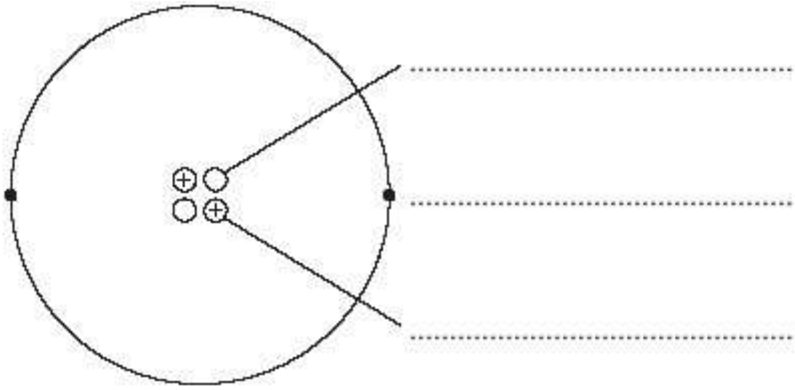
6-4 Atomic structure – Physics

1.0 **Figure 1** shows a helium atom.

Figure 1



1.1 Use the words in the box to label the diagram.

[2 marks]

electron	**neutron**	**proton**

1.2 An alpha particle is the same as the nucleus of a helium atom.

How is an alpha particle different from a helium atom?

[1 mark]

____

____

1.3 Complete the atomic symbol for helium to show helium's atomic number and mass number

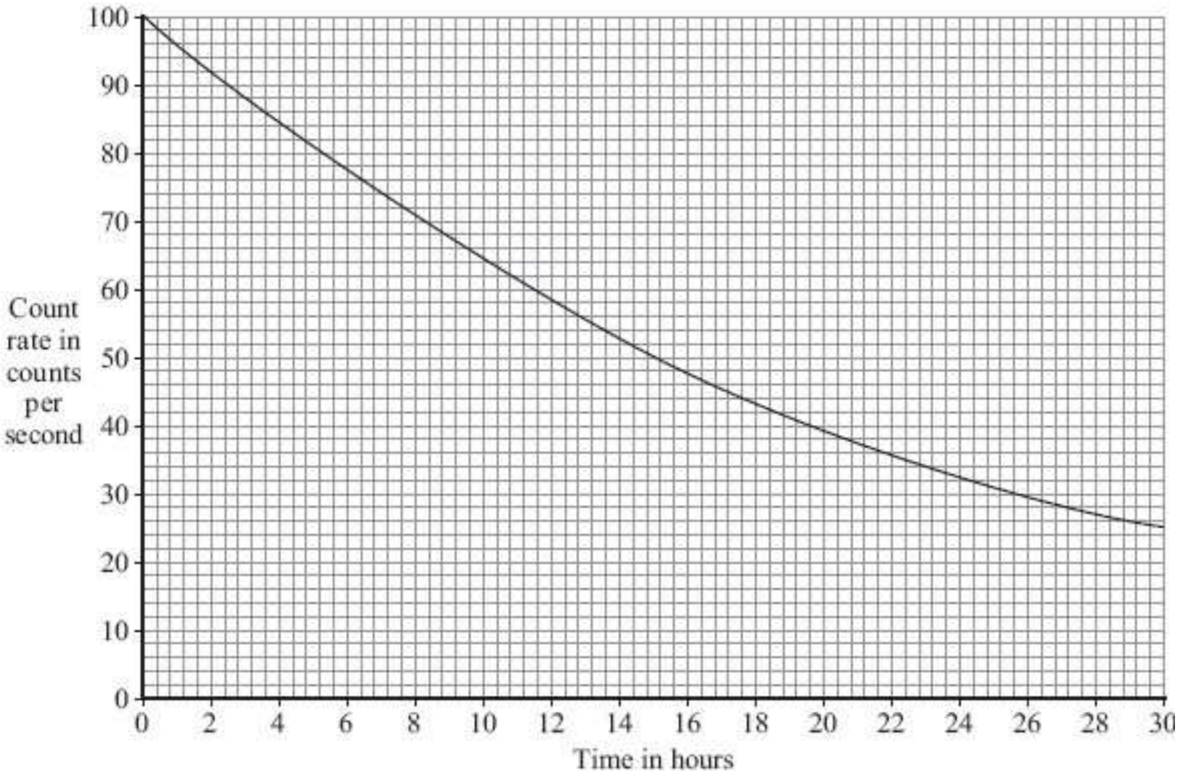
[2 marks]

_____

He

_____

The graph shows how the count rate from a sample of radioactive sodium-24 changes with time.



1.4 What time, in hours, does it take for the count rate to fall from 60 counts per second to 40 counts per second?

[2 marks]

____

____

time = ____________ hours

1.5 What is the half-life of sodium-24?

[1 mark]

half-life = _____________ hours

2.1 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**

[3 marks]

List A Type of radiation	List B Property of radiation
	will pass through paper but is stopped by thin metal
alpha	
	has the shortest range in air
beta	
	will not harm human cells
gamma	
	is very weakly ionising

2.2 Complete the following sentences using the words from the box.

[4 marks]

alpha	**beta**	**gamma**	**proton**	**neutron**

The most penetrating type of radiation is ____________ .

