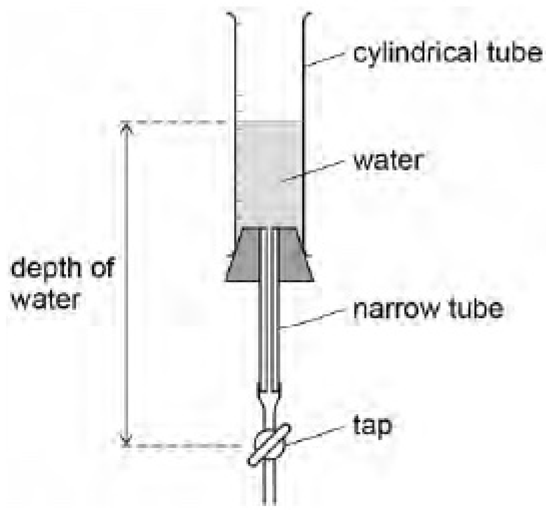
1 **Figure 1** shows how radioactive decay of one nuclide can be modelled by draining water through a tap from a cylindrical tube.

Figure 1

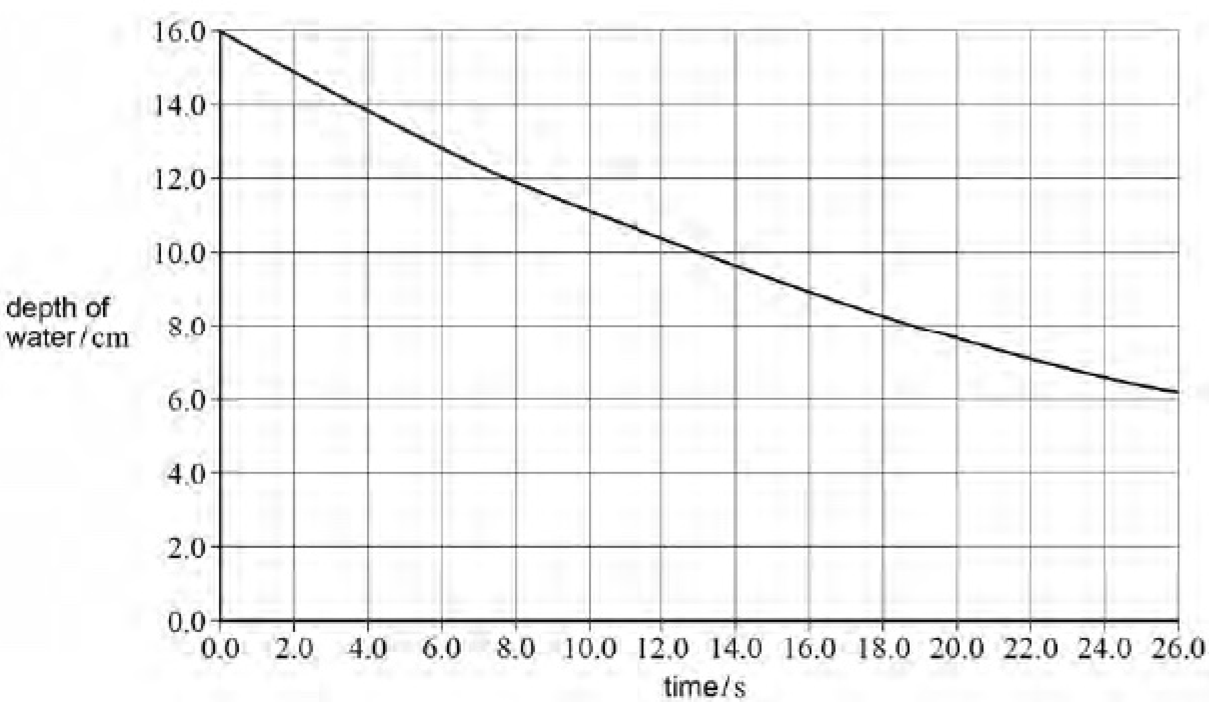


The water flow-rate is proportional to the pressure of the water. The pressure of the water is proportional to the depth of the water. Therefore the rate at which the depth decreases is proportional to the depth of the water.

Before the tap is opened the depth is 16.0 cm

The tap is opened and the depth is measured at regular intervals. These data are plotted on the graph in **Figure 2**.

Figure 2



(a) Determine the predicted depth of water when the time is 57 s

depth = ____________________ cm

(1)

(b) Suggest how the apparatus in **Figure 1** may be changed to represent a radioactive sample of the same nuclide with a greater number of nuclei.

____

____

(1)

(c) Suggest how the apparatus in **Figure 1** may be changed to represent a radioactive sample of a nuclide with a smaller decay constant.

