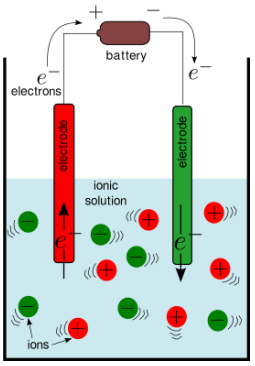
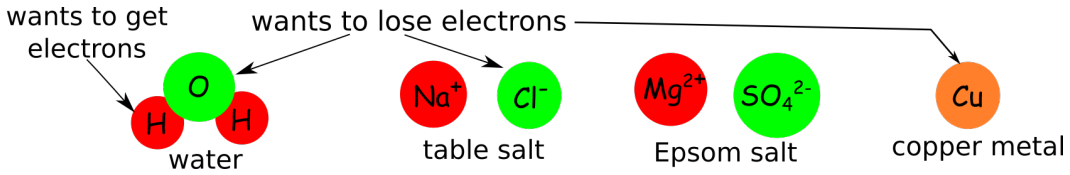
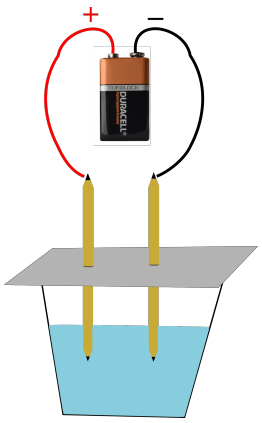
Electrolysis: Breaking Water with Electricity

- **Electric current** is the flow of electrons from the negative (-) terminal of a battery to the positive (+) terminal, through conducting materials (like metal, graphite, or salt solution).
- At the – terminal, electrons get added to atoms. At the + terminal, electrons get ripped off atoms. Atoms with extra or missing electrons are called **ions**.





- Adding or removing electrons can force atoms to rearrange into new molecules. Ripping electrons from chlorine ions (Cl^-) makes chlorine gas (Cl_2). Adding electrons to the hydrogen atoms in water makes hydrogen gas (H_2).



Part 1: Making gas from water and salt

- Make 2 solutions. Mix each one thoroughly.
  1) Half-cup water + 1 full spoon Epsom salt
  2) Half-cup water + 1 full spoon table salt (NaCl)
- Push 2 sharpened pencils through a piece of cardboard. Rest the cardboard on top of each cup, so that pencil tips are in the water.
- Connect the tips of the pencils to the two terminals of a 9V battery. Record what you see at the pencil tips.
- After running the current for about a minute, lift the cardboard, use safe smelling techniques, and record if you smell anything from each solution.

Note: Chlorine gas is poisonous if inhaled in large amounts. You won't make enough of it here to be dangerous. However, have students practice safe wafting techniques, just in case!

Graphite electrodes in various solutions

	What do you see?	What do you smell?
Epsom salt ($MgSO_4$)	bubbles	nothing
Table salt (NaCl)	bubbles	chlorine (pool water)

What did the table salt (NaCl) solution smell like?

(a) rotten eggs (b) bananas (c) pool water (d) mint (e) nothing

Which gas do you think you are smelling? (circle one)

chlorine gas (Cl_2) hydrogen gas (H_2) oxygen gas (O_2)

Where did it come from?

The chloride ions in the salt lost their electrons and combined into Cl_2, chlorine gas.

Part 2: Ripping Electrons off Pennies

Now we'll repeat the experiments using pennies rather than pencils as the electrodes.

Some useful facts:

- Pennies are coated in copper (Cu)
- Copper likes to lose electrons to form Cu^{+} and Cu^{2+} ions
  - Cu^{2+} ions are light blue
  - Cu^{+} ions react with chlorine to form yellow-brown compounds

- Connect a penny to each side of the battery with alligator clips. Place the pennies in epsom salt solution. **Do not let the pennies touch**. Let the reaction run for 1-2 minutes. Record what you see happening near each penny (color? bubbles?). The + and – sides are labeled on the battery.

  Hint: put the cup on white paper to help you see the color change. It will be faint.

Copper electrodes in water + epsom salt

+ side	– side
No bubbles, bluish color	Bubbles, no color

Can you figure out what gas is forming the bubbles? Circle one.

chlorine gas (Cl_2) hydrogen gas (H_2) oxygen gas (O_2)

Electrons get added at the – side and ripped off at the + side. Hydrogen accepts electrons at the – side to make gas bubbles.

What is getting made at the + side?

Cu^{2+} ions hydrogen gas (H_2) chlorine gas (O_2)

Electrons are getting ripped off the copper in the pennies to make blue-ish Cu^{2+} ions

- Repeat your experiment with the two pennies submerged in the water + table salt solution. Let the reaction go for a couple of minutes.

Copper electrodes in water + table salt

+ side	– side	solution color?
nothing	lots of bubbles	yellowish-green

What is being made at the + side?

Copper-chloride compounds hydrogen gas (H_2) chlorine gas (Cl_2)

Discuss: Does the reaction still smell like it did when you used the graphite electrodes (pencils)? Why do you think this is the case?