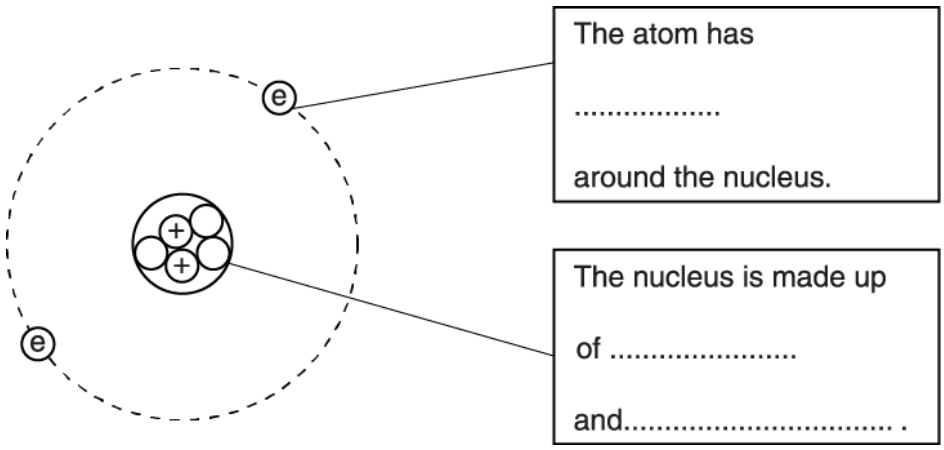
1. This question is about ionising radiation.

Ionising radiation affects atoms.

(i) Complete the labels on the diagram of an atom.



[3]

(ii) What is the effect of ionising radiation hitting an atom?

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[2]

2(a). Read the following article.

> Some cancers are treated with a form of radiation therapy called brachytherapy. A small piece of material that is radioactive is placed inside a tumour. The radioactive material then decays, releasing ionising radiation that destroys the tumour.

(i) Write down words or phrases **from the article** that mean the following:

breaks down over time _____

produces ionising radiation _____

[2]

(ii) The three types of ionising radiation from radioactive materials travel different distances.

Write **alpha, beta** and **gamma** in the boxes to show how far each type of ionising radiation travels through the body.

travels the **shortest** distance → travels the **greatest** distance		
_____	_____	_____

[1]

(b).

(i) Which two statements explain why the ionising radiation “destroys the tumour”?

Put ticks (✓) in the boxes next to the **two** best answers.

Ionising radiation…

… can break molecules into bits. ☐

… gets stronger over time. ☐

… is produced from the electrons in atoms. ☐

… can be destroyed using acid. ☐

… kills living cells. ☐

[2]

(ii) Which statement explains why the radioactive material decays at the same rate both inside and outside the body?

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

The movement of the body speeds up the decay. ☐

The heat from the body increases the radioactivity. ☐

The decay is not affected by chemicals in the body. ☐

The body shields the radioactive material from light. ☐

[1]

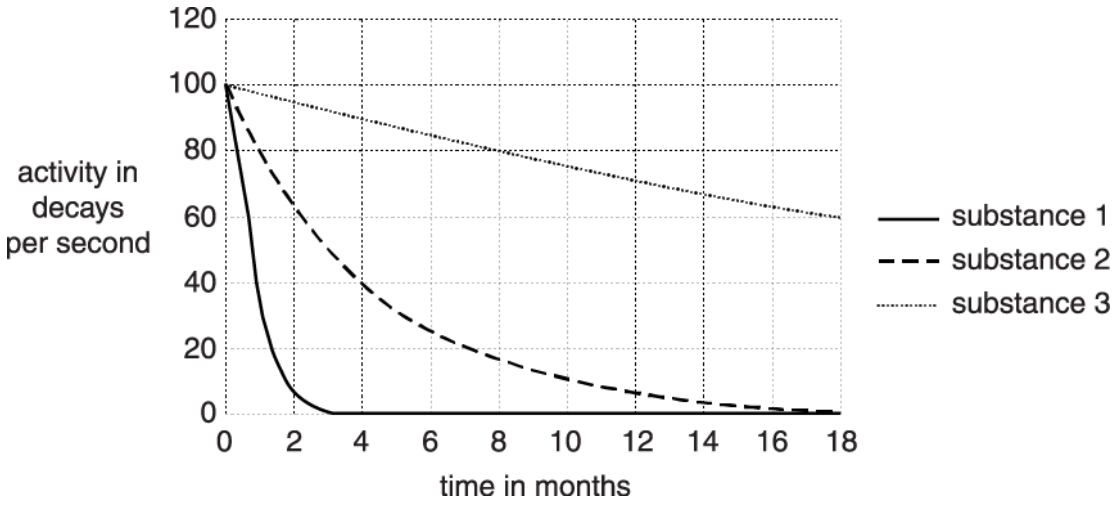
(c). For brachytherapy to be effective:

