1 Figure 7 shows the

$^{234}_{92}U$	$^{235}_{92}U$	$^{238}_{94}Pu$	$^{238}_{95}Am$
uranium-234	uranium-235	plutonium-238	americium-238

Figure 7

(a) Which two nuclei have the same number of neutrons?

(1)

- ☐ **A** plutonium-238 and uranium-235
- ☐ **B** uranium-235 and americium-238
- ☐ **C** uranium-234 and americium-238
- ☐ **D** americium-238 and plutonium-238

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

(1)

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.....

(ii) Plutonium-238 is used in spacecraft to provide heat to power generators.

One of these generators contains 925 g of plutonium-238 when it is manufactured.

One gram of plutonium-238 has a power density of 0.54 W/g.

Plutonium-238 has a half-life of 87.7 years.

Calculate the average energy released per second by the generator after 263 years.

(4)

average energy released per second = ... (J)

(c) The nucleus of americium-238 can absorb an electron.

When this happens, one of the protons in the nucleus becomes a neutron, as shown in Figure 8.

$$ {}^{1}_{1}\mathrm{p} + {}^{0}_{-1}\mathrm{e} \longrightarrow {}^{1}_{0}\mathrm{n} $$

Figure 8

(i) Describe how absorbing an electron affects the proton number and the nucleon number of a nucleus.

(2)

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(ii) Deduce which nucleus is formed when americium-238 absorbs an electron.

(1)

☒ **A** uranium-234

☒ **B** uranium-235

☒ **C** plutonium-238

☒ **D** americium-238

(Total for Question 6 = 9 marks)

2 In a nuclear reactor, a chain reaction is produced and controlled.

(a) (i) Uranium-235 is the isotope used in many nuclear reactors.

Explain how the fission of uranium-235 can lead to a chain reaction.

(4)

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(ii) Nuclei of beryllium-9 do not absorb neutrons.

Instead, nuclei of beryllium-9 absorb alpha particles and emit neutrons.

Give a reason why a chain reaction can result from the emission of neutrons by uranium nuclei but not by beryllium nuclei.

(1)

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(b) Explain what happen inside a nuclear reactor if neutron speeds are not controlled.

(3)

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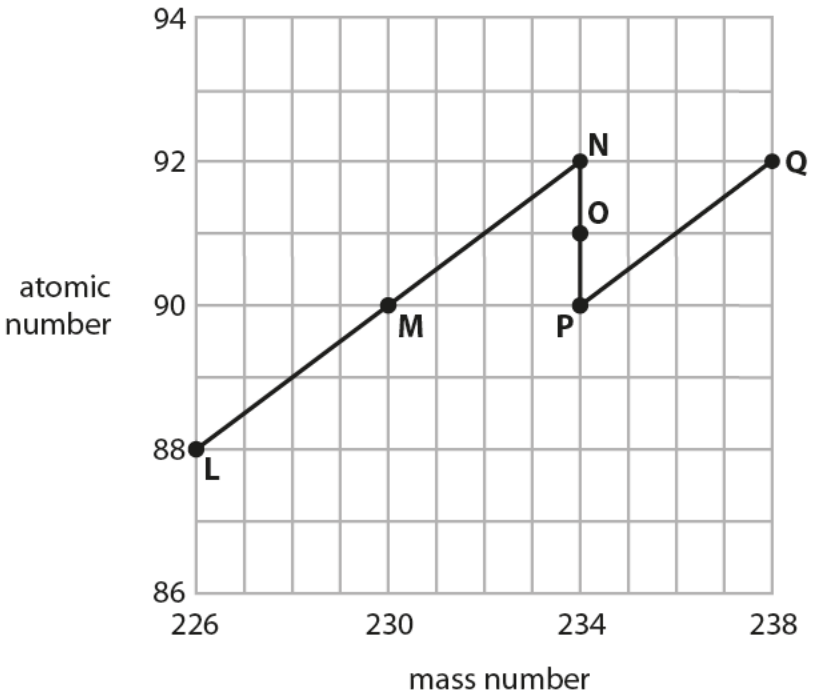
(c) Describe how the energy released in the chain reaction in a nuclear reactor is used to drive a turbine in a nuclear power station.

(3)

(Total for Question 10 = 11 marks)

3 Uranium-238 is an isotope of uranium. It may undergo either radioactive decay or nuclear fission.

A nucleus of uranium-238 is shown as **Q** in the chart.



(a) State **two** letters from the chart which show isotopes of the same element.

(1)

and

(b) Explain what happens when **Q** decays to **P**.

(2)

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(c) Explain what happens when **P** decays to **O**.

