

THE EVOLUTION OF THE EH4 CHONDRITE INDARCH AT HIGH PRESSURE AND TEMPERATURE: THE FIRST EXPERIMENTAL RESULTS.

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Introduction: Chondrite groups are characterized by variations in bulk composition and oxidation state, illustrating in part heterogeneity in the early solar nebula. Planetary accretion could be explained by at least two different scenarios: the homogeneous [1] and heterogeneous accretion models [2, 3]. In particular, for the formation of the Earth, some studies (e.g. [2, 3]) assume that one component is highly reduced material comparable to enstatite chondrites, devoid of volatile elements but containing all other elements in C1 abundance ratios. To derive constraints on the understanding of early differentiation processes, studies of the silicate phase relations and their interactions with metal, at relevant P-T-fO₂, are required. Melting relations and equilibrium partitioning behaviour have been studied on peridotitic and chondritic starting compositions at pressures and temperatures corresponding to the transition zone and lower mantle [4, 5, 6]. However, enstatite chondrites, which are highly reduced primitive meteorites, have not yet been studied experimentally under such conditions. Thus, multi-anvil experiments have been performed at 20-25 GPa and 2000-2400°C on the EH4 chondrite Indarch.

Experimental and analytical methods: The starting material, natural powdered Indarch, was doped at the 0.1 wt % maximum level with a selection of different trace elements in order to extract trace element partitioning data. The multi-anvil experiments were carried out in a 1200-ton press at the Bayerisches Geoinstitut, Bayreuth (Germany) under the European facility. Details of these experimental procedures are given by [7]. Samples were analyzed with a Scanning Electron Microscope (SEM) equipped with an energy-dispersive X-ray analyzer (EDX). A CAMECA SX electron probe microanalyzer (EPMA), equipped with wavelength dispersive X-ray spectrometer (WDX) was also used to analyze the samples.

Results: The silicate material in the run products is mostly majoritic garnet or perovskite, plus a silicate liquid (Table 1). The oxygen fugacity of each experiment has been calculated relative to the iron-wüstite (IW) buffer. An ideal behavior of FeO in the solid silicate phase was assumed in the calculation and the activity of Fe in the metallic phase was extrapolated from the model given by [8]. Despite the effort to maintain the very reducing conditions

prevailing during Indarch formation ($\Delta IW \sim -5.9$ [9]), the results have shown that all the samples have been oxidized during the experiments since the redox conditions range between 2.1 and 2.7 log units below the IW buffer. Quenched melt textures have been characterized in the metallic phases as already observed in previous studies with Fe-S phases [10]. EPMA analyses revealed the same mean global compositions for the metallic phase, for the silicate liquids, and a homogeneous solid silicate composition, suggesting that the run durations were sufficient to achieve chemical equilibrium. The evolution of the partition coefficients (wt% in solid silicate/wt% in silicate liquid) with pressure and temperature for Cr between solid silicate (majorite or perovskite) and silicate liquid are presented in Fig. 1 and compared to previous studies.

Discussion: Our first Cr results are in good agreement with previous studies (Fig. 1). Thus, the major parameters controlling these partition coefficients are certainly not the redox conditions, or the liquid compositions. The garnet-silicate liquid partition coefficients decrease very weakly with increasing pressure (Fig. 1 (a)) and the performance of more experiments at these pressure conditions could confirm that behavior. The perovskite-silicate liquid partition coefficients do not show evidence of pressure dependence (Fig. 1 (b)). Within the pressure range 20-26 GPa, $D^{Cr}_{pv/sl} = 1.05 \pm 0.45$. Furthermore, Fig. 1 (c) and (d) reveal the absence of temperature effect on both majoritic garnet-silicate liquid and perovskite-silicate liquid partition coefficients for Cr. The results of the present study allow a determination of the preliminary P-T phase diagram of Indarch compared to the ones of the Allende meteorite and peridotite (Fig. 2). This illustrates the first high pressure and high temperature melting relations of the EH chondrite, already done at atmospheric pressure by [9]. According to Fig. 2, the liquidus of Indarch is below the one of Allende at atmospheric pressure. However, at pressures higher than 20 GPa, the liquidus of Indarch must be attained for temperatures much higher than 2000-2400°C. The Table 1 illustrates as well that the high pressure peridotite, Allende and Indarch silicate liquids are much closer in MgO/SiO₂ than are the values of the bulk silicates, an observation already made by [5]. These comparisons as well as the further study of the

elemental partitioning behavior between the metallic and silicate phases should allow to obtain some new insights regarding the understanding of early planetary differentiation processes.

