Atomic Structure part 5 AQA Triple Physics

Name: ________________________

Class: ________________________

Date: ________________________

Time: **94 minutes**

Marks: **94 marks**

Comments:

1. The equation below shows the process by which two atomic nuclei join to form a different nucleus.

$$^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He$$

(a) Where does the process shown by the equation above happen naturally?

Tick (✓) **one** box.

Inside the Earth	☐
Inside a nuclear power station	☐
Inside the Sun	☐

(1)

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

fission	**force**	**fusion**

The process of joining two atomic nuclei to form a different nucleus is called

nuclear ____________________________ .

(1)

(c) What is released during this process?

Draw a ring around the correct answer.

charge **energy** **force**

(1)

(Total 3 marks)

2. (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?

____

____

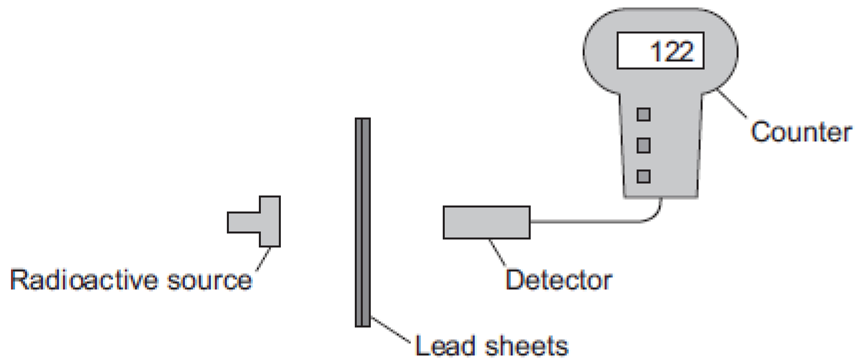
(1)

(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**.

Figure 1



(i) When using a radioactive source in an experiment, how could the teacher reduce the risk to her health?

Suggest **one** way.

____

____

(1)

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

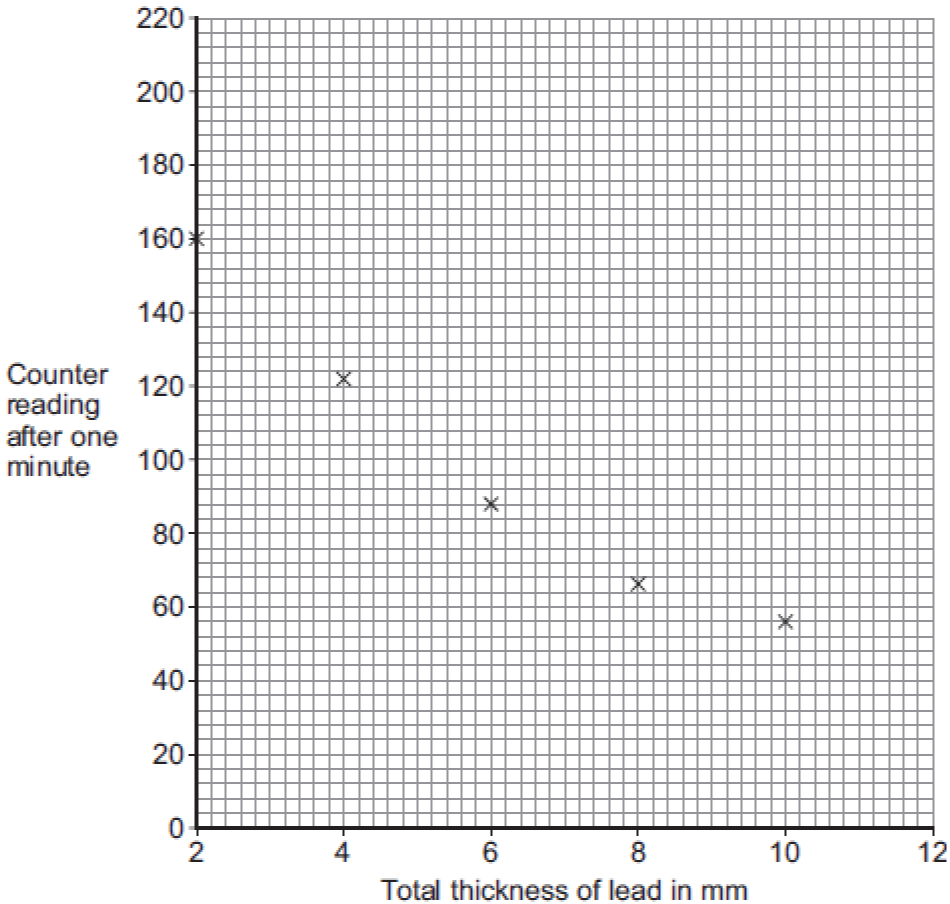
Complete the following word equation.

The number recorded on the counter	=	The amount of radiation detected from the source	+	______________________ radiation

(1)

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

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?

