THE ELECTROLYTIC CAPACITOR

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(Why and How it Works)

To understand the electrolytic capacitor, you must first understand the atom. Everything around you is composed of atoms. The air, this paper, everything. Atoms are composed of a very many particles. The most important particles are the proton, the neutron, and the electron. Some of these particles have a charge. Some have weight.

What is a charge? Have you ever walked on a rug and then touched something metal and gotten shocked? Before you touched the metal, you had a charge.

There are two kinds of charges: positive and negative. These charges exert force on each other and themselves like magnets. Here is a chart to tell when they attract and when they repel.

Charge 1	Charge 2	Result
Positive	Negative	Attraction
Negative	Negative	Repultion
Positive	Positive	Repultion
Negative	Positive	Attraction

Charges	Result
Like Charges	Repel Each Other
Opposite Charges	Attract Each Other

By looking at these charts, you can see that like charges repel and opposite charges attract (just like magnets).

To measure weight of particles, it is necessary to have a unit of weight. Pounds and ounces are much too bit. We will use a unit with the weight of a proton. Here is a chart that tells the weight and charge of each particle.

Particle	Charge	Weight
Proton	Positive	1
Neutron	None	1
Electron	Negative	0

Since the proton and the electron have opposite charges, they attract each other. But they cannot meet because of outside energy. So, we end up with orbitting systems like this (figure A). Notice the electron does most of the moving, but the proton does move some too. When the electron is at "1", the proton is at "a". When the electron is at "2", the proton is at "b". When the electron is at "3", the proton is at "c". This orbitting system is like the earth orbitting the sun.

This proton-electron system is the simplest atom — the hydrogen atom. Notice the hydrogen atom has no neutrons.

Protons and neutrons have a strange attraction for each other. This attraction is very strong.

Suppose we shoot a neutron into the hydrogen atom. We now get heavy hydrogen or H^2. The "2" refers to weight. The neutron and proton have joined to make a new center. This center of protons and neutrons is called the neucleus.

It is the number of electrons going around the nucleus that gives the atom its name.

The number of protons in the nucleus determines the number of electrons: 2 protons, 2 electrons; 5 protons, 5 electrons; 20 protons, 20 electrons; 103 protons, 103 electrons.

How can a nucleus with more than one proton hold together? The protons repel each other so the nucleus should explode. Remember the neutron-proton attractions? To hold together, a nucleus needs about as many neutrons as protons.

Suppose we put more and more electrons in orbit. The one orbit will get crowded. So some electron(s) will take a new orbit (figure B). But this new shell fills up, so a new shell is formed (figure C). In this way, shell after shell is built.

Here is a chart to show what each shell can hold (in electrons).

Shell No.	1	2	3	4	5
Electrons	2	8	8	10	8

An electron configuration chart is shown on figure D . It has some elements and tells if they conduct electricity.

Atoms with just a few electrons on the outer shell (with the exception of hydrogen) have loose hold of them because it is shielded from the nucleus' field by the other shells and not a big field is left to go the big distance.

Just a small amount of energy can send these electrons flying from orbit.

On the other hand, atoms with the outer shell nearly, but not quite full, not only can hold their own electrons but, under proper conditions, steal electrons from atoms with loosely held electrons.

Atoms with their outer shell exactly full can neither take nor loose electrons easily.

Why do some materials conduct electricity and some don't? What is electricity?

Suppose you have some solid copper. Copper atoms have loosely held electrons. Suddenly, some moving electrons invade the copper. When an electron collides with a copper atom, it makes the copper eject one of its loosely held electrons in the same direction it was going with the same energy it had. But, in doing so, it is captured by copper. The ejected electron collides with another copper atom and so on. This movement of electrons is electricity.

What happens if you take a substance with loosely bound outer electrons and put it with a substance with tightly bound electrons but with an uncompleted outer shell?

Consider the loosely bound one "L" and the tightly bound on "T". Electrons would be transferred from "L" to "T". Then "L", being positively charged from the loss of an electron, would be attracted to "T" which would be negatively charged from gaining one or more electrons. We now have an ionic salt.

Another type of reaction could take place under the conditions discussed in the last paragraph. The electron transfer begins as before. This time, however, there isn't enough power to complete the transfer. Both atoms, being attracted to the half-transferred electron, hold together.