- the radioactive material must remain in the tumour long enough for the tumour to be destroyed
- the activity must be low after that time.

One particular tumour will have to be treated for 6 months to be destroyed.

A doctor has a choice of three different substances to treat the tumour.

Each substance gives out the same type of radiation.



Which substance should the doctor use to treat this tumour?

Justify your answer.

substance _____

_____

_____

_____

_____ [3]

3. There are many arguments for and against nuclear power.

Some people are worried about the materials left over as waste from nuclear power stations.

Three of the materials left over are caesium-134, technetium-99 and zirconium-93.

They have very different half-lives.

(i) What is half-life?

Place a tick (✓) in the box next to the correct answer.

The time taken for the radioactive material to completely change into another material.	☐
The time taken for a radioactive material to become safe.	☐
The time taken for half of the radioactive material to decay.	☐

[1]

(ii) Caesium-134 has a half-life of about 2 years.

Technetium-99 has a half-life of about 200 000 years.

Zirconium-93 has a half-life of about 1.5 million years.

Samples of each material start with the same activity.

Which material will take the **longest** time for its activity to halve?

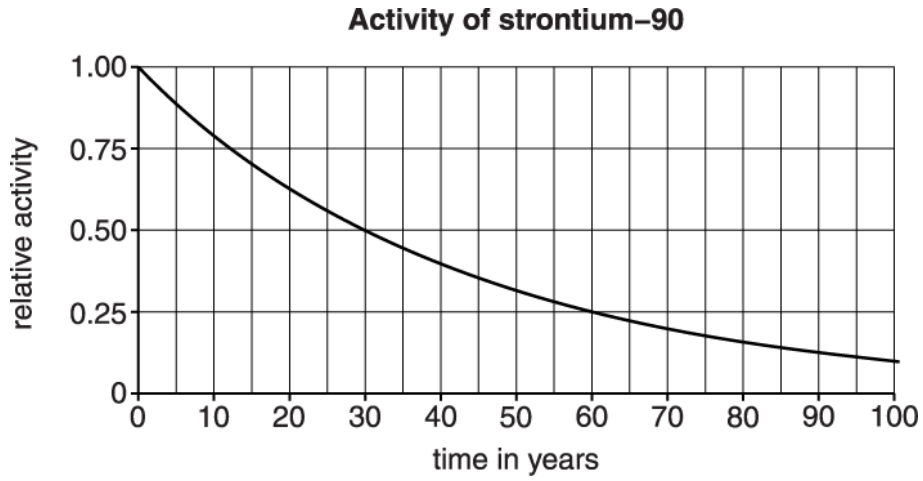
Which material will take the **shortest** time for its activity to halve?

---

[2]

(iii) Another material often left over from nuclear power stations is strontium-90.

The graph below shows how strontium-90 decays.



How long does it take strontium-90 to decay to a quarter of its starting activity?

