What is the Noble gas composition and inventory in Venus interior?

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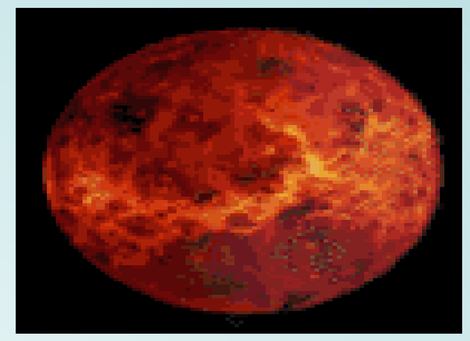


Venus

Introduction:

Terrestrial planetary objects (Mercury, Venus, Earth, Mars and asteroid Vesta) are all differentiated and have three-layer structure: a metallic core, a silicate shell (mantle and crust). They are believed to have formed by the accretion of early solarsytem objects that are represented by chondrites, but the proportionate of chondrites vary in terrestrial planets.

The size and geological activity differs in these terrestrial objects. Trapped noble gases serve as benchmarks in study of atmosphere and interior components of terrestrial objects. The geological history of Venus is the most unknown among the terrestrial planets, preventing a full understanding of the processes that led to its current state. As very few data exist regarding venus atmosphere, the isotopic composition 40/36Ar is 1.03 ,for mars(meteorites) is 1615 and Earth is 295.The noble gas data of atmosphere of these planets differs. Due to unavailability of the sample from the interior of the Venus, we don't know much about the Venus interior. So, we have studied trapped noble gases in a parent body vesta which is also differentiated and have samples from interior.

Scientific Objectives-

- To understand the differences and similarities of the terrestrial planets: genesis
- To understand the inventory of noble gases in the mantle of Venus.

Time scale involved

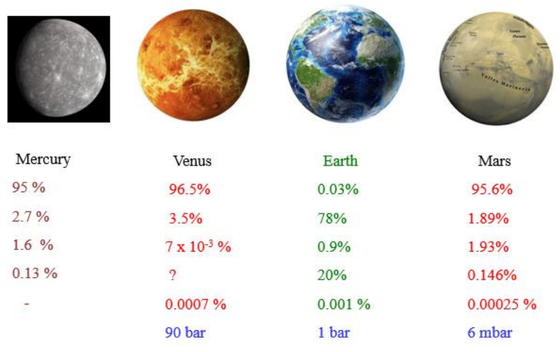
>4.567 Ga : before nebula /nebular gas
4.567 Ga : formation of solar system/ accretion of planets
4.567 to 4.50 :heating /melting/ differentiation/ impacts...
4.4 to 3.7: intense heavy bombardment in inner solar system objects
3.7 to present day

Noble Gases

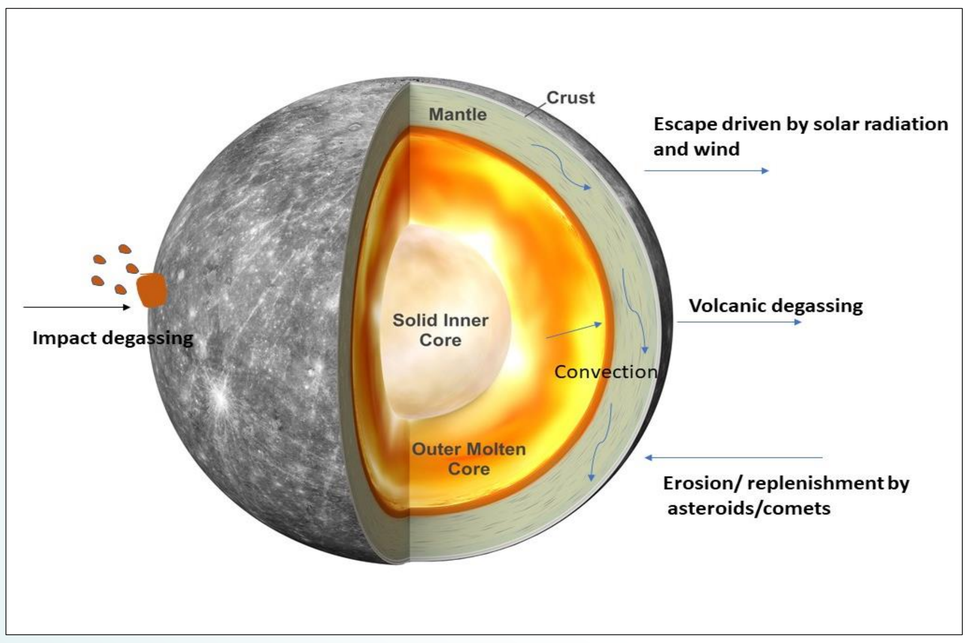
Helium : 2
Neon : 3
Argon : 3
Krypton : 6
Xenon : 9

