19 Nuclear decay is described as being spontaneous and random.

(a) (i) State what is meant by spontaneous and random in this context.

(2)

(ii) Explain why the decay constant of an isotope can be determined even though nuclear decay is random.

(2)

(b) A radioactive source used in a school laboratory emits alpha and beta radiation.

Describe how the percentage of the activity due to beta radiation may be determined using a Geiger–Müller tube and ratemeter.

(4)

(c) Americium-241 is used in schools as a source of alpha radiation.
A pure americium-241 source was bought 34 years ago by a school.

(i) Determine the percentage of the initial activity that would be expected today for the americium-241 source.

half-life of americium-241 = 432 years

(3)

Expected percentage of initial activity = ...

(ii) The decay products of americium are unstable and undergo a series of further decays.

The table shows the first three decays in this sequence.

Isotope	Decay product	Emission	Half-life
americium-241	neptunium-237	alpha	432 years
neptunium-237	protactinium-233	alpha	2 100 000 years
protactinium-233	uranium-233	beta	27 days

A student states, “Protactinium-233 emits beta particles when it decays, so by now the americium-241 source bought 34 years ago will be emitting a significant amount of beta radiation.”

Discuss the student’s statement.

(3)

(Total for Question 19 = 14 marks)