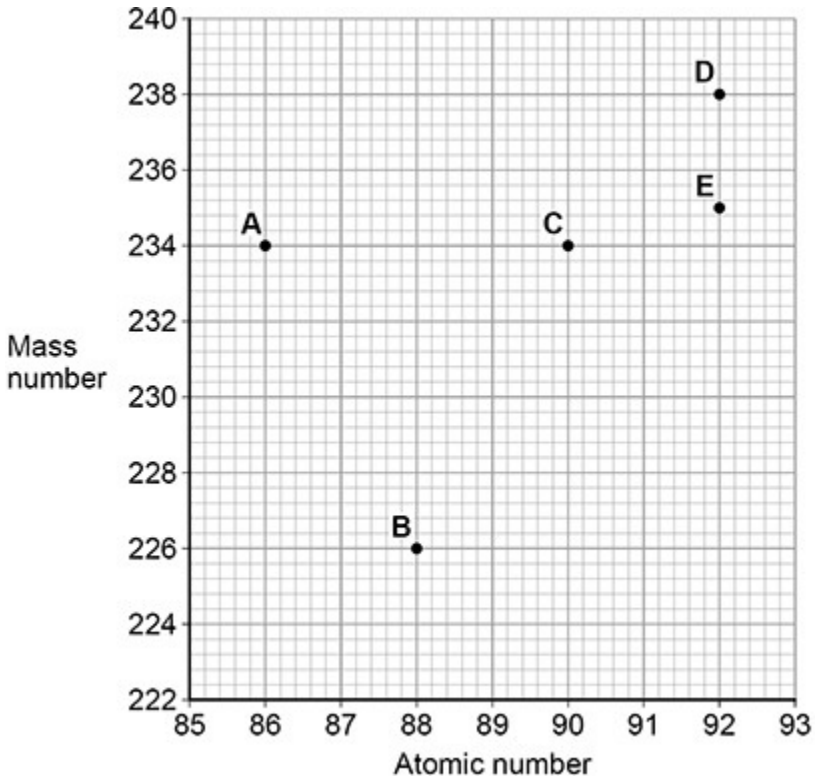
Questions are for both separate science and combined science students unless indicated in the question

1. **Figure 1** shows the mass number and the atomic number for the nuclei of five different atoms.

Figure 1



(a) How many neutrons are there in a nucleus of atom **A**?

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(1)

(b) Which **two** atoms in **Figure 1** are the same element?

Tick (✓) **one** box.

A and **B** ☐

A and **C** ☐

C and **D** ☐

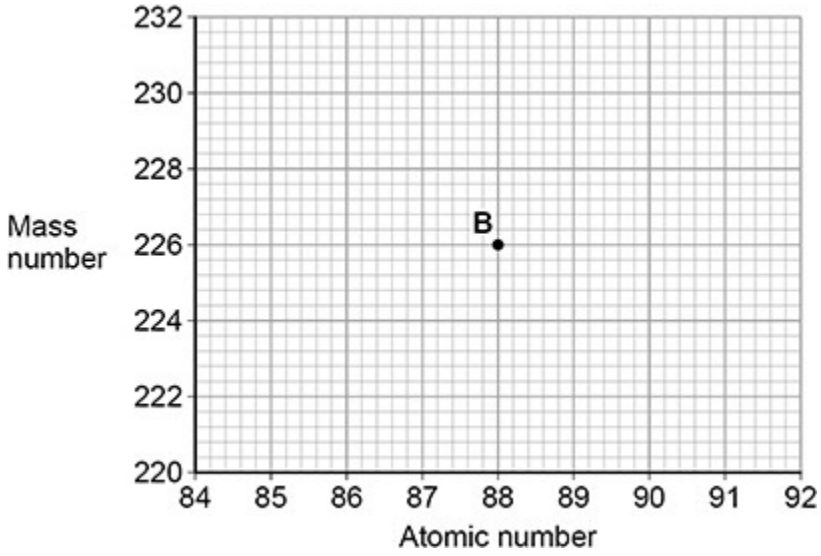
D and **E** ☐

(1)

(c) Nucleus **B** decays by emitting an alpha particle.

