Essential Pre-Uni Physics J2.1

A Level

A ‘mole’ of nuclei contains 6.02×10^{23} nuclei. The mass of one mole of nuclei (the ‘molar mass’) is approximately equal to $0.001\,\mathrm{kg} \times$ the mass number of the nucleus. Use this approximation wherever you have a question and are not given the molar mass explicitly.

Complete the questions in the table:

Half life	Decay constant / s^{-1}
$53\ \mathrm{s}$	(a)
$12\ \mathrm{years}$	(b)

Part A Half life of $53\,\mathrm{s}$

a) What is the decay constant?

Part B Half life of $12\,\mathrm{years}$

b) What is the decay constant?

Essential Pre-Uni Physics J2.8

A Level

P P P

A 'mole' of nuclei contains 6.02×10^{23} nuclei. The mass of one mole of nuclei (the 'molar mass') is approximately equal to $0.001\,\mathrm{kg}\times$ the mass number of the nucleus. Use this approximation wherever you have a question and are not given the molar mass explicitly.

Part A Number of nuclei

$^{238}\mathrm{U}$ has a half life of $4.47 \times 10^{9}\,\mathrm{years}$. How many $^{238}\mathrm{U}$ nuclei would you need in order to have an activity of $5000\,\mathrm{Bq}$? Give your answer to 2 significant figures (strictly the answer to this question should be given to 1 sig fig, but 2 sig figs allows us to check your method is correct)

Part B Mass of the sample

What is the mass of the $^{238}\mathrm{U}$ sample? Give your answer to 2 significant figures (strictly the answer to this question should be given to 1 sig fig, but 2 sig figs allows us to check your method is correct).

Gameboard:

STEM SMART Physics 32 - Exponentials in radioactivity

Essential Pre-Uni Physics J2.10

A Level

C C C

A ‘mole’ of nuclei contains 6.02×10^{23} nuclei. The mass of one mole of nuclei (the ‘molar mass’) is approximately equal to $0.001\,\mathrm{kg} \times$ the mass number of the nucleus. Use this approximation wherever you have a question and are not given the molar mass explicitly.

A 'radioactive battery' for a long range space probe uses a radioisotope with a decay constant of $4.4 \times 10^{-12}\,\mathrm{s^{-1}}$, and a molar mass of $0.236\,\mathrm{kg}$. Each time one nucleus decays, $2.5 \times 10^{-12}\,\mathrm{J}$ of electrical energy is 'made' by the generator. Calculate the mass of the radioactive sample if the spacecraft requires $200\,\mathrm{J}$ of electricity every second (i.e. this is a $200\,\mathrm{W}$ spacecraft). Give your answer to 2 significant figures.

Gameboard:

STEM SMART Physics 32 - Exponentials in radioactivity

Physics. You work it out.

Home Gameboard Physics Waves & Particles Wave Motion Inverse Square Intensity 16.6

Inverse Square Intensity 16.6

A Level

P P P

When dentists take X-rays, they stand by the door, or outside the room. Calculate the intensity at $3.5\,\mathrm{m}$ from the source as a fraction of the intensity $0.32\,\mathrm{m}$ from it.

Gameboard:

STEM SMART Physics 32 - Exponentials in radioactivity

Physics. You work it out.

Inverse Square Intensity 16.7

A Level

The background count in a laboratory is 36 counts in $40\,\mathrm{s}$. When a gamma source is placed $1.5\,\mathrm{m}$ from the detector, there are 236 counts each minute.

Part A Background-corrected count rate

Calculate the background-corrected count rate in Bq.

Part B Expected background-corrected count rate

Calculate the expected background-corrected count rate $15\,\mathrm{cm}$ from the source.

Gameboard:

STEM SMART Physics 32 - Exponentials in radioactivity

Essential Pre-Uni Physics J3.5

A Level

Tritium has a half life of about 12 years. If you put $3.0\,\mu\mathrm{g}$ of tritium into a luminous sign, how much will still be there $50\,\mathrm{years}$ later?

Gameboard:

STEM SMART Physics 32 - Exponentials in radioactivity

Essential Pre-Uni Physics J3.8

A Level

Carbon-14 has a half life of about $5700\,\mathrm{years}$. What fraction of the original amount of carbon-14 would you expect to find in the timbers of a boat built $8000\,\mathrm{years}$ ago? Give your answer as a decimal to 4 significant figures.

Gameboard:

STEM SMART Physics 32 - Exponentials in radioactivity

Physics. You work it out.

Essential Pre-Uni Physics J3.9

A Level

Uranium-238 has a half life of $4.47 \times 10^9\ \mathrm{years}$ and decays to thorium-234. The thorium decays (by a series of further nuclear processes which are relatively brief) to lead. Assuming that a rock was originally entirely uranium, and that at present, 1.5% of the nuclei are now lead, calculate the age of the rock. Give your answer in years to 2 significant figures.

Gameboard:
STEM SMART Physics 32 - Exponentials in radioactivity

isaac Physics. You work it out.

Isotope Concentrations and Ocean Circulation

A Level

Tritium (hydrogen with two neutrons and one proton) is produced naturally on Earth by the interaction of cosmic rays with nitrogen and oxygen in the upper atmosphere.

Tritium (T) decays to $^{3}\mathrm{He}$ by beta decay. $^{3}\mathrm{He}$ is stable.

$$^{3}_{1}\mathrm{T} \xrightarrow{\beta-} {}^{3}_{2}\mathrm{He} + \mathrm{e}^{-} + \bar{\nu}_{e}$$

In the ocean, tritium can be used as a 'clock' to find the age of 'water parcels'. The clock is reset to zero every time the water parcel reaches the surface, as the $^{3}\mathrm{He}$ can escape to the atmosphere. After leaving the surface, the changing relative concentrations of T and $^{3}\mathrm{He}$ in the water can be used to calculate the time elapsed since the parcel last reached the surface.

Part A Decay constant

Tritium (T) decays to Helium-3 $(^{3}\mathrm{He})$ with a half-life of $12.45\,\mathrm{years}$. Calculate the decay constant of T in years^{-1}.

Part B Fluid parcel age

At the sea surface, $^{3}\mathrm{He}$ escapes to the atmosphere and hence $[^{3}\mathrm{He}] \approx 0$. Given that $^{3}\mathrm{He}$ is the only decay product of T, derive an expression for the time elapsed since a fluid parcel was last at the sea surface t, in terms of the T decay constant λ and the concentrations of $^{3}\mathrm{He}$ and T.

Assume that the concentrations of $^{3}\mathrm{He}$ and T in the water parcel only change by radioactive decay. There is no mixing between water parcels.

Use X for the concentration of $^{3}\mathrm{He}$ and T for the concentration of T.

The following symbols may be useful: `T`, `X`, `lambda`, `t`

Part C Fluid parcel age

At a depth of $250\,\mathrm{m}$ in the seas of Bermuda, the ratio of the concentration of $^{3}\mathrm{He}$ to the concentration of T is 0.23. Calculate the time elapsed since this fluid parcel was last at the sea surface.

Created for Isaac Physics by Chun Hay Brian and Heather Corden.