

Alpha beta gamma penetration and shielding

AQA GCSE Combined Science Trilogy 8464 and Separate Physics 8463 | F/H | Paper 1

Suggested: 35–40 minutes + 15–20 review | 27 parts | 46 marks

Specification points covered

8463 4.4.2.1 / 8464 6.4.2.1: radiation properties, count rate and applications
8463 4.4.2.4 / 8464 6.4.2.4: irradiation, contamination, precautions and peer review

A materials-inspection laboratory identifies three sealed sources, chooses a beam for checking plastic film and reviews shielding. Use the supplied records only. This is a data exercise, not instructions for handling radioactive sources.

Answer all questions. Use a calculator. Count rate = number of counts / time. Subtract the background for the same time interval. Give units and use evidence when explaining decisions.

1 Reading the laboratory record

With all test sources removed, a detector records 44, 48 and 52 counts in three separate 120 s intervals. Use the mean as the background estimate throughout this worksheet.

1(a) What is meant by ionisation of an atom? **[1 mark]**

1(b) Which one of alpha, beta and gamma radiation is electromagnetic radiation? **[1 mark]**

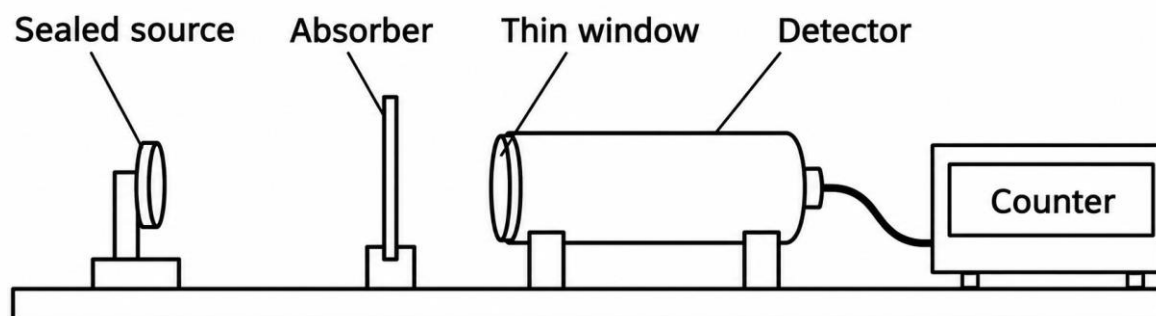
1(c) Calculate the mean background count in 120 s from the three readings. **[1 mark]**

1(d) Calculate the mean background count rate in counts per second. **[1 mark]**



2 Checking the detector arrangement

Figure 1 is a schematic of the laboratory test. The source windows allow the emitted radiation to escape. The detector can detect alpha, beta and gamma radiation. The source face is 30 mm from the detector window in air; the drawing is not to scale.



Not to scale

Figure 1

2(a) The technician changes only which absorber is placed in the holder. Identify the independent variable. **[1 mark]**

2(b) Explain why both the counting time and the source-to-window separation must remain the same when comparing total counts for different absorbers. **[2 marks]**

2(c) With no absorber, an alpha-emitting source gives a clear reading at 30 mm, but a reading close to background after the air gap is increased to 150 mm. Explain the change. Assume the source activity is unchanged. **[2 marks]**



3 Identifying three sealed sources

Each source P, Q or R emits just ONE of alpha, beta or gamma radiation in this model. Its activity changes negligibly during these tests. Table 1 gives mean TOTAL counts in 120 s, including background. Only the absorber is changed; source and detector positions are fixed. Use 48 background counts per 120 s.

