Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 474

MC-ICPMS - The Good, the Small and the Massive

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The Nu Instruments "Nu Plasma" (Belshaw et al., 1998) is an extremely reliable and accurate high sensitivity multiple collector inductively coupled plasma mass spectrometer. Like other recent MC-ICPMS instruments (Halliday et al., 2000) it has a laminated magnet allowing one to scan the mass spectrum rapidly. However, it is to be distinguished by very modern and stable electronics, excellent vacuum and a novel zoom lens for varying the dispersion, providing a simple and rigorous test on peak flat and relative collector efficiency. At ETH we currently measure $^{92}Zr/^{90}Zr$ with a routine external 2σ reproducibility of ±30 ppm. Similar reproducibilities are obtained for W and Mo. The absolute values obtained are in excellent agreement with accepted values independent of which collectors are deployed. The most demanding test on accuracy is for Nd for which the composition is very well established but the zooming required is maximized. Our data for all isotopes are very close to accepted values. At the time of writing the sensitivity of the ETH Nu Plasma is 2.3×10^{-9} A ppm^{-1} of Pb using an uptake rate of 40 µl s^{-1} (approaching 1% ions detected per atom used). Even higher values are anticipated with further development. The excellent relative peak flats (within 15 ppm relative to the axial), abundance sensitivity (<5 ppm for U), and stability of the electronics, allow us to achieve a routine long-term (> 1 month) external 2σ reproducibility for $^{207}Pb/^{206}Pb$ of ±11 ppm using $^{208}Pb/^{206}Pb$ and ±18 ppm using $^{205}Tl/^{203}Tl$, in both cases deploying exponential fractionation laws. The isotopic ratios show no dependence on Tl/Pb, so far tested through a range of values from 1 to 20. This outstanding performance renders the basic design of the Nu Plasma ideal from the point of view of developing a larger geometry instrument that can achieve high sensitivity, accuracy and reproducibility at high mass resolution, something that is currently beyond the reach of a standard-sized mass spectrometer. A vast array of spectral interferences can be generated from a typical solution at masses of < 80 (e.g. Reed et al., 1994). The problem is ameliorated by using separated elements and a dry plasma. So high precision isotopic analyses of light elements can be made with a regular (R=400) MC-ICPMS such as the P54 (Maréchal et al., 1999, Anbar et al., 2000) or Nu Plasma (Zhu et al., 2000) given adequate precautions. However, it is easy to generate apparent isotopic anomalies with small interferences. The standard procedure for checking the integrity of a result - extensive replication, is not an easy option when analysing extra-terrestrial materials or conducting *in situ* measurements for example. To measure Mg isotopes without interferences the highest mass resolution (R, 10% valley definition) needed is ~1,600 for $^{12}C_2$. One might need to check for $^{48}Ca^{++}$ which requires a mass resolution of <2,800 at 24. The highest R needed for Cr is 3,000 for $^{32}S^{18}O$ on mass 50. Other interferences can be resolved with a mass resolution of <2,400. For Ni the highest R needed is <3,300 for $^{29}Si_2$ on 58. Another interference can be found at mass 60 (^{44}CaO) requiring a resolution of <3,100. One might also need to measure ^{56}Fe (which requires R ~ 2,500) for the Fe/Ni ratio and correction of ^{58}Fe on ^{58}Ni. Although standard-sized MC-ICPMS instruments have the capability to measure at high mass resolution (Halliday et al., 2000), it is at the expense of transmission and/or peak shape. Given that the major rationale for MC-ICPMS is highly accurate isotopic data for elements for which sensitivity is poor by alternative methods, this approach is self-defeating. Accurate isotopic ratio measurements can be better accomplished with a new large double focussing instrument being designed and built by Nu Instruments. The Nu Plasma 1700 uses a single 750 mm radius, 70 magnet, combined with a 943 mm radius 70 ESA to provide double focusing. The dispersion is increased with an asymmetric arrangement of the magnet. Image demagnification is deployed to further increase resolution. A magnetic hexapole before the ESA reduces aberrations. As with the Nu Plasma, electrostatic quadrupole lenses are used to accomplish zooming after the magnet. The instrument has a fixed array of 10 Faraday collectors (plus some interspersed ion counting electron multipliers), with adjustable slits placed in front. Outside of the fixed array, three adjustable Faraday collectors to both the low and the high mass side provide the instrument with the ability to measure at high resolution simultaneously across a ΔM/M of 16% with a peak flat of 80 ppm. The mass resolution will be > 2,500 on the axial collector and 1,600 on the wings, with apertures fully open. At a mass resolution of ~5,000 the transmission would be reduced by no more than a third.

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