Materials
For this paper you must have:
- Ruler
- Pencil, Rubber, Protractor and Compass
- 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
- Do all rough work in this book. Cross out any rough work you don't want to be marked

Information
- The marks for the questions are shown in brackets
Atoms contain three types of particle.

(a) Draw a ring around the correct answer to complete the sentence.

The particles in the nucleus of the atom are

- electrons and neutrons.
- electrons and protons.
- neutrons and protons.

(1)

(b) Complete the table to show the relative charges of the atomic particles.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Relative charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>$-1$</td>
</tr>
<tr>
<td>Neutron</td>
<td></td>
</tr>
<tr>
<td>Proton</td>
<td></td>
</tr>
</tbody>
</table>

(2)

(c) (i) A neutral atom has no overall charge.

Explain this in terms of its particles.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(2)

(ii) Complete the sentence.

An atom that loses an electron is called an _____________________
and has an overall _________________________ charge.

(2)

(Total 7 marks)
(a) The figure below shows a helium atom.

(i) Which one of the particles in the atom is not charged?

Draw a ring around the correct answer.

- electron
- neutron
- proton

(ii) Which two types of particle in the atom have the same mass?

__________________________ and __________________________

(iii) What is the atomic number of a helium atom?

Draw a ring around the correct answer.

- 2
- 4
- 6

Give a reason for your answer.

______________________________________________________________

______________________________________________________________

(b) Alpha particles are one type of nuclear radiation.

(i) Name one other type of nuclear radiation.

______________________________________________________________

(1)
(ii) Use the correct answer from the box to complete the sentence.

| electrons | neutrons | protons |

The difference between an alpha particle and a helium atom is that the alpha particle does not have any _________________.

(1)

(iii) Which one of the following is a property of alpha particles?

Tick (✓) one box.

- Have a long range in air
- Are highly ionising
- Will pass through metals

(1)

(c) Doctors may use nuclear radiation to treat certain types of illness.

Treating an illness with radiation may also harm a patient.

(i) Complete the following sentence.

The risk from treating a patient with radiation is that the radiation may ________________ healthy body cells.

(1)

(ii) Draw a ring around the correct answer to complete the sentence.

Radiation may be used to treat a patient if the risk from the radiation is ________________ the possible benefit of having the treatment.

- much bigger than
- about the same as
- much smaller than

(1)

(Total 9 marks)
(a) The names of three types of radiation are given in List A. Some properties of these three types of radiation are given in List B.

Draw one line from each type of radiation in List A to its correct property in List B.

<table>
<thead>
<tr>
<th>List A</th>
<th>Type of radiation</th>
<th>List B</th>
<th>Property of radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha</td>
<td></td>
<td></td>
<td>will pass through paper but is stopped by thin metal</td>
</tr>
<tr>
<td>beta</td>
<td></td>
<td></td>
<td>has the shortest range in air</td>
</tr>
<tr>
<td>gamma</td>
<td></td>
<td></td>
<td>will not harm human cells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>is very weakly ionising</td>
</tr>
</tbody>
</table>

(b) The radioactive isotope iodine-123 can be used by a doctor to examine the thyroid gland of a patient. The iodine, taken as a tablet, is absorbed by the thyroid gland. The gamma radiation emitted as the iodine atoms decay is detected outside the body.
The doctor uses an isotope emitting gamma radiation to examine the thyroid gland rather than an isotope emitting alpha or beta radiation.

Which one of the following gives a reason why gamma radiation is used?

Tick (✓) one box.

- Gamma radiation will pass through the body.
- Gamma radiation is not deflected by a magnet.
- Gamma radiation has a long range in air.

(c) Iodine-123 has a half-life of 13 hours.

Use a word from the box to complete the sentence.

After 13 hours __________________ of the iodine-123 atoms the thyroid absorbed have decayed.

(d) Iodine-123 and iodine-131 are two of the isotopes of iodine.

Draw a ring around the correct answer to complete the sentence.

The nucleus of an iodine-123 atom has the same number of ___________ as the

nucleus of an iodine-131 atom.

(Total 6 marks)
(a) The diagram represents a helium atom.

(i) Which part of the atom, K, L, M or N, is an electron?

Part

(ii) Which part of the atom, K, L, M or N, is the same as an alpha particle?

Part

(b) A radioactive source emits alpha particles.

What might this source be used for?

Put a tick (✓) in the box next to your answer.

to monitor the thickness of aluminium foil as it is made in a factory

to make a smoke detector work

to inject into a person as a medical tracer

(1)
The graph shows how the count rate from a source of alpha radiation changes with time.

