Name:

Date:

P4 - Test 6
ATOMIC STRUCTURE
Advanced

GCSE

PHYSICS

AQA - Combined Science

Mark

Grade

Materials

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

Information

- The marks for the questions are shown in brackets

1. (a) Complete the following table for an atom of uranium-238 ($^{238}_{92}U$)

mass number	238
number of protons	92
number of neutrons	

(1)

(b) Complete the following sentence.

The name given to the number of protons in an atom is the proton number or the

_____ .

(1)

(c) An atom of uranium-238 ($^{238}_{92}U$) decays to form an atom of thorium-234 ($^{234}_{90}Th$).

(i) What type of radiation, alpha, beta or gamma, is emitted by uranium-238?

_____

(1)

(ii) Why does an atom that decays by emitting alpha or beta radiation become an atom of a different element?

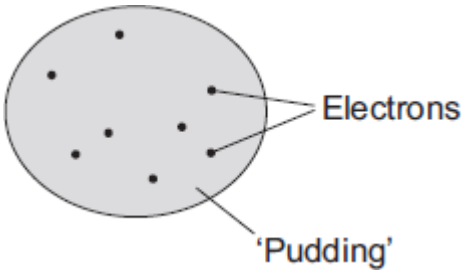
_____

_____

(1)

(Total 4 marks)

2. The 'plum pudding' model of the atom was used by scientists in the early part of the 20th century to explain atomic structure.



(a) Those scientists knew that atoms contained electrons and that the electrons had a negative charge. They also knew that an atom was electrically neutral overall.

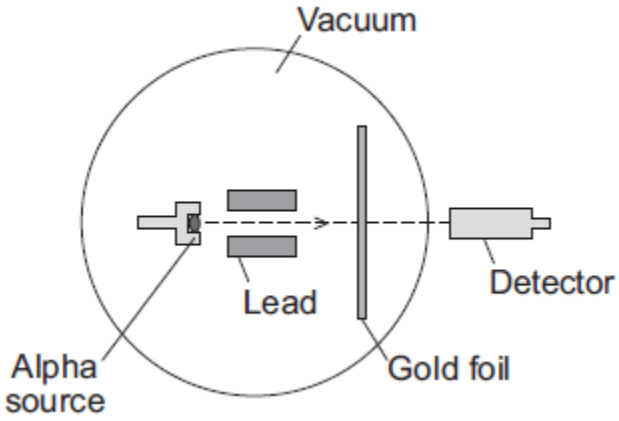
What did this allow the scientists to deduce about the ‘pudding’ part of the atom?

_____

_____

(1)

(b) An experiment, designed to investigate the ‘plum pudding’ model, involved firing alpha particles at a thin gold foil.



If the ‘plum pudding’ model was correct, then most of the alpha particles would go straight through the gold foil. A few would be deflected, but by less than 4°.

The results of the experiment were unexpected. Although most of the alpha particles did go straight through the gold foil, about 1 in every 8 000 was deflected by more than 90°.

Why did this experiment lead to a new model of the atom, called the nuclear model, replacing the ‘plum pudding’ model?

