

2A The lemon battery

What kind of chemistry creates electricity in a battery?

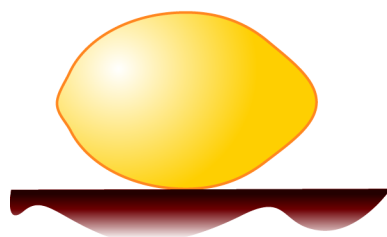
Everything on earth stores and uses energy to stay alive. The ultimate source of this energy is the sun. By what process does life collect and store its energy? In this experiment you will see how the process of energy storage (and use) in living things is described by electrochemistry! We, and the lemon, are both living batteries!

Materials

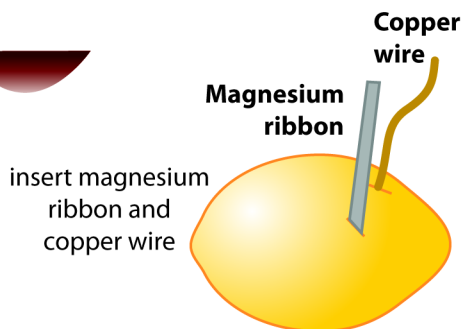
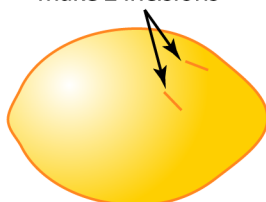
- One lemon
- A light emitting diode (led)
- A 5 cm piece of copper wire
- A 5 cm piece of magnesium ribbon
- two clip-leads
- The chemistry probe system with voltage probe.

Part 1: Making a lemon light up

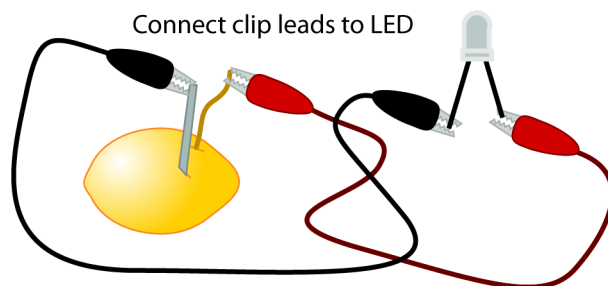
Squash the lemon by rolling it along the table to loosen up the juices inside



make 2 incisions



insert magnesium ribbon and copper wire



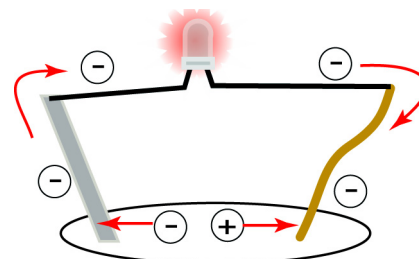
Connect clip leads to LED

Does it work?

1. Roll the lemon on a table so that the juice can flow easily.
2. Make two small incisions on the lemon about 2 cm apart.
3. Insert the piece of magnesium and the piece of copper in the lemon.
4. Use the clip-leads to connect the leads of the LED to the copper wire and the magnesium ribbon.
5. (1) The LED should light up.
(2) If the LED does not light, switch the way that the LED leads are connected to the copper and the magnesium.

Part 2: What just happened?

1. Why did the LED light up?
2. Where did the electricity come from?

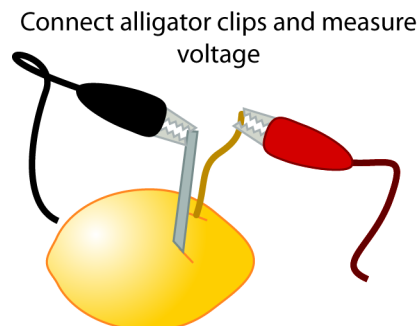


Part 3: Try something new

1. What happens if you replace the magnesium ribbon with a copper wire? Does the light go on?
2. What happens to the intensity of the light if you use two copper wires and two magnesium ribbons? Does the light intensity increase, stay the same or decrease?

Part 4: Let's measure the electricity that comes out of the lemon

1. Connect the red alligator clip of the voltage probe to the copper wire and the black to the magnesium ribbon.
2. Connect the voltage probe to the probe system and measure the voltage
3. Insert a second copper wire and a second magnesium ribbon and measure the voltage
4. Now reverse the red and black alligator clips and measure the voltage again.

