3.27 Radioactivity, Half-Life and Nuclear Uses: 30-minute Pack

Total Marks

AQA 8464 · Calculator allowed · about 30 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Radiation dose is measured in sieverts (Sv) and takes into account the type of radiation and the amount absorbed by the body's tissues.

(a) State two factors that affect the radiation dose a person receives from a source. **(2)**

(b) Workers at a nuclear power station are only allowed to spend a limited, carefully controlled amount of time in areas of the plant with higher radiation levels, and they wear a radiation dose badge at all times. Explain why limiting their time reduces their radiation dose, and why wearing a dose badge does not, by itself, reduce the dose they receive. **(2)**

(Total for Question 1 is 4 marks)

© Revision Library | revisionlibrary.co.uk

2 A technician places a GM tube near an unknown radioactive source. She measures the count rate (with background already subtracted) using different absorbers placed between the source and the tube:

Absorber: none, corrected count rate = 620 counts/min
Absorber: paper, corrected count rate = 618 counts/min
Absorber: 5 mm aluminium, corrected count rate = 15 counts/min
Absorber: 25 mm lead, corrected count rate = 14 counts/min

Absorber	Corrected count rate (counts/min)
none	620
paper	618
5 mm aluminium	15
25 mm lead	14

(a) Identify the type(s) of radiation emitted by the source, using the results above to explain your reasoning. **(3)**

(b) State one variable that should be kept the same throughout this investigation to make it a fair test. **(1)**

(c) Explain why the technician subtracts a background count rate (measured with no source present) from each of her readings before recording the results shown above. **(2)**

(Total for Question 2 is 6 marks)

© Revision Library | revisionlibrary.co.uk

3 Cobalt-60 (60/27 Co) is a β-emitting source used to sterilise medical equipment. During β decay, a neutron in the nucleus changes into a proton and an electron, and the electron is emitted from the nucleus as a β particle, written 0/-1 e.

(a) Write the balanced nuclear equation for the β decay of cobalt-60 to form nickel (Ni). **(2)**

(b) Explain why the mass number stays the same during β decay, but the atomic number increases by 1. **(2)**

(Total for Question 3 is 4 marks)

---

4 A radioactive source has an initial activity of 480 Bq. Its half-life is constant. After 3 hours, the activity of the source has fallen to 60 Bq.

(a) Define the term half-life. **(1)**

(b) Show that the half-life of this source is 1 hour. **(3)**

(Total for Question 4 is 4 marks)

© Revision Library | revisionlibrary.co.uk

5 Radon gas is a naturally occurring radioactive gas that can build up inside some homes, especially in areas with granite rock, and is an α emitter.

(a) Explain why breathing in radon gas is much more hazardous than being near a sealed α source held at a safe distance outside the body. **(2)**

(b) Suggest one practical way homeowners in high-radon areas can reduce radon levels inside their homes. **(1)**

(Total for Question 5 is 3 marks)

6 A radioactive isotope used in industry has a half-life of 8 days. A newly-prepared sample has an activity of 640 Bq.

(a) Calculate the activity of the sample after 24 days. **(2)**

(b) The sample can only be disposed of as low-level waste once its activity has fallen to 40 Bq or below. Calculate the minimum time that must pass before this is possible. **(2)**

(Total for Question 6 is 4 marks)

© Revision Library | revisionlibrary.co.uk

Mark scheme · 3.27 Radioactivity, Half-Life and Nuclear Uses: 30-minute Pack

Question 1

(a) one correct factor affecting the radiation dose, from: type of radiation; distance from the source; time exposed to the source; amount of shielding used; activity of the source, oe **B1**

(a) a second, different correct factor from the same list (max 2 marks; do not credit the same factor twice) **B1**

(a) Answer: Any two of: type of radiation, distance from the source, time of exposure, shielding used, activity of the source.

