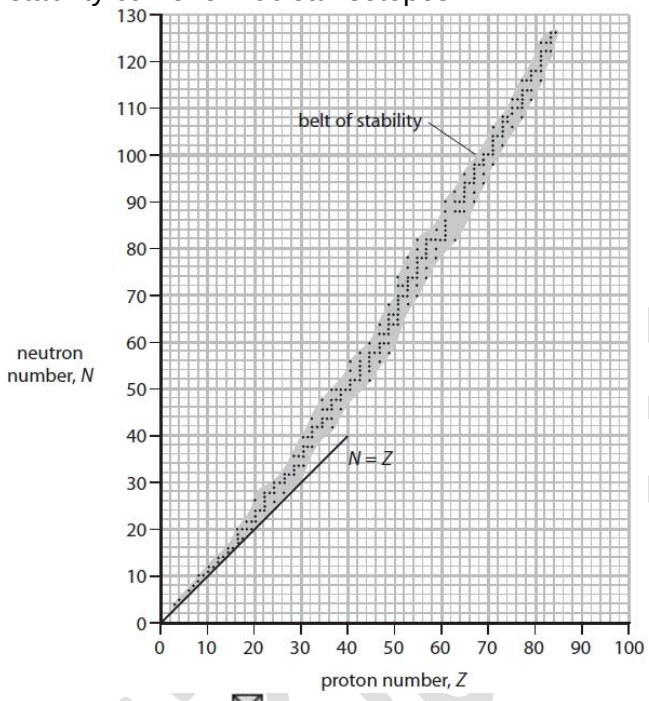
Q1.

Some rocks contained uranium when they were formed.
Radioactive decay in these rocks produces radon gas.
Explain why people living near these rocks have an increased health risk from background radiation.

(3)

Q2.

(a) The diagram shows the stability curve for nuclear isotopes.



Complete the sentence by putting a cross (☒) in the box next to your answer.
An isotope above the curve will undergo β^- decay because it has

(1)

☐ **A** too few protons
☐ **B** too many protons
☐ **C** too few neutrons
☐ **D** too many neutrons

(b) Which statement is correct for β^+ and β^- particles?
Put a cross (☒) in the box next to your answer.

(1)

☐ **A** a β^+ is positively charged and a β^- is negatively charged
☐ **B** the mass of a β^+ is 1800 times the mass of a β^-
☐ **C** the charge on a β^+ is twice the charge on a β^-
☐ **D** a β^+ is a proton and a β^- is an electron

(c) Carbon-14 decays by emitting a β^- particle to form an isotope of nitrogen.
Complete the nuclear equation for this decay by filling in the boxes.

(2)

$$^{14}_{6}C \rightarrow \,^{\square}_{\square}N + \,^{\square}_{\square}\beta^-$$

(d) Protons and neutrons both contain quarks.
Describe the arrangement of quarks in a proton.

(2)

(e) Explain what happens to a nucleus during β^+ decay.

(2)

HT Radioactivity

Q3.

A G-M tube is connected to a counter.
A teacher places the G-M tube near to a radioactive source.
A student starts the counter and clock at the same time and writes down the readings shown on the counter every 15 s.
The student plots the readings with a line of best fit, as shown in Figure 8.