____

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(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.

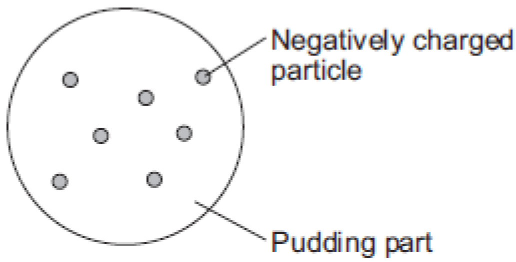
____

____

(2)

(Total 8 marks)

3. (a) Over 100 years ago, scientists thought the atom was like a 'plum pudding'. The diagram below shows the plum pudding model of the atom.



The scientists knew that an atom has negatively charged particles. They also knew that an atom has no overall charge.

What did the scientists conclude about the **charge** on the 'pudding part' of the atom?

____

____

(1)

(b) Two scientists named Rutherford and Marsden devised an experiment to investigate the plum pudding model of the atom. The experiment involved firing alpha particles at a thin sheet of gold. The scientists measured how many of the alpha particles were scattered.

Using the plum pudding model, the scientists predicted that only a few of the alpha particles would be scattered by more than 4°.

Over several months, more than 100 000 measurements were made.

(i) The results from this experiment caused the plum pudding model to be replaced by a new model of the atom.

Explain why.

____

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____

(2)

(ii) Suggest **one** reason why other scientists thought this experiment provided valid evidence for a new model of the atom.

____

____

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(1)

(c) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

Describe the model now used for the structure of an atom.

In your answer you should:

- give details of the individual particles that make up an atom
- include the relative masses and relative charges of these particles.

Do **not** include a diagram in your answer.

(6)

(Total 10 marks)

4. Many countries use nuclear power stations to generate electricity.
Nuclear power stations use the process of nuclear fission to release energy.

(a) (i) What is nuclear fission?

(1)

(ii) Plutonium-239 is one substance used as a fuel in a nuclear reactor. For nuclear fission to happen, the nucleus must absorb a particle.

What type of particle must be absorbed?

(1)

(b) Nuclear **fusion** also releases energy.
Nuclear fusion happens at very high temperatures. A high temperature is needed to overcome the repulsion force between the nuclei.

(i) Why is there a repulsion force between the nuclei of atoms?

___

___

(1)

(ii) Where does nuclear fusion happen naturally?

___

(1)

(c) In 1991, scientists produced the first controlled release of energy from an experimental nuclear **fusion** reactor. This was achieved by fusing the hydrogen isotopes, deuterium and tritium.

Deuterium is naturally occurring and can easily be extracted from seawater. Tritium can be produced from lithium. Lithium is also found in seawater.

The table gives the energy released from 1 kg of fusion fuel and from 1 kg of fission fuel.

Type of fuel	**Energy released from 1 kg of fuel in joules**
Fusion fuel	3.4×10^{14}
Fission fuel	8.8×10^{13}

(i) Suggest **two** advantages of the fuel used in a fusion reactor compared with plutonium and the other substances used as fuel in a fission reactor.

1. ___

___

___

2. ___

___

___

(2)

(ii) Some scientists think that by the year 2050 a nuclear fusion power station capable of generating electricity on a large scale will have been developed.

Suggest **one** important consequence of developing nuclear fusion power stations to generate electricity.

____

____

____

(1)

(d) Tritium is radioactive.

After 36 years, only 10 g of tritium remains from an original sample of 80 g.

Calculate the half-life of tritium.

Show clearly how you work out your answer.

____

____

Half-life = ___________________ years

(2)

(Total 9 marks)

5. 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.

Particle	Relative charge
Electron	–1
Neutron	
Proton	

(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)

6. Different radioactive isotopes have different values of half-life.

(a) What is meant by the 'half-life' of a radioactive isotope?

