Analyzing Magnesium Isotopic Composition of Martian Meteorites with Inductively Coupled Plasma Mass Spectroscopy

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Introduction: Analyzing Magnesium isotopes in terrestrial and extra-terrestial samples help us change what we think about the formation and early history of the planets in the Solar System. According to recent studies on the isotopes in terrestrial rocks, the Earth and the moon have the same magnesium isotopic composition as chondrites[4]. But what about the magnesium isotopic composition of Mars? Does Mars have the same chondritic magnesium isotopic compositions as Earth?

There are three isotopes of magnesium of ^{24}Mg, ^{25}Mg, ^{26}Mg and they have an abundance of 78.99%, 10.00%, and 11.01%. They make useful tracers in the crust and meteorites because of their larger fractionations had been produced, which is why they are good for isotopic analysis[2]. The isotopes are separted and collected by the process of chromatography. Then the isotopes are analyzed in a machine called MC- ICP-MS (multi-collector inductively coupled plasma mass spectrometer).

Thirty-two samples of Martian meteorites, ten samples of basalt weathered soils from the Columbia Plateau, and olivine from Kileaua and seawater as standards. The compostion and structure of the terrestrial basalts and Martian meteorites are similar because they are mainly igneous[3]. The types of Martian meteorites I studied were shergottites, nakhites, and chassignites, which are also called SNCs[3]. Shergottites are basalts and enriched with iron. The compositions of nakhlites are mostly augites and are also enriched with light rare Earth elements[1]. The grains of chassignites are chromites, olivine, and augites, which are crystallized earlier than shergotites and nakhlites[1]. Based on the compositions of the Martian meteorites, the Martian crust is mainly made of basalts.

The formation of Mars was very differently because the core differentiated early than Earth, which would also cause early fractionation of volatile elements in the mantle[5]. The core would have also formed before the planet's formation was complete, which would cause the material in the mantle to be mixed with the meteors and asteroids bombarding the planet[1]. The composition of the Martian meteorites and crust and the early formations of the Martian core could make the planet have a higher amount of magnesium isotopes than the amount of isotopes on Earth.

Experimental: The magnesium isotopes are separated by the process of cation exchange chromatography. To prepare the separation, the samples must be ground up, dissolved in a solution mixed with HF-HNO_3 (3:1), evaporated to dryness, and then dissolved in 1 N HNO_3[4]. The columns are washed with 10 ml of MΩ water and 5 ml of 6N HCl. Then resin is used to fill the columns to separate magnesium from other elements in the samples which are then loaded into the columns. As the samples are loaded into the columns containing resin, the magnesium cuts are collected. This chemical process must be done twice in order to get pure magnesium.

Once the pure magnesium cuts are collected, they are evaporated to dryness, then dissolved in 1 N HNO_3 so they can be ready to be analyzed by the MC-ICP-MS. This machine has Faraday Cups, where the magnesium isotopes are placed and analyzed more than four times to get the precision of the ^{26}Mg/^{24}Mg ratio. The MC-ICP-MS can tolerated temperatures close to about 70 degress fahrenheit and low sensivity of movement. The weather has been so humid that the MC-ICP-MS is not working properly, so this data was from a previous project similar to this research. Later, the isotopes from the Martian meteorites will be analyzed later and would show similar results as the previous research.

Results:

Distance from the Sun	Planets and other Planetary Objects	d26Mg	2SD
1	Earth	-0.25	0.07
2	Moon	-0.25	0.07
3	Chondrites	-0.28	0.07
4	Mars	-0.25	0.07

Table 1: Amount of d26Mg on Earth, Mars, Moon, and Chondrites from the previous research.

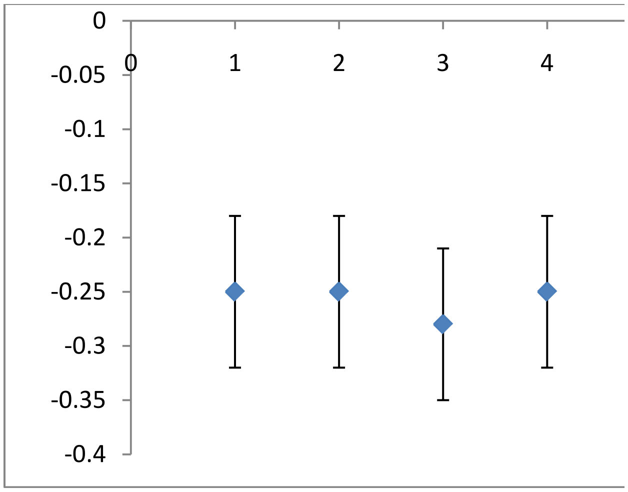

Figure 1: This graph shows the amount of d26Mg on Earth, Moon, Mars, and Chondrites from Table 1.