Draw an arrow on **Figure 2** to represent the alpha decay. (separate only)

Figure 2



(2)

(d) What is meant by the 'random nature of radioactive decay'? (separate only)

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(1)

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(e) A polonium (Po) nucleus decays by emitting an alpha particle and forming a lead (Pb) nucleus.

$$Po \rightarrow Pb + \alpha$$

The lead (Pb) nucleus then decays by emitting a beta particle and forms a bismuth (Bi) nucleus.

$$Pb \rightarrow Bi + \beta$$

The bismuth (Bi) nucleus then decays by emitting a beta particle and forms a polonium (Po) nucleus.

$$Bi \rightarrow Po + \beta$$

Explain how these three decays result in a nucleus of the original element, polonium. (separate only)

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(3)

(Total 8 marks)

2. Radioactive waste from nuclear power stations is a man-made source of background radiation.

(a) Give **one** other man-made source of background radiation. (separate only)

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(1)

Nuclear power stations use the energy released by nuclear fission to generate electricity.

(b) Give the name of **one** nuclear fuel. (separate only)

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(1)

(c) Nuclear fission releases energy.

Describe the process of nuclear fission inside a nuclear reactor.(separate only)

(4)

(d) A new type of power station is being developed that will generate electricity using nuclear fusion.

Explain how the process of nuclear fusion leads to the release of energy. (separate only)

(2)

(e) Nuclear fusion power stations will produce radioactive waste. This waste will have a much shorter half-life than the radioactive waste from a nuclear fission power station.

Explain the advantage of the radioactive waste having a shorter half-life. (separate only)

(2)

(Total 10 marks)

3. Polonium-210 ($^{210}_{84}Po$) is a radioactive isotope that decays by emitting alpha radiation.

(a) Complete the decay equation for polonium-210

(2)

(b) Explain why contamination of the inside of the human body by a radioactive material that emits alpha radiation is highly dangerous. (separate only)

(3)

(c) A sample of polonium-210 was left for 414 days.

After this time it had a mass of 1.45 × 10−4 g

The half-life of polonium-210 is 138 days.

Calculate the initial mass of the sample.

Initial mass = _____ g

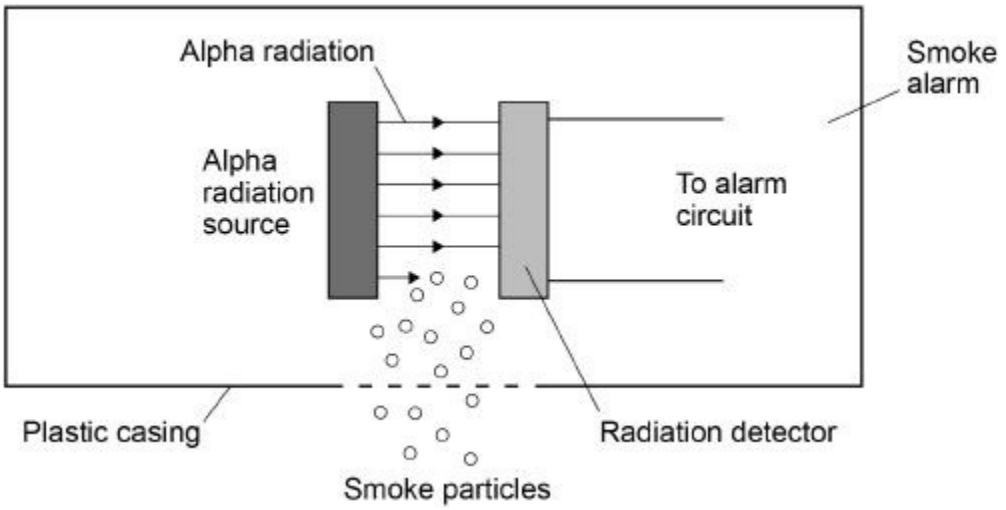
(3)

(Total 8 marks)

4. Smoke alarms contain an alpha radiation source and a radiation detector.

Figure 1 shows part of the inside of a smoke alarm.

Figure 1



(a) The smoke alarm stays off while alpha radiation reaches the detector.

Why does the alarm switch on when smoke particles enter the plastic casing?

