MEASUREMENTS OF ISOTOPE RATIOS AND ABUNDANCES IN THE ATMOSPHERE OF MARS BY A MASS SPECTROMETER: PALOMA. E. Quemerais, E. Chassefiere, J. J. Berthelier, A. Jambon, P. Agrinier, M. Javoy, J. Kunz, and P. Sarda, Service d'Aeronomie du CNRS.

A mass spectrometer is proposed to be landed on the surface of Mars. It is aimed at measuring the isotope ratios and abundances of noble gases and of some of the major elements in the bulk atmosphere. Although previous measurements were obtained from the Viking landers or from telescopic observations from, the detailed composition of the Martian atmosphere, in particular the isotopic pattern of noble gases, is still poorly known and understood. While some measurements are available from SNC meteorites, assumed to have a Martian origin, there are many uncertainties connected with understanding their relationship to the Martian atmosphere.

One of the most important mechanisms yielding isotopic fractionation of atmospheric gases is escape to space. Depending on solar UV radiation and solar wind conditions, and also on some important characteristics of the planet like the presence (and amplitude) of an intrinsic magnetic field, or the chemical composition of the atmosphere (which controls its thermal structure), different types of escape processes may take place, thermal (Jeans, hydrodynamic) and/or non-thermal (dissociative recombination, sputtering by pick-up ions). They are associated with different fractionation patterns, which signatures are expected to be retained in the present isotope spectrum. For this reason, isotopic composition is the most important clue toward understanding the history of volatiles. Escape mechanisms are supposed to have played an important role because of the small gravitational field of the planet, and this approach is particularly relevant to Mars. In this way, stable isotopes of CHON compounds (CO2, H2O, N2), as well as neon and argon, would provide a good quantitative estimate of the processes that affected the evolution of the atmosphere during the last four billion years.

One major problem is that the composition of the early atmosphere, before fractionation by escape, is poorly known. On Earth, the strong depletion of non-radiogenic noble gases in the mantle with respect to the atmosphere suggests that : either the atmosphere has been outgassed from the mantle, which is now strongly depleted ; or the two reservoirs (atmosphere and mantle) are mostly independent : the atmosphere does not originate in the mantle. For example, the isotopic composition of atmospheric neon on Earth may be considered as the mixture of "planetary" (90%), "solar" (10%) and weak "radiogenic" components. Mantle neon is rather interpreted as a solar component, plus a small radiogenic one. Therefore, either atmospheric neon does not originate in the mantle, or it has been strongly fractionated, possibly by escape. Similarly, some characteristics of xenon isotopic composition (apparent deficiency with respect to other noble gases, enrichment in heavy isotopes) are not well understood. It may be thought that a comparison analysis of Mars and Earth noble gases would allow to better discrimate between the different components, which are expected to behave differently for the two planets. For example, Mars is supposed to have lost an important part of its atmosphere by impact erosion (non-fractionating in nature), as inferred from strong relative enrichments in radiogenic 40Ar eand 129Xe (with respect to Earth), which must have modified the relative weights of planetary, solar and radiogenic components.

From another point of view, these atmospheric measurements could be used as a reference in interpreting some other direct or indirect measurements:

- Volatile composition of the glassy inclusions of one of the SNC meteorites (EETA 79001) ; correlations between SNC meteorites and Viking abundances, although generally good, are not well established for Ne, Kr and Xe because of the low accuracy of Viking measurements ; the way atmospheric gases were trapped in these meteorites when they were ejected from Mars, if they are of Martian origin, deserves further observation and analysis
- Analysis of samples of the Martian subsurface which at aim detecting possible organic molecules preserved in the subsurface material ; atmospheric measurements performed by the PALOMA mass spectrometer should provide a reference for purpose of cross-calibration and comparison between subsurface and atmospheric volatile abundances.
- Analysis of returned samples, including possible samples of atmospheric gas ; in situ measurements will provide a useful reference to check that samples have not been altered in the time lapse between sampling and analysis.

The use of a mass spectrometer measuring isotope ratios and abundances in the bulk Martian atmosphere should be of a great value for better understanding, in a comparative approach, the volatile and climate evolutions of telluric planets. It would be quite complementary of the science to be done on the Dynamo orbiter (Chassefière et al, "Dynamo : a micro-orbiter aimed at investigating Mars crustal magnetism and atmospheric interactions"), dedicated to deciphering the past evolution of the Martian magnetic dynamo and fully characterizing present atmospheric escape. Such an instrument, which could be relatively light and robust, could be put at the surface of Mars by a classical lander (2005). Monitoring isotope ratios of condensible species (H2O, and in some cases CO2) over the diurnal and seasonal cycles might allow to evidence significant variations, as observed in Earth atmosphere. More generally, the proposed instrument would provide an unquestionable reference atmosphere for any related future investigation of chemical, mineralogical and possibly biological properties of Martian rocks, soils and ices.