____

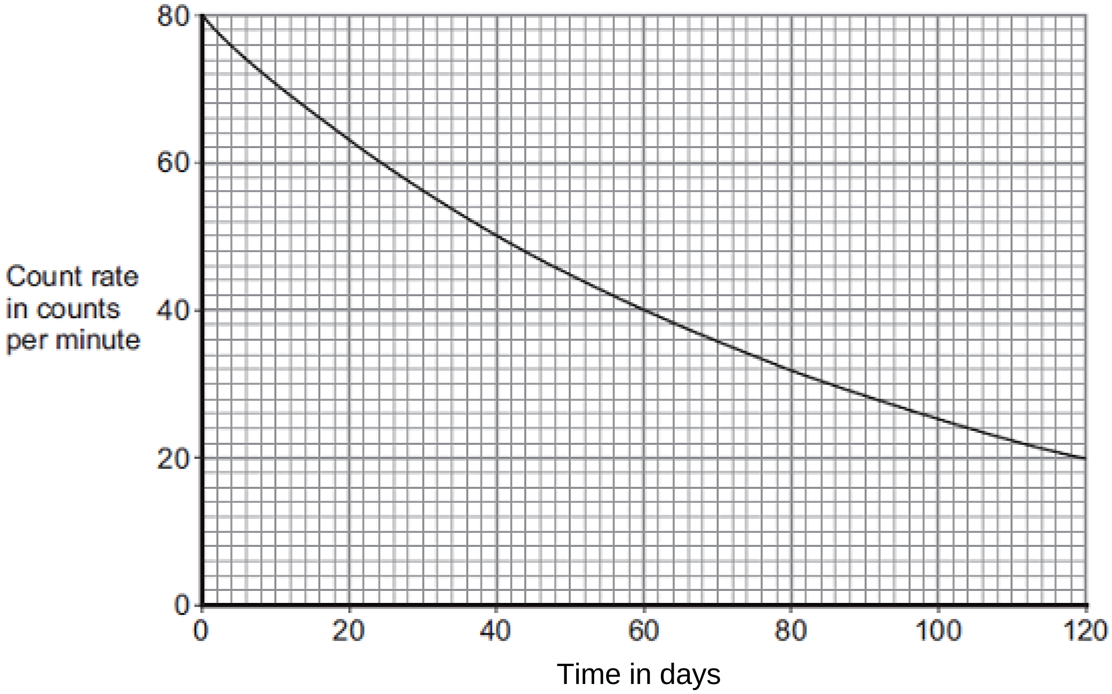
____

____

(1)

(b) **Figure 1** shows how the count rate from a sample of a radioactive isotope varies with time.

Figure 1



Use information from **Figure 1** to calculate the half-life of the radioactive isotope.

Show clearly on **Figure 1** how you obtain your answer.

Half-life = ___________________ days

(2)

(c) The table below shows data for some radioactive isotopes that are used in schools.

Radioactive isotope	**Type of radiation emitted**	**Half-life in years**
Americium-241	Alpha and gamma	460
Cobalt-60	Gamma	5
Radium-226	Alpha, beta and gamma	1600
Strontium-90	Beta	28
Thorium-232	Alpha and beta	1.4×10^{10}

(i) State which radioactive isotope in the table above emits only radiation that is **not** deflected by a magnetic field.

Give a reason for your choice.

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____

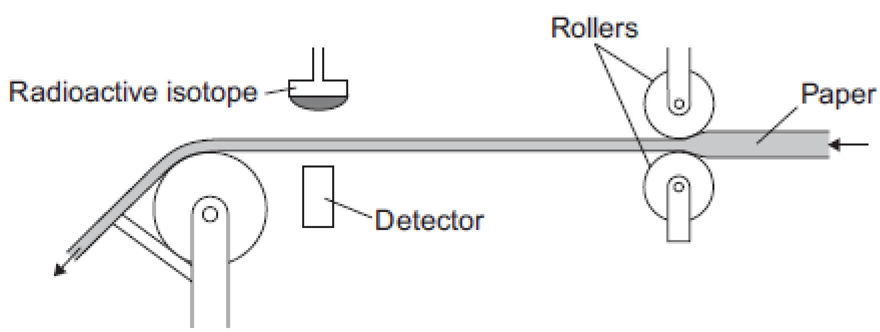
____

____

(2)

(ii) **Figure 2** shows a radioactive isotope being used to monitor the thickness of paper during production.

Figure 2



State which radioactive isotope in the table should be used to monitor the thickness of the paper.

Explain your choice.

___

___

___

___

___

(3)

All the radioactive isotopes in the table have practical uses.

State which source in the table would need replacing most often.

Explain your choice.

___

___

___

___

___

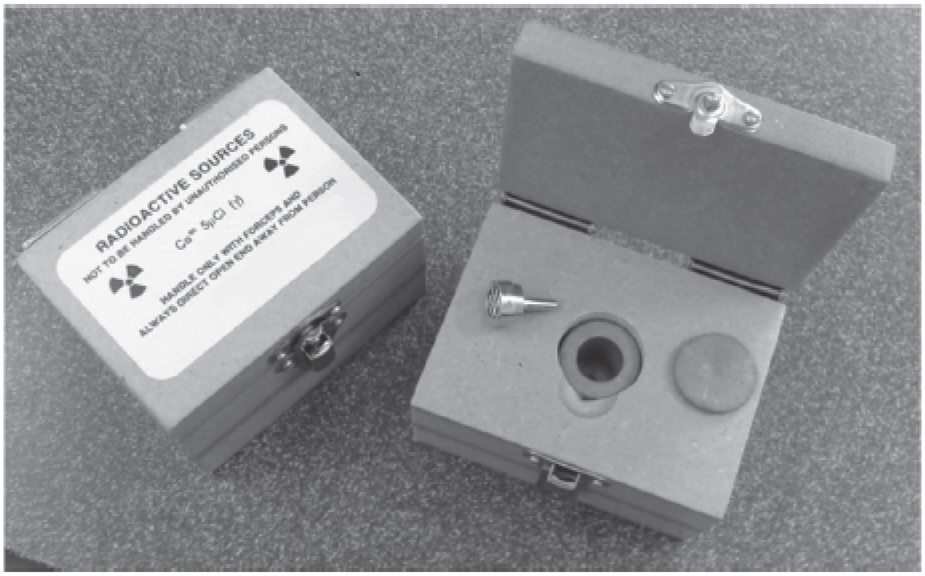
(3)

(iii) When the radioactive isotopes are not in use, they are stored in lead-lined wooden boxes.

