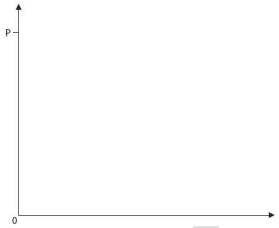
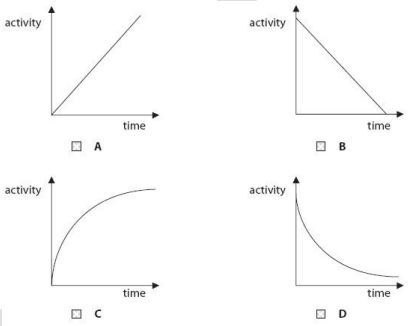
**Q1.**
Carbon-14 is a radioactive isotope that occurs naturally. Scientists use carbon-14 to help find the age of old pieces of wood. This technique is called carbon dating. It uses the idea of half-life.

Sketch a graph to show how the activity of a radioactive isotope changes with time.
Use the axes below. Start your line from point P.




**(3)**

**Q2.**
Which graph best shows how the activity of a radioactive isotope changes with time?




**(1)**

**Q3.**
(a) Which **one** of these statements about alpha radiation is correct?

- ☒ **A** Alpha radiation has no charge.
- ☒ **B** Alpha radiation is very ionising.
- ☒ **C** Alpha radiation travels very far in air.
- ☒ **D** Alpha radiation is an electromagnetic wave.

**(1)**

(b) When an atom emits an alpha particle its nucleus changes.
Which describes the changes in the nucleus?

| | proton number | mass number |
|---|---|---|
| ☐ A | decreases by 2 | decreases by 4 |
| ☐ B | increases by 2 | decreases by 4 |
| ☐ C | decreases by 2 | increases by 4 |
| ☐ D | increases by 2 | increases by 4 |

**(1)**

**Q4.**
Alpha, beta and gamma are types of ionising radiation.
State **two** ways in which gamma radiation is different from alpha radiation.

**(2)**

**Q5.**
A teacher sets up an experiment to show some students how far beta particles travel in air.
Figure 5 shows some of the equipment she uses.


(Source: *www.einstein.yu.edu*)

**Figure 5**

(i) State the scientific name for the radioactivity detector shown in Figure 5.

**(1)**

The teacher also has:

- a radioactive source that emits only beta particles
- a metre rule.

(ii) State **two** precautions the teacher must take to protect herself from the effects of radioactivity.

**(2)**

(iii) Describe how the teacher could show how far beta particles travel in air.

**(4)**

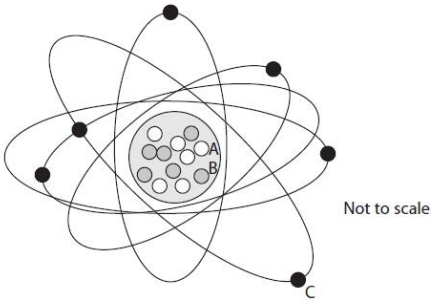
**Q6.**
An isotope of krypton, krypton-89, is produced in a nuclear reactor.
A nucleus of this isotope can be represented as

$$^{89}_{36}Kr$$

Describe the structure of a nucleus of krypton-89.

**(4)**

**Q7.**
The diagram shows an atom of carbon.
A, B and C are three different particles.




(i) Name the three different particles shown.

**(3)**

(ii) What is the mass (nucleon) number of this carbon atom?

**(1)**

Key
A ○
B ○
C ●

**Q8.**

Everyone is exposed to background radiation. Some of this radiation comes from natural sources.

(i) One example of a source of background radiation that does not occur naturally is radiotherapy.
State **one** other source of background radiation that does not occur naturally.

**(1)**

(ii) Radon gas is a natural source of background radiation.
In some parts of the country, a lot of the background radiation comes from radon gas.
Explain why there is no radon gas in some other parts of the country.

**(2)**

**Q9.**
Beryllium-9 is a stable isotope of beryllium. (i) State the meaning of the term **stable.**

**(1)**

(ii) Beryllium-9 has an atomic number of 4 and a mass number of 9.
A nucleus of this isotope can be described using this symbol.

$^{9}_{4}Be$

The number of neutrons in this nucleus is

**(1)**

**A** 4
**B** 5
**C** 9
**D** 13

$^{8}_{4}Be$ ☐ A $^{8}_{5}Be$ ☐ B $^{9}_{4}B$ ☐ C $^{9}_{5}Be$ ☐ D

(iii) Which one of these symbols describes the nucleus of a different isotope of beryllium?

**(1)**

**Q10.**
Ionising radiations are emitted by unstable nuclei.
(i) Which particle has the same mass as but opposite charge to a $\beta^+$ particle?

**(1)**

☒ **A** electron
☒ **B** positron
☒ **C** proton
☒ **D** neutron

(ii) Suggest why a beta particle will travel further in air than an alpha particle.

**(2)**

**Q11.**
Alpha, beta and gamma are types of ionising radiation.
(i) A beta particle is emitted by

**(1)**

☒ **A** an alpha particle
☒ **B** a fusion particle
☒ **C** a gamma ray
☒ **D** an unstable nucleus

(ii) A beta particle has an identical charge to

**(1)**

☒ **A** an alpha particle
☒ **B** an electron
☒ **C** a neutron
☒ **D** a nucleus

**Q12.**
The mass of a proton is $1.6726 \times 10^{-27}$ kg.
The mass of an electron is $9.1094 \times 10^{-31}$ kg.
Calculate how many times the mass of a proton is greater than the mass of an electron.
Give your answer to two significant figures.

**(3)**

**Q13.**
A sample of a radioactive isotope has a mass of 520 g.
The half-life of the radioactive isotope is 18 days.
(i) Calculate the mass of the original radioactive isotope remaining after 18 days.

**(1)**

(ii) Calculate the mass of the original radioactive isotope remaining after 54 days.