Another thing to consider is valence. Valence is the number of electrons the atom takes or gives (figures D → E). Some atoms have a number of valences.

If hydrogen and oxygen were to combine, what would the resulting compound contain? By looking at the chart (figure D), you can see that hydrogen's valence is 1, and oxygen's valence is 2. It would take two hydrogens to neutralize one oxygen. So, the substance formed should be "Hydrogen $_2$ Oxygen$_1$". This proves to be the case. "Hydrogen$_2$ Oxygen$_1$" is water. In water, the hydrogen electrons are not completely transferred.

Suppose we melt a compound with its electrons completely transferred. Once melted, the compound consists of positively and negatively charged atoms (atoms missing, or with an excess of electrons) shooting around. Suppose we try to run an electric current (electricity) through the molten compound. Suppose we use conduting rods to impose the voltage (figure F).
By looking at figure F , you can see that the rods become charged. Because they are charged, each attracts atoms with an opposite charge. When these atoms strike the rod, the charge they possess (crowding or loosing electrons) is neutralized by receiving or giving up (an) electron(s). After this, they become normal atoms again. So it is conducting electricity.

Suppose you mix some water and some compound with its electrons completely transferred. This compound's atoms spread out and shoot all over as if the compound was a liquid. What happens if we try to run electricity through this mixture? The same thing that happened in the molten compound — breaking up and conducting. Hopefully, you are now ready for the explanation.

Direct Explanation

Now comes the direct explanation of the electrolytic capacitor. For those who skipped the first part: if you should become confused about the language or properties, turn back and read the first part. For the experts who skipped the first part: I am using simpler language. I have dropped words like mass and ion. I want to keep as simple as possible.

A capacitor (in general) consists of two conducting plates separated by an insulator such as air (figure 6). Each plate is a terminal. Suppose we move electrons into the wire leading to plate A. The electrons move into plate A, charging the plate. It exerts force on plate B repelling electrons from plate B. These electrons run down the B wire.

Therefore, plate A is negatively charged and plate B is positively charged. Because they are trying to get together, they offer little resistance to being charged more. However, as they charge more, this resistance gets larger and larger until it equals the force that charges them. The time that it takes to reach this point varies.

It may be lengthened in two ways: by adding more surface area to the plates or by making the insulator less thick.

What happens when we connect the two plates? Electricity flows until the plates loose their charge.

An electrolytic capacitor consists of a solution (mixture) of sodium carbonate (sodium$_2$, carbon, oxygen$_3$) in water in a container with the strips of conducting material in it. One of the conducting strips is made of copper, the other is made of aluminum (figure 2). Suppose we take electrons from rod A, the aluminum rod, and give these electrons to rod B, the copper rod continuously. In other words, we are trying to run current through. However, note the direction. Sodium atoms are attracted to the copper rod. The charged carbonates ($\text{Carbon}_1\ \text{Oxygen}_3$--) move toward the positively (+) charged aluminum rod. When they strike, they give up their two extra electrons. Because of this, the carbonate immediately partially decomposes ($\text{Carbon}_1\ \text{Oxygen}_3^{--} - 2e^{-} \longrightarrow \text{Carbon}_1\ \text{Oxygen}_2 + \text{Oxygen}$) into carbon dioxide and oxygen. The oxygen steals some electrons from the aluminum making an $\text{Aluminum}_2\ \text{Oxygen}_3$ (which is a solid coat). Aluminum oxide is an insulator. Therefore, it stops actual conduction. The conducting liquid and the copper rod act as one plate while the aluminum acts as another plate. This device is now a capacitor.

Consider the $\text{Aluminum}_2\text{Oxygen}_3$ (aluminum oxide) coat. It is extremely thin. This gives the capacitor very high storage power. However, it has some drawbacks. This device is polar. If you try to run current through the wrong way, you destroy the oxide coating. This capacitor cannot stand high voltage.

All capacitors slowly leak their charge away.

USES FOR THE ELECTROLYTIC CAPACITOR

The electrolytic capacitor finds use in power converters. It is used to smooth surges of direct current produced by a transformer-diode circuit (see figure 1). Coil A also smoothes the current.

