For Teachers **Electrochemistry lab experiences with CRMs**

Module 1

Objective: Electrolysis of water and graphite conductivity

Necessities

Reagents	Formula		Quantity (g) or Concentration (M)
Water	H_2O		500 g
Common Salt	NaCl		50 g

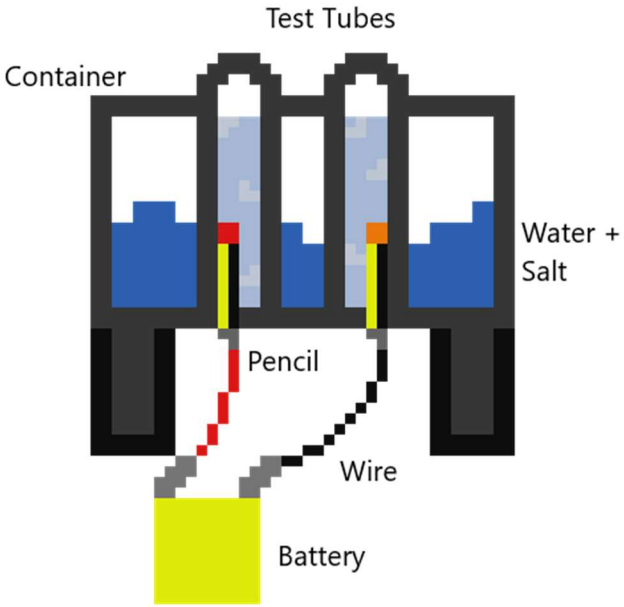
List of materials/tools

- Plastic container (you can recycle one that you already have, size around 10 x 15 cm)
- 2 carpenter pencils (sharpen them so pencil lead is in both sides)
- Sharpener
- Silicone gun
- 2 test tubes
- Battery (4.5 V)
- 3 cables with alligator clip wires
- 3 pencils of different hardness (e.g. 2H, HB and 2B)
- Multimeter

Procedure

- Create the structure where we will perform the experiment, making two holes at the bottom of the container, the size that carpenter pencils pass through them.
- Take the silicone gun and stick the pencils to the holes (try to cover the best you can the space left, to avoid the water from licking out of the container). The pencils need to be half inside the container and the other half outside of it.
- Pour the water into the container, add the salt and stir until it dissolves.
- Take a test tube, fill it with the water of the container and put it vertical and backwards, so a pencil is inside it. Do the same with the other test tube. To prevent water from licking out of the tube while you are putting it backwards, try to put the entrance of the tube inside of the water as fast as you can. Once it is inside the water will not go out.
- Strip the cable´s ends until you remove the insulation.

- Put one side of the cable around the graphite and the other side around one of the two parts of the battery (positive or negative side). Proceed in the same way with the other cable.
- After connecting the second cable with the battery the circuit will be closed and the electrolysis will begin.



Now that we have proved that graphite is a good electricity conductor, it is possible to measure its conductivity using Ohm's law.

The experimental procedure would consist in:

- Use the pencil sharpener to sharpen both ends of the 3 pencils of different hardness.
- Take a wire and attach one end to one terminal of the battery and the other to the pencil lead portion, using the alligator clips. Make sure the clips are attached to the graphite and not to the wood because it is an insulator material and thus do not conduct electricity.
- Connect the multimeter by clipping the alligator wires to the other free battery terminal and pencil lead, making sure that the circuit is closed.
- Use the multimeter to measure both, the current and voltage and record the results in a table.
- Repeat the process with the two remaining pencils.
- Once you have all the results in a table, use the Ohm's Law and its formula to calculate the electrical resistance. Compare the values between the three pencils and draw a conclusion.

Given that graphite is more conductive than clay, as the concentration of graphite increases, the conductivity should increase. The resistance of an object, a measure of the conductivity of a circuit component, can be calculated using Ohm's law, which considers electrical resistance as the ratio of the voltage applied to the current which flows through it, or the degree to which the voltage is resisted (see Table below)

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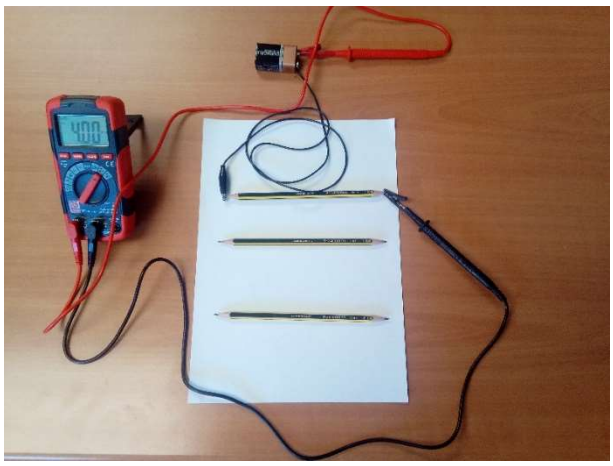

Calculations

Calculate the resistance of each pencil applying Ohm´s equation. Use the current and voltage measured with the multimeter for each pencil.

$$R = \frac{V}{I}$$

R = resistance (Ω), V= voltage (V) and I = current (A)

Conclusions

From electricity (that could come from surplus renewable energy) we can produce hydrogen from water, which can then be reused to produce energy again.

Graphite is an economic material which has a high electrical conductivity which can be used for many applications.

Questions/Quiz  and Solutions

Q1) Which is the reaction related with the electrolysis?

A1) $2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH$

Q2) Why the water in the test tubes went down slowly?

A2) Because the gases generated (in one tube chlorine and in the other hydrogen) have less density, accumulates in the upper part and displaces the water from the test tubes.

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Q3) Identify which gas is formed in the anode and which one in the cathode during the electrolysis.

A3) The hydrogen will be around the cathode (negative pole) and the chlorine gas will be around the anode (positive pole).

Q4) Write the three reactions that happen in the process: oxidation, reduction and net reaction during the electrolysis.

A4) Oxidation: $2Cl^- \rightarrow Cl_2 + 2e^-$ (Chlorine loses 2 electrons)

Reduction: $2H^+ + 2e^- \rightarrow H_2$ (Hydrogen ions gain electrons)

Net Reaction: $2Cl^- + 2H^+ \rightarrow Cl_2 + H_2$ (Hydrogen gas and 'power')

Q5) Complete the table and draw your conclusions.

Pencil	Graphite (%)	Current (A)	Voltage (V)	Resistance (Ω)
2H	60			
HB	68			
2B	74			

A5) When an electric current was applied to pencils of varying hardness, it was found that as proportion of graphite increases, resistance declines according to Ohm's equation. This supports that resistance decrease with the percentage of graphite.

Sousa and Buchanan (2000), Models of pencils materials

Pencil Number	Graphite	Clay	Wax
9H	0.41	0.53	0.05
8H	0.44	0.50	0.05
7H	0.47	0.47	0.05
6H	0.50	0.45	0.05
5H	0.52	0.42	0.05
4H	0.55	0.39	0.05
3H	0.58	0.36	0.05
2H	0.60	0.34	0.05
H	0.63	0.31	0.05
F	0.66	0.28	0.05
HB	0.68	0.26	0.05
B	0.71	0.23	0.05
2B	0.74	0.20	0.05
3B	0.76	0.18	0.05
4B	0.79	0.15	0.05
5B	0.82	0.12	0.05
6B	0.84	0.10	0.05
7B	0.87	0.73	0.05
8B	0.90	0.04	0.05

Table 2: *Percentage values of the mass amount of graphite, clay, and wax particles for the entire range of pencil grades based on information received from pencil manufacturers.*