

APOLLO

# Radioactive decay

## SL

Physics

First assessment 2025

9 questions | questions

**23.** Three statements about gamma radiation are:

- I. It travels faster than beta radiation in a vacuum.
- II. It has a greater penetration ability than beta radiation.
- III. It has a greater ionizing ability than beta radiation.

Which statements are correct?

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

- 22.** Thorium-232 ( $^{232}_{90}\text{Th}$ ) is an unstable nuclide. It decays by emitting an alpha particle followed by a beta minus ( $\beta^-$ ) particle.

What is the number of protons and neutrons in the final nuclide?

|    | Number of protons | Number of neutrons |
|----|-------------------|--------------------|
| A. | 87                | 139                |
| B. | 87                | 141                |
| C. | 89                | 139                |
| D. | 89                | 141                |

- 23.** A pure sample of radon-222 decays into polonium with a half-life of 4 days. A measurement is made of its radioactivity. The initial count rate is 420 counts per second. The measured background count is 20 counts per second.

What is the measured count rate after 8 days?

- A. 85
- B. 100
- C. 105
- D. 120

3. (a) A stationary isotope of  $_{88}\text{Ra}$  (Radium) decays into Rn (Radon) and an alpha particle.

- (i) Identify the proton number of Rn. [1]

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The following data are available:

Atomic mass of Ra = 226.02540 u

Atomic mass of Rn = 222.01757 u

Mass of  $\alpha$  = 4.00260 u

- (ii) Show that the energy released in this decay is about 5 MeV. [2]

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- (iii) Show that about 98 % of the energy released is carried by the alpha particle. [2]

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(Question 3 continued)

(b) In an experiment performed by Geiger, Marsden and Rutherford to investigate the atomic structure, alpha particles were directed into a thin metal foil.

(i) Describe two observations of this experiment. [2]

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(ii) Outline how the experiment was interpreted. [2]

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22. Radioactive oxygen-15 ( $^{15}_8\text{O}$ ) decays according to the following equation:

$$^{15}_8\text{O} \rightarrow \text{X} + \beta^+ + \nu_e$$

What are the proton number and the nucleon number of nuclide X?

|    | Proton number of X | Nucleon number of X |
|----|--------------------|---------------------|
| A. | 7                  | 14                  |
| B. | 9                  | 14                  |
| C. | 7                  | 15                  |
| D. | 9                  | 15                  |

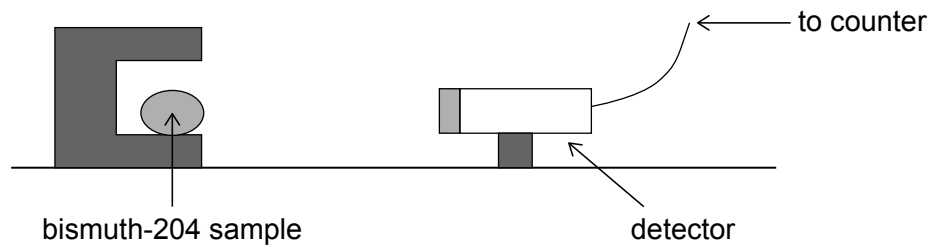
- 23.** The table shows how the count rate from a sample of a radioactive nuclide varies with time  $t$ . The nuclide has a half-life of 50 s.

| $t/\text{s}$ | Count rate/ $\text{s}^{-1}$ |
|--------------|-----------------------------|
| 0            | 72                          |
| 50           | 40                          |

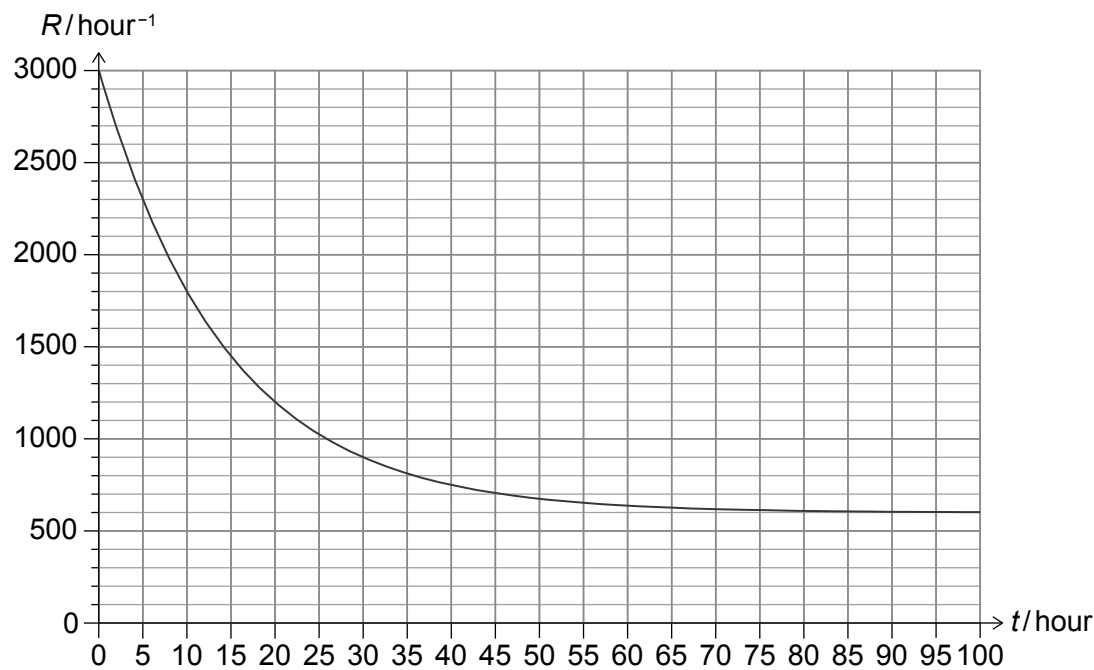
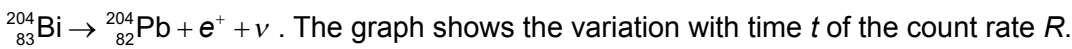
What is the background count rate?

