make certain chemical reactions take place. In this case we will work with water electrolysis and break the bonds that hold the components of water molecules together

3. **Fuel Cell:** A device that produces electricity and heat from a chemical reaction.

→ Activity 1: Build your own battery

The voltaic pile was the first battery ever invented by Alessandro Volta in 1800. Batteries generate electricity from chemical reactions, and the invention of the voltaic pile marked the beginning of electrochemistry.

Batteries are often used on spacecraft as a means of electricity (power) storage and distribution. Traditional batteries contain all their usable energy and can only be discharged. Batteries used on space missions are often re-chargeable. They can be recharged with power from other sources, for example by solar energy. Batteries are crucial because they can provide electricity during periods with no access to other power sources (for example, when it is not in direct sunlight).

In this activity, students will construct a voltaic pile – a simple battery from metal plates, dishcloth and vinegar. A voltaic pile uses a spontaneous chemical reaction to create electricity.

Health and safety

The voltaic piles should not be left connected in a closed container or unventilated room.

Equipment

- 6 zinc plates (per group)
- 6 cooper plates (per group)
- 1 dishcloth (per group)
- Scissors
- Vinegar
- Sandpaper
- 2 elastic rubber bands
- Wires with crocodile clips
- Multimeter
- (optional) AA Batteries

Figure 1



↑ Equipment needed for building a voltaic pile

Exercise

Start by introducing the concept of electrochemistry and the definition of electrical potential difference.

Building one voltaic cell
Divide the class into groups of 3 to 4 students. The students should follow the instructions 1 and 2 in their student worksheet to assemble a simple voltaic cell. After assembling the cell they should connect a multimeter and measure the electrical potential difference.

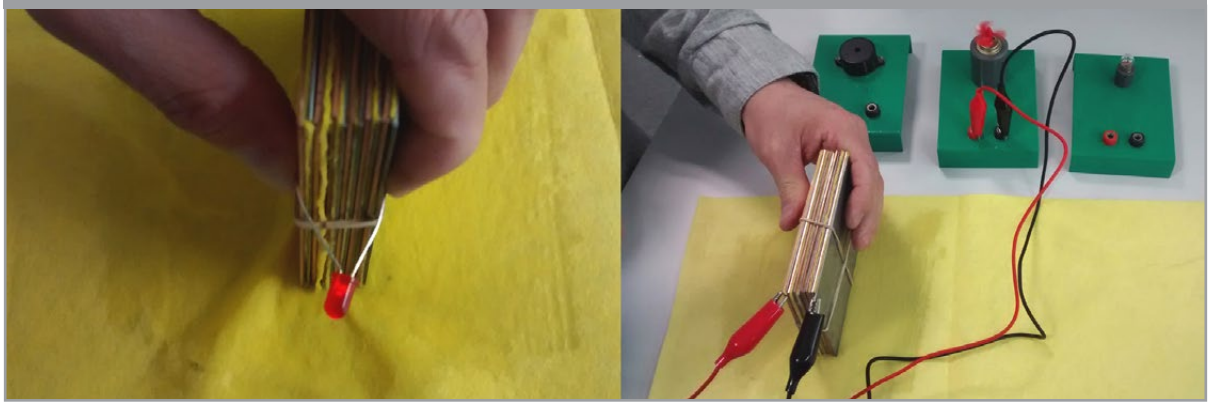
Ask the students to explain why they get an electrical potential difference and to explain what the function of each layer is in the voltaic cell. Have the students write down the ionic equations of the reactions that occur in the voltaic cell. Ask them to answer question 4 to 7 in their student worksheet.

Building a voltaic pile
Now students should pile several voltaic cells to get a voltaic pile. Students should measure the electrical potential difference of the pile once per minute for 10 minutes and record the measurements in Table 1 in their student worksheets. In between measurements they should answer the related questions in their student worksheets.

Ask the students to plot the electrical potential difference of the voltaic pile as a function of time. They should discover that the electrical potential difference decreases with time. Ask the students why they think this is happening.

To demonstrate that the voltaic pile can generate current you can use it to light a LED or make a motor run as seen in Figure 2 and investigate how long the voltaic pile is able to power the actuator.

Figure 2



↑ Making an LED light up using a voltaic pile (left) and powering a motor with a voltaic pile (right).

Ask the students to compare their voltaic pile with a normal AA battery. Talk about how a normal battery works and what the limitations of the voltaic pile are. If time permits, let the students connect the battery and the voltaic pile to different electrical appliances and measure the current in the circuit.

Results

These are the answers to the student worksheet activity 1:

3. From one voltaic cell you should obtain approximately 1 V.

4. The net ionic equation is:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

The redox half reactions for the two half cells are:

OXIDATION (anode): $Zn \rightarrow Zn^{2+} + 2e^-$

REDUCTION (cathode): $2H^+ + 2e^- \rightarrow H_2$

$$Zn\,|Zn^{2+} \;||\; 2H^+|H_2|Cu$$

(OXIDATION) || (REDUCTION)

(Electro-chemical chain notation)

The copper metal plate only serves as a "chemically inert" noble metallic conductor for the transport of electrons in the circuit and does not chemically participate in the reaction. The copper plate could be replaced by any sufficiently metallic conductor.

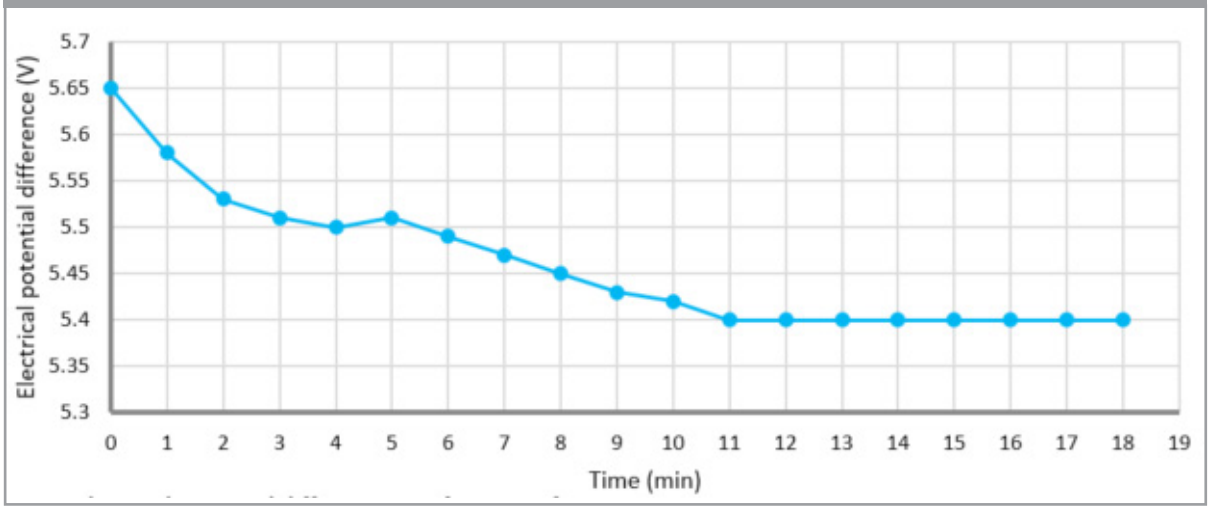
5. Zinc is oxidised and releases electrons (anode). hydrogen (hydronium = H_3O^+) is reduced and gains electrons (cathode).

6. An oxidised layer accumulates on the plate's surface (which makes the metal look dull). This decreases the useful area for ion exchange. Sanding removes the oxidised layer.

7. Vinegar is an electrolyte. It allows the exchange of ions between the plates and increases the electrical potential difference. All acids, like vinegar, release H^+ ions that are necessary for the reaction. Even water releases H^+ ions, but in a very low quantity. Adding a salt or an acid increases conductivity. We could use any other substance that acts as an electrolyte (salt or acid)

10. Example result obtained from a voltaic pile consisting of six voltaic cells

Figure 3



↑ Electrical potential difference as a function of time.

11. The voltage drops with time because the internal resistance of pile increases. The zinc surface is oxidized, which results in the reaction surface area being reduced. Vinegar (and other acids) also cause oxidation. Furthermore, in the voltaic pile, hydrogen bubbles are accumulating on the copper surface (polarization). Commercial batteries use very different materials, which oxidise far less than zinc. Some types of batteries use a substance that removes the accumulated hydrogen or vents it off. For these reasons, commercial batteries can continue operating much longer.

12. An AA battery usually has an electrical potential difference of 1.5 V unless otherwise specified by the manufacturer. In our example we obtain 1 V from one voltaic cell and we obtain 5.5 V with the voltaic pile (six voltaic cells). When we increase the number of cells, we increase the total contact surface for ion exchange. The limiting factor to the current output is the internal resistance (which is high).

13. Batteries would be useful for Moon exploration as a way to store energy. Batteries used on space missions are often re-chargeable from other sources, for example by solar energy. Batteries are crucial because they can provide electricity during periods without access to any other power source (for example, when there is no direct sunlight). Bringing non-rechargeable batteries as the only power supply would be both heavy, inefficient and not sustainable.

Discussion

Discuss with the students the importance of the invention of the voltaic pile. How would our lives be without batteries? Could we design a limitless battery? Discuss the reasons for inefficiencies: weight and limited lifetime versus storing capability and power output.

Talk about how energy can only be transformed, not lost or created. Discuss why we still talk about losing energy (because heat is a difficult form of energy to use).

The voltaic pile can be reset by cleaning the metal plates with sandpaper and soak the dishcloth with the electrolyte again. Discuss if any rechargeable battery can be recharged indefinitely.

→ Activity 2: Electrolysis

Electrolysis uses electricity to make chemical reactions occur that would not happen spontaneously. In this activity, students will build an electrolyser: a device that introduces an electric current into a liquid using two electrodes. They will use the device for water electrolysis and discover that it is possible to split water into its components: oxygen and hydrogen.

Health and safety

When testing the gases be sure to keep a safe distance and use long matches or splits to avoid being burned.

Equipment (per group)

- Plastic container with lid (with two holes – see preparation)
- 2 test tubes
- 2 steel push pins
- 2 beakers
- Copper wire
- Battery (optional: a solar cell)
- 400 cm^3 distilled water + 12 g NaOH (3% dissolution)
- Distilled water
- Gloves

Figure 4



↑ Equipment needed for building an electrolyser

Preparation

Drill two small holes in the bottom of the container and two holes in the lid (with the diameter of the test tubes) as shown in Figure 5.

Figure 5



↑ Preparation of box for electrolyser

Exercise 1

Have the students balance the global equation for the water electrolysis process. Then help them write and understand the oxidation and reduction reactions.