(b) reducing the time spent exposed to a radiation source reduces the total dose received, since dose builds up the longer a person is exposed, oe **B1**

(b) a dose badge only measures/records the radiation dose a worker has received; it does not block, absorb or reduce the radiation reaching them, oe **B1**

(b) Answer: Less exposure time means a lower total dose; the badge only measures the dose received, it does not shield the worker or reduce the radiation itself.

Question 2

(a) the count rate barely changes when paper is added (620 to 618), so no significant α radiation is present, since α would be almost completely absorbed by paper, oe **B1**

(a) the count rate drops sharply (from about 618 to about 15 counts/min) when aluminium is added, showing that β radiation is present, since β is absorbed by a few mm of aluminium, oe **B1**

(a) the count rate changes very little between aluminium and lead (15 to 14), showing the remaining radiation is γ, since γ is only slightly reduced even by thick lead; conclusion: the source emits β and γ radiation, oe **B1**

(a) Answer: The source emits β and γ radiation (no significant α radiation is present).

(b) any one of: the distance between the source and the GM tube; the counting time for each reading; the GM tube/detector used, oe **B1**

(b) Answer: The distance between the source and the GM tube (or the counting time for each reading).

(c) there is always some radiation present from natural background sources (e.g. cosmic rays, rocks) that the GM tube would detect even with no source present, oe **M1**

(c) subtracting this background gives a corrected count rate due only to the source under investigation, making the results accurate/valid, oe **A1**

(c) Answer: So the recorded count rate is due only to the source being investigated, not background radiation, giving accurate, valid results.

Question 3

(a) nickel nuclide correctly identified as 60/28 Ni, oe **M1**

(a) 60/27 Co -> 60/28 Ni + 0/-1 e, cao **A1**

(a) Answer: 60/27 Co -> 60/28 Ni + 0/-1 e

(b) a neutron changes into a proton (and an emitted electron), so the total number of nucleons (protons + neutrons) in the nucleus stays the same, oe **B1**

(b) the number of protons increases by 1, as a neutron becomes a proton, which increases the atomic number by 1, oe **B1**

(b) Answer: A neutron converts into a proton, so the nucleon (mass) number is unchanged, but the proton (atomic) number increases by 1.

Question 4

(a) the time taken for the activity (or count rate, or number of undecayed nuclei) of a radioactive sample to halve, oe **B1**

(a) Answer: The time taken for the activity of a radioactive source to fall to half its original value.

(b) 480 -> 240 after 1 half-life **M1**

(b) 240 -> 120 -> 60 after 2 further half-lives (3 half-lives in total to reach 60 Bq) **M1**

(b) 3 half-lives occur in 3 hours, so half-life = 1 hour, cao **A1**

(b) Answer: 1 hour

Question 5

(a) outside the body, α particles have a very short range and are absorbed by a few cm of air (or the outer dead layer of skin), so they cannot reach living cells, oe **B1**

(a) if inhaled, the gas is inside the lungs in direct contact with living tissue, and α radiation is strongly ionising, so it deposits all its energy over a very short distance, causing intense localised damage to lung cells/DNA, oe **B1**

(a) Answer: Outside the body α radiation is stopped before it reaches living cells; inhaled radon is in direct contact with lung tissue, where strongly ionising α radiation causes serious localised cell/DNA damage.

(b) any sensible answer, e.g. improve ventilation (fit an extractor fan or a radon sump beneath the floor to vent the gas outside); seal cracks in floors/walls to stop gas entering the building, oe **B1**

(b) Answer: Improve ventilation, for example by fitting a radon sump or extractor fan beneath the floor to vent the gas safely outside.

Question 6

(a) 24 / 8 = 3 half-lives **M1**

(a) 640 -> 320 -> 160 -> 80; activity = 80 Bq, cao **A1**

(a) Answer: 80 Bq

(b) 640 / 40 = 16 = 2^4, so 4 half-lives are needed (or: continuing from 80 Bq, one further half-life gives 40 Bq, 4 half-lives in total) **M1**

(b) time = 4 x 8 = 32 days, cao **A1**

(b) Answer: 32 days

© Revision Library | revisionlibrary.co.uk