- A. Zero
- B.  $8\text{ s}^{-1}$
- C.  $16\text{ s}^{-1}$
- D.  $24\text{ s}^{-1}$

4. (a) A pure radioactive sample of bismuth-204 ( $^{204}_{83}\text{Bi}$ ) is placed near a detector, which is connected to a counter.



Bismuth-204 decays into lead ( $^{204}_{82}\text{Pb}$ ) by beta-plus decay according to the equation



- (i) State the background count rate. [1]

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(Question 4 continued)

(ii) Estimate the half-life of  $^{204}_{83}\text{Bi}$ . [3]

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(iii) State and explain how the binding energy per nucleon of  $^{204}_{83}\text{Bi}$  compares with that of  $^{204}_{82}\text{Pb}$ . [2]

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(iv) The distance between the sample and the detector is 20 cm. State why this would be an inappropriate distance for a sample that decayed by alpha decay. [1]

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(b) The following data are available for **nuclear** masses:

bismuth = 203.932254 u  
 lead = 203.928034 u

Calculate the energy released in the decay of one nucleus of bismuth-204. [2]

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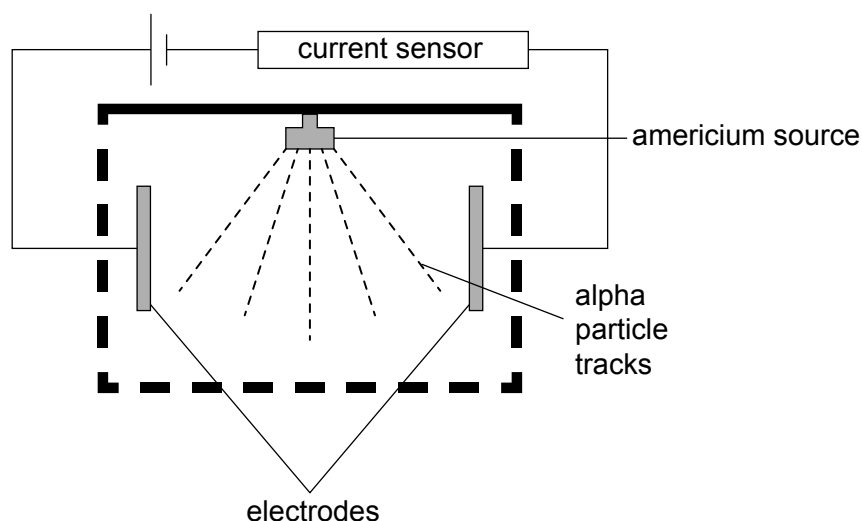
- 23.** Two radioactive samples X and Y have the same half-life. Initially the ratio  $\frac{\text{activity of X}}{\text{activity of Y}}$  is 4.

What is this ratio after 2 half-lives?

- A.  $\frac{1}{2}$
- B. 1
- C. 2
- D. 4

4. A smoke detector uses the radioactive nuclide americium-241.

The americium is contained in a chamber that is open to the air. There are two electrodes in the chamber that are connected to a power supply and a current sensor.



Americium-241 emits alpha particles that ionize the air in the chamber. Each ionization forms one positive ion and one electron; these are called an ion pair. The electrons and the positive ions move towards the electrodes and the sensor detects a current in the air.

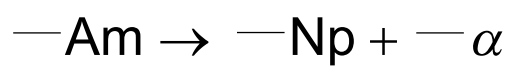
When smoke enters the chamber, fewer ion pairs are formed and the current in the sensor decreases, sounding an alarm.

The chamber is 0.10 m in each dimension.

- (a) A nucleus of americium-241 has 146 neutrons. This nuclide decays to neptunium through alpha emission.

Complete the nuclear equation for this decay.

[2]



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**(Question 4 continued)**

(b) Outline why the radioactive source is safe for use in a house. [1]

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The initial activity of the source is 42 kBq. 33% of the alpha particles emitted by this source enter the chamber and form an ion pair.  
Each alpha particle has an initial kinetic energy of 5.5 MeV.  
The energy required to form one ion pair is 15 eV.

(c) Calculate the maximum current in the chamber due to the electrons when there is no smoke in the chamber. [3]

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