ATOMS: HALF LIFE QUESTIONS AND ANSWERS

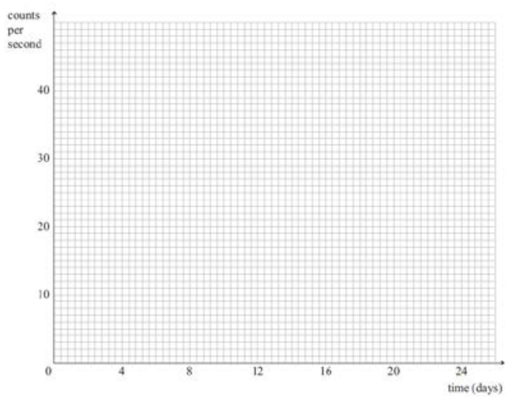
RADIOACTIVE DECAY AND HALF LIFE (2011;3)

(b) Describe what is meant by the term, “half life of a radioactive nuclide”.

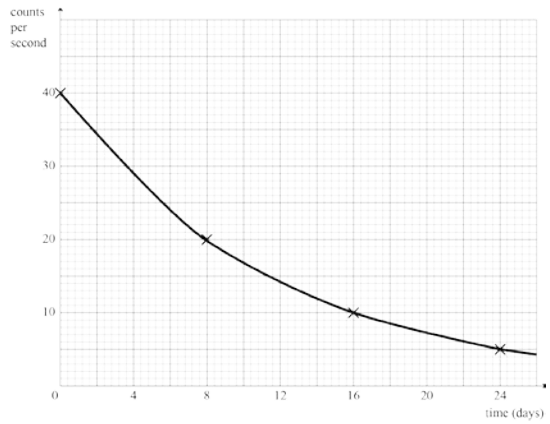
The time taken for half the (number of) radioactive nuclei / atoms to decay.
OR the time for the rate of decay to halve.
OR the time for the activity / count rate to halve
OR the time taken for half the **radioactive** mass to decay*
OR the time taken for half the **radioactive** sample to decay*
OR the time taken for half the **radioactive** substance to decay*
(OR similar but cannot accept any of these * type of answer without the term radioactive)

(c) A Geiger counter is an instrument used to detect radiation. A Geiger counter detects 40 counts per second from a sample of iodine-131. The half life of iodine-131 is 8 days.

(i) Using the axes given below, sketch a graph showing the count rate from the sample of iodine-131 over a period of 24 days.



ANSWER:



(ii) From the graph, deduce the activity of the sample of iodine-131 after 20 days.

Correct value for cps after 20 days is between 6 – 8 cps based on graph.

NUCLEAR MEDICINE (2010;1)

Another useful isotope is Technetium 99m. The letter m stands for metastable, which means it does not decay into a different element. Technetium 99m can be introduced into the body. It emits gamma rays that are detected outside the body, and these are used to make images of various organs. Technetium 99m decays as follows:

$$^{99m}_{43}\text{Tc} \rightarrow {}^{99}_{43}\text{Tc} + {}^{0}_{0}\gamma$$

The half-life of Technetium 99m is 6.0 h.

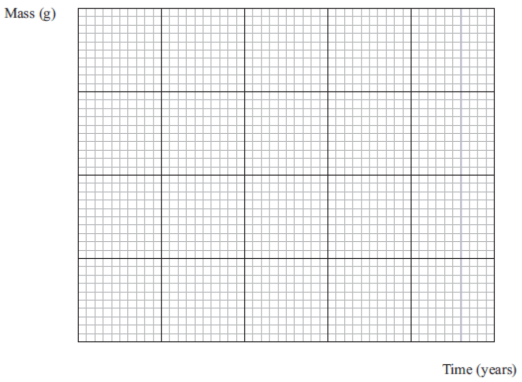
(f) 12 mg (12 x 10^{-3} g) of Technetium 99m is injected into a patient and starts to decay into Technetium 99. Calculate the amount of Technetium 99 present in the patient after 24 hours.