What is the count rate after 4 hours?

_______________________ counts per second

(Total 4 marks)

Alpha particles, beta particles and gamma rays are types of nuclear radiation.

(a) Describe the structure of an alpha particle.

___________________________________________________________________

___________________________________________________________________

(Total 1 mark)

(b) Nuclear radiation can change atoms into ions by the process of ionisation.

(i) Which type of nuclear radiation is the least ionising?

Tick (✔) one box.

alpha particles

beta particles

gamma rays

(Total 1 mark)
(ii) What happens to the structure of an atom when the atom is ionised?

___________________________________________________________________

___________________________________________________________________

(1)

(c) People working with sources of nuclear radiation risk damaging their health.

State one precaution these people should take to reduce the risk to their health.

___________________________________________________________________

___________________________________________________________________

(1)

(Total 4 marks)

(a) Radioactive sources that emit alpha, beta or gamma radiation can be dangerous.

What is a possible risk to health caused by using a radioactive source?

___________________________________________________________________

___________________________________________________________________

(1)

(b) In an experiment, a teacher put a 2 mm thick lead sheet in front of a radioactive source. She used a detector and counter to measure the radiation passing through the lead sheet in one minute.

She then put different numbers of lead sheets, each 2 mm thick, in front of the radioactive source and measured the radiation passing through in one minute.

The apparatus the teacher used is shown in Figure 1.
(i) When using a radioactive source in an experiment, how could the teacher reduce the risk to her health?

Suggest one way.

________________________________________________________________________
________________________________________________________________________

(ii) The number recorded on the counter is actually higher than the amount of radiation detected from the source.

Complete the following word equation.

\[
\text{The number recorded on the counter} = \text{The amount of radiation detected from the source} + \underline{\text{radiation}}
\]

(c) The readings taken by the teacher are plotted in Figure 2.

(i) Draw a line of best fit to complete Figure 2.

(1)
(ii) How does the amount of radiation absorbed by the lead change as the total thickness of the lead is increased?

________________________________________________________________________________________
________________________________________________________________________________________

(1)

(iii) Use Figure 2 to estimate the reading on the counter when the total thickness of the lead is increased to 12 mm.

Estimated counter reading = _____________________

(1)

(d) What type of radiation was emitted from the radioactive source?

Draw a ring around the correct answer.

alpha  beta  gamma

Give a reason for your answer.

________________________________________________________________________________________
________________________________________________________________________________________

(2)

(Total 8 marks)

Atoms are different sizes.
One of the heaviest naturally occurring stable elements is lead.

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

(a) (i) What is meant by ‘isotopes’?

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

(2)

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

__________________________

(1)
(iii) How many neutrons are in the nucleus of a \( ^{206}_{82}\text{Pb} \) 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](image)

(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.

\[
\begin{align*}
58\text{Fe} + \boxed{\text{Pb}} &= 265\text{Hs} + 108\boxed{X} \\
\end{align*}
\]

(3)

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

<table>
<thead>
<tr>
<th>an electron</th>
<th>a proton</th>
<th>a neutron</th>
</tr>
</thead>
</table>

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 \( 3.00 \times 10^8 \) 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 (\(^{265}_{108}\text{Hs}\)) decays by alpha emission with a half-life of 0.002 seconds.

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

Tick (✓) two boxes.

| 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.

\[ {^{265}_{108}\text{Hs}} = \square\text{Sg} + \square\alpha \]
(d) The table below shows how the atomic radius of some atoms varies with atomic number.

<table>
<thead>
<tr>
<th>Atomic number</th>
<th>Atomic radius in picometres (pm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>35</td>
<td>115</td>
</tr>
<tr>
<td>50</td>
<td>130</td>
</tr>
<tr>
<td>70</td>
<td>150</td>
</tr>
<tr>
<td>95</td>
<td>170</td>
</tr>
</tbody>
</table>

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

(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

(Total 20 marks)
The figure below shows how the activity of a radioactive isotope changes over an 8 hour period of time.

(a) Predict how long it will take for the count rate to fall from 100 to 1.56 Bequerels.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Time = _______________ hours

(2)

(b) Lead-210 is a radioactive isotope that decays to an isotope of mercury by alpha decay.

Complete the nuclear equation to show the alpha decay of lead-210.

\[ ^{210}\text{Pb} \rightarrow \text{^{80}Hg} + \text{____} \]

(3)
(c) Explain how ionising radiation can have hazardous effects on the human body.