A COMPACT, HIGH-RESOLUTION PAUL ION TRAP MASS SPECTROMETER WITH ELECTRON-IMPACT IONIZATION

O. J. Orient and A. Chutjian

Atomic and Molecular Collisions Team
Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena CA 91109, USA

It is well known that a hyperbolic ion trap can be used as a mass spectrometer[1]. The equation for a mass-selective instability scan of the trap is,

$$m/e = \frac{8V_o}{q_z\Omega^2(r_o^2 + 2z_o^2)},$$

where V_o is the peak voltage of the applied trapping radio frequency (*rf*) signal, e is the electron charge, q_z (0.908) is a dimensionless parameter related to the ion's stability in the z-direction, Ω is the *rf* trapping angular frequency, r_o (10 mm) is the inner radius, and $z_o = r_o/\sqrt{2}$ is the center-to-endcap electrode distance. At a given V_o all the ions are trapped having a mass less than *m/e*. Above mass *m/e* the ions are unstable in the z-direction and can be injected into a detector. Mass analysis is performed by measuring the detected signal while ramping the amplitude V_o.

There are three methods for introducing ions in a trap: (1) The ions are injected from an external source. In this case a high background gas pressure (about 10^{-3} torr) is needed to thermalize the ions. (2) Create the ions within the trap by irradiation with an ionizing (ultraviolet) laser. (3) Use electron-impact ionization of the analyte within the trap. This last is perhaps the most convenient for many applications.

In the present experiments the ions are generated by method (3) using a 75 eV electron beam which traverses the trapping region. The resulting thermal ions are then trapped, and can be mass-analyzed. The mass resolution is determined by the mechanical precision of the hyperboloid surfaces, and the stability of the *rf* amplitude and frequency Ω. The mechanical tolerance of the trap employed here is less than 0.1%. Detailed calculation shows that for this mechanical tolerance, and for an *rf* amplitude stability of 0.1%, one may achieve a resolution of $m/\Delta m = 3000$. The present *rf* stability of the home-built electronics is only 1%, and this limits the present resolution to only about 400. Work is underway to increase the stability of the rf unit to achieve resolutions which can routinely resolve the molecular ions CO^+(27.995 amu) and N_2^+ (28.006 amu).

To illustrate the performance of the trap, shown in Fig. 1 is a mass spectrum from 1-40 amu, with a resolution of 0.1 amu (FWHM). This spectrum was acquired *via* multichannel scaling, and includes effects of electronics instability. At low mass, one clearly sees trapping and detection of H^+ and H_2^+; while at higher masses one sees clear resolution of the isotopes $^{20,21,22}Ne^+$ and $^{36,38,40}A^+$. We note in passing that one can reduce the size of this trap by another factor of two (to r_o =10 mm), with no sacrifice in machining tolerance, hence resolution. However, present-day electronics are quite large, and have *not* kept up with the sensor miniaturization pace. Efforts are underway at JPL to reduce electronics size to compatible dimensions.

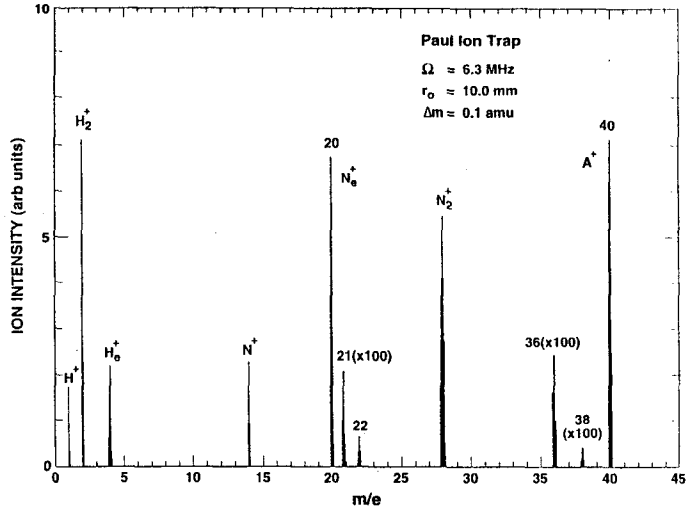

Figure 1. Sample mass spectrum from the compact Paul ion trap at angular frequency $\Omega = 2\pi \times 1.0 = 6.3$ MHz.

Acknowledgment: This work was carried out at JPL/Caltech, and was supported by NASA.

References:

1. W. Paul and H. Steinwedel, Z. Naturforsch. **A8**, 448 (1953).

2. J. M. Wells, E. R. Badman, and R. G. Cooks, Anal. Chem. **70**, 438 (1998).

email: otto.j.orient@jpl.nasa.gov