In this circuit, the plug brings in alternating current. The voltage is stepped down by the transformers. Let's say that a surge moving in direction "A" (see figure 1) comes first. Finding no opposition from diode D_2 but much opposition from D_1, it charges the normal capacitor. When the current moves in direction "B", diode D_2 prevents flow but D_1 permits it. The voltage moving through D_1 is aided by the discharging normal capacitor. So, we have surging direct current.

This current is temporarily blocked by Coil A. It charges the electrolytic capacitor. After a little time, Coil A gives way to the electrolytic capacitor. However, it still blocks powerful surges. The resulting current is direct.

It also serves in some amplifier circuits. Most of its use is due to its very high storage power. Its main disadvantage is the fact that it is polar. It charges in one direction, but, if charged in the other direction, its Al_2O_3 is destroyed. It may be recoated by charging in the right direction.

THE EXPERIMENT

Switch the switch to position A. This will charge the electrolytic capacitor. Next, switch it to position B, and watch the voltme~~n~~ter. The needle will go to the high mark. After about seven seconds, (I timed it with a stop watch) it will move down.

THE LEAKAGE GRAPH

The graph shows leakage of my electrolytic capacitor.

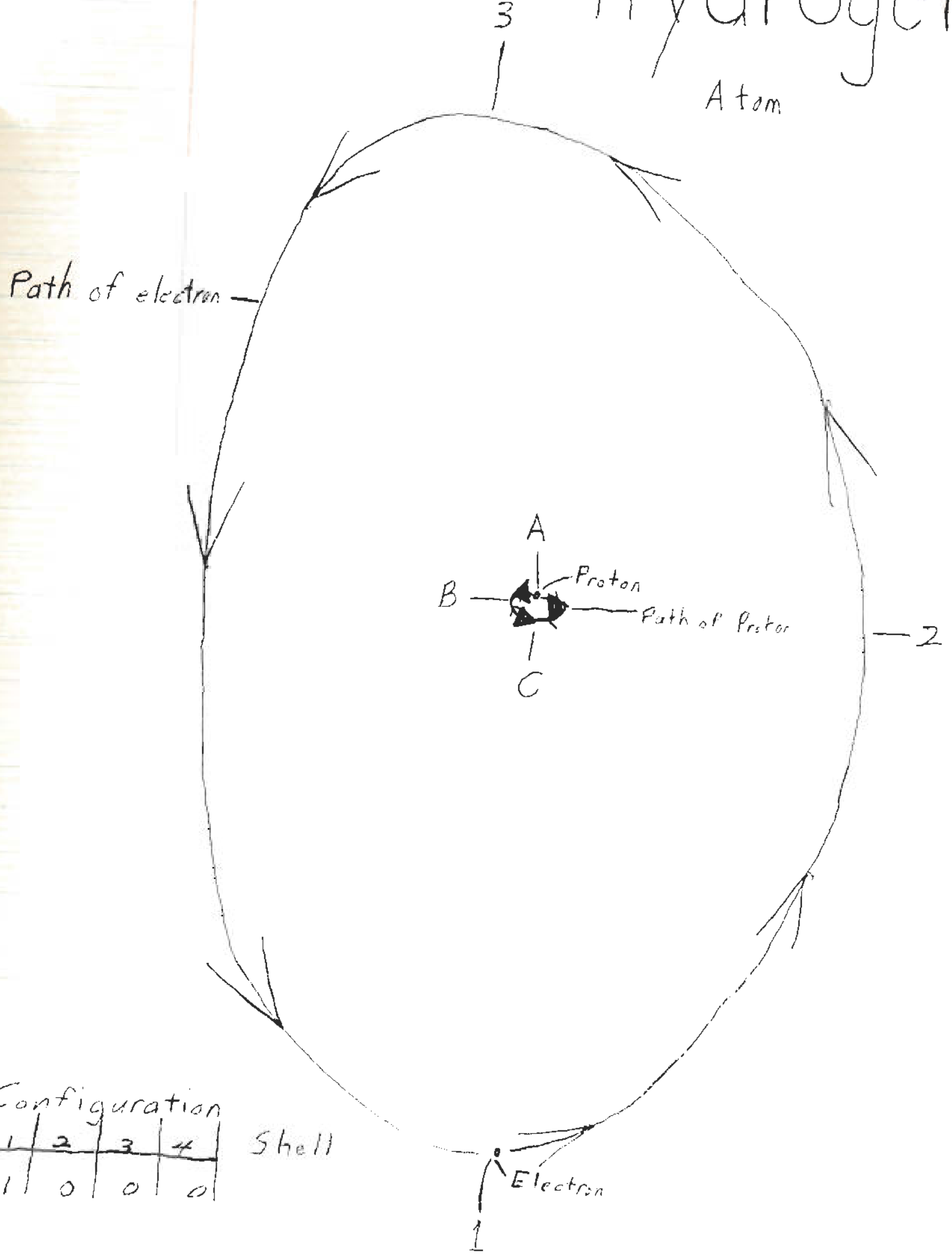
Most of the leakage is from impuities in the electrolyte. The resulting impurities in the Al_2O_3 produce leakage, and the device acts like a voltic cell when the impurities are present (impurities in Al_2O_3).

