

## Chapter 1

- Given the atomic mass of uranium ( $^{238}\text{U}$ ) is 238.0289 u and that it has a nuclear radius of  $7.5 \times 10^{-15} \text{ m}$ , calculate the density of the nucleus of  $^{238}\text{U}$ . Hence, estimate the mass of a fuel pellet of diameter 10 mm and height 8 mm if it were possible for it to be comprised entirely of uranium with the composition of its nucleus.

**Answer**

Assuming the  $^{238}\text{U}$  nucleus is spherical, the volume  $V$  is:

$$V = \frac{4}{3} \pi r^3 = \frac{4}{3} \pi (7.5 \times 10^{-15})^3 \sim 1.8 \times 10^{-42} \text{ m}^3$$

The mass  $m_U$  of 1 atom of  $^{238}\text{U}$  is:

$$m_U = 238.0289 \times 1.66 \times 10^{-27} = 4.0 \times 10^{-25} \text{ kg}$$

Hence, the density  $\rho$  is as follows:

$$\rho = \frac{4.0 \times 10^{-25}}{1.8 \times 10^{-42}} = 2.2 \times 10^{17} \text{ kg m}^{-3}$$

Thus the mass of the pellet would be:

$$m = 2.2 \times 10^{17} \times \pi (5 \times 10^{-3})^2 \times 8 \times 10^{-3} = 1.4 \times 10^{11} \text{ kg}$$

- Caesium-137 decays via  $\beta$  decay to an excited state of barium-137 which decays subsequently via the emission of a single  $\gamma$  ray having an energy of 662 keV. Convert this energy to joules. How many  $^{137}\text{Cs}$   $\gamma$  rays would need to be absorbed by 1 kg of water to raise its temperature by 1 °C if its specific heat capacity is  $4.2 \text{ kJ kg}^{-1} \text{ °C}^{-1}$ ?

**Answer**

$$1 \text{ keV} = 1.6 \times 10^{-16} \text{ J}$$

$$E_\gamma = 662 \times 1.6 \times 10^{-16}$$

$$= 1.06 \times 10^{-13} \text{ J}$$

$$E = mc\Delta T$$

$$= 1 \times 4200 \times 1$$

$$= 4200 \text{ J}$$

$$N_\gamma = \frac{4200}{1.06 \times 10^{-13}} = 4.0 \times 10^{16} \text{ } \gamma \text{ rays}$$

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