Evaluation of the Earth's radiogenic heat and He–Ar budgets

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1. Given a Bulk Silicate Earth (BSE) model composition (Table 1), you can calculate the present-day total radiogenic heat production in BSE from decay of the long lived radionuclides of K, Th, U.

2. What are the relative contributions to the radiogenic heat production from the different nuclides?

3. How has the radiogenic heat production rate changed over time?

4. How has the amount of K, Th, U in the Earth evolved over time?

5. There are 1.65×10^{18} moles of argon in the atmosphere[1] with isotopic composition $^{40}Ar/^{36}Ar = 295.5$[2], $^{39}Ar/^{40}Ar = 8 \times 10^{-16}$[3]. Why is there so much argon in the atmosphere? How did it get there?

6. How does the amount of ^{40}Ar in the atmosphere compare to the amount produced in the Silicate Earth over the age of the Earth?

7. Analyses of isotopic composition of basalts from mid-oceanic ridges (MORB) yield values of $^{40}Ar/^{36}Ar$ ranging from 296 to 40000. Values measured for OIB (ocean island basalts, erupting at hot spots such as Hawaii) range between 4000 and 8000. Speculate how these observations might be tied to the picture of Earth's dynamics.

8. The concentration of ^{39}Ar in the atmosphere is at steady state where the cosmogenic production balances the radioactive decay. At what rate does decay of ^{39}Ar heat up the atmosphere?

9. How much He has the Earth produced over its age?

10. Would you expect to measure a higher $^{4}He/^{3}He$ in MORBs or OIBs?

Table 1: Silicate Earth compositional models. Concentrations in g/g. Uncertainties are 1-sigma. †*McDonough and Sun* (1995) model with updated K value. ‡Baked according to Marc Javoy's recipe.

Reference	K	Th	U
Arevalo et al. (2009)†	280 ± 60 ppm	80 ± 13 ppb	20 ± 4 ppb
Javoy et al. (2010)‡	146 ± 29 ppm	43 ± 4 ppb	12 ± 2 ppb

Table 2: Masses of Earth's shells. Calculated from CRUST1.0 (*Laske et al.*, 2013) and PREM (*Dziewonski and Anderson*, 1981) models.

Mass of continental crust	1.97×10^{22} kg
Mass of oceanic crust	8.9×10^{21} kg
Mass of the mantle	4.004×10^{24} kg
Mass of the core	1.940×10^{24} kg

[1] *Porcelli and Turekian* (2014)
[2] *Nier* (1950)
[3] *Benetti et al.* (2007)

Table 3: Useful(?) quantities

	^{40}K	^{232}Th	^{235}U	^{238}U	Reference
Natural isotopic mole fraction	0.000117	1	0.007204	0.992742	*NIST*
Standard atomic mass (g/mol)	39.0983	232.038	238.029	238.029	*NIST*
Half-life (10^9 yr)	1.248	14.0	0.704	4.468	*NNDC*
Energy released per decay (10^{-12} J)	0.213	6.833	7.434	8.282	*Dye* (2012)
Energy carried by $\bar{\nu}_e/\nu_e$ per decay (10^{-12} J)	0.103	0.358	0.325	0.634	*Dye* (2012)

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