The type of radiation with the greatest charge is _____________ .

The type of radiation with the greatest range in air is __________ .

The two types of radiation that have no charge are ___________and __________.

3.0 The table shows the average background radiation dose from various sources that a person living in the UK receives in one year.

Source of background radiation	Average radiation dose received each year in mSv
Cosmic rays (from space)	0.40
Food and drink	0.30
Medical treatments (including X-rays)	0.55
Radon gas	1.25
Rocks	0.50
TOTAL	**3.00**

3.1 A student looked at the data in the table and then wrote down four statements.

Which of the following statements are true?

[2 marks]

Tick **two** boxes.

More than half of the average radiation dose comes from radon gas. ☐

On average, cosmic rays produce less background radiation than rocks. ☐

Everyone living in the UK receives the same background radiation dose. ☐

Having no X-rays reduces a person's radiation dose. ☐

3.2 Each time a chest X-ray is taken, the patient receives about 0.12 mSv of radiation.

How many chest X-rays would just exceed the yearly average dose for medical treatments?

[2 marks]

____

____

number of chest X-rays = ____________

3.3 What percentage of the total dose comes from natural sources?

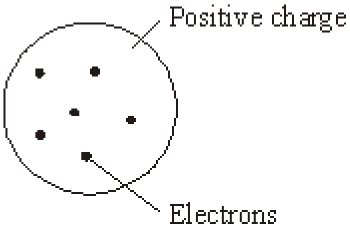
[3 marks]

____

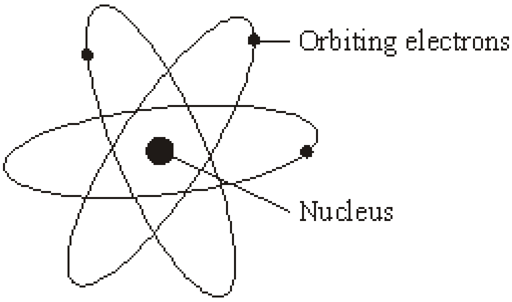
____

Percentage = ____________

4.0 The discovery of the electron led to the plum pudding model to explain the structure of the atom.



The results from the alpha particle scattering experiment led to the plum pudding model being replaced by the nuclear model.



4.1 Describe the differences between the two models of the atom.

[6 marks]

____

____

____

____

____

5.0 There are many isotopes of the element technetium (Tc).

5.1 What do the nuclei of different technetium isotopes have in common?

[1 mark]

5.2 The isotope technetium-99 is produced when a nucleus of a molybdenum-99 decays, it emits radiation when it decays.

[2 marks]

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

What type of radiation is emitted by molybdenum-99? ______________

Give a reason for your answer.

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

What happens during the process of nuclear fission?

[1 mark]

____

5.4 Inside which part of a nuclear power station would molybdenum be produced?

[1 mark]

____

5.5 Technetium-99 has a short half-life and emits gamma radiation.

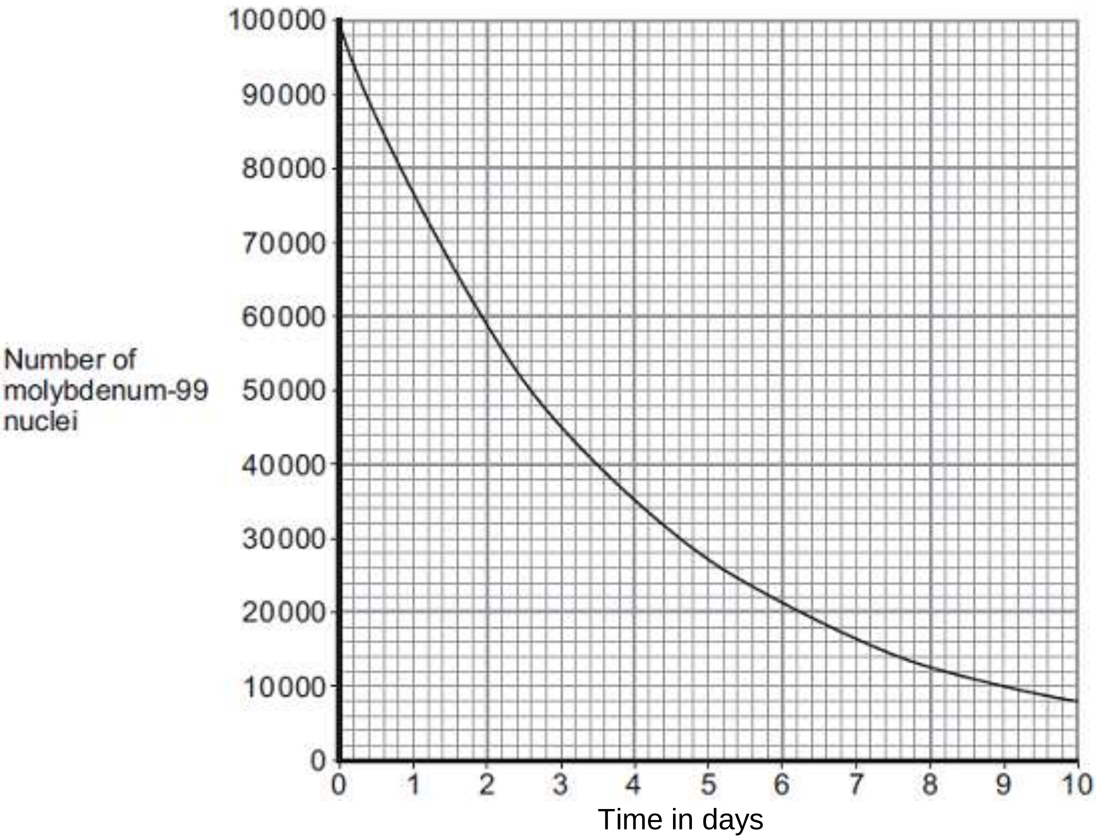
What is meant by the term 'half-life'?