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Wt %	Indarch	Indarch	Allende	Allende	KLB-1	KLB-1
	BS	SL	BS	SL	BS	SL
SiO ₂	61.26	47.12	36.63	38.55	44.48	45.55
TiO ₂	0.10	0.15	0.16	0.12	0.16	0.12
Al ₂ O ₃	2.52	1.07	3.50	4.01	3.59	3.50
Cr ₂ O ₃	0.82	0.43	0.56	0.55	0.31	0.38
FeO	0.00	15.46	29.06	23.90	8.1	9.04
MgO	30.37	28.48	26.35	29.76	39.22	36.63
MnO	0.43	0.42	0.19	0.20	0.12	0.14
CaO	1.65	4.05	2.79	2.42	3.44	3.26
NiO	0.00	0.05		0.15	0.25	0.21
CoO	0.00	0.00		0.03		
Na ₂ O	1.75	1.50	0.48	0.39	0.30	0.33
K ₂ O	0.19		0.03	0.01	0.02	
P ₂ O ₅	0.90		0.25	0.27		
Total	100.00	98.73	100.00	100.36	99.99	99.16
Mg#	1.00	0.77	0.62	0.69	0.90	0.88
MgO/SiO ₂	0.74	0.90	1.07	1.15	1.31	1.20

Table 1: Chemical composition of silicate Indarch [BS:15,SL:this study], Allende[BS:11,SL:5] and peridotite KLB-1[BS:4,SL:12]. (BS:bulk silicate, SL:silicate liquid)

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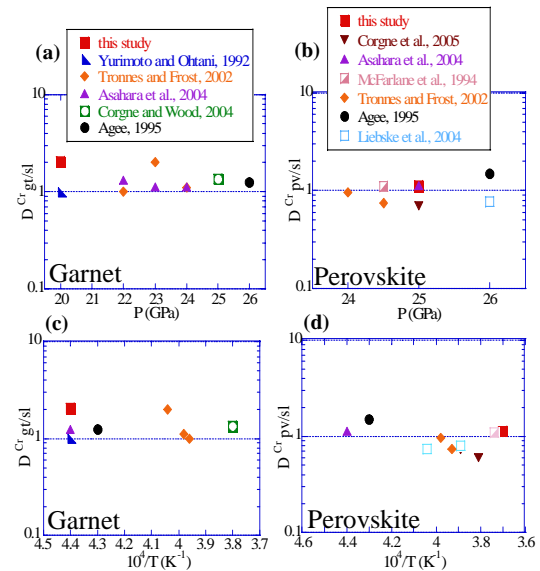


Fig. 1: Summary of experimental results of this study for Cr and previous work. (a) The $D^{Cr}_{gt/sl}$ between garnet (gt) and silicate liquid (sl) are plotted vs P. (b) The $D^{Cr}_{pv/sl}$ between perovskite (pv) and sl are plotted vs P. (c) The $D^{Cr}_{gt/sl}$ between gt and sl are plotted vs T. (d) The $D^{Cr}_{pv/sl}$ between pv and sl are plotted vs T.

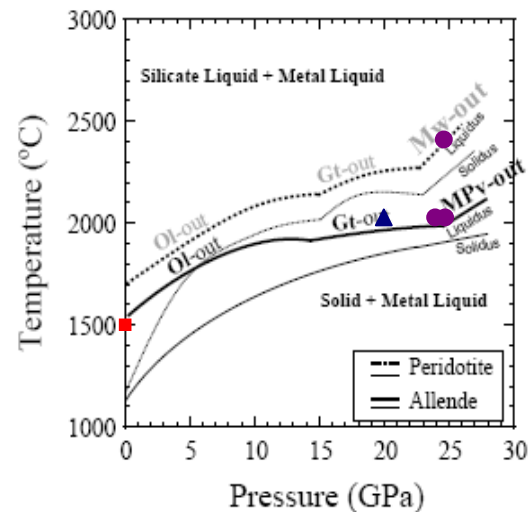


Fig.2: P-T phase diagram of the Allende meteorite and peridotite and first results of the present study. Liquidus and solidus of the Allende CV3 chondrite from 0 to 20 GPa are from [5] and those above 20 GPa are from [13]. Liquidus and solidus of peridotite from 5 to 20 GPa are from [12] and those above 20 GPa are from [14]. ■ [9] sl, ● [this study] sl+pv, ▲ [this study] sl+gt.