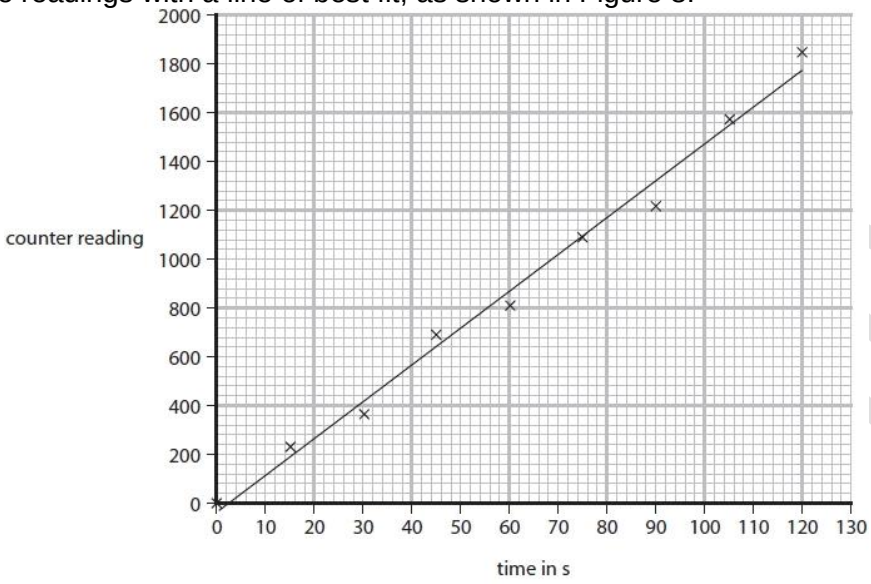


Figure 8

(i) Calculate the average count rate, in counts / s, from the graph.
Show your working on the graph.

(2)

(ii) The student says that the experiment must have been done carelessly because the data seemed quite scattered away from the best fit line.
The teacher claims such results should be expected in radioactivity experiments.
Justify the teacher's claim.

(2)

Q4.

Radio waves and gamma radiation are at opposite ends of the electromagnetic spectrum.
Compare how these two electromagnetic radiations are produced.

(6)

Q5.

Fluorine-19 is a stable isotope of the element fluorine.
The element fluorine also has several radioactive isotopes.
Describe **one** similarity and **one** difference between the numbers of particles in one nucleus of fluorine-19 and one nucleus of a radioactive isotope of fluorine.

(2)

Q6.

* Gamma radiation is produced by radioactive decay.
Alpha radiation and beta radiation are also produced by radioactive decay.
Compare the processes of alpha decay and beta decay.
Your answer should include what each radiation is and what effect each decay has on the original nucleus.

(6)

Q7.

Carbon-13 and carbon-14 are isotopes of carbon.
Nuclei of carbon-13 and carbon-14 can be represented by these symbols

$^{13}_{6}C$ and $^{14}_{6}C$

Complete the table for an atom of carbon-13 and an atom of carbon-14.

(2)

	number of neutrons in the nucleus	number of electrons in orbit around the nucleus
carbon-13		
carbon-14		

Q8.
State what is meant by the term 'half-life'.

(1)

Q9.
Students are given the apparatus shown in Figure 8 and a protractor.

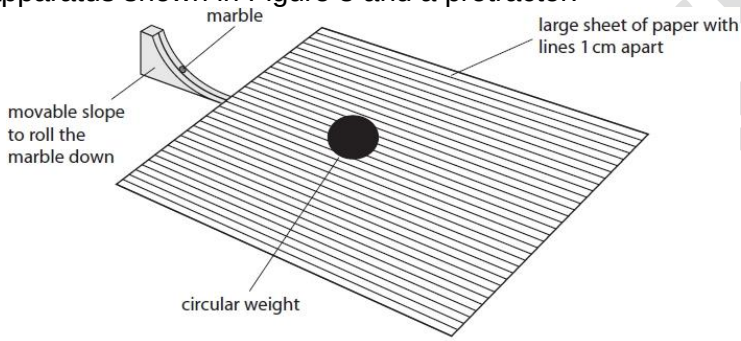


Figure 8

(i) Describe how the students could use the apparatus to model the scattering of alpha particles.

(2)

(ii) Give **one** limitation of this model.

(1)

Q10.
Radium-223 is a radioactive substance.
Radium-223 is an alpha emitter.
The half-life of radium-223 is 11 days.
A radioactive source contains 1.7×10^{23} nuclei of radium-223.
Calculate the number of radium-223 nuclei remaining in the source after a time of 33 days.

(2)

Q11.
Sometimes food can become contaminated with radioactive substances.
Describe the harmful effects of eating food contaminated with radioactive substances.

(2)

Q12.
Carbon-14 is radioactive and has a half-life of 5 700 years.
The number of radioactive carbon-14 atoms in a very old piece of wood is found to have decreased from 1 000 000 to 125 000.
Determine the age of the piece of wood.

(2)

Q13.
The nucleus of americium-238 can absorb an electron.
When this happens, one of the protons in the nucleus becomes a neutron, as shown in Figure 8.

$$^{1}_{1}p + ^{0}_{-1}e \longrightarrow ^{1}_{0}n$$

Figure 8

(i) Describe how absorbing an electron affects the proton number and the nucleon number of a nucleus. **(2)**

(ii) Deduce which nucleus is formed when americium-238 absorbs an electron.

