Nuclear Physics

1.

Energy from the Sun is released by nuclear fusion.

Complete the sentences.

[2 marks]

Nuclear fusion is the joining together of _____.

During nuclear fusion the total mass of the particles _____.

Nuclear fusion of deuterium is difficult to achieve on Earth because of the high temperature needed.

Electricity is used to increase the temperature of 4.0 g of deuterium by 50 000 000 °C.

specific heat capacity of deuterium = 5200 J/kg °C

Calculate the energy needed to increase the temperature of the deuterium by 50 000 000 °C.

Use the Physics Equation Sheet.

[3 marks]

The idea of obtaining power from nuclear fusion was investigated using models.

The models were tested before starting to build the first commercial nuclear fusion power station.

Suggest **two** reasons why models were tested.

[2 marks]

1 _____

_____

_____

2 _____

_____

_____

Generating electricity using nuclear fusion will have fewer environmental effects than generating electricity using fossil fuels.

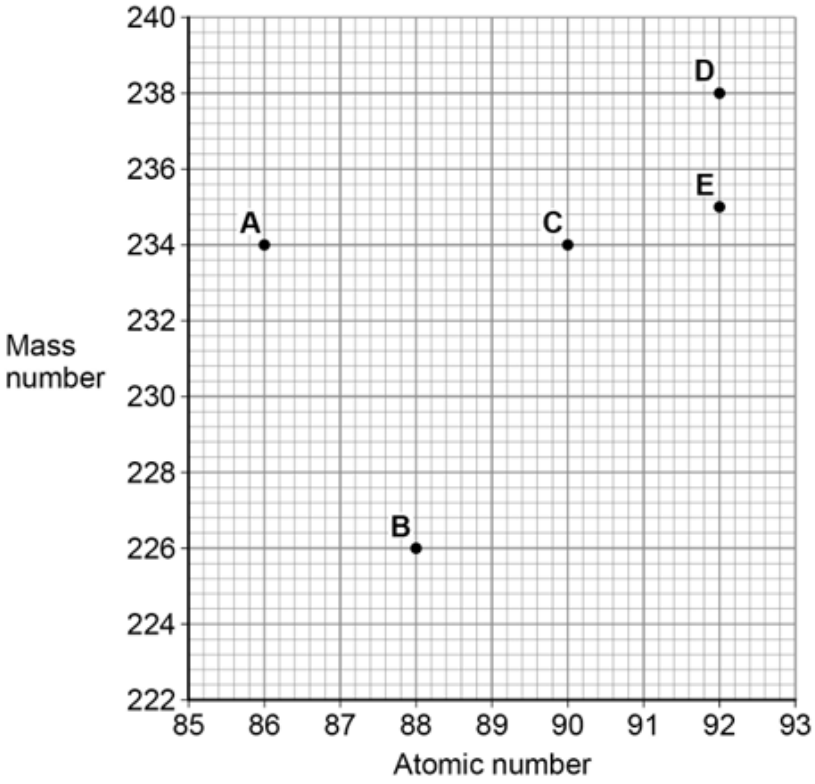
Explain **one** environmental effect of generating electricity using fossil fuels.

[2 marks]

2.

Figure 6 shows the mass number and the atomic number for the nuclei of five different atoms.

Figure 6



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

[1 mark]

Which **two** atoms in **Figure 6** are the same element?

[1 mark]

Tick (✓) **one** box.