**(2)**

**Q14.**
A teacher uses a Geiger-Müller tube and a counter to measure background radiation.
The reading on the counter tube is 34 counts per minute.
(i) The teacher puts a source of beta radiation 15 cm in front of the same Geiger-Müller tube.
The reading on the counter tube is now 468 counts per minute.
Calculate how much radiation detected by the Geiger-Müller tube comes from the source of beta radiation. **(1)**

(ii) The teacher puts a thick sheet of aluminium between the source of beta radiation and the Geiger-Müller tube. Estimate the reading on the counter tube.

**(1)**

(iii) Give a reason why the answer to (ii) is only an estimate.

**(1)**

**Q15.**

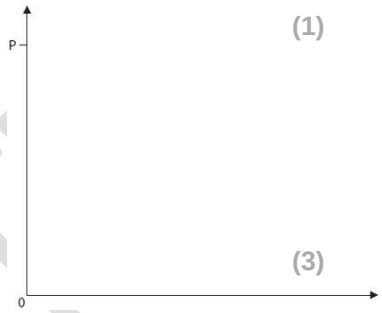
Carbon-14 is a radioactive isotope that occurs naturally. Scientists use carbon-14 to help find the age of old pieces of wood. This technique is called carbon dating. It uses the idea of half-life.

(a) Which of these describes half-life?

**(1)**

- ☒ **A** the time it takes for half of the undecayed nuclei to decay
- ☒ **B** the time it takes for all of the undecayed nuclei to decay
- ☒ **C** half the time it takes for all of the undecayed nuclei to decay
- ☒ **D** half the time it takes for half of the undecayed nuclei to decay

(b) Sketch a graph to show how the activity of a radioactive isotope changes with time. Use the axes below. Start your line from point P.




**(3)**

(c) A scientist investigates an old wooden comb.

The activity of the carbon-14 in it is 0.55 Bq.
The estimated age of the comb is 11 400 years.
The half-life of carbon-14 is 5700 years.

(i) Calculate the activity of the carbon-14 in the comb when it was new.

**(3)**

(ii) The scientist takes several readings of background radiation. Explain why this is necessary to improve the accuracy of the investigation.

**(2)**

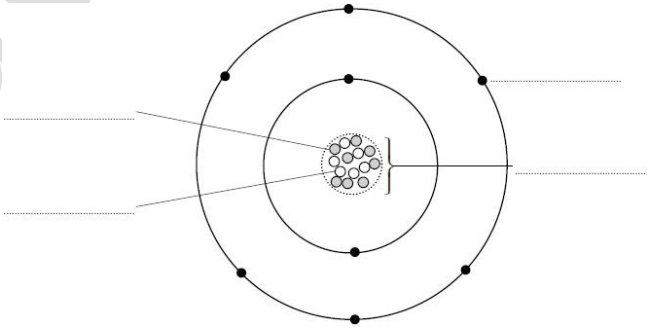
(iii) Old objects like the comb emit a very small amount of radiation. The activity from the comb is about the same as comes from background radiation. Scientists have stopped measuring the activity of carbon-14 for carbon dating. Instead, they can measure the mass of undecayed carbon-14 left in the sample. Suggest a reason for this change.

**(1)**

**Q16.**

Figure 3 shows the structure of an oxygen-14 atom.

(i) Complete the four labels on Figure 3.



**(4)**

(ii) Which of these particles has a negative charge?

**(1)**

- ☒ **A** alpha particle
- ☒ **B** electron
- ☒ **C** neutron
- ☒ **D** nucleus

(iii) State the overall charge of the oxygen-14 atom.

**(1)**

**Q17.**

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)**

**Q18.**

The half-life of strontium-90 is 29 years.
The table in Figure 4 gives some information about how the mass of a sample of strontium-90 changes with time.

Complete the table in Figure 4.

| mass of strontium-90 in g | time in years |
|---|---|
| 1600 | 0 |
| ..... | 29 |
| 400 | ..... |

**Figure 4**

**Q19.**

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.

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

(2)

**Q20.**

* Exposing people to radioactive sources can be dangerous.
Describe the dangers of exposure to radioactive sources and what can be done to protect hospital staff when they are working with radioactive sources.

(6)

**Q21.**

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)

**Q22.**

Sulfur-35 is a radioactive isotope of sulfur. Figure 8 represents a nucleus of sulfur-35.

$^{35}_{16}S$

**Figure 8**

Draw one line from each type of particle to the number of that type of particle in a nucleus of sulfur-35.

(3)

| type of particle | number of particles |
|---|---|
| proton | 35 |
| neutron | 16 |
| nucleon | 51 |
| | 19 |

**Q23.**

The electromagnetic spectrum is continuous.
Different regions of the spectrum have different properties.

(a) (i) Name an electromagnetic wave that is also an ionising radiation.

(1)

(ii) Genuine banknotes contain a special ink.
This ink is invisible under normal light.
Suggest why the ink glows when ultraviolet radiation is shone on it.

(2)

(b) An electromagnetic wave has a frequency of $7 \times 10^9$ Hz.
The speed of the wave is $3 \times 10^8$ m/s.
Calculate the wavelength of the wave.

(3)

*(c) Radiation from different regions of the electromagnetic spectrum can affect the human body in many ways.
Discuss the different ways in which excessive exposure to electromagnetic radiations of various frequencies may cause damage to the human body.

(6)

**Q24.**

(a) The table shows most of the waves in the electromagnetic spectrum.
One type of wave is missing.

| |
|---|
| gamma rays |
| ..... |
| ultraviolet |
| visible light |
| infrared |
| microwaves |
| radio waves |

(i) Write the missing wave in the space in the table.

(1)

(ii) State which type of wave can be split into different colours.

(1)

(iii) State which type of wave has the longest wavelength.

(1)

(iv) State **one** type of wave that is ionising.

(1)

(b) The Sun emits all the waves in the electromagnetic spectrum.
Explain why all these waves take the same time to travel to Earth from the Sun.

