



Unit 5 Topic 5 Nuclear decay

1 Background radiation:

Two sources of different origin, e.g. cosmic radiation, rocks, food, radon gas (2)

Complete the boxes:

37 (1), 4 (1)

Time:

$$1.6 \times 10^6 = 5.8 \times 10^{15} e^{-\lambda t} \text{ (OR } N_t = N_0 e^{-\lambda t} \text{)} \quad (1)$$

Correct value of λ (1)

Correct use of \ln 's (1)

OR Use of $\frac{1.6 \times 10^6}{5.8 \times 10^{15}} = \left(\frac{1}{2}\right)^n$ for full credit

Number of years = 950–960 (1)

Storage:

Two problems which are relevant to the very long storage time involved, e.g. deterioration of container; finding a site which will remain safe; long-term monitoring (2)

(Total 10 marks)

2 Experiment (Max 5 marks):

An appropriate set up for detecting α radiation. (1)

Measurement of successive count rates. (1)

At 10–20 second intervals OR total duration ≤ 5 min (1)

G–M tube methods: take background into account OR Ionisation chamber: calibrate meter (1)

Plot appropriate graph (1)

Measure $t_{1/2}$ directly OR find gradient of \ln graph. (1)

Repeat for different coordinates OR $t_{1/2} = \ln 2 / \text{gradient}$ (1)

Sample (Max 2 marks):

Count rate so low, difficult to distinguish from background radiation OR from random fluctuations (1)

Very slow change in count rate difficult to detect over normal experimental times (1)

β absorbed within sample. (1)

(Total 7 marks)

3 Half-life of radionuclide:

One value for half-life: 33 to 36 s (1)

Repeat and average/evidence of two values (u.e.) (1)

Decay constant:

$\ln 2 \div \text{their value for } t_{1/2} \text{ calculated correctly} = (0.02) \text{ s}^{-1} \text{ (u.e.) } \lambda \quad (1)$

Rate of decay:

Tangent drawn at $N = 3.0 \times 10^{20}$ (1)

Attempt to find gradient, ignore minus sign (1)

$= 5.5\text{--}6 \times 10^{18}$ [OR Use of $N = N_0 e^{-\lambda t}$, calculate λ , or other graphical means] (1)



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Decay constant:

Substitute in $dN/dt = -\lambda N$ (1)

e.g. $6 \times 10^{18} = (-)\lambda \times 3 \times 10^{20}$ [their dN/dt] $\lambda = 0.02$ [their λ correctly calculated] (1)

Methods:

EITHER value chosen with a valid reason, e.g. 1st because can take several and average,
1st because difficult to draw tangent (1)

(Total 9 marks)

4 Alpha particle penetration

Strongly/highly likely to collide OR lost e energy rapidly (1)

Description of the process/ionising (1)

Significance (Max 2 marks):

(Average) time for half nuclei/atoms (not particles or mass) to decay OR (1) activity to halve

If short (most decay before excretion) so large dose (1) consequent damage (1) OR

If long (few decay before excretion) so small dose (1) consequent damage (1)

[Do not accept argument in terms of what would happen if material not excreted]

(Total 4 marks)

5 Labels of elements:

D close to O: AND $U \geq 200$ (1)

Fe at peak (1)

Meaning of binding energy (Max 2 marks):

Energy needed to split/separate a nucleus (1) into protons and neutrons/nucleons (1)

OR

Energy released when nucleus formed (1) from protons and neutrons/nucleons (1)

OR

Energy released due to mass change/defects (1); sum of masses of protons and neutrons
> mass of nucleus (1)

[In each of the cases above, the second mark is consequent upon the first]

Explanation (Max 3 marks):

Uranium (1)

Binding energy per nucleon of products is higher (1)

OR Products/atoms/element/nuclei nearer peak (1)

Therefore more stable (1)

(Total 6 marks)



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6 Graph

Sensible scale + point (0, 192) plotted (1)

Rest of points [-1 mark for each misplot] [(1, 96); (2, 48); (4, 12)] (2)

[Accept bar chart]

Random process

Cannot predict which nuclei will decay/when a particular nucleus will decay (1)

Model

Cannot predict which children will flip a head/which coins will be heads/when a particular coin/child will flip a head (1)

Half-life

Time taken for activity/count rate to drop by half/time taken for half the atoms/nuclei to decay (1)

How model illustrates half-life

Yes, if children were told to flip coin at regular time interval

OR

Yes, because about half of the children flipped a head each time

OR

No, because time is not part of the experiment (1)

(Total 7 marks)