(1)

- ☒ **A** uranium-234
- ☒ **B** uranium-235
- ☒ **C** plutonium-238
- ☒ **D** americium-238

Q14.

Figure 4 shows a Geiger-Müller (GM) tube used for measuring radioactivity.

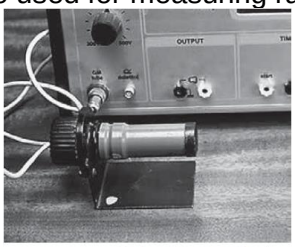


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Figure 4

One radioactive source used in hospitals is technetium (Tc).
Technetium is produced from the radioactive decay of molybdenum (Mo).
Complete the following nuclear equation.

(1)

$$^{99}_{42}\text{Mo} \rightarrow \text{.....} + {}^{0}_{-1}\beta$$

Q15.

Rutherford devised an experiment to fire alpha particles at thin gold foil.
The apparatus that was used in the experiment is shown in Figure 6.

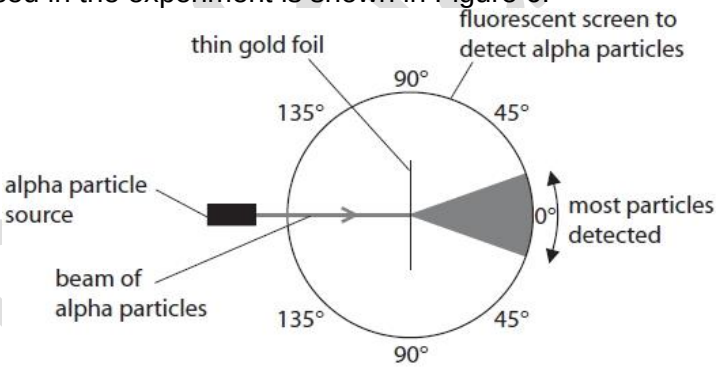


Figure 6

(i) The number of particles detected at each angle in a given time is shown on the graph in Figure 7.

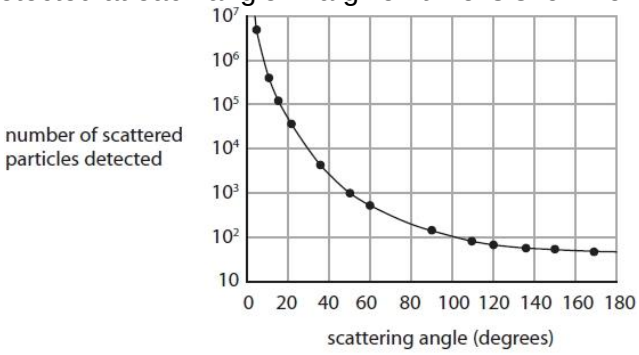


Figure 7

Use information from the graph.
Estimate the ratio of the number of particles scattered through 5° to the number of particles scattered through 100°.

(2)

(ii) Explain how the difference in the number of particles scattered at different angles gives evidence for the current model of the structure of the atom.

(4)

Q16.
Rutherford devised an experiment to fire alpha particles at thin gold foil.
It was found that alpha particles were scattered by the gold foil.
The gold foil was about 4.0×10^{-7} m thick.
A gold atom has a diameter of about 0.15 nm.
Estimate how many gold atoms would fit across this thickness of gold foil.

(2)

Q17.
The half-life of cobalt-60 is 5 years.
A school cobalt source had an activity of 38.5 kBq in the year 2000.
Estimate the activity of this source in the year 2020.

(3)

Q18.
Some isotopes are unstable.
They emit β^- particles when they decay.
Explain how a nucleus changes when a β^- particle is emitted.

(2)

Q19.
Early in the twentieth century, scientists fired a beam of alpha particles at thin gold foil.
Figure 2 shows the main parts of their experiment with some results.

