Answer on Question #42233-Physics-Molecular Physics-Thermodynamics

PuO2 has a density of 11.5 gcm-3 and a specific heat capacity of 330 J kg-1 K-1. A fresh sample (i.e. one that has not decayed) of PuO2 produces 0.540 kW kg-1 of heat due to internal radioactive decay*. For this question we will consider a 1 cm^3 block of PuO2.

a) How much heat does a fresh 1 cm^3 block of PuO2 produce?

A fresh 1 cm^3 block sitting on the bench in the lab glows red hot at 700 K as it looses heat to its environment.

Answer

$$P = m \cdot \frac{dP}{dm} = \rho \cdot V \cdot \frac{dP}{dm} = 11.5 \frac{g}{cm^3} \cdot 1 \text{ cm}^3 \cdot 0.540 \frac{\text{kW}}{\text{kg}} = 6.21 \text{ W}.$$

b) If we place the block, initially at 700K, in a very well insulated container, its temperature will

start to rise. How long does it take for the block to reach 1000 K?

Answer

$$P\Delta t = \Delta Q = cm\Delta T \to \Delta t = \frac{cm\Delta T}{P} = \frac{c\Delta T}{\frac{dP}{dm}} = \frac{330 \frac{\text{J}}{\text{kgK}} \cdot (1000 \text{ K} - 700\text{K})}{0.540 \frac{\text{kW}}{\text{kg}}} = 183 \, s.$$

c) PuO2 melts at 2673 K and its latent heat of fusion is 245 kJ kg-1. If we place our block in a well insulated and heat resistant container when it is at 700 K, then how long is it before the whole block is melted?

Answer

$$P\Delta t = cm\Delta T + qm \to \Delta t = \frac{cm\Delta T + qm}{P} = \frac{c\Delta T + q}{\frac{dP}{dm}} = \frac{330 \frac{\text{J}}{\text{kgK}} \cdot (2673 \text{ K} - 700\text{K}) + 245 \frac{\text{kJ}}{\text{kg}}}{0.540 \frac{\text{kW}}{\text{kg}}}$$

$$= 1.66 \cdot 10^3 \, s.$$