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ES1201 MID-SEMESTER EXAMINATION

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Q1. Given :-

$a = 10^{-3}$ m (1mm)
$\varphi = 0.2$ (20% of volume melt)
$\Delta\rho = 3500\ kgm^{-3}$
$g = 9.8\ ms^{-2}$
$\eta = 0.005\ kgm^{-1}s^{-1}$

Applying Darcy's Law,

$$v = \left(\frac{k}{\eta}\right)\Delta\rho g$$

$$= \left(\frac{a^2\varphi}{24\pi\eta}\right)\Delta\rho g$$

$$= \left(\frac{(10^{-3})^2 \times 0.2}{24 \times \pi \times 0.005}\right) \times 3500 \times 9.8$$

$$= \left(\frac{10^{-6} \times 0.2}{24 \times \pi \times 0.005}\right) \times 3500 \times 9.8$$

$$\simeq 0.01819\ ms^{-1}$$

$$\simeq 0.0182\ ms^{-1}$$

$$= 0.0182 \times 10^{-3}\ kms^{-1}$$

$$= 18.2 \times 10^{-6}\ kms^{-1}$$

$$= 18.2 \times 10^{-6} \times 3.2 \times 10^{7}\ kmyr^{-1}$$

$$= 58.24 \times 10^{1}\ kmyr^{-1}$$

$$= \boxed{582.4\ kmyr^{-1}}$$ ans.

Q2. Given :-

$m = 10^{18}$ kg.

$M = 6 \times 10^{22}$ kg.

$v = 10,000 \ ms^{-1}$

$C = 750 \ J \ kg^{-1} K^{-1}$

Because m is much smaller than M, the effect of m is negligible and can be ignored, so the eqⁿ can be simplified to :

$$\Delta T = \frac{mv^2}{2MC} = \frac{10^{18} \times (10000)^2}{2 \times 6 \times 10^{22} \times 750} = \frac{10^{18} \times 10^8}{12 \times 750 \times 10^{22}}$$

$$= \frac{10^{18+8-22}}{12 \times 750} = \frac{10^4}{9 \times 10^3} = \frac{10}{9} = 1.1\dot{1} \ K$$

The no. of planetesimals of mass 10^{18} kg each reqd. to construct the Earth is,

$$\frac{6 \times 10^{22} \ kg}{10^{18} \ kg} = 6 \times 10^{22-18} = 6 \times 10^4$$

If each of these produced the temperature rise in the previous part, the total temperature rise in Earth would be = $(6 \times 10^4) \times (1.1\dot{1} \ K) = \underline{6.6\dot{6} \times 10^4 \ K}$.

$\simeq \underline{6.67 \times 10^4 K}$

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Q3. Half-life of U^{235} is 0.9 Ga.

$\therefore$, in 0.9 Ga, half of the initial amount of U^{235} would have decayed into daughter isotopes and the remaining will continue to decay into half every 0.9 Ga.

If the age of the Earth is 8.1 Ga, then total no. of half-lives of U^{235} completed in the time is,

$$= \frac{8.1}{0.9} = \underline{\underline{9}}$$

Now, after each half-life, the heat production gets halved. So, heat production after 9 half lives,

$$= \left(\frac{1}{2}\right)^9 = 2^{-9} = 1.95 \times 10^{-3} = \underline{0.195\%}$$

of what it was initially.

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Q4. The half-life of ^{26}Al is only 0.73 Ma, so the time between the supernova explosion that generated the ^{26}Al and the accretion of the meteorite parent body must have happened on a similar timescale of a few million years. Given that after 10 half-lives only 2^{-10} of the original no. of ^{26}Al atoms remain, then for any measureable amt. of radiogenic ^{26}Mg to be found, chondritic meteorites must have formed within, at most, 7.3 Ma of the supernova.

Q5. Samples of the core are not available at the surface of the Earth, so any scientific investigation of the composition of the core has to be done either remotely or by using laboratory analogues and simulations. The latter involves subjecting materials to the temperatures and pressures of the core in the laboratory, measuring their properties and comparing them with Earth reference models. One of the most useful properties is density. The density versus depth curves of the Earth's core and pure iron do not match. Thus, the density of the core is less than that experimentally determined for pure iron. The mismatch between curves for the core and pure iron requires the core to include other elements that reduce its overall density.

Siderophile elements were the potential elements proposed to coexist with iron in the core.
(Siderophile Elements: $\underbrace{\text{Os, Re, Ru, Ir, Pt, Rh}}_{\text{RSE}}$, $\underbrace{\text{Mo, W}}_{\text{moderately SE.}}$)

But their densities are either similar to or even greater than that of iron, so the problem gets worse. The unavoidable conclusion is that the core includes a significant fraction of element(s) with an atomic no. and density less than liquid Fe-Ni alloy.

Some experiments reveal that Si has increasing siderophile tendencies at very high pressures. Other elements that have been suggested are O and S in forms of FeO and FeS respectively. Both FeO and FeS can dissolve in molten Fe in sufficient quantities to reduce its density enough to match that of the core. But, sulphur is a volatile element and so may have been lost from Earth before the core formed and the very high electronegativity of O means that it is dominantly lithophile.

However, experimental studies have shown that at the conditions appropriate for the core-mantle boundary, oxygen can dissolve in molten Fe as FeO. Thus, mechanisms for transferring oxygen from the mantle to the core can be demonstrated on the bases of high-pressure experiments, and oxygen remains the leest possible element to be present (as a light element) in the Earth's core.