The voltage produced is in the wrong direction; so it speeds discharge, and then it charges in the wrong direction.

This is why the graph goes below zero. The backwardness is not strong enough to attack the Al_2O_3.

Fig A

The Hydrogen Atom



Configuration

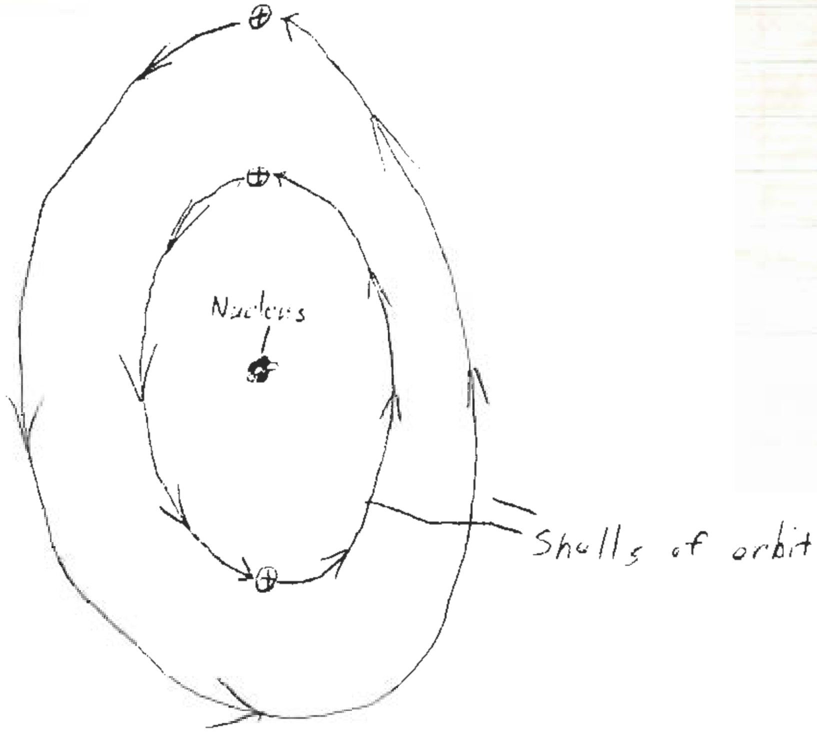
1	2	3	4	Shell
1	0	0	0	

Fig A

Fig B

The Lithium Atom

Proton = ●
Neutron = o
Electron ⊕



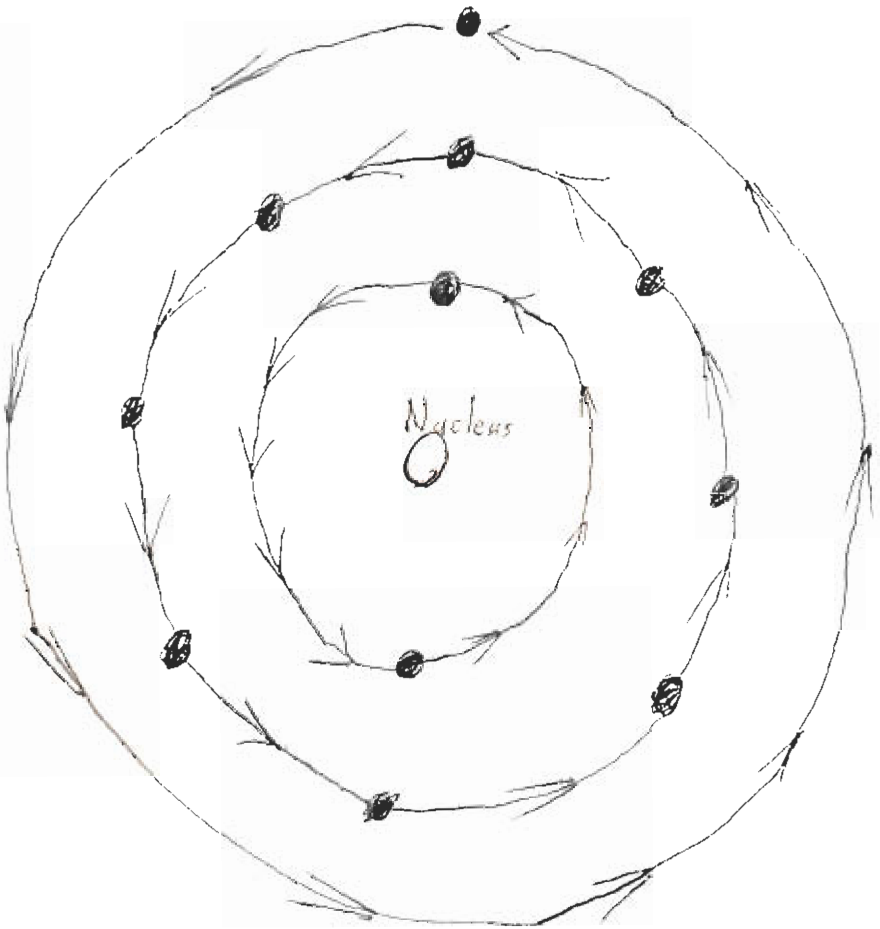
The Lithium Atom

Configuration

1	2	3	4
2	1	0	0

Fig B

Fig C



The Sodium Atom

Configuration

1	2	3	4
2	8	1	0

Fig C

