How do free electrons originate?

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Scientists at Max Planck Institute of Plasma Physics (IPP) in Garching and Greifswald and Fritz Haber Institute in Berlin, Germany, have discovered a new way in which high-energy radiation in water can release slow electrons. Their results have now been published in the renowned journal, *Nature Physics*. Free electrons play a major role in chemical processes. In particular, they might be responsible for causing radiation damage in organic tissue.

When ionising radiation impinges on matter, large quantities of slow electrons are released. It was previously assumed that these electrons are ejected by the high-energy radiation from the electron sheath of the particle hit - say, a water molecule. In their experiment the Berlin scientists bombarded water clusters in the form of tiny ice pellets with soft X-radiation from the BESSY storage ring for synchrotron radiation. As expected, they detected the slow electrons already known. In addition, however, they discovered a new process: Two adjacent water molecules work together and thus enhance the yield of slow electrons.

First the energy of the X-radiation is absorbed in the material: A water molecule is then ionised and releases an electron. But this electron does not absorb all of the energy of the impinging X-ray photon. A residue remains stored in the ion left behind and causes another electron to be released just very few femtoseconds later. (A femtosecond is a millionth of a billionth of a second. For example, the electrons in a chemical process take a few femtoseconds to get re-arranged.) This process is known as autoionisation, i. e. the molecule ionises itself.

The Max Planck scientists have now discovered that two adjacent water molecules can work together in such an autoionisation process. Working in conjunction, they achieve a state that is more favourable energy-wise when each of them releases an electron. What happens is that the molecular ion produced first transfers its excess energy to a second molecule, which then releases an electron of its own. This energy transfer even functions through empty space, no chemical bonding of the two molecules being necessary.

This discovery did not really come as a surprise. More than ten years ago theoreticians at the University of Heidelberg around Lorenz Cederbaum had predicted this "Intermolecular Coulombic Decay". It had already been observed in frozen rare gases. Identifying it beyond doubt now in water called for a sophisticated experimentation technique by which the two electrons produced are identified as a pair.

By demonstrating that the process is possible in water - thus presumably in organic tissue as well - the IPP scientists might now be able to help clarify the cause of radiation damage. "Slow electrons released in an organism may have fatal consequences for biologically relevant molecules," states Uwe Hergenhahn from the Berlin IPP group at BESSY: "It was just a few years ago that it was found that deposition of such electrons can cut organic molecules in two like a pair of scissors. Very little is known as yet about how this and other processes at the molecular level give rise to radiation damage. What is clear, though, is that this constitutes an important field of research." Intermolecular Coulomb decay is also important for other chemical processes: The paired action of a water molecule and a substance dissolved in the water could clarify how dissolving processes function at the molecular level.

The results of the IPP scientists were recently published in the renowned journal, Nature Physics. The same issue also features a complementary experiment in which a research group at the University of Frankfurt observed intermolecular Coulombic decay in the tiniest possible water cluster conceivable, comprising just two water molecules.

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