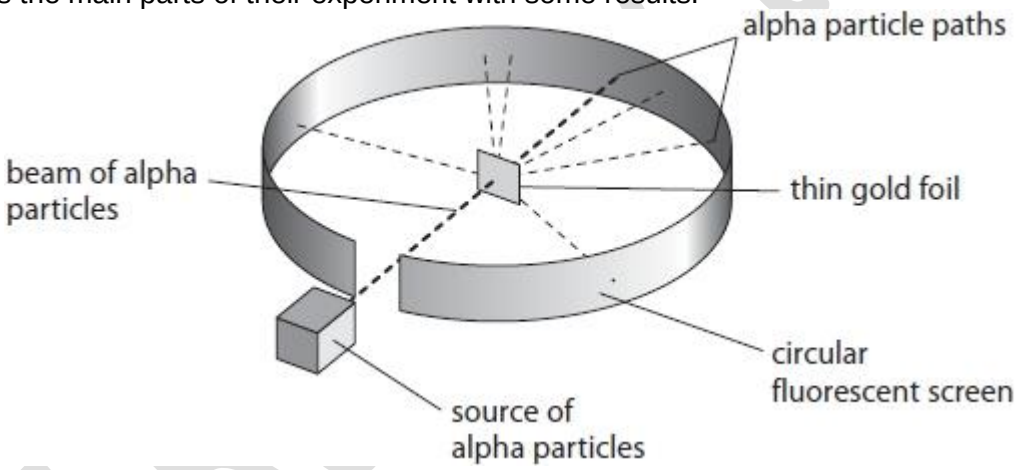


Figure 2

Explain how the results of the experiment shown in Figure 2 support the nuclear model of an atom.

(3)

Q20.
Carbon-14 decays into nitrogen-14.
The symbol for nitrogen-14 is $^{14}_{7}\mathrm{N}$
Explain what happens in a carbon-14 nucleus when it decays to a nitrogen-14 nucleus.

(2)

Q21.
Figure 3 shows a Geiger–Muller (G–M) tube attached to a counter.
The G–M tube is used to measure the activity of a source of beta (β) radiation.
There is an aluminium sheet between the beta source and the G–M tube.
The counter is switched on and after 1 minute shows a count of 268.

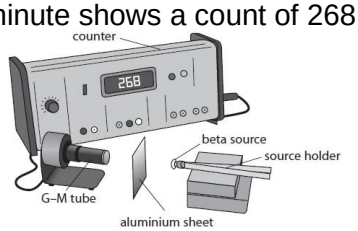


Figure 3

(i) The aluminium sheet is taken away.
The counter is reset to zero and then switched on again.
A new count is taken for 1 minute.
Explain why the new count is greater than 268.

(2)

(ii) The beta source is then also taken away.
The counter is reset to zero and switched on again.
A new count is taken for 1 minute.
Give a reason why there would now be a reading on the counter.

(1)

(iii) State the SI unit for the activity of a radioactive source.

Q22.

Figure 1 is a diagram of three atoms.

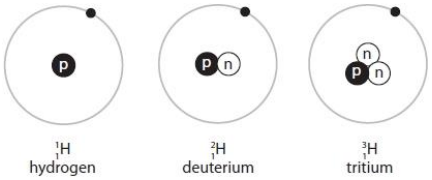


Figure 1

Give reasons why these atoms are isotopes.

(2)

Q23.

The following descriptions describe waves from different parts of the electromagnetic spectrum.
Complete each description by adding the name of the wave.
Use the name of each wave only once. Each description refers to a different part of the electromagnetic spectrum.

(4)

Description 1
used in cooking
used in short-range communication
typical wavelength 900 nm

name of wave .....

Description 2
used in cooking
used in communication
typical wavelength 150 mm

name of wave .....

Description 3
used in communication
produced by oscillations in electrical circuits
typical wavelength 150 m

name of wave .....

Description 4
used in medical scanning
is emitted by the nucleus of an atom
typical wavelength 2.0×10^{-3} nm

name of wave .....

Q24.

Figure 4 shows a Geiger-Müller (GM) tube used for measuring radioactivity.

Figure 4

Describe how a teacher should use a Geiger-Müller (GM) tube to compare the count-rates from two different radioactive rocks. **(4)**

HT Radioactivity

Q25.

(i) State the name of an instrument that can be used to measure radioactivity.

(1)

(ii) State **two** sources of background radiation.

(2)

Q26.

Plutonium-238 is used in spacecraft to provide heat to power generators.
One of these generators contains 925 g of plutonium-238 when it is manufactured.
One gram of plutonium-238 has a power density of 0.54 W/g.
Plutonium-238 has a half-life of 87.7 years.
Calculate the average energy released per second by the generator after 263 years.

