GAS-ANALYTIC PACKAGE FOR THE RUSSIAN LUNAR-RESOURCE AND LUNA-GLOBE MISSIONS. M.V. Gerasimov[1], I.I. Vinogradov[1], A.G. Sapgir[1], A.V. Kalyuzhnyi[1], O.E. Kozlov[1], A.V. Stepanov[1], A.Yu. Titov[1], D.S. Rodionov[1], Yu.V. Lebedev[1], M.M. Gerasimov[1], M. Cabane[1], C. Szopa[2], D. Coscia[2], J.-P. Goutail[2], F. Goesmann[3], P. Wurz[4], D. Abplanalp[4], and M. Tulej[4], [1]Space Research Institute of the RAS, Moscow, Russia, (mgerasim@mx.iki.rssi.ru), [2]LATMOS, IPSL, CNRS, Paris, France, [3]Max Planck Ins. for Solar System Res., Katlenburg-Lindau, Germany, [4]Physics Institute, University of Bern, Switzerland

Introduction: Lunar-Resource and Luna-Globe missions are now under preparation in Russia. Both missions have landers to be put in northern and southern polar regions of the Moon. These regions are of great interest due to the possibility of depositions of water and other volatile components. The gas-analytic experiment is dedicated to comprehensive investigation of inventory of the 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, etc.) 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 failed Russian Phobos-Grunt mission [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 instrument is aimed to release volatiles from the lunar regolith and to measure temperatures of the release. The volatiles can be frozen on regolith particles surfaces and/or bound to particles matrixes. The release of frozen volatile components can occur in a very low temperature range while the bound volatiles are released at rather high temperatures. For this reason TA-L has two types of ovens. The first one is a multi-use low temperature (<250°C) oven which is sealed immediately after direct load from the manipulator. The second type of ovens is a single-use high-temperature ones (~1000°C). 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 high-temperature 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 release and transfer to GC-L frozen volatile components.
2. To measure exo- and endothermal reactions in the soil sample to determine minerals with phase transitions at temperatures < 1000°C;
3. To perform the release of bound volatile components into the gas phase and provide their transfer into GC-L and NGMS instruments;
4. To perform pyrolysis of heavy organics (kerogens?) and provide their transfer into GC-L and NGMS instruments.

GC-L instrument: The prototype of the GC-L instrument is the KHMS-1F instrument built for the Phobos-Grunt mission.

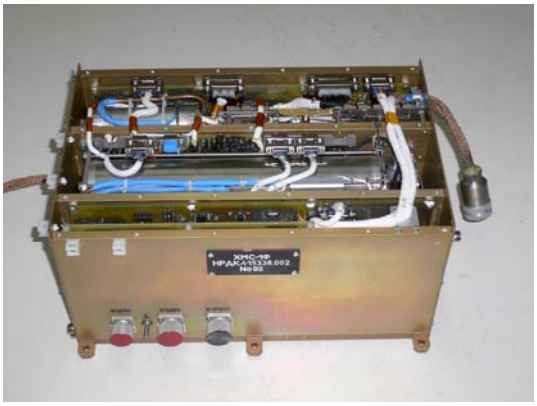

Fig. 1. General view of the KHMS-1F with removed upper cover.

GC-L has two capillary columns (CC): one coated by carbobond for analysis of permanent gases; and the second coated by Porapac-Q 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 Porapac-Q 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 by decision in one case directly into low-temperature oven or in the second case into the SAS of the TA-L instrument. Low-temperature oven provides release of frozen components and TA-L transfers them into GC-L. In case of loading the SAS, it provides selection of a dose of the regolith sample (~0.5 cm^3), its loading into the high-temperature PC and its sealing. 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 to do mass spectrometric analysis for their proper identification and measurement of isotopic composition of key volatile element.

NGMS instrument itself can measure composition of the lunar exosphere being open to the space.

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 Inst. for Solar System Res. (Germany)
Physics Institute, University of Bern, (Switzerland)

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