Use the graph.

answer _____ years **[1]**

4. The diagram below is a way of showing the particles that make up an atom.

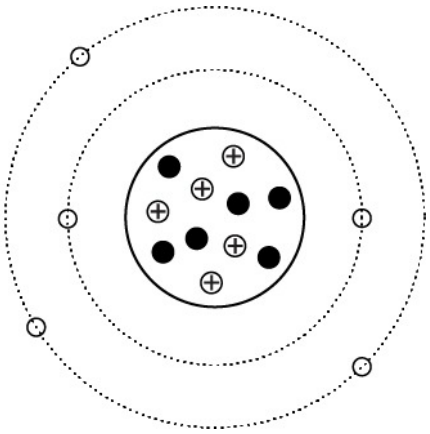
Draw a straight line from each box to show where the particles are in the atom.

particle

electron

neutron

proton



[2]

5(a). A teacher does an experiment to measure the half-life of a radioactive source.

She begins by measuring the background radiation.

State a source of background radiation.

---

[1]

(b). She places the source in front of a Geiger counter, which measures the amount ofionising radiation.

Radioactive materials give out ionising radiation.

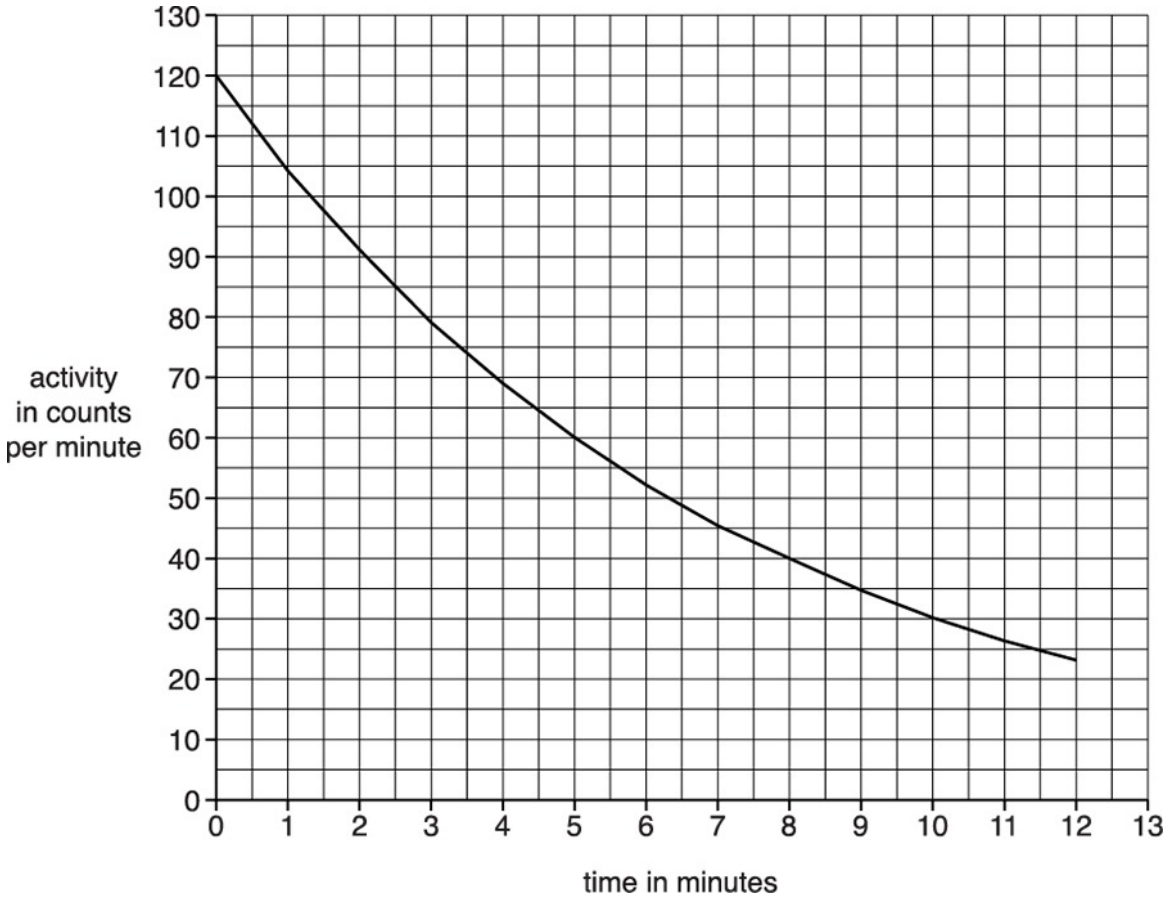
Which of the following types of radiation are given out by radioactive materials?

