# Nuclear Decay & Radioactivity

## Question paper

| | |
|---|---|
| **Level** | International A Level |
| **Subject** | Physics |
| **Exam Board** | Edexcel |
| **Topic** | Physics from Creation to Collaps |
| **Sub Topic** | Nuclear Decay & Radioactivity |
| **Booklet** | Question paper |

**Time Allowed:** **76 minutes**

**Score:** **/63**

**Percentage:** **/100**

**Grade Boundaries:**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | '77.5% | 70% | 62.5% | 57.5% | 45% | <45% |

**1** A student is using a Geiger counter to measure the number of counts per minute from a weak radioactive source.

To determine the background count rate their best procedure is to measure the count for

☒ **A** 1 minute before the source is in position.

☒ **B** 1 minute with the source in position.

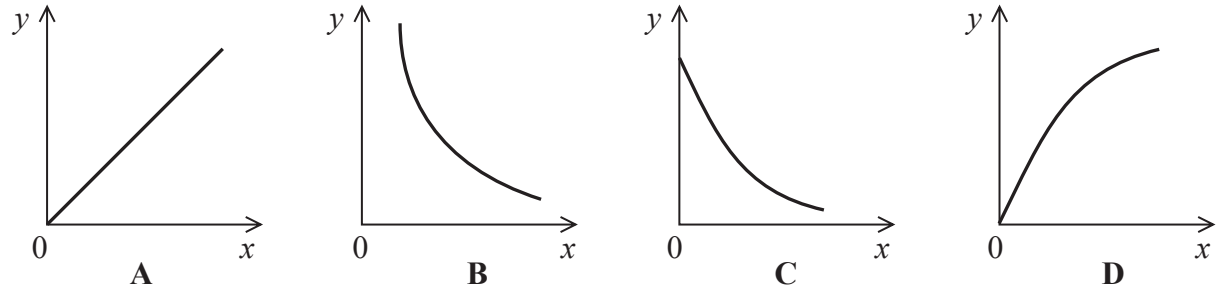
☒ **C** 10 minutes before the source is in position.

☒ **D** 10 minutes with the source in position.

**(Total for Question 1 = 1 mark)**

---

**Question 2 refer to the graphs below.**




**2** A sample of a radioactive isotope decays to a stable isotope.

Which graph shows how the number of daughter nuclei varies with time?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

**(Total for Question 2 = 1 mark)**

---

**3** A sample of radioactive material has a known half life. Radioactive decay is a random process. This means that we can predict

☒ **A** when a given nucleus will decay.

☒ **B** the time for the whole sample to decay.

☒ **C** the next nucleus that will decay.

☒ **D** the fraction of a sample that will decay in a second.

**(Total for Question 3 = 1 mark)**

**4** A radioactive sample is a beta-emitter. Beta particles are able to pass through

☒ **A** air only.

☒ **B** thick card.

☒ **C** 1 cm of aluminium.

☒ **D** 1 mm of lead.

**(Total for Question 4 = 1 mark)**

---

**5** A source of alpha radiation is dangerous if taken into the body.

This is because alpha particles are

☒ **A** charged.

☒ **B** massive.

☒ **C** very ionising.

☒ **D** very penetrating.

**(Total for Question 5 = 1 mark)**

---

**6** Uranium-238 decays by emitting alpha particles. It is **not** possible to influence when the decay of a particular nucleus of uranium-238 will occur.

This is because radioactive decay

☒ **A** involves high energy.

☒ **B** is spontaneous.

☒ **C** occurs randomly.

☒ **D** occurs very quickly.

**(Total for Question 6 = 1 mark)**

---

**7** A physics student reads in a textbook that radioactive decay is a random process. This means that, for a sample of a given radioactive isotope, we cannot tell

☒ **A** what the radioactive isotope will decay into.

☒ **B** when the sample will start to decay.

☒ **C** which radioactive nucleus will decay next.

☒ **D** which type of radiation will be emitted.

**(Total for Question 7 = 1 mark)**

**8** Cobalt-60 is an artificially produced radioisotope that can be used to treat cancer. It emits beta particles of energy 0.3 MeV and gamma rays of energy 1.3 MeV.

(a) Complete the nuclear equation for the beta decay of cobalt-60.

**(2)**

$$^{60}_{27}\text{Co} \rightarrow \text{\_\_\_}\text{Ni} + \text{\_\_\_}\beta^-$$

(b) State, with a reason, the penetrating powers of each of the two types of radiation emitted by the cobalt-60.

**(2)**

.....

.....

.....

.....

(c) State one risk to a patient associated with the use of radioisotopes to treat cancer.

**(1)**

.....

.....

.....

**(Total for Question 8 = 5 marks)**

**9** Technetium-99m is an unstable isotope which decays by emitting $\gamma$ radiation. The decay process is random. The half life of this isotope is $2.16 \times 10^4$ s.

(a) (i) State what is meant by 'random'.

**(1)**

.....

