1 A scientist placed a radioactive source in front of a Geiger-Muller detector and measured the count rate every 20 minutes.

The table shows her data.

Time in minutes	Count rate in counts per minute	Corrected count rate in counts per minute
0	660	630
20	462	432
40	330	300
60	240	210
80	180	150
100	142	112

(a) The scientist corrects the count rate readings to allow for background radiation.

(i) State two sources of background radiation.

(2)

1 .....

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2 .....

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(ii) Describe how the scientist should measure the background radiation and correct the count rate readings.

(3)

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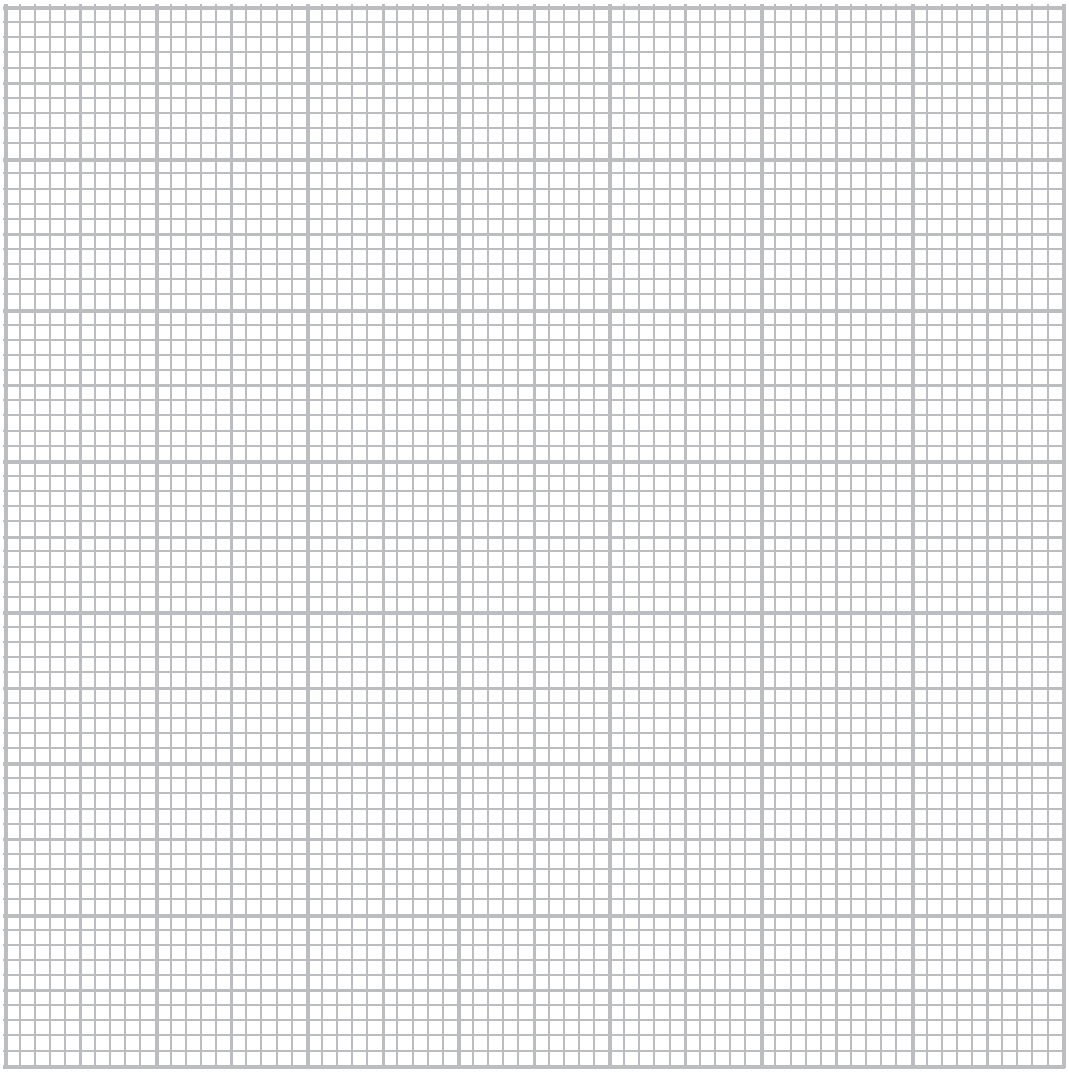
(iii) Plot a graph of corrected count rate against time and draw the curve of best fit.

(5)



(iv) Use your graph to find the half-life of the radioactive source.

(2)

half-life = ... minutes

(b) The radioactive nuclei in the source emit beta radiation.

What effect does the emission of a beta particle have on a nucleus?

(2)

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(c) The scientist needs to reduce the risks when working with radioactive sources.

(i) Explain why radioactive sources can be dangerous.

(2)

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(ii) Describe how the risks of working with radioactive sources can be reduced.

(3)

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(Total for Question 1 = 19 marks)

2 Carbon-14 is a radioactive isotope of carbon.

It has the symbol

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

(a) (i) The number of **nucleons** in a carbon-14 nucleus is

(1)

☒ **A** 6

☒ **B** 8

☒ **C** 14

☒ **D** 20

(ii) The number of **neutrons** in a carbon-14 nucleus is

(1)

☒ **A** 6

☒ **B** 8

☒ **C** 14

☒ **D** 20

(iii) The number of **electrons** in a neutral carbon-14 atom is

(1)

☒ **A** 6

☒ **B** 8

☒ **C** 14

☒ **D** 20

(b) When carbon-14 decays it emits a beta particle.

What is a **beta particle**?

(1)

- ☒ **A** an electron
- ☒ **B** a neutron
- ☒ **C** a nucleus
- ☒ **D** a proton

(c) Carbon-14 has a half-life of 5700 years.

A sample of cloth contains 6.0 g of carbon-14.

What mass of carbon-14 will remain in the cloth after 11 400 years?

(1)

- ☒ **A** 1.5 g
- ☒ **B** 2.0 g
- ☒ **C** 2.5 g
- ☒ **D** 3.0 g

(d) The carbon atoms in the cloth are mainly atoms of carbon-12, a different isotope of carbon.

What are **isotopes**?

(2)

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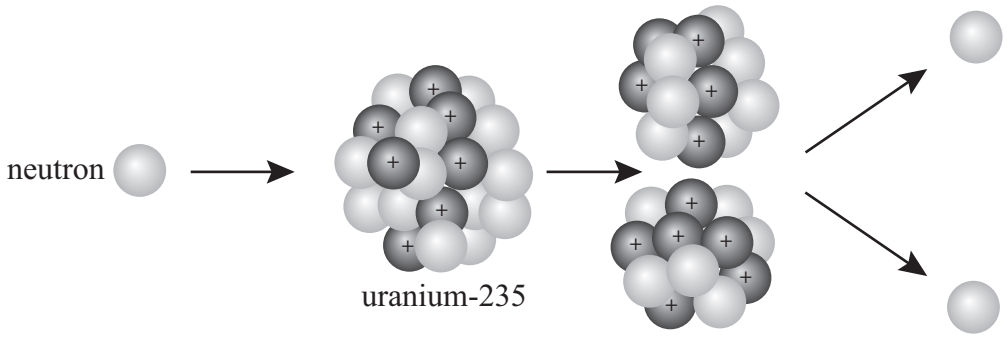
(Total for Question 2 7 marks)

3 The diagram shows a neutron colliding with a nucleus of uranium-235, producing a number of products.



(a) Name the process shown in the diagram.

(1)

(b) Explain how the process shown in the diagram can lead to a chain reaction.

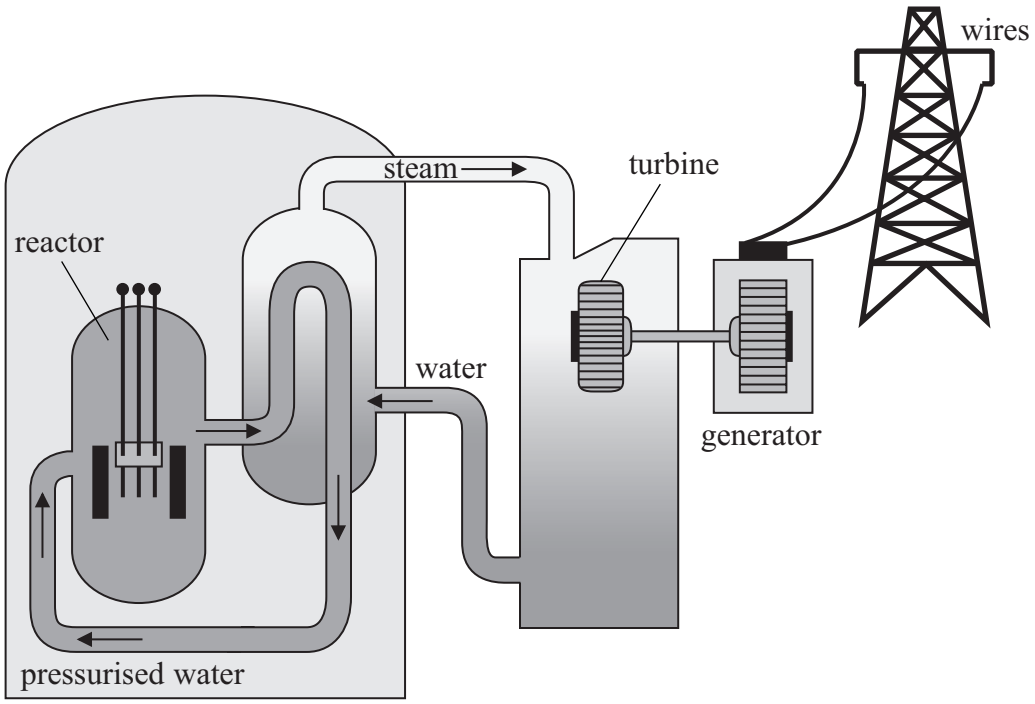
(3)

(c) This process releases energy.

Explain the form that this energy takes.

(2)

(d) The energy released in this process can be used in a nuclear power station.



(i) The pressurised water acts as a coolant. It also acts as a moderator.

What is the purpose of a **moderator**?

(1)

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(ii) Complete the chart below to show the main useful energy transfers in a nuclear power station.

(4)

Heat energy released by reactor	..... energy in water/steam	..... energy in turbine	..... energy in generator	..... energy in wires

(Total for Question 3 11 marks)

4 A teacher shows his class how to investigate the half-life of a radioactive source.

(a) The readings from the counter need to be corrected for background radiation.

(i) State **one** source of background radiation.

(1)

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(ii) Describe the method the teacher should use to correct for background radiation.

