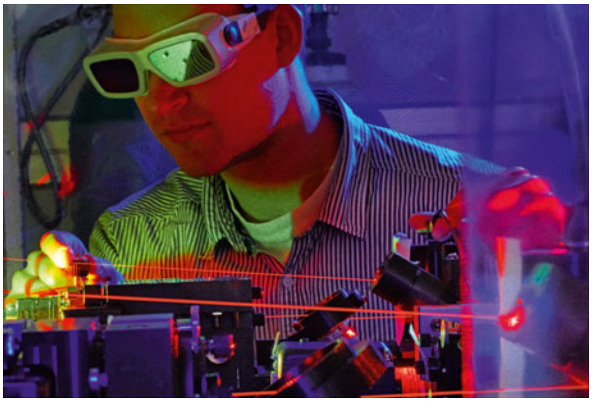
Camouflaged ions

Every molecule has its own spectrum – its specific fingerprint – which researchers use to try and ascertain the properties of particles. Professor Frédéric Merkt of ETH Zurich University in Switzerland has achieved a breakthrough – the laser light sources, spectroscopic instruments and methods he has developed enable key ions to be characterized for the first time. This achievement has now won him the Otto Bayer Award.

Particle experts: Professor Frédéric Merkt (left) and his team, including Pitt Allmendinger, have carried out spectroscopic research into ions.

Supporting cutting-edge research



The Otto Bayer Award is presented by the Bayer Science & Education Foundation. It honors scientists who have made pioneering research contributions in innovative fields of chemistry and biochemistry.
The primary objectives of the foundation are the recognition of outstanding research achievements, the promotion of talented researchers and support for significant school projects of a scientific nature.

Seeing through the light spectrum – chemists including Heiner Sassmannshausen have themselves developed some of the laser light sources and equipment they work with in ETH Zurich's laser laboratory.

The world is being measured in ever greater detail, from one size extreme to the other. Physical chemistry experts are also involved in this task: they characterize atoms and molecules and model complex chemical reactions such as combustion in power plants and engines and the greenhouse effect in the atmosphere. In addition to providing more accurate predictions of changes to the climate, this also optimizes production processes in the chemical and automotive industries. The knowledge chain starts with understanding individual molecules and elementary processes. But some of these present puzzles for researchers. One type of molecule has always proved scientifically problematic – the electrically charged particles known as ions.

The trick is to skillfully camouflage ions

The problem is their charge. Ions repel each other in the same way as two identical poles of a magnet. "This interferes with measurements, making them insensitive and inaccurate," says Professor Frédéric Merkt, a chemist at ETH Zurich University in Switzerland. He and his team have succeeded in defining the properties of key ions such as the methane cation CH_4^+, the ozone cation O_3^+ and the hydrogen molecular ion H_2^+. They have done so by transferring the molecules to a Rydberg state. "This camouflages the ions to a certain extent and removes the undesirable charge," continues Merkt. The 47-year-old has received the Otto Bayer Award in recognition of his work.

As Merkt explains, anyone who is looking to characterize a molecule needs to know how it rotates, how the atoms oscillate around their center of gravity and how the electrons move around the nucleus. This enables the exact chemical and physical properties to be defined. In molecular spectroscopy, light – electromagnetic radiation – excites the molecules and induces further photochemical and photophysical processes in them. This creates a specific spectrum for each molecule.

"It also proves molecules are actually present," says Merkt. This is of interest to scientists including astrophysicists and atmospheric physicists, who use molecular spectra to investigate how the atmosphere changes. They can benefit from Merkt's work, because ions are also generated in the upper layers of the gaseous geosphere. The solar radiation there contains so much energy that a large number of molecules are ionized. A negatively charged electron splits off from the molecule, leaving behind a positively charged particle – a cation.

The spectra of many key cations were previously unknown, but Merkt's team tracked down the reluctant molecules. "We transfer uncharged molecules to a hybrid state between charged and uncharged," he explains. To do so, the researchers excite one of the outer electrons with vacuum ultraviolet light that causes thousand-fold swelling of the molecules. The outermost electron in these giant molecules adopts a very high orbit. Merkt compares it with a satellite that is just still held by the Earth's gravity. "A little more energy and the electron would split off, leaving behind a cation," he says. This highly excited state is also called the Rydberg state.

Rydberg state enables ions to be measured

The molecules are uncharged but resemble a cation. "This means they behave almost like ions but don't repel each other," explains Merkt. The findings of spectroscopic research on Rydberg states can therefore be transferred to ions. "The spectra also enable detailed research into the interactions between ion and electron and the elementary process of photoionization," he says. Consequently, there's still a long way to go in the field of molecular measurement.

www.research.bayer.com/spectroscopy
provides further information on this topic

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