BEHAVIOUR OF CHLORINE AND ARGON DURING IMPACT MELTING OF ORDINARY CHONDRITES. B. E. Farrant, G. Holland, R. H. Jones and P. L. Clay, University of Manchester, United Kingdom (Email: Benjamin.farrant@manchester.ac.uk).

Introduction: The presence of vesiculation within chondritic impact melt implies volatile redistribution during melting [1]. We are carrying out a study to attempt to quantify the extent and nature of volatile redistribution resulting from impact melting, focusing on the behavior of the noble gases and halogens in both unmelted host (OC) and impact melted (IM) fractions of ordinary chondrites. We will be considering the behavior of volatiles in relation to the petrology and chemistry of the OC and IM fractions. We are also carrying out ^{40}Ar-^{39}Ar dating on the two fractions to determine if differences in volatile budgets could be explained by examining determined ages and produced Ar release spectra for the separate fractions.

Here we report preliminary Cl abundances and Ar concentrations from the OC and IM fractions of Chelyabinsk (LL5) and Chico (L6). Although the halogen and noble gas budgets of both meteorites were reported previously [2,3], our goal is to directly compare the OC and IM fractions, and to understand the relative distributions of noble gases and halogens in these two chondrites as well as within a broader suite of OCs.

Methods: For noble gas and halogen analyses, samples of OC or IM weighing 5 - 12 mg were sectioned well away from fusion crust. Noble gas concentrations were determined through step heating with a 75 W diode laser to full fusion, followed by sample gas analysis using the Thermo Scientific Helix MC^{TM} noble gas mass spectrometer. The neutron irradiation noble gas mass spectrometric technique (NINGMS) [4] was used to determine the halogen content of samples. Samples were heated with a 55 W CO_2 laser using a step-heating program of between 13-15 steps for each sample, up to ~21 W laser power to ensure samples reached full fusion and all gas was released. Sample gas was analyzed using the Thermo Scientific Argus VI^{TM} noble gas mass spectrometer. Determining Cl abundances then involved employing the technique outlined in [5]. The Cl abundances in each sample step were summed and any value where the ^{40}Ar/^{36}Ar ratio resembled air was excluded.

Results: Table 1 shows analyses of the Cl content of OC and IM fractions of Chelyabinsk and Chico. These lie within reported literature values for equilibrated ordinary chondrites [5,6]. The OC fraction of Chelyabinsk has around two thirds the amount of Cl of the IM fraction. However, in Chico the OC fraction contains over triple the Cl abundance of the IM. Chelyabinsk has a far higher percentage of ^{38}Ar produced from Cl than Chico (Table 1) meaning Chico has a higher component of trapped (up to 14%) and cosmogenic (up to 50%) components than Chelyabinsk. In both meteorites, however, the Cl-derived ^{38}Ar makes up a larger fraction of the release from the OC fraction than it does from the IM fraction. In both meteorites, the IM fraction has at least double the concentration of total Ar than the OC fraction (Table 1).

Sample	IM/ OC	Cl (ppm)	±	^{38}Ar (%)	Total Ar (10^{-6} cc/g)	±
Chelya-binsk	OC	57.7	2.7	98	2.25	0.01
	IM	88.5	3.8	97	14.44	0.05
Chico	OC	154.8	5.8	45	8.10	0.02
	IM	46.6	1.9	39	18.69	0.04

Table 1. Total Cl and Ar budgets of Chelyabinsk and Chico. Cl content and Cl-derived ^{38}Ar release are from irradiated OC and IM fractions, and total Ar concentration is from unirradiated fractions.

Fig. 1 shows the step heating Cl-derived ^{38}Ar release spectra from Chelyabinsk and Chico. The IM fraction of Chelyabinsk increases steadily, reaches a maximum release at ~10 W laser power, then decreases to the point of full fusion. The OC fraction of Chelyabinsk also shows the main release at ~10 W laser power. However, it appears that OC has a lower abundance of the lower temperature component released between ~4 and 7 W laser power. The OC fraction also shows a decrease from peak release to fusion.