(2)

*(c) Infrared and ultraviolet waves have different frequencies. Both types of wave can have harmful effects on human beings. Describe the harmful effects of infrared and ultraviolet waves, relating them to the frequencies of the waves.

(6)

**Q25.**

(a) Microwaves and X-rays are both electromagnetic waves.

(i) Which row of the table is correct for microwaves and X-rays in a vacuum?

(1)

| | their speeds are | their frequencies are |
|---|---|---|
| ☐ A | different | different |
| ☐ B | different | the same |
| ☐ C | the same | different |
| ☐ D | the same | the same |

(ii) State **one** harmful effect of X-rays on living matter.

(1)

(b) X-rays are ionising radiation.

(i) State **one** other ionising radiation in the electromagnetic spectrum.

(1)

(ii) State **one** use of an ionising radiation.

**(1)**

(c) (i) State **one** way in which microwave radiation can be harmful to people.

**(1)**

The microwaves used in ovens have a frequency of about 2450 MHz.
Mobile phones emit microwaves with a frequency of about 2000 MHz.
Microwave ovens have shielding to protect people from the microwave radiation.

(ii) Suggest why the same shielding is **not** necessary for mobile phones.

**(3)**

**Q26.**
An atom contains electrons, neutrons and protons.

| | | |
|---|---|---|
| neutral | negative | d |
| much larger than a neutron | much smaller than a neutron | d |
| positive | the same size as a neutron | d |

(i) The charge on an electron is ..... **(1)**
(ii) An electron has a mass that is ..... **(1)**

**Q27.**
Figure 17 shows a Geiger-Müller (GM) tube used for measuring radioactivity.


* A radioactive rock is placed near to the front of a Geiger-Müller (GM) tube.
A radioactivity count-rate is first made in air.
The count-rate is measured again with each of three different absorbers between the rock and the GM tube.
Figure 19 shows the count-rates measured.

| absorber | count-rate in counts per minute |
|---|---|
| 3 cm of air | 1272 |
| thin sheet of paper | 931 |
| 3 mm thick sheet of aluminium | 328 |
| 2 cm thick sheet of lead | 21 |

A scientist has an idea that the rock emits three different types of radiation.
Explain how the data in this table supports the scientist's idea.

**(6)**

**Q28.**

* Some scientists carry out an experiment to measure the radioactivity from a source to be used in a factory.
They measure the background radiation before and after their experiment.
They take the background count at the same place as they do their experiment.

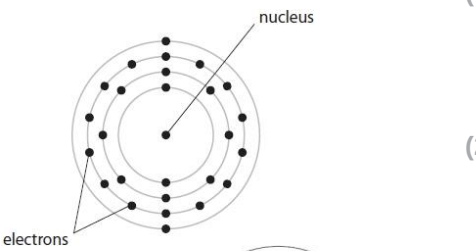
Explain how this procedure helps to make sure that the results of the experiment are valid.

**(6)**

**Q29.**
Some isotopes are unstable.
They emit $\beta^-$ particles when they decay.
Explain how a nucleus changes when a $\beta^-$ particle is emitted.

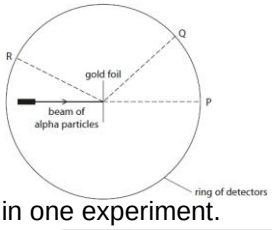
**(2)**

**Q30.**
Figure 6 shows an atom of iron with its electron orbits.
Explain what happens to the electrons during this process.




**(3)**

**Q31.**
In 1908 a scientist called Rutherford was investigating ideas about atoms.
His students fired a beam of alpha particles at a thin piece of gold foil.
Figure 5 shows the arrangement of the experiment.
Some alpha particles were found at all parts of the ring of detectors.
The table in Figure 6 shows how many alpha particles were detected at P, at Q and at R, in one experiment.



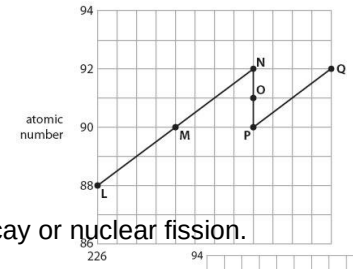

| position | number of alpha particles detected |
|---|---|
| P | 72340 |
| Q | 25 |
| R | 2 |

Explain what the information in Figure 5 and Figure 6 shows about the structure of an atom.

**(6)**

**Q32.**
Uranium-238 is an isotope of uranium. It may undergo either radioactive decay or nuclear fission.

A nucleus of uranium-238 is shown as **Q** in the chart.




Explain what happens when **Q** decays to **P.**

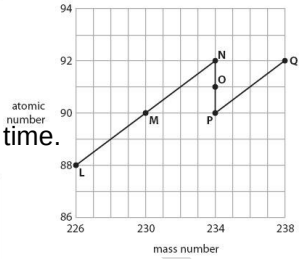
**(2)**

**Q33.**

Uranium-238 is an isotope of uranium. It may undergo either radioactive decay or nuclear fission.

A nucleus of uranium-238 is shown as **Q** in the chart.

Explain what happens when **P** decays to **O**.

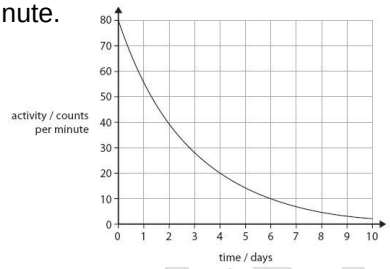



**(2)**

**Q34.**

The graph shows how the activity of a sample of a radioactive material changes with time.

The sample has an initial activity of 80 counts per minute.




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

**(1)**

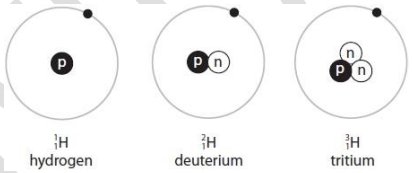
(ii) Another sample of the material has an initial count rate of 40 counts per minute.