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(1)

(b) Why is it safe to use a source of alpha radiation in a house?

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(1)

(c) The smoke alarm would not work with a radiation source that emits beta or gamma radiation. Explain why.

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(2)

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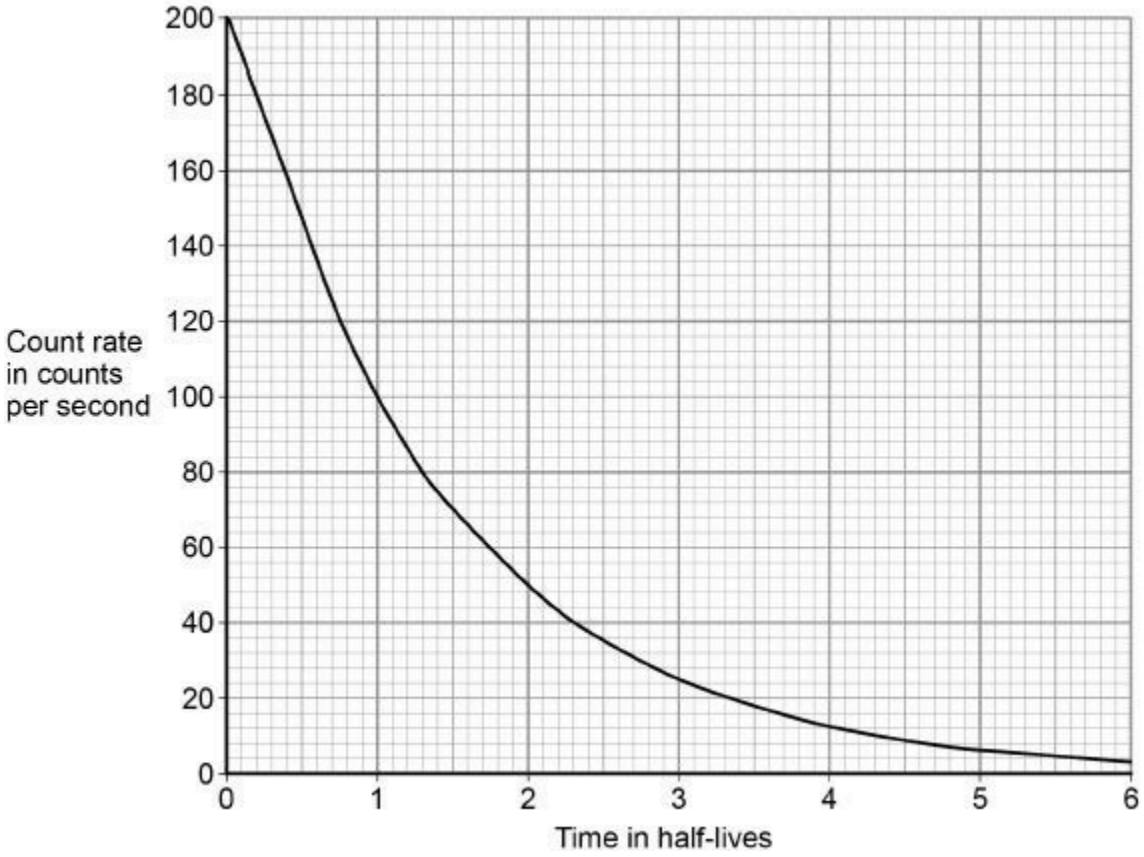
(d) **Figure 2** shows how the count rate detected from the radiation source in the smoke alarm changes with time.

Figure 2



The smoke alarm switches on when the count rate falls to 80 counts per second.

Explain why the radiation source inside the smoke alarm should have a long half-life.
(separate only)

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(2)

(e) **Figure 3** shows a patient who has been injected with a radioactive source for medical diagnosis.

Figure 3

Explain the ideal properties of a radioactive source for use in medical diagnosis. (separate only)

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(4)

(Total 10 marks)

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5. Nuclear power stations generate electricity through nuclear fission. Electricity can also be generated by burning shale gas.

(a) Shale gas is natural gas trapped in rocks. Shale gas can be extracted by a process called fracking. There is some evidence that fracking causes minor earthquakes. Burning shale gas adds carbon dioxide to the atmosphere.

