9 **(a)** State what is meant by the mass defect of a nucleus.

....

....

.... [2]

(b) The nuclear fusion reaction for the formation of helium-4 from deuterium is represented by

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He.$$

Table 9.1 shows the masses of the nuclides involved in this reaction.

Table 9.1

nuclide	nuclide mass / u
$^{2}_{1}H$	2.013 553
$^{4}_{2}He$	4.001 505

Calculate the energy released in the formation of 1.00 mol of helium-4.

energy = ... J [4]

(c) The star Sirius has a radius of 1.19×10^{9} m and loses mass due to nuclear fusion at a rate of 1.09×10^{11} kg s^{-1}. Assume that the power of the radiation emitted by the star is equal to the power released by this process.

(i) Determine a value for the luminosity of Sirius. Give a unit with your answer.

luminosity = ... unit .... [2]

(ii) Use your answer in **(c)(i)** to determine the surface temperature of Sirius.

surface temperature = ... K [2]

(d) Explain how cosmologists use standard candles to estimate the distance of a galaxy from the Earth.

....

....

....

....

.... [3]

[Total: 13]

11 The deuterium nucleus ($^{2}_{1}H$) has a mass defect of 0.002 388 u. The helium-4 nucleus ($^{4}_{2}He$) has a mass defect of 0.030 377 u. Helium-4 is formed from deuterium in a nuclear reaction that can be represented by the equation

$$3\,^{2}_{1}H \longrightarrow \,^{4}_{2}He + \,^{1}_{1}p + \,^{1}_{0}n.$$

(a) **(i)** State the name of this type of nuclear reaction.

.... [1]

(ii) Show that the energy released when one nucleus of helium-4 is formed from deuterium is 3.47×10^{-12} J.

[3]

(b) A star has a radius of 6.96×10^{8} m. Helium-4 is produced in this star, from deuterium, at a mass rate of $7.34 \times 10^{11}\,\text{kg}\,\text{s}^{-1}$. All the energy released from this process is radiated away from the star. All the energy that is radiated from the star is released by this process.

(i) Calculate the luminosity of the star.

luminosity = ... W [3]

(ii) Use your answer in **(b)(i)** to determine the surface temperature of the star.

temperature = ... K [2]

[Total: 9]

9 Polonium-193 ($^{193}_{84}Po$) is an unstable nuclide. A nucleus of polonium-193 decays to a nucleus of lead-189 ($^{189}_{82}Pb$) by emitting an alpha-particle.

(a) Radioactive decay is both random and spontaneous.

State what is meant by:

(i) random

....

.... [1]

(ii) spontaneous.

....

.... [1]

(b) Define half-life.

....

....

.... [1]

(c) Data for the binding energy per nucleon of the particles involved in the decay of a nucleus of polonium-193 are given in Table 9.1.

Table 9.1

particle	binding energy per nucleon / eV
$^{193}_{84}Po$	7.774
$^{189}_{82}Pb$	7.826
$^{4}_{2}\alpha$	7.074

Determine the energy, in eV, released when a nucleus of polonium-193 decays into a nucleus of lead-189.

energy = ... eV [2]

(d) A pure sample of polonium-193 contains N_0 nuclei. After a time t the sample contains N nuclei of polonium-193. The variation of $\ln(N/N_0)$ with t is shown in Fig. 9.1.

