8 **(a)** State what is meant by a photon.

.....

.....

..... [2]

(b) A stationary nucleus of uranium-238 ($^{238}_{92}$U) undergoes alpha decay to produce a nucleus of thorium-234 ($^{234}_{90}$Th). The kinetic energy of the emitted alpha particle is 4.200 MeV. A gamma-ray photon is also emitted during the decay.

Assume that the rebound kinetic energy of the thorium nucleus is negligible.

Table 8.1 shows the masses of the nuclides involved in the decay reaction. The mass of the uranium-238 nuclide is missing.

Table 8.1

nuclide	nuclide mass / u
$^{4}_{2}\alpha$	4.000 407
$^{234}_{90}$Th	233.915 174
$^{238}_{92}$U	

The total energy released in the decay of the nucleus of uranium-238 is 4.274 MeV.

(i) Calculate the mass, in u, of the uranium-238 nuclide. Give your answer to five decimal places.

mass = ... u [3]

(ii) Determine a value for the wavelength of the gamma radiation emitted during the decay of the uranium-238 nucleus.

wavelength = ... m [3]

(iii) In practice, the rebound kinetic energy of the thorium nucleus is **not** negligible.

Explain, without further calculation, how your answer in **(b)(ii)** compares with the true wavelength of gamma radiation emitted during the decay of the uranium-238 nucleus.

.....

.....

..... [1]

(c) Gamma radiation emitted during the decay of a sample of uranium-238 has a single wavelength.

Nuclei of cobalt-60 ($^{60}_{27}$Co) decay by beta emission, and also emit gamma radiation in the process.

Suggest why there is **not** a single wavelength for the gamma radiation emitted during the decay of a sample of cobalt-60.

.....

.....

..... [2]

[Total: 11]

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

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

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

Table 9.1

nuclide	nuclide mass / u
$^{2}_{1}\mathrm{H}$	2.013 553
$^{4}_{2}\mathrm{He}$	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 $1.09 \times 10^{11}\,\mathrm{kg\,s^{-1}}$. 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]

8 Oxygen-15 ($^{15}_{8}O$) is radioactive and has a half-life of 2.04 minutes.

The decay of oxygen-15 produces positrons. For this reason, oxygen-15 is sometimes used as a tracer in positron emission tomography (PET scanning).

(a) State what is meant by a tracer.

.....

.....

..... [2]

(b) The equation for the decay of oxygen-15 is

$$^{15}_{8}O \rightarrow {}^{P}_{Q}X + {}^{R}_{S}\beta^{+} + Z$$

where X is the nucleus formed during the decay and Z is another particle.

(i) State the values of the integers *P*, *Q*, *R* and *S*.

P = ... *R* = ...

Q = ... *S* = ...

[2]

(ii) State the name of particle Z.

..... [1]

(c) **(i)** Define the activity of a sample.

.....

..... [1]

(ii) Calculate the decay constant of oxygen-15. Give a unit with your answer.

decay constant = ... unit ..... [2]

(iii) Determine the rate at which positrons are produced in a sample of oxygen-15 that has a mass of 2.85×10^{-6} kg.

rate = ... s^{-1} [4]

(d) The particles that are emitted from the body and detected outside it during PET scanning are not positrons but another type of particle.

(i) State the name of the particles that are detected.

..... [1]

(ii) Explain how these particles are formed inside the body.

.....

.....

.....

..... [2]

[Total: 15]

38 A nucleus W of a radioactive isotope emits a β^- particle and forms nucleus X.

Nucleus X emits an α-particle to form nucleus Y.

Nucleus Y emits a β^- particle to form nucleus Z.

Which statement about Z is correct?

A Z is a nucleus of a different element from W and has a higher nucleon number.

B Z is a nucleus of a different element from W and has a lower nucleon number.

C Z is a nucleus of the same element as W and has a higher nucleon number.

D Z is a nucleus of the same element as W and has a lower nucleon number.