**Part 5: Did you observe this?**

1. What happened to the voltage reading when you inserted the second piece of copper wire and magnesium ribbon?
2. What? The voltage reading did not change? But how do you explain the increase in the intensity of the light when you doubled up the copper and the magnesium??
3. If the two pieces of metal that are inserted into the lemon are the same the LED does not light. Why? Does this mean that the choice of metal somehow affects the experiment.

Part 6: Another variation

1. Replace the copper wire with a zinc coated (galvanized) nail.
2. Connect the red alligator clip of the voltage probe to the zinc nail and the black alligator clip to the magnesium
3. What is the voltage reading now?
4. Is it higher or lower than the case with the magnesium/copper?
5. If you connect the led as you did on part 1 does it light up?
6. Do you think that the type of metal has something to do with the voltage that is generated?

2A Electrochemical Cell: The Battery

How do batteries store energy?

Why is the energy of a battery used only when something is connected across its terminals?

Batteries store chemical energy and convert it to electrical energy by connecting the positive and the negative terminals. When the terminals are connected electricity flows. The flow of electricity is a result of a chemical reaction that takes place inside the battery. The chemical reaction depends on the materials that the battery is made of.

Materials

- 1M solution of MgSO_4 (Epsom salt)
- 1M solution of CuSO_4
- A light emitting diode (LED)
- A 5 cm piece of bare copper wire
- A 5 cm piece of magnesium ribbon
- A 10 cm of copper wire with stripped ends
- two clip-leads
- two small test tubes
- A piece of cotton cloth 5mmX50mm
- Sodium chloride solution
- The chemistry probe system with voltage probe.

Part 1: Voltaic Cell

Magnesium ribbon



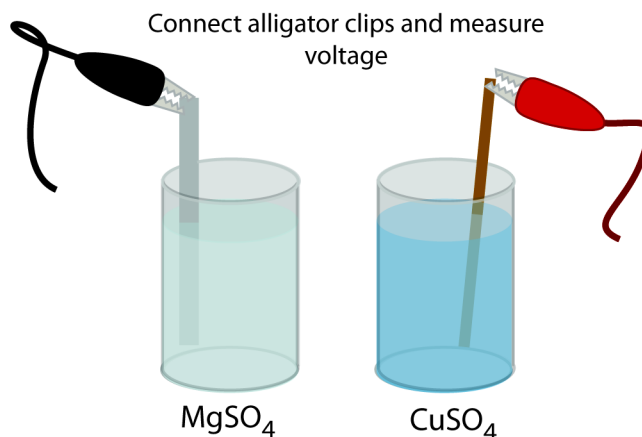
MgSO_4

Copper wire



CuSO_4

insert magnesium ribbon and copper wire



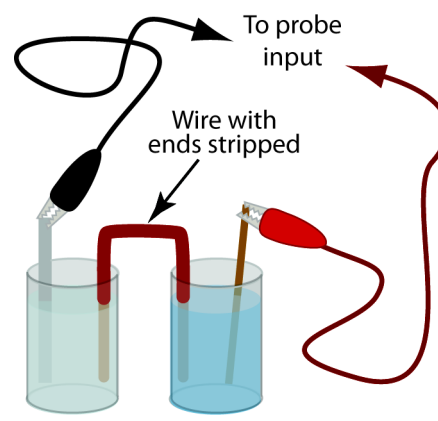
1. Fill up the test tubes with the MgSO_4 and the CuSO_4 solutions
2. Place the magnesium ribbon in the MgSO_4 solution and the copper wire in the CuSO_4 solution
3. Connect the red alligator clip of the voltage probe to the copper wire and the black alligator clip to the magnesium ribbon.
4. Turn on the probe system and measure the voltage

Part 2: What did you observe?

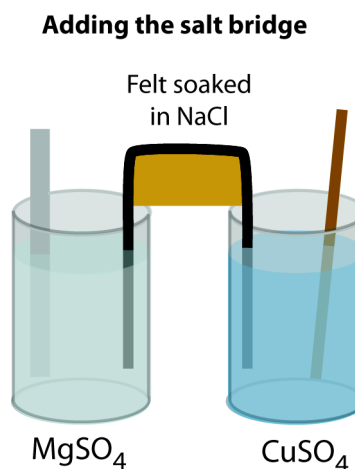
1. What voltage did you measure?
2. Does it make sense that the voltage is zero?