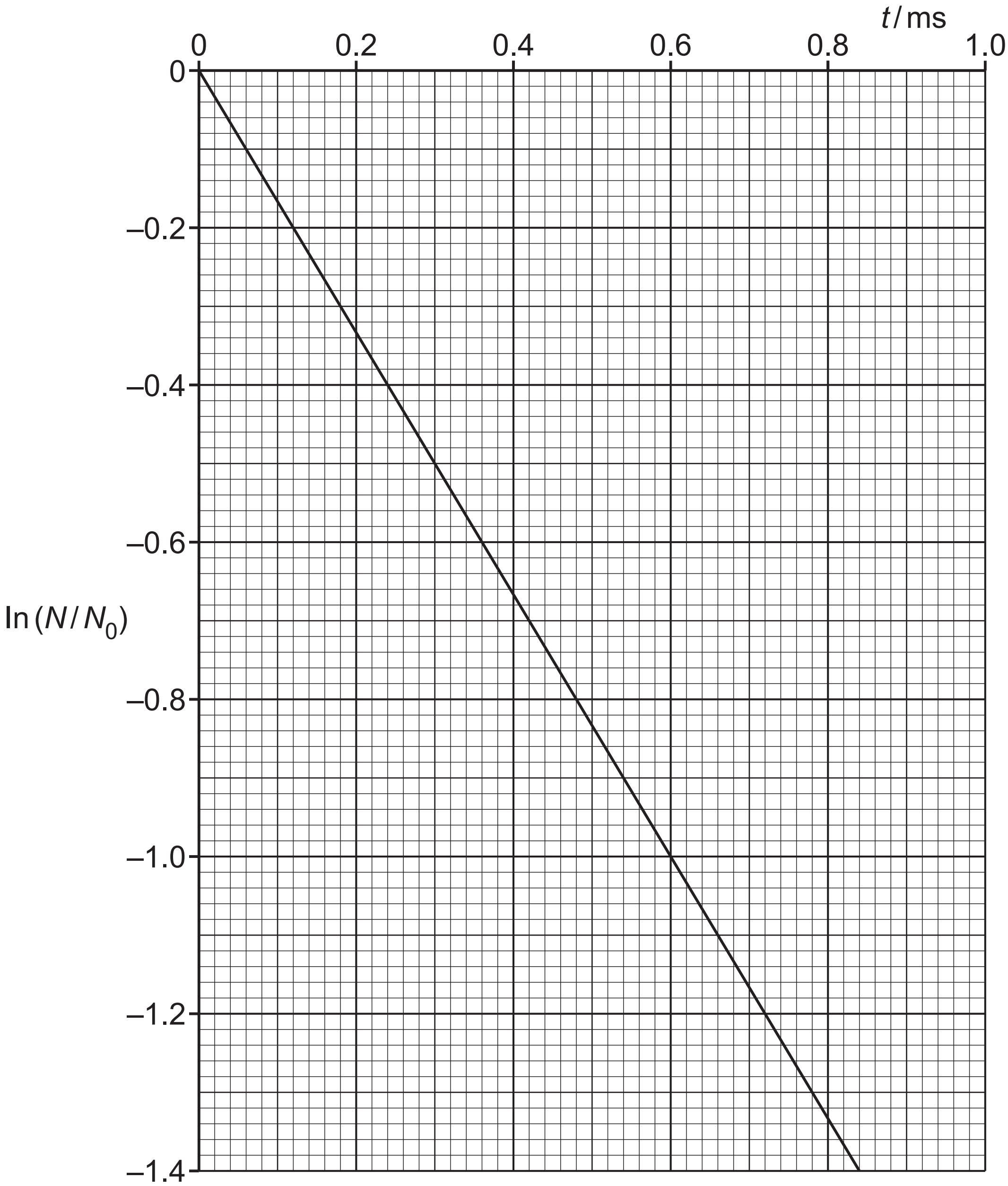

Fig. 9.1

(i) State the name of the quantity that is represented by the magnitude of the gradient of the line in Fig. 9.1.

.... [1]

(ii) Use Fig. 9.1 to determine the half-life, in ms, of polonium-193.

half-life = ... ms [2]

(e) Positron emission tomography (PET scanning) uses a radioactive tracer.

(i) State what happens to the positrons emitted by the tracer.

....

.... [1]

(ii) Explain why a tracer with a half-life of approximately 2 hours is a suitable tracer to use.

....

.... [1]

[Total: 10]