The boxes reduce the level of radiation that reaches the surroundings.

Figure 3 shows two of these boxes.

Figure 3



State **one** source from the table which emits radiation that could penetrate the box.

Explain your answer.

____

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____

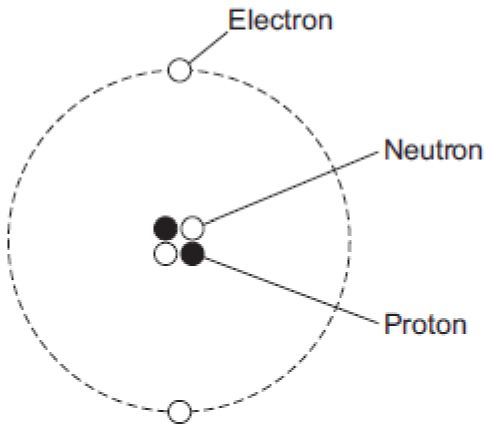
____

____

____

(3)
(Total 14 marks)

7. (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**

(1)

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

___________________________ and ___________________________

(1)

(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.

____

____

(2)

(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	much bigger than about the same as much smaller than	the possible benefit of having

the treatment.

(1)

(Total 9 marks)

8. (a) There are many isotopes of the element molybdenum (Mo).

What do the nuclei of different molybdenum isotopes have in common?

____

(1)

(b) The isotope molybdenum-99 is produced inside some nuclear power stations from the nuclear fission of uranium-235.

(i) What happens during the process of nuclear fission?

____

____

(1)

(ii) Inside which part of a nuclear power station would molybdenum be produced?

____

(1)

(c) When the nucleus of a molybdenum-99 atom decays, it emits radiation and changes into a nucleus of technetium-99.

$$^{99}_{42}\text{Mo} \longrightarrow {}^{99}_{43}\text{Tc} + \text{Radiation}$$

What type of radiation is emitted by molybdenum-99?

____

Give a reason for your answer.

____

____

(2)

(d) Technetium-99 has a short half-life and emits gamma radiation.

What is meant by the term 'half-life'?

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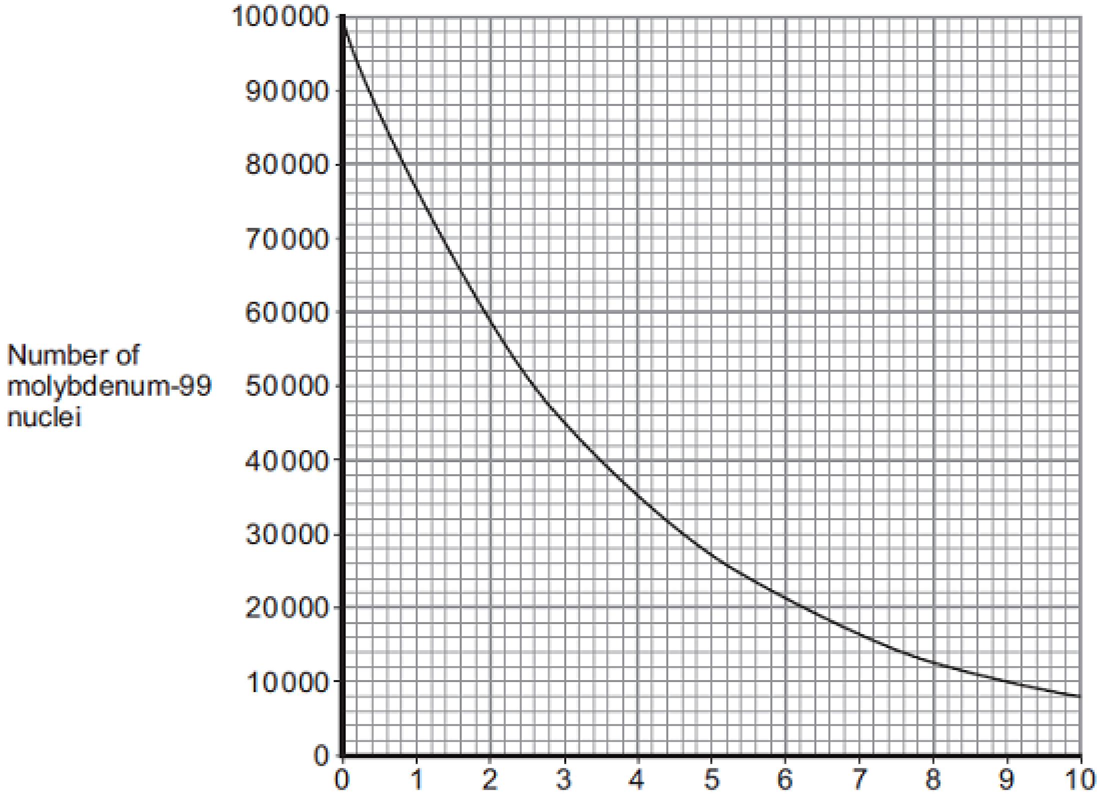
(1)

