Title: Lemon Power!!
Lesson Type: Module
Target Grade: Elementary/High School
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Brief Overview:
This lesson is about showing how the chemical energy of a lemon cell can be transformed into electrical energy which can be used to do work like light up an LED when connected in a circuit. We will also talk about how Voltages “stack up” when the lemons are connected in series.

Agenda:

- Lecture
- Show that lemon cell has a potential difference
- Show that potential difference increases when lemon cells are connected in series
- Connect lemon cells to make a huge lemon cell and light up an LED

Teaching Goals
- Chemical Energy can be converted into Electrical Energy
- Voltages stack up when cells are connected in series.

Lesson Introduction
- Talk about the reaction that takes place in the lemon cell and how this creates a flow of electrons.
- For primary/middle school use analogies like “electrons in a wire are like cars on a highway”
- Lecture should include (for high school) an explanation of the redox half equations and how they combine to form the overall chemical reaction.
- Talk about how batteries work and do a brief introduction to the circuit they’re going to make.

Module : Making The Cell and Lighting up the Led

Introduction
To show students how batteries work. Lemons may not be the best world’s energy source, but we can demonstrate working electricity in a safe and interesting manner. They will learn a bit more about electricity, possibly some new science terms, and we can build more on the abstract concept of a meter reading.

Materials

Material	Amount per Class	Expected $$	Vendor (or online link)
Lemon	N students	$0.5N	
Copper Strips/Pennies	N+1		
Galvanized Nails	N+1		
Connecting Wires	N+2		
Voltmeter	2 (for the whole class)		
Red 1.5 V LED	1/2		
Sandpaper	1 sheet		

Material to Teach

- How to make a lemon cell, connect them in series, and light up the LED.

Procedure for each Module

- To create the battery, roll the lemon around and squeeze it gently to release the juice inside.
- Insert part of copper strip or penny about two inches into the lemon.
- Next, take a Zinc strip and stick it about two inches into the lemon.
- When connecting the alligator clips to the LED light, make sure to connect the negative jumper cable to the flat prong, and the positive jumper cable to the rounded prong. (Also, the Copper is positive and the Zinc strip is negative.)
- If you connect the multimeter to the lemon cell, you will see that the lemon is indeed giving off a charge. But is it enough to power the LED light? As you can see on the multimeter, a single lemon cell gives off about .9 volts. LED lights require 1.5 to 4 volts of electricity to light up, depending on the color.
- So to create more power, create another lemon cell in the same way you created the first one. Repeat steps (1 - 4)
- Attach the positive lead of one lemon to the negative lead of the next. Now attach the LED light, and you should get a faint light. If you add a third lemon to the battery, it will glow even brighter.

By playing around with the different kinds of metals the kids should be asked to rank the metals in terms of their reactivity. Hint: this can be done by setting one metal as the standard negative terminal and varying the positive terminal. The combination which produces the greater reading of potential difference on the multimeter will be higher up in the reactivity series.

Once the kids have toyed around with a single lemon, we will ask them to use the lemon to try and light up an LED (which will not light up). We will then teach them to connect multiple lemons in series until the LED does light up.

Notes for Mentors

In a lemon cell, the lemon juice acts as the electrolyte and the two pieces of metal which we will vary will act as either the positive or negative terminal. It is important to clean the pieces of metal with sandpaper before the experiment to remove any dirt/metal oxides on the surface and to expose clean metal to the surface.

Safety Note: be sure no one eats the lemon, it will have dilute dissolved metals in the juice

The general idea is that if we stick two different metals into the lemon and connect them through an external circuit, one metal will be oxidized (lose electrons and in the process become an ion) and the other metal will act as the surface at which the hydrogen ions from the lemon juice will be reduced to dihydrogen through the addition of electrons from the oxidization of the other metal. The metal which will be oxidized is the metal which is higher up the reactivity series and the metal which will act as the surface at which the dihydrogen will be produced is the metal lower in the series.

The energy for the battery comes from the chemical change in the zinc (or other metal) when exposed to an acid. The energy does not come from the lemon or potato. The zinc is oxidized inside the lemon, exchanging some of its electrons with the acid in order to reach a lower energy state, and the energy released provides the power

The chemical equations for these reactions are as follows:

At the Oxidation Terminal, also known as the Positive Terminal
$M \Rightarrow M^+ + e^-$

At the Reduction Terminal, also known as the Negative Terminal
$2H^+ + 2e^- \Rightarrow H_2$

It is important to note that the electron flow has a directionality from the more reactive metal to the less reactive metal. This can be shown by connecting a multimeter to the two terminals in the lemon cell. When the connections are first made, a reading of X Volts will appear. However, when the connections are reversed, the reading will change signs to -X Volts.

Different metal combinations will have different voltages because some metals are able to lose their electrons more easily (such as sodium) and some metals such as silver are very stable (hence making them better metals for jewelry).

A simple convention which can be used to identify which terminal is which is to think of the Positive terminal as the terminal with the “surplus” of electrons, which then move to the Negative terminal which is “deficient” of electrons.

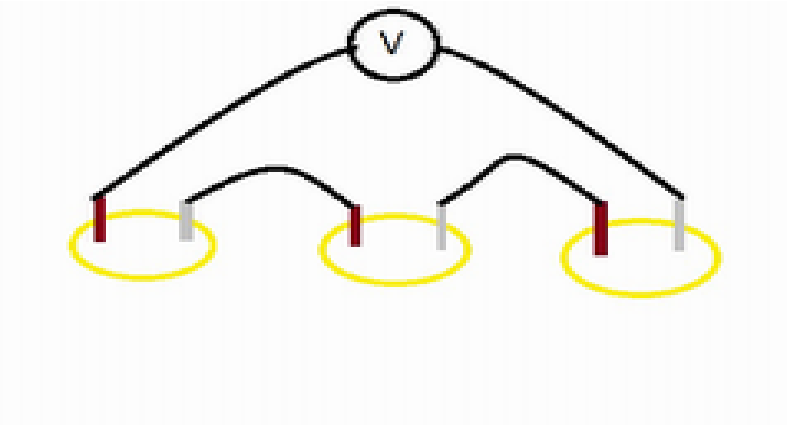
To connect the lemon batteries in series, we will take multiple lemons, all with the metals stuck in them and using crocodile clips we will connect them in this pattern:

The series pattern is preferred over parallel because when things are connected in series, the voltage increases and not the current, this will be useful when we connect the LED because it only requires a certain voltage to light up and high currents will destroy its function.

Veq = V1 + V2 + V3 + …

where V1, V2, and V3 are the voltages of the individual lemon cells

The kids should be able to predict the Veq by using the equation above



Summary Materials List

- Lemons
- Galvanized Nails
- Copper Strips/Pennies
- Connecting Wires
- Sandpaper
- LED
- Voltmeter