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

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

Youtube walkthrough

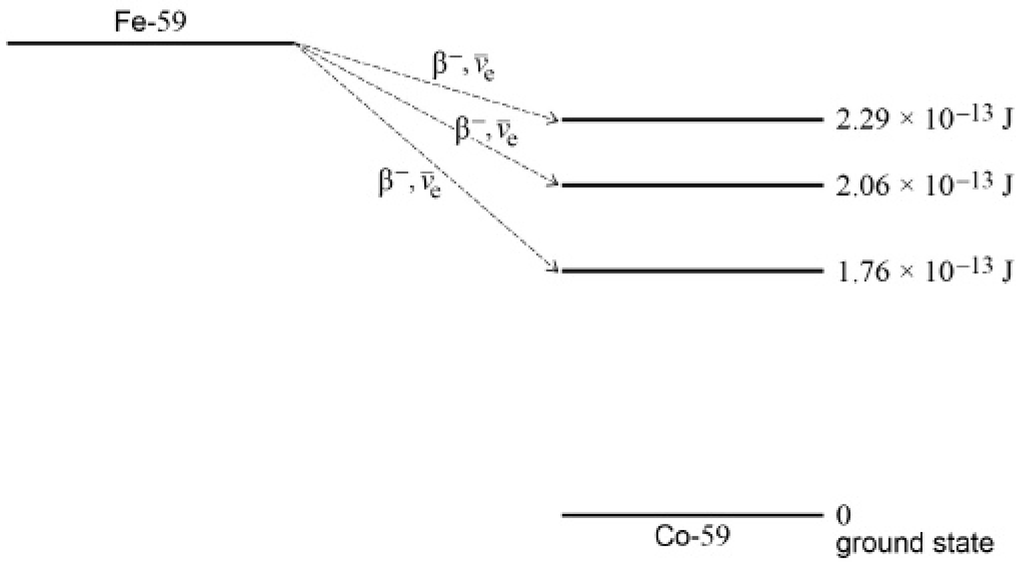
binding energy = ____________________ MeV

(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)

2 The isotope of uranium, $^{238}_{92}U$, decays into a stable isotope of lead, $^{206}_{82}Pb$, by means of a series of α and β^- decays.

(a) In this series of decays, α decay occurs 8 times and β^- decay occurs *n* times.
Calculate *n*.

answer = ____________________

(1)

(b) (i) Explain what is meant by the binding energy of a nucleus.

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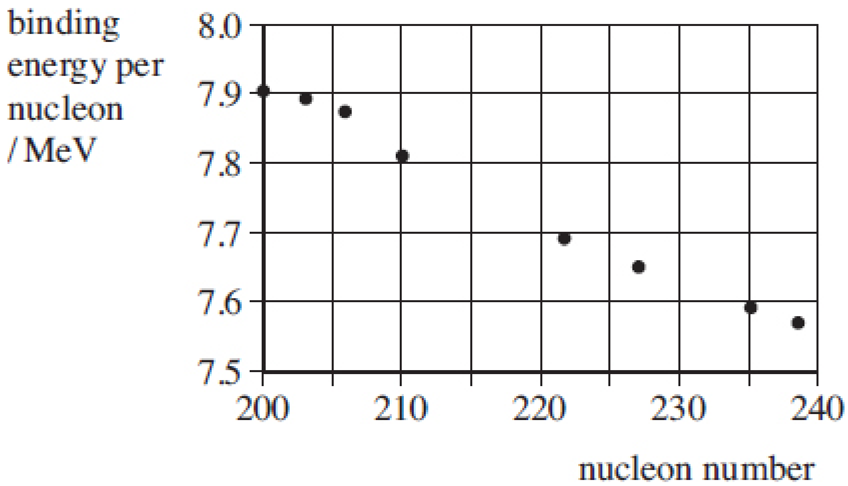
(2)

(ii) **Figure 1** shows the binding energy per nucleon for some stable nuclides.