Describe the advantages of nuclear power compared with the use of shale gas to generate electricity.

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(3)

(b) What is the name of **one** fuel used in nuclear power stations?

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(1)

(c) Describe the process of nuclear fission. (separate only)

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(4)

(Total 8 marks)

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6. Nuclear fission and nuclear fusion are two processes that release energy.

(a) The following nuclear equation represents the fission of uranium-235 (U-235).

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

Chemical symbols:

- Ba =
- barium Kr =
- krypton $^{1}_{0}n$ = neutron

Describe the process of nuclear fission. (separate only)

Use the information in the equation.

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(4)

(b) Explain what happens in the process of nuclear fusion. (separate only)

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(3)

(c) Fission reactors are used in nuclear power stations.

Engineers are developing fusion reactors for use in power stations.

Fusion uses isotopes of hydrogen called deuterium and tritium.

- Deuterium is naturally occurring and can be easily extracted from seawater.
- Tritium can be produced from lithium. Lithium is also found in seawater.

The table shows the energy released from 1 kg of fusion fuel and from 1 kg of fission fuel.

Type of fuel	**Energy released from 1 kg of fuel in joules**
Fusion	3.4 × 1014
Fission	8.8 × 1013

Suggest **two** advantages of the fuel used in a fusion reactor compared with the fuel used in a fission reactor. (separate only)

1. _____

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2. _____

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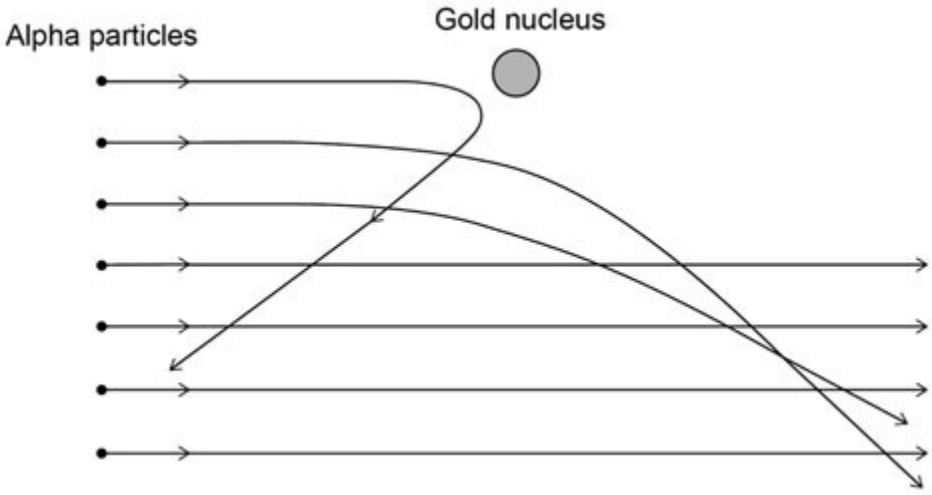
(2)

(Total 9 marks)

7. In the early 20th century, scientists developed an alpha particle scattering experiment using gold foil.

The diagram shows the paths of some of the alpha particles in the alpha particle scattering experiment.



(a) Explain how the paths of the alpha particles were used to develop the nuclear model of the atom.

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(4)

(b) Niels Bohr adapted the nuclear model by suggesting electrons orbited the nucleus at specific distances.

Explain how the distance at which an electron orbits the nucleus may be changed.

(3)

(Total 7 marks)

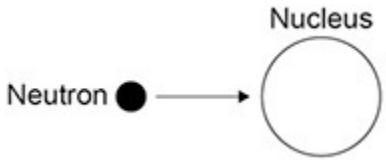
8. Electricity is generated in a nuclear power station.

Fission is the process by which energy is released in the nuclear reactor.

(a) **Figure 1** shows the first part of the nuclear fission reaction.