(3)

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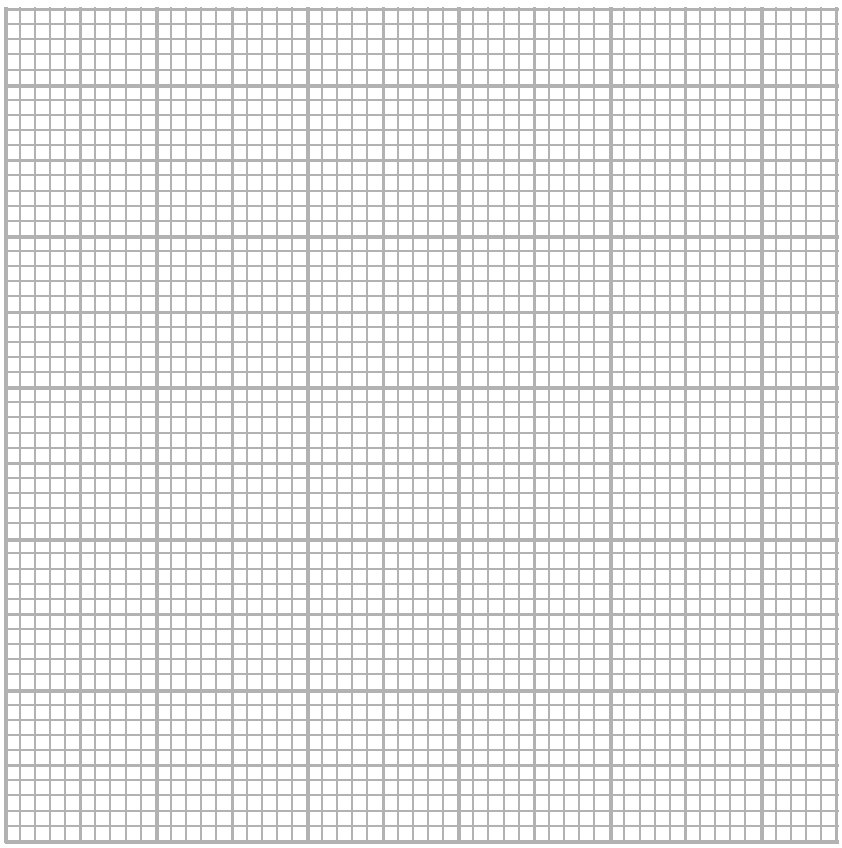
(b) Every half a minute, the teacher records the count rate.

He corrects for background radiation and produces this results table.

Time in minutes	Corrected count rate in Bq
0	49
0.5	30
1.0	24
1.5	18
2.0	15
2.5	11
3.0	10
3.5	9
4.0	5
4.5	6

(i) Draw a graph of corrected count rate against time for these results.

(5)



(ii) Use your graph to estimate the half-life for this material.

(1)

Half-life = ... minutes

(c) The isotope technetium-99 is a gamma emitter with a half-life of 6 hours. It is used as a radioactive tracer in medicine.

The technetium-99 is injected into a patient's bloodstream and carried around the body by the blood. The radiation it emits is detected outside the body.

Explain why technetium-99 is suitable for use as a tracer in this way.

(3)

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(Total for Question 4 = 13 marks)

5 John Leslie was a scientist who investigated heat and thermometers.

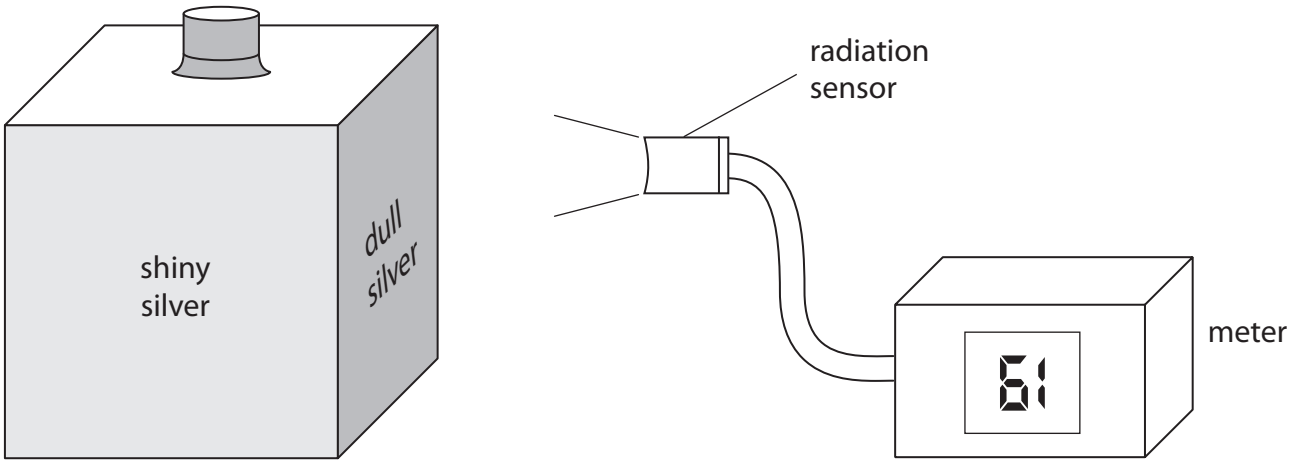
He experimented with a hollow metal cube. The cube had different surfaces on each side and was filled with boiling water.

(a) A student uses a modern version of Leslie's cube to investigate how the surface of a hot object affects the radiation emitted.

She uses a cube with four different vertical surfaces.

She fills the cube with boiling water so that the temperature of each surface is the same.

She uses the radiation sensor to measure the radiation emitted from each surface.



(i) The student's results are shown below.

Draw a line linking each surface colour with its correct meter reading.

One has been done for you.

(2)

surface colour	meter reading
shiny black	87
dull black	61
dull silver	70
shiny silver	47

(ii) The temperature of each surface is the same, but the radiation sensor gives a different reading for each surface.

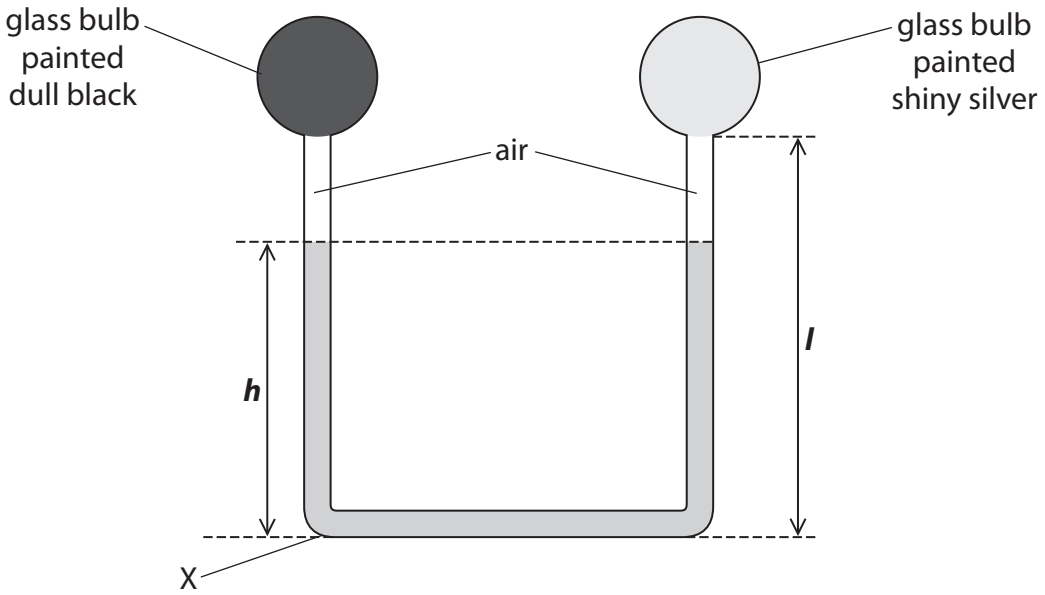
What can you conclude from this?

(1)

(b) John Leslie also invented a differential thermometer.

The diagram shows this thermometer.

The bulbs are filled with air and are connected by a tube which contains liquid.



(i) State the equation linking pressure difference, height, density and *g*.

(1)

(ii) The density of the liquid is 1260 kg/m^3.

Calculate the pressure due to the liquid at X when the height, *h*, of the column of liquid is 0.25 m.

Give the unit.

(3)

pressure = ... unit .....

(iii) The student places the differential thermometer in bright sunlight for a few minutes.

She observes that the liquid level

- falls on the side of the dull black bulb making *h* lower
- rises on the side of the shiny silver bulb

Use ideas about heat transfer and particle theory to explain these observations.

(3)

(iv) Explain what would happen to the levels of the liquid if the student repeated the experiment with a denser liquid in the thermometer.

(2)

(v) Two students discuss the effect of changing the length, *l*, of the tube on both sides, while keeping the total volume of liquid constant.

If the length of the tube is increased, the thermometer can measure higher temperatures.

Changing the length of the tube will not make any difference to the range of temperatures that the thermometer can measure.

Explain which of these ideas is correct.