Part 3: Try something new

1. Now take a piece of copper wire, bend into U shape and place it as a bridge connecting the test tubes as indicated in the drawing.
2. What is the voltage reading now?
3. What happens to the voltage reading if you remove the U shaped piece of copper wire?
4. Leave the wire in place for about three minutes. Remove the wire and look at the two ends.
5. What do you observe?
6. Does the end of the wire placed in the MgSO_4 solution change color?
7. It seems like something has deposited on the copper wire.

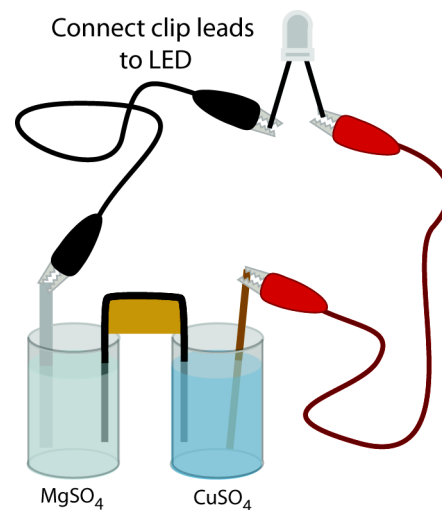
**Part 4: Learn about the salt bridge**

1. Soak the cotton cloth in the NaCl solution and place it as a bridge connecting the two test tubes. This is the “salt bridge”.
2. Measure the voltage between the copper wire and the magnesium ribbon with the voltmeter
3. What voltage do you read?
4. What happens when you switch the connection of the red and the black alligator clips
5. What happens to the voltage reading if you remove the salt bridge?



Part 5: Is this a real battery?

1. Using the clip-leads connect the led to the magnesium ribbon and the copper wire.
2. If the led does not light up switch the way that the led is connected to the magnesium and the copper. Why does switching the connections to the LED make a difference? HINT: a diode is an electrical device that only allows current to flow in one direction, like a one-way street.
3. Try connecting two pieces of copper and/or two pieces of magnesium. Does the intensity of the light coming from the led change? Can you think of a possible explanation for the change, or lack of change



