Science in School
The European journal for science teachers

ISSUE 73 – June 2025 **Topics** Chemistry | Physics

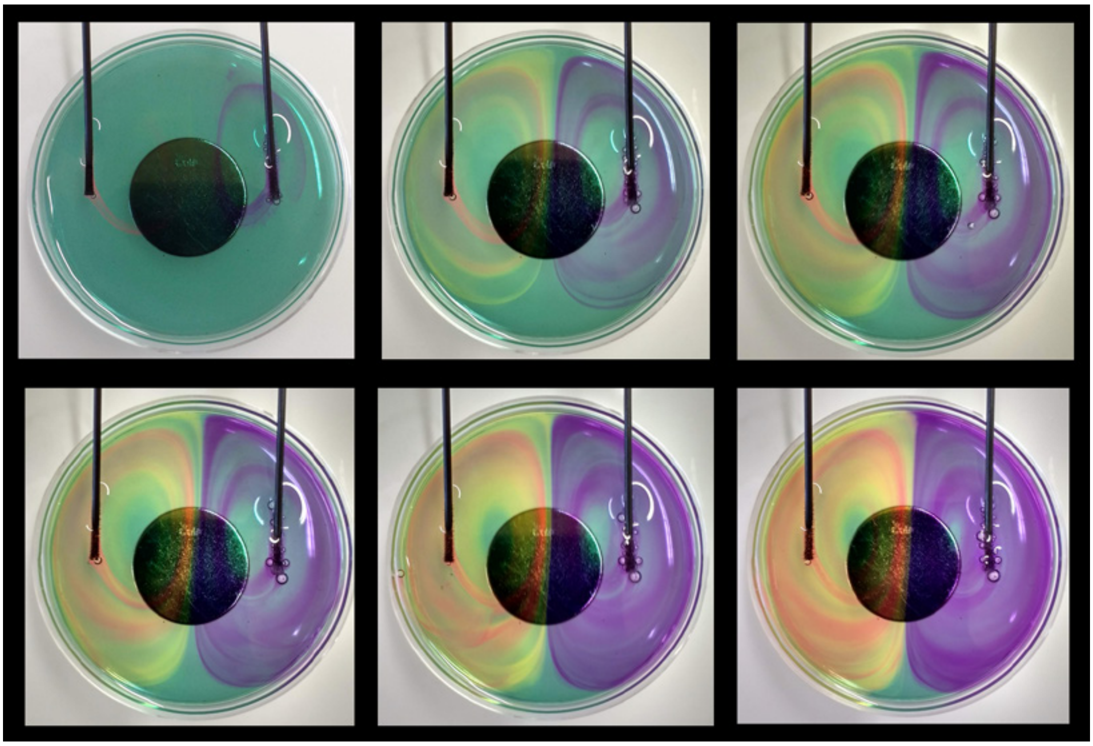
Colourful electrolysis vortex in a magnetic field

Klemens Koch

Chasing rainbows: the interaction of an electric current and magnetic field in a solution with pH indicator gives amazing colour patterns as electrolysis occurs.

Water electrolysis requires an electric current to pass through water and, in addition to the formation of the elements hydrogen and oxygen, leads to acid–base chemical reactions. Electrolysis produces new ions, H^+ (aq) and OH^- (aq), which have an alkaline or acidic effect and change the colour of pH indicators.

The electric current is part of the electromagnetic phenomenon. It produces magnetic effects and, conversely, a magnet exerts forces on a conductor and can set it in motion. Combining electrolysis, colour changes, an electric current, and a magnetic field creates dynamic colour effects,[1,2] which provide a particularly engaging way to demonstrate these topics.



Motion in an electrolysis cell with pH-indicator-coloured salt water in a magnetic field
Image courtesy of the author

The following activities are simple, safe, produce surprising effects, awaken the spirit of research, and allow students to conduct their own experiments, as the conditions (polarity of the magnets, position of the electrodes, stirring, etc.) can be easily varied.