Sketch, on the same axes, the activity of this sample for the first 4 days.

**(2)**

**Q35.**

Figure 5 is a diagram of three atoms.




Give reasons why these atoms are isotopes.

**(2)**

**Q36.**

Carbon-14 is a radioactive isotope that occurs naturally. Scientists use carbon-14 to help find the age of old pieces of wood. This technique is called carbon dating. It uses the idea of half-life.Which of these describes half-life? **(1)**

- ☒ **A** the time it takes for half of the undecayed nuclei to decay
- ☒ **B** the time it takes for all of the undecayed nuclei to decay
- ☒ **C** half the time it takes for all of the undecayed nuclei to decay
- ☒ **D** half the time it takes for half of the undecayed nuclei to decay

**Q37.**

Which of these is correct for half-life? **(1)**

- ☒ **A** It is half the time for all the atoms to decay
- ☒ **B** It is the time it takes for an atom to half decay
- ☒ **C** It is the time it takes for half an atom to decay
- ☒ **D** It is the time it takes for half the atoms to decay

$^{90}_{38}Sr$

**Figure 3**

**Q38.**

Figure 3 shows the symbol for the nucleus of an atom of strontium-90.

(i) How many protons are in the nucleus of an atom of strontium-90? **(1)**

- ☒ **A** 38
- ☒ **B** 52
- ☒ **C** 90
- ☒ **D** 128

(ii) How many neutrons are in the nucleus of an atom of strontium-90 **(1)**

- ☒ **A** 38
- ☒ **B** 52
- ☒ **C** 90
- ☒ **D** 128

**Q39.**
Other unstable isotopes emit alpha particles. Which of these describes an alpha particle? **(1)**

- ☐ **A** a hydrogen nucleus
- ☐ **B** a hydrogen atom
- ☐ **C** a helium nucleus
- ☐ **D** a helium atom

**Q40.**
What is the approximate size of a hydrogen atom? **(1)**

- ☐ **A** $10^{-3}$ m
- ☐ **B** $10^{-10}$ m
- ☐ **C** $10^{-19}$ m
- ☐ **D** $10^{-31}$ m

**Q41.**
The typical size of an atom is **(1)**

- ☐ **A** $10^{-5}$ m
- ☐ **B** $10^{-10}$ m
- ☐ **C** $10^{-15}$ m
- ☐ **D** $10^{-20}$ m

**Q42.**
Alpha, beta and gamma are types of ionising radiation. Explain how an atom becomes ionised by radiation.
**(2)**

**Q43.**
(a) (i) Which particle has the same mass as but opposite charge to a $\beta^+$ particle? **(1)**

- ☐ **A** electron
- ☐ **B** positron
- ☐ **C** proton
- ☐ **D** neutron

(ii) Suggest why a beta particle will travel further in air than an alpha particle.
**(2)**

(b) Following the radioactive decay of a nucleus, the nucleus might undergo some rearrangement, losing energy as **(1)**

- ☐ **A** gamma radiation
- ☐ **B** a proton
- ☐ **C** a neutron
- ☐ **D** an X-ray

(c) Some unstable nuclei decay by emitting $\beta^-$ radiation.
(i) Describe the process of $\beta^-$ emission.
**(3)**

(ii) Explain what happens to the mass number and the atomic number of a nucleus when $\beta^-$ emission occurs.
**(3)**

**Q44.**
Alpha, beta and gamma are types of ionising radiation.
(a) State **two** ways in which gamma radiation is different from alpha radiation.
**(2)**

(b) (i) A beta particle is emitted by **(1)**

- ☐ **A** an alpha particle
- ☐ **B** a fusion particle
- ☐ **C** a gamma ray
- ☐ **D** an unstable nucleus

(ii) A beta particle has an identical charge to **(1)**

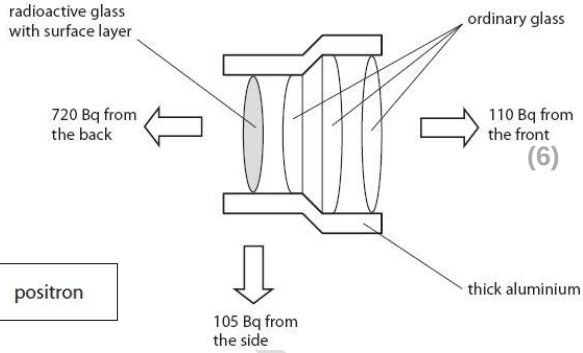
- ☐ **A** an alpha particle
- ☐ **B** an electron
- ☐ **C** a neutron
- ☐ **D** a nucleus

(c) Explain how an atom becomes ionised by radiation.


**(2)**

*(d) The removable lens of this old camera has four pieces of glass in it.

One of the pieces of glass is radioactive. Its surface is covered with a thin layer of magnesium fluoride.
Radioactive isotopes in the glass emit alpha, beta and gamma radiation in all directions.
A scientist removes the lens from the camera. She measures the radiation coming from the back, front and side of the lens.
The amount of radiation is different in each direction.
No alpha radiation is detected.
The readings are shown on the diagram.
Explain why the readings in the three directions are different.




**(6)**

**Q45.**
Choose words from the box to complete the following sentences.
Words may be used once, more than once or not at all.

| alpha | beta | gamma | positron |
|---|---|---|---|

The radiation that is a wave is .....

**(1)**

The particle that is negatively charged is .....

**(1)**

**Q46.**
Many different types of radiation are used by doctors.
Which type of radiation comes from radioactive sources?

**(1)**

- ☒ **A** gamma rays
- ☒ **B** ultrasound
- ☒ **C** ultraviolet
- ☒ **D** X-rays

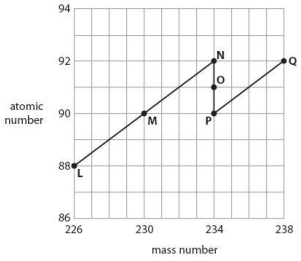
**Q47.**
Explain how radiation from radioactive sources can be dangerous to people.