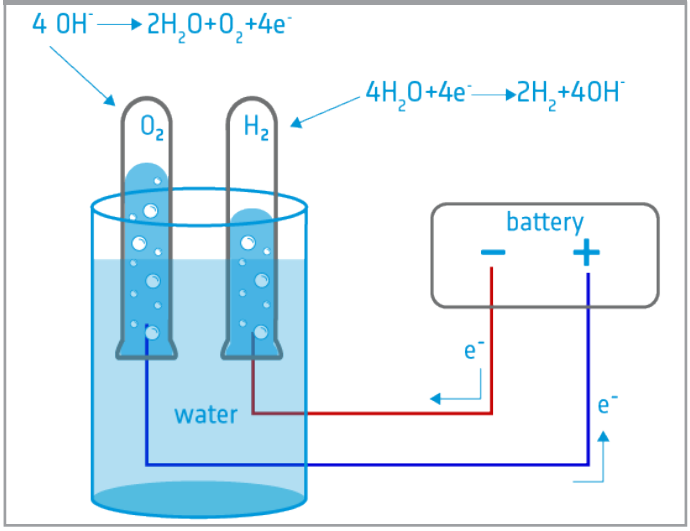
An illustration of the electrolysis setup can be seen in Figure 6.

Let them build their own electrolyser following the instructions in Annex 1. Remind them to time the electrolysis process in order to later calculate the production rate of oxygen. Ask the students to answer question 5 to 7 in their student worksheet about the electrolysis process.

Relate the experiment with oxygen production for space missions. Ask the students to answer questions 8 and 9 in their student worksheet to investigate if their electrolyser could produce enough oxygen for astronauts on the Moon.

If you wish to extend the exercise, students can do the experiment with distilled water, tap water (containing salts) and water with electrolyte.

Figure 6



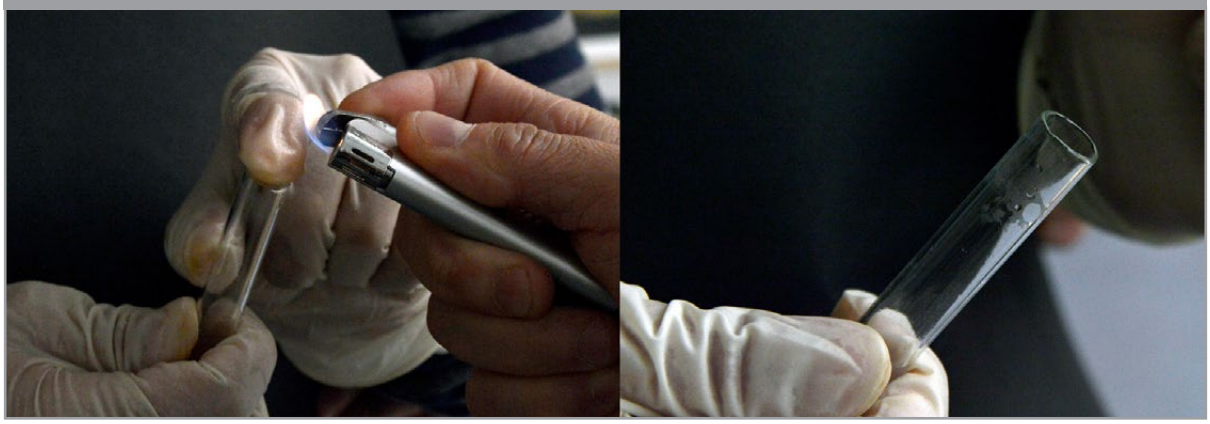
↑ Illustration of the electrolysis setup and process

Identifying the gases

You can do this test as a classroom demonstration or let the students test it themselves. Before performing the test, ask the students if they have any ideas how they could test the gases in the tubes.

Hydrogen test: Place a finger on the opening of the test tube to prevent the hydrogen from escaping, then turn the test tube around and place a long match (or lighter) at the opening of the tube (see Figure 7). You should hear a squeaky pop which confirms the presence of hydrogen (the sound indicates a mini explosion). The reaction $2\ H_2(g) + O_2(g) \rightarrow 2H_2O(L)$ will produce a small amount of water at the bottom of the test tube.

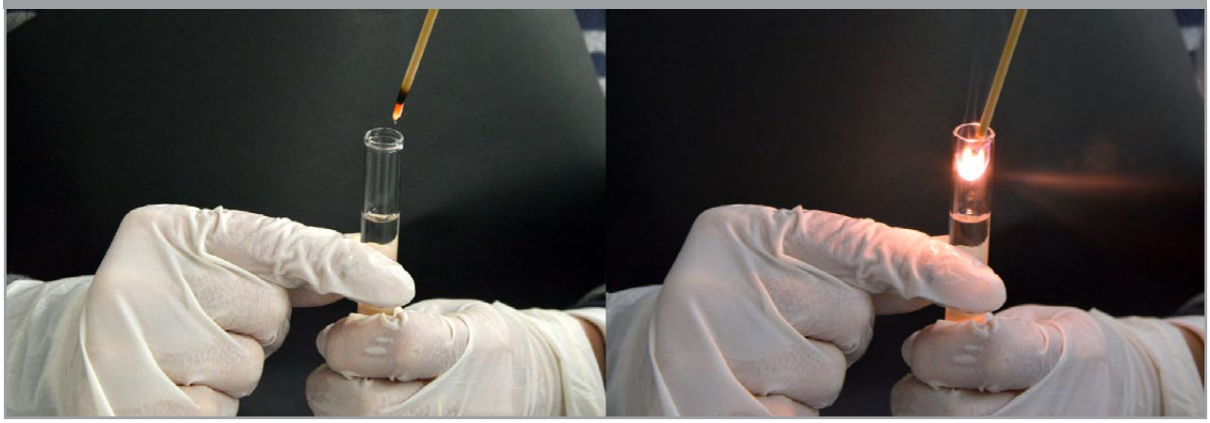
Figure 7



↑ Testing for hydrogen with lighter (left) and presence of water in the test tube (right)

Oxygen test: Place a finger on the opening of the test tube to prevent the oxygen from escaping, then turn the test tube around and place a lit splint at the opening of the tube (see Figure 8). The presence of oxygen will reignite the stick.

Figure 8



↑ Testing for oxygen with lit splint (left). Splint re-ignites in the presence of pure oxygen (right)

Results

These are the answers to the student worksheet activity 2:

1. The global reaction of water electrolysis:
   $2H_2O\ (l) \rightarrow 2H_2\ (g) + O_2\ (g)$

2. Anode oxidation:
   $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

3. Cathode reduction:
   $4H_2O + 4e^- \rightarrow 2\ H_2 + 4OH^-$

6. NaOH is an electrolyte. Adding an electrolyte speeds up electrolysis because it increases the electrical conductivity of water (i.e. deceases resistance to electricity). Salt, acid or base could be used as an electrolyte. For the specific case of alkaline water electrolysis, a strong base like sodium hydroxide (or potassium hydroxide) is used as the electrolyte, thus avoiding the corrosion problems caused by acid electrolytes (corrosion of metallic electrodes) .

7. In the equation $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$ the products are two hydrogen atoms for each oxygen atom. For that reason, we observe twice the amount of hydrogen than oxygen.

8. Using a voltaic pile of six voltaic cells with an electrical potential difference of 6 V, it is possible to produce 3ml of O_2 in 4 hours = 18 ml/day of molecular oxygen (O_2).

9. Obtaining 18 ml/day is equivalent to $1.8*10^{-5}$ m^3/day. We can use the ideal gas law to calculate the number of mole of O_2, and from that the mass:

$$P * V = n * R * T$$

$$n = \frac{P*V}{R*T} = \frac{101325pa*1.8*10^{-5}m^3}{8.314\frac{m^3*pa}{K*mol}*293\ K} = 7.48*10^{-4}mol$$

$$m = n*M = 7.48*10^{-4}mol*32\frac{g}{mol} = 0.0239g$$

   This is the same as $2.4 * 10^{-5}$ kg and hence only supplies:

$$\frac{2.4*10^{-5}kg}{0.84kg}*100\% = 0.0028\%$$

   of the amount needed by one astronaut per day.

10. We could make the production go faster by increasing the electrolyte concentration (in this case the concentration of NaOH) or by using a more powerful battery.

11. Oxygen is vital in order for the astronauts to breathe on the Moon. Hydrogen in combination with an oxidant (for example oxygen) can be used as a source of fuel to propel spacecraft going further into space or to propel rovers to explore the lunar surface and expand human presence. If we had to bring the oxygen and hydrogen we would need containers and a lot of mass and volume. This would be very expensive. In order to make an outpost on the Moon sustainable we need to recycle as much as possible and transform waste products (for example CO_2, urine, sweat, food waste, metabolic waste etc.) into O_2 and water that can be used again. This is what Life Support Systems are designed to do and technologies for optimizing recycling are being tested on the International Space Station. However, to be more independent from Earth re-suppling the outpost we also have to learn to produce most of what we need on the Moon (in-situ resource utilization).

→ Activity 3: Fuel cell

In this activity, students will use the products of water electrolysis (H_2 and O_2) in a fuel cell. They will investigate how fuel cells produces electricity and heat from a chemical reaction. Students will consider the possibilities and limitations of fuel cells for Moon exploration.

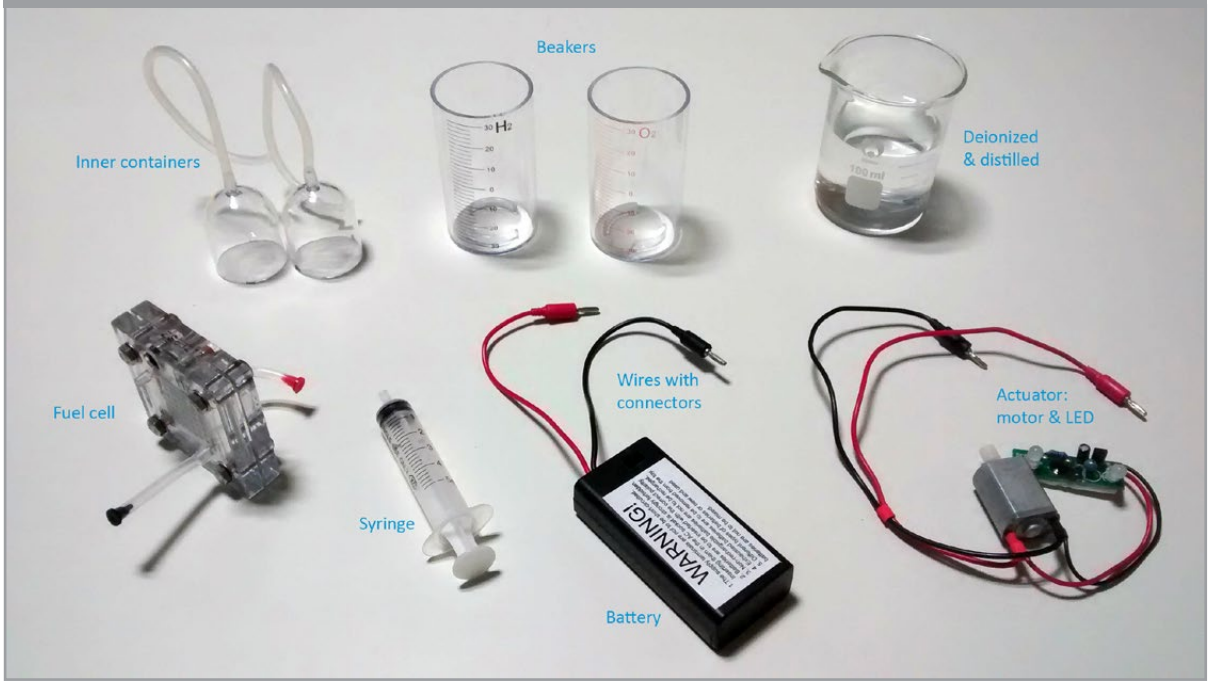
This exercise can be done either as a demonstration or if time permits as a hands-on activity. The experiment requires a fuel cell, which can be acquired online[1].

