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High Temperature Equilibrium Sulphur Isotope Fractionation model between Melt and Sulphide from experiments using a 1-atm Gas-mixing Furnace

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Sulphur isotope fractionation factor is a critical parameter describing evolution of sulphur concentration and isotopes in a natural magmatic system. However, currently available values are tied to analogue systems and models. An effort has been made to establish a model for equilibrium sulphur isotope fractionation in a magma with sulphides, by conducting laboratory experiments. To this end, a new and safe gas-mixing furnace using the gas mixture CO-CO_2-SO_2 has been designed to simulate desired fO_2-fS_2 conditions at temperatures up to 1600 °C [1]. Experiments were carried out using ~Fo_{90} crystals as capsules with basalt powder and 99.99% Fe powder as the starting materials. A dominant proportion of sulphur in this system is acquired from the gas. Experiments were carried out under fO_2 conditions ranging from -8.5 to -11.1 (ΔQFM -0.65 to -3.27) and fS_2 conditions ranging from -1.1 to -1.8 at 1200 – 1400 °C. The samples were analysed for their major element compositions using an EPMA and $\delta^{34}S$ using a SIMS. Time-series experiments demonstrate that the system reaches equilibrium, both in terms of major element and sulphur isotope composition within 8 hours. From over 25 equilibrium experiments, each lasting 8 hours, the fractionation observed is significant and follows a trend, higher the fO_2 and lower the temperature, the larger the fractionation is. At 1300 °C, the fractionation ($\Delta^{34}S_{melt-sulphide}$) is as high as 4.36 ± 0.47 ‰ for a fO_2 of -9 (ΔQFM -1.79) and tends to 0 at a fO_2 of -10.71 (ΔQFM -3.49). This fractionation is significantly greater than what is predicted by analogue models [2]. Our experimentally determined equilibrium sulphur fractionation model could explain the evolution of $\delta^{34}S$ from -1 to +5.6 ‰ observed among the lower crustal cumulates of the Talkeetna arc [3], in which sulphide precipitation under oxidising conditions raises the $\delta^{34}S$ of the magma. Thus, $\delta^{34}S$ trends in cumulates may be an indicator of magmatic redox condition.

[1] Prabha Mohan et al., Eur. J. Mineral., in revision

[2] Marini et al. 2011, Rev. Mineral. Geochem., 73, 423–492

[3] Rezeau et al., 2023, Chem. Geol., 619, 121325