Fig D

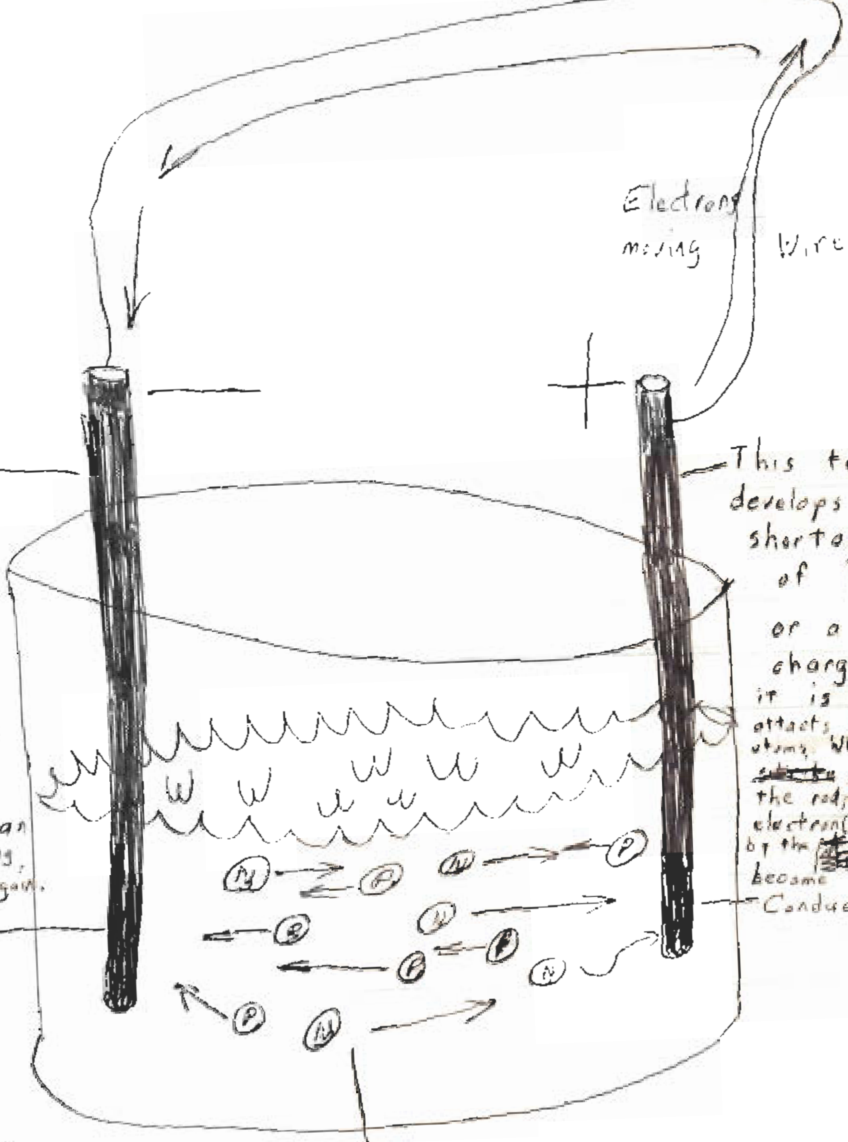
Elements	1	2	3		Valence	Conducts electricity
Hydrogen	1				$1^+, 1^-$	No
Helium	2				0	No
Lithium	2	1			1^+	Ya
Beryllium	2	2			2^+	Ya
Boron	2	3			$3^+, 5^-$	Ya
Carbon	2	4			$4^+, 4^-$	Ya
Nitrogen	2	5			$-3, +5$	No
Qxygen	2	6			-2	No
Flourine	2	7			-1	No
Neon	2	8			0	No
Sodium	2	8	1		+1	Ya
Magnesium	2	8	2		+2	Ya
Aluminum	2	8	3		+3	Ya
Silicon	2	8	4		+4, -4	Ya
Posphorus	2	8	5		+5, -3	No
Sulpher	2	8	6		+6, -2	No
Chlorine	2	8	7		-1	No
Argon	2	8	8		0	No
Potassium	2	8	8	1	+1	Ya
.	.	.	.	.		.
.	.	.	.	.		.
.	.	.	.	.		.