Equipment

A Fuel cell car science kit[1] or:

- A fuel cell
- A syringe
- Deionized & distilled water
- Power supply (battery, solar cell)
- Silicon tubing and caps
- 30 ml beakers and inner containers (see annex 2)
- Wires with connectors
- Actuators (Motor, LEDs, car etc.)

Figure 9



↑ Equipment needed for building a fuel cell system.

Exercise

Start by introducing fuel cells to the students. Fuels cells builds on the knowledge of water electrolysis and the voltaic pile and offers an opportunity to wrap up the resource.

Ask the students to follow the instructions in Annex 2 (or prepare the experiment beforehand for a demonstration). Ask the students to fill in questions 1 to 5 in their student worksheets and reflect on the advantages and limitations of fuel cells.

[1] This resource uses the Fuel cell car science kit that can be bought online http://www.horizonfuelcellshop.com/europe/product/fuel-cell-car-science-kit/.

Results

1. Overall reaction in the fuel cell:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + \text{electric energy} + (\text{waste}) \text{ heat}$$

2. Anode and cathode reactions

Anode:
$H_2(g) \rightarrow 2H^+(aq) + 2e^-$

Cathode:
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O\ (l)$

3. A fuel cell is a cheap and clean energy source if oxyden and hydrogen are readily available. It does not pollute: it only produces water and energy. This makes it a potential solution for clean energy on Earth. If we need to produce H_2 and O_2 with electrolysis before we can run the fuel cell, or if H_2 and O_2 are valuable and limited, then fuel cells might not be the optimal solution. We will lose energy since we are need another power source in the first place to create the components for the reaction. However, if we combine fuel cell technology with a renewable energy source (for example solar energy) then we can use fuel cells without polluting.

4. Both the voltaic pile, the electrolysis and the fuel cell are examples of electrochemistry in practise. A voltaic pile uses a chemical reaction to generate electricity, water electrolysis uses electricity to make a chemical reaction happen that would not otherwise occur, and a fuel cell reverses the electrolysis reaction and generates electricity again from the products of the electrolysis.

→ POWER FROM WATER

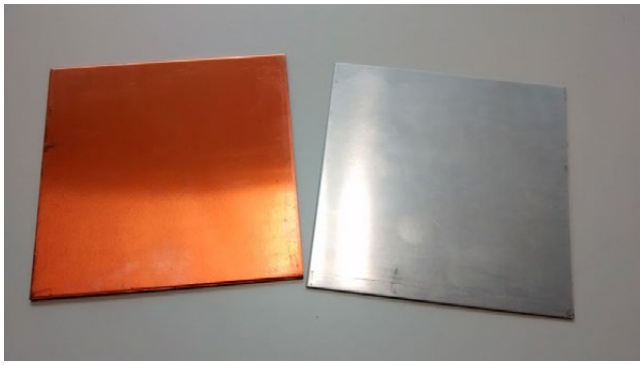
How to produce oxygen and hydrogen on the Moon

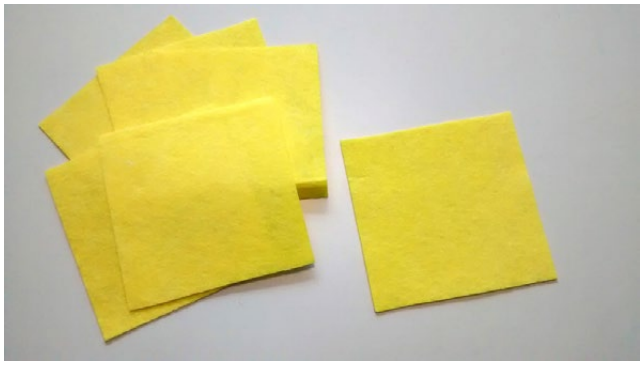
→ Activity 1: Build your own battery

In 1800 Alessandro Volta, one of the pioneers of electricity and power, invented the first battery: the "voltaic pile". With this invention, he proved that certain chemical reactions can create electricity. Now you will follow in his footsteps and build your own voltaic pile.

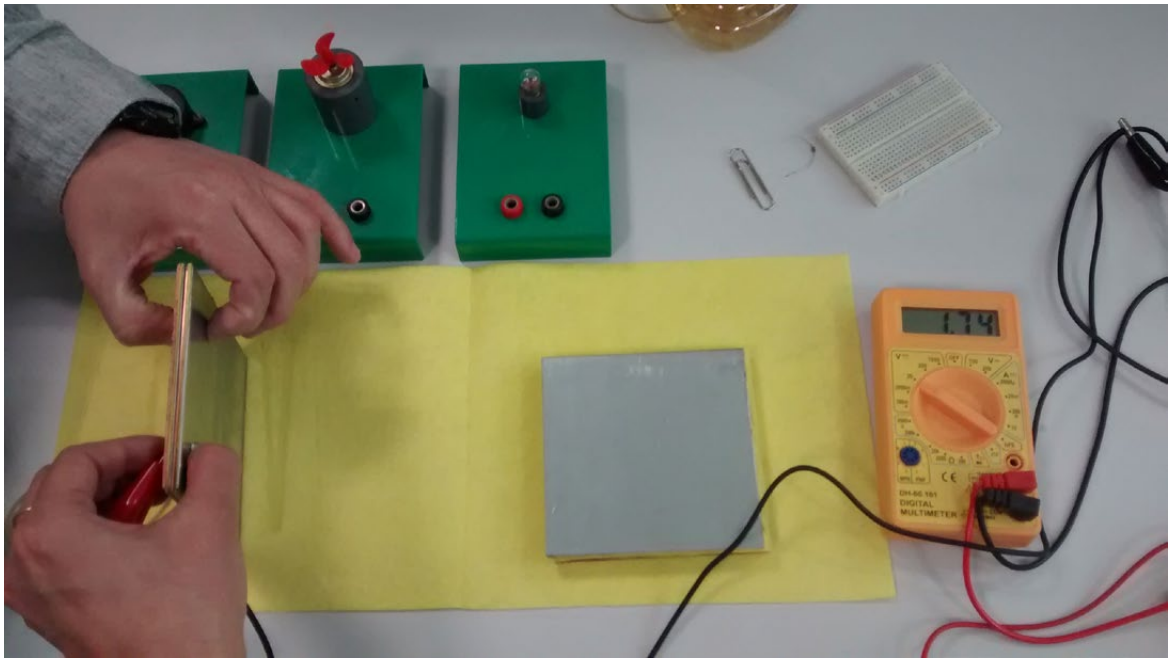
Exercise 1

1. Sand both sides of the zinc and copper plates with sandpaper and cut 6 squares from the dishcloth in the same size as the plates.





2. Place one dishcloth square on top of a zinc plate and soak it in vinegar. Then place one copper plate on top of the dishcloth. You now have one voltaic cell. Connect the wires with the crocodile clips to the first and last plate, then connect to a multimeter.



3. What is the electrical potential difference from one voltaic cell? _____ V

4. Write down the net ionic equation, which shows the overall process occurring in the cell:

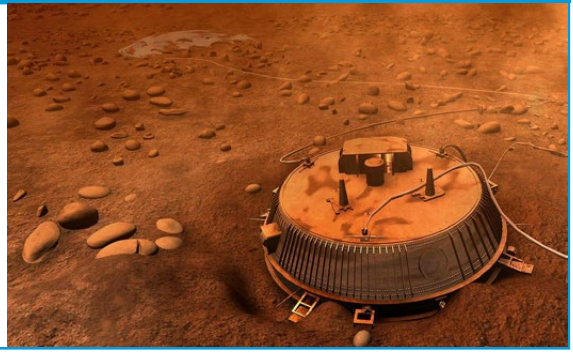
5. Which component is oxidised and which one is reduced in this reaction?

6. Why is it a good idea to sand the metal plates?

7. Why do we soak the cloth in vinegar? Could we use another substance? Explain.

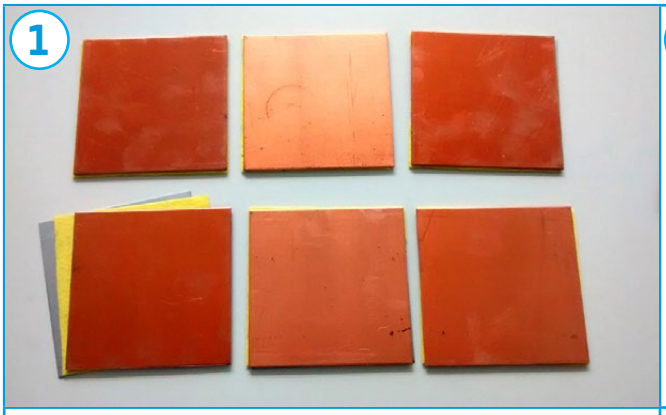
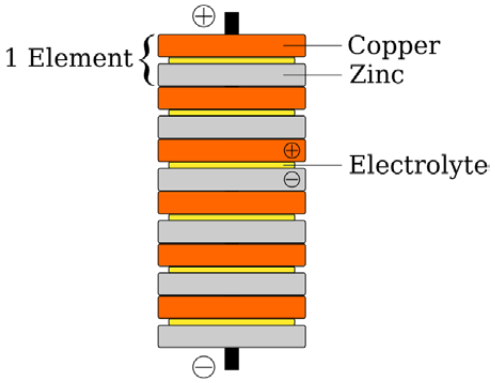
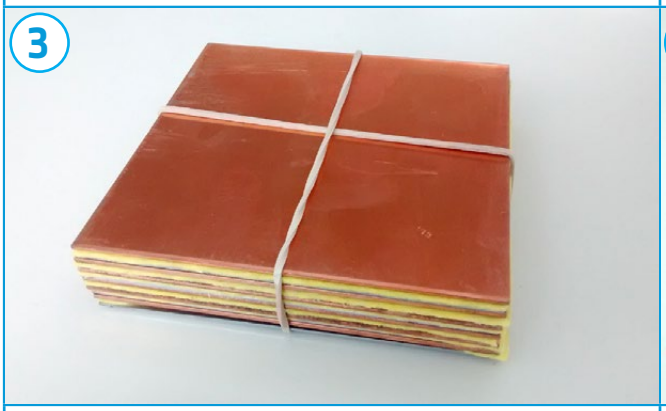
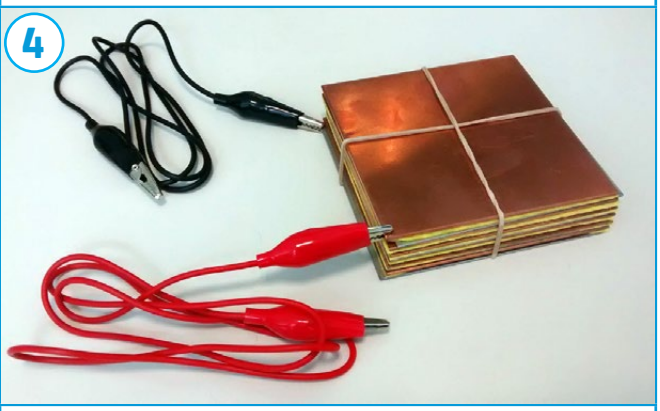
Did you know?

