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Gas-Analytic Package for the Russian Luna-Globe and Lunar-Resource missions

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Abstract

The paper considers possible sources of polar volatile depositions on the Moon and presents the experiment which is in preparation for Russian polar landers to characterize polar regolith volatiles.

Introduction:

Luna-Globe and Lunar-Resource missions are now under preparation in Russia for launch in 2014. Both missions have landers to be put in northern and southern polar regions of the Moon, which may possess depositions of water and other volatile components. The gas-analytic experiment is dedicated for the comprehensive investigation of the inventory of volatiles in the regolith of the lunar polar regions. This information is valuable for understanding of the real content and chemical composition of volatiles in polar regions regolith. Chemical composition and abundance of volatile components bears information about the source and dynamics of volatiles on the Moon. Information about isotopic ratios of key volatile elements (C, H, O, N, noble gases, …) is also of great importance for understanding of sources of the lunar volatile components.

Tasks of the Gas-Analytic Package:

The main tasks of the Gas-Analytic Package (GAP) are:

1. Detailed investigation of chemical composition and abundances of volatile compounds (H_2O, CO_2, N_2, H_2, noble gases, organics, etc.) in the surface regolith material of the Moon at the landing place;
2. Investigation of forms of incorporation of volatile components into the solid surface material;
3. Investigation of organic components in the surface material;
4. Measurement of isotopic composition of CHON elements ($^{13}C/^{12}C$, D/H, $^{17}O/^{16}O$, $^{18}O/^{16}O$, $^{15}N/^{14}N$) and noble gases.
5. Measurements of the exosphere composition of the Moon.

Description of the GAP:

Design of the GAP is based mainly on the heritage of the GAP developed for the Russian Phobos-Grunt mission to be launched in November 2011 [1, 3]. The GAP consists of three individual instruments: 1) Thermal Analyzer (TA-L); 2) Gas Chromatograph (GC-L); and 3) Neutral Gas Mass-Spectrometer (NGMS).

TA-L instrument

TA-L has the Soil Acquisition System (SAS) and a carousel with 8 single-use pyrolytic cells (PC). SAS handles the portion of regolith, which it receives from the manipulator and loads the PC. PCs provide programmed heating of the imbedded regolith sample. Gases released during the heating are transferred to GC-L instrument via transfer capillary tubes.

Tasks of the TA-L instrument are:

1. To measure exo- and endothermal reactions in the soil sample to determine minerals with phase transitions at temperatures < 1000°C;
2. To perform the release of volatile components into the gas phase and provide their transfer into GC-L and NGMS instruments;
3. To perform pyrolysis of heavy organics (kerogens?) and provide their transfer into GC-L and NGMS instruments.

GC-L instrument

Gas chromatograph instrument GC-L has two capillary columns (CC): one coated by carbobond for analysis of permanent gases; and the second coated by MXT-5 for analysis of high boiling components. Each column is equipped by thermal conductivity detector (TCD). GC-L instrument has two injection traps (IT), the first filled by Carbosieve and the second by Tenax absorbents, which are cooled by Peltier elements down to –50°C. It sequentially collects high boiling components and permanent gases for injection by pulse heating into respective CCs. GC-L instrument is a combination of a gas chromatograph with a tunable diode laser absorption spectrometer (TDLAS). TDLAS has four tunable diode lasers aimed on the measurement of CO_2 and H_2O molecules and the C, O, and H isotopes in these molecules.

Tasks of the GC-L instrument are:

1. Accumulation of gases that are released from the regolith sample during pyrolysis;
2. Redistribution of gases of different types (permanent gases, organics, etc.) between respective columns;
3. Separation of different gases by time of retention;
4. Measurement of the abundance of each separate gas component;
5. Measurement of the isotopic ratios of $^{13}C/^{12}C$, D/H, $^{17}O/^{16}O$, $^{18}O/^{16}O$, in CO_2 and H_2O.

NGMS instrument

The NGMS instrument is a time-of-flight mass-spectrometer based on an earlier development for stratospheric research [2].

Tasks of the NGMS instrument are:

1. Mass spectrometric identification of gas components that are released from the gas chromatograph;
2. Measurement of isotopic ratios of volatile elements.
3. Measurements of the exosphere composition of the Moon.

Method of analysis.

The GAP receives a portion of soil from the Sampling Device of the manipulator. This portion is loaded into the SAS of the TA-L instrument. SAS provides selection of a dose of the regolith sample (~0.5 cm^3), its loading into the pyrolytic cell and sealing of PC. The PC performs programmed heating of the sample up to 1000ºC to do thermal analysis of the sample and provides the release of volatiles into gaseous phase. Released gases are transported to the gas chromatograph GC-L by a flow of carrier gas (helium). Gases in time of pyrolysis are analyzed in GC-L using TDLAS to measure H_2O and CO_2 molecules and isotopic ratios $^{13}C/^{12}C$, D/H, $^{17}O/^{16}O$, $^{18}O/^{16}O$ in them. Afterwards gases are separated between two injection traps and accumulated in them. Collected gases are than analyzed on both chromatographic capillary columns. Separated gases are transferred to mass spectrometer for mass spectrometric analysis for their proper identification and measurement of isotopic composition of key volatile element.

Cooperation:

Main partners of the Gas Analytic Package team are:
Space Research Institute (IKI) of the RAS (Russia),
LATMOS and LISA, University of Paris (France),
Max Planck Ins. for Solar System Res. (Germany)
Physics Institute, University of Bern, (Switzerland)

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