1. $^{12}_{6}C$ and $^{14}_{6}C$ are two isotopes of carbon.

State the number of electrons in a neutral atom of $^{14}_{6}C$.

.....

State the number of neutrons in a neutral atom of $^{14}_{6}C$.

.....

(2)

$^{14}_{6}C$ decays by beta minus emission. Complete the nuclear equation below.

$$^{14}_{6}C \rightarrow \quad N \; +$$

(2)

Describe briefly how you would test whether $^{14}_{6}C$ decays *only* by beta emission

.....

.....

.....

.....

.....

.....

(3)
(Total 7 marks)

2. In 1909 Geiger and Marsden carried out an important experiment to investigate alpha particle scattering. Alpha particles were directed towards a thin gold sheet and detectors were used to observe the distribution of scattered alpha particles.

State what was observed in this experiment.

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.....

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(3)

Explain why these observations led to the conclusion that an atom was composed mainly of space, with a very small positive nucleus.

.....

.....

.....

.....

.....

(3)

State an approximate value for

(i) the diameter of a gold atom

.....

(ii) the diameter of a gold nucleus

.....

(2)
(Total 8 marks)

3. Name *two* sources of natural background radiation.

1 .....

2 .....

(2)

Caesium-137 is a by-product of nuclear fission within a nuclear reactor. Complete the two boxes in the nuclear equation below which describes the production of $^{137}_{55}Cs$.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{55}Cs + \boxed{{}^{95}Rb} + \boxed{{}^{1}_{0}n}$$

(2)

The half-life of caesium-137 is 30 years. When the fuel rods are removed from a nuclear reactor core, the total activity of the caesium-137 is 5.8×10^{15} Bq. After how many years will this activity have fallen to 1.6×10^{6} Bq?

.....

.....

.....

.....

.....

.....

Number of years = ...

(4)

Comment on the problems of storage of the fuel rods over this time period.

.....

.....

.....

.....

(2)

(Total 10 marks)

4. Radon-220 (also know as thoron) is a radioactive gas which decays by α emission to polonium $^{216}_{84}\text{Po}$. The half-life of this decay is approximately 1 minute.

Write a nuclear equation for this decay.

.....

(1)

Describe an experiment you could perform in a school laboratory to determine the half-life of an α emitter of half-life approximately 1 minute.

.....

.....

.....

.....

.....

.....

(5)

A sample of milk is contaminated with a very small quantity of strontium-90. This isotope decays by β^- emission with a half-life of approximately 28 years.

Give two reasons why it would be very difficult to use this contaminated sample of milk to obtain an accurate value for the half-life of strontium-90.

.....

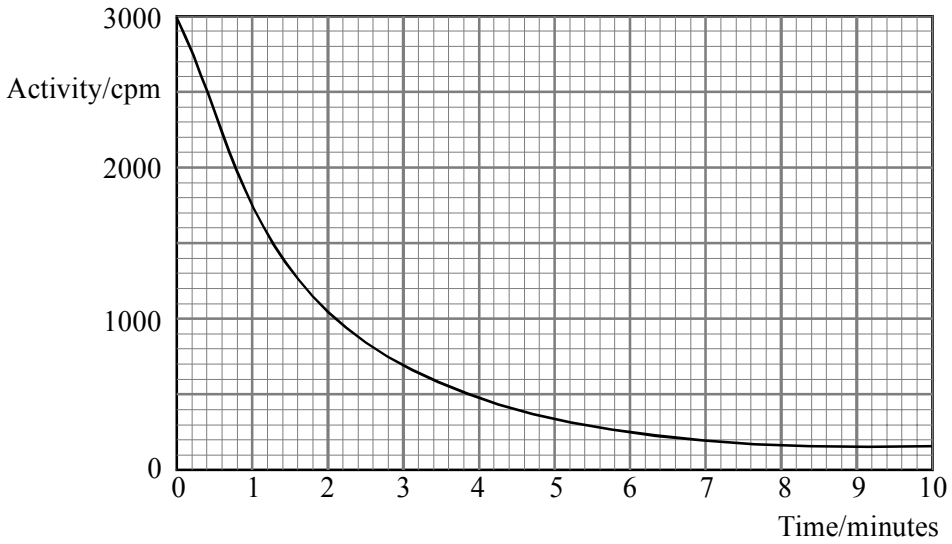
.....

