Chapter 4.5 Exam Q
Question 1

Year 11

(4 marks)

A worker with a mass of 85.5 kg was involved in a nuclear accident and received 9.55 J of radioactive energy from an alpha source. Calculate the dose equivalent the worker received. Include the correct unit in your answer. Show **all** workings.

Question 2

(3 marks)

Medical workers are instructed to reduce their health risk from exposure to radioisotopes by following the procedures listed below. Explain how each procedure protects medical workers.

Limit time of exposure

Maximise distance from radiation sources

Wear protective clothing and use protective shielding devices

Question 3

(10 marks)

Technetium-99m (Tc-99m) has a half-life of 6 hours and emits only gamma rays. It is used as a radioactive tracer to diagnose illness, which means it is swallowed and collects in the part of the body that needs to be seen. A detector is then used to form an image of that part of the body.

(a) Select a characteristic of Tc-99m that makes it a good choice for use as a radioactive tracer and explain the benefit of this characteristic. (2 marks)

(b) The initial activity of a sample used as a radioactive tracer is 320 Bq. While no activity is safe, it is considered that an activity of 5.00 Bq gives a significantly-reduced risk. How long after swallowing can a patient expect to wait to achieve a significantly-reduced risk? (3 marks)

(c) The energy released to a particular body organ of mass 3.00 kg that Tc-99m collects in is 3.10×10^{-2} J in one minute. What is the absorbed dose in this time? (3 marks)

(d) If a different radioisotope that emitted only alpha radiation was used by mistake to produce the same absorbed dose, it would have a much higher dose equivalent. Give an explanation for this difference. (2 marks)

Question 4

(15 marks)

Food that is intended for storage needs to be treated to minimise the presence of organisms that could cause the food to become spoiled and unfit for eating. One method used to prolong storage is irradiation, which is achieved by exposing the food to a radioactive isotope to kill any contaminating organisms. The isotope caesium-137, which has a half-life of 30.2 years, is commonly used for this process.

(a) Caesium-137 is not available naturally and must be produced through nuclear fission. Neutron bombardment of uranium-235 creates the parent isotope uranium-236 which undergoes fission. One possible fission outcome would create caesium-137, rubidium-96 and some neutrons as shown in the equations below.

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U$$

$$^{236}_{92}U \rightarrow ^{137}_{55}Cs + ^{96}_{X}Rb + Y\,^{1}_{0}n$$

Determine the values for X and the number of neutrons Y. (2 marks)

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Question 4 continued

(b) Caesium-137 undergoes radioactive decay to form a short lived, excited, metastable barium-137m (m for metastable) and another particle. The barium-137m then undergoes gamma emission to become a stable barium isotope.

(i) Complete the equation below for this decay chain, showing clearly the missing particle. (2 marks)

$$^{137}_{55}Cs \rightarrow {}^{137m}_{56}Ba + \_\_\_\_\_$$

$$^{137m}_{56}Ba \rightarrow {}^{137}_{56}Ba + {}^{0}_{0}\gamma$$

(ii) Outline **two (2)** properties that make caesium-137 a good choice for food irradiation. (2 marks)

(c) Caesium-137 has a half-life of 30.2 years, whereas barium-137m has a half-life of 153 s and barium-137 is stable. Using this half-life information, explain which of these two unstable isotopes would be more abundant in a sample used for irradiation in the following situations. (4 marks)

A newly processed sample of caesium-137 ready to be used for irradiation would contain more of the unstable isotope _____ because

A 25 year old sample of caesium-137 ready to be replaced would contain more of the unstable isotope _____ because

(d) To increase the shelf life of some chicken meat, it is exposed to radiation. How much energy is absorbed by 1.50 kg of meat when given a dose of 3000 Gy? (3 marks)

(e) Name a precaution used by workers in this situation to limit their exposure to ionising radiation and explain how it reduces exposure. (2 marks)

Question 5

(4 marks)

The Fukushima nuclear disaster in March 2011 was a result of a combined earthquake and tsunami. Radioactive caesium and iodine were released into the atmosphere and, while most of Japan's population received little additional radiation, workers at the plant itself received, on average, 400 mSv.

Determine the amount of energy in joules that a worker with a mass of 57.0 kg could have received from radiation in the accident if caesium and iodine are both beta and gamma emitters.