EPSC Abstracts
Vol. 12, EPSC2018-293, 2018
European Planetary Science Congress 2018

Loss of potassium during the Moons history

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Abstract

To understand the origin of the Earth-Moon system and further evolution of the lunar composition one has to understand the unique chemical and isotopic signatures of the Moon compared to other planetary bodies. The Moon is significantly depleted in volatile elements such as potassium (K) and sodium (Na) compared to the bulk silicate Earth. We study the K loss of the K during the short expected magma ocean phase after the Moon forming event, and model the loss induced by surface sputtering due to the plasma (solar wind and coronal mass ejections) of the young Sun during the past 4.5 billion years. We discuss our results in relation with Moon-forming hypotheses and point out which future observations at the Moon are needed to quantify the escape rates from the Earth-Moon system and their variability due to different solar activity. This knowledge is important to understand the long-term evolution of the atmosphere and is essential to the understanding of the history of the Moon and Earth as well as their interaction processes with the early Sun. Finally, particle observations near or at the Moon will allow us to examine the exact composition of the escaping minor elements in the Earth magnetotail

1. Scientific Relevance

Potassium (K) and its isotopes are crucial elements for testing the giant impact theory and related processes during the Moon-forming event. This is because K is a moderately volatile element and the lunar environment is significantly depleted in K and other volatile elements such as Na relative to the bulk silicate Earth composition and the compositions of carbonaceous chondrites. The ratio between K and the heavier element uranium K/U is an important indicator of such depletion because U is a refractory element so that this ratio is expected to be largely preserved during the Moon-forming event.

On the Moon, the K/U ratio is about five times lower than that of the Earth and about twenty-five times lower than that of the CI chondrites. So far, the mechanism that caused this depletion is not well understood [1]. Some researchers think that volatile-element-depleted bodies such as the Moon should have been enriched in heavy potassium isotopes during the loss of volatiles. Because such enrichment was never found, hypotheses like high-angular-momentum giant impact scenarios, etc. are proposed [2]. However, outgassed elements like K during the magma ocean [1] phase may result in very efficient loss rates that do not separate between small mass differences [3]. We therefore study the depletion of K, its isotopes and other elements during the magma ocean phase after the Moon-forming events and investigate if these losses fractionate K isotopes or not. After the magma ocean solidified, the Moon was continuously bombarded by solar wind plasma and radiation, and by enhanced terrestrial outflow during its transitions through the magnetotail [4]. In the beginning, the CME occurrence rates and solar wind parameters (e.g., density, velocity) were much higher compared to that of today's Sun. We also estimate the loss of K during the past 4.5 billion years from the lunar surface by applying a surface sputtering model [5,6] during the Moon's orbit around the Earth. We also discuss the possible shielding effect of the Earth's magnetosphere. Finally, we discuss the relevance to measure the particle outflow from the Moon into space by a lunar orbiter or platform with dedicated instruments: plasma, magnetic field measurements, energetic neutral imager, and neutral particle detectors outside the spacecraft to continuously monitor the plasma and particle environment [see also 7].

2. Summary and Conclusions

We estimate the atmospheric loss and thus depletion of volatile elements with a focus on the radioactive heat-generating element K during and after the magma ocean phase of the Moon. This is important for reproducing the K/U ratio during the Moon's history. Understanding the K/U fraction will help to constrain the solar activity evolution of the young Sun and the thermal history of the Moon during the first 100 Myrs after its formation.

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