AQA · GCSE · PHYSICS • EXERCISE SHEET

4.3 Radioactive decay and nuclear radiation

Name: _____ Class: _____ Date: _____ **Total: 17 marks**

KEY WORDS Activity • becquerel • Count-rate

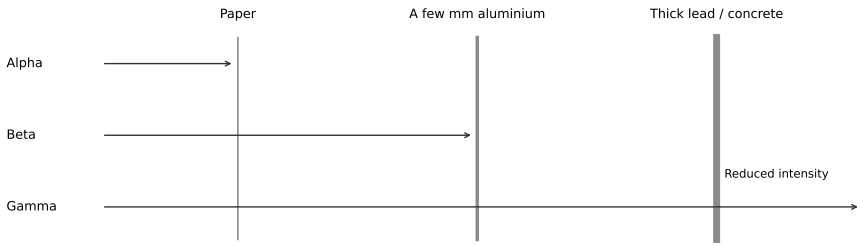
Objective

Match alpha, beta, gamma and neutron radiation to their properties, and choose sources for uses. Original questions for spec statement 4.4.2.1.

1 Key knowledge and worked examples

Some nuclei are unstable and give out radiation to become more stable – a **random** process called radioactive decay.

- **Activity**: the rate of decay of a source, in **becquerel (Bq)**.
- **Count-rate**: detector counts per second. It is not automatically the source activity: detector efficiency and position affect the fraction recorded.



Alpha and beta stop at their barriers. Thick shielding reduces gamma intensity.

Range in air: alpha a few cm, beta tens of cm, gamma many metres.

Radiation	Identity	Ionising	Shielding
alpha α	2 protons + 2 neutrons (helium nucleus)	strongest	paper / skin
beta β	high-speed electron (neutron $\rightarrow$ proton)	medium	few mm aluminium
gamma γ	EM radiation from nucleus	weakest	thick lead reduces it
neutron n	a neutron	–	thick concrete, water

Choosing a source (each justified by a property):

Use	Source	Why
smoke alarm	alpha	smoke reduces the ionisation current; sealed to limit contamination
thickness gauge for paper/foil	beta	partly passes thin sheets; count tracks thickness
medical tracer / sterilising	gamma	escapes the body / penetrates packaging

Activity from a number-of-nuclei graph. Activity is the magnitude of the tangent gradient at the stated time, in Bq. Use two points on the tangent and keep any axis multiplier. For example, a tangent falling from 68 000 nuclei to 12 000 nuclei in 200 s gives:

$$\text{activity} = \frac{\text{decrease in number of nuclei}}{\text{time interval}} = \frac{68000 - 12000}{200\ \text{s}} = 280\ \text{Bq}$$

This teacher-written example prepares the method used in AQA June 2024 8463/1H Q09.5; it is not that paper's numerical data.

2 Practice

2.1 State the composition of an alpha particle. [1]

2.2 Which radiation is the most ionising, and which has the longest range in air? [2]

2.3 A factory checks the thickness of aluminium foil with radiation. State the best radiation and why not the others. [3]

3 Exam-style questions

3.1 A teacher keeps the source and detector positions fixed and subtracts background. The net count rate is 100 counts/s without an absorber, 100 counts/s with paper, 40 counts/s with 5 mm of aluminium, and 20 counts/s when 5 cm of lead is also added. Assume only alpha, beta and gamma emissions are possible, and that paper and aluminium have negligible effects on the gamma component in this test.

Identify the radiation components detected, using each absorber result. [3]

3.2 A source emits beta particles. Explain what happens in the nucleus when a beta particle is emitted, and the effect on the atomic number. [2]

3.3 A hospital needs a source to sterilise sealed pre-packed syringes in their boxes.

(a) State the most suitable radiation and justify your choice with two properties. [3]

(b) Give one reason the source should have a long half-life. [1]

(c) Workers stand behind a shield while the source is exposed. Explain why the syringes are not radioactive afterwards. [2]

Solutions

2.1 Two protons and two neutrons – the same as a helium nucleus.

2.2 Most ionising: alpha. Longest range in air: gamma.

2.3 Beta: alpha would not pass through any metal foil; gamma is too penetrating to give a useful change for this thin foil; beta is partly absorbed by thin metal, so count-rate follows thickness.

3.1 No detected alpha component: paper does not reduce the net count rate. Beta is present: aluminium stops the beta component, reducing the rate. Gamma is present: radiation remains after aluminium and is further reduced by lead. The evidence supports a beta–gamma mixture, not gamma alone.

3.2 A neutron in the nucleus turns into a proton; the atomic number increases by 1 while the mass number is unchanged – the high-speed electron is ejected.

3.3 (a) Gamma: it passes through the boxes; its ionisation damages or kills the microorganisms inside. (b) So the source does not need frequent replacement (activity stays high for years). (c) The syringes were irradiated, not contaminated: irradiation exposes them to radiation but does not transfer radioactive material, so nothing radioactive remains on them.