Rare : very low abundances in rocks
Inert : no chemical reaction
Highly Volatile in nature

Atmosphere of inner solar system planets



	Mercury	Venus	Earth	Mars
Carbon Dioxide:	95 %	96.5%	0.03%	95.6%
Nitrogen:	2.7 %	3.5%	78%	1.89%
Argon	1.6 %	7 x 10^{-3} %	0.9%	1.93%
Oxygen	0.13 %	?	20%	0.146%
Neon	-	0.0007 %	0.001 %	0.00025 %
Pressure		90 bar	1 bar	6 mbar



Changing Interior

Differentiation: early solar system event
Volcanism: Earth [4.5 Ga to till date], Mars [4.5 Ga to 180 Ma].

Changing Surface

Geological Activity
Large Impacts : 4.4 Ga to 3.8 Ga
Smaller impacts 3.8 Ga to till date

Changing Atmosphere

- Impacts : asteroids, comets : both remove and replenish atmospheric species
- Sputtering : gas atoms in upper atmosphere are ionized, pickup by magnetic fields of SW, re-impact on upper atmosphere and sputter away atoms and molecules. e.g. sputtering by oxygen (O-) ions , loss
- Photochemical escape : various photochemical processes, e.g. nitrogen and carbon, loss
- Volcanic degassing : based on geologic history of planet , replenishment
- Ablation of meteorites in atmosphere, gas deposition
- Interplanetary dust particle, gas deposition

fig.1(a)

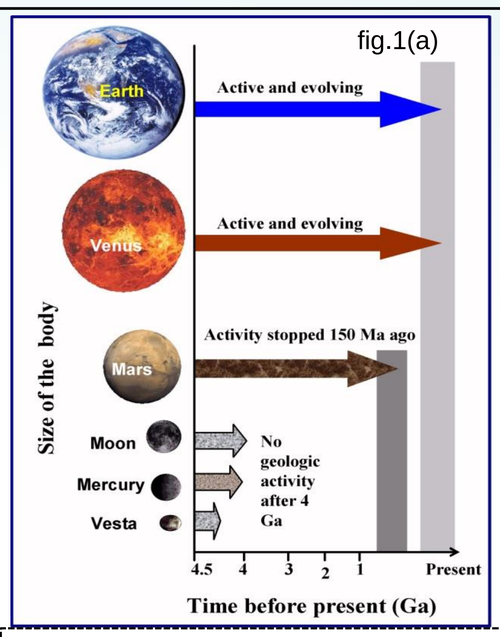


fig.1(b)

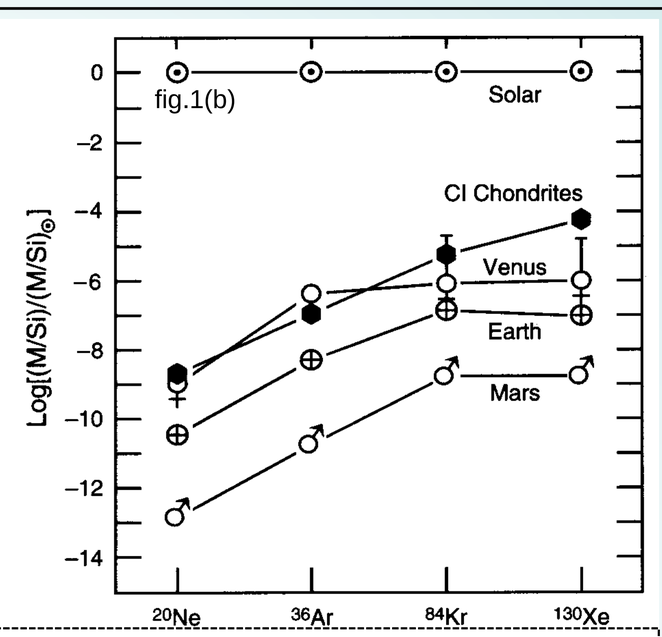


Fig.1(a Geological activity of inner solar system objects Fig.1(b) Noble gases in terrestrial planets(Vogt 2019)

Isotopic ratios

fig.2(a)

