Name	Date started	Target end date

GCE A LEVEL — DECAY LAW & HALF-LIFE QUESTION PACK

Legacy PH5 · New spec Unit 3 Topic 5b · A2 unit, 25% of A-level

REVISE
.wales

PHYSICS — UNIT 3 · DECAY LAW & HALF-LIFE

3.5 Nuclear decay — the exponential decay law, activity and half-life

The decay constant λ, activity $A = \lambda N$, the exponential law $N = N_0 e^{-\lambda t}$, $t_{½} = \ln 2 / \lambda$, plus background corrections and Geiger–Müller measurement technique.

NEW 2015 SPEC · UNIT 3 TOPIC 5B

Estimated time for entire question pack: ~55m

Derived from the legacy PH5 paper's pace of 120 marks in 1h 45m.

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH5 papers (2008 modular spec) that maps onto new-spec Unit 3 Topic 5b (3.5).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

For Examiner's use only

Q	Source	Max	Mark
1	PH5 Jun 10 Q2	10	
2	PH5 Jun 16 Q1	11	
3	PH5 Jun 14 Q2	10	
4	PH5 Jun 15 Q4	8	
	Total	**39**	

Decay Law & Half-Life — what the new spec asks

WJEC GCE A Level Physics (from 2015) · Unit 3: Oscillations & Nuclei · Topic 3.5.

Decay constant & activity A

- λ = probability of decay per nucleus per second (units s^{-1}).
- Activity $A = \lambda N$; unit becquerel (Bq).
- Decay is random at the single-nucleus level — only large-N behaviour is predictable.

Exponential decay law A

- $dN/dt = -\lambda N \Rightarrow N = N_0 e^{-\lambda t}$; $A = A_0 e^{-\lambda t}$.
- Half-life $t_{1/2} = \ln 2 / \lambda$ — constant for a given nuclide.
- Half-life is independent of N_0, T, p and chemical environment.

Detection A

- Geiger–Müller tube + scaler gives a count rate proportional to activity (subject to efficiency & geometry).
- Always subtract background count rate before fitting a decay curve.

Working with data A

- Time to fall to a fraction f: $t = (1/\lambda) \ln(1/f)$.
- Integer half-lives: $N/N_0 = (1/2)^n$.
- Convert years to seconds: $\times 3.156 \times 10^7$.

Decay Law & Half-Life in one page

Quick-reference notes — revisit before each section.

Decay constant

Probability of decay per nucleus per second.

Units s^{-1}.

Random at the single-nucleus level.

Activity

Rate of decay, unit becquerel (Bq).

1 Bq = 1 decay per second.

Decreases over time as N falls.

Exponential law

$N = N_0 e^{-\lambda t}$.

$A = A_0 e^{-\lambda t}$ (same shape).

Take ln to linearise: $\ln N = \ln N_0 - \lambda t$.

Half-life

$t_{1/2} = \ln 2 / \lambda \approx 0.693 / \lambda$.

Independent of N_0, T, p, chemistry.

From a graph

Time between any two count-rate values one factor of 2 apart.

Subtract background first — otherwise low-count tail is wrong.

n half-lives

$N/N_0 = (1/2)^n$.

Useful when n is an integer (or low half).

Detection

Geiger–Müller tube + scaler / counter.

Count rate ∝ activity (with fixed geometry & efficiency).

Always subtract background count rate.

Number of nuclei

$N = (\text{mass} / M) \times N_A$.

M in kg mol^{-1}, mass in kg.

Strategy

Given a fraction f at time t: solve $N = N_0 e^{-\lambda t}$ for λ.

Given $t_{1/2}$: $\lambda = \ln 2 / t_{1/2}$.

Given a half-integer of $t_{1/2}$: use $(1/2)^n$.

Questions begin overleaf.

Section index

Use this index to jump straight to the section you need.

A2. Caesium-137 ($^{137}_{55}Cs$) is a radioactive byproduct from fission nuclear power stations. It has a half life of 30 years and emits β^- radiation.

(a) Complete the following reaction equation by entering the appropriate numbers in the boxes. [2]

$$^{137}_{55}Cs \longrightarrow {}^{\square}_{\square}Ba + {}^{\square}_{\square}\beta^-$$

(b) Show that the decay constant of caesium-137 is approximately $7 \times 10^{-10}\ s^{-1}$. [2]

(c) Show that the initial activity of 1.0 kg of caesium-137 is approximately 3×10^{15} Bq. [2]

(d) Explain why 1.0 kg of caesium-137, although it has an activity of 3×10^{15} Bq, would be quite safe in a sealed metal box of thickness 1 cm. [1]

(e) When the activity of 1.0 kg of caesium has dropped to 1000 Bq (comparable to soil) it can be disposed of by mixing with soil and scattering on the ground. Calculate how long it takes for the caesium sample to reduce its activity from 3×10^{15} Bq to 1000 Bq. [3]

Examiner only

SECTION A

Answer **all** *questions.*

1. Polonium-211 decays to lead-207 with a decay constant (λ) of $1.343\,s^{-1}$.

(a) Calculate the half-life of polonium-211. [2]

(b) Calculate the initial activity of 4.22×10^{-11} kg of polonium-211. (The molar mass of polonium-211 is $0.211\,kg\,mol^{-1}$.) [3]

(c) Calculate the percentage of polonium-211 nuclei remaining after 2.4 s. [2]

(d) Calculate the time taken for the number of polonium nuclei to decrease to 0.1% of their initial number. [2]

....