(2)

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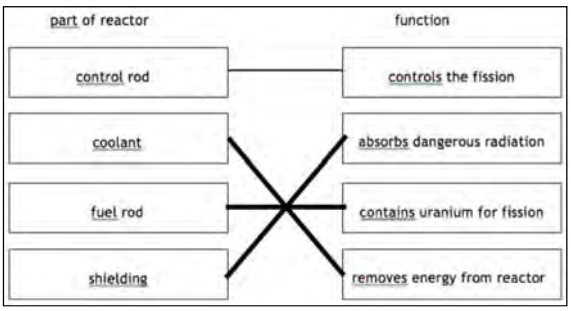
(Total for Question 5 = 14 marks)

Question number	Answer	Notes	Marks
1 (a)	All lines correct = 2 marks Any correct added line = 1 mark  		2
(b)	kinetic energy;		1
(c)	slows neutrons/reduces KE of neutrons; and any one from (which)allows fission to continue; (which) causes (induced) fission; (so) neutrons can be absorbed by uranium;	makes the neutrons thermal/eq ignore moderator absorbs neutrons ignore • neutrons collide with uranium • successful collisions	2
(d)	any three of - MP1 each fission (of a nucleus) caused by a single neutron; MP2 each fission releases more than one neutron; MP3 excess neutrons can speed up the reaction; MP4 (more) fissions release excess energy; MP5 control rods absorb neutrons; MP6 control rods regulate the rate of fission/reaction;	e.g. a nucleus splits when neutron has been absorbed ignore 'block'/ eq allow control rods speed up/slow down rate of fission	3

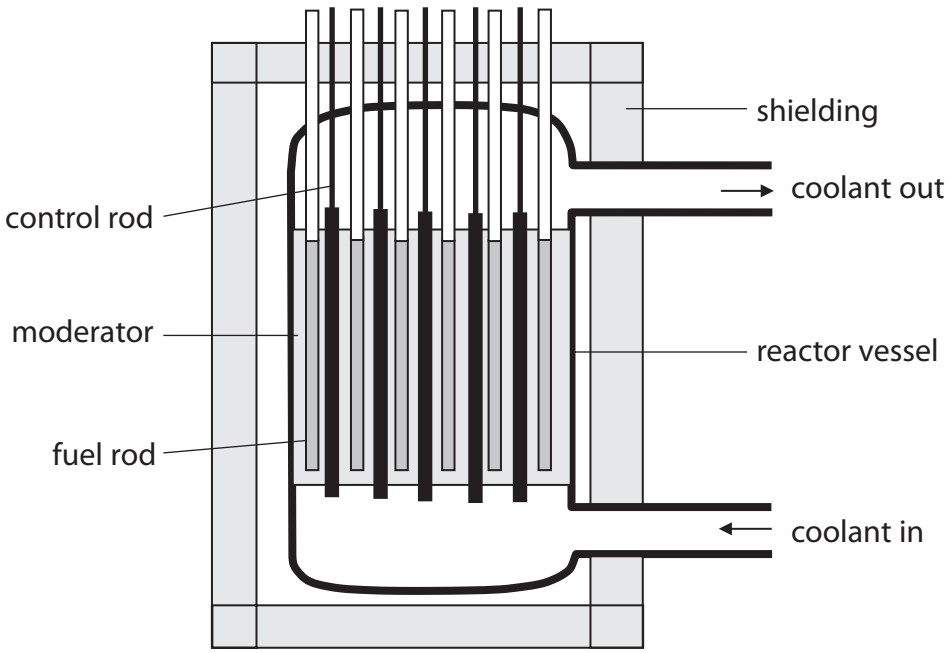
Total 8 marks

Question number	Answer	Notes	Marks
2 (a)	any 3 of: MP1. neutron absorbed by (U) **nucleus**; MP2. (U nucleus) splits; MP3. (producing 2) daughter nuclei; MP4. extra **neutrons** released;	 accept collides with/hits/bombards/eqn for neutron condone breaks up must be plural reject 'daughter cells' for MP3 must be plural	3
(b)	kinetic (energy)	accept phonetic spellings e.g. 'kenetic'	1

Total 4 marks

Question number		Answer	Notes	Marks
3 (a)		A description to include any 5 of MP1 nucleus absorbs neutron OR nucleus hit by neutron; MP2 splits into (two) fragments/parts OR daughter atoms OR daughter nuclei; MP3 extra neutrons released; MP4 (kinetic) energy released; MP5 released neutrons hit further nuclei OR uranium nuclei; MP6 moderator slows down the neutrons/ makes it more likely for a neutron to be absorbed; MP7 control rods absorb extra neutrons; MP8 idea that control rods help prevent a "runaway" chain reaction;	Correct process using consistently incorrect particle instead of neutron (e.g. electron) = max 4 NB uranium, U-235 or nucleus must be mentioned Reject cells, molecules, more uranium Ignore heat allow atoms OR uranium atoms	5
(b)		kinetic/movement energy;		1
(c)		Idea that the shielding **absorbs** radiation / particles / energy;	Allow "stops radiation /particles from escaping" Ignore "radioactvity" escaping	1
			Total	**12**

1 The diagram shows the main parts of a nuclear reactor.



(a) Draw a line linking each part of the reactor with its main function.

The first one has been done for you.

(2)

part of reactor	**main function**
control rod	controls the rate of fission
coolant	absorbs dangerous radiation
fuel rod	contains uranium for fission
shielding	removes energy from the reactor

(b) State the type of energy released in a fission reaction.

(1)

(c) Explain the role of the moderator in a fission reaction.

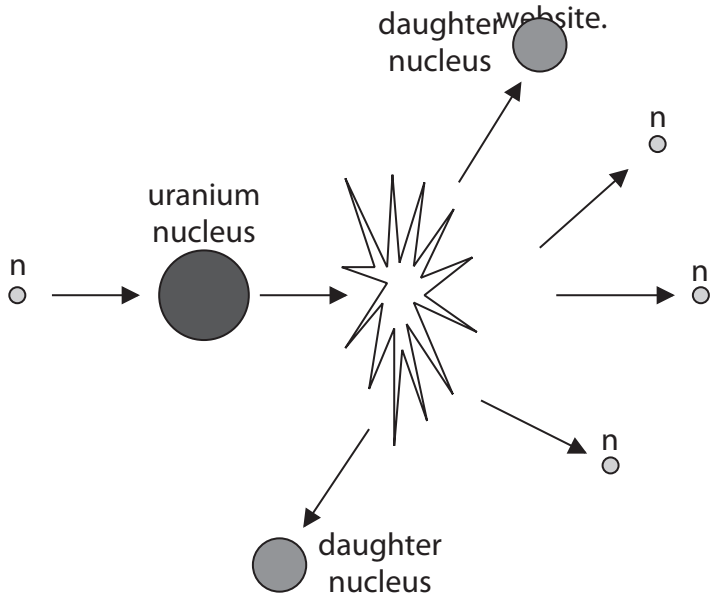
(2)

(d) Explain, in terms of neutrons, what is meant by controlled nuclear fission.

(3)

(Total for Question 1 = 8 marks)

2 A student finds this representation of nuclear fission on a website.



(a) Describe what happens when nuclear fission of uranium occurs.

(3)

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.....

(b) The daughter nuclei move off with high speed.

Name the type of energy that this gives them.

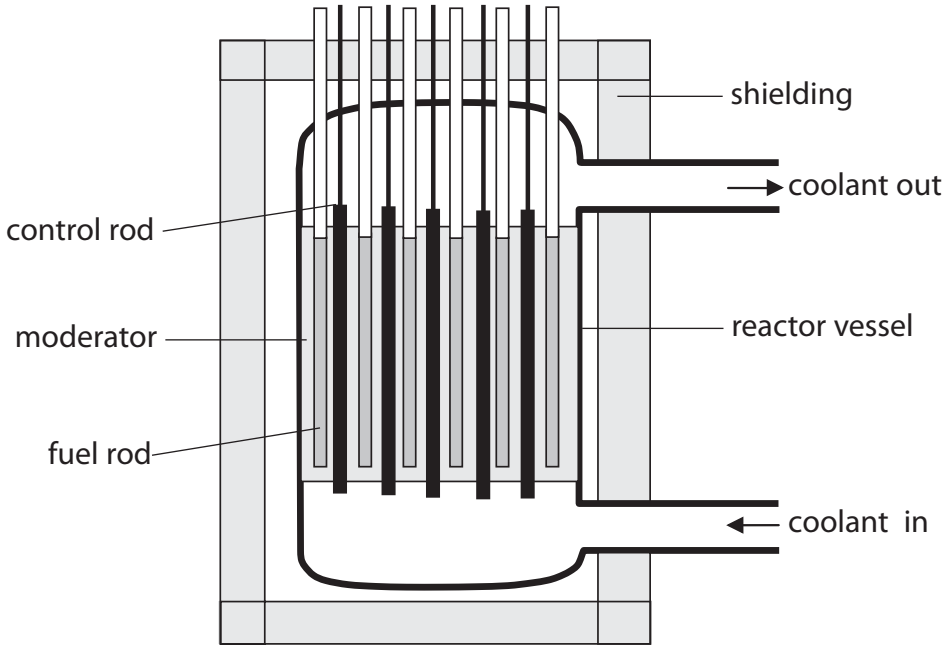
(1)

.....

(Total for Question 2 = 4 Marks)

3 The diagram shows the main parts of a nuclear reactor.

In the nuclear reactor uranium-235 nuclei undergo fission in a controlled chain reaction.



(a) Describe nuclear fission and how the chain reaction is controlled.

Use terms from the diagram to help you.

(5)

(b) State the form of energy that is released during fission.

(1)

.....

(c) How does the shielding improve safety?

(1)

.....

.....

(Total for Question 3 = 7 marks)

Question number	Answer	Notes	Marks
1 (a) (i)	number of protons = 1; number of neutrons = 2;		2
(ii)	any three of the following **comparisons**: MP1. beta particle is negatively charged <u>and</u> alpha is positively charged; MP2. beta particle has lower/less mass ORA; MP3. beta particle has 1 charge but alpha has 2 charges; MP4. beta particle is an electron but alpha is 2p + 2n /eq; MP5. beta is less ionising; MP6. beta has higher speed; MP7. beta particles have larger range; MP8. beta has higher penetrating ability;	ignore descriptions of applications of types of radiation allow 'beta is lighter' ORA allow beta can pass through paper but alpha will be stopped	3
(iii)	any sensible suggestion; e.g. • alpha is 4 nucleons, tritium has (only) 3 / eq • tritium has only 1p, 2p are in alpha • tritium has not got enough mass / mass number too low • tritium has not got enough nucleons • tritium has not got enough p / atomic number too low • tritium has not got enough p+n	ignore tritium is too small	1
(b)	any two from: MP1. energy explanation; e.g. beta particles have given up all their KE on impact MP2. absorption explanation; e.g. beta particles have hit (and been absorbed by) phosphor MP3. penetration explanation; e.g. beta cannot penetrate (thick) glass / tube MP4. range explanation; e.g. signs are further away than the range of beta	ignore: • beta particles have low ionisation /OWTTE • no gas can escape	2

Question number	Answer	Notes	Marks
1 (c) (i)	time taken; and either of • for (radio)activity to **halve**; • for **half** of (radioactive) nuclei / atoms / isotope to decay;	allow how long it takes reject 'half the time' allow count rate for activity reject: • particles • molecules • substance • 'break down' • 'reactivity' • a nucleus / an atom • halve in mass • to completely/fully decay	2
(ii)	working seen/appropriate line(s) on graph seen; 13.5 years;	 tolerance ± 0.5 years	2
(d)	MP1. correct judgment re claim; MP2. (because) EITHER correct statement re time (at which the activity is 400); OR activity (at 20 years); e.g. the manufacturer is correct because the time would be 21.5 years (to reach an activity of 400) OR the manufacturer is correct because the activity is 420 (counts per minute) (at 20 years)	 allow range of 21-22 years allow range of 410 to 440 total marks = 14	2

Question number	Answer	Notes	Marks
2 (a)	A - fission		1
(b)	A - absorbing some of the neutrons		1