The experiment demonstrates basic chemical and electromagnetic phenomena, is safe, and can be explained and deepened on different levels. It can be carried out by everyone and adequately discussed in terms of content; at school, it is most relevant for students aged 14–19. Due to the many references to topics in physics and general chemistry, such as material properties, acids/bases, and redox reactions, it is also suitable for first-year university students.

Colourful electrolysis vortex

In this activity, electrolysis is carried out in a solution containing a pH indicator placed above a neodymium magnet. This leads to colourful swirls shaped by the magnetic field. The experiment is fairly easy and safe and can be carried out by the students themselves. To save time and materials, the experiment can first be demonstrated by the teacher, and then, after discussing the results, the students can carry out their own experiments to test their hypotheses on the effect of changing variables.

The time required is about 10 minutes to prepare the solutions, 10 minutes for each variant/hypothesis test, and 5 minutes for clearing up, with additional time for discussion.

Safety notes

There is a minor risk from a possible short circuit if electrically conductive parts touch each other without resistance. This is particularly possible with the electrodes or the crocodile clips. This could lead to overheating of the batteries or the power supply unit.

The neodymium magnets generate strong magnetic fields and forces that can cause injury if they snap together. This can lead to pinching of the skin if they are handled without spacing and caution.

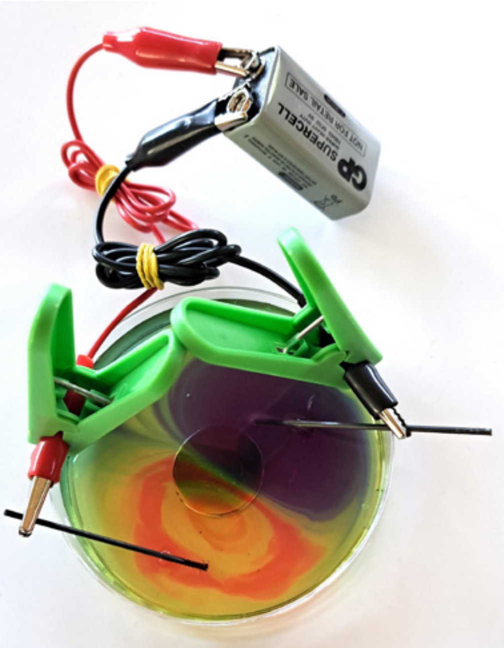
The solutions present a low hazard and can be reused or poured down the sink in most places (please follow local regulations).

Materials

- Petri dishes (glass or polystyrene, 4–9 cm in diameter)
- Carbon electrodes (carbon rod for kite making or pencil leads)
- Crocodile clips and cables
- Tap water
- A sulfate or nitrate salt, e.g., sodium sulfate (Glauber's salt), magnesium sulfate (bitter salt), sodium nitrate (Chile saltpeter).
- Optional: table salt
- Sodium bicarbonate (baking soda, sodium hydrogen carbonate)
- Universal indicator solution
- Power supply (9 V or 18 V for demonstration by the teacher, at least 2 A) or 9 V battery
- Disc-shaped neodymium magnet (approx. 3 mm x 22 mm)
- Student instructions
- Colourful vortex infosheet
- Optional: table salt
- Optional: red-cabbage juice
- Optional: ground pepper

