8 **(a)** Cobalt-60, an isotope widely used in medicine, decays by emitting an electron (β^- decay) with a half-life of 5.272 years into an excited state of nickel-60, which then de-excites very quickly to the ground state of nickel-60 by emitting a number of gamma photons.

(i) Complete the nuclear equation for the Co-60 decay below.

$$^{60}_{\ldots\ldots}\mathrm{Co} \rightarrow {}^{\ldots\ldots}_{28}\mathrm{Ni} + {}^{\ldots\ldots}_{\ldots\ldots}\mathrm{e} + \gamma$$

[2]

(ii) Calculate the activity of 1.0 g of Cobalt-60.

activity = ... Bq [3]

(b) The emission spectrum of the gamma photons emitted by the de-excitation of nickel-60 is shown in Fig. 8.1.

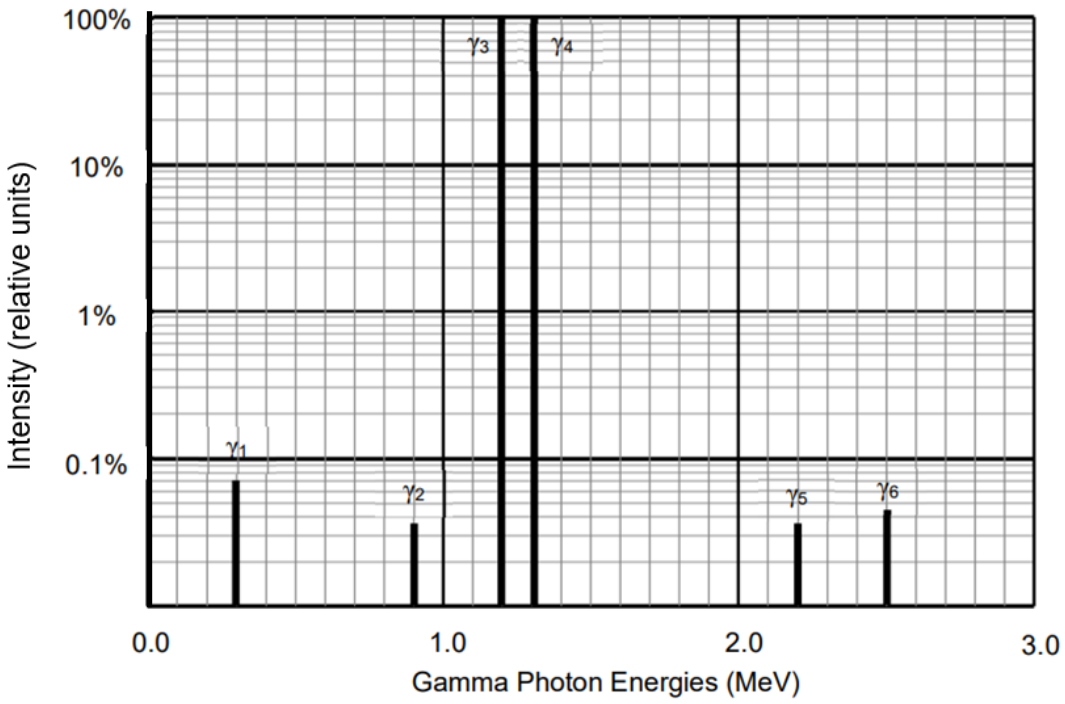

Fig. 8.1

(i) Explain what is meant by a *gamma photon*.

.....

.....

..... [2]

(ii) Explain why Fig. 8.1 provides evidence that the nucleus has discrete energy levels.

.....

.....

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.....

..... [2]

(iii) A few energy levels of the nucleus of nickel-60 are shown in Fig. 8.2.

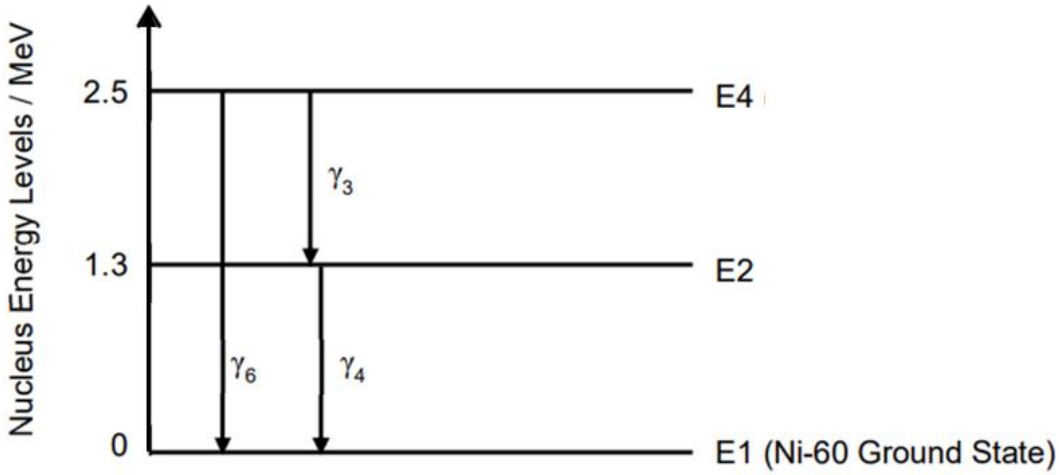

Fig. 8.2

1. There is a missing energy level E3 (between E2 and E4) in Fig. 8.2. With reference to Fig. 8.1, deduce the energy of this level. Draw and label the missing energy level E3 on Fig. 8.2.

energy of E3 level = ... MeV [2]

2. Hence sketch and label the transitions which correspond to the emission of γ_1, γ_2 and γ_5 photons on Fig. 8.2. [2]

3. The rest-mass of the Ni-60 nucleus at the ground state E1 is 59.93079 *u*.
Calculate the mass, in *u*, of the Ni-60 nucleus at its excited state E4. Leave your answer to 7 s.f..

mass = ... *u* [3]

(c) Co-60 sources are often kept in lead containers. The interaction between the β^- particles and the lead atoms give rise to a continuous spectrum of X-ray radiation.

(i) Explain the origin of the **continuous** spectrum of X-ray.

.....

.....

.....

.....

.....

..... [2]

(ii) Given that the maximum energy of the β particle is 0.30 MeV, calculate the cut-off wavelength of the continuous spectrum of X-ray.

wavelength = ... m [2]

[Total: 20]

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