ESA's Huygens probe, which landed on the surface of Titan (Saturn's largest moon), relied on non-rechargeable lithium sulphur dioxide batteries. These were chosen because they could be left inactive during the seven-year trip to Saturn, but still retain sufficient capacity for the landing on Titan.



Artist impression of the Huygens probe on the surface of Titan.→

8. Follow the instruction below to build a voltaic pile.

1 	2 
Create six voltaic cells following the instructions from exercise 1	Stack the cells in the order shown
3 	4 
Tie elastic rubber bands around the pile to keep the pile in place.	Connect the wires with the crocodile clips to the first and last plate and connect to a multimeter.

9. Measure the electrical potential difference of the voltaic cell immediately after you have finished assembling it. Take measurements every minute for 10 minutes and record your measurements in Table 1.

Table 1

Time (min)	Electrical potential difference (V)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

↑ Recordings of electrical potential difference for 10 minutes.

10. Draw a graph of electrical potential difference as a function of time.



11. What do you observe? Explain.

12. What is the electrical potential difference of the voltaic pile compared to a normal AA battery?

13. How could batteries be used for Moon exploration? What are the advantages and disadvantages of batteries?

→ Activity 2: Water electrolysis

Exercise

1. Balance the global reaction below:

$$\square H_2O(l) \rightarrow \square H_2(g) + \square O_2(g)$$

2. Write the equation of the reaction that takes place in the anode:

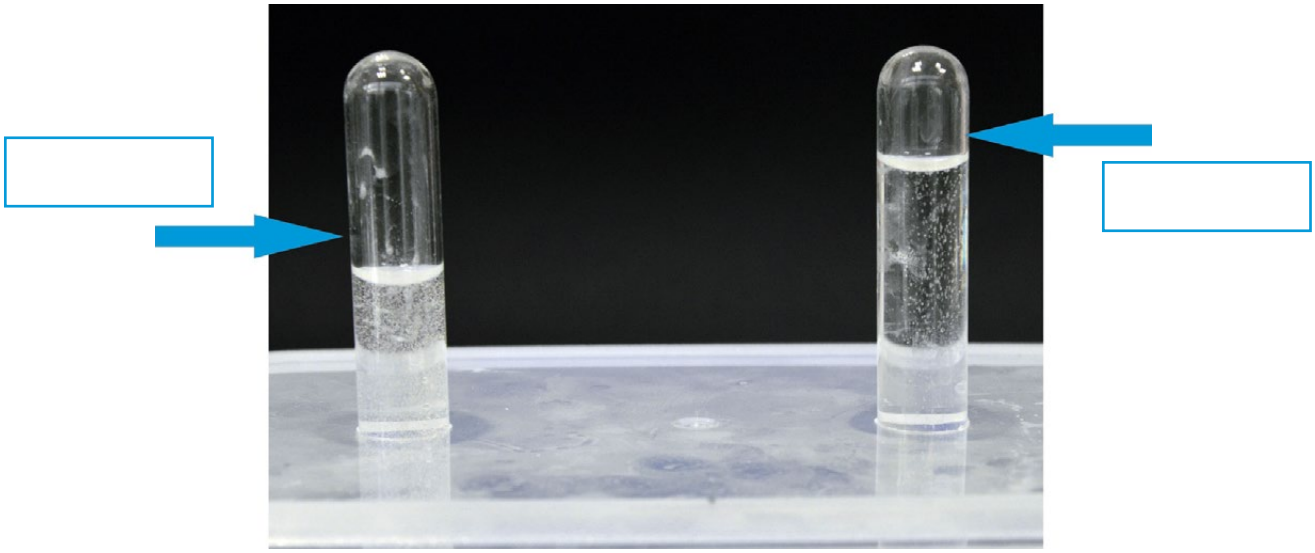
3. Write the equation of the reaction that takes place in the cathode:

4. Build your own electrolyser by following the steps in Annex 1. When starting the electrolysis make sure to start a stopwatch too. You will need the time of the electrolysis to calculate the oxygen production.

5. Describe what happens during the electrolysis.

6. What is the function of dissolving NaOH in the water?

7. Which of the tubes contains oxygen and which hydrogen? How do you know?



8. Measure how much oxygen you have produced and calculate your production rate per minute.

9. Assume that one astronaut breathes 0.84 kg of molecular oxygen (O_2) per day. Can your electrolysis system supply the required oxygen?

10. How can you produce more oxygen per day?

11. What are the advantages and disadvantages of using water electrolysis on the Moon?

Did you know?

Electrolysis of water is the main method of generating oxygen on board the International Space Station (ISS). Water is collected from urine, wastewater, and condensation and split into oxygen and hydrogen in the Oxygen Generation System (OGS). The station's football-field-sized solar arrays are the power source. A similar system could be used on the Moon.



The international Space Station (ISS) orbiting Earth →

NASA, ESA, JAXA and Roscosmos.

→ Activity 3: Fuel cell

Fuel cells can be used to power rovers or space ships or anything in between. Fuel cells do the opposite of electrolysis: they combine H_2 and O_2 and produce H_2O(water) and energy.

After observing how a fuel cell works, answer the questions below:

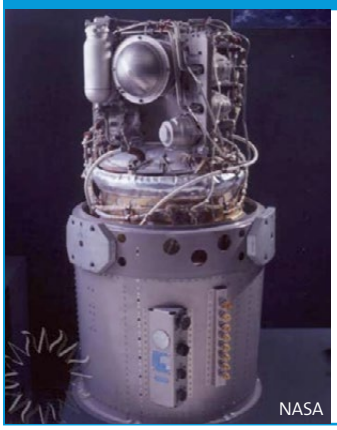
1. Balance the global reaction:

$$\square H_2(g) + \square O_2(g) \rightarrow \square H_2O(l) + \text{energy} + \text{heat}$$

2. Write the chemical reactions occurring at the anode and the cathode:

3. What are the advantages and disadvantages of fuel cells? How can we use them for missions to the Moon?

Did you know?


NASA

Fuel cells were the primary source of electric power on the Apollo programme that landed humans on the Moon. Apollo fuel cells used oxygen and hydrogen, stored as liquids at extremely cold temperatures, that when combined chemically yielded electric power and water for drinking. Fuel cells were also used on the Space Shuttle fleet as one component of the electrical power system. The space shuttle fleet flew 135 missions between 1981 and 2011.

← Apollo fuel cell.

4. What are the differences and similarities between the voltaic pile, electrolysis and the fuel cell?

→ Links

ESA resources

Moon Camp Challenge
esa.int/Education/Moon_Camp

Moon animations about the basics of living on the Moon.
esa.int/Education/Moon_Camp/The_basics_of_living

ESA classroom resources:
esa.int/Education/Classroom_resources

Extra information

Voltaic cell:
youtube.com/watch?v=9OVtk6G2TnQ

Electrolysis:
youtube.com/watch?v=dRtSjJCKkIo

Fuel cells:
youtube.com/watch?v=OmVnIIgDA7o

Fuel cell car science kit:
www.horizonfuelcellshop.com/europe/product/fuel-cell-car-science-kit

→ Annex 1: Electrolyser

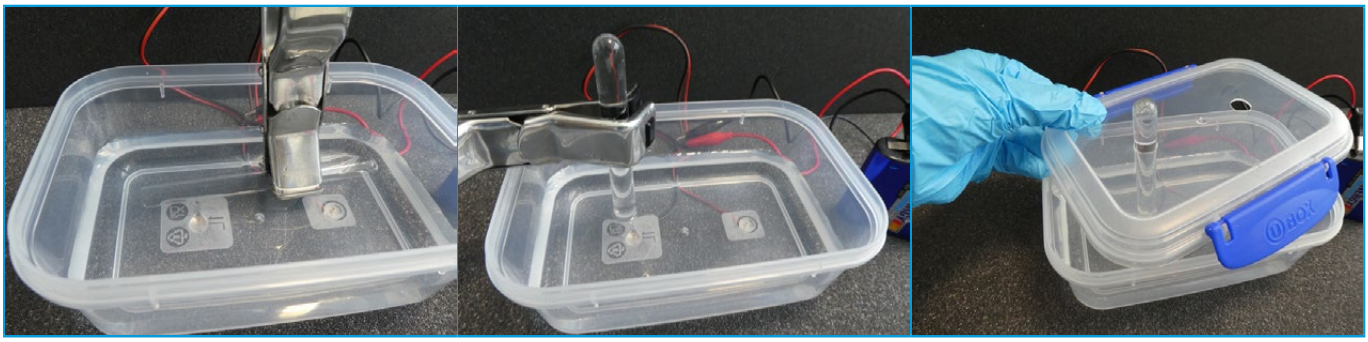
1. Use push pins to fasten the wires to the box



2. Dissolve NaOH in water (3%) and fill the container



3. Raise the test tubes over the punch pins (make sure they stay filled with water). Place the lid on top to keep the tubes in place

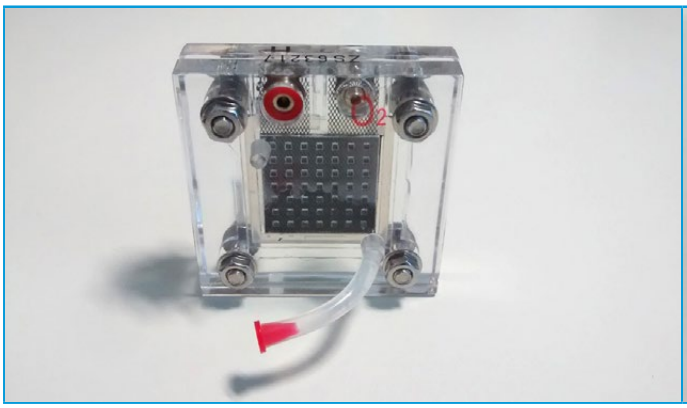


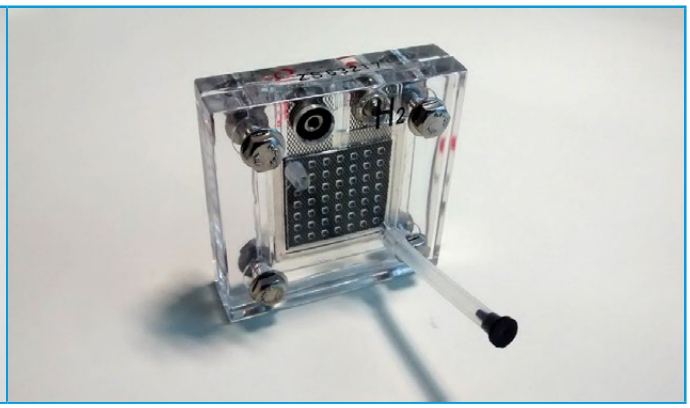
4. Connect the power source and start the electrolysis. Start a timer and record how long the process takes.