(e) Technetium-99 is used by doctors as a medical tracer. In hospitals it is produced inside a technetium generator by the decay of molybdenum-99 nuclei.

(i) The figure below shows how the number of nuclei in a sample of molybdenum-99 changes with time as the nuclei decay.



A technetium generator will continue to produce sufficient technetium-99 until 80% of the original molybdenum nuclei have decayed.

After how many days will a source of molybdenum-99 inside a technetium-99 generator need replacing?

Show clearly your calculation and how you use the graph to obtain your answer.

____

____

____

Number of days = ________________________

(2)

(ii) Medical tracers are injected into a patient's body; this involves some risk to the patient's health.

Explain the risk to the patient of using a radioactive substance as a medical tracer.

____

____

____

____

(2)

(iii) Even though there may be a risk, doctors frequently use radioactive substances for medical diagnosis and treatments.

Suggest why.

____

____

(1)

(Total 11 marks)

9. Nuclear fission and nuclear fusion are two processes that release energy.

(a) (i) Use the correct answer from the box to complete each sentence.

Geiger counter	**nuclear reactor**	**star**

Nuclear fission takes place within a ______________________________ .

Nuclear fusion takes place within a _______________________________ .

(2)

(ii) State **one** way in which the process of nuclear fusion differs from the process of nuclear fission.

____

____

(1)

(b) The following nuclear equation represents the fission of uranium-235 (U-235).

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{236}_{92}U \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + \text{energy}$$

Chemical symbols:

Ba - barium

Kr - krypton

(i) Use the information in the equation to describe the process of nuclear fission.

____

____

____

____

____

____

____

____

(4)

(ii) An isotope of barium is Ba-139.
Ba-139 decays by beta decay to lanthanum-139 (La-139).

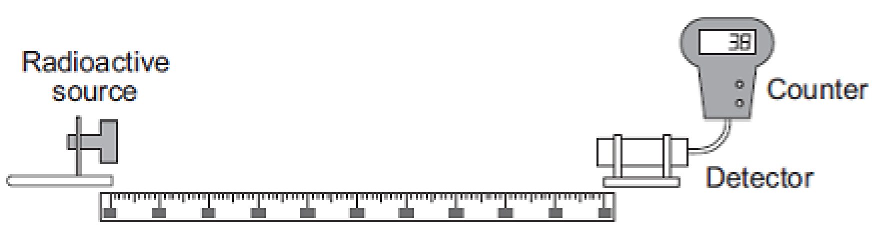
Complete the nuclear equation that represents the decay of Ba-139 to La-139.

$$^{139}_{\_\_\_}Ba \longrightarrow ^{139}_{\_\_\_}La + \_\_\_$$

(3)

(Total 10 marks)

10. A teacher used the equipment shown in the diagram to measure the count rate at different distances from a radioactive source.



Metre rule

(a) Her results are shown in **Table 1**.

Table 1

Distance in metres	Count rate in counts per minute	Corrected count rate in counts per minute
0.4	143	125
0.6	74	56
0.8	49	31
1.0	38	20
1.2	32	14
1.4	28	10
1.6	18	0
1.8	18	0
2.0	18	0

The background count rate has been used to calculate the corrected count rate.

(i) What is the value of the background count rate?

Background count rate = ________________ counts per minute

(1)

(ii) What information does the corrected count rate give?

____

____

(1)

(iii) The radioactive source used in the demonstration emits only one type of radiation.

The radioactive source is **not** an alpha emitter.

How can you tell from the data in the table?

