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Analysis of frozen salt solutions with laser-induced breakdown spectroscopy under Martian conditions

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Laser-induced breakdown spectroscopy (LIBS) is a powerful analytical technique for determining the elemental composition of materials. It can be applied in-situ to geological surfaces on planetary missions. Since pure liquid water is unstable at the current surface conditions on Mars, i.e. low surface pressure and temperatures ranging from 140 K to 300 K, salt solutions or brines are of particular interest. It has been suggested that salts could stabilize liquid water on Mars lowering the freezing point of the solution and suppressing evaporation rates. The appropriate salts have been found on Mars in different locations. In this study LIBS is employed for the investigation of frozen sulphate and chloride solutions under Martian conditions in a dedicated simulation chamber.

For the laboratory experiments, various salt solutions were prepared with different concentrations. To produce ice with only little inclusions of air, the samples were degassed before freezing them in a copper container. The measurements were performed at 240 K by cooling with liquid nitrogen and controlled heating. A constant flow of a Martian atmosphere-like gas mixture at a pressure of approximately 6 hPa was maintained through the chamber during the measurements. A Q-switched Nd:YAG laser operating at 1064nm and at 10 Hz was used to ablate material and to generate a plasma on the frozen sample's surface. The emitted light of the plasma was collected into the entrance slit of an echelle spectrometer (LTB Aryelle Butterfly) by a toroid mirror. A time-gated ICCD camera (Andor) at the exit of the spectrometer recorded the plasma emission signal. The laser beam was focused at a new position for each measurement.

The delay time and the integration time of the spectrometer have been optimized to obtain good signal-to-noise ratios up to 150 while at the same time not losing signals from fast recombining ions. First, the spectra of several frozen salt solutions were investigated qualitatively focusing on the major elemental composition as well as on minor elements. In general, the alkali metal and alkaline earth metal elements were clearly detectable in the LIBS spectra in the 280-900 nm region. This allowed for a good distinction between different frozen solutions. Also the oxygen and hydrogen lines gave good signal-to-noise ratios. On the other hand, in particular, sulphur, as known, is difficult to detect in this spectral range as only weak sulphur lines are apparent in this region. The experiments demonstrate the capability of LIBS for detection and identification of frozen salt solutions under Martian conditions.