24 hours is 4 half-lives. The Technetium 99**m** reduces to **0.75 mg** (or 0.75×10^{-3} g or 7.5×10^{-4} g or 0.0075). There is 12 – 0.75 = **11.25 mg** (or 11.25×10^{-3} g or 1.125×10^{-2} g or 0.01125 or variants to 2 s.f., e.g. 1.1×10^{-2} g or 11 g) of Technetium 99.

HALF-LIFE (2009;3)

Plutonium-241 ($^{241}_{94}Pu$), which has a half-life of 14 years, is a typical product from a nuclear reactor. Plutonium-241 decays to americium-241($^{241}_{95}Am$).

(a) Draw a graph to show the decay of 32 g of plutonium-241. Use the graph to find the mass of plutonium-241 after 20 years.

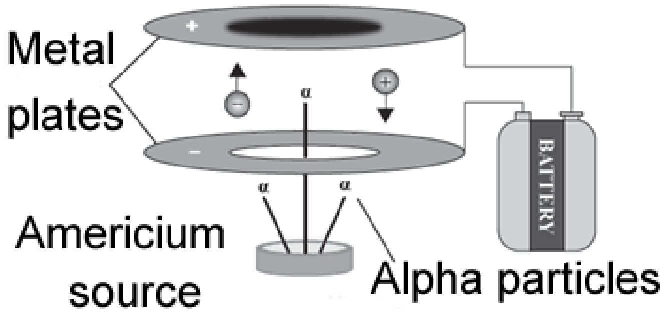


ANSWER:

This response requires a graphical solution.
If a mathematical solution is used, this can only be used to support the graphical solution – it **cannot replace the graphical solution**.
ONLY the graphical solution is to be marked.
If a student confirms their graph mathematically, the confirmation is neutral e.g. an interpolation of 12 g **confirmed** as 11.8 g is acceptable.

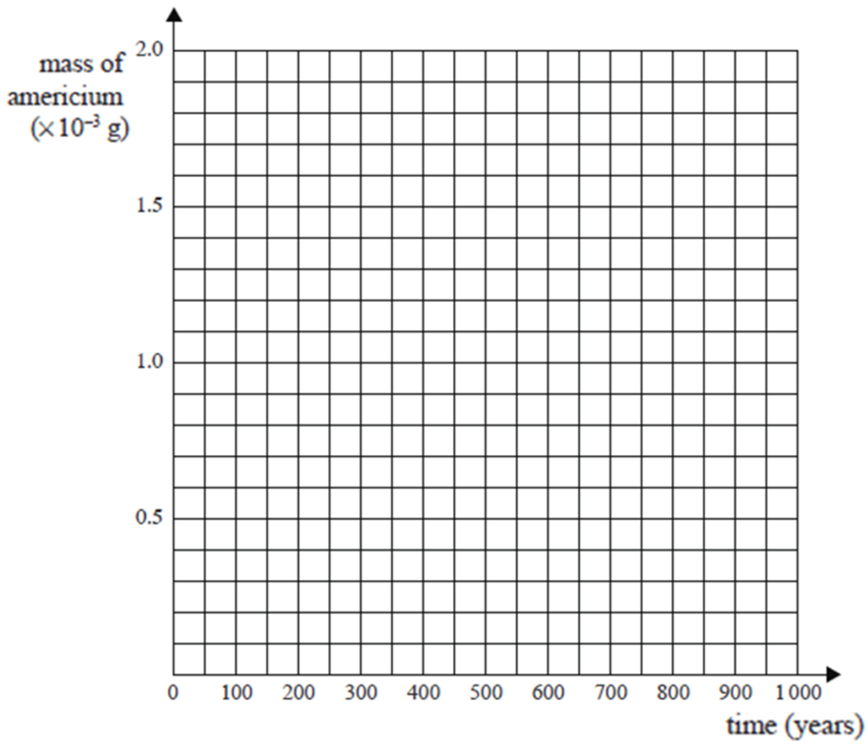
THE SMOKE DETECTOR (2008;1)

Common smoke detectors contain a small amount of the radioactive isotope Americium 241. Americium 241 is an alpha emitter, and decays with a half-life of 432 years. The alpha particles ionise the gases in the air between two metal plates.