Table 1

Absorber	P / counts	Q / counts	R / counts
None	1248	2448	3648
Paper	48	2328	3528
3 mm aluminium	48	48	3288
20 mm lead	48	48	288

3(a) Identify the radiation from P. Justify your answer using the paper reading and the reading without an absorber. **[2 marks]**

3(b) Identify the radiation from Q. Use both its paper and aluminium readings to justify your answer. **[2 marks]**

3(c) Identify the radiation from R. Explain what its aluminium and lead readings show. **[2 marks]**

3(d) For R with 20 mm lead, calculate the background-corrected count rate in counts per second. **[2 marks]**

3(e) A trainee says that inserting paper has switched off source P because the detector now reads background only. Explain why this is wrong. **[2 marks]**



4 Choosing a beam to check plastic film

The laboratory tests a gauge that measures plastic-film thickness by placing film between a source and detector. Table 2 gives background-corrected count rates for three possible sources at fixed positions. The desired film thickness is 0.40 mm. Source activities stay unchanged. For beta and gamma, count rate decreases as thickness increases over the tested range.

Table 2

Film thickness / mm	Alpha / counts s ⁻¹	Beta / counts s ⁻¹	Gamma / counts s ⁻¹
0.20	0	16	24.0
0.40	0	10	23.9
0.60	0	4	23.8

4(a) Choose the most useful radiation type for monitoring changes around 0.40 mm thickness. Justify your choice using the pattern in Table 2. **[2 marks]**

4(b) Use Table 2 to explain why alpha radiation cannot distinguish the three film thicknesses. **[1 mark]**

4(c) Using the beta source, the gauge records 15 counts s⁻¹ after background correction. Is the film thinner or thicker than the desired 0.40 mm? Explain using the evidence. **[2 marks]**

4(d) Later the corrected beta reading is 5 counts s⁻¹. Explain whether the film is now thinner or thicker than 0.40 mm. **[2 marks]**



5 Choosing a gamma shield

A separate design test uses source R. Table 3 gives mean TOTAL counts in 120 s for different lead thicknesses; background is still 48 counts per 120 s. The test criterion is a background-corrected rate of at most $5.0 \text{ counts s}^{-1}$. This criterion alone is not a complete safety assessment.

Table 3

Lead thickness / mm	Total counts in 120 s
0	3648
5	1848
10	1008
20	288

5(a) For 10 mm lead in Table 3, calculate the background-corrected count rate in counts per second. **[2 marks]**

5(b) Choose the smallest TESTED lead thickness that meets the $5.0 \text{ counts s}^{-1}$ criterion. Justify your choice using the corrected rates for 10 mm and 20 mm lead. **[2 marks]**

5(c) A report says that 20 mm lead stops all gamma radiation. Use the data to correct this statement. **[2 marks]**

5(d) Repeated 120 s measurements with the same 20 mm shield give 276, 288 and 312 total counts. Why need the readings not be identical? **[1 mark]**

5(e) Describe one change to the measurements that would make the estimated mean count rate more reliable. Explain why it helps. **[2 marks]**



6 Reviewing exposure and contamination

A robot moves test products through a closed inspection cabinet. Normally its radioactive source is sealed and no radioactive material is transferred to the products. The laboratory also considers what would happen if a damaged source released radioactive dust.

6(a) Which event is contamination: only radiation passing into a product, or radioactive dust settling on the product? **[1 mark]**

6(b) A product leaves the cabinet after irradiation by the intact sealed source. Explain why the product does not become a radioactive source in this situation. **[2 marks]**

6(c) In the damage scenario, radioactive dust remains on a product after the cabinet shutter closes. Explain why the product can still present a radiation hazard. **[2 marks]**

6(d) The dust emits alpha radiation. Compare its ionising power with gamma radiation and explain why breathing in the dust can damage cells despite alpha's short range. **[2 marks]**

6(e) The system is controlled remotely from behind shielding, and its source shutter closes between inspections. Explain how each feature reduces the operator's exposure. **[2 marks]**

6(f) The laboratory publishes a study of its shielding results. State the name of the process in which other scientists check the work, and explain why this check matters. **[2 marks]**

Review: correct one explanation by distinguishing the source activity, the detector count rate and the effect of shielding.

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