.....

.....

(2)
(Total 8 marks)

5. A student carries out an experiment to determine the half-life of a radioactive isotope M. After subtracting the mean background count from the readings, the student plots the smooth curve shown on the graph below.



From this graph the student concludes that the isotope M is not pure, but contains a small proportion of another isotope C with a relatively long half-life.

State a feature of the graph that supports this conclusion.

……

……

(1)

Estimate the activity of isotope C.

……

(1)

Determine the half-life of isotope M. Show clearly how you obtained your answer.

……

……

……

……

Half-life of M = …….

(3)

Isotope M decays by β^- emission. Write down a nuclear equation showing how the β^- particles are produced.

……

(1)

Describe briefly how the student could determine the nature of the radiation emitted by isotope C.

……

……

……

……

……

(3)
(Total 9 marks)

6. It is thought that an extremely short-lived radioactive isotope $^{269}_{110}X$, which decays by *?*-emission, has a half-life of 200 ?s.

After a series of *?* decays the element $^{A}_{104}Y$ is formed from the original isotope. There are no *?* decays.

Deduce the value of A.

.....….....….....…

.....….....….....…

(2)

Calculate the decay constant λ of $^{269}_{110}$X.

.....

.....

λ = ...

(1)

The number of nuclei *N* of $^{269}_{110}$X in a sample of mass 0.54 ?g is 1.2 ?10^{15}. Determine the activity of 0.54 ?g of $^{269}_{110}$X

.....

.....

Activity = ...

(2)

Why is this value for the activity only approximate?

.....

.....

.....

(1)
(Total 6 marks)

7. Geiger and Marsden carried out a scattering experiment which led to a revised understanding of the structure of the atom. The tables below refer to this experiment. Complete the tables and sentences.

	Name
Incoming particle	
Target atoms	

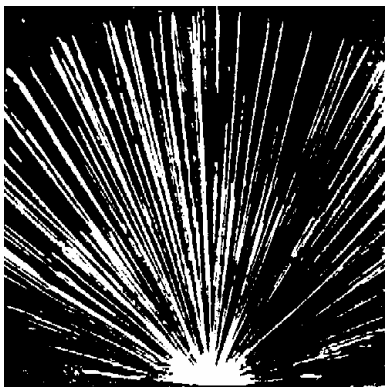
Observation	Conclusion about atomic structure
The incoming particles were mostly undeflected.	
A few particles were deflected by angles greater than 90°.	

The diameter of ……..... is approximately 10^{-15} m.

The diameter of .....……..... is approximately 10^{-11} m.

(Total 6 marks)

8. The photograph shows α particle tracks.



What properties of the α particles can be deduced from this photograph?

.....

.....

.....

.....

(4)

A different source emits both α and β particles. How would you use a Geiger counter to determine the approximate count rate due to the α radiation only?

.....

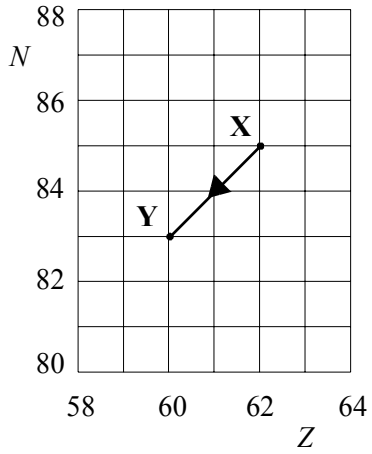
.....

.....

.....

(2)
(Total 6 marks)

9. The grid enables different nuclei to be represented by plotting the number of neutrons *N* against the number of protons *Z* in a nucleus. The arrow shows a nucleus X decaying to a nucleus Y.



What type of radioactive decay is taking place?

.....

Write a nuclear equation for this decay.

.....

Add another arrow to the grid to represent what happens if nucleus Y subsequently decays by β⁻ emission to nucleus W.

Mark a point P on the grid that could represent the nucleus of an isotope of X.

(Total 5 marks)

10. It is thought that some soil could be contaminated with a radioisotope.

You have a sample of this soil. Design an experiment to find what types of radiation are emitted.

.....

.....

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.....

(Total 5 marks)

11. Read the following paragraph carefully and CIRCLE the correct response to the choices in the brackets.

Geiger and Marsden carried out an experiment to investigate the structure of the atom.