One smoke detector has a radioactive source containing 1.6×10^{-3} g of the isotope Americium 241.

(g) Use the graph axes below (or other method) to show how long it takes for 1.0×10^{-3} g of Americium from the original radioactive source to decay. Americium 241 has a half-life of 432 years.



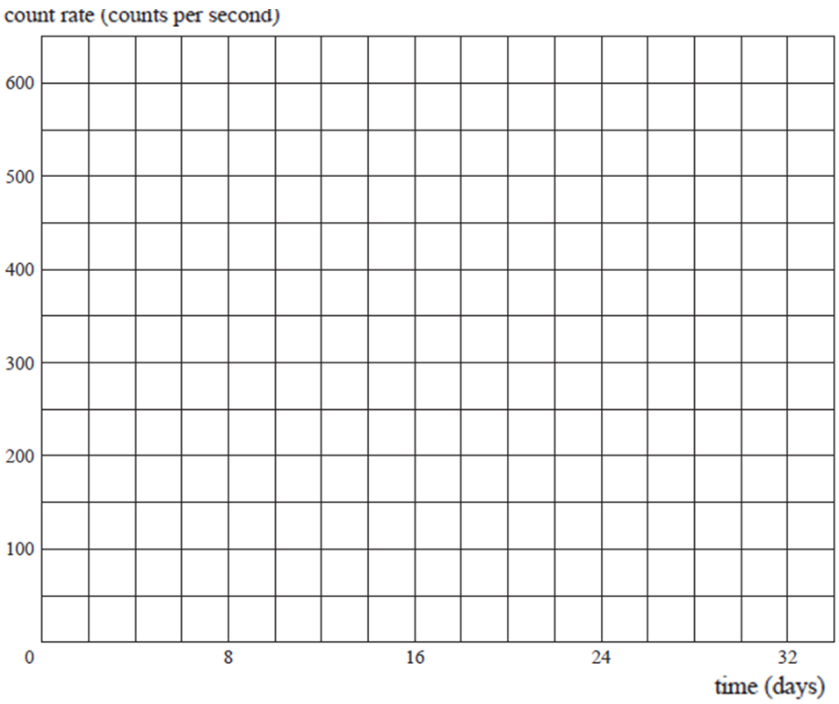
Graph drawn correctly.
Intercept lines for 1.0 mg drawn correctly.
Approx 610 years.

(h) Explain why the mass of the radioactive source is not 0.6×10^{-3} g after this time.

When the Americium decays, it doesn't disappear, but changes into a slightly smaller nucleus (Np). The Neptunium is still there so the **mass is virtually unchanged.**

RADIOACTIVITY (2007;2)

(h) A sample of pure iodine-131 has a decay rate of 600 s^{-1}(counts per second). 16 days later the decay rate has dropped to 150 s^{-1}. Use a graph (or other method) to determine the decay rate after 28 days. **You must show your working**.



By calculation:

One half-life is 8 days (since the rate falls to ¼ after 16 days). 28 days is 3.5 half-lifes.

$$\text{Rate} = 600 \times \left(\frac{1}{2}\right)^{3.5}$$

Rate = 53

OR

By graphing:

After 1 half-life, count rate $= \frac{600}{2} = 300$

After 2 half-lives, count rate $= \frac{300}{2} = 150$

After 3 half-lives, count rate $= \frac{150}{2} = 75$

After 4 half-lives, count rate $= \frac{75}{2} = 37.5$

From graph, decay rate after 28 days is about 50 counts per second.

RADIOACTIVE HALF-LIFE (2006;4)

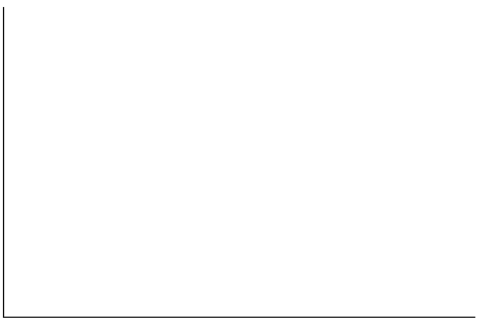
Cobalt 60 is a beta emitter used in medicine. It is created in a nuclear reactor, and decays with a half-life of 5.2 years. It is stored in a lead container until it is used.

