

Ionic crystal generates molecular ions upon positron irradiation

October 10 2023



The apparatus is installed at Tokyo University of Science (TUS). Positrons emitted from a ^{22}Na source capsule by β^+ decay are moderated using a moderator made of tungsten mesh, extracted into vacuum, and transported to a sample using a static magnetic field. The research group at TUS has achieved various results using this apparatus, including experiments on the emission of positronium neutral atoms or positronium negative ions from solid surfaces. Credit: Professor Yasuyuki Nagashima from Tokyo University of Science

The positron, the antiparticle of the electron, has the same mass and charge as that of an electron but with the sign flipped for the charge. It is an attractive particle for scientists because the use of positrons has led to important insights and developments in the fields of elementary particle physics, atomic physics, materials science, astrophysics, and medicine.

For instance, positrons are known to be components of antimatter. They are also powerful in detecting lattice defects in solids and semiconductors and in structural analysis of the topmost surface of crystals.

Positronic compounds, namely bound states of positrons with regular atoms, molecules, or ions, represent an intriguing aspect of [positron](#)–matter interactions and have been studied experimentally via observation of positron annihilation in gases. It may be possible to generate new molecules and ions via the formation of positron compounds, but no research has ever been done from such a perspective.

Against this backdrop, a research team including Professor Yasuyuki Nagashima from Tokyo University of Science (TUS), Japan, has found an innovative way to explore the interactions between positrons and ionic crystals. Their work, [published in *Physical Review Letters*](#), involved collaborative efforts from Dr. Takayuki Tachibana, former Assistant Professor at TUS and currently affiliated with Rikkyo University, and Mr. Daiki Hoshi, a former graduate student at TUS.

The researchers used a technique based on a well-explored phenomenon arising from the bombardment of a solid with an [electron beam](#). "It has long been known that when electrons are injected into a [solid surface](#), atoms that make up the surface are ejected as monoatomic positive ions," explains Dr. Tachibana. This process, known as electron-stimulated desorption, motivated the team to explore what would happen if a crystal was instead bombarded with positrons.

In their experiments, the researchers shot either a positron or electron beam at the (110) surface of a lithium fluoride (LiF) crystal. Using carefully placed electric fields generated by deflectors, they controlled the incident energies of the charged particles. Moreover, the deflectors enabled them to redirect any ions desorbed from the crystal towards an ion detector. The detected signals were then used to conduct spectroscopic analysis to identify the precise composition of the desorbed ions.

They found that when the LiF crystal was irradiated with electrons, only the expected monoatomic ions, namely Li^+ , F^+ , and H^+ (due to residual gases in the experimental chamber) were detected. However, injecting the crystal with [positrons](#) led to the detection of positive molecular fluorine ions (F_2^+) and positive hydrogen fluoride ions (FH^+). Notably, this is the first-ever report of molecular ions being ejected upon positron irradiation.

After further analysis and experimentation, the researchers developed a desorption model to explain their observations. According to this model, as positrons are injected into a solid, some of them return to the surface after losing their energy. In the case of LiF crystals, these positrons may attract two neighboring fluorine negative ions on the surface to form a positronic compound.

If the bound positron annihilates with one of the fluorine ion's core electrons, a special type of electron, known as an Auger electron, is emitted, resulting in a charge swap and the generation of a positive F_2^+ molecular ion. This ion is pushed out of the crystal by the repulsing forces of the nearby Li^+ ions.

The findings of this study could further our understanding of matter–antimatter interactions. "The stability and binding properties of positronic compounds provide unique perspectives on the interaction of

antiparticles with ordinary substances, paving the way for novel investigations in the field of quantum chemistry," said Dr. Tachibana. "The proposed method could thus pave the way for the generation of new molecular ions and molecules in the future."

Notably, the approach could be leveraged in many applied fields. In [materials science](#), it could be used to modify the surface of materials and study their properties with unprecedented precision. Other potential applications include cancer therapy, quantum computing, energy storage, and next-generation electronic devices.

More information: T. Tachibana et al, Molecular Ion Desorption from LiF(110) Surfaces by Positron Annihilation, *Physical Review Letters* (2023). [DOI: 10.1103/PhysRevLett.131.143201](https://doi.org/10.1103/PhysRevLett.131.143201)

Provided by Tokyo University of Science

Citation: Ionic crystal generates molecular ions upon positron irradiation (2023, October 10) retrieved 29 April 2024 from <https://phys.org/news/2023-10-ionic-crystal-generates-molecular-ions.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.