Fig D

Element	Valc.
Calcium	+2
Scandium	+3
Titanium	+4
Vanadium	+5
Chromium	+6
Manganese	+7
Iron	+3
Cobalt	+4
Nickel	+2
Copper	+3
Zinc	+2
Gallium	+3
Germanium	+4, -4
Arsenic	+5, -3
Selenium	+6, -2
Bromine	-1
Krypton	0
Rubidium	+1
Strontium	+2
Ytterium	+3
Zirconium	+4
Niobium	+5
Molybium	+6
Technetium	+7
Ruthenium	+3

Fig E

How a Molten Ionic Compound Conducts Electricity



This terminal develops a crowding of electrons, or a negative charge. Because it is negatively charged, it attracts the positive atoms. When the atoms strike the rod, they recieve an (some) electron(s) becoming, a normal atom again.

Conducting rod

This terminal develops a shortage of electrons, or a positive charge. Because it is positive, it attacts negative atoms. When the negative ~~strike~~ atoms strike the rod, their extra electron(s) are(is) stolen, by the rod. They become normal atoms.

Conducting rod

Ⓟ = Positive atom
Ⓝ = Negative atom

This is the molten compound. It is composed of positively and negatively charged atoms flying about. However, they are not flying about normally, because of the charged rods.

Note: When two opposite charges collide, they natrolize each other.