Figure 1



Use **Figure 1** to estimate the binding energy, in MeV, of the $^{206}_{82}Pb$ nucleus.

answer = ____________________ MeV

(1)

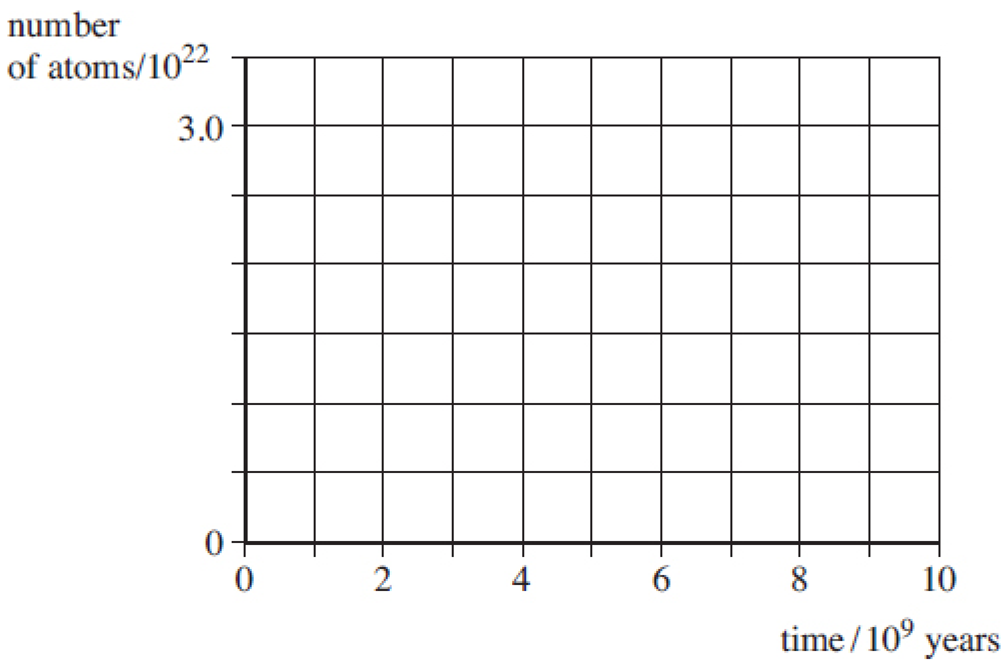
(c) The half-life of $^{238}_{92}U$ is 4.5×10^9 years, which is much larger than all the other half-lives of the decays in the series.

A rock sample when formed originally contained 3.0×10^{22} atoms of $^{238}_{92}U$ and no $^{206}_{82}Pb$ atoms.

At any given time most of the atoms are either $^{238}_{92}U$ or $^{206}_{82}Pb$ with a negligible number of atoms in other forms in the decay series.

(i) Sketch on **Figure 2** graphs to show how the number of $^{238}_{92}U$ atoms and the number of $^{206}_{82}Pb$ atoms in the rock sample vary over a period of 1.0×10^{10} years from its formation.
Label your graphs U and Pb.

Figure 2



(2)

(ii) A certain time, *t*, after its formation the sample contained twice as many $^{238}_{92}U$ atoms as $^{206}_{82}Pb$ atoms.
Show that the number of $^{238}_{92}U$ atoms in the rock sample at time *t* was 2.0×10^{22}.

(1)

(ii) Calculate t in years.

answer = ____________________ years

(3)

(Total 10 marks)

3 (a) (i) Sketch a graph to show how the neutron number, N, varies with the proton number, Z, for naturally occurring stable nuclei over the range Z = 0 to Z = 90. Show values of N and Z on the axes of your graph and draw the N = Z line.

(ii) On your graph mark points, one for each, to indicate the position of an unstable nuclide which would be likely to be

an α emitter, labelling it A,

a β^- emitter, labelling it B.

(5)

(b) State the changes in N and Z which are produced in the emission of

(i) an α particle,

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(ii) a β^- particle.

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(2)

(c) The results of electron scattering experiments using different target elements show that

$$R = r_0 A^{\frac{1}{3}}$$

where A is the nucleon number and r_0 is a constant.

Use this equation to show that the density of a nucleus is independent of its mass.

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(3)
(Total 10 marks)

4 (a) (i) Explain why, despite the electrostatic repulsion between protons, the nuclei of most atoms of low nucleon number are stable.

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(ii) Suggest why stable nuclei of higher nucleon number have greater numbers of neutrons than protons.

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(iii) All nuclei have approximately the same density. State and explain what this suggests about the nature of the strong nuclear force.

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(6)

(b) (i) Compare the electrostatic repulsion and the gravitational attraction between a pair of protons the centres of which are separated by 1.2×10^{-15} m.

proton charge	=	1.6×10^{-19} C
proton mass	=	1.7×10^{-27} kg
gravitational constant	=	6.7×10^{-11} N m^2 kg^{-2}
permittivity of free space	=	8.9×10^{-12} F m^{-1}

(ii) Comment on the relative roles of gravitational attraction and electrostatic repulsion in nuclear structure.

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(5)

(Total 11 marks)