Copper isotope insights into planetary differentiation

University of St Andrews
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Key Words

Overview

It is of fundamental importance to understand how our planet evolved from a sphere of accreting dust and gas in the solar nebula, to the differentiated body, with a metallic core and silicate mantle, on which we live today. Knowing the chemical composition of Earth’s core would tell us the physiochemical conditions during its formation but direct sampling of the core is impossible. However, core formation also left its fingerprint on the chemical composition of Earth’s mantle [1].

Each element has a distinct geochemical affinity whereby it prefers to partition in the silicate (lithophile), metal (siderophile) or sulphide (chalophile) phase during equilibration [1]. By experimentally parametrising this partitioning behaviour, the concentration of elements in the Earth’s mantle can be used to infer pressure, temperature and oxygen fugacity during Earth’s differentiation. Isotopes of an element also are affected by phase equilibration, and can fractionate differently depending on which phases are equilibrating – if this fractionation is experimentally constrained, compositional information can be elucidated [2].

Copper is a multi-isotope element that has the potential to reveal important aspects of planetary differentiation. This is because it is both siderophile and chalcophile (around 2/3 of Earth’s Cu is thought to be in the core) so it is effected by core formation. A recent study showed that the Cu isotope composition of Earth’s mantle is fractionated from the bulk Earth (defined by meteorites) [3]. The study used a set of experiments to infer that the sense of isotope fractionation suggests that a discrete sulphide liquid separated from Earth’s mantle during its differentiation and entered the core. This work also placed a broad bound on the S content of Earth’s core, a topic that is still very contentious [4].

However, the application of Cu isotopes to high temperature problems is still in its infancy, and much is left to constrain. Importantly, the fractionation behaviour of Cu isotopes is still poorly understood, and a robust parametrisation of this process would have significance not only for planetary differentiation, but for future studies of continent formation and ore bodies.
Methodology

The main aim of this project is to investigate and parametrise the fractionation behaviour of Cu isotopes between metal, silicate and sulphide – with an ultimate goal of placing robust constraints on what the Cu isotope composition of the mantle is telling us about Earth’s differentiation. This will be accomplished by coupling an experimental study with analysis of natural samples.

The experiments will be performed in the high pressure/temperature experimental laboratories at the IPGP and St Andrews, wherein materials can be taken to pressures and temperatures relevant to that in Earth’s mantle. Sample characterisation will be made at the microprobe and mass spectrometer facilities at St Andrews. Isotope measurements will be made using high resolution multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS) at the facilities at St Andrews and Durham.

The Skaergaard Intrusion, Greenland is a natural laboratory for closed-system magmatic differentiation, and has been identified as an ideal locality to study the behaviour of Cu isotopes during formation of sulphides. These sulphides show a range of compositions and morphologies, allowing for the elemental and isotopic measurement of individual sulphides.

The insights from the above will be included into models of continuous core formation to predict core composition and the physiochemical conditions present during this event. The student may also have the opportunity to apply the results of their work to core formation on other planets, using meteorite analyses.

Timeline

Year 1: Literature review and compilation of existing Cu isotope data for mantle and meteorite (bulk Earth) samples; posting at IPGP for training in experimental petrology and initial experimental study; characterisation of experimental charges; training in and start of Cu isotope analysis (experiments); write and defend Year 1 Research Proposal. Year 2: Selection and characterisation of Skaergaard samples; continued Cu stable isotope analysis of all samples; begin stable isotope modelling of data. Further experiments, as needed. Prepare research for presentation/publication; attend Goldschmidt geochemistry conference. Year 3-3.5: Completion of isotope work and interpretation and modelling of data, writing up. Presentation of results at national/international conferences; complete thesis.

Training & Skills

- Training in experimental petrology techniques.
- Training in the measurement of Cu stable isotopes using high precision MC-ICP-MS at St Andrews and Durham, as well as routine elemental sample characterisation.
- Interpretation and modelling of isotope and elemental data to place new constraints on the core composition and planetary differentiation.
- Presentation of research at both national and international geochemistry conferences.

References & Further Reading


Further Information

For further information please contact Paul Savage (pss3@st-andrews.ac.uk) or Kevin Burton (k.w.burton@dur.ac.uk).