____

____

(1)

(d) The age of the Moon has been estimated from rock samples containing rubidium (Rb) and strontium (Sr), brought back from Moon landings.

$^{87}_{37}Rb$ decays to $^{87}_{38}Sr$ with a radioactive decay constant of 1.42×10^{-11} year^{-1}

Calculate, in years, the half-life of $^{87}_{37}Rb$

half-life = ____________________ years

(1)

(e) A sample of Moon rock contains 1.23 mg of $^{87}_{37}Rb$.

Calculate the mass, in g, of $^{87}_{37}Rb$ that the rock sample contained when it was formed 4.47×10^9 years ago.

Give your answer to an appropriate number of significant figures.

mass = ____________________ g

(3)

(f) Calculate the activity of a sample of $^{87}_{37}Rb$ of mass 1.23 mg

Give an appropriate unit for your answer.

activity = ____________________ unit ___________

(3)

(Total 10 marks)

2 The radius of a uranium $^{238}_{92}U$ nucleus is 7.75×10^{-15} m

What is the radius of a $^{12}_{6}C$ nucleus?

A 1.10×10^{-18} m ⬭

B 3.91×10^{-16} m ⬭

C 2.86×10^{-15} m ⬭

D 3.12×10^{-15} m ⬭

(Total 1 mark)

3 (a) In a radioactivity experiment, background radiation is taken into account when taking corrected count rate readings in a laboratory. One source of background radiation is the rocks on which the laboratory is built. Give **two** other sources of background radiation.

source 1 ____

source 2 ____

(1)

(b) A γ ray detector with a cross-sectional area of 1.5×10^{-3} m^2 when facing the source is placed 0.18 m from the source.
A corrected count rate of 0.62 counts s^{-1} is recorded.

(i) Assume the source emits γ rays uniformly in all directions.
Show that the ratio

$$\frac{\text{number of } \gamma \text{ photons incident on detector}}{\text{number of } \gamma \text{ photons produced by source}}$$

is about 4×10^{-3}.

(2)

(ii) The γ ray detector detects 1 in 400 of the γ photons incident on the facing surface of the detector.
Calculate the activity of the source. State an appropriate unit.

answer = ____________________ unit ___________

(3)

(c) Calculate the corrected count rate when the detector is moved 0.10 m further from the source.

answer = ____________________ counts s^{-1}

(3)

(Total 9 marks)

4 (a) Calculate the binding energy, in MeV, of a nucleus of $^{59}_{27}Co$.

nuclear mass of $^{59}_{27}Co$ = 58.93320 u

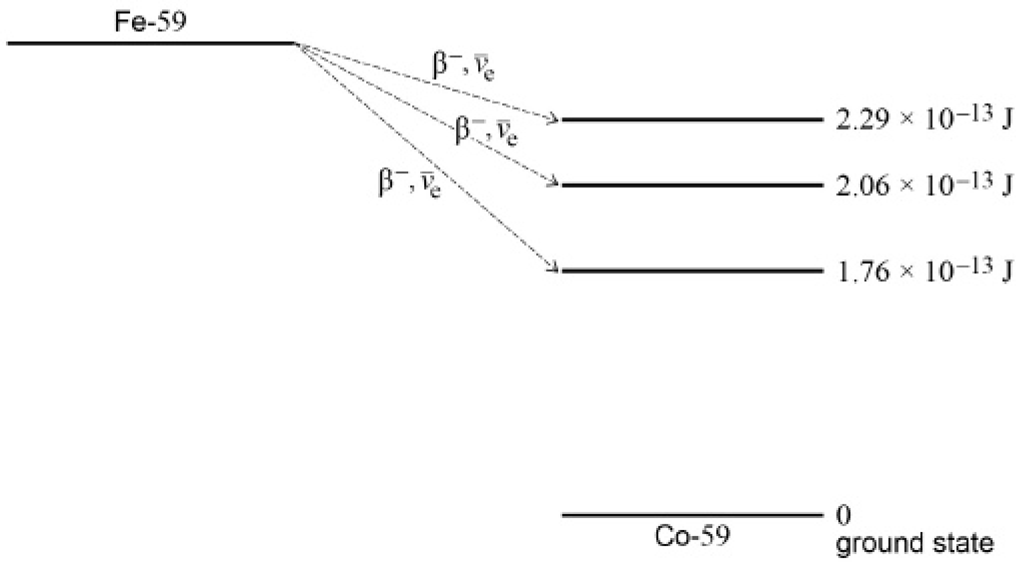
binding energy = ____________________ MeV

(3)

(b) A nucleus of iron Fe-59 decays into a stable nucleus of cobalt Co-59. It decays by β^- emission followed by the emission of γ-radiation as the Co-59 nucleus de-excites into its ground state.