**(2)**

**Q48.**
Medical staff who use radioactive materials need more protection than their patients.
Describe some precautions that medical staff can take to ensure their safety from radioactive materials.

**(3)**

**Q49.**
Uranium-238 is an isotope of uranium. It may undergo either radioactive decay or nuclear fission.
A nucleus of uranium-238 is shown as **Q** in the chart.

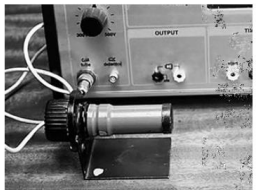



State **two** letters from the chart which show isotopes of the same element.

**(1)**

**Q50.**
Figure 17 shows a Geiger-Müller (GM) tube used for measuring radioactive

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



**(4)**

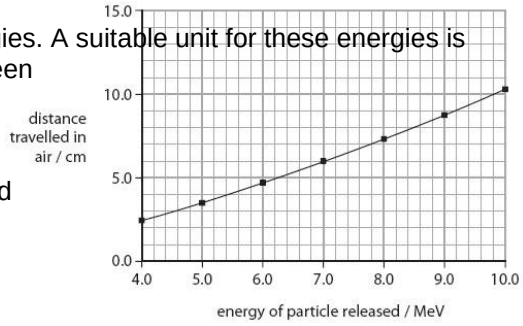
**Q51.**
(i) State the name of an instrument that can be used to measure radioactivity.

**(1)**

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

**(2)**

**Q52.**
Particles released during radioactive decay can have different energies. A suitable unit for these energies is MeV. For one type of decay, the particles released have energies between 4.0 MeV and 10.0 MeV. The graph shows how far the particles with these energies travel in air.

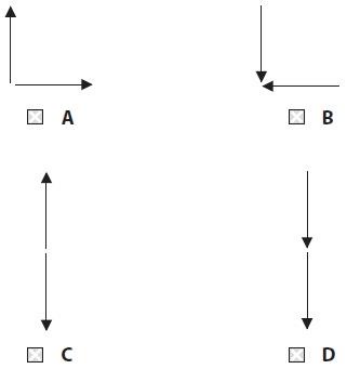



(i) State the name of this type of particle.
(ii) Use information from the graph to describe how the distance travelled in air depends on the energy of the particle.

**Q53.**
Ionising radiations are emitted by unstable nuclei.
Following the radioactive decay of a nucleus, the nucleus might undergo some rearrangement, losing energy as

(1)

- **A** gamma radiation
- **B** a proton
- **C** a neutron
- **D** an X-ray




**Q54. Q55.**
Some radioactive isotopes emit positrons.
Positrons are used to make gamma rays.
When a positron annihilates an electron, two gamma rays are produced.

(i) Which diagram shows the directions of the two gamma rays produced?

(1)

(ii) Explain how charge is conserved when an electron annihilates a positron.

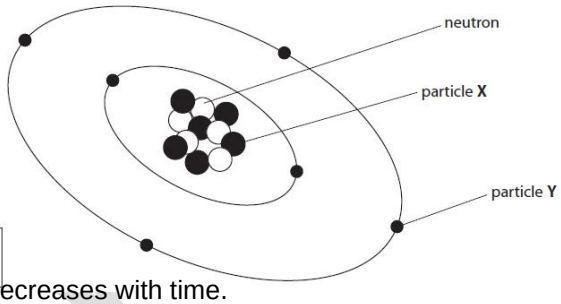
(3)

(iii) Explain how mass and energy are conserved when an electron annihilates a positron.

(2)

**Q56.**

(a) The diagram represents an atom of carbon.



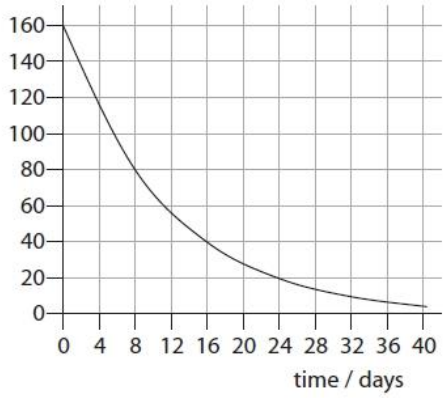

(i) State the name of particle **X**.

(1)

(ii) State the name of particle **Y**.

(1)

(b) Iodine-131 is a radioactive isotope of iodine.
The graph shows how the activity of a sample of iodine-131 decreases with time.




(i) Use the graph to calculate the half-life of iodine-131.

(2)

(ii) Another sample of iodine-131 has an activity of 800 Bq.
Calculate how long it will take before its activity decreases to 200 Bq.

(2)

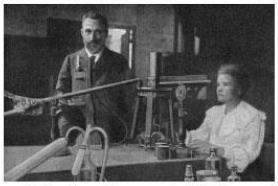
*(c) There are plans to build more nuclear power stations to supply electricity to the National Grid.
Discuss the advantages and disadvantages of using nuclear power to generate electricity.

(6)

**Q57.**
Describe **two** precautions that scientists now take when they use radioactive materials.

(2)

Marie Curie investigated radioactivity over 100 years ago.

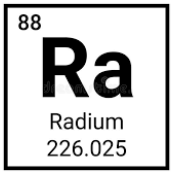


She often carried radioactive materials in her pocket.
She stored them in her desk drawer.
She liked the coloured light they gave off.
Marie probably died from exposure to their radiation.

**Q58.**
The element radium has a radioactive isotope, radium-226.
This can be written as

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 82 | 84 | 86 | 90 | 222 | 224 | 228 | 230 |

This radioactive isotope emits alpha particles.
The alpha particle has a mass number of 4 and contains two protons.
Using the numbers in the box complete the following sentences.

