NREL Transforming ENERGY

EXPERIMENTS

Batteries

At this point, we are dependent on batteries. Cars, cell phones, tablets, computers, remotes, and so on all use them. However, it's pretty obvious that AA batteries could not fit into a cell phone, and a nine-volt battery is much smaller than a car battery, even though a car battery is only twelve volts. What makes all of these batteries so different?

Well, the answer lies in the chemical reactions occurring inside the core of each of these batteries. Batteries are a great example of coupled reduction and oxidation reactions, often shortened to RedOx reactions. In these types of reactions, electrons transfer from one element to another and this flow of electrons can be used to create electricity.

Reduction Potential

Each element on the periodic table has some ability to accept electrons and some ability to donate electrons—what path it takes is dependent on what other elements are present in the reaction.

We have learned through experimentation the reduction potentials of many elements (and some compounds!), and we can use these values to predict the possible voltages created by reactions between two elements. These values represent the potential voltage created, but many of these combinations will not be as highly efficient in the real world, where the voltage created will most likely be considerably less. To solve for the possible voltage, we need to remember a little more about the aforementioned RedOx reactions.

Reduction and Oxidation Reactions (RedOx Reactions)

As stated above, RedOx reactions occur because one element in a reaction donates its electrons and one element accepts those electrons. The element that donates electrons has been reduced and the element that accepts the electrons has been oxidized. When we set up these reactions with a **salt bridge** in between, usually an acid, we can "catch" the electrons as they are flowing to produce electricity. This set-up is called a galvanic cell, and it is the backbone of a battery cell.

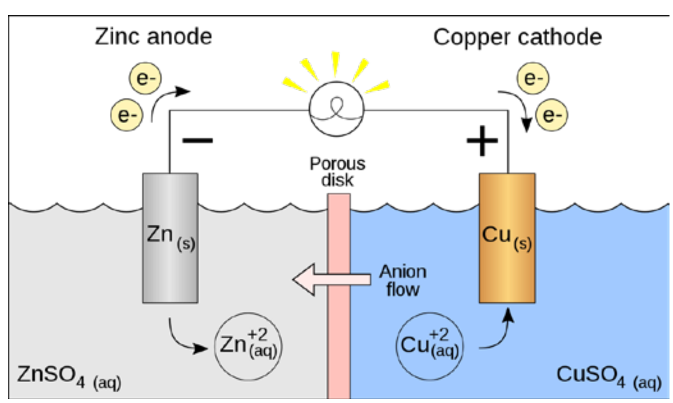

Image from Wikipedia-Galvanic Cell. CC BY-SA 4.0

Batteries can be comprised of a single galvanic cell that produces the required voltage, as in AA or AAA batteries, or they can consist of multiple galvanic cells laid out in series with one another to make all the cell voltages additive. Your students will use this same principle to wire multiple energy sources together to get a higher voltage.

AA and AAA battery: Zinc (Zn) and Manganese dioxide (MnO_2)

$$Zn_{(s)} + MnO_{2(s)} \longrightarrow ZnO_{(s)} + Mn_2O_3$$

In the above reaction, zinc and manganese dioxide make up the two electrodes of the battery. They pass electrons back and forth through potassium hydroxide to create the 1.5 volts of the AA and AAA batteries. Six of these cells are used to create a 9 volt battery. This reaction is not reversable, so once the zinc is used up, the battery is dead.

The chemical reactions are written out like this:

$$Zn_{(s)} \rightarrow Zn^{2+} + 2e^-$$

$$Mn^{4+} + 2e^- \rightarrow Mn^{2+}$$

Car Battery: Lead acid battery—Lead (Pb), Lead oxide (PbO_2), Sulfuric acid (H_2SO_4)

$$Pb_{(s)} + PbO_{2(s)} + H_2SO_{4(l)} \longrightarrow 2PbSO_4 + H_2O$$

In this reaction, lead is both oxidized and reduced. Both the lead metal and the lead oxide react with the sulfuric acid to allow the electrons to flow. Sulfuric acid is a strong acid. This is why car battery acid leaking is very bad.

The chemical reactions are written out like this:

$$Pb_{(s)} \rightarrow Pb^{2+} + 2e^-$$

$$Pb^{4+}\ 2e^- \rightarrow Pb^{2+}$$

The other big difference between the car battery and the AA and AAA batteries is how much current they allow. AA and AAA batteries allow for very low current and amperage so they can last a long time. Car batteries have less internal resistance so they can supply a large amount of current very quickly, basically draining themselves, but they are able to recharge as the car drives.

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Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-6A42-82715 • April 2022