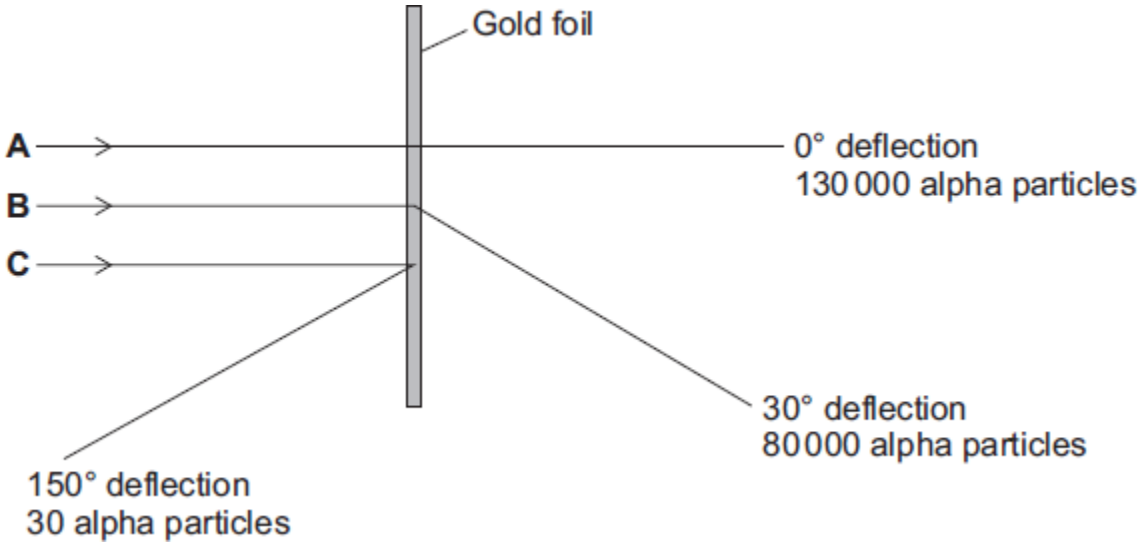
_____

_____

_____

(1)

(c) The diagram shows the paths, **A**, **B** and **C**, of three alpha particles. The total number of alpha particles deflected through each angle is also given.



(i) Using the nuclear model of the atom, explain the three paths, **A**, **B** and **C**.

A _____

_____

B _____

_____

C _____

_____

(3)

(ii) Using the nuclear model, the scientist E. Rutherford devised an equation to predict the proportion of alpha particles that would be deflected through various angles.

The results of the experiment were the same as the predictions made by Rutherford.

What was the importance of the experimental results and the predictions being the same?

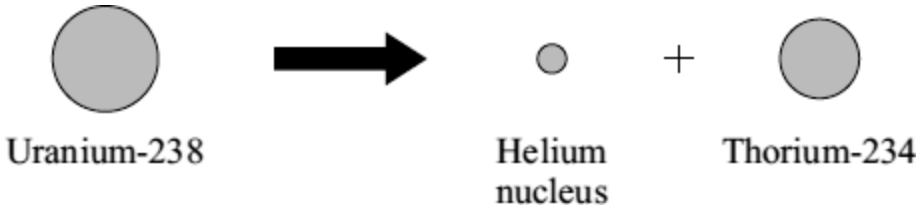
_____

_____

(1)

(Total 6 marks)

3. (a) Some rocks inside the Earth contain uranium-238, a radioactive isotope of uranium. When an atom of uranium-238 decays, it gives out radiation and changes into a thorium-234 atom.



(i) What type of radiation is emitted when a uranium-238 atom decays?

_____

(1)

(ii) From which part of a uranium-238 atom is the radiation emitted?

_____

(1)

(iii) Uranium-235 is another isotope of uranium.

How is an atom of uranium-235 similar to an atom of uranium-238?

_____

(1)

(b) Uranium-238 has a half-life of 4500 million years.

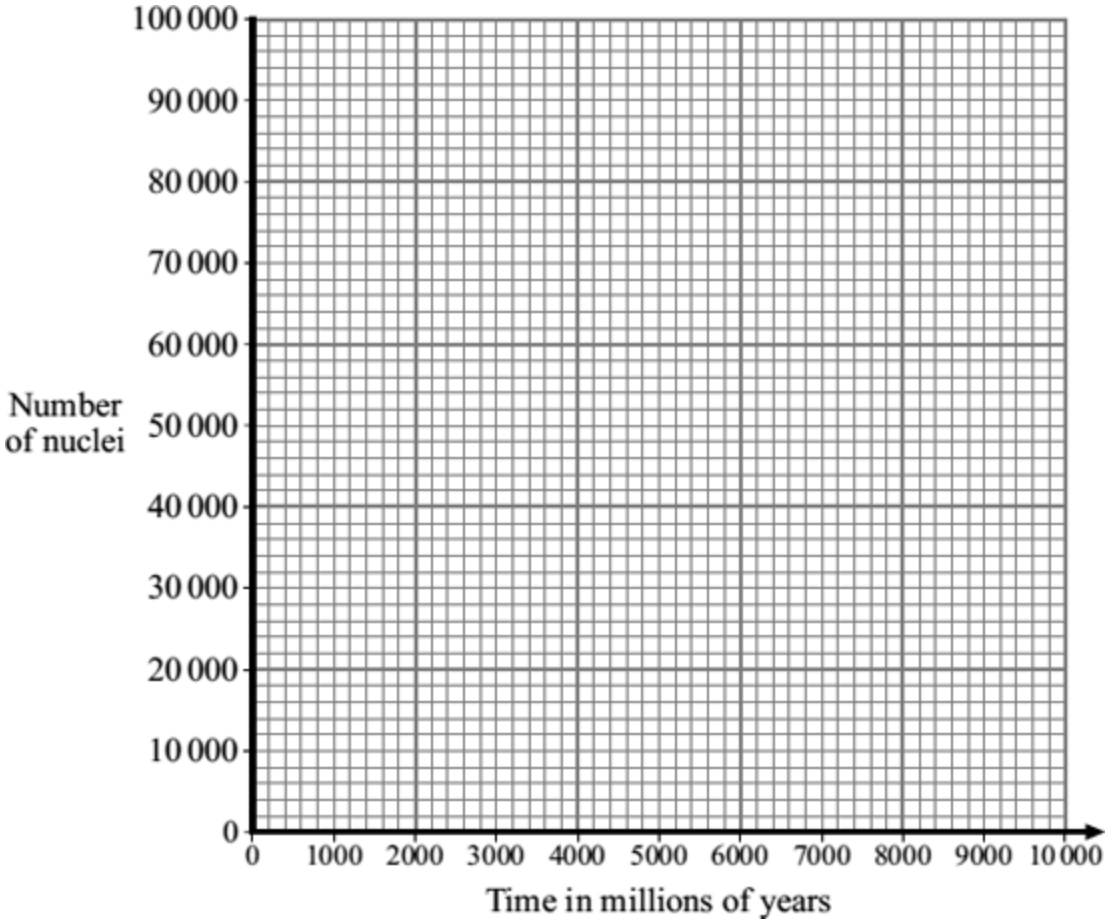
(i) When the Earth was formed, there was twice as much uranium-238 in the rocks as there is now.