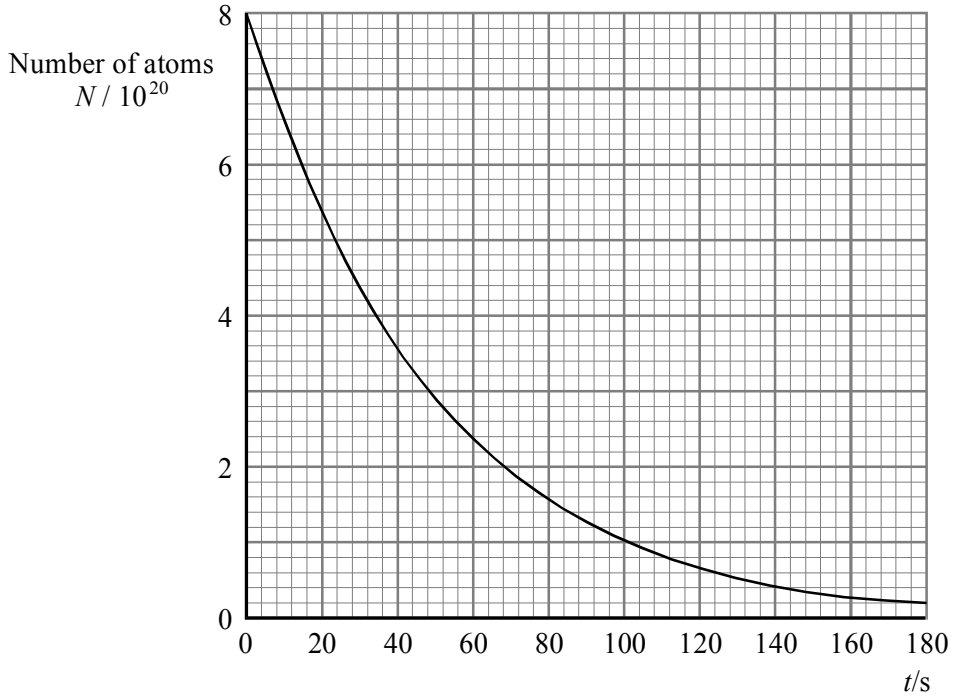
In this experiment $\left\{\begin{matrix}\text{Alpha particles}\\ \text{Beta particles}\\ \text{Gamma rays}\end{matrix}\right\}$ were $\left\{\begin{matrix}\text{diffracted}\\ \text{refracted}\\ \text{scattered}\end{matrix}\right\}$ by thin films of metals such as gold.

The experiment led to the conclusion that the atom had an $\left\{\begin{matrix}\text{uncharged}\\ \text{negatively charged}\\ \text{positively charged}\end{matrix}\right\}$ nucleus of

diameter approximately $\left\{\begin{matrix}10^{-15}\,\text{m}\\ 10^{-10}\,\text{m}\end{matrix}\right\}$ and containing $\left\{\begin{matrix}\text{all the mass}\\ \text{most of the mass}\\ \frac{1}{2000}\text{ of the mass}\end{matrix}\right\}$ of the atom.

(Total 5 marks)

12. The graph shows the decay of a radioactive nuclide.



Determine the half-life of this radionuclide.

.....

.....

.....

Half-life = ...

(2)

Use your value of half-life to calculate the decay constant λ of this radionuclide.

.....

.....

Decay constant = ...

(1)

Use the graph to determine the rate of decay dN/dt when N = 3.0×10^{20}.

.....

.....

.....

.....

Rate of decay = ...

(3)

Use your value of the rate of decay to calculate the decay constant λ of this radionuclide.

.....

.....

.....

Decay constant = ...

(2)

Explain which method of determining the decay constant you consider to be more reliable.

.....

.....

(1)
(Total 9 marks)

13. Uranium decays into thorium, Th, by emitting an alpha particle.

The thorium produced is itself radioactive and decays by beta minus emission to element X.

Complete the nuclear equations for both decays below. Ensure that all symbols have the appropriate nucleon and proton number.

$$\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + $$

$${}^{234}_{90}\mathrm{Th} \rightarrow + $$

(4)

How could a strong magnetic field be used to distinguish alpha particles from beta particles?

.....

.....

.....

.....

(2)
(Total 6 marks)