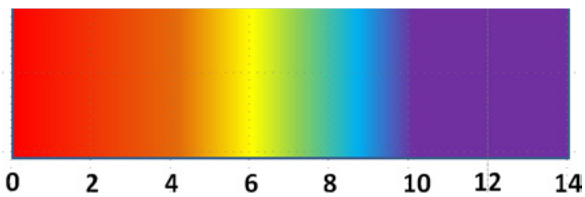
Procedure

1. Divide the students into small groups and hand out the student instructions. They should then carry out the following steps.
2. Prepare 50 mL of a sulfate or nitrate salt solution in tap water ($c \approx 0.1$ mol/l or 0.5 g/50 ml). The material should be prepared, but ideally the solution should be mixed by the students themselves to better understand what is happening.
3. Add some synthetic universal pH indicator. Tap water is slightly alkaline because calcium bicarbonate from lime is dissolved in it. If it is not alkaline, add a few grains of sodium bicarbonate to adjust the pH to neutral or slightly alkaline (green colour).
4. Pour about 20 mL of the solution into a Petri dish so that it is about half full. Place the Petri dish on the disc-shaped neodymium magnet.
5. Connect one end of the carbon electrode to a 9 V battery or a power-supply unit and place the other end in the solution.



Experimental setup. In the photo, pegs hold the electrodes in place. To better influence the dynamics, you can hold the clips connected to the electrodes yourself.
Image courtesy of the author

6. At the end of the experiment, students can disconnect the power source, remove the electrodes, and gently swirl or stir the liquid in the dish. The solution should return to its starting colour.
7. Discuss the results (see discussion section below) and ask the students to explain what they see. The indicator colour scale can be provided to help them explain the results. As a hint to the patterns seen, draw their attention to the charges on the products of the electrolysis reaction.



Universal indicator solution at different pH values
Image courtesy of the author

8. Ask students which variables they could change (e.g., different starting pH, different salt or indicator concentration, reversing the current or magnet, moving the electrodes during the experiment) and to formulate a hypothesis on how this would change the results.
9. Recommended: have the students try one of the suggested changes to test their hypothesis.

Discussion

After discussing the results, the students should understand the electrolysis reaction that has taken place:

Positive electrode (anode):

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

Negative electrode (cathode):

$2H_2O + 2e^- \rightarrow H_2\ (g) + 2OH^-\ (aq)$ (2×)

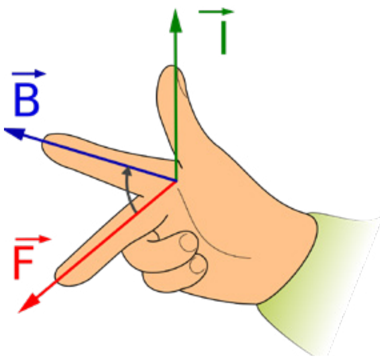
Total reaction:

$6H_2O \rightarrow 2H_2\ (g) + O_2\ (g) + 4H^+\ (aq) + 4OH^-\ (aq)$

They should understand that the H^+ and OH^- ions make the solution acidic or alkaline at the respective electrodes, which causes the colour change in the indicator solution.

The ions Na^+, SO_4^{2-}, and NO_3^- are below or above water in the electrochemical series: they conduct the current required for electrolysis, but do not react.

The movement can be explained by the Lorentz force *F* which is exerted by the magnetic field *B* on the electrolysis current *I*, whereby the orientation follows the right-hand rule.



Orientation of Lorentz force *F* in magnetic field *B* on current *I*: right-hand rule
Image: Canarris/Wikimedia Commons, CC BY-SA 3.0

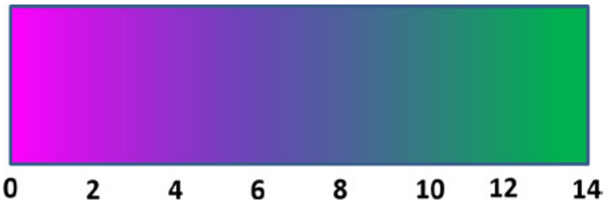
These explanations are summarized in the colourful vortex infosheet, which can be handed out during the discussion. It may be helpful for the basic results to be discussed and understood before the students start to formulate their own hypotheses on the results of changing difference variables.

Optional variations

This experiment also lends itself to several optional variations, which can help engage students or help them understand different aspects of the phenomenon.

