5 (a) When a star has fused all its hydrogen to helium, it will start to fuse helium into carbon through the following reaction.

$$^{4}_{2}\text{He} + {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} \rightarrow {}^{12}_{6}\text{C}$$

The binding energy per nucleon of helium and carbon are given in Fig. 5.1.

nuclide	binding energy per nucleon / MeV
$^{12}_{6}\text{C}$	7.680
$^{4}_{2}\text{He}$	7.074

Fig. 5.1

(i) Calculate the energy, in MeV, produced from this fusion reaction.

energy produced = …………………… MeV [2]

(ii) A star in the milky way gives off energy at a rate of 2.75×10^{26} W solely due to the fusion of helium into carbon in its core.

Calculate the number of helium nuclei *N*, that reacted in one second.

N = ………………………. s^{-1} [3]

(b) The nuclide ${}^{14}_{6}C$ (carbon-14) is unstable and undergoes β decay, emitting a high-energy electron and a neutrino to form a nuclide X.

(i) The equation for this decay is shown.

$${}^{14}_{6}C \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}X + {}^{\cdots\cdots}_{\cdots\cdots}e + {}^{0}_{0}\nu$$

Complete the equation.

[2]

(ii) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β-decay.

1. State an observation about β-decay that is explained by the existence of neutrinos.

....

.... [1]

2. Suggest how the existence of neutrinos explains the observation in **(b)(i)1**.

....

....

.... [2]

(c) The variation with time t of the number N of undecayed nuclei in a sample of a radioactive isotope is shown in Fig. 5.2.

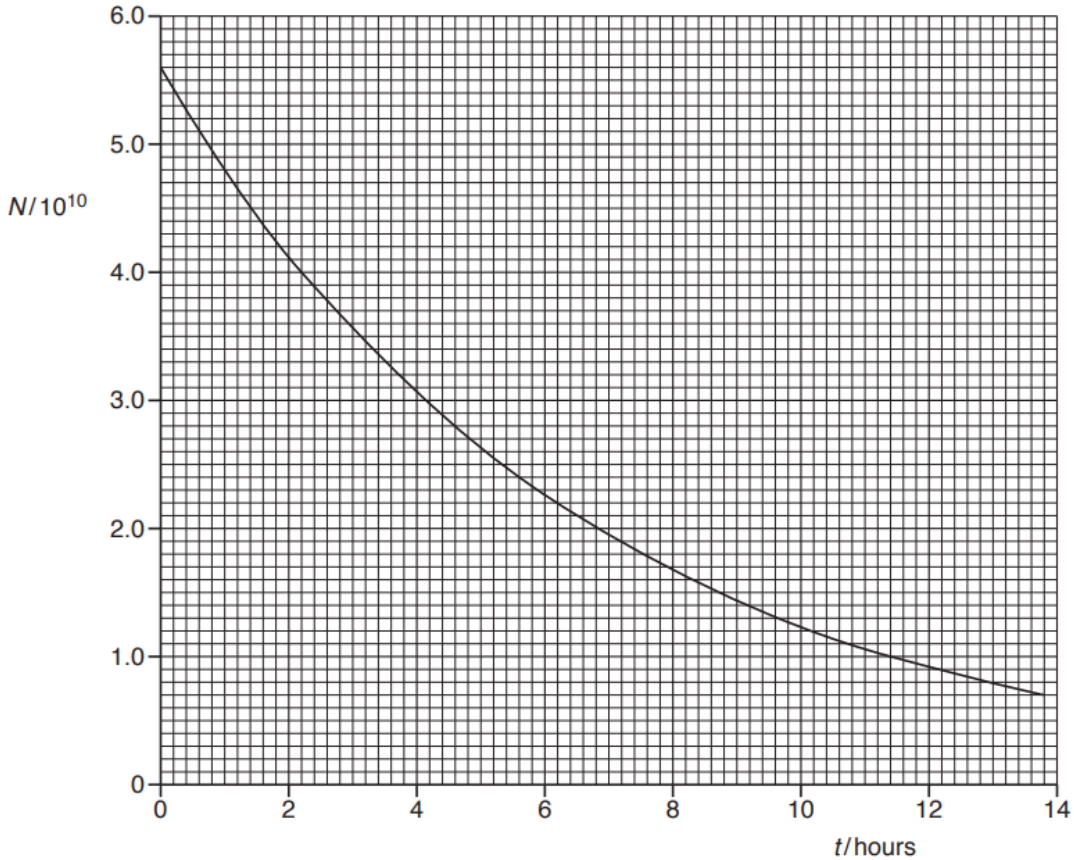

Fig. 5.2

(i) Using Fig. 5.2, determine the activity, in Bq, of the sample at time t = 4.0 hours.

activity = ... Bq [2]

(ii) Use your answer in **(c)(i)** to show that the decay constant λ of the isotope is approximately $4 \times 10^{-5}\ s^{-1}$

[2]

[Total: 14]

Section B

Answer **one** question from this Section in the spaces provided.