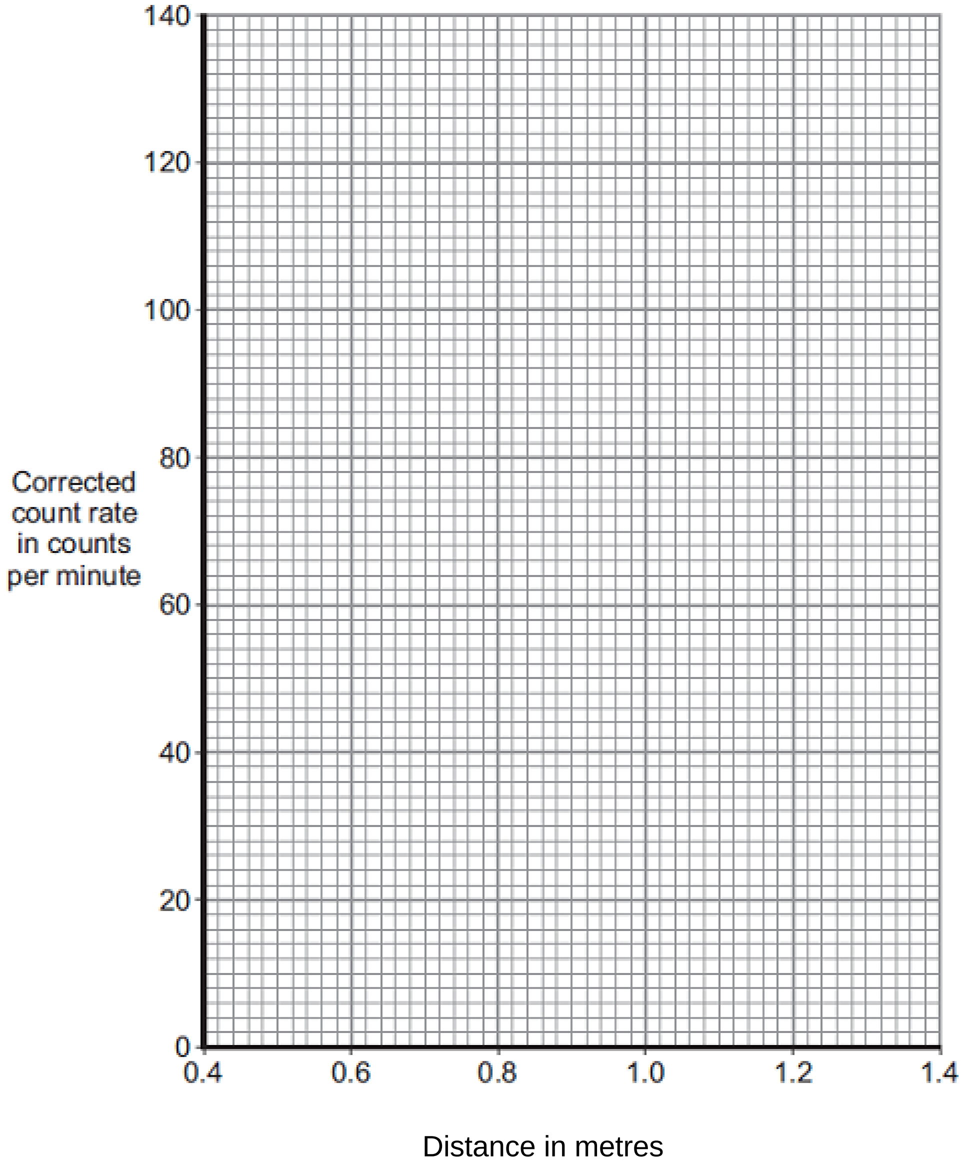
____

____

(1)

(iv) Plot a graph of corrected count rate against distance for distances between 0.4 m and 1.4 m.

Draw a line of best fit to complete the graph.



(3)

(v) The ‘half-distance’ is the distance a detector has to be moved away from a radioactive source for the corrected count rate to halve.

A student has the hypothesis:
A radioactive source has a constant ‘half-distance’.

Table 1 has been repeated for your information.

Table 1

Distance in metres	**Count rate in counts per minute**	**Corrected count rate in counts per minute**
0.4	143	125
0.6	74	56
0.8	49	31
1.0	38	20
1.2	32	14
1.4	28	10
1.6	18	0
1.8	18	0
2.0	18	0

Use **Table 1** to determine if the hypothesis is correct for this radioactive source.

You should use calculations in your answer.

____

____

____

____

____

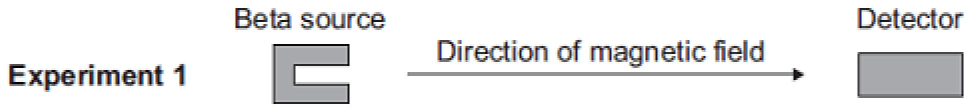
____

____

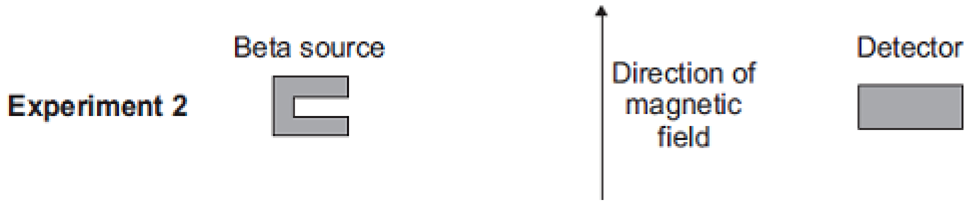
(3)

(b) A teacher places a beta source and a detector in a magnetic field.