What is the age of the Earth?

_____

(1)

(ii) Complete the graph to show how the number of nuclei in a sample of uranium-238 will change with time.
Initially, there were 100 000 nuclei in the sample.



(2)

(Total 6 marks)

4. (a) Atoms of the isotope bismuth-212 decay by emitting either an alpha particle or a beta particle.
The equation represents what happens when an atom of bismuth-212 decays by beta emission into an atom of polonium-212.

$$^{212}_{83}\text{Bi} \longrightarrow {}^{212}_{84}\text{Po} + \text{beta particle}$$

(i) The bismuth atom and the polonium atom have the same mass number (212).

What is the *mass number* of an atom?

_____

(1)

(ii) Beta decay does **not** cause the mass number of an atom to change.

Explain why not.

_____

_____

_____

_____

(2)

(b) When an atom of bismuth-212 emits an alpha particle, the atom decays into an atom of thallium.

An alpha particle is the same as a helium nucleus.
The symbol below represents an alpha particle.

$$^{4}_{2}He$$

(i) The equation below represents the alpha decay of bismuth-212.

Complete the equation by writing the correct number in each of the two boxes.

$$^{212}_{83}Bi \longrightarrow \square \; Tl + {}^{4}_{2}He$$

(2)

(ii) It is impossible for the alpha decay of bismuth-212 to produce the same element as the beta decay of bismuth-212.

Explain why.

_____

_____

_____

_____

(2)

(Total 7 marks)

5. In 2011 an earthquake caused severe damage to a nuclear power station in Japan.

The damage led to the release of large amounts of radioactive iodine-131 ($^{131}_{53}I$) into the atmosphere.

(a) The table gives some information about an atom of iodine-131 ($^{131}_{53}I$).

Complete the table.

mass number	131
number of protons	53
number of neutrons	

(1)

(b) Complete the sentence.

The number of protons in an atom is called the proton number or

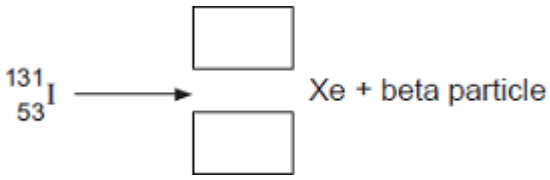
the _____ number.

(1)

(c) An atom of iodine-131 decays into an atom of xenon (Xe) by emitting a beta particle.

(i) The decay of iodine-131 can be represented by the equation below.

Complete the equation by writing the correct number in each of the **two** boxes.



(2)

(ii) A sample of rainwater contaminated with iodine-131 gives a count rate of 1200 counts per second.

Calculate how many days it will take for the count rate from the sample of rainwater to fall to 75 counts per second.

Half-life of iodine-131 = 8 days

Show clearly how you work out your answer.

_____

_____

_____ days

(2)

(iii) If people drink water contaminated with iodine-131, the iodine-131 builds up in the thyroid gland. This continues until the thyroid is saturated with iodine-131 and cannot absorb any more. The radiation emitted from the iodine-131 could cause cancer of the thyroid.

