8 **(a)** The masses of various nuclides and of various sub-atomic particles, are shown in Fig. 8.1.

nuclide or sub-atomic particles	proton number	mass / u
electron	n/a	0.000549
proton	n/a	1.007276
neutron	n/a	1.008664
helium-4	2	4.002603
thallium-205	81	204.974428
bismuth-209	83	208.980399
polonium-209	84	208.982430

Fig. 8.1

(i) Bismuth-209 is radioactive.

Use the data in Fig. 8.1 to determine which type(s) of radiation (α or β) it is possible for bismuth-209 to emit. Explain your reasoning.

radiation emitted: ..... [4]

(ii) Determine the binding energy per nucleon of bismuth-209.

binding energy per nucleon = ... MeV [4]

(b) A radiation detector is placed close to a radioactive source. The variation with time *t* of the measured count rate is shown in Fig. 8.2.

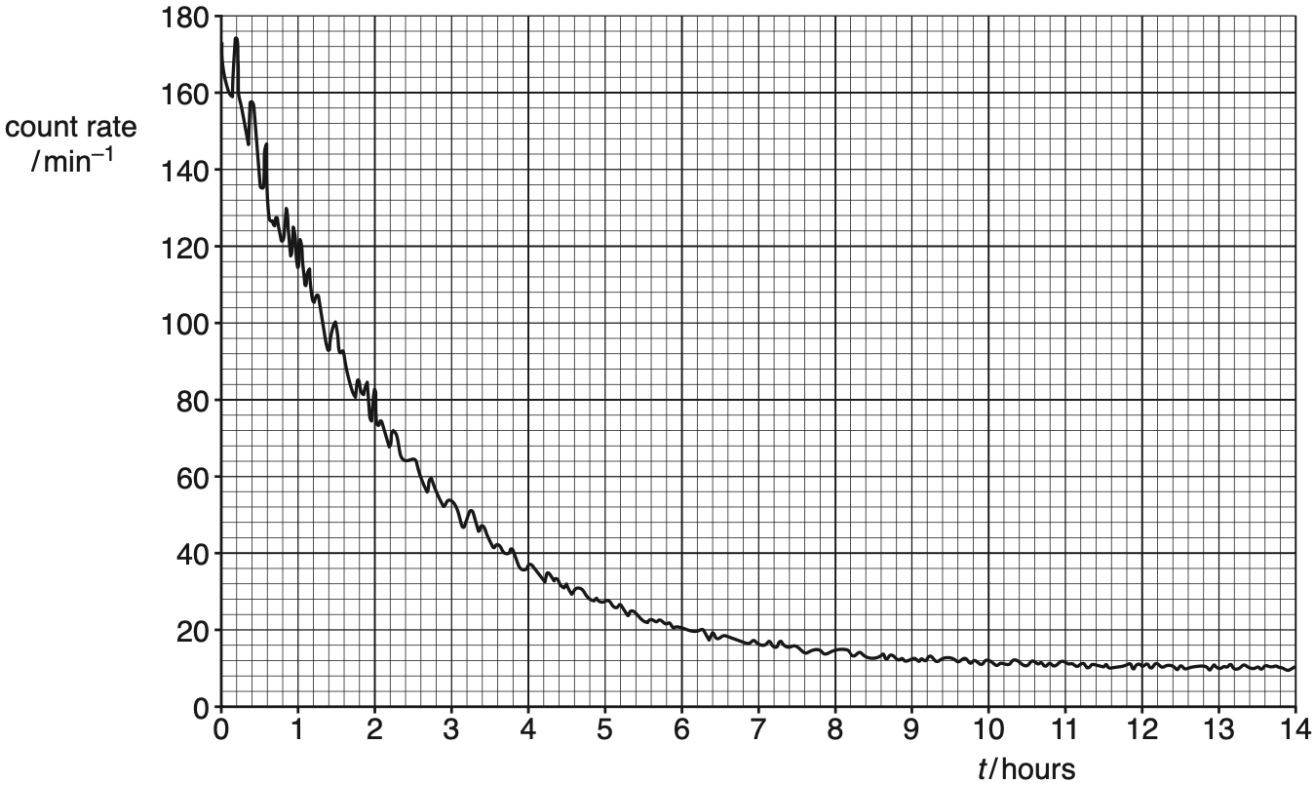

Fig. 8.2

(i) State the feature of Fig. 8.2 that indicates the random nature of radioactive decay.

……
……

…… [1]

(ii) State the background count rate recorded by the radiation detector.

background count rate = …… min^{-1} [1]

(iii) Use Fig. 8.2 to determine the half-life of the radioactive isotope in the source.

half-life = …… hours [3]

(c) Samples of Moon rock were collected by Apollo astronauts.

Scientists measure the relative abundance of strontium isotopes in samples of Moon rock to determine the age of the rocks.

The isotope rubidium-87, found in Moon rock, is radioactive. It decays by beta emission. The nuclide decay equation is

$$3787Rb \rightarrow 3887Sr + -10e + \text{neutrino}$$

(i) The decay constant of rubidium-87 is 1.44×10^{-11} yr^{-1}.
Calculate, in years, the half-life of rubidium-87.

half-life = …… yr [1]

(ii) When Moon rocks were formed about 4.0×10^9 years ago they contained rubidium-87, strontium-87 and strontium-86. The two strontium isotopes are stable. The rate at which strontium-87 atoms are created is equal to the rate of decay of the rubidium-87 atoms.

Use the half-life your answer in **(c)(i)**, show that this rate has remained almost constant over the age of the rock.

[2]

(iii) The ratio *R* of the strontium isotopes found in Moon rock is given by

$$R = \frac{number\ of\ atoms\ ^{3887}Sr}{number\ of\ atoms\ ^{3886}Sr}$$

On Fig. 8.3, sketch a graph to show how the ratio *R* has varied with time since the rock samples formed.

Fig. 8.3

[2]

(iv) Explain how a measure of the ratio *R* in **(c)(iii)** could be used to estimate the age of the Moon rock. State any additional information that would be required.

……

……

……

……

…… [2]

[Total: 20]