Complete **Figure 1** to show how the fission process starts a chain reaction. (separate only)

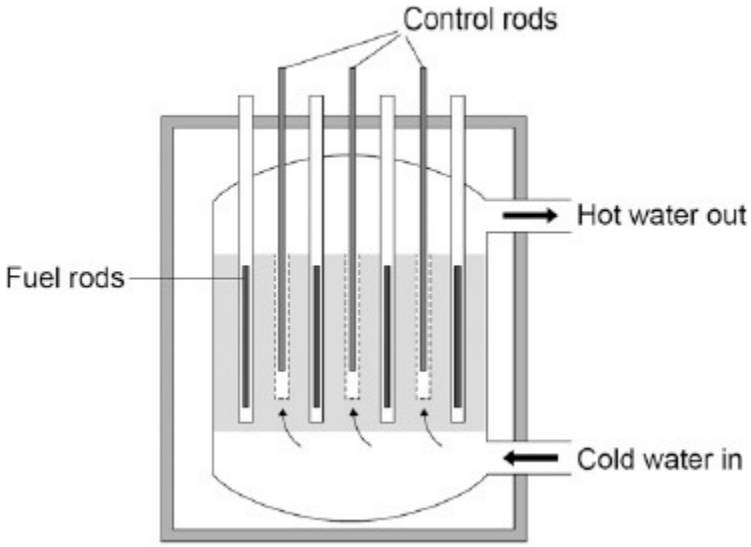
Figure 1



(3)

(b) **Figure 2** shows the inside of a nuclear reactor in a nuclear power station.

Figure 2



In a nuclear reactor a chain reaction occurs, which causes neutrons to be released. The control rods absorb neutrons. The control rods can be moved up and down. Explain how the energy released by the chain reaction is affected by moving the control rods.

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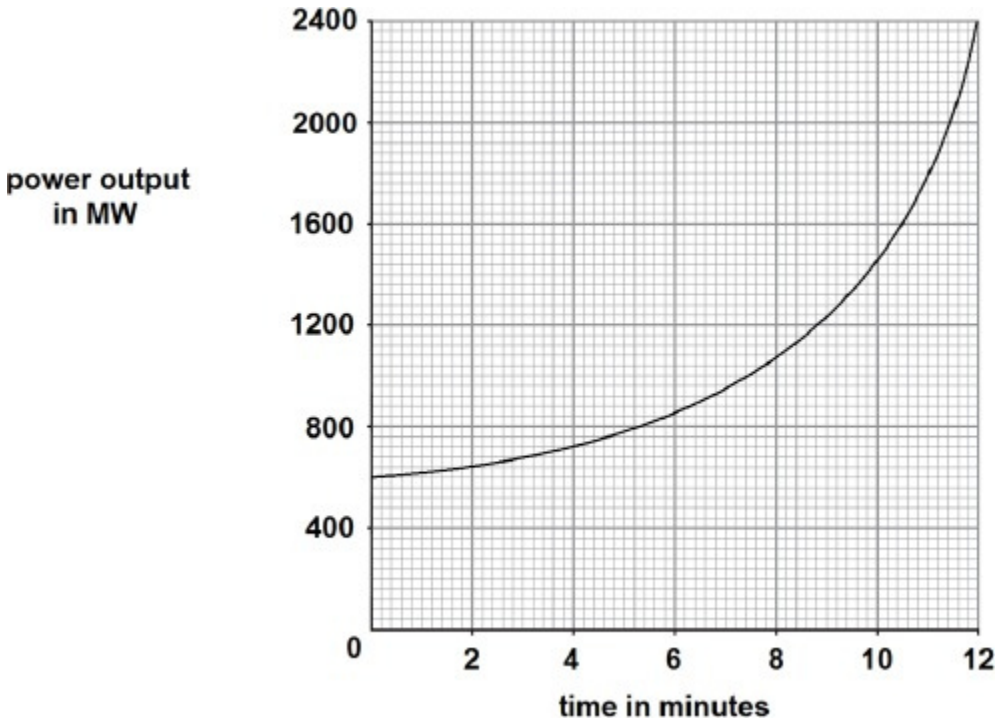
(2)

(c) **Figure 3** shows how the power output of the nuclear reactor would change if the control rods were removed.

Figure 3



Calculate the rate of increase of power output at 10 minutes.

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_____Rate of increase of power output = _____MW / minute

(2)

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