A and **B** ☐

A and **C** ☐

C and **D** ☐

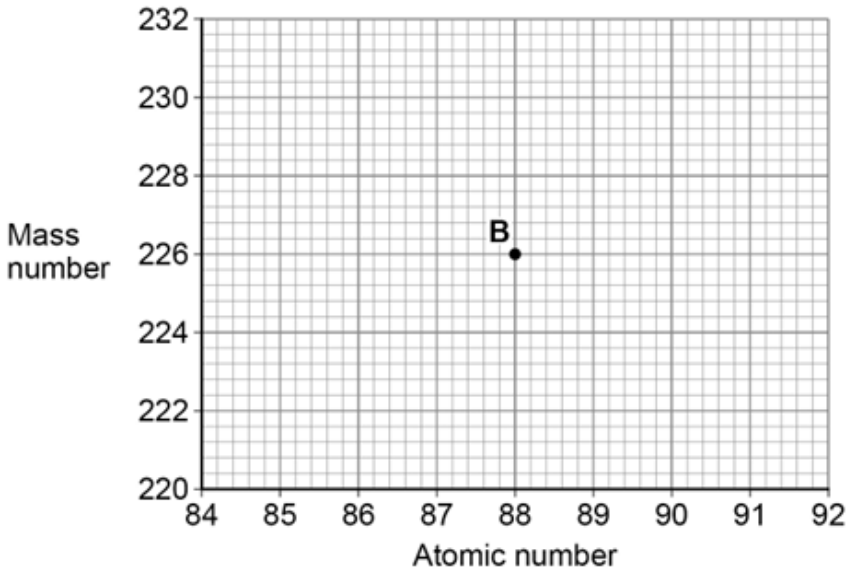
D and **E** ☐

Nucleus **B** decays by emitting an alpha particle.

Draw an arrow on **Figure 7** to represent the alpha decay.

[2 marks]

Figure 7



What is meant by the 'random nature of radioactive decay'?

[1 mark]

_____

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.

[3 marks]

3.

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

Give **one** other man-made source of background radiation.

[1 mark]

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

Give the name of **one** nuclear fuel.

[1 mark]

Nuclear fission releases energy.

Describe the process of nuclear fission inside a nuclear reactor.

[4 marks]

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.

[2 marks]

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.

[2 marks]

4.

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

Complete the decay equation for polonium-210

[2 marks]

$${}^{210}_{84}\mathrm{Po} \longrightarrow \square\!\!\square\mathrm{Pb} + {}^{4}_{2}\mathrm{He}$$

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

[3 marks]

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.

[3 marks]

Initial mass = _____ g

5.

A teacher used a Geiger-Muller tube and counter to measure the number of counts in 60 seconds for a radioactive rock.

The counter recorded 819 counts in 60 seconds. The background radiation count rate was 0.30 counts per second.

Calculate the count rate for the rock.

[3 marks]

Count rate = _____ per second

A householder is worried about the radiation emitted by the granite worktop in his kitchen.

1 kg of granite has an activity of 1250 Bq. The kitchen worktop has a mass of 180 kg.

Calculate the activity of the kitchen worktop in Bq.

[2 marks]

Activity = _____ Bq

The average total radiation dose per year in the UK is 2.0 millisieverts.

Table 1 shows the effects of radiation dose on the human body.

Table 1

Radiation dose in millisieverts	**Effects**
10 000	Immediate illness; death within a few weeks
1000	Radiation sickness; unlikely to cause death
100	Lowest dose with evidence of causing cancer

The average radiation dose from the granite worktop is 0.003 millisieverts per day.

Explain why the householder should **not** be concerned about his yearly radiation dose from the granite worktop.

One year is 365 days.

[2 marks]

Bananas are a source of background radiation. Some people think that the unit of radiation dose should be changed from sieverts to Banana Equivalent Dose.

Suggest **one** reason why the Banana Equivalent Dose may help the public be more aware of radiation risks.

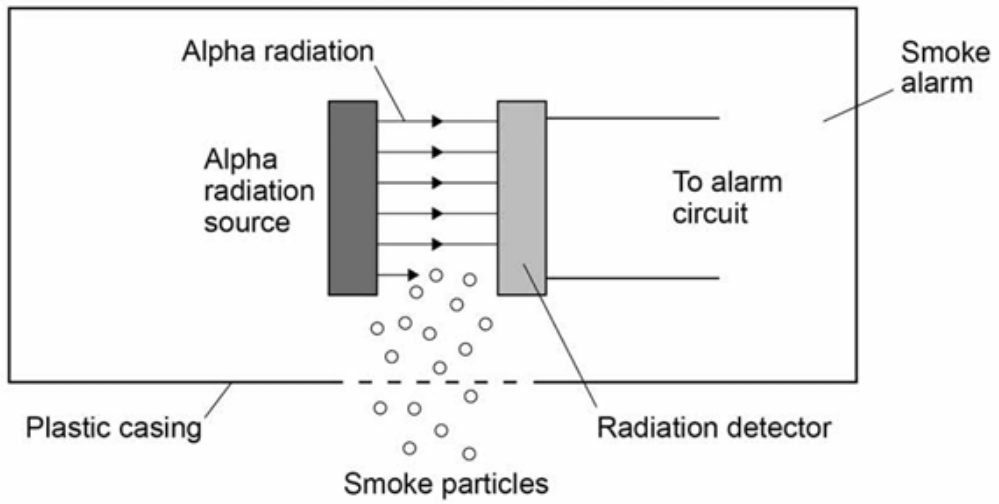
[1 mark]