Total 2 marks

Question number	Answer	Notes	Marks
3 (a) (i)	A – electromagnetic waves		1
(ii)	time; for amount of (radioactive) isotope to halve; OR for (radio)activity to halve;	accept how long it takes do not accept 'half of the time' accept for 'amount' (number of un-decayed) nuclei / atoms / molecules / (un-decayed) mass of isotope	2
(b)	Any two of - MP1. (α or β) would have insufficient **range**; MP2. (α or β) would be absorbed by patient/air; MP3. (α or β) are more ionising (than gamma rays);	specific concepts and terminology are needed if the source is external max mark is ONE allow ORA **penetration** ORA stopped by skin / bone Allow (α or β) would be (more) likely to cause cancer/ damages cells (than gamma rays), ORA	2
(c) (i)	Any two of - MP1. Idea that activity is due to **nucleus** decaying; MP2. (after some time) fewer radioactive nuclei /atoms left; MP3. Number (of nuclei) decaying per second decreases;	specific concepts and terminology are needed do not credit repeat of stem Reject for 1 mark. (it/nucleus) breaks down allow • nucleus is unstable • nucleus emits gamma • nucleus changes into new isotope fewer atoms of the same isotope left decay rate decreases	2

(ii)	one halving calculated; Idea of four half-lives / halvings; Evaluation; e. (420/2=) 210 for 1 mark 24 ÷ 6 = 4 (half-lives) 26 MBq (26.25)	 • 4 repeated halving seen • fraction remaining is 1/16 of activity Allow • four divisions by 2 seen for 2nd mark • remaining fraction = 1/16 = 0.0625 Correct answer without working scores full marks	3

Total 10 marks

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>4 (a) (i)</td><td>
<table>
<tr><th>safety precaution</th><th>needed</th><th>not needed</th></tr>
<tr><td>not touch the source with bare hands</td><td>(✓)</td><td></td></tr>
<tr><td>use tongs</td><td>✓</td><td></td></tr>
<tr><td>wear gloves</td><td></td><td>(✓)</td></tr>
<tr><td>wear goggles</td><td></td><td>✓</td></tr>
<tr><td>students sit at least two metres away</td><td>✓</td><td></td></tr>
<tr><td>wear a lead apron</td><td></td><td>✓</td></tr>
<tr><td>store source in a lead box</td><td>✓</td><td></td></tr>
</table>
3 ticks correct in first column;

2 ticks correct in second column;
</td><td>Ignore incorrect ticks in first column (award 1 mark as long as the three correct boxes are ticked)</td><td>2</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>(b) (i)</td><td>(because distance is a) controlled variable;</td><td>allow idea of fair test/affecting results

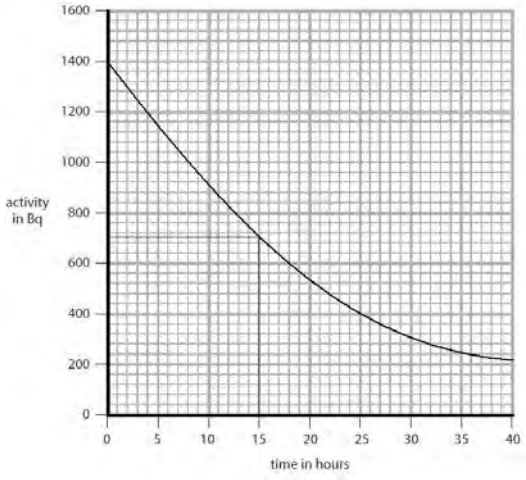
ignore comments relating to accuracy, reliability</td><td>1</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>(ii)</td><td>MP1. idea of background radiation;

MP2. any ONE sensible source;
e.g.
cosmic rays
rocks/Earth/buildings
some foodstuffs (coffee)
radon</td><td>allow ‘sources of radiation all around us’
allow nuclear weapons testing/disasters</td><td>2</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

(iii)	MP1. lead; MP2. idea of best absorber giving lowest count rate; MP3. for Ba-133/can't evaluate using Sr-90 data;	 dependent on MP1 dependent on MP1	3
(iv)	any 3 of: MP1. stone absorbs better than {plastic / wood / paper} for Sr-90/beta; MP2. stone worst absorber for Ba-133/gamma; MP3. use of data to justify MP1 or MP2; MP4. may not be worse absorber than paper as paper much thinner/not tested for Ba-133;	no mark for 'I agree with this conclusion /OWTTE' allow stone best absorber for Sr-90 e.g. the count rate for plastic is about half that of stone for Ba-133	3
(v)	MP1. beta; MP2. it's not alpha *because* {alpha would not reach the detector at this distance/ alpha would not go through paper}; MP3. it's not gamma *because* gamma is not stopped by metals ;	allow 'beta and gamma' allow 'it goes through paper' allow 'it doesn't go through metals' MP2 and MP3 dependent on MP1	3
(vi)	reading would be too high/eq;		1
(vii)	idea that count rate needs to be constant during the investigation/ORA;	allow either idea that would not need to replace the source often/ORA; or idea that shorter half-life has higher activity and therefore is more hazardous;	1

Total 16 marks

Question number	Answer	Notes	Marks
5 a	(Atoms / nuclei with the) same number of protons; Different numbers of neutrons;	ALLOW relevant correct alternatives e.g. • atomic number, proton number • nucleon number, atomic mass ignore comments about electrons	1 1
b i	Electron;	ignore comments about properties of electrons e.g. speed ALLOW • e^- or e^+ • positron	1
ii	any suitable detector e.g. Geiger(-Muller) tube/detector/counter; photographic film; zinc sulfide; gold leaf electroscope;	ALLOW • phonetic/incorrect spelling	1
iii	beta penetrates paper; beta absorbed/stopped by lead +/or aluminium ;	IGNORE • all details of experimental setup • beta goes through aluminium/eq DO NOT ALLOW • bounced back for absorbed • contradictions in answers e.g. re aluminium	1 1

	MP1. line goes through 0,1400 and (first half-life plotted at) 15, 700; MP2. line goes through/second half-life plotted at 30, 350; MP3. a correctly **curved line** between 15 and 30 hours AND the line extends beyond 35 hours; i.e.  	ALLOW for MP2 an ecf from incorrect first half-life to 'correct' second half-life e.g. 800---400 IGNORE • a *slight* upcurve at 35 to 40 hours • Bar charts • **Since this is a sketch then allow tolerance of + / - 1 square on the points**	1 1 1

Question number	Answer	Notes	Marks
d i	any FOUR from: MP1. there is a known proportion / composition / activity when rocks formed; MP2. measure/determine the proportion of uranium or the activity now; MP3. compare activity now to original activity/eq; MP4. (hence) determine the time / number of half-lives elapsed; MP5. (hence) calculate age from reference to half-life;	allow as a numerical example ignore work out the proportion when rocks were formed ALLOW • Bq for activity • radioactivity for activity • amount for proportion IGNORE • measure half-life of uranium • they know its activity ALLOW colloquial expressions such as 'see how long it took to decay this much'	1 1 1 1

ii	MP1. idea that it/half-life is **too** short OR idea that decay occurs **too** quickly/rapidly; PLUS MP2. (hence) **U / isotope** would (all) have decayed (long ago) OR **U activity** would be too small (to distinguish from background / to measure);	comparative of some sort needed for MP1 allow not enough time care that you do not award both alternatives for MP2 IGNORE granite decays it decays	1 1

(Total for Question 5 = 15 marks)

1 Tritium is an isotope of hydrogen that decays by emitting beta particles.

It is used in some luminous signs.

(a) (i) The symbol for tritium is $^{3}_{1}H$.

Determine the number of protons and the number of neutrons in a single atom of tritium.

(2)

number of protons .....

number of neutrons .....

(ii) Describe three differences between an alpha particle and a beta particle.

(3)

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(iii) Suggest why tritium cannot emit alpha particles.

(1)

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.....

(b) Tritium is used in this luminous sign.

In this sign

- the letters are made up of glass tubes containing tritium gas
- the inside of each tube is coated with a phosphor
- the phosphor emits light when beta particles hit it

Suggest why this sign is safe to use even though beta particles are ionising and can be dangerous.

(2)

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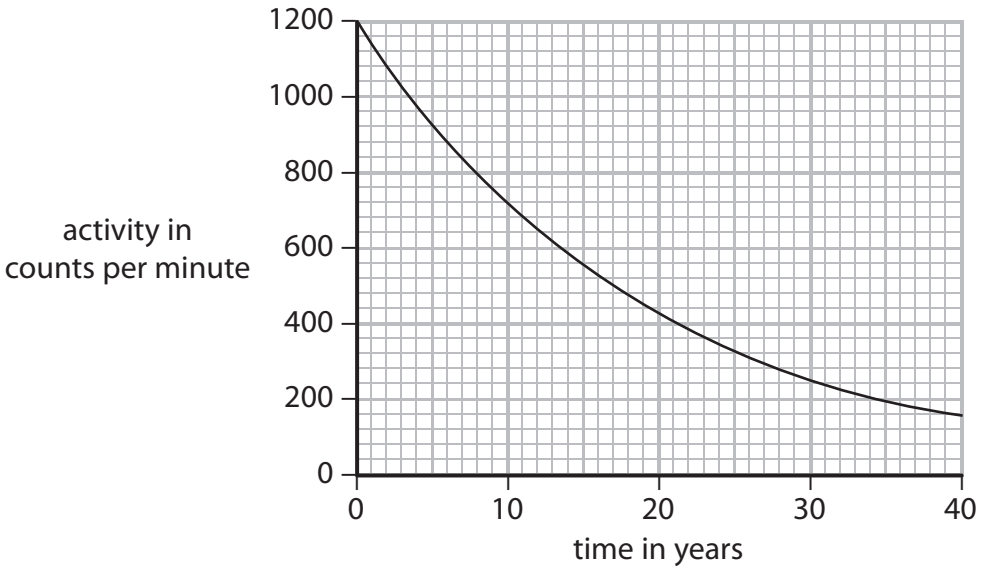
(c) The graph shows how the activity of tritium in this luminous sign varies with time.



(i) Explain what is meant by the term **half-life**.

(2)

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.....

(ii) Use the graph to estimate the half-life of tritium.

Show your working.

(2)

half-life = ... years

(d) The manufacturer of this luminous sign claims that the sign will work for more than 20 years.

The minimum activity required for the tubes to emit sufficient light is 400 counts per minute.

Evaluate the manufacturer's claim.

