# 3.27 Radioactivity, Half-Life and Nuclear Uses: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

**Answer ALL questions. Show all your working.**

**1** A student investigates the half-life of a radioactive source using a Geiger-Muller (GM) tube connected to a counter (required practical style).

| Time (min) | Raw count rate (cpm) | Corrected count rate (cpm) |
|---|---|---|
| 0 | 818 | 800 |
| 1 | 418 | 400 |
| 2 | 218 | X |
| 3 | 118 | 100 |
| 4 | 68 | Y |
| 5 | 43 | 25 |

**(a)** Before the experiment, the student records the background count rate three times: 18, 20 and 16 counts per minute (cpm). Calculate the mean background count rate. **(1)**

.....


© Revision Library | revisionlibrary.co.uk

**(b)** The student then measures the count rate from the source every minute. Her results are shown below (corrected count rate = raw count rate minus the mean background count rate found in part (a)). **(2)**

Time (min): 0, 1, 2, 3, 4, 5
Raw count rate (cpm): 818, 418, 218, 118, 68, 43
Corrected count rate (cpm): 800, 400, X, 100, Y, 25

Calculate the missing corrected count rate values X (at 2 minutes) and Y (at 4 minutes).

.....

**(c)** Use the corrected count rate values from part (b) to determine the half-life of the source. Show your working. **(3)**

**(d)** The student repeats the whole experiment two more times and calculates a mean half-life from her three sets of results. Explain how this improves the quality of her conclusion. **(1)**

.....

**(e)** State one precaution the student should take when handling the radioactive source, to reduce her exposure to radiation. **(1)**

**(f)** The source used in this experiment emits β radiation. Suggest why a GM tube is a more suitable method of detecting this radiation than simply observing the source. **(2)**

.....

.....

.....

.....

.....

**(Total for Question 1 is 10 marks)**


© Revision Library | revisionlibrary.co.uk

**2** Gamma radiation is often used in radiotherapy to treat cancer, aiming a beam of radiation from outside the body at a tumour. Evaluate the use of γ radiation for treating cancer in this way, referring to the properties of γ radiation that make it suitable, and to the risks involved.

**(Total for Question 2 is 6 marks)**

**3** Nuclear fission is the process used to release energy in nuclear power stations. This content applies to separate/triple Physics only.

**(a)** Describe what happens during the nuclear fission of a uranium-235 nucleus, starting from a slow-moving (thermal) neutron being absorbed. **(3)**

**(b)** Explain what is meant by a chain reaction, and state the condition needed for a chain reaction to be self-sustaining. **(2)**

**(c)** In a nuclear reactor, control rods (for example, made of boron) are raised or lowered in the reactor core. Explain how control rods are used to control the rate of fission reactions. **(2)**

**(Total for Question 3 is 7 marks)**


© Revision Library | revisionlibrary.co.uk

**4** A radioactive source used in an industrial thickness gauge has a half-life of 4 hours. At the start of a shift its activity is 2000 Bq.

**(a)** Calculate the activity of the source 12 hours later. **(2)**

.....

**(b)** Health and safety rules state that the source must be replaced once its activity falls below 100 Bq. By finding the activity after each successive half-life, determine the minimum number of complete half-lives, and hence the minimum time, needed for the activity to fall below 100 Bq. **(3)**

**(Total for Question 4 is 5 marks)**

---

**5** Nuclear fusion is the process that releases energy in stars, including the Sun. This content applies to separate/triple Physics only.

**(a)** Describe what happens during nuclear fusion, using hydrogen nuclei fusing to form helium as an example. **(2)**

.....

.....

**(b)** Explain why extremely high temperature and pressure are needed for nuclear fusion to take place. **(2)**

.....

.....

**(c)** State one similarity and one difference between the energy released in nuclear fusion and in nuclear fission. **(2)**

**(Total for Question 5 is 6 marks)**


© Revision Library | revisionlibrary.co.uk

# Mark scheme · 3.27 Radioactivity, Half-Life and Nuclear Uses: 1-hour Pack

## Question 1

(a) 18 cpm, cao **B1**

**(a) Answer: 18 counts per minute**

(b) X = 200 (218 - 18), cao **B1**

(b) Y = 50 (68 - 18), cao **B1**

**(b) Answer: X = 200 cpm, Y = 50 cpm**

(c) recognises the corrected count rate halves at each successive time shown: 800, 400, 200, 100, 50, 25 **M1**

(c) identifies that this halving occurs at regular 1-minute intervals throughout the data **M1**

(c) half-life = 1 minute, cao **A1**

**(c) Answer: 1 minute**

(d) repeating and taking a mean reduces the effect of random error/anomalous readings, giving a more precise and reliable half-life value, oe **B1**

**(d) Answer: Repeating and averaging reduces the effect of random error, giving a more precise and reliable half-life value.**

(e) any one of: use tongs/forceps (never handle directly); keep the source at arm's length/maximise distance; store it in a lead-lined container when not in use; minimise the time the source is out of its container; do not point the source at herself or others, oe **B1**

**(e) Answer: Use tongs to handle the source (or another valid precaution, e.g. maximise distance, minimise handling time, or use shielding).**

(f) β radiation cannot be seen, heard or felt, so it cannot be detected using human senses, oe **M1**

(f) a GM tube detects ionising radiation directly, producing an electrical pulse each time a particle enters it, which can be counted to give an objective, quantitative measurement, oe **A1**