6.

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

Figure 9 shows part of the inside of a smoke alarm.

Figure 9



1 The smoke alarm stays off while alpha radiation reaches the detector.

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

[1 mark]

2 Why is it safe to use a source of alpha radiation in a house?

[1 mark]

. 3 The smoke alarm would not work with a radiation source that emits beta or gamma radiation.

Explain why.

[2 marks]

7.

A student models the random nature of radioactive decay using 100 dice.

He rolls the dice and removes any that land with the number 6 facing upwards.

He rolls the remaining dice again.

The student repeats this process a number of times.

Table 1 shows his results.

Table 1

Roll number	Number of dice remaining
0	100
1	84
2	70
3	59
4	46
5	40
6	32
7	27
8	23

1 Give **two** reasons why this is a good model for the random nature of radioactive decay.

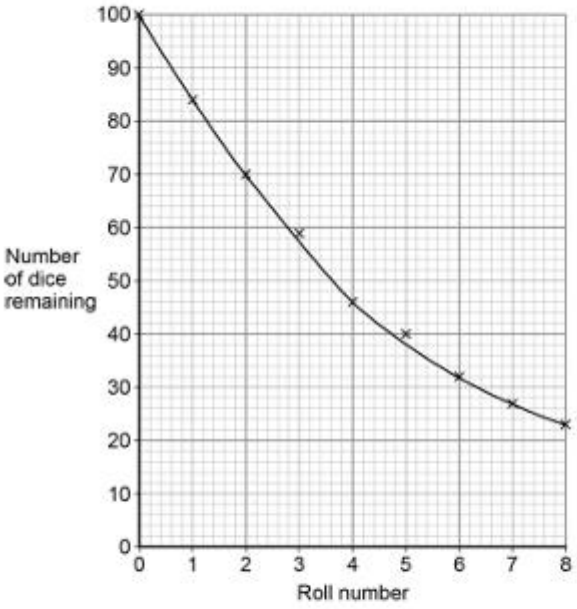
[2 marks]

1

2

The student's results are shown in **Figure 11**.

Figure 11



1 . 2 Use **Figure 11** to determine the half-life for these dice using this model.

Show on **Figure 11** how you work out your answer.

[2 marks]

Half-life = _____ rolls

A teacher uses a protactinium (Pa) generator to produce a sample of radioactive material that has a half-life of 70 seconds.

In the first stage in the protactinium generator, uranium (U) decays into thorium (Th) and alpha (α) radiation is emitted.

The decay can be represented by the equation shown in **Figure 12**.

Figure 12

$$^{238}_{92}U \longrightarrow \boxed{}^{234}Th + \alpha$$

. **3** Determine the atomic number of thorium (Th) 234.

[1 mark]

Atomic number = _____

When protactinium decays, a new element is formed and radiation is emitted.

The decay can be represented by the equation shown in **Figure 13**.

Figure 13

$$^{234}_{91}Pa \rightarrow {}^{234}_{92}X + radiation$$

. **4** When protactinium decays, a new element, **X**, is formed.

Use information from **Figure 12** and **Figure 13** to determine the name of element **X**.

[1 mark]

_____

. 5 Determine the type of radiation emitted as protactinium decays into a new element.

Give a reason for your answer.

[2 marks]

. 6 The teacher wears polythene gloves as a safety precaution when handling radioactive materials.

The polythene gloves do **not** stop the teacher's hands from being irradiated.

Explain why the teacher wears polythene gloves.

[2 marks]