Press Release – December 4th, 2011

“Seeing” the energy of molecules using synchrotron light

French, Swedish and Japanese researchers have broken down a fundamental scientific barrier by developing, at the SOLEIL synchrotron, a cutting-edge method to characterize the energy that binds atoms within a molecule. These results appear today in *Nature Physics*.

What does optimizing the use of renewable energy have in common with the fight against cancer or infectious diseases, the development of new materials, understanding the origin of the Universe and life or increasing the storage capacity of digital information? These are examples of research areas the results of which have an impact on our daily lives, at different levels. The scientists involved have all, sooner or later, had the same goal: understanding the properties of matter in its various forms, whether this builds a tumor cell, an electronic chip or exhaust fumes. Ultimately, the aim is to change these properties, so that the tumor stops spreading, the chip becomes versatile or catalytic converters are more efficient.

The key to all these phenomena is to be found in the interactions between the building blocks of matter: the atoms. They bind to each other to form molecules, the smallest quantity of matter having the same features as the "macroscopic" object. These chemical bonds, of various strength, are at the origin of the properties of molecules and their reactivity (ability to transform themselves) and, by extension, of the properties of matter.

At the PLEIADES beamline at the SOLEIL synchrotron, a group of French (synchrotron SOLEIL, Gif-sur-Yvette), Swedish (Royal Institute of Technology, Stockholm) and Japanese (Institute for Molecular Science, Okazaki) researchers have just made atoms "talk": they had access to information never obtained before, as it was unobservable in previous experiments. To obtain this, the researchers needed to innovate and achieved a technical feat: the information, hidden until now by a dense forest of peaks, was extracted and isolated in order that it could be interpreted with the help of high-level theoretical analysis.

These first results obtained for N_2, one of the simplest molecules composed of two nitrogen atoms, have been greeted not only by the electron spectroscopy community (since this was the analysis technique used) but also by all physicists. These results demonstrate the exceptional interest of this technique for research on the intrinsic properties of molecules and for science in general. Similarly, exactly a century earlier, X-ray diffraction gave access for the first time to the arrangement of atoms in solids. It has nowadays become the main technique for determining protein structure - an essential step in understanding the functioning of any cellular machinery.

While many analytical techniques exist to examine or to probe matter at the atomic level, that developed at SOLEIL is the only one allowing access to such accurate and complex information on the energy that binds two atoms together. Synchrotron radiation facilities have the advantage of combining in the same place, some of the most efficient instruments to simultaneously apply these techniques. This involves seeking out the atoms with X-ray beams. The molecule’s response to this excitation then provides a wealth of information. Researchers try to detect any vibration, light emission, electron ejection, etc. – all these are some of the multiple possible responses of the molecule. These reactions usually occur more or less simultaneously, on time scales of the order of a few millionths of a billionth of a second. In other words, the tool that will measure this response has to be extremely sensitive and have a very high resolution. This means that it must be able to distinguish two almost simultaneous events resulting from this response of the molecule by registering them separately.

SOLEIL synchrotron offers not only X-rays of exceptional brightness, but has the advantage of having analysis tools that are unique in the world, by means of which it was possible to obtain these results. They touch at the most fundamental level of science, the basic composition of matter. Let there be no mistake: with this performance in the understanding of the mechanisms at the origin of atomic interactions in systems of increasing complexity, a whole new field of possibilities opens up to other scientific disciplines in understanding the intimate behavior of matter.

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Reference

« Imaging molecular potentials using ultrahigh-resolution resonant photoemission », C. Miron et al., Nature Physics (2011) DOI 10.1038/NPHYS2159.

NOTE

Located on the Saclay Plateau in the Essonne department, SOLEIL is the third-generation French synchrotron. SOLEIL is a research centre directed by the CNRS (French National Centre for Scientific Research) and the CEA (French Atomic Energy Commission). The building of this type of facility involves major construction work as well as precision mechanical work. Its purpose is to accelerate bunches of electrons until they radiate extremely bright light covering a very wide range of wavelengths: from infrared to x-ray, with ultraviolet in between. The characteristics of this light (intensity, focus, stability, polarization, etc.) allow scientists to observe matter down to the atomic level and perform experiments that would previously not have been possible, in the interests of fundamental, applied, and industrial research. SOLEIL serves many areas currently of particular interest to the scientific and industrial communities: biology, chemistry, materials science, the environment, physics, Earth sciences, cultural ancient materials. SOLEIL's specifications (operating energy, number of undulators, broad spectrum from infrared to x-ray, brilliance, continuous injection for beam stability to within a micron, etc.) make it competitive at the top level on the international scene.

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The team of three researchers from the PLEIADES beamline at Synchrotron SOLEIL who lead the research, and the experimental set-up used to obtain the results published in Nature Physics: Catalin MIRON, Christophe NICOLAS and Oksana TRAVNIKOVA (from left to right).