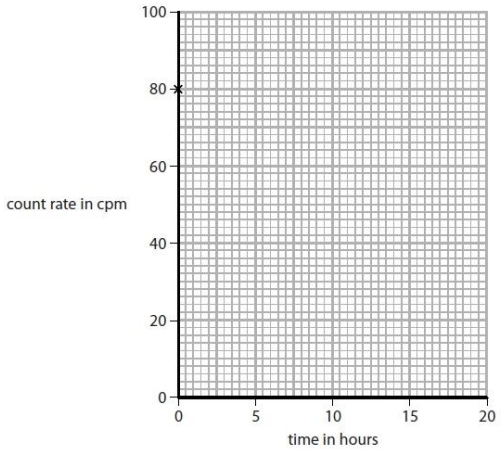



(i) When an alpha particle is emitted by the mass number becomes .....

(1)

(ii) When an alpha particle is emitted by the atomic number becomes .....

(1)




**Q59.**

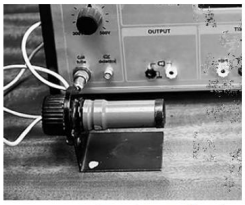



Figure 17 shows a Geiger-Müller (GM) tube used for measuring radioactivity.

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.

Complete the graph on Figure 18, 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 18.

**(3)**

**Q60.**

Figure 7 shows a safety sign on the door of a laboratory where radioactive materials are used.


**Figure 7**

(i) State **one** way that radioactivity can be dangerous to humans.

**(1)**

(ii) State **one** piece of equipment that can be used to measure radioactivity.

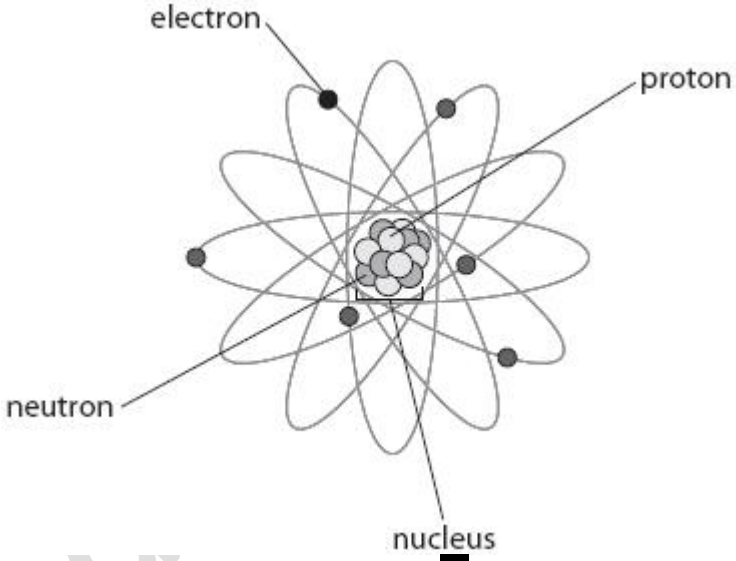
**(1)**

(iii) Alpha ($\alpha$) radiation and ultraviolet (UV) radiation are ionising radiations.
Give **two** other ionising radiations.

**(2)**

**Q61.**

The diagram shows the structure of an atom.




(i) Complete the sentence by putting a cross ( ■ ) in the box next to your answer.
The size of the charge on each electron is

**(1)**

- ☒ **A** a third of the charge on the proton
- ☒ **B** half the charge on the proton
- ☒ **C** the same as the charge on the proton
- ☒ **D** twice the charge on the proton

(ii) Complete the sentence by putting a cross ( ■ ) in the box next to your answer.
The atomic number of a neutral atom is always the same as the number of

**(1)**

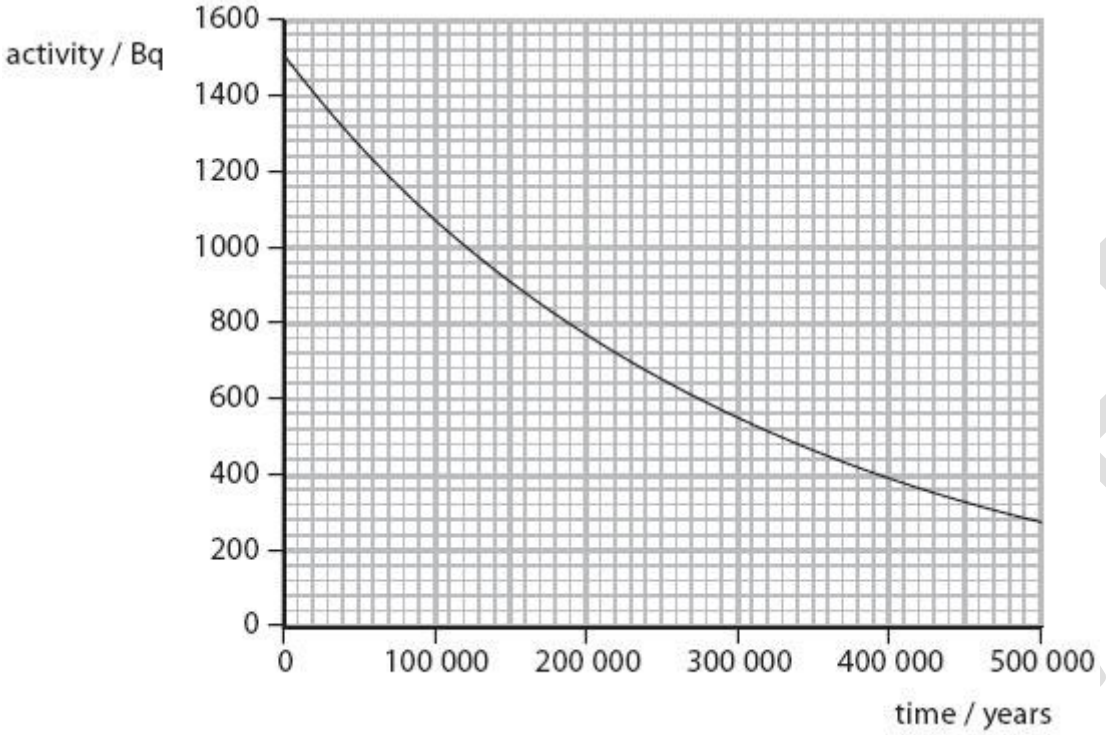
- ☒ **A** electrons
- ☒ **B** electrons and neutrons
- ☒ **C** protons and neutrons
- ☒ **D** neutrons

**Q62.**

Everyone is exposed to background radiation. Some of this radiation comes from natural sources.

