Atmospheric Constituent Explorer System (ACES)

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Abstract

We report on the Atmospheric Constituent Explorer System (ACES), a mass spectrometer (MS) based instrument for atmospheric probe missions. In its current embodiment, ACES has been specifically matured to address the top three decadal science measurements of the Venus and Ice Giant atmospheres; to determine abundances and isotopic ratios of the noble-gases, to inventory and quantify the trace species, and to measure key isotopic ratios of the elements. ACES is designed to perform these measurements rapidly and to exceed the required precision and accuracy. The rapid measurement capability is specifically valuable for proposed investigations of Venus, enabling rapid atmospheric profiling of, for example, the unknown UV absorber at high altitudes.

ACES employs the JPL quadrupole ion trap mass spectrometer (QITMS) that has been developed over more than a decade (since 2001). The ACES QITMS is based on the mass spectrometer that flew in the successful Vehicle Cabin Atmosphere Monitor (VCAM), which monitored the atmosphere of the International Space Station (ISS) continuously for two years. The QITMS has been improved and matured for the ACES instrument. The QITMS is engineered in a “wireless” design, where all electrical connections are made through the structure, obviating all wires. The structural posts then plug directly into the vacuum flange electrical connectors. This approach significantly improved the shock and vibration loads the QITMS can survive and operate under, more than sufficient for the entry and descent loads for a Venus mission (300G axial, ±30G random radial). The QITMS employs two *rf* signals, applied to the MS cap electrodes, in addition to the main (high voltage) *rf*. Operating the QITMS in resonant injection modes enables, selective mass trapping (or ejection) and high mass resolution ($m/\Delta m \geq 5000$ @ 28 Da, full width at half maximum) and high mass range (1000 Da) with unprecedented long-term instrument stability. The ACES has been developed to introduce atmospheric gases such that the QITMS operate QITMS in the ultra-high vacuum environment (≤ 5E-10 Torr base pressure with operating pressure of <5E-8 Torr). This is highly advantages as, for example, it minimizes or eliminates ion-molecule reactions that are typically commonplace in ion trap MS. In combination with stability and virtually no background signal, the QITMS has a signal to noise/background ratio greater than 10^8.
The front end gas inlet system, has been matured under a 2014 NASA Homesteader award. It is comprised of as a system of valves (4) and micro leaks (4) which maintain gas flow within to the sensor as probe descends through planetary atmosphere. Our approach is unique in a sense that all valves but one as well as microleaks are based on MEMS technology which makes them light, high G load insensitive, low power consumption (mW) small mass and volume.

As part of the ACES instrument development we are performing a numerous measurements with analog gas mixtures of planetary atmospheres. Shown in Figure 1 is an ACES measurement of the ratio of intensities of 44 Da and 45 Da mass lines from CO2 using a Venus atmosphere analogue. The measurement, requiring only 10 sec of integration time, yields the expected 44/45 intensity ratio to within 5% uncertainty.

Figure 1: Isotopic measurement of CO2 with Venus analogue sample