.....

(ii) State what is meant by 'half life'.

**(1)**

.....

.....

(b) A sample containing $7.30 \times 10^{19}$ atoms of technetium-99m is prepared for use in a medical application.

(i) Show that the activity of the sample when it is prepared is about $2.3 \times 10^{15}$ Bq.

**(3)**

(ii) Calculate the activity of the sample 1 day after the sample was prepared.

1 day = 86 400 s

**(2)**

Activity of sample after 1 day = .....

**(Total for Question 9 = 7 marks)**

**10** In the early part of the 20th century the Nobel Prize winner George de Hevesy made the first use of a radioactive tracer. He studied the transportation of a small sample of the isotope lead-212 in a broad bean plant.

(a) Complete the nuclear equation for the decay of Pb-212.

**(2)**

$$^{212}_{82}Pb \rightarrow \text{.....} Bi + \text{.....} \beta^-$$

(b) The half life of $^{212}Pb$ is $3.83 \times 10^4$ s.

(i) State what is meant by the term half life.

**(1)**

.....

.....

(ii) Show that the decay constant of $^{212}Pb$ is about $2 \times 10^{-5}$ $s^{-1}$ and hence calculate the fraction of the original sample that will remain after a time of 1 day (86 400 s).

**(4)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

Fraction remaining = .....

(iii) The energy released in this decay is $9.12 \times 10^{-14}$ J.

Calculate the decrease in mass in kg that occurs in the decay of one Pb-212 atom.

**(2)**

.....

.....

.....

Decrease in mass = ..... kg

(c) The isotope of bismuth produced by the decay of Pb-212 is itself radioactive. It produces both alpha and beta particles with an overall half life which is much shorter than that of the lead.

Discuss how the decay of the bismuth isotope could affect the measurements made on the activity of the broad bean plant.

**(2)**

.....

.....

.....

.....

(d) George de Hevesy also discovered the element hafnium, which is a good absorber of neutrons. Hafnium is sometimes used to control the rate of fission in a nuclear fission reactor.

Suggest why a material which is a good absorber of neutrons would enable the rate of fission to be controlled.

**(1)**

.....

.....

(e) Fusion reactors could become a better alternative to fission reactors.

Explain why this is the case and give reasons why practical fusion reactors are still only at the experimental stage.

**(5)**

**(Total for Question 10 = 17 marks)**

**11** The first example of an artificially produced radioactive isotope was produced in 1934 by Frederic and Irene Joliot-Curie. They bombarded aluminium with alpha particles to produce an unstable isotope of phosphorus.

(a) (i) Complete the nuclear equation representing this process and identify the particle X.

**(3)**

$$^{27}_{13}\text{Al} + \text{.....}\alpha \rightarrow ^{30}_{15}\text{P} + \text{.....}X$$

X is .....

(ii) The alpha particle had a kinetic energy of 5.3 MeV.

Calculate the total kinetic energy of the reaction products.

| | **Mass / u** |
|---|---|
| proton | 1.007276 |
| neutron | 1.008665 |
| alpha particle | 4.001506 |
| Al-27 | 26.98154 |
| P-30 | 29.97831 |

**(4)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

Total kinetic energy = .....

(b) P-30 is a positron emitter.

State what is meant by a positron, and suggest why positron emission is unlikely to occur for nuclei with an excess of neutrons.

**(2)**

(c) P-30 has a half-life of 150 s. At a particular instant a sample of P-30 contains $2.2 \times 10^{16}$ atoms.

(i) Calculate the activity of the sample at this instant.

**(3)**

Activity of sample = .....

(ii) Determine the activity of the sample 15 minutes later.

**(3)**

Activity after 15 minutes = .....

**(Total for Question 11 = 15 marks)**

**12** From the 1960s to the 1980s nuclear-powered electronic pacemakers were sometimes used to regulate the heartbeat. Such pacemakers were used inside the body and were powered by a small radioactive source.


One type of pacemaker used an isotope of plutonium, Pu-238, as its energy source.

Pu-238 decays by alpha emission with a half-life of 88 years.

(a) Explain why the alpha particles were not harmful to the person fitted with the pacemaker.

**(2)**

.....

.....

.....

(b) Complete the equation for plutonium decaying into thorium.

**(2)**

$$^{238}_{92}\text{Pu} \rightarrow \text{.....} \text{Th} + \text{.....} \alpha$$

(c) The activity of the source in one such pacemaker, when the pacemaker was fitted, was $9.3 \times 10^{10}$ Bq. The energy released by each alpha decay is 5.5 MeV.

Calculate the power of the source 30 years after fitting.

**(6)**

Power of source = ..... W

(d) Modern pacemakers use a lithium (chemical) battery with a lifetime of about 5 years.

Suggest **one** advantage and **one** disadvantage of using a lithium battery pacemaker compared with one powered by a plutonium source.

**(2)**

Advantage .....

Disadvantage .....

**(Total for Question 12 = 12 marks)**