Technetium-99 is one of the radioactive isotopes in nuclear waste.

The graph shows the decay curve for technetium-99.




(i) Use the graph to show that the half-life of technetium-99 is about 200 000 years.

**(2)**

(ii) Technetium-99 emits beta particles.

Give **one** reason that beta particles can cause harm to people.

**(1)**

**Q63.**

The electromagnetic spectrum is continuous.

Different regions of the spectrum have different properties.

(i) Name an electromagnetic wave that is also an ionising radiation.

**(1)**

(ii) Genuine banknotes contain a special ink.

This ink is invisible under normal light.

Suggest why the ink glows when ultraviolet radiation is shone on it.

**(2)**

**Q64.**

Every hospital radiographer who works with radiation wears a radiation badge.

The badge is used to monitor the amount of radiation the radiographer absorbs each month.

(i) Explain why it is important to monitor the amount of radiation a radiographer absorbs each month.

**(2)**

(ii) Radiographers are restricted to a smaller annual dose of radiation nowadays compared to 50 years ago.

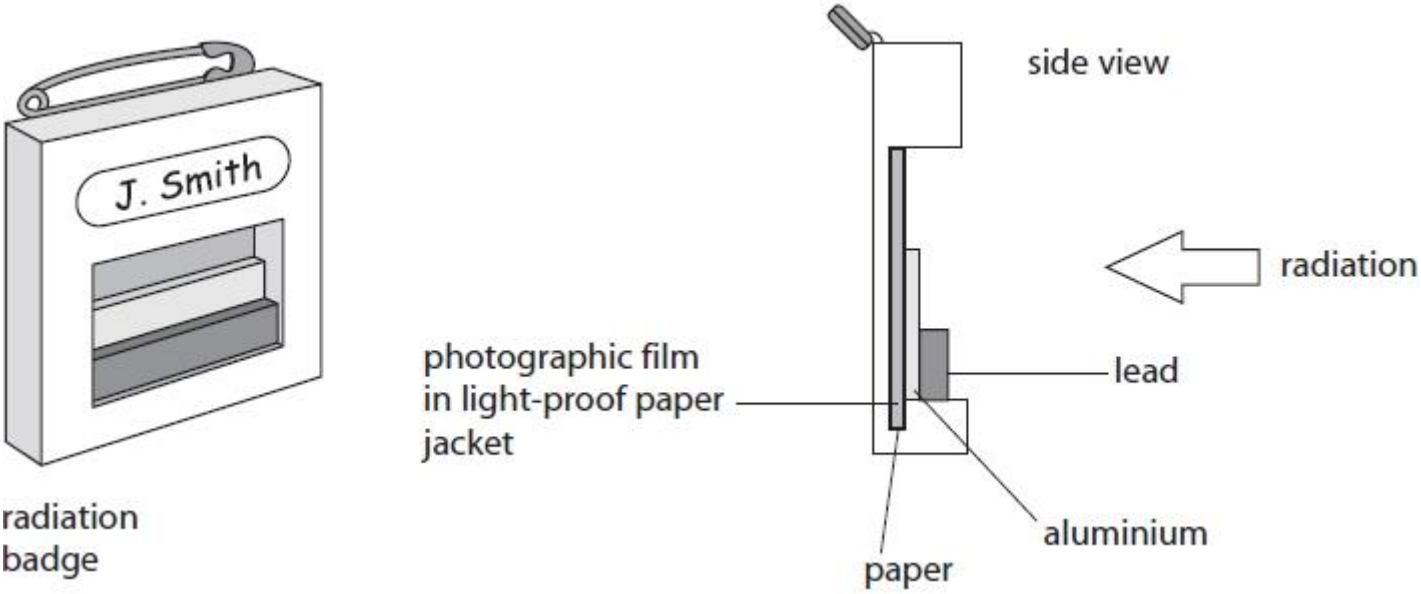
Complete the sentence by putting a cross (☒) in the box next to your answer.

This is because nowadays,

**(1)**

- ☒ **A** the radioactive sources have decayed
- ☒ **B** we can measure radiation more accurately
- ☒ **C** we have a better understanding of the risks from radiation
- ☒ **D** we have more effective ways of shielding against radiation

*(iii) The radiation badge contains a photographic film which is sensitive to radiation.




The radiation badge is sent to a laboratory after a month and the film is checked.
Explain how the badge shows the amount of different types of radiation that the radiographer has been exposed to.

**(6)**

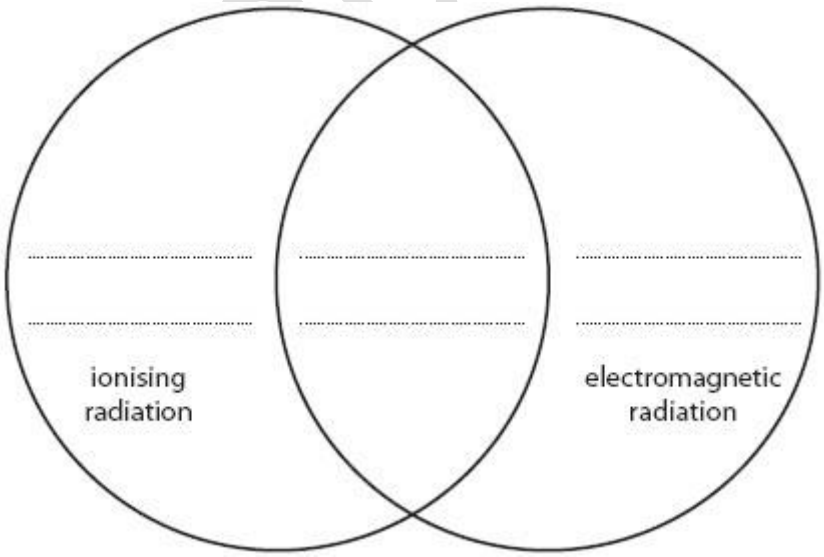
**Q65.**

The word box contains the names of three types of radiation.

| gamma rays | infrared radiation | alpha particles |
|---|---|---|

Use this diagram to classify the three types of radiation given in the word box.
Write the name of the radiation in the correct section of the diagram.

