Solutions Ch 4.5 Year 11

Answer 1

(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.

Description	Marks
Absorbed dose = energy / mass = 9.55 / 85.5 = 0.112 Gy	1–2
Dose equivalent = absorbed dose × quality factor = 0.112 × 20 = 2.23	1
Sv	1
Total	**4**

Answer 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

Description	Marks
Reduces total absorbed dose	1
Reduces concentration of radiation (inverse square)	1
Blocks radiation from penetrating to living tissue	1
	Total 3

Answer 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)

Description	Marks
Gamma emitter radiation needs to penetrate to be detected outside the body	1 1
OR Short half-life – decays to a safe level relatively quickly	
	Total 2

Answer 3 continued

(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)

Description	Marks
320 160 80 40 20 10 5	1
n = 6 half lives	1
t = 6×6 = 36 hours	1
	Total 3

(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)

Description	Marks
Absorbed dose = $\frac{\text{energy}}{\text{mass}}$	1
= $\frac{0.031}{3}$	1
= 1.03×10^{-2} Gy	1
	Total 3

(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)

Description	Marks
Explain dose equiv = abs dose × QF	1
QF of alpha is 20× greater	1
	Total 2

Answer 4

(15 marks)

(a) Determine the values for X and the number of neutrons Y

X = ____**37**_____ Y = _____**3**_____ (2 marks)

Description	Marks
X = 37	1
Y = 3	1
Total	2

(b) Caesium-137 undergoes radioactive decay to form a short lived metastable barium-137m (m for metastable) and another particle. The barium-137m then undergoes gamma emission to become a stable barium isotope. (4 marks)

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

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

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

Description	Marks
Identifies beta decay	1
Properly shows $^{0}_{-1}\beta$ or $^{0}_{-1}e$ in equation	1
Total	**2**

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

Description	Marks
Produces gamma particles which has higher penetrating ability.	1
Reasonably long half-life	1
Total	**2**

(c) 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 _____

Description	Marks
Caesium-137	1
A new sample will contain mostly what was put in it	1
Caesium-137	1
Still has not yet reached its half life, so there should still be more than half left in the sample	1
Total	**4**

(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)

Description	Marks
E = Absorbed dose × m (identifies absorbed dose)	1
= 3000 × 1.5	1
= 4.50×10^3 J	1
Total	**3**

(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)

Description	Marks
Precaution and explanation 1 mark each. For example: Use shielding – blocks radiation; Increase distance from source – decreases exposure; Use dosimeter – monitor exposure to limit; etc	1–2
Total	**2**

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Answer 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 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.

Description	Marks
Students must show understanding that mSv is dose equivalent and include appropriate calculations for explanation Absorbed dose = dose equivalent / QF = 0.400 / 1 = 0.400 Gy	1–2
Energy = absorbed dose × mass = 0.400 × 57.0 = 22.8 J	1–2
Total	**4**