Put ticks (✓) in the boxes next to the **two** correct answers.

beta	☐
gamma	☐
red light	☐
ultraviolet	☐
X-rays	☐

[2]

(c). This graph shows how the activity of the radioactive source changes with time.



(i) Jo says the half-life is 5 minutes.

Use the graph to decide if she is correct.

Justify your answer.

---

[2]

(ii) A source is considered safe when its activity becomes the same as background radiation.

The background radiation is 30 counts per minute.

Use the graph to estimate when this source is considered safe.

time = _____ minutes **[1]**

6. Some smoke alarms contain the radioactive isotope americium-241.

Americium-241 can be represented as

$$^{241}_{95}\text{Am}$$

(i) Which is the number of protons in americium-241?

[1]

Put a (ring) around the correct answer.

95 241 241 + 95 241 – 95

(ii) Which is the number of neutrons in americium-241?

[1]

Put a (ring) around the correct answer.

95 241 241 + 95 241 – 95

7. There is a film about an astronaut named Mark Watney. He is left alone on the planet Mars. He has to use science to stay alive until he can be rescued.

Mars is a cold planet. Watney uses a radioactive thermal generator to heat himself. The generator contains radioactive plutonium-238 which emits alpha-particles (α).

(i) Complete the radioactive decay equation for plutonium-238.

$$^{238}_{94}\mathrm{Pu} \longrightarrow {}^{\ldots\ldots}_{\ldots\ldots}\mathrm{U} + {}^{4}_{2}\alpha$$

[2]

(ii) The radioactive plutonium-238 is sealed inside a case with thin walls made of aluminium.
The plutonium-238 emits a large number of high energy alpha-particles each second.

Two of the following statements, taken together, explain why Watney is not at any risk from irradiation.

Tick (✓) **two** boxes

Alpha particles cannot penetrate a thin sheet of paper. ☐

Alpha radiation is never dangerous. ☐

Alpha radiation is not part of the electromagnetic spectrum. ☐

The aluminium in the case is thicker and denser than thin paper. ☐

He always wears safety glasses when he handles the plutonium-238. ☐

[2]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1		i	electron(s)	1	**ignore** any numbers next to the words
		i	proton(s) neutron(s)	2	either order Examiner's Comments Many candidates correctly named the three different particles in an atom.
		ii	removal of bit of atom	1	**allow** description of ionising, breaking up atoms into bits
		ii	this bit is an electron / turning the atom into an ion	1	**ignore** effects of radiation on nucleus Examiner's Comments Only a small minority of candidates knew the effect of ionising radiation hitting an atom. The most popular incorrect answers were that the atom became radioactive, or that it died.
			Total	**5**	
2	a	i	decays (1) (is) radioactive (1)	2	**allow** material decays (1) **allow** radioactive material (1) **NOT** radioactive material decays **Examiner's Comments** This question was about radioactivity. Candidates were expected to recall and use ideas about ionising radiation, interpret a graph to justify a choice of radioactive substance and use ideas about benefit and risk. Overall this question differentiated well. In (i) most candidates were able to select at least one correct definition from the article. The common error here was to quote too much.

Question			Answer/Indicative content	Marks	Guidance
		ii	alpha – beta – gamma	1	**allow** correct symbols or a mixture of words and symbols **Examiner's Comments** The common error in (ii) was to put beta as having a shorter traveling distance than alpha radiation.
	b	i	can break molecules into bits ✓ kills living cells ✓	2	
		ii	the decay is not affected by chemicals in the body. ✓	1	**Examiner's Comments** This objective question was answered quite well.

