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QUESTION WORKBOOK

Radioactive decay and half-life

Nuclear physics · Year 13

AQA 3.8.1.3, 3.8.1.4 · CIE 11.1.6, 11.1.11, 23.2.1, 23.2.2, 23.2.3, 23.2.4, 23.2.5, 23.2.6
OCR A 6.4.2(h), 6.4.3(a), 6.4.3(c), 6.4.3(d), 6.4.3(e)(i), 6.4.3(f)(i), 6.4.3(f)(ii), 6.4.3(g), 6.4.3(h)

20 questions · 54 marks

PRINT EDITION

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SECTION A · Warm-up

A1 Define the half-life of a radioactive isotope. [2]

A2 A sample contains 1.0×10^{20} undecayed nuclei of an isotope with a decay constant of $0.02\ s^{-1}$. Calculate the activity of the sample. [2]

A3 State the relationship between the half-life of an isotope and its decay constant. [1]

A4 Radioactive decay is described as a random process. Explain what this means. [2]

A5 Define the activity of a radioactive source and state its SI unit. [2]

A6 A nucleus left in an excited state after a decay emits a gamma photon. State what happens to the proton number and the nucleon number of the nucleus, and explain why the photon is emitted. [2]

SECTION B · Standard

B1 An isotope has a half-life of 6.0 hours. Calculate its decay constant in hour^{-1}. [2]

B2 A sample initially contains 8.0×10^{20} undecayed nuclei of an isotope with a half-life of 5.0 days. Calculate the number of undecayed nuclei remaining after 15 days. [3]

B3 A source has an initial activity of 400 Bq. Calculate its activity after two half-lives. [2]

B4 A sample contains 5.0×10^{18} undecayed nuclei of an isotope with a half-life of 8.0 s. Calculate the activity of the sample. [3]

B5 A sealed medical source contains 4.2 μg of iodine-131, which has a half-life of 8.0 days and a molar mass of 131 g mol^{-1}. Calculate the activity of the source.
$N_A = 6.02 \times 10^{23}$ mol^{-1}, 1 day = 86 400 s [4]

B6 A student measures the activity A of a sample at intervals and plots ln (A/Bq) against time. The graph is a straight line with gradient -0.046 $minute^{-1}$. State what the straight line shows about the decay, and determine the half-life of the sample. [4]

B7 Cobalt-60, $^{60}_{27}Co$, decays by beta-minus emission to an isotope of nickel, Ni. Write the equation for this decay. [2]

B8 A nuclide lies below the line of stability on a graph of neutron number against proton number, so it has too few neutrons for its number of protons. State two decay processes by which it could move towards the line, and describe the change inside the nucleus that both processes produce. [3]

SECTION C · Stretch

C1 A source has an initial activity of 600 Bq and a half-life of 10 hours. Calculate its activity after 25 hours. [3]

C2 The activity of a source falls from 800 Bq to 50 Bq. The half-life of the isotope is 3.0 days. Determine the time taken. [3]

C3 A nuclide lies above the line of stability on a neutron-proton plot, so it has too many neutrons for its number of protons. Predict its likely mode of decay and explain your reasoning. [3]

C4 An engineer injects a radioactive tracer into an underground pipe to locate a leak. The tracer has a half-life of 6.0 hours and an activity of 6.4×10^7 Bq when injected. The leak can be located only while the activity exceeds 1.0×10^7 Bq. Determine the time available to find the leak. [4]

C5 Engineers add a radioactive tracer to the water in a buried pipe to find a leak, detecting the radiation from the surface 0.5 m above. Three tracers are available. P: alpha emitter, half-life 4.0 days; Q: gamma emitter, half-life 8.0 hours; R: gamma emitter, half-life 30 years. Deduce which tracer is most suitable, giving a reason for rejecting each of the others. [4]

C6 Regulations require the activity of a container of radioactive waste to fall below one thousandth of its initial value before it may be moved for disposal. The activity is dominated by an isotope with a half-life of 30 years. Determine the minimum storage time. [3]