(2)

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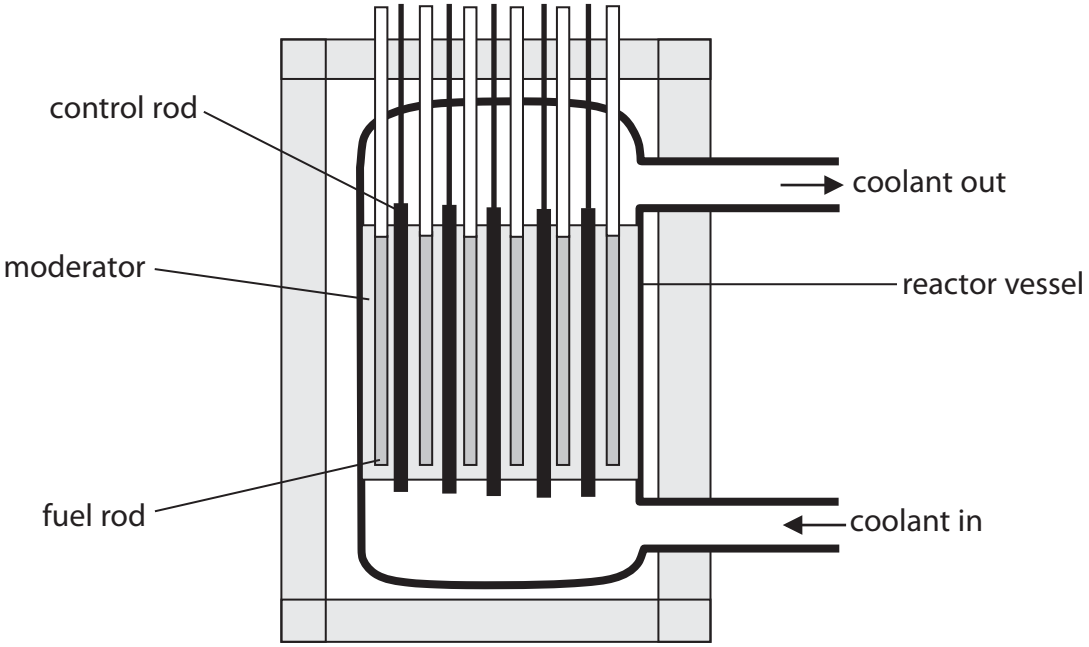
(Total for Question 1 = 14 marks)

2 The diagram shows a nuclear reactor.



(a) A uranium nucleus in the fuel rod may split when a neutron hits it.

This process of splitting is known as

(1)

☒ **A** fission

☒ **B** moderation

☒ **C** reflection

☒ **D** refraction

(b) The control rods control the reaction by

(1)

☒ **A** absorbing some of the neutrons

☒ **B** cooling the reactor vessel

☒ **C** removing uranium nuclei from the reaction

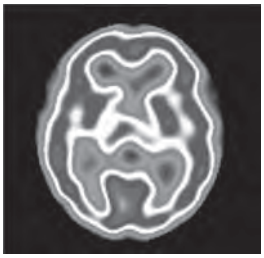
☒ **D** slowing the neutrons slightly

(Total for Question 2 = 2 marks)

3 A doctor uses gamma radiation to produce an image of a person's brain.

A radioactive isotope called technetium-99m is used in this process.

Technetium-99m emits gamma rays and has a short half-life.



(a) (i) Gamma radiation consists of

(1)

☒ **A** electromagnetic waves

☒ **B** negatively charged particles

☒ **C** positively charged particles

☒ **D** unstable atoms

(ii) What is meant by the term **half-life**?

(2)

.....

.....

.....

.....

(b) The doctor injects a solution of technetium-99m into the patient.

A detector outside the patient receives gamma radiation to form the image.

Suggest why isotopes that emit alpha particles or beta particles are not suitable for this use.

(2)

.....

.....

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.....

(c) Technetium-99m has a half-life of 6 hours.

A sample of technetium-99m has an activity of 420 MBq.

(i) Explain why the activity of a radioactive sample reduces with time.

(2)

.....

.....

.....

.....

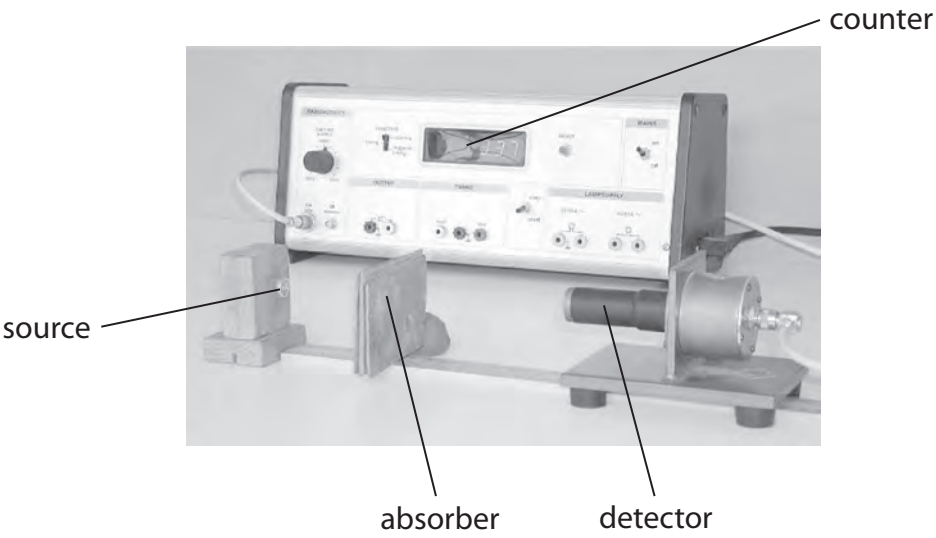
(ii) Calculate the activity of the technetium-99m sample after 24 hours.

(3)

activity = ... MBq

(Total for Question 3 = 10 marks)

4 A teacher uses this apparatus to demonstrate radioactivity to his students.



(a) The teacher needs to take some safety precautions.

Put one tick (✓) on each row to show whether the safety precaution is needed or not.

Two have been done for you.

(2)

safety precaution	needed	not needed
not touch the source with bare hands	✓	
use tongs		
wear gloves		✓
wear goggles		
students sit at least two metres away		
wear a lead apron		
store source in a lead box		

(b) The teacher uses this method to investigate radioactivity.

- place the detector 10 cm from the radioactive source
- record the count with different absorbent materials between the source and the detector
- repeat the investigation using a different radioactive source
- also repeat the investigation without a source

The table shows his results.

Source used	Counts in 30 s for each material					
	5 mm of aluminium	5 mm of lead	0.2 mm of paper	5 mm of plastic	5 mm of stone	5 mm of wood
barium-133	3 843	1 989	not taken	4 551	10 408	4 557
strontium-90	14	15	42 770	182	13	331
none	15	15	14	15	14	15

(i) State why the teacher keeps the distance constant between the source and the detector.

(1)

.....

.....

(ii) Explain why there is a reading when no source is used.

(2)

.....

.....

.....

.....

(iii) Explain which of the materials the teacher used is the best absorber of radiation.

(3)

(iv) A student makes this conclusion.

'Stone is the worst absorber of radiation.'

Evaluate this conclusion.

(3)

(v) Explain what type of radiation strontium-90 emits.

(3)

(vi) Suggest why the teacher does not take a reading for barium-133 and paper.

(1)

(vii) Barium-133 and strontium-90 both have a half-life of over 10 years.

Suggest why isotopes with a much shorter half-life are not suitable for this investigation.

(1)

(Total for Question 4 = 16 marks)

5 Sodium-24 is a radioactive isotope.

(a) What are isotopes?

(2)

.....

.....

.....

.....

(b) Sodium-24 decays by emitting beta particles.

(i) Describe the nature of a beta particle.

(1)

.....

(ii) Name a piece of equipment that can be used to detect beta particles.

(1)

.....

(iii) Describe how a detector can be used with sheets of lead, aluminium and paper to show that a sample of sodium-24 emits beta particles.

(2)

.....

.....

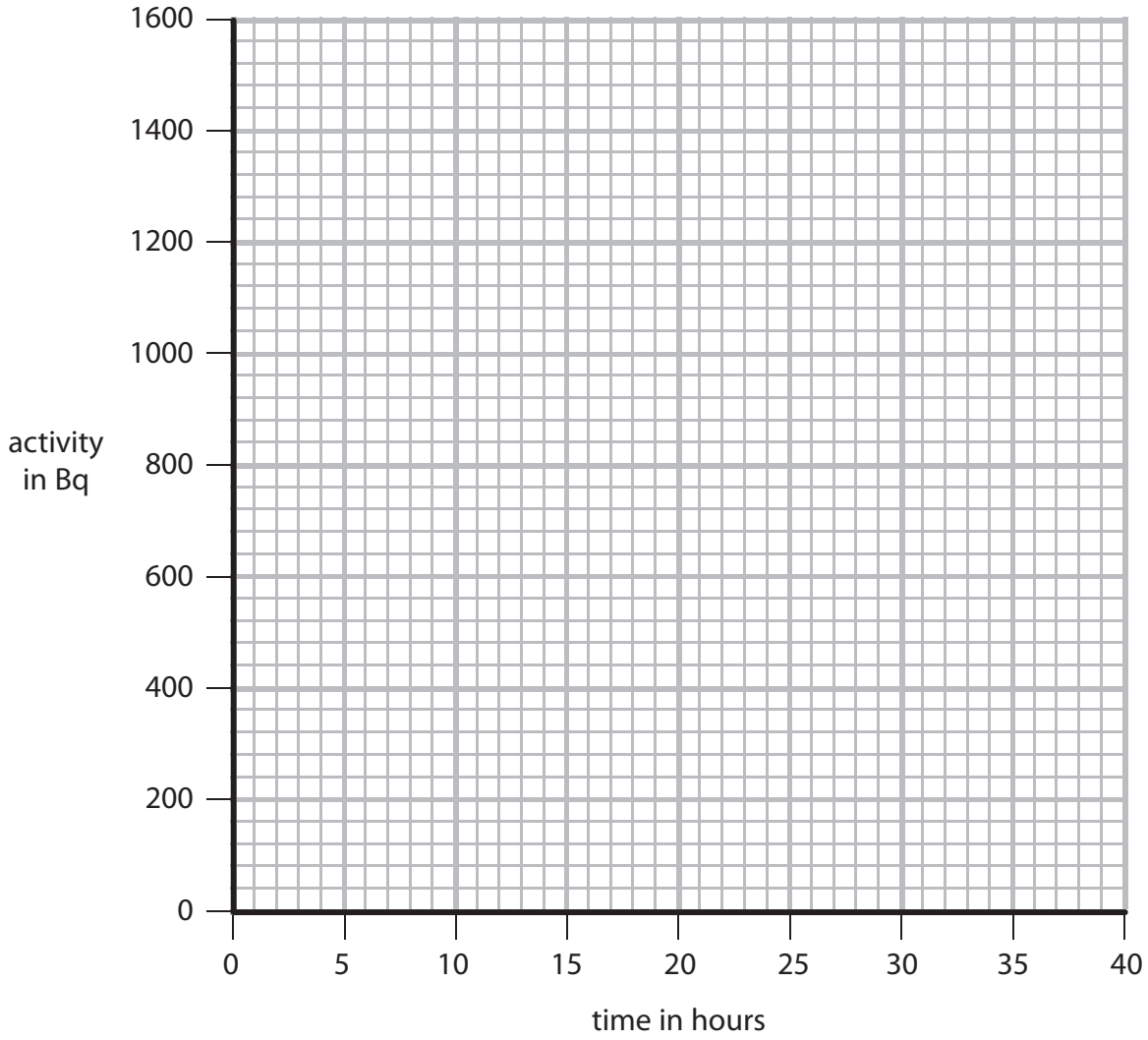
.....

