Weight determination of individual viruses with a miniature ion trap

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Viruses are the simplest life forms on our planet, consisting of only DNA or RNA and a shell. After the prokaryotes (bacteria and archebacteria), viruses are the second most common type of organism. In our oceans they are the most common life form. In order to gain a better understanding of the structure and characteristics of these genetically varied little organisms, it would be highly useful to be able to determine their masses and how much these vary within a given population.

Researchers in Taiwan have now used very gentle ionization techniques and a miniaturized ion trap of their own devising to accurately analyze the masses of individual, intact viruses.

Previous methods for determining the masses of viruses had a margin of error of ±15%, which made them too inaccurate to ensure the resolution of small differences in mass. A team led by Huan-Cheng Chang has developed a new concept to attain higher precision.

In order to determine their mass, viruses must first be converted to the gas phase, given an electric charge, and accelerated in an electric field. However, this process must leave the viruses intact. The researchers thus chose to use a very gentle method known as LIAD (laser-induced acoustic desorption).

The virus particles are released from the sample by laser-induced sound waves. They are then caught in an “ion trap”. This is an electric field that holds charged particles prisoner by means of its special geometry and alternating voltage. Once trapped, the virus particles are ready for mass determination. Laser light is beamed into the ion trap. If a particle is present, it scatters the light.

The scattered light can be detected through the transparent surfaces of the ion trap. A portion of the light is sent to a CCD camera, which records the flight path of the trapped particle. The rest of the light goes to a measuring device that precisely analyzes the scattering signal. The scattered light is different from the initial light beam because the virus particle in the electric field of the ion trap begins to oscillate. This oscillation depends on the mass (and charge) of the virus.

The team was thus able to determine the masses of three different types of viruses with diameters between 80 and 300 nm—with an astonishingly low margin of error of ±1%. The masses of the viruses can, in combination with other analytical processes, be used to infer how many building blocks are used to make up the shell of the virus or how many copies of the genetic material it contains.

These highly precise measurements were made possible by the special structure of the ion trap; instead of a classic quadrupole ion trap, Chang and co-workers chose to use a cylindrical ion trap (CIT). In this type of trap, the movement of the trapped ions is considerably more complex and not mathematically ascertainable. However, it has the advantage of a much simpler geometry.

The team constructed a CIT with smaller dimensions than usual, optimized the geometry, and exchanged the usual terminal electrodes of the cylinder with transparent, electrically conducting plates. This special construction is what made application of the precise light-scattering technique for the mass determination of a single virus possible.

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a Single Whole Virus in a Cylindrical Ion Trap, *Angewandte Chemie International Edition* 2006, 45, No. 48, 8131–8134, doi: 10.1002/anie.200603839

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