Standard Reduction Potentials at 298K, 1M, 1atm

HALF-REACTION	E° (V)
$F_{2(g)} + 2 e^- \rightarrow 2 F^-_{(aq)}$	+2.87
$O_{3(g)} + 2 H^+_{(aq)} + 2 e^- \rightarrow O_{2(g)} + H_2O_{(l)}$	+2.07
$Co^{3+}_{(aq)} + e^- \rightarrow Co^{2+}_{(aq)}$	+1.82
$H_2O_{2(aq)} + 2 H^+_{(aq)} + 2 e^- \rightarrow 2 H_2O_{(l)}$	+1.77
$PbO_{2(s)} + 4 H^+_{(aq)} + SO_4^{2-}_{(aq)} + 2 e^- \rightarrow PbSO_{4(s)} + 2 H_2O_{(l)}$	+1.70
$Ce^{4+}_{(aq)} + e^- \rightarrow Ce^{3+}_{(aq)}$	+1.61
$MnO_4^-_{(aq)} + 8 H^+_{(aq)} + 5 e^- \rightarrow Mn^{2+}_{(aq)} + 4 H_2O_{(l)}$	+1.51
$Au^{3+}_{(aq)} + 3 e^- \rightarrow Au_{(s)}$	+1.50
$Cl_{2(g)} + 2 e^- \rightarrow 2 Cl^-_{(aq)}$	+1.36
$Cr_2O_7^{2-}_{(aq)} + 14 H^+_{(aq)} + 6 e^- \rightarrow 2 Cr^{3+}_{(aq)} + 7 H_2O_{(l)}$	+1.33
$MnO_{2(s)} + 4 H^+_{(aq)} + 2 e^- \rightarrow Mn^{2+}_{(aq)} + 2 H_2O_{(l)}$	+1.23
$O_{2(g)} + 4 H^+_{(aq)} + 4 e^- \rightarrow 2 H_2O_{(l)}$	+1.23
$Br_{2(l)} + 2 e^- \rightarrow 2 Br^-_{(aq)}$	+1.07
$NO_3^-_{(aq)} + 4 H^+_{(aq)} + 3 e^- \rightarrow NO_{(g)} + 2 H_2O_{(l)}$	+0.96
$2 Hg^{2+}_{(aq)} + 2 e^- \rightarrow Hg_{2}^{2+}_{(aq)}$	+0.92
$Hg_2^{2+} + 2 e^- \rightarrow 2 Hg_{(l)}$	+0.85
$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$	+0.80
$Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$	+0.77
$O_{2(g)} + 2 H^+_{(aq)} + 2 e^- \rightarrow H_2O_{2(aq)}$	+0.68
$MnO_4^-_{(aq)} + 2 H_2O_{(l)} + 3 e^- \rightarrow MnO_{2(s)} + 4 OH^-_{(aq)}$	+0.59
$I_2(s) + 2 e^- \rightarrow 2 I^-_{(aq)}$	+0.53
$O_{2(g)} + 2 H_2O + 4 e^- \rightarrow 4 OH^-_{(aq)}$	+0.40
$Cu^{2+}_{(aq)} + 2 e^- \rightarrow Cu_{(s)}$	+0.34
$AgCl_{(s)} + e^- \rightarrow Ag_{(s)} + Cl^-_{(aq)}$	+0.22
$SO_4^{2-}_{(aq)} + 4 H^+_{(aq)} + 2 e^- \rightarrow SO_{2(g)} + 2 H_2O_{(l)}$	+0.20
$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(aq)}$	+0.15
$Sn^{4+}_{(aq)} + 2 e^- \rightarrow Sn^{2+}_{(aq)}$	+0.13
$2 H^+_{(aq)} + 2 e^- \rightarrow H_{2(g)}$	0.00
$Pb^{2+}_{(aq)} + 2 e^- \rightarrow Pb_{(s)}$	-0.13
$Sn^{2+}_{(aq)} + 2 e^- \rightarrow Sn_{(s)}$	-0.14
$Ni^{2+}_{(aq)} + 2 e^- \rightarrow Ni_{(s)}$	-0.25
$Co^{2+}_{(aq)} + 2 e^- \rightarrow Co_{(s)}$	-0.28
$PbSO_{4(s)} + 2 e^- \rightarrow Pb_{(s)} + SO_4^{2-}_{(aq)}$	-0.31
$Cd^{2+}_{(aq)} + 2 e^- \rightarrow Cd_{(s)}$	-0.40
$Fe^{2+}_{(aq)} + 2 e^- \rightarrow Fe_{(s)}$	-0.44
$Cr^{3+}_{(aq)} + 3 e^- \rightarrow Cr_{(s)}$	-0.74
$Zn^{2+}_{(aq)} + 2 e^- \rightarrow Zn_{(s)}$	-0.76
$2 H_2O_{(l)} + 2 e^- \rightarrow H_{2(g)} + 2 OH^-_{(aq)}$	-0.83
$Mn^{2+}_{(aq)} + 2 e^- \rightarrow Mn_{(s)}$	-1.18
$Al^{3+}_{(aq)} + 3 e^- \rightarrow Al_{(s)}$	-1.66
$Be^{2+}_{(aq)} + 2 e^- \rightarrow Be_{(s)}$	-1.85
$Mg^{2+}_{(aq)} + 2 e^- \rightarrow Mg_{(s)}$	-2.37
$Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$	-2.71
$Ca^{2+}_{(aq)} + 2 e^- \rightarrow Ca_{(s)}$	-2.87
$Sr^{2+}_{(aq)} + 2 e^- \rightarrow Sr_{(s)}$	-2.89
$Ba^{2+}_{(aq)} + 2 e^- \rightarrow Ba_{(s)}$	-2.90
$K^+_{(aq)} + e^- \rightarrow K_{(s)}$	-2.93
$Li^+_{(aq)} + e^- \rightarrow Li_{(s)}$	-3.05

strong oxidizing agents

strong reducing agents