Question			Answer/Indicative content	Marks	Guidance
	c		(substance 2) **any three from** substance 2 – is active at 6 months (1) **or** activity decreases after 6 months (1) **or** is low after 6 months (1) substance 2 – less risk after 6 months (1) **or** less risky than substance 3 (1) substance 1 – not active for long enough / not active after 2 months (1) substance 3 – high activity for too long is risky (1) OR (substance 3) substance 3 – is active at 6 months (1) substance 1 – not active for long enough / not active after 2 months (1)	3	substance 1 chosen = 0 marks **allow** it will last long enough (1) not just 'the activity decreases' **allow** it won't be effective / it won't work (1) maximum of 2 marks for choosing substance 3 **allow** it will last long enough (1) **allow** it won't be effective / it won't work (1) **Examiner's Comments** Candidates were presented with a graph of the activity of three substances over a number of months. Candidates were given two criteria for selecting the most appropriate substance. The commonest error was to choose substance 1 with the associated misconception that its rapid decay implied a faster cure. Candidates who selected the correct substance often only gained one mark as their responses did not show consideration of why the other substances were not suitable.
			Total	9	

Question			Answer/Indicative content	Marks	Guidance
3		i	The time taken for the radioactive material to completely change into another material. ☐ The time taken for a radioactive material to become safe. ☐ The time taken for half of the radioactive material to decay. ☐	1	**Examiner's Comments** The first two parts of this question were answered well. Candidates showed that they knew the meaning of half life in part (i) and were able to identify the correct materials.
		ii	zirconium (1) caesium (1)	2	**Examiner's Comments** In part (ii). Technetium-99 proved a distracter for the longest time material. About half the candidates were able to read a value of about 60 from the graph. The most commonincorrect answer was 12, which suggests that these candidates misread the question and found the time to decay by a quarter rather than to a quarter.
		iii	60	1	**accept** 57–62
			Total	**4**	
4			proton to circle with + ⊕ neutron to black ● electron to white circle (in rings) ○	2	all correct = 2 marks 2 or 1 correct = 1 mark **Examiner's Comments** The majority of candidates correctly identified all three particles in the atom.
			Total	**2**	

Question			Answer/Indicative content	Marks	Guidance
5	a		radon / rocks / ground / buildings / food drink / cosmic rays / medical / nuclear waste / fallout / Sun	1	**Ignore** X-rays / gamma / alpha / beta / UV etc. **Examiner's Comments** Many candidates confused “source of” with “type of” and named an ionising radiation rather than a source.
	b		beta √ gamma √ red light ultra violet X-rays	2	**Examiner's Comments** Strong candidates correctly identified both types of ionising radiation.
	c	i	Quotes two values from the graph, one half the other; States they are five minutes apart;	1	**Accept** just pairs of lines drawn on graph **Accept** just one pair of lines from 60 c.p.m. **Examiner's Comments** Candidates were able to explain why the graph showed that the half-life was 5 minutes. Interestingly, many weak candidates assumed that since the graph stopped at 12 minutes, this was the lifetime of the sample, leading to a half-life of 6 minutes.
		ii	10 (minutes)	1	**Examiner's Comments** Most candidates agreed that the source was safe after 10 minutes, showing that they had good skills at reading data off graphs.
			Total	6	
6		i	95 ✓	1 (AO 1.1)	(95) 241 241 + 95 241 – 95
		ii	241 – 95 ✓	1 (AO 1.1)	95 241 241 + 95 (241 - 95)
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
7		i	U has A = 234 ✓ U has Z = 92 ✓	2 (AO 2.2 ×2)	
		ii	Alpha particles cannot penetrate a thin sheet of paper ✓ The aluminium in the case is thicker and denser than thin paper ✓	2 (AO 1.1) (AO 2.1)	1st and 4th boxes
			Total	4	