→ Annex 2 – Fuel cell

1. Connect two silicon tubes (4cm) to the nozzles on the fuel cell located on the lower section on both sides of the fuel cell.





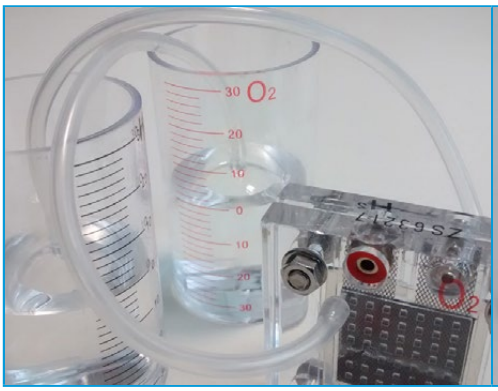
2. Remove the red cap from the tube connected to the oxygen side of the fuel cell. Using the syringe, inject distilled water into the fuel cell until the fuel cell is half filled with water

3. Place the dome shaped inner containers into the beakers and add water up to the "0" ml (the water should almost cover the inner container). Make sure there is no air trapped inside the inner containers.

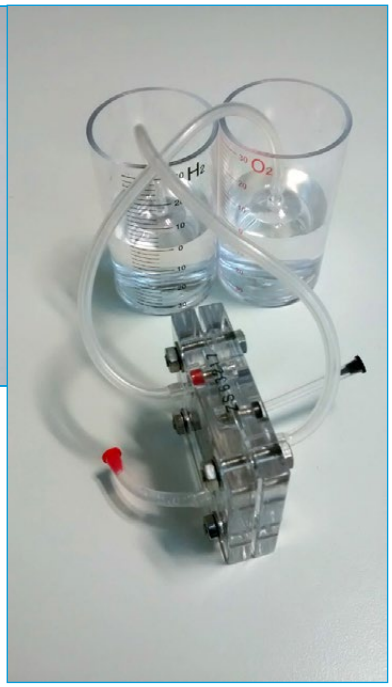




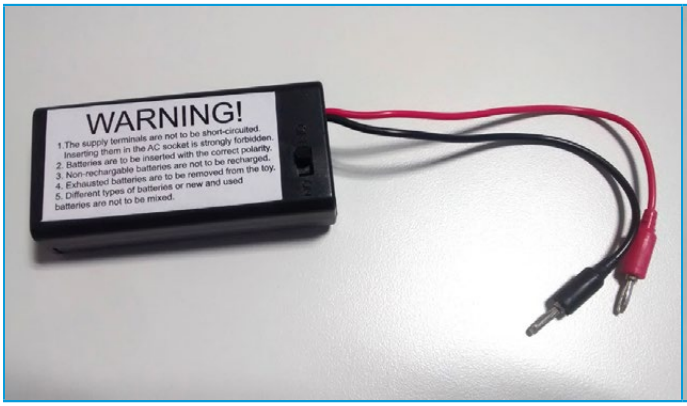
4. Connect the silicon tubes to the upper nozzles of both the O_2 and H_2 side of the fuel cell.

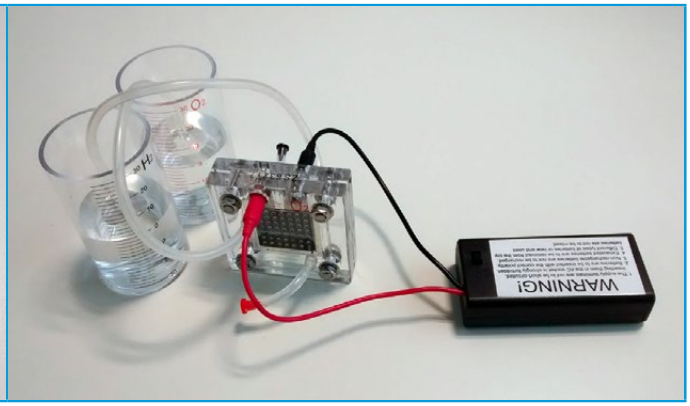






5. Connect the battery pack as seen below. Switch the battery pack to the “on” position and electrolysis should begin.

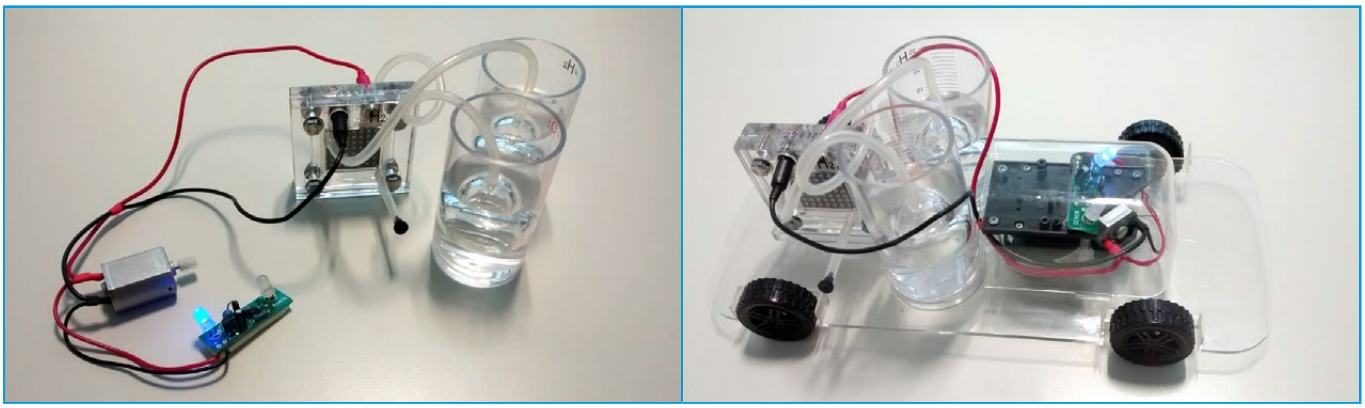




6. Observe how H_2 and O_2 start to fill the inner containers. When H_2 begins to bubble out of the container the tank is full.



5. Disconnect the battery and connect an actuator (car, motor, LED etc.). H_2 and O_2 combines again producing H_2o and energy to power the motor.

