New Insights into Hydrated Electrons

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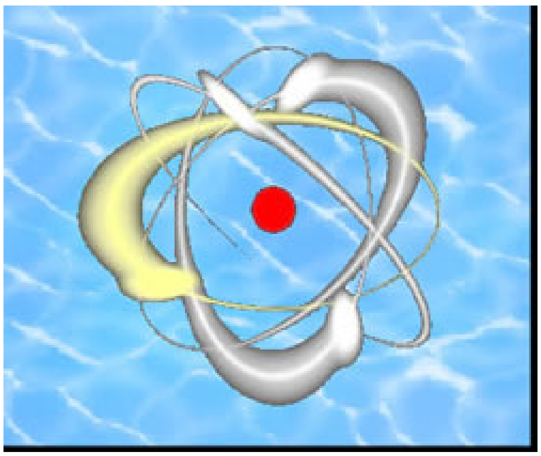

Sometimes, it pays to think small. By observing how a single electron behaves amid a cluster of water molecules, a team of scientists has gained a better understanding of a fundamental process that drives a myriad of biological and chemical phenomena, such as the formation of reactive molecules in the body that can cause disease.

The researchers, led by Lawrence Berkeley National Laboratory's Chemical Sciences Division Director Daniel Neumark, used **an extremely fast imaging technique** to observe an excited electron, surrounded by several dozen water molecules, relax back to its original energy state. This journey occurred much more quickly than one theory predicts, lending credence to an opposing theory and helping **to solve a longstanding puzzle in the world of hydrated electrons**.

“Our work tells us something very basic about the nature of the interactions between electrons and water, which is of general, cross-cutting interest to many scientists,” says Neumark, who conducted the study with scientists from the University of California at Berkeley and Israel’s Tel-Aviv University. Their research is published in the September 16, 2004 edition of Science Express.

As their name implies, hydrated electrons are electrons that are dissolved in water. They occupy an elliptical void formed by six water molecules, and they’ve intrigued scientists since their discovery in 1962. The simple fact that they exist is interesting, as is their little understood role in many biological and chemical processes. Although it is too early to tell how Neumark’s work will elucidate the behavior of hydrated electrons in the real world, such as how they conspire to form free radicals (highly reactive molecules that can damage tissue and contribute to diseases such as cancer, rheumatoid arthritis, and heart disease), it will help shape future research.

Leading up to this study, scientists had been divided as to how hydrated electrons react after they’ve been excited. One theory holds that electrons convert back to their original energy state in about 50 femtoseconds, or 50 millionths of a billionth of a second. The other theory contends this conversion takes much longer, about 500 femtoseconds.

Most research into this phenomenon has explored the behavior of hydrated electrons in a large quantity of water, called a bulk. Bulk experiments can yield very precise measurements, but they have trouble portraying the various components of the electrons’ journey between energy states. To get a more precise look, Neumark’s team instead observed a single electron in a tiny cluster of between 25 and 50 water molecules. Such clusters give scientists an extremely close look at the electron’s dynamics. For example, they can determine whether water molecules are simply rearranging themselves around an electron in an excited or a ground state, or whether these dynamics indicate the actual transition of the electron between these states.

The team created an electronic excitation by zapping the cluster with a femtosecond laser pulse. They then used time-resolved photoelectron imaging to take snapshots of the electron as it relaxed back to its ground state. The dynamics and rate of this conversion, when extrapolated to how hydrated electrons behave in bulk, suggest that hydrated electrons relax back to their unexcited state in about 50 femtoseconds — a finding that tips the scales in favor of this theory.

"Resolving which of these two models is correct is a key step. We've used time-resolved studies of finite clusters to resolve an issue of fundamental importance, namely the dynamics of an excited hydrated electron," says Neumark. "More generally, this work represents a fairly unique example of how studies of clusters can elucidate bulk phenomena."

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Source: Berkeley Lab