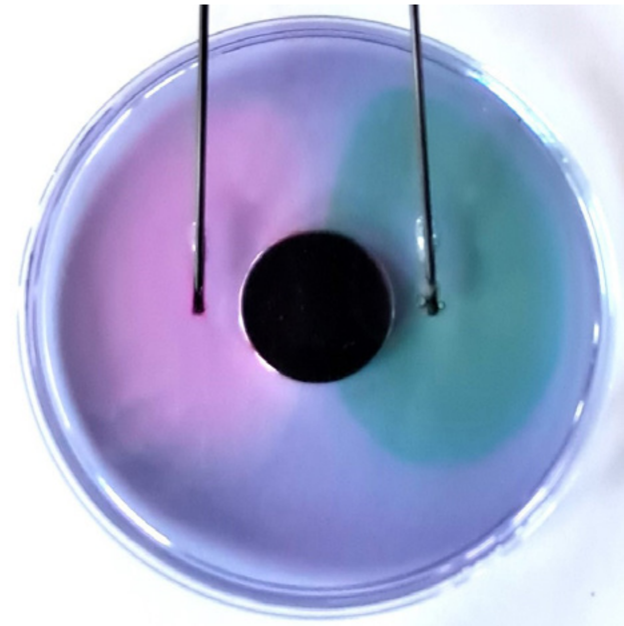
Variant 1 – red-cabbage indicator

Use red-cabbage juice instead of a synthetic universal indicator.



Red-cabbage-juice colours at different pH values
Image courtesy of the author

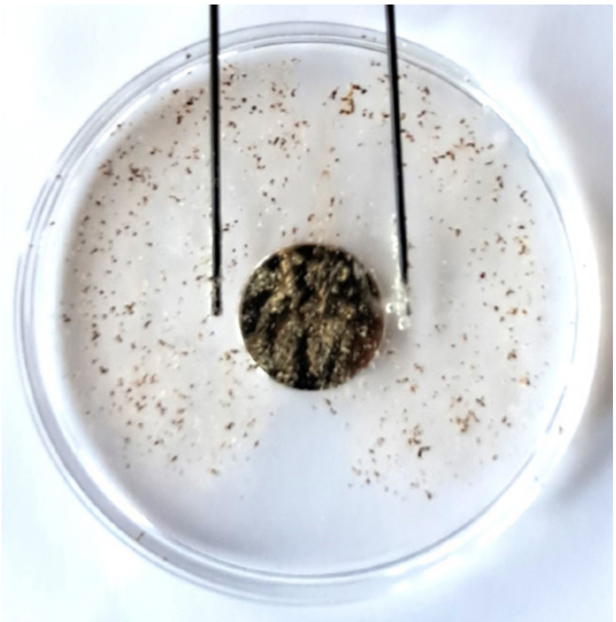
It gives beautiful colours, and it can be more accessible and motivating to work with an indicator extracted from food. One disadvantage is that it turns yellow over time due to slow secondary reactions in the alkaline range.



Electrolysis with red-cabbage juice as an indicator
Image courtesy of the author

Variant 2 – ground pepper

Use ground powder instead of a pH indicator. The aqueous solution must be calm before a little pepper powder is sprinkled on the surface. It provides a visual demonstration of the process because in homogeneous solutions you cannot see the particles move, whereas the pepper particles visibly move, making the movement patterns directly observable.



Electrolysis with pepper powder as an indicator
Image courtesy of the author

Variant 3 – table-salt solution

Table salt can be used as an everyday product instead of sulfate and nitrate salts in all variations. However, caution is needed since the electrolysis of table salt produces small amounts for chlorine gas. This is a cognitive extension of the basic experiment, because the chloride ions here are not inert and react to give a small amount of chlorine.

Safety note

This electrolysis of sodium chloride produces small amounts of chlorine gas, so this reaction should be done in a fume hood or well-ventilated area in limited numbers/duration.