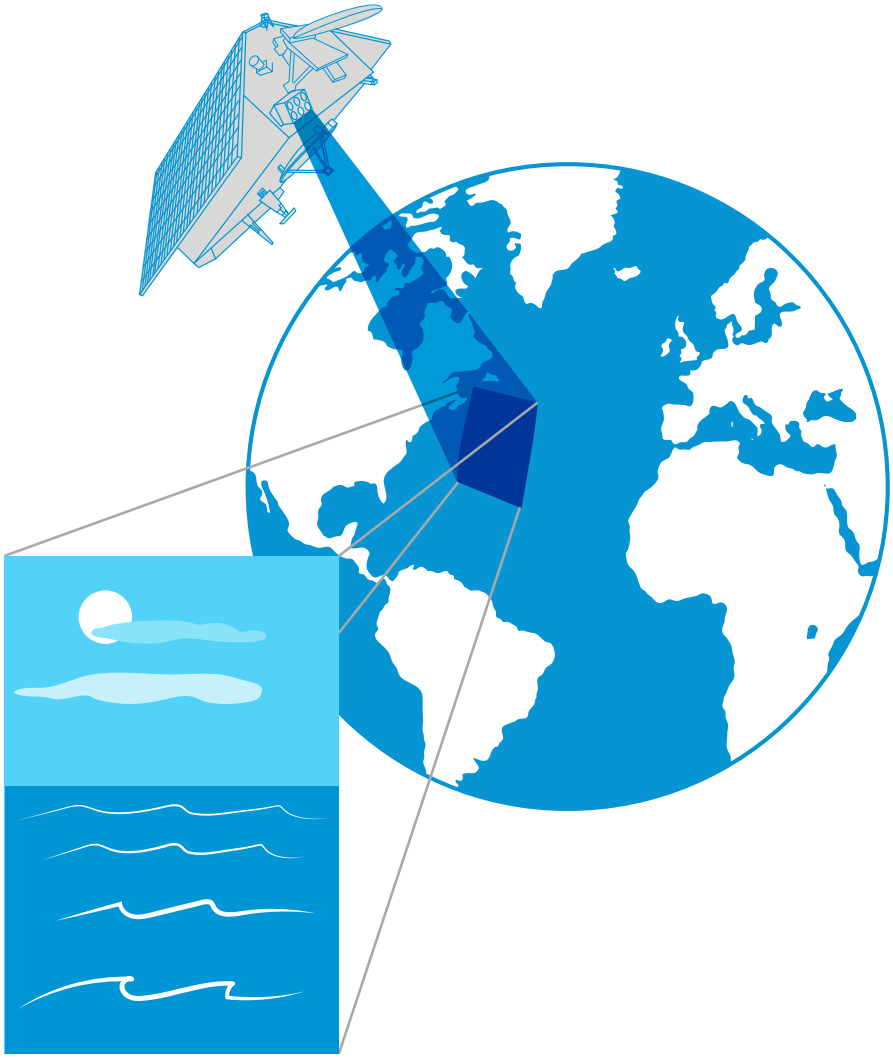


Geography | G02

teach with space

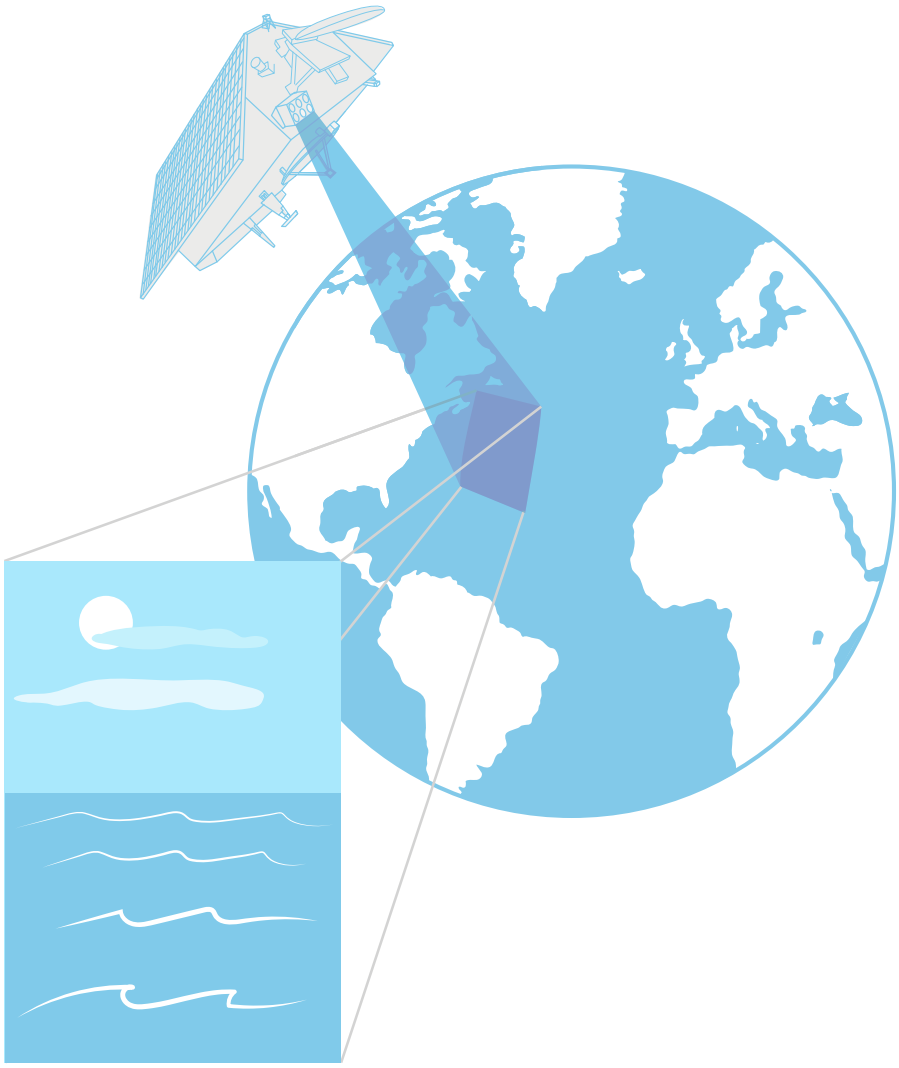
→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate



teacher guide & student worksheets

European Space Agency



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→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate

Fast facts

Subject: Geography, Science, Physics
Age range: 12-15 years old
Type: student activity
Complexity: easy
Lesson time required: 45 minutes for each activity
Cost: low (0 -10 euros)
Location: indoors
Includes the use of: multimedia module; computer and internet
Keywords: Earth observation, Sea currents, Sea surface temperature, Climate, Geography, Science, Physics

Brief description

In this set of activities students will use an multimedia module to learn about sea currents, the highways of the oceans, and how they are important for understanding local climates. Using a hands on activity they will investigate what causes ocean currents. They will also use satellite images to analyse the temperature of the sea surface and understand why satellite observations are useful for monitoring sea currents.

Learning objectives

- Elaborate on global ocean and air currents and discuss what they mean to the climate.
- Identify local and global weather processes and climatic phenomena and their causes.
- Use tools available on the internet to collect and analyse satellite data.
- Understand how Earth observation can be used to monitor oceans.
- Interpret sea surface temperature maps.

→ Summary of activities

Summary of activities					
	Title	**Description**	**Outcome**	**Requirements**	**Time**
1	Ocean in motion	Ocean currents and how they connect remote places. The great Pacific garbage patch.	To identify main ocean currents. To understand what drives ocean currents and how ocean currents have a global influence.	None	45 minutes
2	How does water sink?	A practical experiment to model water movements and investigate how deep ocean currents are created.	To understand that deep ocean currents are driven by differences in the water's density, which is controlled by temperature and salinity.	Activity 1	45 minutes
3	Feeling the heat	Analysing measurements of sea surface temperature taken by satellites.	To describe and understand the general distribution of sea surface temperatures.	None	45 minutes

→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate

→ Introduction

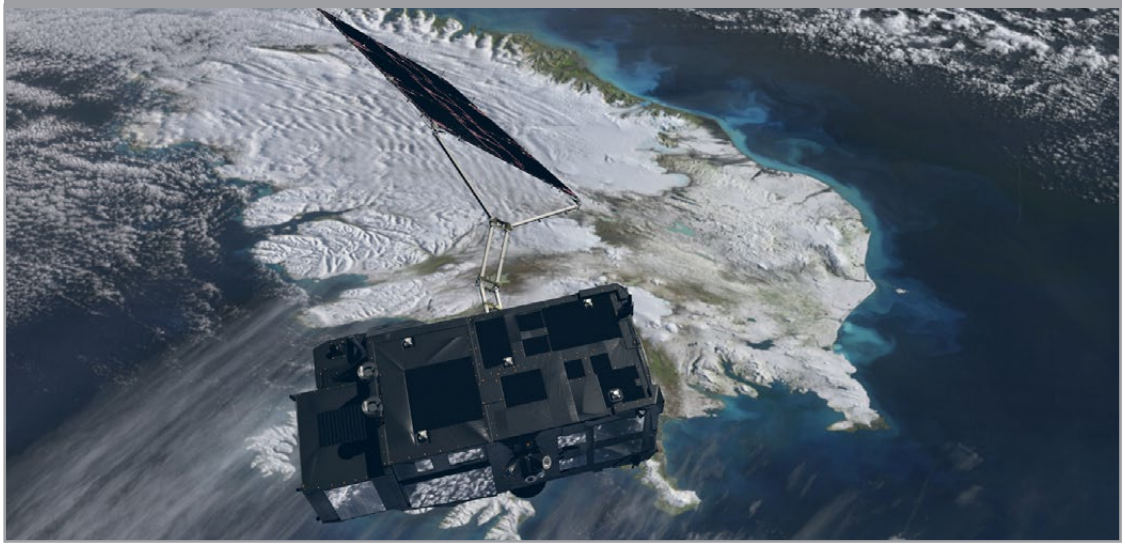
Covering 71% of the planet, the oceans are intrinsically linked to our weather and climate. They are also essential for global transport and provide a wealth of resources. What happens far out to sea has a direct impact on societies all over the world.

Ocean currents are driven by surface winds, differences in water density due to salinity and temperature variation, and by Earth's rotation. Ocean circulation and the ocean's capacity to accumulate and slowly release the energy it receives from the Sun play a crucial role in moderating the climate.

The oceans directly absorb the majority of solar heat, retaining it for much longer periods of time than either the land or the atmosphere. The equator receives much more energy from the Sun than the polar regions. The major ocean currents, together with the wind, help redistribute this energy around the world.

Satellites in combination with in-situ instruments provide important information to understand and monitor the oceans. Through Earth observation, scientists have been able to model and monitor global sea surface temperatures in unprecedented detail over the last decades. Considering that oceans are vast reservoirs of heat, measuring the sea surface temperature can improve our understanding of global warming and climate change.

Figure 1



↑The European satellite Sentinel-3 carries a suite of state-of-the-art instruments, including an infrared radiometer to provide global maps of sea surface temperature for monitoring climate change, ocean and weather forecasting.

→ Activity 1: Ocean in motion

In this activity, students will explore an multimedia module to learn about sea currents and how they connect remote places on our planet. Students will learn that winds and Earth's rotation are the main causes of surface currents. At the end, students will discuss ocean pollution, and debate possible actions to lessen the problem.

Equipment

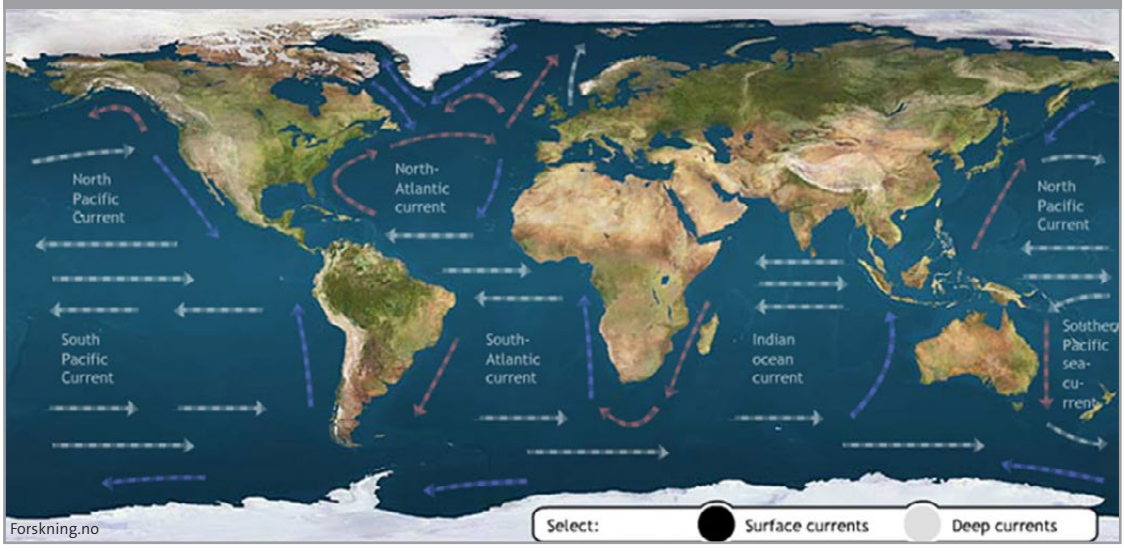
- PC and multimedia module "Sea_currents.exe" by Forskning.no and/or other information sources

Exercise

To introduce the topic, ask students to imagine dropping a message in a bottle into the ocean at a given location. Students should then answer question 1 on the student worksheet. Discuss in small groups where they think the bottle would wash up as a result of ocean currents. When the bottle is thrown into the Atlantic Ocean in Florida, the Gulf Stream will transport it eastwards towards Europe and Northern Africa. Then it will either follow the Canary current to the South, or the Norwegian Atlantic current to the North. The bottle will reach destination 2 or 4.

Students then work with the multimedia module, either in groups of two or independently. Teachers can also analyse the module with the whole class with a projector . Students answer question 2 on their worksheet while exploring slides 1 (Figure 2) to 3 of the module.

Figure 2



↑Sea currents, multimedia module.

Answers exercise 2

2. a. Identify two countries/cities that are affected by currents: one related to a warm current (red arrows), and another to a colder current (dark blue arrows).

   - UK – Norwegian Atlantic stream – warm current
   - Florida (USA) – Gulf stream – warm current
   - Canary Islands – Canary current – cold current

c. How are surface currents powered?

Surface currents in the ocean are primarily driven by the wind.

d. Identify a wind current and write down the sea surface current/s it powers.

- West wind belt (northern hemisphere westerlies): north Atlantic current.
- Northeast trade winds: northern equatorial current.

e. Try to answer the question from slide 3: why are both winds and ocean currents deflected to the right in the Northern Hemisphere?

