Student experiment (5th - 10th grade)	**A lemon battery**	**Time:** max. 15 min.

Safety:

safety glasses

Instruments:

- copper foil
- a pencil sharpener (or zinc foil)
- two alligator clips
- two wires
- electric current meter

Chemicals:

- a lemon

Preparation: Remove the blade from the pencil sharpener.

Experiment:

- Press a rolled rod of copper and a pencil sharpener body made of a light metal into a lemon.
- Use alligator clips to fasten a wire to each metal object. Hook the wires to an electric current meter and measure the current.

Observations: The voltage shows a large jump on the current meter.

Results: Hydronium ions from acidic solutions (from the lemon) react with non-noble metals. The metal releases electrons and forms metal ions (cations) by being oxidized. The protons from the acid solution pick up the electrons to form hydrogen atoms, which immediately combine into hydrogen diatoms, H_2. Different metals dipped into the citric acid react differently. The metal which is less noble (in our case the zinc in the pencil sharpener) makes up the anode, which releases more cations in the presence of an acid as the more noble metal (for us, copper), which acts as the cathode of our electrical cell. This means that zinc has an overwhelmingly negative charge and copper an excess of positive charge. If we connect the two through an electrical circuit (wiring) zinc gives its excess electrons to copper. This process continues until the citric acid can no longer pull any more ions out of zinc or until an equality of charge results between zinc and copper (a "dead" battery).

Redox reaction:

$$\text{Oxidation : } Zn \rightarrow Zn^{2+} + 2\,e^-$$

$$\text{Reduction (Red): } 2\,H_3O^+ + 2e^-\ H_2 + 2\,H_2O$$

$$\text{Overall: } Zn + 2\,H_3O + H_2 + 2\,H_2O + Zn^{2+}$$

Disposal:	The lemon can be disposed of in the normal trash.
Advice for the teacher:	The electrical current can be heightened by connecting several lemons together, so that each copper electrode is connected to a pencil sharpener electrode in series.