Fig F

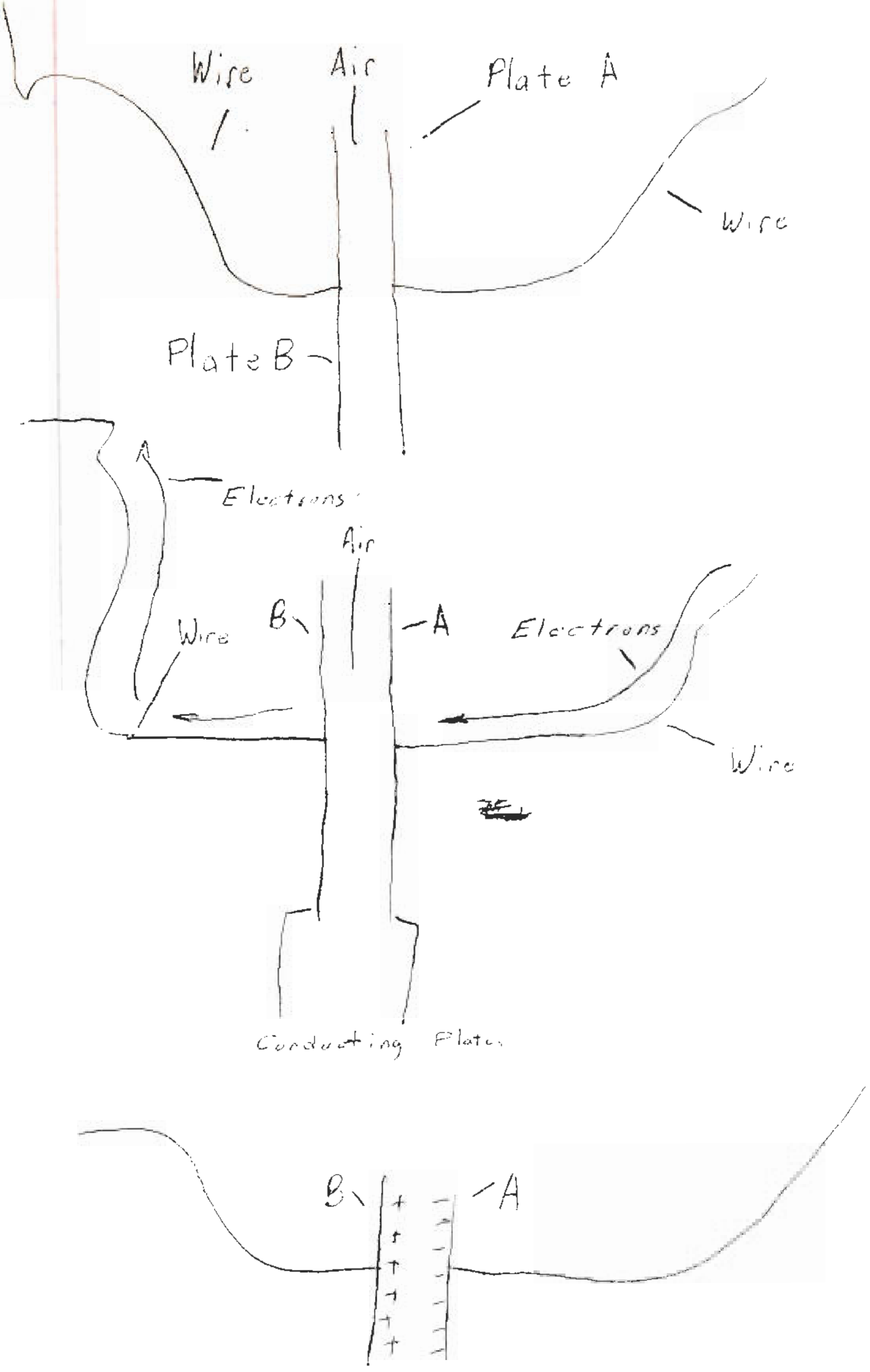

Wire
Air
Plate A
Wire
Plate B
Electrons
Air
B
A
Wire
Electrons
Wire
Conducting Plates
B
A
+ + + + + +
- - - - - - -

Fig G

THE ELECTROLYTIC CAPACITOR

This project covers construction, uses, and the hows and whys of the electrolytic capacitor.

I have constructed an electrolytic capacitor. It is basically a jar filled with a sodium bicarbonate (baking soda) solution with two metal strips dipped in. One is aluminum and the other is copper. Each one is a terminal.

This sounds more like a voltic cell (battery). True, this device is polar and may act like a voltic cell, but it is a capacitor when the polarities are right.

Let's see why. When you run the current through (polarities right of course), you get the reaction:

$$2NaHCO_3 \longrightarrow 2Na + H_2 + O_2 + 2CO_2 .$$

The sodium (Na) and hydrogen (H_2) form on the copper. The sodium immediately reacts with the water ($2Na + 2H_2O \longrightarrow 2NaOH + H_2$).

On the aluminum, the oxygen (O_2) and carbon dioxide (CO_2) form. The oxygen combines with the aluminum in the reaction:

$$4Al + 3O_2 \longrightarrow 2(Al_2O_3).$$

Aluminum oxide is an insulator. This separates the electrolyte and the aluminum.

The electrolyte acts as one plate of a normal capacitor and the aluminum as the other. Because the oxide is so thin, the capacitance is high.

The electrolytic capacitor is used in power converters.

I did some experiments with leakage.