....

....

....

(e) Explain why 4.22×10^{-11} kg of polonium-211 could be highly dangerous even though it emits alpha particles which cannot penetrate human skin. [2]

....

....

....

....

Examiner only

2. *(a)* Radon gas ($^{222}_{86}Ra$) is radioactive and can be a significant health hazard in areas that have a high natural concentration of the gas. Radon decays to a stable form of lead (Pb) via 4 alpha decays and 4 beta decays and radon has a half-life of 3.8 days.

(i) Calculate the mass number and atomic number of this stable isotope of lead (Pb). [2]

....

....

....

....

(ii) Give **three** reasons why radon gas is particularly dangerous. [3]

....

....

....

....

....

....

(b) Calculate the time taken for the number of radon gas particles to decrease to 9.0% of their initial number. [4]

....

....

....

....

....

....

Examiner only

(c) When radon gas is kept in a lead lined container for 3.8 days, the number of radon gas particles halves. However, the activity inside the container is considerably higher than half the original activity. Suggest a reason why. [1]

....

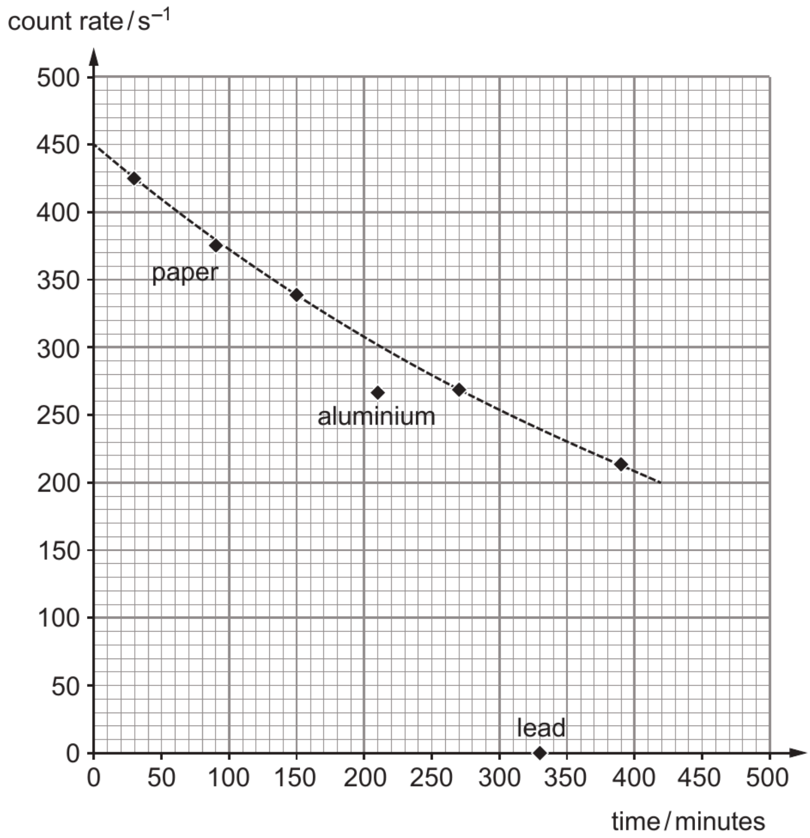
....

....

4. Technetium-99 emits **only** γ (gamma) radiation. An experiment was carried out to show this. Various absorbers were placed between the source and detector at the times shown in the table below and the mean count rate was obtained.

Absorber	Time from the start of the experiment / min	Count rate / s^{-1}
none	30	425
1 sheet (0.1 mm) of paper	90	374
none	150	338
3 mm of aluminium	210	267
none	270	268
10 cm of lead	330	1
none	390	213

These results were plotted on a graph. The decay curve of the technetium-99 itself is plotted as a dotted line which shows the activity dropping continuously as the experiment proceeded.



(a) Determine the half-life of technetium-99. [1]

(b) Explain why the results are consistent with technetium-99 only emitting γ radiation. [3]

(c) The detector only detects 0.6% of the γ radiation emitted by the source. Use the graph and the half-life of technetium-99 to calculate the initial mass of technetium-99 (the mass of a technetium-99 atom is 99 u). [4]

END OF QUESTION PACK

4 questions · 39 marks · ~55m
Source: WJEC PH5 (2008 modular spec)
Curated for WJEC Physics 2015 spec A2 Unit 3 — Topic 5b (3.5)