The Origins of Volatiles in Habitable Planets: The Solar System and Beyond

Session 4: Differentiation and Outgassing

(Andrew Jephcoat
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Terrestrial Context: Materials & Experiments

- Core formation trades off with "volatility".
- e.g., "Evaporating Planetesimals", (Ed Young, N&V, Nature 2017)
- Long-lived "hidden" Terrestrial Reservoirs
- Volatile Sequestration: "Missing Xenon"

Some inferences on early Earth: Rare gases

Rare gases were acquired from solar nebula and then lost again.
Mechanisms are still unclear.

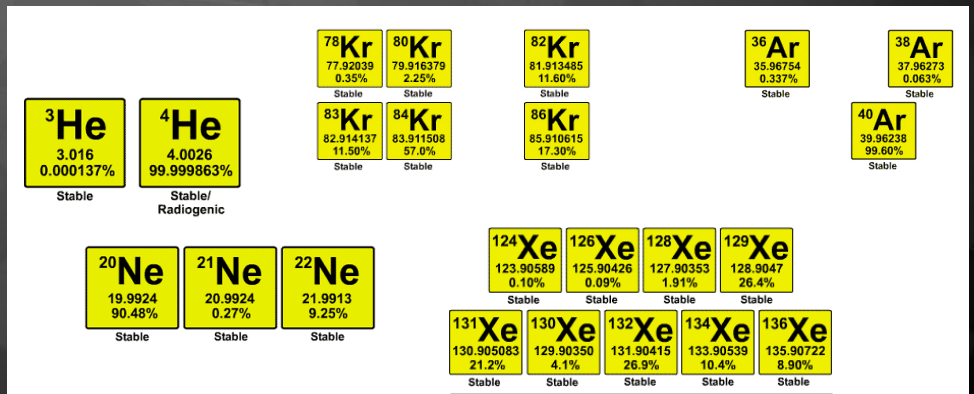
At least one deep mantle (or core) reservoir exists rich in ^{3}He trapped early as Earth formed.

Supported by features in Ne, Xe isotope systematics.
Where/how?

Xe isotope proportions indicate a massive loss of atmosphere occurred with mantle degassing, >97% gas loss occurred 100 Ma after Earth formation

Question: How could early Earth store 10^{2} greater gas content than now?

(Porcelli, Woolum, Cassen, 2001.)



Late-stage Impacts, Moon Formation

- 30-100 MYr after Earth formation.
- Whole-planet melting debated, but collisions likely partially melted surface.
- Initial surface cooling in 5-10 Ma
- → Serial Magma Ocean phases, punctuated by mantle cumulate formation partitioning of volatiles, and dense atmosphere formation (>100 bar). Elkins-Tanton (2012)

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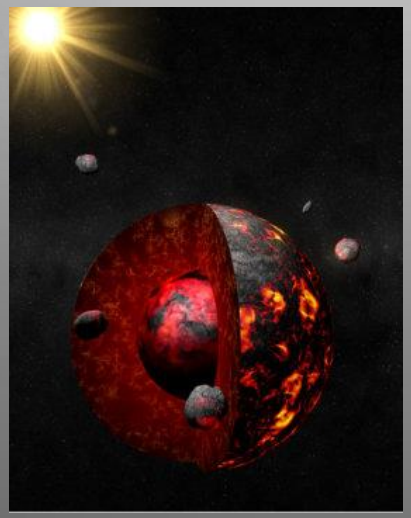
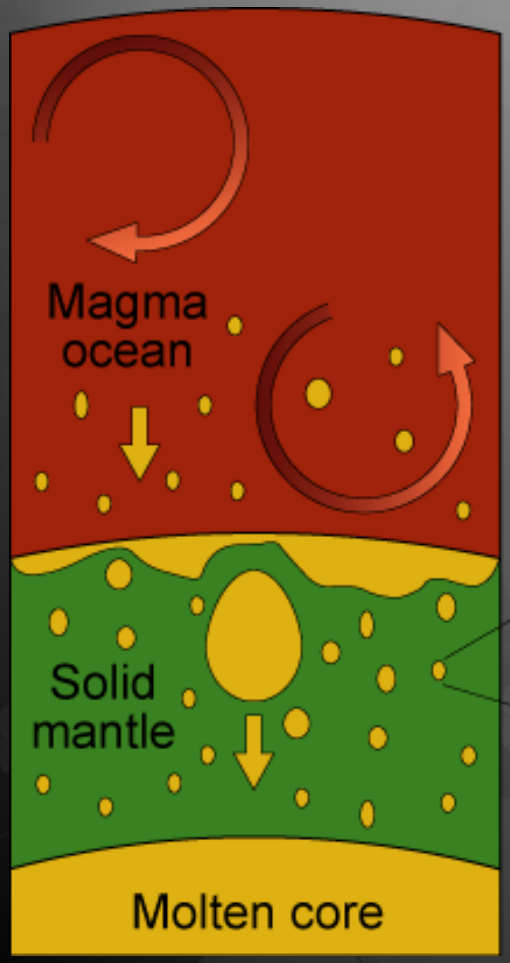
Planetary In-Gassing ⇨ Earth/Super Earth Degassing

Early, dense Atmosphere





^3He, H_2, H_2O, Ne+

Deep interior transport

The disk

H_2-rich atmosphere

$H_2 \rightarrow H_2O$

Magma ocean

O

Ikoma & Genda (2006)