The Earth rotates on its own axis, and because of that circulating air is deflected. Instead of circulating in a straight pattern between the poles (high pressure areas) and the equator (a low-pressure area), the air deflects toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. This effect is called the Coriolis effect. The Coriolis effect deflects the circulating air that causes the movement of the water's surface. Therefore, it also deflects the surface ocean currents to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Discussion

The millions of tonnes of plastic ending up in the oceans every year are a global challenge. Teachers can use the exercise about a message in a bottle to make an analogy with the transport of plastic and waste by ocean currents. In small groups, students investigate where plastic would end up from the beach closest to their home town based on the knowledge they have acquired about oceans currents and investigate the Great Pacific garbage patch.

Students discuss their expectations and answer question a) and b) from the discussion. In the "Did you know" section students can discover some examples of what the European Space Agency is doing to respond to this global challenge.

→ Activity 2: How does water sink?

Winds drive ocean surface currents. However, ocean currents also flow thousands of metres below the surface. In this activity, students will investigate why these masses of water sink to form the deep ocean currents.

Equipment

- Two 250ml beakers
- Coloured ice cubes
- 1 teaspoon
- Salt
- Water

Health and Safety

- Students should wet fingers before touching ice cubes.
- Coloured water/ice could stain fingers/clothes/tables.

Exercise

As a starting point, students discuss in small groups their expectations about why they think ocean water sinks to form deep ocean currents. After answering question 1, students set-up the experiment. Instructions for doing the experiment are provided in the student worksheet.

Discussion

Beaker 1 contains salt water, which has a higher density than the fresh water in beaker 2. Therefore, the coloured water from the melting ice cubes accumulates as a layer on top of the water in beaker 1 (see figure 3). In beaker 2, the melting water is colder than the water in the beaker, and therefore students can see how the coloured water is sinking. This creates some turbulence and mixing, resulting in colouring of all the water in the beaker. Students should compare their expectations to the question, "How does the ocean water sink to form deep ocean currents?" to their answer to question 4 of the discussion.

Figure 3



↑ Experimental results: the coloured melting fresh water accumulates on the top of the more dense salt water in beaker 1 (left).

To conclude and link with Activity 1, teachers can show students slides 5 to 8 from the multimedia module.

Extension – The Gulf Stream current

Teachers can use the Gulf Stream current example and ask students to answer the question from slide 9 from the multimedia module: "How can the ocean's currents be affected by the ice melting?", and explore possible impacts on the climate.

The Gulf Stream current, which carries warm surface water northwards from the Gulf of Mexico to the sub-polar ocean east of Greenland, is very important for the climate in Europe. The coastal waters of Europe are a few degrees warmer than waters at the equivalent latitude in the North Pacific. These warm waters mix with surrounding water, and cool and sink as they reach the Arctic. If this circulation pattern were disturbed by melted ice in the Arctic, there could be a profound effect on the strength and direction of this current. This current could become weaker or even stop.

Students should be able to explain that ice consists of freshwater, and as ice melts there is an influx of freshwater into the surrounding ocean. This reduces the salinity and, consequently, the density of the water. Students should be able to explain why, therefore, global warming can affect sea currents and the impacts this may have. Students should understand that combining satellite measurements along with ground measurements, can produce a unique view of ocean-surface circulation, helping us to predict how our planet will react to a changing climate.

→ Activity 3: Feeling the heat

In this activity, students will use satellite images to analyse the temperature of the sea surface. Students will investigate the relation between ocean currents and the sea surface temperature (SST), and understand the importance of monitoring the temperature of the oceans.

Equipment

- PC and internet access

Exercise

To introduce the topic, ask students to answer question 1 on their worksheets. Students should be able to identify the heating from the Sun as the main mechanism responsible for the distribution of the temperature of the sea.

Then students analyse measurements of the sea surface. For that they download the latest Sea Surface Temperature image from the website of University of Wisconsin-Madison Space Science and Engineering Center (see Links section). Guide students so they conclude that temperature varies by latitude, from the warm region along the equator to the cold regions near the poles. The large areas of sea ice around Antarctica appear in shades of grey, indicating no data were collected.

Students can identify the western coasts of South America, and Africa as well as the Norwegian coast as areas that deviate from the general behaviour of the distribution of the sea temperature. In the western coast of South America and South Africa, the water is colder due to the Humboldt current and Benguela current, respectively. The temperature of the water in the Norwegian coast is warmer when compared with other place at the same latitude due to the influence of the Gulf Stream.

Teachers can show again the multimedia module from Activity 1 (slide 1) for students to identify the effects of the ocean currents in the SST image that they downloaded.

As a final exercise, students analyse the seasonality in sea surface temperatures. Before starting the exercise, students should discuss their expectations regarding the changes of the sea surface temperature with seasons. In order to complete the exercise, students download one SST image for each season. Teachers can choose to download the images in advance and complete the exercise with the whole class, or in small groups with a printed version of the images.

Students can also analyse the animation from ESA's Climate Change Initiative (see Links section) showing changes in global sea-surface temperature between 1991 and 2010. They can investigate the seasonality as well as possible changes of the sea surface temperature.

Students conclude that the seasonality in sea surface temperatures is largest in mid-latitudes and lowest in the tropical ocean near the equator. This seasonality derives from changes in atmospheric conditions such as winds and temperature. Since the sea surface is in direct contact with the atmosphere, its temperature follows atmospheric seasonal patterns. Teachers can also ask students to compare oceanic seasons with respect to their atmospheric equivalents, and discuss the high heat capacity of water.

→ STUDENT WORKSHEET

→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate

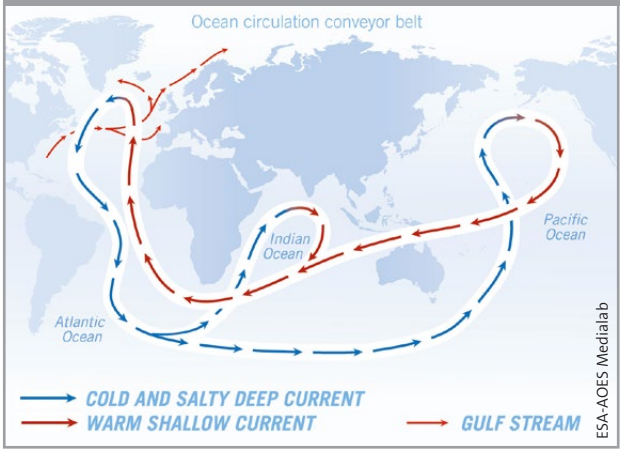
Ocean currents transport warm and cold water over enormous territories. Many of these currents have a major influence on the climate on land. Satellites are important tools for monitoring of oceans, surveying current changes, and contributing to increased knowledge about the pattern of ocean currents.

The ocean in constant circulation

The ocean covers about 71% of the globe and is therefore essential to the environment and to life on Earth. These enormous quantities of water are in constant circulation, and transport heat and energy from one area of the globe to another, for instance along the coast of Europe.

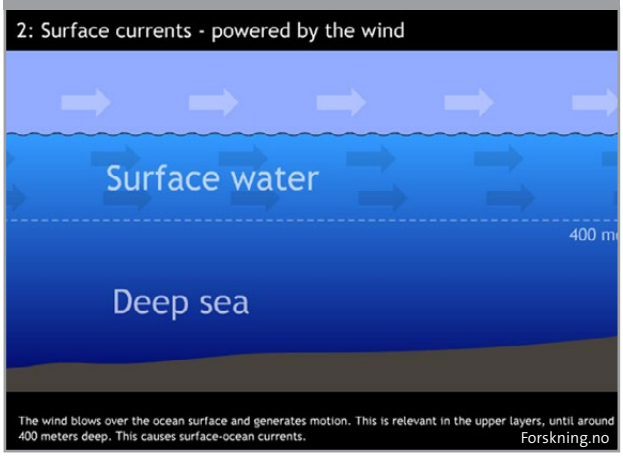
The systems of ocean currents are primarily driven by a combined effect of wind, atmospheric pressure on the surface, and the differences in density between various water masses. This density depends on the temperature and salinity of the water. Therefore, many effects define the 'highways of the oceans'.

Figure A1



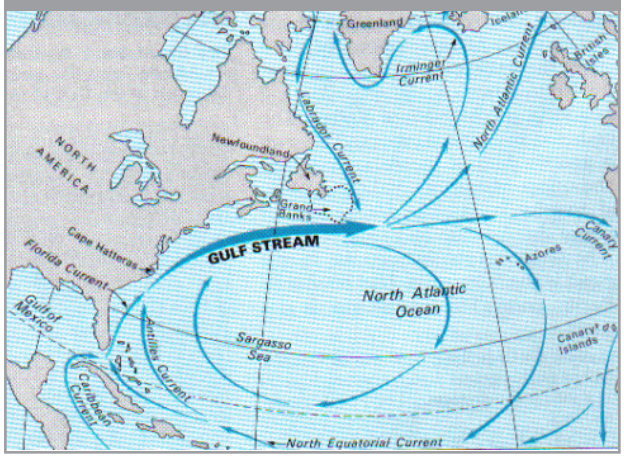
↑ Ocean currents have a key role in climate.

Figure A2



↑Surface and deep sea currents.

Figure A3



↑ Gulf Stream current.

→ Activity 1: Ocean in motion

In this activity, you will use an multimedia module to learn about sea currents – the highways of the oceans – and how they connect completely remote places on our planet. You will also learn what drives surface currents and discuss the importance of these highways.

Did you know?


ESA/ATG Medialab

Christopher Columbus used the Gulf Stream current to be able to reach America by sailing from the Canary Islands during his voyages. In the past, exploration and navigation across the Atlantic provided knowledge of this warm current. Today, Earth Observation satellites offer a frequent overview of our entire planet – covered mostly by water – and provide valuable data to monitor and understand this and other ocean currents. Measurements of ocean surface currents are fundamental to a number of practical applications, such as marine search and rescue and emergency response, ship routing, and water pollution monitoring.

Equipment

- PC and multimedia module "Sea_currents.exe" by Forskning.no and/or other information sources

Exercise

1. In this exercise you will explore the ocean currents. Before you start doing that, let us think about currents:

   Imagine that you are in Florida, USA, marked with a 📍 in figure A4, and want to send a message inside a bottle. Where do you expect this message can go? Mark the possible correct answer. Take into account that there can be more than one correct answer. Discuss with your colleagues in the classroom.

   ☐ 1. We will find it on the south-eastern coast of South America (Brazil or Argentina).

   ☐ 2. We will find it in the Canary Islands.

   ☐ 3. We will find it on the south-western coast of Africa.

   ☐ 4. We will find it in north Norway.

   ☐ 5. After some time, the bottle will return to the beach in Florida.

Figure A4



↑Where does the bottle go?

2. You will now start exploring the multimedia module: analyse slides 1 to 3 and answer the following questions:

a) Identify two countries/cities that are affected by currents: one related to a warm current (red arrows), and another to a colder current (dark blue arrows).

b) Follow the North Atlantic current. Think again about the bottle experiment from question 1 and revise which area/s the bottle can reach.

c) How are surface currents powered?

d) Identify a wind current and write down the sea surface current/s it powers.