.....

(c) A sample of sodium-24 has an activity of 1400 Bq.

On the axes, sketch a graph to show how the activity of this sample changes over the next 40 hours.
(the half-life of sodium-24 is 15 hours)

(3)



(d) Granite is a rock.

It contains a radioactive isotope of uranium that decays very slowly.

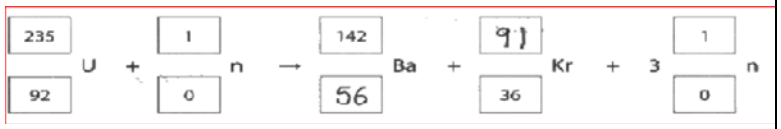
(i) Explain how scientists can use this radioactivity to find the age of a piece of granite.

(4)

(ii) Suggest why the age of a piece of granite could **not** be found using a uranium isotope with a half-life of 15 hours.

(2)

(Total for Question 5 = 15 marks)

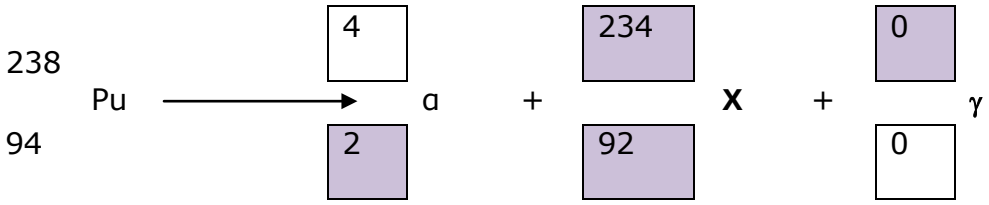
Question number	Answer	Notes	Marks
1 a	91; 56;  		1 1
b	Three FROM – MP1. Neutrons released; MP2. neutrons slowed by moderator; MP3. Can be absorbed by **other** (U) **nuclei**; MP4. Causing further fissions;	ignore comments about control rods collide or react for absorb if MP3 or 4 or both not given then award 1 mark for a description of a first absorption	3
c i	Correct labels for – Control rods; Shielding;	Accept • lines with or without arrow heads (in either direction) • any part of control rod (black in diagram) • any part of external box for shielding	1 1 2

ii	Two from: MP1. Reactor material / waste is **radioactive**; MP2. (radiation) ionises cells/ tissues / organs / body or causes cancer; MP3. radiation is very penetrating;	allow damages for ionises NOT ALLOW bald 'it is dangerous' do not award marks for 'shielding prevents escape of radiation'/eq	

(Total for Question 1 = 9 marks)

Question number	Answer	Notes	Marks
2 (a)	D americium-238;		1
(b) (i)	either order: uranium -234, uranium-235;	accept symbols but not just the numbers	1
(ii)	either order: plutonium-238, americium-238	accept symbols	1
(iii)	either order: uranium-235, americium-238	accept symbols	1
(c) (i)	will decay/ emit radioactive particles (or gamma);	allow named particles 'they are radioactive' 'they emit radioactivity'	3

(ii)	time taken; and either • For **half** of (radioactive) nuclei / atoms /isotope to decay; OR • For (radio)activity to halve;	allow how long it takes Ignore particles /molecules 'break down' 'reactivity' **Reject** for ONE mark ideas of • half of a time • half a nucleus/ an atom • complete decay	

Question number	Answer	Notes	Marks
(d) (i)	 one mark for alpha correct; one mark for gamma correct; one line for **balancing** the top line; NB ECF from alpha and or gamma one mark for **balancing** the bottom line; NB ECF from alpha and or gamma		4
(ii)	Uranium;		1
(e) (i)	proton number / atomic number decreases by 1; nucleon number /mass number remains unchanged (as p and n have same mass);		2
(ii)	plutonium -238;	condone plutonium without nucleon number	1

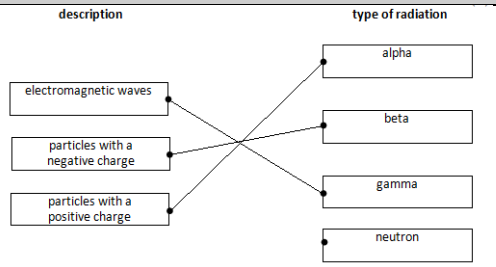
(Total for Question 2 = 15 marks)

Question number	Answer	Notes	Marks
3 (a) i	(Nuclei / atoms) with same number of protons OR same atomic number; different number of neutrons OR different mass number;	Ignore electrons Allow "(nuclei) of the same element" Allow different number of nucleons	2
ii	(stable isotopes) do not emit (ionising) radiation OR (stable isotopes) do not emit alpha, beta and gamma radiation ;	Ignore "radioactive", "decay" ignore idea of remaining the same element for ever	1
(b) i	210 – 84 OR 126		1
ii	ideas that proton number increases by 1; neutron number decreases by 1;	allow a calculation / nuclear equation Ignore discussion of "number of nucleons"	2
iii	beta decay	allow β **or** β^- **or** β^+	1
(c)	Any two of idea that gamma is not a particle; e.g. gamma rays have no (rest) mass gamma rays do not have a proton number gamma rays do not contain any protons or neutrons gamma rays are electromagnetic radiation OR energy; no particles are lost (from the nucleus) when a gamma ray is emitted;	Allow photons	2
		Total	**9**

Question number	Answer	Notes	Marks
4 (a)	A (background radiation)		1
(b)	Any TWO of 1. Range / penetration of alpha radiation is low; 2. R on (is a gas so) particles /atoms mobile OR americium (solid so) particles / atoms stay in place; 3. R on can be inhaled / damage internal tissue OR radiation from americium stays within smoke detector / absorbed by the plastic;	WTTE throughout this part ACCEPT 'cannot penetrate skin' / 'travel a few cm in air' ACCEPT 'all around us', 'more likely to come into contact', ACCEPT 'contained', 'stays in detector' ACCEPT 'can be breathed in', 'can get inside body', 'can damage (internal) cells /organs' ACCEPT 'high up', 'far from people'	2
(c) (i)	A (86)		1
(ii)	B (134)		1
(d) (i)	Bq / becquerel(s);	ACCEPT approximate / phonetic spellings of becquerel / Becquerel / bekerel REJECT B, BQ, bQ, bq	1

Question number	Answer	Notes	Marks
(ii)	Time for halving / time for 50% decrease; of the (radio)activity / no of (radioactive) atoms / no of (radioactive) nuclei /emissions;	ACCEPT Number of radon-220 nuclei IGNORE references to 'mass'	2
(iii)	55±4 (s);;	Answer in tolerance, but without obvious working gain full marks IGNORE misread from graph if answer within tolerance If final value missing or outside tolerance, look for evidence of using graph correctly for one mark e.g. appropriate use of activity axis such as lines across at 600 Bq and 300 Bq. or single line across at 350 Bq)	2

Total 10 Marks

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>5 (a)</td><td> 

positive charge to alpha;
negative charge to beta;
electromagnetic waves to gamma;</td><td>One mark for each correct line
Minus one mark for two lines from any one box on the left</td><td>(3)</td></tr>
<tr><td>(b) (i)</td><td>in this order only:
gamma, beta, alpha;</td><td></td><td>(1)</td></tr>
<tr><td>(ii)</td><td>any two from:
can damage cells;
can cause mutation;
can cause cancer;</td><td>allow
kill cells/tissues
radiation burns
radiation poisoning
change genes</td><td>(2)</td></tr>
<tr><td>(c)</td><td><table>
<tr><th></th><th>0.1 cm paper</th><th>0.5 cm aluminium</th><th>0.5 cm lead</th></tr>
<tr><td>alpha radiation</td><td>stopped</td><td>stopped</td><td>stopped</td></tr>
<tr><td>beta radiation</td><td>goes through</td><td>stopped</td><td>stopped</td></tr>
<tr><td>gamma radiation</td><td>goes through</td><td>goes through</td><td>goes through</td></tr>
</table>
Each row correct for 1 mark;;;</td><td></td><td>(3)</td></tr>
<tr><td>(d)</td><td>any suitable device
e.g.
(thin window) GM tube;
cloud chamber;
spark chamber;
semiconductor detector;</td><td>accept spelling mistakes
Geiger counter
NB do not accept repeat of stem (film badge or photographic film)</td><td>(1)</td></tr>
</table>

Total for Question 5 = 10 marks

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>6 (a)</td><td>3 or 4 ticks correct;;
OR
2 ticks correct;

<table><tr><td rowspan="2">Property</td><td colspan="3">Type of radiation</td></tr><tr><td>Alpha particles</td><td>Beta particles</td><td>Gamma rays</td></tr><tr><td>most ionising</td><td>(✓)</td><td></td><td></td></tr><tr><td>largest mass</td><td>✓</td><td></td><td></td></tr><tr><td>most penetrating</td><td></td><td></td><td>✓</td></tr><tr><td>highest speed</td><td></td><td></td><td>✓</td></tr><tr><td>negatively charged</td><td></td><td>✓</td><td></td></tr></table></td><td>ignore top line as this is given</td><td>2</td></tr>
<tr><td>(b) (i)</td><td>Number of neutrons = 2;
Number of protons 2;</td><td>Allow same ideas expressed in words</td><td>2</td></tr>
<tr><td>(ii)</td><td>Any one of-
MP1. Charge is larger (than other radiations);
MP2. Mass is larger (than other radiations);</td><td>comparative statement needed
ignore
• incorrect terminology e.g. more powerful
• references to protons and neutrons
no RA unless particles/radiation specified
condone
‘alpha particles have more momentum’</td><td>1</td></tr>
<tr><td>(c) (i)</td><td>Idea of background radiation;</td><td>Allow
Idea that some alpha particles (from source) will get through smoke
air is all around = insufficient</td><td>1</td></tr>
<tr><td>(ii)</td><td>Idea that radioactivity is random;</td><td>allow
• fluctuates
• source emits different numbers of alphas
• background radiation varies
ignore
• random movement of particles</td><td>1</td></tr>
<tr><td>(iii)</td><td>Idea that α particles are absorbed / deflected /stopped / scattered;

Idea that α particles are affected by <u>smoke</u>;</td><td>allow for both marks
smoke blocks the (alpha) particles</td><td>2</td></tr>
</table>

Total 9 marks

1 In a nuclear reactor, a uranium-235 nucleus absorbs a neutron and fission occurs.

(a) Complete the equation below that shows a typical fission reaction.