In Japan, people likely to be drinking water contaminated with iodine-131 were advised to take tablets containing a non-radioactive isotope of iodine.

Suggest why this advice was given.

_____

_____

_____

_____

(2)

(Total 8 marks)

6. Some small fractures do not show up on an X-ray image.

To see the fracture doctors inject the patient with a radioactive isotope.

The image is formed by detecting radiation as it leaves the body.

The figure below shows an image of a foot after the patient was injected with the radioactive isotope technetium-99.

Technetium-99 emits gamma radiation.

(a) What is gamma radiation?

_____

_____

(1)

(b) Explain why a gamma emitter is used.

(2)

(c) Technetium-99 has a **half-life** of 6 hours.

Give the meaning of the term **half-life**.

(1)

(d) After treatment, hospital equipment may become contaminated.

Describe the level of the hazard associated with contamination with technetium-99.

You should include in your answer a description of how the level of hazard changes over time.

(3)

(e) Some of the hospital equipment may also be irradiated during treatment.

Describe how equipment becomes irradiated.

(1)

(f) Why is irradiated equipment not hazardous?

_____

_____

(1)

(Total 9 marks)

7. Most elements have some *isotopes* which are *radioactive*.

(a) What is meant by the terms:

(i) *isotopes*

_____

_____

(1)

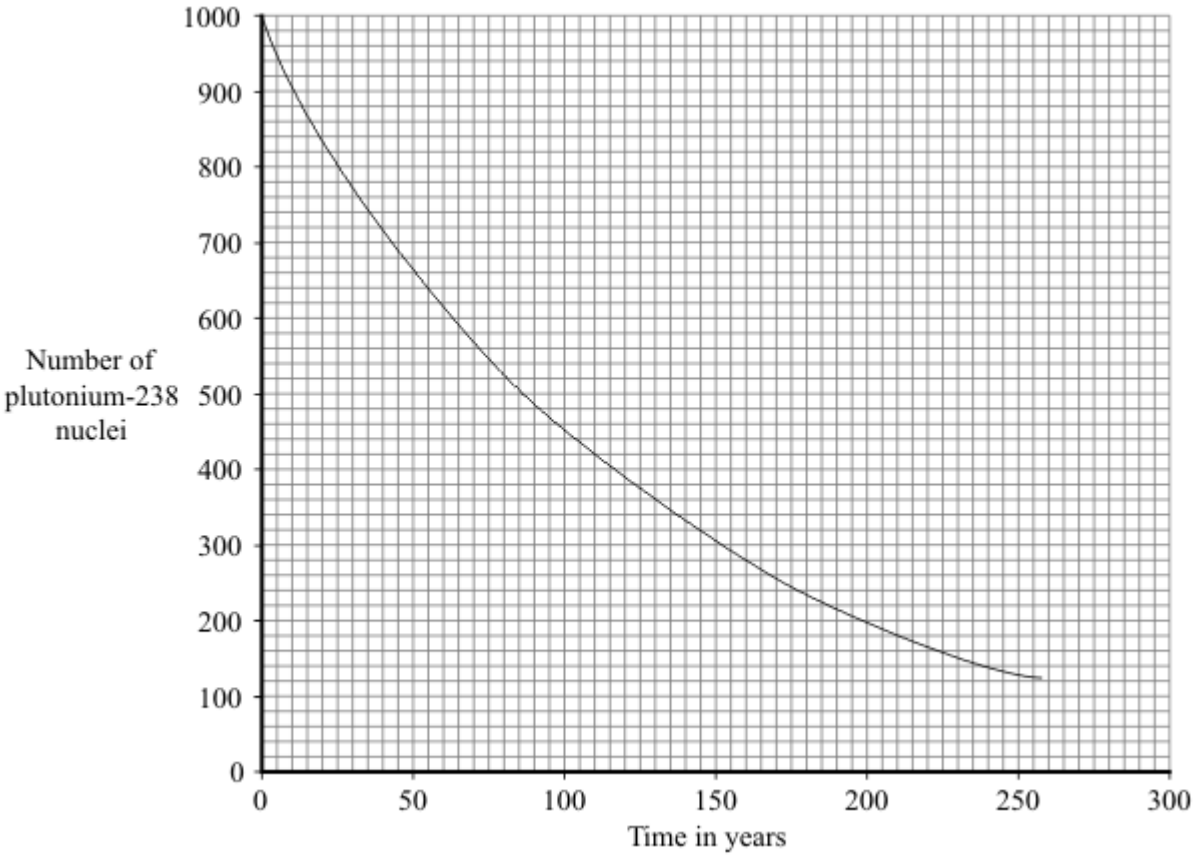
(ii) *radioactive*?