(4)

Q27.

One isotope of the element potassium is potassium-40.
A nucleus of potassium-40 is represented by:

$^{40}_{19}K$

(ii) Which of these symbols is correct for the nucleus of a different isotope of potassium?
Put a cross (☒) in the box next to your answer.

(1)

$^{39}_{19}K$ ☒ **A**

$^{40}_{20}K$ ☒ **B**

$^{19}_{40}K$ ☒ **C**

$^{39}_{20}K$ ☒ **D**

(iii) A sample of potassium-40 is left for a long time.
Some of the potassium-40 nuclei will emit gamma radiation as they turn into argon-40 nuclei.
Argon-40 nuclei never change.
Describe what information this gives about the isotope potassium-40.

(2)

Q28.

The table gives the average dose of radiation a person received from various sources.

radiation source	average radiation dose (arbitrary units)
average yearly background	3000
one chest X-ray	20
one CT scan of the chest	6000
one whole body CT scan	20000
one PET scan	6000

(i) Explain why a CT scan of the chest gives a much higher dose of radiation than a chest X-ray.

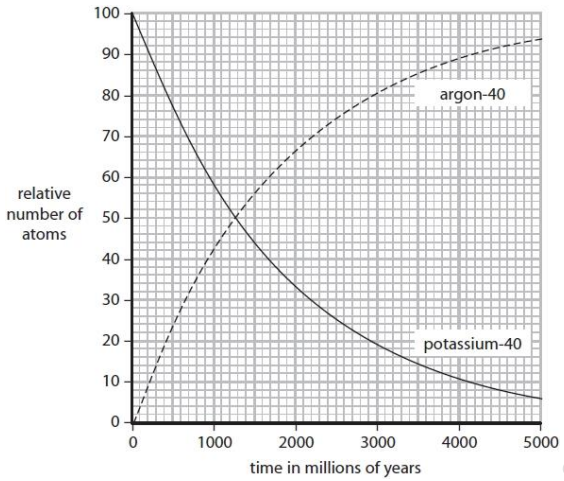
(2)

(ii) Justify the use of medical procedures which give patients large doses of radiation.

(2)

Q29.

Some rocks containing potassium were formed many millions of years ago.
There was no argon-40 in the rocks when they were formed.
When scientists analyse samples of these rocks, they find small amounts of argon-40 trapped inside.
The graph shows how the relative amounts of potassium-40 and argon-40 change over time.



(i) Use the graph to find the half-life of potassium-40.

(1)

(ii) Scientists analyse a sample taken from inside a rock.
They find that there is exactly 3 times as much argon-40 as there is potassium-40.
Use the graph to find the age of the rock.

(2)

Q30.

Many different types of radioactive isotope are used for the diagnosis and treatment of medical conditions.

(i) Iodine-123 is used as a radioactive tracer to diagnose thyroid problems.
Complete the sentence by putting a cross (☒) in the box next to your answer.
This tracer must have a half-life of

(1)

- ☐ **A** a few days
- ☐ **B** a few hours
- ☐ **C** less than a second
- ☐ **D** several weeks

(ii) Pellets which contain radium-223 can be put inside the body to treat cancers.
Radium-223 has a half-life of 11.4 days and emits alpha radiation.
Explain why radium-223 is suitable for use inside the body to treat cancers.

(3)

Q31.

Figure 4 shows a Geiger-Müller (GM) tube used for measuring radioactivity.

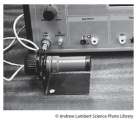


Figure 4

A hospital uses a radioactive isotope with a half-life of 6 hours.
A technician measures a count rate of 80 counts per minute (cpm) from this isotope.

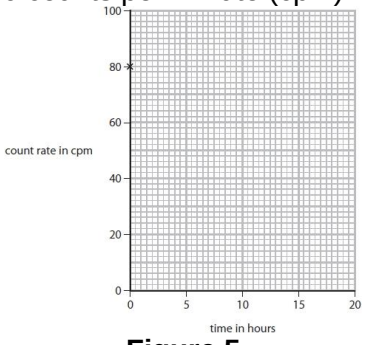


Figure 5

Complete the graph on Figure 5, as accurately as possible, to show how the count-rate from this isotope will change from the time of the first measurement.
The first point is already drawn in Figure 5.

(3)

HT Radioactivity