The arrangement of the magnetic field is shown.



The teacher repeated the experiment with the magnetic field in a different direction.



A set of results is shown in **Table 2**.

Table 2

Distance between source and detector in metres	**Count rate in counts per minute without magnetic field**	**Count rate in counts per minute in Experiment 1**	**Count rate in counts per minute in Experiment 2**
0.8	48	48	32

(i) Describe **and** explain the effect of the magnetic field on the count rate detected by the detector.

____

____

____

____

____

____

(2)

(ii) The experiment is repeated with a different distance between the source and the detector.

Table 3 shows the repeated results.

Table 3

Distance between source and detector in metres	**Count rate in counts per minute without magnetic field**	**Count rate in counts per minute in Experiment 1**	**Count rate in counts per minute in Experiment 2**
1.8	19	18	20

Explain these results.

____

____

____

____

____

____

(2)

(Total 13 marks)

Mark schemes

1. (a) inside the Sun 1

(b) fusion 1

(c) energy 1

[3]

2. (a) cell damage or cancer

accept kills / mutates cells

radiation poisoning is insufficient
ionising is insufficient

1

(b) (i) any **one** from:

- use tongs to pick up source
- wear gloves
- use (lead) shielding
- minimise time (of exposure)
- maximise distance (between source and teacher).

accept any other sensible and practical suggestion

ignore reference to increasing / decreasing the number / thickness of lead sheets

1

(ii) <u>background</u> 1

(c) (i) curve drawn *from point 2,160*

*do **not** accept straight lines drawn from dot to dot*

1

(ii) (also) increases

less radiation passes through is insufficient

1

(iii) 50

accept any value from 40 to 56 inclusive

1

(d) gamma 1

only gamma (radiation) can pass through lead

*accept alpha **and** beta cannot pass through lead*
a general property of gamma radiation is insufficient

1

[8]

3. (a) (an equal amount of) positive charge

*do **not** accept charge on the atom / nucleus is positive*

1

(b) (i) a (significant) number of alpha particles were scattered by more than 4°

or

alpha particles deflected backwards

accept (some) measurements / results were unexpected

1

measurements / results could not be explained by 'plum pudding' model

or

measurements / results did not support predictions

can be explained by the nuclear model is insufficient

accept measurements / results did not support hypothesis

1

(ii) many / (over)100 000 measurements / results taken

accept Rutherford(and Marsden) were respected scientists

or

scientists were respected

accept measurements / results taken over several months

the experiment was repeated many times is insufficient

1

(c) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information on page 5 and apply a 'best-fit' approach to the marking.

0 marks
no relevant content

Level 1 (1−2 marks)
A brief description is given with some particles correctly named

Level 2 (3−4 marks)
A description is given with all three particles named
plus either
the polarity of charge associated with the three particles
or
the relative mass of the three particles
or
the relative mass for one particle and the relative charge for one particle given

Level 3 (5−6 marks)
A more detailed description is given, naming the particles and polarity of charge
and either
the relative mass is given for at least two particles
or
the relative charge is given for at least two particles

Examples of the points made in the response

brief description
contains protons, neutrons and electrons

protons are positive
electrons are negative
neutrons are uncharged

has a nucleus

relative charge
proton +1
electron − 1
neutron 0

relative mass
proton 1
neutron 1
electron (about) 1 / 2000

accept protons and neutrons have the same mass

accept electrons have tiny / negligible mass
zero mass is neutral

more detailed description
protons and neutrons make up the nucleus
electrons orbit the nucleus
electrons are in shells
most of the atom is empty space
nucleus occupies a very small fraction of the volume of the atom
electrons orbit at a relatively large distance from the nucleus
most of the mass of the atom is contained in the nucleus
the nucleus as a whole is positively charged total number of protons in the nucleus
equals the total number of electrons orbiting it in an atom

6

[10]

4. (a) (i) splitting of a(n atomic) nucleus

do not accept splitting an atom

1

(ii) Neutron

1

(b) (i) nuclei have the same charge
or
nuclei are positive

accept protons have the same charge

1

(ii) (main sequence) star

accept Sun or any correctly named star

accept red (super) giant

1

(c) (i) any **two** from:

- easy to obtain / extract
- available in (very) large amounts
- releases more energy (per kg)

  *do **not** accept figures only*
- produces little / no radioactive waste.

  naturally occurring is insufficient

  seawater is renewable is insufficient

  less cost is insufficient

2

(ii) any **one** from:

- makes another source of energy available
- increases supply of electricity
- able to meet global demand
- less environmental damage
- reduces amount of other fuels used.

  accept any sensible suggestion

  accept a specific example

  accept a specific example

1

(d) 12

*allow **1** mark for obtaining 3 half-lives*

2

[9]