_____

_____

(1)

(b) The graph shows how the number of nuclei in a sample of the radioactive isotope plutonium-238 changes with time.



Use the graph to find the half-life of plutonium-238.

Show clearly on the graph how you obtain your answer.

Half-life = _____ years

(2)

(c) The Cassini spacecraft launched in 1997 took seven years to reach Saturn.

The electricity to power the instruments on board the spacecraft is generated using the heat produced from the decay of plutonium-238.

(i) Plutonium-238 decays by emitting alpha particles.

What is an alpha particle?

_____

(1)

(ii) During the 11 years that Cassini will orbit Saturn, the output from the generators will decrease.

Explain why.

_____

_____

_____

_____

(2)

(d) Plutonium-238 is highly dangerous. A tiny amount taken into the body is enough to kill a human.

(i) Plutonium-238 is unlikely to cause any harm if it is outside the body but is likely to kill if it is inside the body.

Explain why.

_____

_____

_____

_____

(2)

(ii) In 1964, a satellite powered by plutonium-238 was destroyed, causing the release of radioactive material into the atmosphere.

Suggest why some environmental groups protested about the launch of Cassini.

_____

_____

(1)

(Total 10 marks)

8. Atoms are different sizes.

One of the heaviest naturally occurring stable elements is lead.

Two of its isotopes are lead-206 ($^{206}_{82}Pb$) and lead-208 ($^{208}_{82}Pb$).

(a) (i) What is meant by 'isotopes'?

_____

_____

_____

_____

(2)

(ii) How many protons are in the nucleus of a $^{206}_{82}Pb$ atom?

_____

(1)

(iii) How many neutrons are in the nucleus of a $^{206}_{82}Pb$ atom?

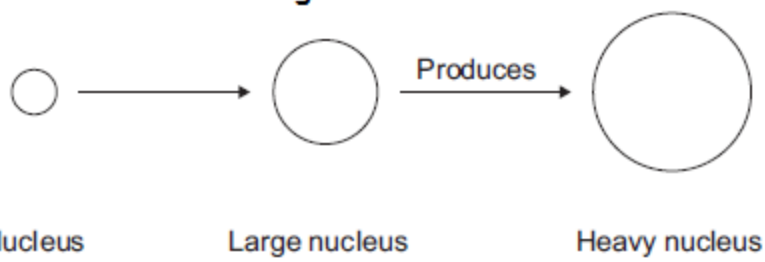
_____

(1)

(b) A nucleus can be accelerated in a particle accelerator and directed at a large nucleus. This produces a heavy nucleus that will decay after a short time.

This is shown in **Figure 1**.

Figure 1



(i) In 1984, nuclei of iron (Fe) were directed at nuclei of lead (Pb). This produced nuclei of hassium (Hs).

Complete the equation for this reaction by writing numbers in the empty boxes.

$$\square^{58}Fe + \square^{\square}Pb = {}^{265}_{108}Hs + {}^{1}_{0}X$$

(3)

(ii) Use the correct answer from the box to complete the sentence.

an electron	**a proton**	**a neutron**

The particle **X** in part (b)(i) is _____ .

(1)

(iii) After acceleration the iron nuclei travel at a steady speed of one-tenth of the speed of light.

The speed of light is 3.00×10^8 m/s.

Calculate the time taken for the iron nuclei to travel a distance of 12 000 m.

_____

_____

Time taken = _____ s

(2)

(iv) Linear accelerators, in which particles are accelerated in a straight line, are **not** used for these experiments. Circular particle accelerators are used.

Suggest why.

_____

_____

_____

_____

_____

_____

(3)

(c) Hassium-265 ($^{265}_{108}Hs$) decays by alpha emission with a half-life of 0.002 seconds.

(i) What is meant by 'half-life'?

Tick (✓) **two** boxes.

	Tick (✓)
The average time for the number of nuclei to halve	
The time for count rate to be equal to background count	
The time for background count to halve	
The time for count rate to halve	

(2)

(ii) Complete the equation for the decay of Hs-265 by writing numbers in the empty boxes.

$$^{265}_{108}Hs = \frac{\square}{\square}Sg + \frac{\square}{\square}\alpha$$

(2)

(d) The table below shows how the atomic radius of some atoms varies with atomic number.