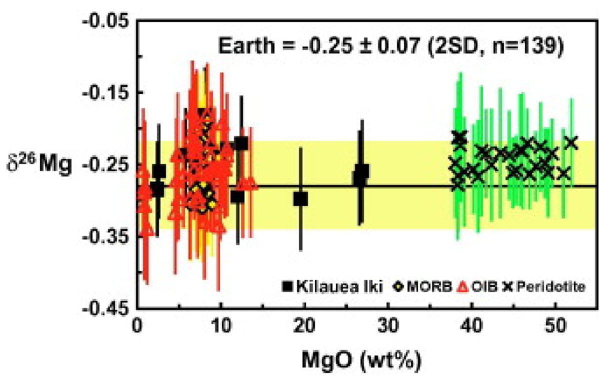

Figure 2: This graph shows the δ^{26}Mg vs MgO in all terrestrial samples and chondrites have the same average δ^{26}Mg of about -0.28. [4]

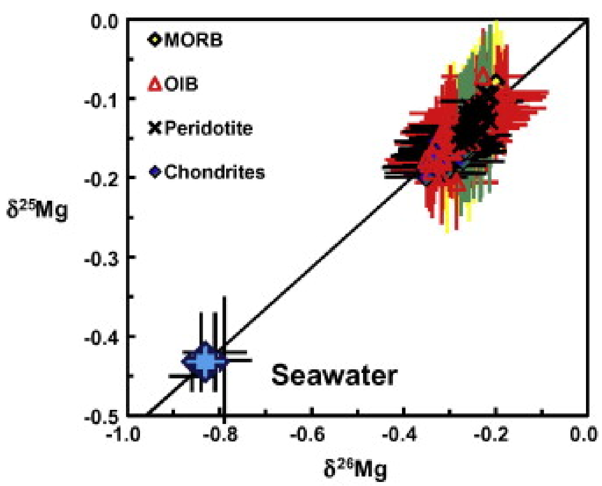

Figure 3: This graph shows all the samples including chondrites with a very précised value of the δ^{26}Mg/δ^{25}Mg ratio on a fractionation slope of 0.515. [4]

Conclusion: According to the previous research, Mars and Earth had the same Magnesium isotopic composition of -0.25 and the 2SD of 0.07 at table 1 and figure 1. This would tells us that the magnesium isotopes from the Martian meteorites that were extracted, collected, and later be analyzed would have the average d26Mg of -0.25 with a 2SD of 0.07.

Figure 2 has the terrestrial and chondrites with the similar average δ^{26}Mg based on the previous data. All of the samples on figure 3 have a précised ratios of δ^{26}Mg/δ^{25}Mg.

The surface of Mars is made up of mainly basalts because of it's early history of high volcanism. The Martian core has been formed and differentiated during the bombardment. Since it is closer to the Asteroid Belt, it would have been hit more than Earth. The astroids and meteorites that have bombarded the planet would have been mixed together with the Martian and alter the planet's composition.

Despite of the different structure and composition of the crust and mantle and the differentiation of the core, Mars surprisingly have the same magnesium isotopic composition as Earth and the Moon. The planet does have more magnesium than Earth, but the amount of isotopes are the same.

According to this research, Mars, Earth, and the Moon have the same Magnesium isotopic composition as the chondrites. This would tells that all the planets and moons in the Solar System have been made by the accretion of chondrites. This changes on what we think of the formation of the whole Solar System and possibly other star systems as well.

References: [1] McSween, Harry. (1994) *Meteoritics, 29*, 757-779. [2] Teng, F.-Z., et al. (2007) *Earth and Planetary Science Letters*, *261*, 84-92. [3] McSween, Harry et al. (2009) *Science*, *324*, 736-739. [4] Teng, F. –Z., et al. (2010) *Geochim. Cosmochim. Acta*, *74*, 4150-4166. [5] Marty, B., et al. (2002) *Earth and Planetary Science Letters, 196*, 251-263.

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