Measurement of isotope ratios at high mass resolution using a collision cell interfaced, multicollector ICPMS

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Collision cells are well known to be able to remove Argon and Argon molecular species from the mass spectrum produced from an ICP mass spectrometer. Measurements of for example Fe and Ca isotopes can be made at low mass resolution. High resolution mass scans at 3000 resolution confirm that the removal of Argon molecular species is almost 100%, with a combination of argon and hydrogen in the collision cell. The use of argon as a collisional gas results in a reduction in the ion energy (typically 6ev for a shielded torch), but also results in a narrow energy spread, which is the requirement for high mass resolution. The energy spread of ions which exit the cell is typically ~0.5ev. The addition of H_2 into the cell results in a further reduction in energy, (typically 1ev). The collision cell cannot be used to remove molecular species such as N_2 at mass 28, N_2H at mass 29, and NOH at mass 30, however sufficient resolution is produced by thermalisation that the Si isotopes ^{28}Si, ^{29}Si and ^{30}Si can be analysed free of interferences. Si isotopes can be fractionation corrected using an element of similar mass. Sulphur is a good candidate as the contribution of O_2^+ on ^{32}S can be minimised using a desolvation nebuliser, and completely mass resolved. Using $^{34}S/^{32}S$ the Si isotopes can be measured to precisions of 0.02%. In the case of high ionization potential ions e.g. Cl, the addition of H_2 into the cell removes the ^{36}ArH molecule from ^{37}Cl. A reaction occurs whereby Cl $+H_2$ results in the formation of ClH_2^+,this reaction is efficient producing approximately 5 times more ClH_2^+ than Cl.

Evidence for collisional erosion of the Earth

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Improved estimates of the chemical composition of the primitive upper mantle of the earth yield a MgO content of 36.33 ± 0.4 wt% [1]. The FeO content of the Earth’s mantle is well established at 8.10 ± 0.05 %[1]. Adding to this the Fe of the Earth’s core (85 wt%) gives a whole Earth Fe content of 31.52 wt%. Assuming a Mg-free core leads to a whole earth Fe/Mg ratio of 2.12, which is about 12 % above the CI-ratio 1.92 ± 0.08 [2], representative of the average solar system. Thus the Earth has about 10 wt% more Fe than the solar system. The Fe content of the core is about 85% assuming the traditional value of ~10 % for the light element inventory of the core. Recent estimates indicate a higher core density [3] leading to even higher whole earth Fe/Mg ratios and thus to a higher Fe excess. A basic and in our opinion well justified assumption is that the MgO and FeO contents of the upper mantle are representative of the bulk mantle.

The Earth makes up about 55 wt% of the inner planets. The other inner planets have similar Fe contents as Earth, except for mercury which has excess Fe. Thus there is no obvious low-Fe reservoir in the inner solar system that might be complementary to the Earth.

The growth of the Earth by accumulation of Moon- to Mars-sized embryos [4] could provide an explanation for the Fe-excess of the Earth. Presupposing the core had formed early large impacts would preferentially remove mantle silicates. Because the Earth is massive only relatively large impactors contributed to this loss of silicates. If core formation occurred simultaneously with Earth accretion, smaller impacts could have contributed to silicate removal. The present Fe excess can therefore be the integral results of many smaller impacts spread over the formation history of the Earth or, alternatively, the result of one or a few large collisions occurring late. An ultimate example of such a giant collision leading to a large loss of silicates has been proposed [5] to explain the anomalous density of Mercury. In this case, nearly 80% of the mantle is lost in a single event.

References

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