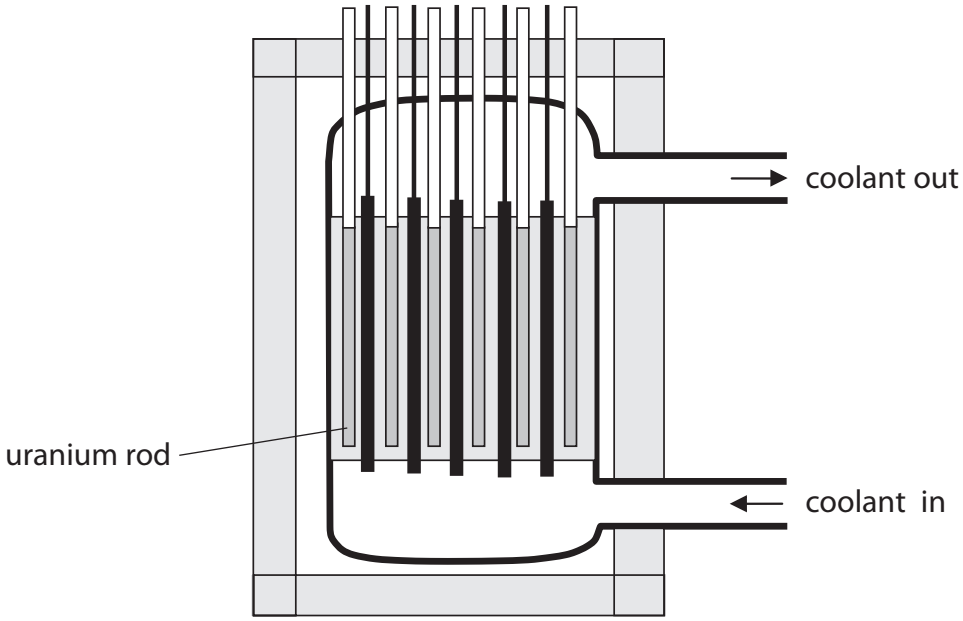
(2)

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{142}_{\ \ }\text{Ba} + ^{\ \ }_{36}\text{Kr} + 3\,^{1}_{0}\text{n}$$

(b) Explain how nuclear fission can lead to a chain reaction.

(3)

(c) The diagram shows a nuclear reactor.



(i) On the diagram, label the control rods and the shielding.

(2)

(ii) Explain why the shielding is needed.

(2)

.....

.....

.....

.....

.....

.....

(Total for Question 1 = 9 marks)

2 The table describes the nuclei of four atoms.

uranium-234	uranium-235	plutonium-238	americium-238
$^{234}_{92}U$	$^{235}_{92}U$	$^{238}_{94}Pu$	$^{238}_{95}Am$

(a) Atoms contain electrons.

Which nucleus needs the largest number of electrons to form a neutral atom?

(1)

☒ **A** uranium-234

☒ **B** uranium-235

☒ **C** plutonium-238

☒ **D** americium-238

(b) (i) Which two nuclei have the same number of protons?

(1)

..... and .....

(ii) Which two nuclei have the same number of nucleons?

(1)

..... and .....

(iii) Which two nuclei have the same number of neutrons?

(1)

..... and .....

(c) All of the nuclei are unstable and have a different half-life.

(i) Explain what is meant by the term **unstable**.

(1)

.....

.....

(ii) Explain what is meant by the term **half-life**.

(2)

.....

.....

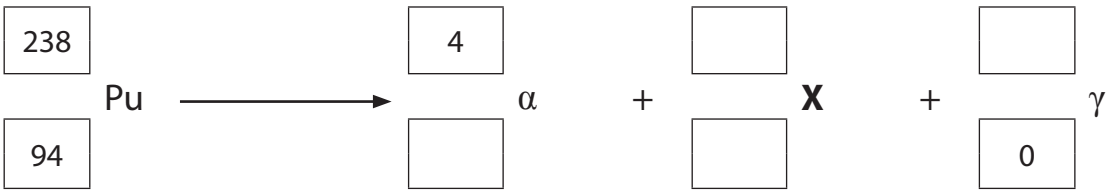
.....

.....

(d) When plutonium decays, it emits an alpha particle and a gamma ray.

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

(4)



(ii) Use information from the table to identify element X.

(1)

element X = ...

(e) The nucleus of americium-238 can absorb an electron.

When this happens, one of the protons in the nucleus becomes a neutron.

This equation describes the process.

$$\begin{array}{ccccc} 1 & & 0 & & 1 \\ p & + & e & \longrightarrow & n \\ 1 & & -1 & & 0 \end{array}$$

(i) Describe how this process affects the proton number and the nucleon number of the nucleus that absorbs the electron.

(2)

.....

.....

.....

.....

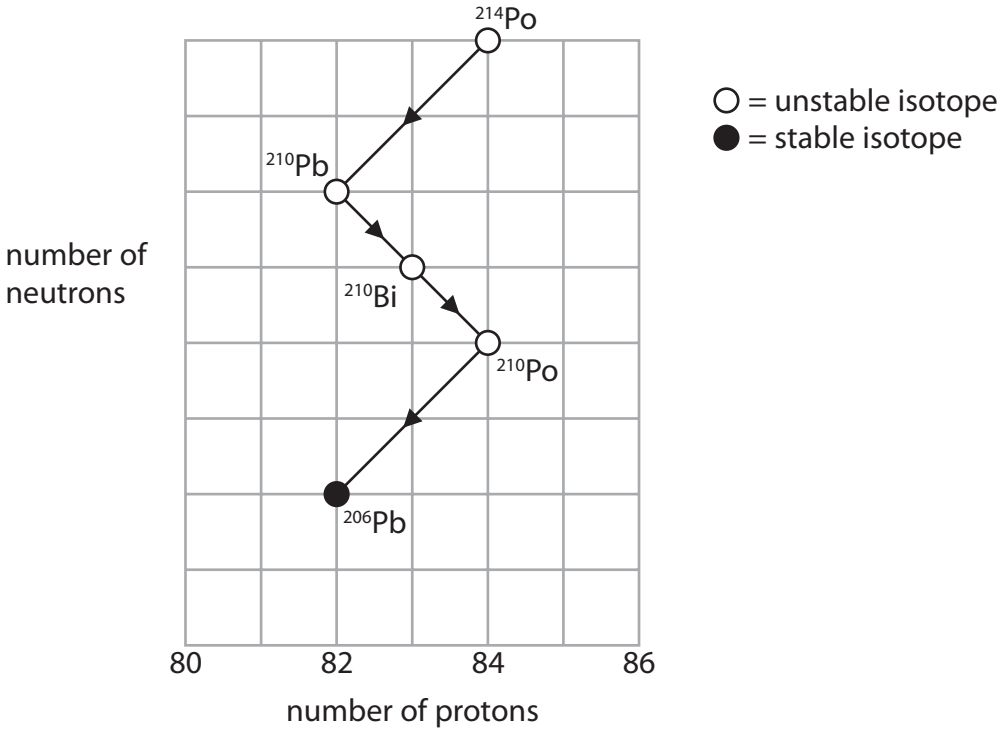
(ii) Identify the new nucleus formed by this process.

(1)

.....

(Total for Question 2 = 15 marks)

3 The grid shows the number of neutrons and the number of protons in some isotopes formed during successive radioactive decays.



(a) (i) What are **isotopes**?

(2)

.....

.....

.....

.....

(ii) Why are some isotopes described as **stable**?

(1)

.....

.....

(b) (i) Use the grid to **calculate** the number of neutrons in a ^{210}Po nucleus.

(1)

number of neutrons = ...

(ii) Describe what happens to the number of protons and the number of neutrons when a nucleus of ^{210}Pb decays to form ^{210}Bi.

(2)

.....

.....

.....

.....

(iii) State the type of decay that occurs when ^{210}Pb decays to form ^{210}Bi.

(1)

.....

(c) Explain why the mass (nucleon) number and the atomic (proton) number do not change when a gamma ray is emitted from a nucleus.

(2)

.....

.....

.....

.....

(Total for Question 3 = 9 marks)

4 Radon is a gas produced by some types of rocks.

(a) Radon is a natural source of radioactivity.

What is the name for this radioactivity?

(1)

- ☒ **A** background radiation
- ☒ **B** chain reaction
- ☒ **C** radioactive dating
- ☒ **D** radiotherapy

(b) There are two sources of alpha radiation in some houses:

- radon gas in the air
- solid americium in a smoke alarm

The alpha particles from radon are a greater risk to health than the alpha particles from americium.

Explain why.

(2)

.....

.....

.....

.....

.....

(c) Radon-222 and radon-220 are both isotopes of radon.

(i) A nucleus of radon-222 has 86 protons.

How many protons are there in a nucleus of radon-220?