**(2)**




**Q66.**

Lead-214 is a radioactive isotope.
(i) State **one** way in which radioactive isotopes can be harmful to people.

**(1)**

(ii) Lead-214 emits $\beta^-$ particles.
Describe what happens to the nucleus of a lead-214 atom when it emits a $\beta^-$ particle.

(2)

**Q67.**

(i) Use words from the box to complete the sentences below about ions.

| absorbing | gaining | inner | losing | outer |
|---|---|---|---|---|

(2)

Atoms may form positive ions by ..... electrons.
The electrons involved in forming positive ions are the ..... electrons.

(ii) Which of these radiations is both electromagnetic and ionising?

(1)

- ☐ **A** alpha
- ☐ **B** beta minus
- ☐ **C** gamma
- ☐ **D** neutron

(iii) Which type of radiation will travel the shortest distance in air?

(1)

- ☐ **A** alpha
- ☐ **B** beta minus
- ☐ **C** beta plus
- ☐ **D** gamma

**Q68.**

Complete the sentence by putting a cross ( ☒ ) in the box next to your answer.
The unit of activity of a radioactive isotope is the

(1)

- ☐ **A** americium
- ☐ **B** becquerel
- ☐ **C** einstein
- ☐ **D** radium

**Q69.**

Ionising radiations are emitted by unstable nuclei.
Some unstable nuclei decay by emitting $\beta^-$ radiation.

(i) Describe the process of $\beta^-$ emission.

(3)

(ii) Explain what happens to the mass number and the atomic number of a nucleus when $\beta^-$ emission occurs.

(3)

**Q70.**

The fuel in a nuclear power station is an isotope of uranium.

The symbol for a nucleus of this uranium isotope is $^{235}_{92}U$.

(i) How many protons are there in a nucleus of this isotope?

Put a cross ( ☒ ) in the box next to your answer.

(1)

- ☐ **A** 92
- ☐ **B** 143
- ☐ **C** 235
- ☐ **D** 327

(ii) Name another particle in a nucleus of this isotope.

(1)

**Q71.**

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about radioactivity.
Alpha (α), beta (β) and gamma (γ) are three types of radioactive emissions.
Which statement describes **all** of these radioactive emissions?

**(1)**

- ☐ **A** ionising and emitted by stable nuclei
- ☐ **B** ionising and emitted by unstable nuclei
- ☐ **C** neutral and emitted by stable nuclei
- ☐ **D** neutral and emitted by unstable nuclei

**Q72.**

Figure 10 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.

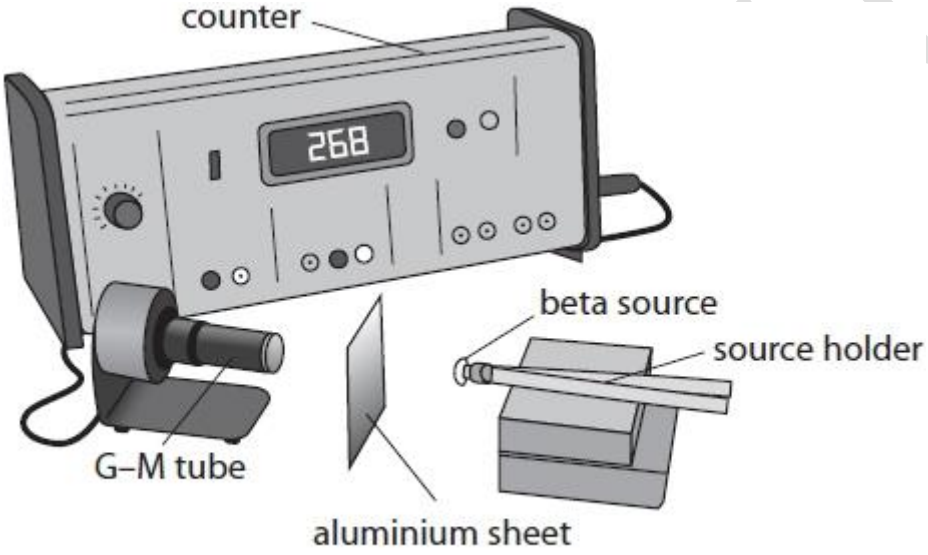



**Figure 10**

(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.

**(1)**

**Q73.**

Carbon-14 is a radioactive isotope that occurs naturally.
Scientists use carbon-14 to help find the age of old pieces of wood.
This technique is called carbon dating.
It uses the idea of half-life.
A scientist investigates an old wooden comb.

The activity of the carbon-14 in it is 0.55 Bq.
The estimated age of the comb is 11 400 years.
The half-life of carbon-14 is 5700 years.
(i) Calculate the activity of the carbon-14 in the comb when it was new.

**(3)**

(ii) The scientist takes several readings of background radiation.
Explain why this is necessary to improve the accuracy of the investigation.

**(2)**

The activity from the comb is about the same as comes from background radiation.
Scientists have stopped measuring the activity of carbon-14 for carbon dating.
Instead, they can measure the mass of undecayed carbon-14 left in the sample.
Suggest a reason for this change.

**(1)**