(2)

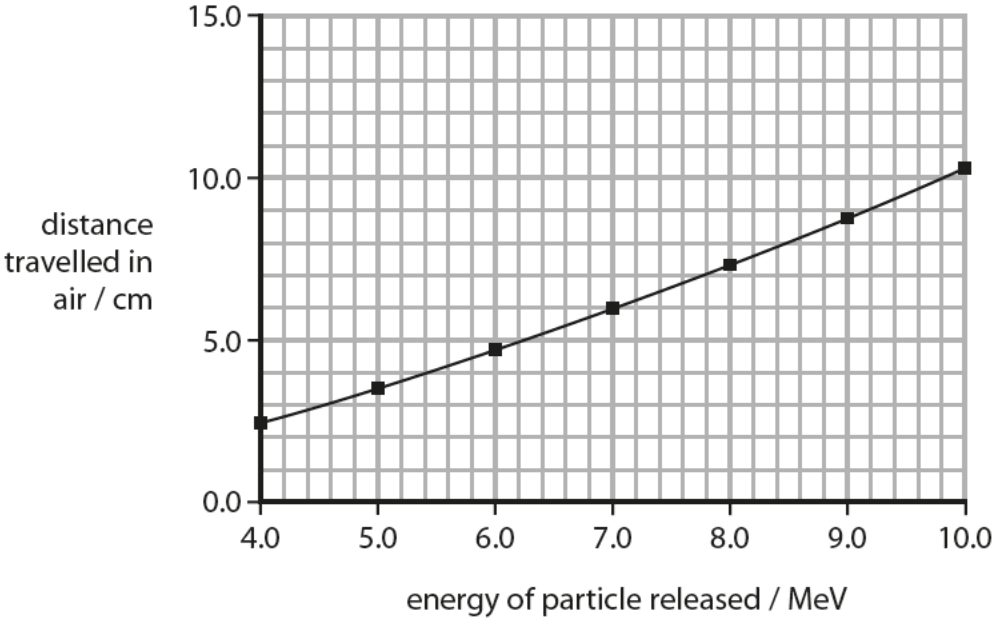
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(d) Particles released during radioactive decay can have different energies.
A suitable unit for these energies is MeV.
For one type of decay, the particles released have energies between 4.0 MeV and 10.0 MeV.
The graph shows how far the particles with these energies travel in air.



(i) State the name of this type of particle.

(1)

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(ii) Use information from the graph to describe how the distance travelled in air depends on the energy of the particle.

(2)

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(e) Uranium-238 can only undergo nuclear fission by absorbing fast neutrons.
The fission emits neutrons which very quickly lose their energy.

Suggest why the fission of uranium-238 does not produce a chain reaction.

(2)

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(Total for Question 4 = 10 marks)

4 (a) (i) One source of background radiation is radon gas.

State another source of background radiation.

(1)

.....

(ii) Which of these two statements about background radiation are correct?

1 Radon gas from nuclear power stations is the main cause of background radiation.

2 Background radiation can be detected during radioactive experiments.

(1)

☒ **A** statement 1 only

☒ **B** statement 2 only

☒ **C** both statement 1 and statement 2

☒ **D** neither statement 1 nor statement 2

(iii) Background radiation from radon gas is different from place to place in the UK.

Explain these differences in background radiation.

(2)

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(b) Scientists have changed their ideas about the hazards from radioactive sources.

Describe how their ideas have changed since radioactivity was first discovered.

(2)

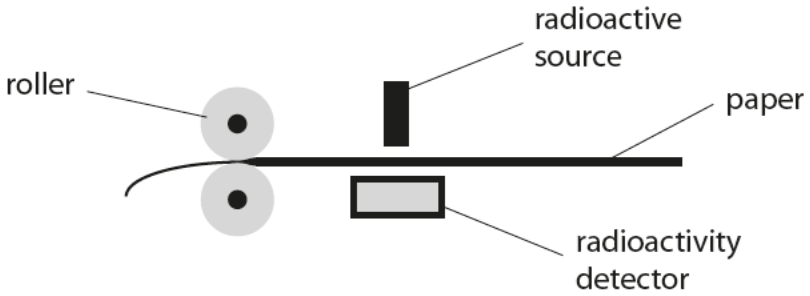
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*(c) The diagram shows how rollers can change the thickness of paper in a factory.
A thickness gauge controls the rollers.
The thickness gauge contains a radioactive source and a detector.
If the paper is too thick, the reading on the detector goes down.
This causes the rollers to be pushed closer together.



The radioactive source used must be chosen carefully to be effective and used in a way that is not a hazard to workers.

Discuss the factors to consider when choosing and using this radioactive source.

(6)

(Total for Question 6 = 12 marks)