1 The physics department in a college has a number of radioactive sources which are used to demonstrate the properties of ionising radiations.

The sources include Am-241 which emits alpha radiation, Sr-90 which emits beta radiation and Co-60 which emits gamma radiation.

(a) The physics teacher checks the internet to assess the risks to students of using the sources.

(i) Explain why Am-241 only poses a health risk when ingested or inhaled.

(2)

(ii) State why external exposure to the Co-60 source is dangerous.

(1)

(iii) Suggest how the Sr-90 source should be handled and stored so that it poses minimal health risk.

(2)

(b) The decay of each radioactive isotope is described in a textbook as being random. A student states that this means that we cannot be sure which nuclei will decay and that we cannot determine when the activity of the source will be at a safe level.

Comment on the student's statement.

(2)

(Total for Question = 7 marks)

2 Tritium is an isotope of hydrogen which can be produced in the upper atmosphere by the bombardment of nitrogen with neutrons produced from cosmic rays.

(a) Complete the nuclear equation for the production of tritium

(2)

$$^{14}N + \quad n \rightarrow \quad {}_{6}C + {}^{3}_{1}H$$

(b) Tritium can be used to date water samples that are less than about 75 years old, as tritium is radioactive with a half-life of 12.3 years. 1 m^3 of water collected in 2015 from an underground pool of water was measured to have a corrected activity of 1.08 Bq.

(i) State why the activity must be corrected.

(1)

(ii) State how the accuracy of the activity obtained for 1 m^3 of water could be improved.

(1)

(iii) Calculate what the corrected activity of 1 m^3 of water from the same pool would have been in 1950. No further water has been added to the pool since 1950.

(4)

Corrected activity =

(c) Tritium is used in nuclear fusion experiments. A large amount of energy is released in its reaction with deuterium.

$$^{3}H + {}^{2}H \rightarrow {}^{4}He + n$$

Nucleus	**Mass / u**
n	1.0087
^{2}H	2.0136
^{3}H	3.0155
^{4}He	4.0015

(i) Calculate the energy, in J, released when a tritium nucleus undergoes fusion with a deuterium nucleus.

(4)

Energy released = J

(ii) Explain the conditions necessary for a nuclear fusion experiment to maintain a continuous power output.

(2)

(Total for Question = 14 marks)

3 In March 2011, a nuclear meltdown occurred at the Fukushima Nuclear Power Plant and radioactive materials were released into the environment.

A month later, seaweed off the coast near Long Beach, California was found to be contaminated with iodine-131, a radioisotope that decays by emitting β particles. In one sample the activity was found to be 2.5 Bq per gram of dry seaweed.

(a) State what is meant by the activity of a radioactive source.

(1)

(b) A Geiger counter is used to measure the count from a sample of seaweed over a period of 10 minutes. The corrected readings obtained are shown in the table below.

Corrected count 1	Corrected count 2	Corrected count 3	Corrected count rate / Bq
3820	3830	3825	6.38

(i) State why the readings obtained from the Geiger counter have to be corrected.

(1)

(ii) Explain why the radioactive count is repeated.

(2)

(iii) The measurements were repeated with the same sample of seaweed 30 days later. Calculate the new corrected count rate of the sample.

half-life of iodine-131 = 8.0 days

(3)

New corrected count rate =

(iv) There is a moderate risk to the public from the accumulation of iodine-131 in the seaweed. Explain why.

(2)

(Total for Question = 9 marks)

4 When a photographic film that is not exposed to light is placed near to a source of ionising radiation the film darkens.

(a) (i) State what is meant by ionising radiation.

(1)

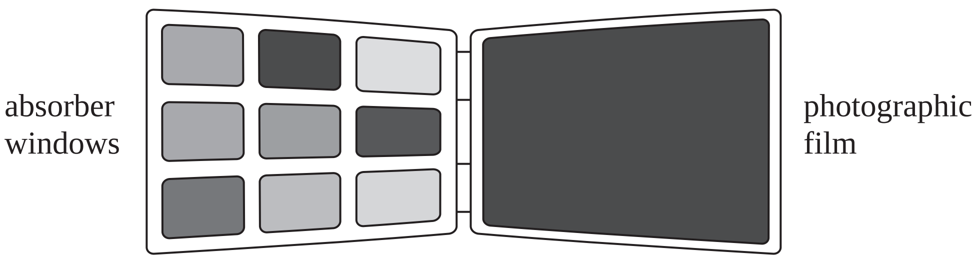
(ii) Complete the table to show α, β, and γ radiations in order of increasing ionising power.

(1)

Least ionising	⟶	Most ionising

(b) In a physics lesson some students are learning about the use of a film badge to monitor exposure to ionising radiation.

Each absorber window is made from a different material and the type of radiation can be determined from the extent to which the film is darkened.



film badge

The students are asked to predict what would happen if α, β, and γ radiations were incident upon absorber windows made from paper, aluminium and lead.

(i) Complete the table to show the penetration of α, β, and γ radiations through each material.

Use the words "passes through" or "stopped".

(3)

	Paper	**0.5 cm aluminium**	**0.5 cm lead**
α **radiation**		stopped	
β **radiation**			stopped
γ **radiation**	passes through		

(ii) In a nuclear power plant there may be other radiation present which would **not** be detected by a film badge.

Suggest what type of radiation this is and why it would not be detected by a film badge.

(2)

(Total for Question = 7 marks)

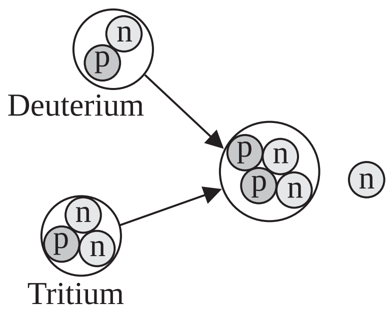
5 The following passage is adapted from a recent article in a British newspaper:

"Every year, one typical coal-fired power station devours several million tonnes of fuel and produces even more carbon dioxide. That volume of carbon dioxide is damaging the atmosphere and, in the longer term, the fuel will run out. It is clear that the world needs an alternative for generating energy.

Nuclear fusion looks like offering a solution to the problem. Using the equivalent of a bath tub of water, fusion has the potential to deliver the same amount of energy as 100 tonnes of coal. There would be no carbon dioxide emission, it would be inherently very safe, and would not produce any significant radioactive waste."

(Adapted from an article in The Observer newspaper, Sunday 16th September 2012)

(a) The latest proposed fusion reactor will fuse deuterium and tritium, which are isotopes of hydrogen. This fusion reaction is illustrated below.



(i) Complete the nuclear equation below to represent this fusion reaction.

(2)

$$\text{H} \; + \; \text{H} \; \rightarrow \; \text{He} \; + \; \text{n}$$

(ii) Calculate the energy released in the fusion of one deuterium nucleus with one tritium nucleus.

Particle	Mass / GeV/c^2
Proton	0.938272
Neutron	0.939566
Deuterium	1.875600
Tritium	2.808900
Helium	3.727400

(2)

Energy released =

(iii) Explain why most of the energy released in the fusion of one deuterium nucleus with one tritium nucleus is transferred to kinetic energy of the neutron.

(3)

(b) A sample of tritium is produced. Tritium is unstable and decays by β^- emission with a half-life of 12.3 years.

Calculate the time taken, in years, for the activity of the sample to fall to 10% of its initial value.

(3)

Time taken = years

*(c) The article states that “it would be inherently very safe, and would not produce any significant radioactive waste.”

Comment on this statement and outline the technical difficulties of producing a practical nuclear fusion reactor.

(5)

(Total for Question = 15 marks)