(b) State what is meant by the term "half-life".
The time taken for half the (number of) radioactive nuclei to decay
or the time for the rate of decay of an isotope to halve.
or the time for the activity of to halve
(c) In 2001, the contents of a sealed lead container were 2.0 g of radioactive Cobalt 60. Determine the approximate mass of the contents five years later. Explain your answer.
M = 2.0 g.
When the cobalt decays, it changes into another type of nucleus which also has mass, it doesn't disappear. The decrease in mass is negligible.
(d) In what year will the rate of decay of the Cobalt 60 be one-quarter of what it was in 2001?
¼ is two half-lives, i.e. 10.4 years, i.e. 2011.

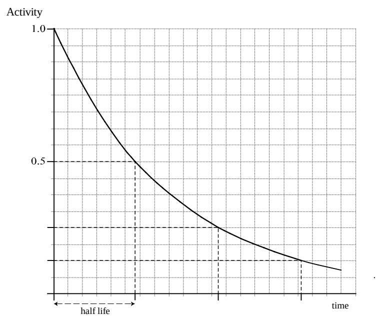
QUESTION SEVEN (2005;7)

Radioactive material decays and becomes less radioactive over time. The rate of decay is not constant, so it is measured in terms of half-life.

(a) On the axes drawn below, sketch a graph that illustrates radioactive decay. Give the axes appropriate labels. On your graph draw two lines to show how you could determine the half-life of the material.



ANSWER:



Exponential graph drawn on axes
Graph starts at y-axis and never reaches x-axis.
Axes labelled *Activity/Counts per second/Number of radioactive atoms* against *time/Half-life* (units not required).
Point at half maximum activity drawn across to graph line with line dropped onto time axis and labelled half-life (but can only accepts if Graph starts at y-axis).
Or
A value on y-axis chosen and interpolated, half the value chosen interpolated – difference in time is half-life

(b) State the meaning of the term half-life.
The half-life of a radioactive material is the time taken for the activity of the sample to decrease to half of its original value.

QUESTION NINE (2005;9)

All living plants and animals contain carbon. All carbon contains a known proportion of the radioactive isotope carbon-14. During the lifetime of a plant or animal, the carbon content is continually replenished, but the process stops once the plant or animal dies.

The half-life of carbon-14 is 5730 years. This length of time makes the isotope appropriate for estimating the time-since-death of archaeological samples of items that were once living. This process is called radio-carbon dating.

A kauri tree trunk is discovered buried in a Northland swamp. A 10 g sample of the timber is sent to a laboratory and is found to have a measured activity of 25 counts per minute. A 100 g sample of timber from a branch that just fell off a living kauri tree is found to have an activity of 2 345 counts per minute.

Estimate the age of the buried specimen.

10 g of a living sample has an activity of 234.5 cpm.
To drop to a count of 25 cpm, the activity has halved a little more than three times.
$3 \times$ half-life = $3 \times 5\,730 = 17\,190$
Hence approximate age = 18 000 years.

RADIO-CARBON DATING (2004;3)

Radio-carbon dating is used to estimate the age of objects that were once living. All living things contain a small amount of radioactive Carbon 14.
Carbon 14, which has a half-life of 5700 years, decays to carbon 12. By measuring the activity of a sample of dead tissue, its approximate age can be determined. Activity is measured in counts per minute (counts min^{-1}).

(a) Calculate the number of neutrons present in a carbon 14 nucleus.
(b) State what is meant by the term "half-life".
(c) (i) A sample of living wood has an activity of 16 counts min^{-1} per gram. Calculate the activity of a 20 g sample of living wood.
(ii) Hence calculate the activity of a 20 g sample of wood from a tree that died 17 100 years ago. State the correct unit for your answer.
(d) A 5.0 g sample of old wood from an archaeological site has an activity of 20 counts min^{-1}.
(e) Calculate the activity of the sample when the wood was living, and hence calculate how long ago the tree died.