State Examination Commission – Physics Higher Level, 2009

Question 12d

Smoke detectors use a very small quantity of the element americium-241. This element does not exist in nature and was discovered during the Manhattan Project in 1944.
Alpha particles are produced by the americium-241 in a smoke detector.
(i) Give the structure of an alpha particle.
(ii) How are the alpha particles produced?
(iii) Why do these alpha particles not pose a health risk? (13)
Americium-241 has a decay constant of 5.1×10^{-11} s^{-1}.
Calculate its half life in years. (9)
Explain why americium-241 does not exist naturally. (6)

Alpha particles are produced by the americium-241 in a smoke detector.
(i) Give the structure of an alpha particle.

An alpha particle is a helium atom nucleus – two protons and two neutrons

(ii) How are the alpha particles produced?

By the decay of the unstable americium nuclei

(iii) Why do these alpha particles not pose a health risk? (13)

The emitted alpha have an extremely short range.

Americium-241 has a decay constant of 5.1×10^{-11} s^{-1}.
Calculate its half life in years. (9)

$t_{½} = 0.693/\lambda = 0.693/(5.1 \times 10^{-11}) = 1.36 \times 10^{10}$ s $\equiv$ 430.6 y

Explain why americium-241 does not exist naturally. (6)

It has a relatively short half-life, and all the americium in the earth when it was formed would have decayed naturally over the massive time span since then.