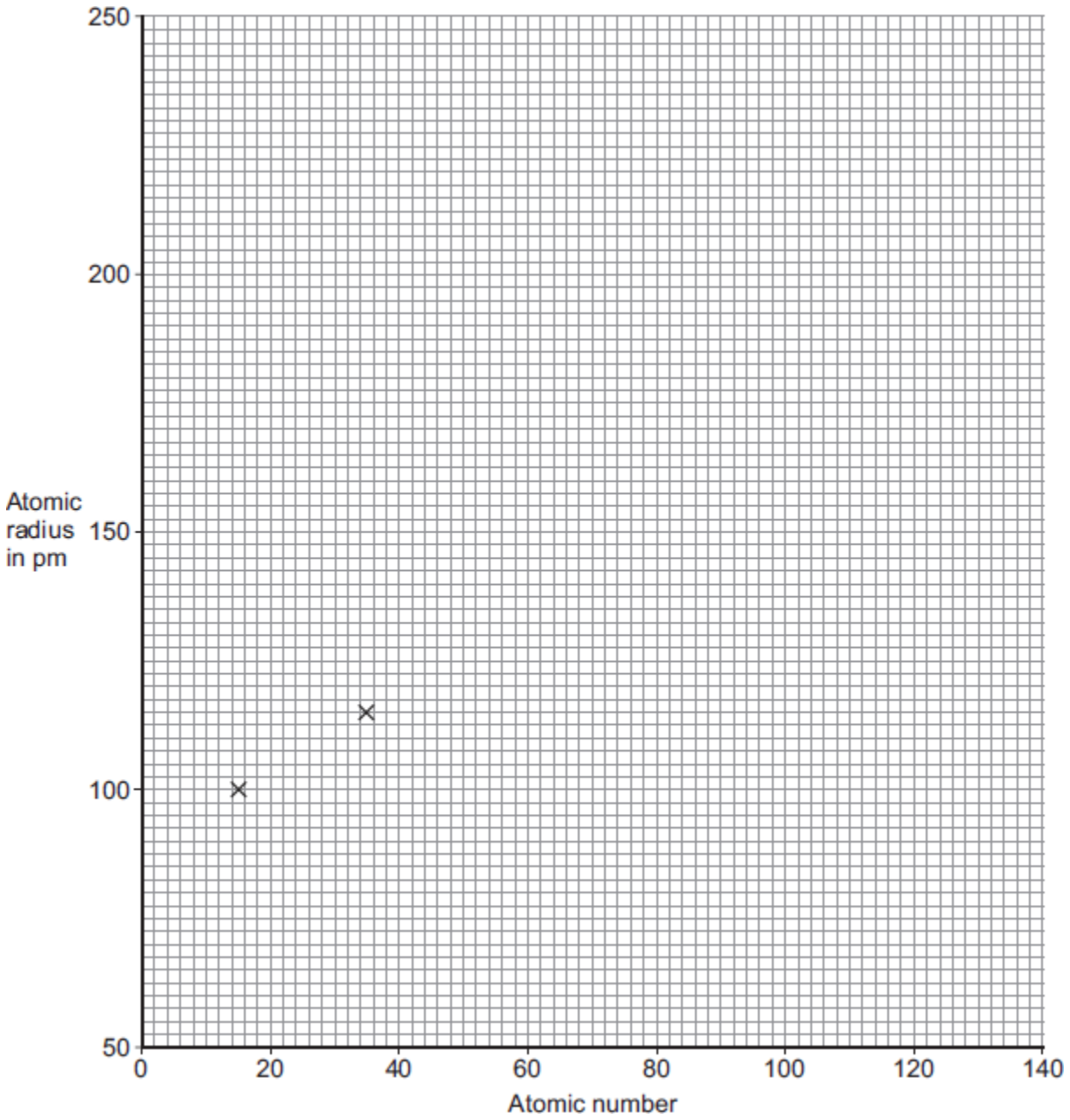
Atomic number	Atomic radius in picometres (pm)
15	100
35	115
50	130
70	150
95	170

1 pm = 10^{-12} m

(i) On **Figure 2**, use the data from the table above to plot a graph of atomic radius against atomic number and draw a line of best fit.

Two points have been plotted for you.

Figure 2



(2)

(ii) Scientists believe that the element with atomic number 126 can be produced and that it will be stable.

Use your graph in **Figure 2** to predict the atomic radius of an atom with atomic number 126.

Atomic radius = _____ pm

(1)

(Total 20 marks)