The total energy released when the Fe-59 nucleus decays is 2.52×10^{-13} J.

The Fe-59 nucleus can decay to one of three excited states of the cobalt-59 nucleus as shown below. The energies of the excited states are shown relative to the ground state.



Calculate the maximum possible kinetic energy, in MeV, of the β^- particle emitted when the Fe-59 nucleus decays into an excited state that has energy above the ground state.

maximum kinetic energy = ____________________ MeV

(2)

(c) Following the production of excited states of $^{59}_{27}Co$, γ-radiation of discrete wavelengths is emitted.

State the maximum number of discrete wavelengths that could be emitted.

maximum number = ____________________

(1)

(d) Calculate the longest wavelength of the emitted γ-radiation.

Longest wavelength = ____________________ m

(3)

(Total 9 marks)

5 Nobelium-259 has a half-life of 3500 s.

What is the decay constant of nobelium-259?

A $8.7 \times 10^{-5}\ s^{-1}$ ⬭

B $2.0 \times 10^{-4}\ s^{-1}$ ⬭

C $1.7 \times 10^{-2}\ s^{-1}$ ⬭

D $1.2 \times 10^{-2}\ s^{-1}$ ⬭

(Total 1 mark)

6 After 64 days the activity of a radioactive nuclide has fallen to one sixteenth of its original value.
The half-life of the radioactive nuclide is

A 2 days. ⬭

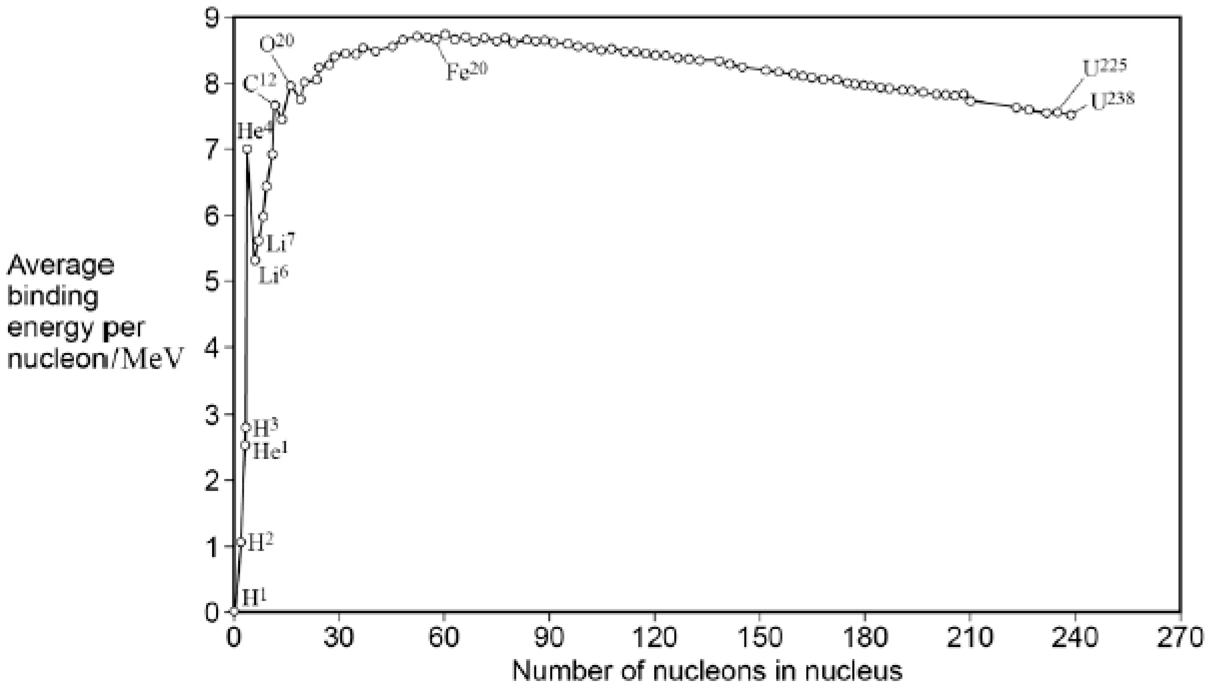
B 4 days. ⬭

C 8 days. ⬭

D 16 days. ⬭

(Total 1 mark)

7 The graph shows how the binding energy per nucleon varies with the nucleon number for stable nuclei.



What is the approximate total binding energy for a nucleus of $^{184}_{74}W$?

A 1.28 pJ

B 94.7 pJ

C 103 pJ

D 230 pJ

(Total 1 mark)