Conclusion

The combination of colour changes and movement leads to beautiful images and curious questions. What happens when I reverse the current or magnet? What happens if I change the pH, concentration, or viscosity of the solution? The hypotheses can easily be tested and confirmed or refuted, which leads to a strengthening of knowledge about electromagnetic phenomena and self-efficacy expectations for scientific work.

The experiment leads to a deeper understanding of electrical conductivity by electrons in the electrode and by ions in the aqueous solution of the electrolyte. Some ions are electrochemically inert and only contribute to conductivity (Na^+, SO_4^{2-}, NO_3^-); other ions are also involved in the electrolysis reactions (Cl^-, OH^-, $H3O^+$).

The electromagnetic relationships observed and understood can be easily transferred to other technical and natural phenomena, which the teacher can explain or the students can research themselves. These include electric motors (especially homopolar motors); dynamos; electric generators; and the aurora [northern lights (aurora borealis) or southern lights (aurora australis)], which are easily associated with the experiment because of their movement and colours, as well as interesting similarities and differences. The magnetic deflection of the ion current can be used to explain mass spectrometry. In this analytical method, the masses of ions are determined in a vacuum through the degree of deflection. «

References

[1] Watch a video on the electrolysis of sodium sulfate solution influenced by a magnet: https://www.youtube.com/watch?v=t2Thrs1axOw

[2] Koch K (2022) Elektrolyse-Wirbel im Magnetfeld. Chemietage Innsbruck (conference proceeding)

Resources

- Discover how solar winds and the Earth's magnetosphere create fascinating auroras.
- Try a safer microscale version of electrolysis using chloride ions: Worley B, Allan A (2022) Elegant electrolysis – the microscale way. *Science in School* **60**.
- Teach electrochemistry by building your own battery, just like Volta did in the 1800s: D'Acquisto G (2025) The birth of electrochemistry: building a simple voltaic pile. *Science in School* **71**.
- Introduce your students to the chemistry of precipitation using microscale chemistry methods: Worley B, Allan A (2022) Pleasing precipitation performances – the microscale way. *Science in School* **57**.
- Use baker's yeast to demonstrate biofuel cells in the classroom: Grandrath R, Bohrmann-Linde C (2023) Simple biofuel cells: the superpower of baker's yeast. *Science in School* **66**.
- Try some activities to test drinking water and encourage sustainable habits: Bergamotti D, Semeghini P (2023) What are you drinking? Tap water versus bottled water. *Science in School* **65**.
- Explore laboratory safety with creative horror stories about lab disasters: Havaste P, Hlaj J (2024) Lab disasters: creative learning through storytelling. *Science in School* **68**.
- Learn more about oxidizing and reducing agents through colourful reactions between lollipops and permanganate salts: Prolongo M, Pinto G (2018) Colourful chemistry: redox reactions with lollipops. *Science in School* **43**: 41–45.
- Learn how a simple device can create a powerful sterilizing solution from just air, water, and electricity: Barth N (2025) The power of plasma: turning water into an eco-friendly disinfectant. *Science in School* **71**.
- Learn about the problem of pseudoscience in the media: Domenici V (2022) Fake news in chemistry and how to deal with it. *Science in School* **59**.
- Read about the colour blue in nature and the chemistry behind it: Bettucci O (2022) Colour in nature: true blue. *Science in School* **60**.
- Discover simple adaptations of experiments to make chemistry accessible to students with vision impairment: Chataway-Green R, Schnepp Z (2023) Making chemistry accessible for students with vision impairment. *Science in School* **64**.
- Read an introduction to microscale chemistry in the classroom: Worley B (2021) Little wonder: microscale chemistry in the classroom. *Science in School* **53**.

AUTHOR BIOGRAPHY

Prof. Dr Klemens Koch studied chemistry in Lausanne and Zurich and teaches at a secondary school in Biel, Switzerland, often in bilingual classes (German–French). He trains chemistry teachers at the Pedagogical University of Bern and is interested in understanding chemistry through small and beautiful experiments.