5. (a) neutrons and protons

1

(b) 0

1

(+)1

1

(c) (i) total positive charge = total negative charge

accept protons and electrons have an equal opposite charge

1

(because) no of protons = no of electrons

1

(ii) ion

1

positive

1

[7]

6. (a) (average) time taken for the amount / number of nuclei / atoms (of the isotope in a sample) to halve
or
time taken for the count rate (from a sample containing the isotope) to fall to half

accept (radio)activity for count rate

1

(b) *60* ±*3* (days)

1

indication on graph how value was obtained

1

(c) (i) cobalt(-60)

1

gamma not deflected by a magnetic field
or
gamma have no charge

dependent on first marking point

accept (only) emits gamma

gamma has no mass is insufficient

*do **not** accept any reference to half-life*

1

(ii) strontium(-90)

1

any **two** from:

- *only* has beta
- alpha would be absorbed
- gamma unaffected
- *beta penetration / absorption depends on thickness of paper*

*if thorium(-232) or radium(-226) given, max **2** marks can be awarded*

2

(iii) cobalt(-60)

1

shortest half-life

accept half-life is 5 years

dependent on first marking point

1

so activity / count rate will decrease quickest

1

(iv) *americium(-241) / cobalt(-60) / radium(-226)*

1

gamma emitter

1

(only gamma) can penetrate lead *(of this box)*

do not allow lead fully absorbs gamma

1

[14]

7. (a) (i) neutron

1

(ii) neutron

proton

both required, either order

1

(iii) 2

1

number of <u>protons</u>

do not accept number of electrons

1

(b) (i) any **one** from:

- beta
- gamma

accept correct symbols

accept positron / neutrino / neutron

cosmic rays is insufficient

1

(ii) electrons

1

(iii) are highly ionising

1

(c) (i) mutate / destroy / kill / damage / change / ionise

Harm is insufficient

1

(ii) much smaller than

1

[9]

8. (a) (same) number of protons

same atomic number is insufficient

1

(b) (i) nuclei split

*do **not** accept atom for nuclei / nucleus*

1

(ii) (nuclear) reactor

1

(c) beta

1

any **one** from:

- atomic / proton number increases (by 1)

  accept atomic / proton number changes by 1
- number of neutrons decreases / changes by 1
- mass number does not change

  (total) number of protons and neutrons does not change
- a neutron becomes a proton

1

(d) (average) time taken for number of nuclei to halve

or

(average) time taken for count-rate / activity to halve

1

(e) (i) 6.2 (days)

Accept 6.2 to 6.3 inclusive

*allow **1** mark for correctly calculating number remaining as 20 000*

or

*allow **1** mark for number of*

80 000 plus correct use of the graph (gives an answer of 0.8 days)

2

(ii) radiation causes ionisation

allow radiation can be ionising

1

that may then harm / kill healthy cells

accept specific examples of harm, eg alter DNA / cause cancer

1

(iii) benefit (of diagnosis / treatment) greater than risk (of radiation)

accept may be the only procedure available

1

[11]

9. (a) (i) nuclear reactor

1

star

1

(ii) nuclei are joined (not split)

accept converse in reference to nuclear fission

do ***not*** *accept atoms are joined*

1

(b) (i) any **four** from:

- neutron
- (neutron) absorbed by U (nucleus)

  ignore atom
  do ***not*** *accept reacts*
  do ***not*** *accept added to*
- forms a larger nucleus
- (this larger nucleus is) unstable
- (larger nucleus) splits into two (smaller) nuclei / into Ba and Kr
- releasing three neutrons and energy

  accept fast-moving for energy

4

(ii) 56 (Ba)

1

57 (La)

if proton number of Ba is incorrect allow ***1*** *mark if that of La is 1 greater*

1

$^{0}_{-1}\beta$

accept e for β

$$^{139}_{56}\text{Ba} \longrightarrow {}^{139}_{57}\text{La} + {}^{0}_{-1}\beta$$

scores ***3*** *marks*

1

[10]

10. (a) (i) 18

1

(ii) the count rate for the source

1

(iii) the alpha radiation would not cover such a distance

1

(iv) plots correct to within ½ small square

allow ***1*** *mark for 4 correct points plotted*

2

correct curve through points as judged by eye

1

(v) two attempts at finding 'half-distance' using the table

20 to 10 cpm d = 0.4 m
125 to 56 cpm d = 0.2 m
31 to 14 cpm d = 0.4 m

allow ***1*** *mark for one attempted comparison*

2

obeyed or not obeyed

dependent on previous two marks

1

(b) (i) there is no effect on the count rate in experiment 1 because the field is parallel **or** beta particles are not deflected **or** there is no force

1

count rate is reduced in experiment 2 because field is perpendicular **or** beta particles are deflected **or** there is a force

1

(ii) only background radiation (as beta do not travel as far)

1

slightly different values show the random nature of radioactive decay

1

[13]