Constraints on Mars’ core composition from a combined geochemical and mineral-physics approach


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InSight: geophysical and geodetical constraints on Mars’ core

- **RISE (MGA)**
- **SEIS (WTS)**

Instrument Electronics – Inside S/C
Pressure Sensor – Inside S/C
Radiometer – Other side of S/C
Calibration Target – Other side of deck
LaRRI (Laser Retroreflector) – Other side of deck
Core composition from combined min-φ and geo-χ

FIND CORE FORMATION SCENARIOS CONSISTENT WITH MANTLE GEOCHEMISTRY

CALCULATE THE PARTITIONING OF ELEMENTS BETWEEN MANTLE AND CORE

CONSTRAIN THE PARTITIONING OF Si, S, O BETWEEN MANTLE AND CORE

CONSTRAIN CORE RADIUS AND THERMAL STATE

COMPOSITION OF THE CORE

MODEL PROPERTIES AND COMPARE WITH GEODETIC OBSERVATIONS

ESTIMATE DENSITY OF THE CORE
Depletion of siderophile elements: Imprint of core formation

Ni and Co as tracer of P and T (i.e. magma ocean depth)

Cr as tracer of silicate composition (i.e. magma ocean composition)

Nb/Ta as tracer of silicate & metal composition (i.e. core composition)
Metal-silicate partitioning experiments

Experiments in piston-cylinder press, multi-anvil apparatus and laser-heated DAC + chemical analysis of recovered samples

- Partitioning coefficients over large P-T range
- Exchange coefficients as a function of P, T and X
- Final equilibration depth 0 to 25 GPa (0 to 2080 km depth)
- Temperature between mantle solidus and liquidus
- Varying magma ocean composition, final FeO concentration given by mantle composition
Ni, Co → final equilibration depth > 14 GPa
Cr, Nb/Ta → constant FeO concentration, high T
→ No significant Si in the core, some O (0.5-1 wt.%), agreement with Brennan 2019 but not as much as predicted by single-stage models (Steenstra 2018, Tsuno 2011)
Interaction between elements

![Graph showing the interaction between oxygen and sulfur concentrations.](image1)

![Graph showing the weight fraction of oxygen as a function of core radius for different Fe-O compositions.](image2)
Core differentiation models with 7 wt.% sulfur

S in the core increase O significantly: 7 wt.% S $\rightarrow$ 2-3 wt.% O
Core differentiation models with 12 wt.% sulfur

$s$ in the core increase $O$ significantly: 12 wt.% $S$ $\rightarrow$ 4-6 wt.% $O$
XRD experiments on liquid Fe-S alloys at high pressure and high temperature
6 GPa < P < 14 GPa; 1200 K < T < 2500 K; 0 wt.% < S < 25 wt.%

Density vs. P → compressibility

Density vs. T → thermal expansion

7 GPa and 1800 K

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Xu et al., in prep.
Liquid Fe-S data set

density: Morard 2013; Morard 2018; Xu in prep.
velocities: Nishida 2017; Kawaguchi 2017
- both density and velocity data accurately described by non-ideal solution model with pressure-dependent excess volume
- Liquid FeS end-member EoS and excess volume from the data
- Liquid Fe end-member EoS from Komabayashi 2018
Core compositions matching geodesy constraints
Different compositional models

14.7 wt.% FeO in BSM (Yoshizaki 2019)
18.1 wt.% FeO in BSM (Taylor 2013)
• Model core composition of Mars while matching the geochemistry of the Martian mantle (Ni, Co, Cr, Nb/Ta, W)

• Accreting with low FeO content not consistent with Cr abundances

• Mars’ core cannot contain Si (< 0.2%)

• Core is too dense if S not present (Si and O not sufficient)

• S in the core increases O significantly:
  • 7 wt% increases O from 1 to 3 wt%
  • 12 wt% increases O to 6-7 wt%

• HP-HT experiments on liquid Fe-S, Fe-O and Fe-S-O alloys to build a reference data set (thermo-elasticity and melting)

• Thermodynamic models accounting for data

→ Ready once constraints on Mars’ core radius will come from InSight
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