**(f) Answer: Beta radiation cannot be detected by human senses; a GM tube detects each ionising particle electronically, giving an accurate, quantitative count rate.**

## Question 2

**Level 1** Basic, isolated statement(s) are made about gamma radiation and/or its use in treating cancer, with little or no linking between ideas. The answer may only state that gamma is used to treat cancer or that it is penetrating. **1-2**

**Level 2** Relevant points are made about how the properties of gamma radiation make it suitable for treating tumours, and at least one associated risk is identified, with some linking of ideas. Reasoning is mostly logical but the evaluation is limited. **3-4**

**Level 3** A detailed, coherent explanation links the properties of gamma radiation (penetration, ionising ability) to its suitability for treating internal tumours, alongside a clear discussion of risks to healthy tissue, and a reasoned judgement weighing benefit against risk. The answer is logically structured throughout and uses correct scientific terminology. **5-6**

**Indicative content:**

- Gamma radiation is highly penetrating, so a beam can be aimed from outside the body at a tumour deep inside without invasive surgery.
- Ionising radiation damages the DNA of the cells it passes through, including cancer cells, preventing them from dividing or killing them.
- The beam can be aimed from several different angles, or rotated around the patient, so the doses overlap and concentrate on the tumour, while any one healthy area only receives a low dose from a single direction.
- Healthy cells near the tumour and along the beam's path can still be damaged or killed, causing side effects such as nausea, fatigue or skin damage.
- Radiation can damage the DNA of healthy cells without killing them, which can cause mutations and a small additional risk of the patient developing further cancers later.
- Treatment is often given in small fractionated doses over several sessions, which helps healthy tissue recover between doses while still damaging the tumour cumulatively.
- Radiotherapy can treat tumours that would be difficult, risky or impossible to remove by surgery, or can be used alongside surgery to destroy any remaining cancer cells.
- An overall judgement should weigh the benefit (destroying the tumour without invasive surgery) against the risks (damage to healthy tissue, side effects, small increased future cancer risk).


© Revision Library | revisionlibrary.co.uk

## Question 3

(a) a slow-moving neutron is absorbed by a U-235 nucleus, forming an unstable (excited) nucleus, oe **B1**

(a) this unstable nucleus splits into two smaller daughter nuclei of roughly similar size, oe **B1**

(a) the fission releases 2 or 3 fast-moving neutrons and a large amount of energy, mainly as the kinetic energy of the fragments and neutrons, oe **B1**

**(a) Answer: A neutron is absorbed, forming an unstable nucleus, which splits into two smaller daughter nuclei, releasing 2-3 neutrons and a large amount of energy.**

(b) the neutrons released by one fission go on to be absorbed by further U-235 nuclei, causing more fissions, which release more neutrons, so the number of fissions rapidly multiplies, oe **B1**

(b) a sufficient mass of fissile material (a critical mass) must be present so that, on average, at least one neutron from each fission goes on to cause another fission, oe **B1**

**(b) Answer: Neutrons from one fission trigger further fissions, multiplying rapidly; this requires at least a critical mass of fissile material to be present.**

(c) control rods absorb some of the free neutrons produced by fission, reducing the number available to cause further fissions, oe **B1**

(c) lowering the rods further into the core absorbs more neutrons and slows the reaction; raising them absorbs fewer neutrons, allowing the rate (and power output) to increase, keeping the chain reaction controlled, oe **B1**

**(c) Answer: Control rods absorb neutrons; lowering them slows the reaction and raising them speeds it up, keeping the chain reaction steady and controlled.**

## Question 4

(a) 12 / 4 = 3 half-lives **M1**

(a) 2000 -> 1000 -> 500 -> 250; activity = 250 Bq, cao **A1**

**(a) Answer: 250 Bq**

(b) continues halving from 250 Bq: after 4 half-lives = 125 Bq (still at or above 100 Bq, not yet below); after 5 half-lives = 62.5 Bq **M1**

(b) identifies that 5 half-lives is the minimum whole number of half-lives needed for the activity to fall below 100 Bq **M1**

(b) minimum time = 5 x 4 = 20 hours, cao **A1**

**(b) Answer: 20 hours (5 half-lives)**

## Question 5

(a) two light nuclei (e.g. hydrogen nuclei) join together to form a single heavier nucleus (e.g. helium), oe **B1**

(a) this releases a large amount of energy (and, depending on the reaction, other particles), oe **B1**

**(a) Answer: Two hydrogen nuclei fuse together to form a heavier helium nucleus, releasing a large amount of energy.**

(b) all nuclei are positively charged, so they strongly repel each other (electrostatic repulsion) as they approach, oe **B1**

(b) extremely high temperature gives nuclei enough kinetic energy, and extremely high pressure pushes them close enough together, to overcome this repulsion so the strong nuclear force can bind them, oe **B1**

**(b) Answer: Positively charged nuclei repel each other; extreme temperature and pressure give them enough energy and closeness to overcome this repulsion and fuse.**

(c) similarity: both release a very large amount of energy compared with chemical reactions, because mass is converted into energy in both, and both involve changes to the nucleus rather than just electrons, oe **B1**

(c) difference: fusion of light nuclei releases more energy per kilogram of fuel than fission of heavy nuclei, oe **B1**

**(c) Answer: Similarity: both convert mass into a large amount of energy through changes to the nucleus. Difference: fusion releases more energy per kilogram of fuel than fission.**


© Revision Library | revisionlibrary.co.uk