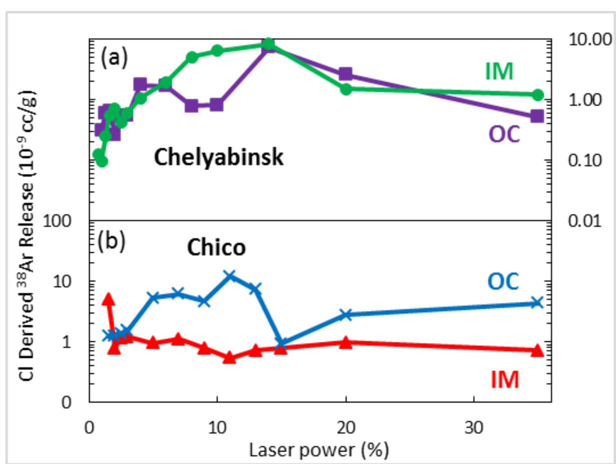

Fig. 1. Cl-derived ^{38}Ar release spectra for OC & IM fractions of (a) Chelyabinsk and (b) Chico.

The OC fraction of Chico has a peak release at 8 W laser power and an elevated release pattern at steps of 4 – 10 W, where the majority of the Cl is released. Following this, a further increase occurs to fusion. The IM fraction has a relatively high release in the first step and then a steady release pattern with no suggestion of the elevated release at ~4 – 10 W laser power indicated by the OC fraction. There is also no increase in release at >10 W laser power as the spectrum remains constant to fusion.

Discussion: Because of the presence of vesiculation within both the Chico and Chelyabinsk IM fractions [2,3], we might expect the IM to be depleted in volatile contents compared to the OC fraction. For Cl, we see this relationship in Chico, but Chelyabinsk shows the opposite relationship. A possible interpretation for this could be the difference in metallographic cooling rates and volumes of melt within the two chondrites. The Chico meteorite is 60 vol% IM which is hypothesized to have formed in a melt region ~0.1 – 1 km thick with a slow cooling rate of ~0.1 ˚C/yr through 500 – 700 ˚C [3]. Conversely, the Chelyabinsk IM typically occurs as discrete veins or pockets, is hypothesized to have formed as a small intrusion, and cooled rapidly at $5x10^6$ ˚C/yr [2]. Therefore, in Chelyabinsk the less abundant microcrystalline IM was essentially quenched [2], potentially trapping volatiles, whereas in Chico, the voluminous melt would have persisted over a longer time, allowing for the diffusion of volatiles such as Cl. The large volume of the Chico IM and consequently large diffusion path length [7] could be the reason it has retained any Cl at all, given its slow cooling rate and therefore a long time in which volatiles could diffuse out.

In addition to differences in overall chlorine abundances, IM and OC in both meteorites differ in their release profiles (Fig. 1). This is likely attributable to differences in petrology, which we are currently investigating. The presence or absence of lower and higher temperature Cl components could be indicating the loss or retention of Cl-hosting phases in IM. This can only be determined through extensive petrologic examination of the IM and OC fractions of both meteorites.

The total Ar concentrations of the meteorites are also possibly affected by all of the reasons outlined above. Both meteorites have higher Ar concentrations in the IM fraction. Therefore, in Chico the Cl and Ar signatures are decoupled. This could indicate that different volatiles are affected differently by the impact melting process. Alternatively, there could have been modification of the Ar budget of either fraction after the IM forming event through, for example, interaction with cosmic rays or the occurrence of impacts which postdate the IM forming event. The decoupling in Chico and coupling in Chelyabinsk could also be an effect of the IM forming event upon the petrology of the meteorites [2,3]. The Chico IM forming event is hypothesized to be large, resulting in the breakup of the L-chondrite parent body at ~500 Ma and almost completely resetting the ^{40}Ar-^{39}Ar chronometer [3]. Conversely, Chelyabinsk's impact history is punctuated by many small events which were not large to enough to reset the chronometer [2]. Therefore, it might be that the differing magnitude of impacts and consequent shock caused the Chico OC fraction to lose more of a Cl-hosting phase than the Chelyabinsk OC fraction. At this stage we do not know whether this decoupling trend holds for the remainder of the noble gases (He, Ne, Kr & Xe), or the heavy halogens (Br & I) within these two meteorites. We have measured these elements and are currently in the process of reducing the data.

Conclusion: Chelyabinsk and Chico contain different halogen abundances and noble gas concentrations and also display different relationships between their OC and IM fractions. This could be due to the IM's of Chelyabinsk and Chico having very different cooling rates which are related to the volume of melt that was produced in the impact event [2,3]. It could also be affected by the petrography and impact histories of the two meteorites. These factors will be investigated further by examining a selection of ordinary chondrites for their complete noble gas and halogen budgets, petrology, and impact history. This information should allow for conclusions to be drawn about differences in the volatile content of the OC and IM fractions of ordinary chondrites, and shed light on impact-related volatile redistribution on chondritic parent bodies.

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