Building a Better Battery

Now that wind and solar power are well established, scientists are looking at ways to improve redox flow batteries to help solve the intermittency problem. But what would make a suitable replacement for the rare and expensive vanadium that is a key component of existing batteries? Whatever it is going to be has to be **conductive** (allow electricity to travel through it), able to store electrons, and be **soluble** in water (dissolve easily in water). Nature may have a solution, a naturally occurring organic molecule known as an *anthraquinone*.

Anthraquinones are sometimes found in plants, where they provide certain types of vegetables and teas with a characteristic red color. The dye industry also often uses anthraquinones for their bright colors. The researchers chose a molecule called 9,10-anthraquinone-2,7-disulphonic acid, shown in **Figure 1**. That name is a mouthful, but thankfully it is abbreviated to AQDS.

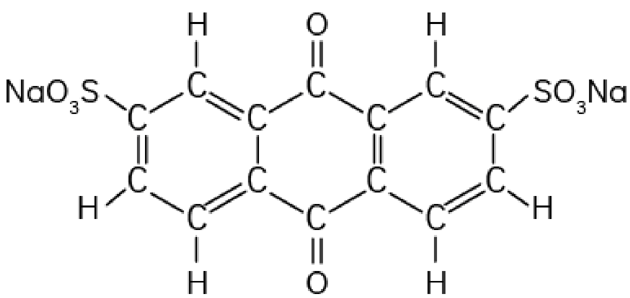

Figure 1. AQDS Molecule. ADQS is one of a group of molecules called anthraquinones. These molecules are known for their red color and are often used as dyes.

Like vanadium, anthraquinones have both a low energy state and a high energy state. The high energy state has two more electrons than the low energy state. These states are shown in **Figure 2** below. When researchers charged the battery and then discharged it completely, (took it from its charged to uncharged form) they were able to get out about 85% of the energy they put in, which is a good result for these types of batteries.

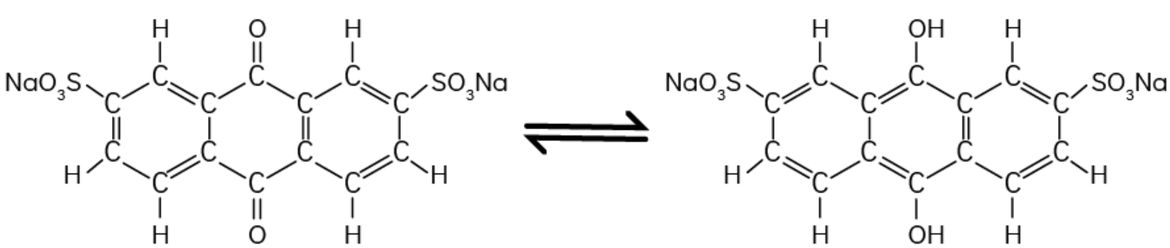

Figure 2. Two States of AQDS. AQDS in its low energy (discharged) form and high energy (charged form). In the high energy reduced form, AQDS has lost two double bonds between carbon and oxygen and gained a double bond in the ring system.

When the battery is charged, the anthraquinone molecule gains two electrons from ions in the solution and the anthraquinone ends up in its high energy form.

Using organic molecules as an energy storage material in batteries presents some new challenges for researchers. With battery designs that used vanadium, researchers and engineers didn't have to worry about the molecule breaking down—a single metal atom isn't going to break down into something else. Organic molecules, on the other hand, are made up of dozens of bonds between different atoms, and atomic bonds can break.

Researchers try to understand how quickly these bonds break by measuring something called capacity retention. **Capacity retention** is the fraction of the original amount of energy the battery can still store. As the battery is used up and then charged again, some of the molecules will break down. Because the molecules that held energy have broken down, the battery won't be able to store as much energy as it did before. By measuring capacity retention, researchers were able to determine that the AQDS battery would lose 10% of its ability to store energy every week, meaning that its useful life is only a few weeks. By comparison, the lithium ion batteries that power cell phones and computers have a lifespan of a couple of years.

Unlike metals, organic molecules can be modified to slow down the decomposition rate and to increase the amount of energy each molecule can store. In the future scientists will try designing and synthesizing molecules other than AQDS for use in this type of battery in the hopes of making cheaper and longer lasting batteries. With time and research, redox flow batteries will likely exceed lithium ion batteries both in terms of lifespan and affordability.

Reference

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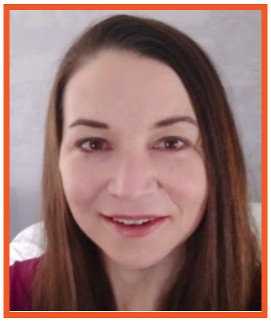
BiteScientist Profiles

Emily Kerr is a chemist interested in the chemistry and engineering behind energy and energy storage technologies to address climate change and in helping students transition to college chemistry. When not in the lab or classroom, she enjoys reading, fencing, and spending time sailing, skiing, and being outdoors.



Kristen L. Cacciatore is a physics and chemistry teacher in Boston. She loves helping students apply what they learn in science classes to their everyday lives, like using physics to understand how to hit a baseball further or applying chemistry to make better tasting cookies. When she's not teaching, Kristen enjoys traveling far and wide, being outdoors, and reading books about everything.