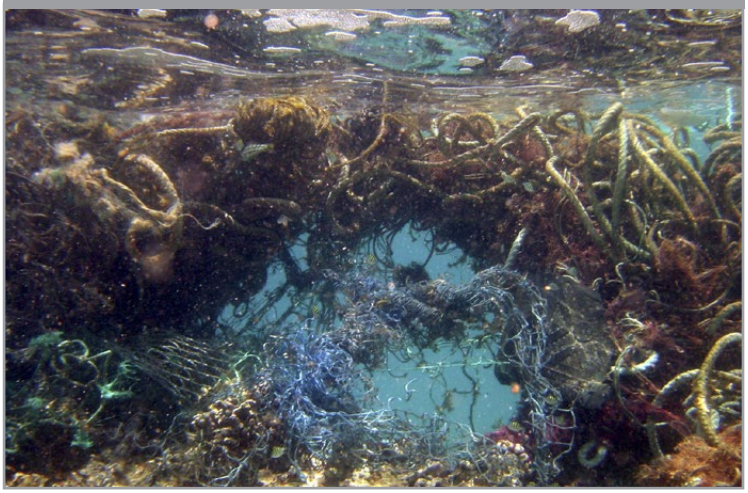
e) Try to answer the question from slide 3: why are both winds and ocean currents deflected to the right in the Northern Hemisphere?

Discussion

a) You have been thinking about a message in a bottle. But the currents are also moving all the trash we throw into the sea, and this is a lot! Due to currents, plastic travels large distances, and huge amounts can accumulate in certain places. Choose the closest sea coast to your local area. Where do you expect the plastic trash that it is thrown there will be accumulated?

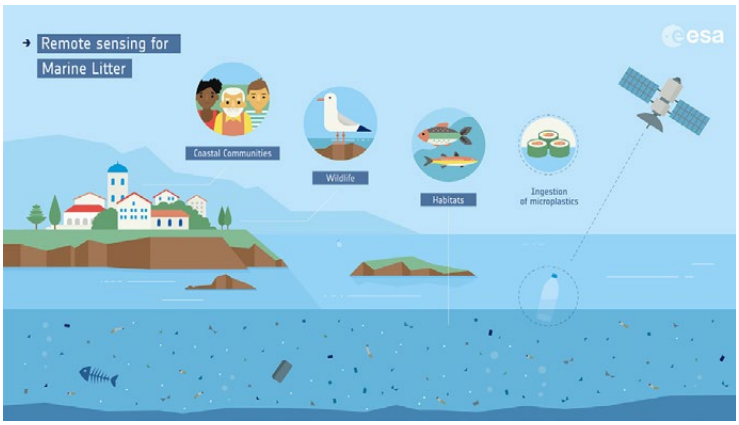
b) Have you ever heard about the Great Pacific garbage patch? It is a massive floating island of plastic between California and Hawaii. Research online to find more information about this "island" and discuss possible actions to mitigate the problem.

Figure A5



↑ Marine debris found in the waters of the Northwestern Hawaiian Islands Marine National Monument.

Did you know?



The European Space Agency (ESA) is investigating technology that would allow satellites to identify the concentration, movement and origin of plastic debris across the world's oceans. Plastics in the ocean can be identified by satellites due to the way floating debris reflects different wavelengths of sunlight, in a similar way to how current satellites can pick out concentrations of phytoplankton, suspended sediments, and water pollution. Satellite measurements have the great advantage of providing global coverage and this can give important insights to scientists to enable them to understand and monitor the problem.

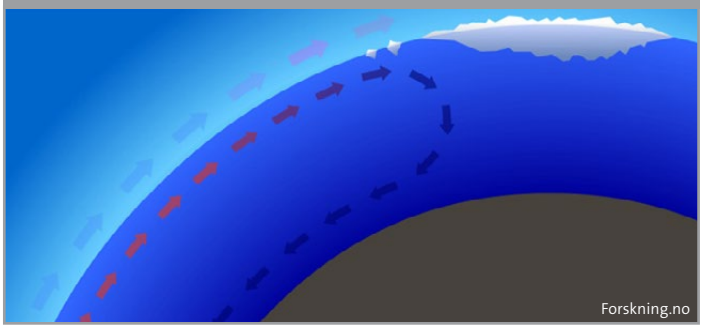
→ Activity 2: How does water sink?

The world's oceans consist of two types of ocean currents: surface currents and deep water currents. In this activity, you will explore why some of these masses of water sink to form the deep ocean currents.

Equipment

- Two 250ml beakers
- 1 teaspoon
- Coloured ice
- Salt
- Water

Figure A6



↑ Sea currents multimedia module, water flow.

Exercise

1. Describe why you think deep water currents are originated by answering the following question:

   How does the ocean water sink to form deep ocean currents?

2. You will now model water movements and investigate how deep ocean currents are caused. Fill two beakers with roughly 200ml of tap water.

3. Mix three teaspoons of salt into one of the beakers (beaker 1) and let it settle until the water is clear. While waiting, answer the following question:

   Prediction: What will happen when you put the ice cubes in the beakers and they start melting?

4. Gently drop one ice cube into each of the beakers.

5. As the ice starts melting, observe and record the behaviour of the fluids. Do not disturb the beakers.

Discussion

1. Describe the differences between what happened in beaker 1 and beaker 2.

2. Are your results similar to your prediction? Explain why or why not.

3. What can you conclude about the density of the water in the beakers in comparison to the cold water released by the melting ice cubes?

4. Based on your observations, what do you think are the main causes of deep ocean currents?

5. Compare your observations and conclusions with what is shown in the multimedia module (slides 5 and 6). Are they similar?

Extension – The Gulf Stream current

Revise all the slides of the sea currents multimedia module. Discuss in small groups the following issues:

1. What may happen to the Gulf Stream current if sea ice continues to melt, and why?

2. Does this have any impact on the climate?

3. How could this affect the economy of the region? For example, Norway's northern coast is very rich in fisheries that provide a major income for many families.

4. How can we monitor the health of the Gulf Stream current?

Did you know?

The European Space Agency is developing a family of innovative satellite missions – the Sentinels – to understand and monitor our planet. Sentinel-6/Jason-CS will map up to 95% of Earth's ice-free ocean every 10 days, providing vital information on sea level variability, wind speeds and wave height for maritime safety. The instruments carried on Sentinel-6 will also measure the ocean surface topography – the hills and valleys of the ocean – to help us to map ocean currents.

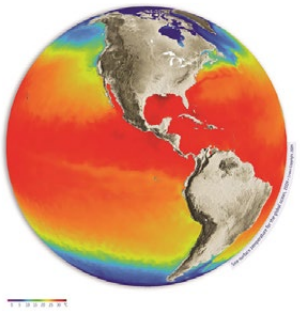


→ Activity 3: Feeling the heat

In this activity, you will use satellite images to analyse the temperature of the sea surface, a key measurement for climate scientists. This is a very important parameter to understand the health of our planet. It also gives indications about sea currents. Measurements of the surface temperature of the water are made from a variety of satellite systems. These types of surface temperature image are called SST – Sea Surface Temperature images.

Did you know?

To measure the sea surface temperature, satellites register different types of light that we cannot see with our eyes. One of these special types of light (or radiation) is called thermal infrared. It is the same radiation registered by night vision cameras. The infrared sensor from the Sentinel-3 satellite provides precise global maps of sea surface temperature. This information is used to monitor oceans and climate change, as well as for weather forecasting.



Equipment

- PC and internet access

Exercise

1. Before you start analysing measurements of the sea surface temperature taken from satellites, discuss in small groups the following questions:

   a) What do you think are the main mechanisms responsible for the distribution of the temperature of the sea? Mark the correct answer(s).

   ☐ Heating from the Sun

   ☐ Pollution

   ☐ The clouds

   ☐ The level of CO_2

b) Where do you expect to find warm water? See figure 7 and identify the beaches with warmer water (order them from warmer to colder).

1- Belem (Brazil), 2- Bleik (Norway), 3- Florida (USA), 4- Tenerife (Spain), 5- Lisbon (Portugal).

Figure A7



↑Localisation of the beaches for task 1.

2. You will now analyse the latest measurement of the sea surface temperature taken by satellites and compare with your expectations.

a) Open the following link from the University of Wisconsin-Madison Space Science and Engineering Center:

www.ssec.wisc.edu/data/sst

Click on "Latest Sea Surface Temperature image" to enlarge and save the picture.

b) Analyse the sea surface image you have downloaded. Looking at the planet, describe the general distribution of temperatures. Where is it warmer and where is it colder?
The scale shows the temperature in Fahrenheit (°F). To convert it to Celsius (°C), remember that $T(°C) = (T(°F) - 32) \times 5/9$.

c) Compare your answer to question 2b) with your answer to question 1b). Are your expectations similar to your observations from the SST image? Explain why or why not.

d) Some areas deviate from the general behaviour of the distribution of sea temperature. Locate two of them on the map and describe how they differ.

3. You will now analyse and compare SST images from different seasons.

   a) Open the following link: www.ssec.wisc.edu/data/sst/archive. The SST images you see are sorted by date. Download one SST image for each season.

   b) Observe and compare the images. Identify two areas where you detect changes in ocean surface temperature and two areas where the temperature is constant for the different seasons.

4. Are the differences in sea surface temperatures according to seasons similar to your expectations? Explain why and compare your answer to your expectations in question 1a).

→ Links

ESA resources

ESA classroom resources:
esa.int/Education/Classroom_resources

ESA space projects

ESA's Earth Observation missions
esa.int/Our_Activities/Observing_the_Earth/ESA_for_Earth

Sentinel-3
esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3

Sentinel-6
esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-6

ESA's Climate Change Initiative
http://cci.esa.int

Extra information

Ocean currents interactive module developed by Forskning.no and translated to English by Nordic ESERO
http://esamultimedia.esa.int/docs/edu/sea_currents_english.zip

University of Wisconsin-Madison Space Science and Engineering Center - Sea Surface Temperature Data
www.ssec.wisc.edu/data/sst

Animation showing changes in global sea-surface temperature between 1991 and 2010, by ESA's Climate Change Initiative
esa.int/spaceinvideos/Videos/2018/05/Global_sea-surface_temperature_1991_2010

Video Sentinel- 3 for oceans
esa.int/spaceinvideos/Videos/2016/02/Sentinel-3_for_oceans

Videos and animations related to ocean's research within ESA
esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth/Oceans/ESA_and_Oceans_videos

Science Education through Earth Observation for High Schools (SEOS) Project
lms.seos-project.eu/learning_modules/oceancurrents/oceancurrents-c00-p01.html

Who are we?

What is ESERO Ireland?

ESERO Ireland is an education project of the European Space Agency (ESA) that is co-funded by Research Ireland while also working with national collaborators. Our aim is to spark young people's passion for STEM (science, technology, engineering, maths) through the exciting world of space, build their skills, and empower them to pursue careers in space. We also raise awareness of the vital role space research, exploration, and applications play in shaping modern society, using engaging resources and creative teaching methods, and inspiration from role models.

Find out more at **esero.ie**, and follow us on social media **@ResearchIreland**.

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