[1 mark]

____

5.6 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.

The graph 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 three half-lives have passed.

After how many days should the technetium generator be replaced?

[2 marks]

____

____

____

____

Number of days = ______________

5.7 A doctor claims that after 13 days the technetium generator will be safe to dispose of.

Calculate the number of molybdenum nuclei remaining after 13 days, and comment on whether it would be safe to dispose of.

[6 marks]

____

____

____

____

number of molybdenum nuclei remaining = ______________

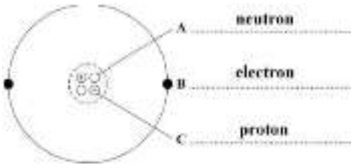
Safety ____

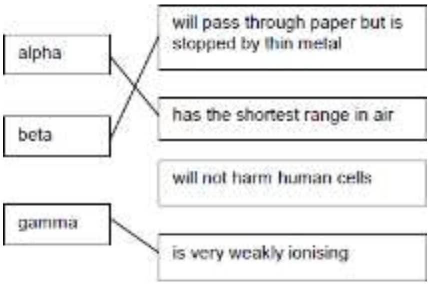
____

____

____

MARK SCHEME

Qu No.		Extra Information	Marks
1.1		all three labels correct allow 1 mark for 1 or 2 correct labels	2
1.2	has no electrons	*allow alpha has a positive(charge)* *allow a helium (atom) has no (charge)*	1
1.3	4 2		1 1
1.4	19.6 - 11.6 8 (hours)	allow ± 0.2 for each reading allow ± 0.4 if consistent with values read from the graph	1 1
1.5	15.2 (hours)	allow ± 0.2	1

Qu No.		Extra Information	Marks
2.1		*allow 1 mark for each correct line* *if more than one line is drawn from any type of radiation box then all of those lines are wrong*	3
2.2	gamma alpha gamma gamma and neutron	 both required for **1** mark	1 1 1 1

Qu No.		Extra Information	Marks
3.1	on average, cosmic rays produce less background radiation than rocks having no X-rays reduces a person's radiation dose		1 1
3.2	0.55/0.12 number of chest X-rays = 5	do not allow 4.583	1 1
3.3	Sum = 2.15 Percentage of total dose = (2.15 / 3.00) × 100 72 %	allow **2** marks for 0.72 or 0.716	1 1 1

Qu No.		Extra Information	Marks
4.1			
Level 3:	A detailed and coherent comparison of the arrangement of the particles in the different models.		5-6
Level 2:	A detailed and coherent description of the arrangement of the particles in the different models.		3-4
Level 1:	A simple description of the arrangement and/or a simple comparison of the arrangement of the particles in the different models		1-2
	No relevant content		0
Indicative content			
	nuclear model mass is concentrated at the centre / nucleus plum pudding model mass is evenly distributed nuclear model positive charge occupies only a small part of the atom plum pudding model positive charge spread throughout the atom nuclear model electrons orbit some distance from the centre / nucleus plum pudding electrons embedded in the (mass) of positive (charge) nuclear model the atom mainly empty space plum pudding model is a 'solid' mass		

Qu No.		Extra Information	Marks
5.1	(same) number of protons		1
5.2	beta atomic / proton number increases (by 1) **or** number of neutrons decreases / changes by 1		1 1
5.3	nuclei split		1
5.4	the reactor		1
5.5	time taken for number of radioactive nuclei to halve **or** (average) time taken for count-rate / activity to halve		1
5.6	1 half-life = 2.6 days number of days = 7.8 days		1 1
5.7	Number of half-lives = 13/2.6 fraction = (½ × ½ × ½ × ½ × ½) or $(½)^5$ 100 000 / 32 3125 safe number is comparatively low, so low activity unlikely to be substantial risk of contamination/irradiation. or unsafe There are still some atoms of molybdenum left so some radiation emitted therefore still a small risk.	 no mark for safe/unsafe	1 1 1 1 1 1