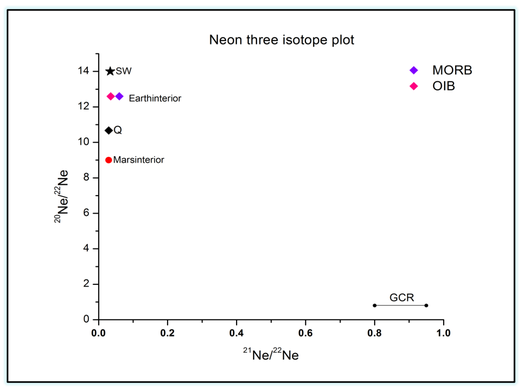
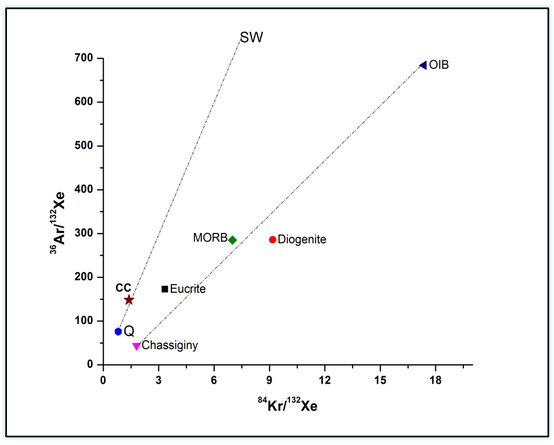


fig.2(b)

Venus			
Isotopic ratio	Diagnostics	Venus Atmosphere	Earth's Atmosphere
$^{3}He/^{4}He$	Impact of solar wind (interior outgasing)	Not measured Expected 3 x 10^{-4}	1.4 x 10^{-6}
$^{20}Ne/^{22}Ne$	Hydrodynamic escape / impact of solar wind	[1]14.3 [2]11.7 & 11.9	9.8
$^{21}Ne/^{22}Ne$		Not measured Expected < 0.067	0.029
$^{40}Ar/^{36}Ar$	Interior outgasing	1.03	295
$^{38}Ar/^{36}Ar$		0.18 ± 0.02	0.187
Kr		Not measured	
Xe	(large atmospheric blow-off)	Not measured	

Fig.2(a) Neon three isotope plot of interior components of planets. Fig.2(b) Atmosphere isotopic ratios of Venus and Earth

Elemental ratios



Component (cc STP/g)	^{20}Ne	^{36}Ar	^{84}Kr	^{132}Xe	References
Carbonaceous Chondrites	37.63 x10^{-8}	6.82x10^{-07}	0.64x10^{-8}	0.46x10^{-08}	Mazor et al., 1970
Chassiginy (Mars)	0.77x10^{-9}	2.02x10^{-09}	8.27x10^{-11}	4.6x10^{-11}	Mathew and Marti 2001
MORB(Earth)	0.48x10^{-9}	0.57x10^{-09}	14x10^{-12}	2x10^{-12}	Ozima and Podosek 2002
OIB(Earth)	0.77x10^{-9}	1.3x10^{-09}	33x10^{-12}	1.9x10^{-12}	Ozima and Podosek 2002

Fig. Elemental plot of SW, Q, CC and differentiated objects. Table-Noble gas trapped values in different reservoirs

Conclusions :

- There is variation in abundances of noble gases, which is imprint of the different geological evolution of objects.
- Elemental ratios of noble gases are distinct in interior of differentiated object.

Case I: Venusian interior is highly degassed: This complies with the differentiated objects, Earth, Mars and Vesta. However, the 40Ar/36Ar ratios in Venusian atmosphere is contrast to this, compared with Earth and Mars. Asteroid Vesta has no atmosphere.

Case II: Venusian interior is less degassed. This is in contrast with the mantle of Earth and Mars. However, the range of trapped noble gases in Venusian interior could be of similar ranges as that of Earth, Mars and Vesta.

References:- **:** [1] Taylor S. R. (1994). Cambridge Univ. Press, 217. [2] Ozima, M., & Podosek, F. A. (2002). Cambridge University Press. [3] Mathew K. J. and Marti K. (2001) JGR-Planets. 106, 1401-1422. [4] Wieler, R. (2002). Pp. 21–70. [5] Hoffman et al., JGR. 85, 7871-7881. [5] Vogt, M., (2019). Geochimica et Cosmochimica Acta, 264, 141-164.