(1)

- ☒ **A** 86
- ☒ **B** less than 86
- ☒ **C** more than 86
- ☒ **D** none

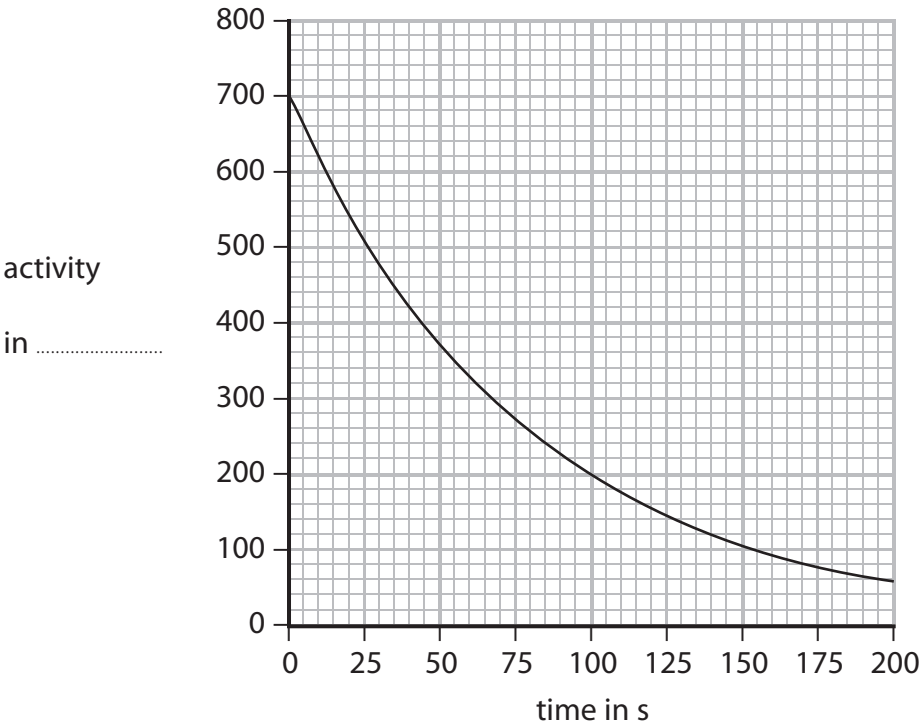
(ii) A nucleus of radon-222 has 136 neutrons.

How many neutrons are there in a nucleus of radon-220 ?

(1)

- ☒ **A** 86
- ☒ **B** 134
- ☒ **C** 136
- ☒ **D** 220

(d) The graph shows how the activity of a sample of radon-220 changes with time.



(i) Complete the graph by adding the missing unit for activity.

(1)

(ii) Explain what is meant by the term **half-life**.

(2)

.....

.....

.....

(iii) Use the graph to find a value for the half-life of radon-220.

(2)

Half-life = ... s

(Total for Question 4 = 10 marks)

5 Scientists use the term radiation in different ways.

Sometimes radiation means streams of particles and sometimes radiation means high frequency waves.

(a) Draw a straight line from each description to the type of radiation it describes.

(3)

description	**type of radiation**
electromagnetic waves	alpha
particles with a negative charge	beta
particles with a positive charge	gamma
	neutron

(b) Alpha, beta and gamma radiations are described as ionising.

(i) Complete the table to show alpha, beta and gamma radiations in order of increasing ionisation.

(1)

least ionising → most ionising

(ii) Describe two ways in which these ionising radiations can cause harm.

(2)

1. .....

.....

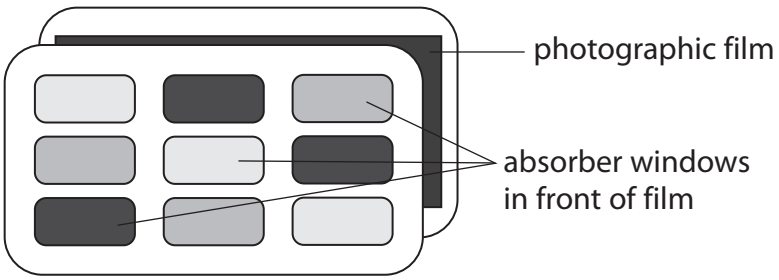
2. .....

.....

(c) People who work with ionising radiations need to measure the amount of radiation they are exposed to.

For many years, a film badge was used to detect the radiations.

The diagram shows how a film badge is constructed.



Each absorber window is made from different thicknesses of paper, aluminium or lead.

Complete the table to show if alpha, beta and gamma radiations penetrate each material. Some have been done for you.

Use the words 'goes through' or 'stopped'.

(3)

	0.1 cm paper	**0.5 cm aluminium**	**0.5 cm lead**
alpha radiation			stopped
beta radiation		stopped	
gamma radiation	goes through		

(d) State the name of another device that can be used to detect alpha radiation.

(1)

.....

(Total for Question 5 = 10 marks)

6 Alpha particles, beta particles and gamma rays have different properties.

(a) Complete the table by ticking the correct type of radiation for each property.

The first one has been done for you.

(2)

Property	Type of radiation		
	alpha particles	**beta particles**	**gamma rays**
most ionising	✓		
largest mass			
most penetrating			
highest speed			
negatively charged			

(b) The symbol for the structure of an alpha particle is

$$^{4}_{2}\alpha$$

(i) State the number of neutrons and the number of protons in an alpha particle.

(2)

number of neutrons.....

number of protons.....

(ii) Suggest why alpha radiation is more ionising than beta or gamma radiation.

(1)

.....

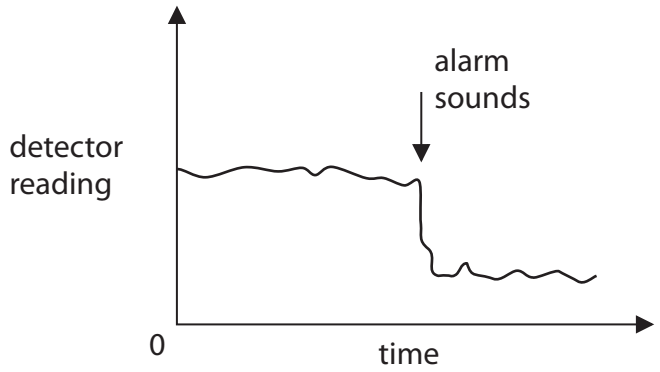
.....

(c) A smoke alarm contains a source of alpha particles and a detector.

The alpha particles reach the detector through a sample of air from the room.

The alarm sounds if there is a sudden drop in the detector reading.

This graph shows changes in the detector reading.



(i) Why is the detector reading never zero?

(1)

.....

.....

(ii) Why is the detector reading never constant?

(1)

.....

.....

(iii) Suggest why fewer alpha particles reach the detector if there is a fire.

(2)

.....

.....

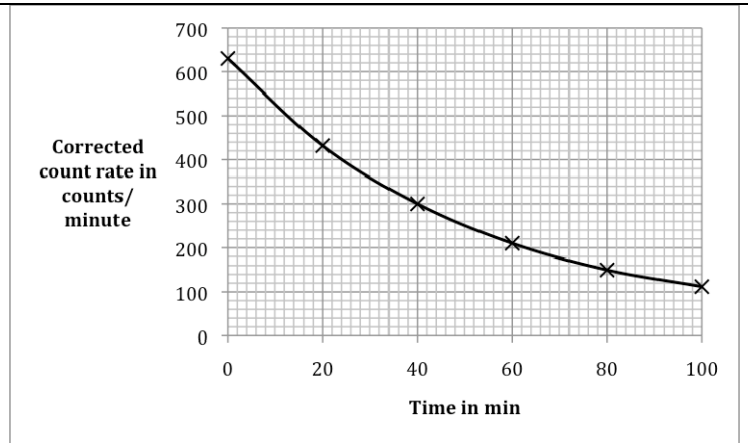
.....

.....

(Total for Question 6 = 9 marks)

Question number			Answer	Notes	Marks
1	(a)	(i)	Any **two** sources: MP1. radiation from rocks/buildings/radon gas; MP2. cosmic radiation / radiation from the Sun / stars; MP3. radiation from medical sources; MP4. nuclear waste / accidents; MP5. some foods e.g. coffee, bananas;	 Ignore : cosmic <u>microwave</u> (background) radiation /<u>cmbr</u> allow named radioactive isotopes accept fire / smoke detector	2
		(ii)	Any three of MP1. Remove the radioactive source; MP2. Measure the (background) count rate; MP3. Repeat the measurement / measure for a long time; MP4. Background radiation is 30 (counts per minute); MP5. Subtract this value from (each) reading(s);	Accept standard abbreviations e.g. cpm Allow for 2 marks: measure the count rate without the source	3

<table>
<tr><th colspan="3">Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>1</td><td>(a)</td><td>(iii)</td><td>scale; at least half the paper
axes labelled including units;
Plotting to nearest sm sq;;
Best fit line to include at least 5 points;</td><td rowspan="2">-1 each plotting error, minimum 0 for plotting

<table><tr><th>Time in min</th><th>Corrected count rate in counts/minute</th></tr><tr><td>0</td><td>30</td></tr><tr><td>20</td><td>432</td></tr><tr><td>40</td><td>300</td></tr><tr><td>60</td><td>210</td></tr><tr><td>80</td><td>150</td></tr><tr><td>100</td><td>12</td></tr></table></td><td></td></tr>
<tr><td></td><td></td><td></td><td> 
</td><td></td></tr>
<tr><td></td><td></td><td>(iv)</td><td>Evidence of correct graph use;
Correct value;</td><td>Allowed range is 35-42</td><td>2</td></tr>
</table>

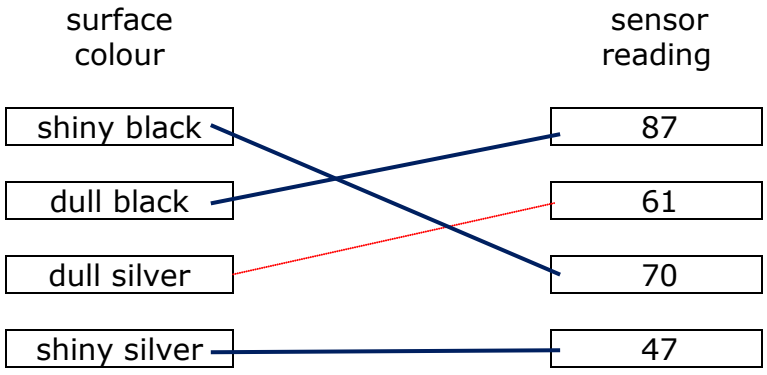
Question number			Answer	Notes	Marks
1	(b)		**correct statement about a neutron;** e. neutron changes neutron number decreases by 1 **correct statement about a proton / atomic / number of positive charges in nucleus;** e. (neutron changes) into a proton proton number increases by 1 number of positive charges increases by 1	ignore : 'it becomes unstable' Accept answers in terms of quarks (down to up) or anti-neutrinos allow for 1 mark if no other mark gained: nucleus becomes another/new element it loses energy nucleus recoils reject: all implication that nucleus becomes ionised	2
	(c)	(i)	MP1. (they emit) ionising radiation; plus any one of - MP2. Cannot be seen; MP3. Can damage/harm cells; MP4. Can cause tumours / cancer;		2
		(ii)	Any three suitable, e.g. MP1. Reduce exposure time; MP2. Handle with tongs/use robotic handling/keep at distance /eq; MP3. Use shielding / work in fume cupboard /eq MP4. Wear film badge / monitor;	NB reduction of risks when WORKING with sources, not how to keep sources safe etc refs to gloves, mask etc are considered as shielding allow keep source in lead container when not in use	3

Total 19 marks

Question number	Answer	Notes	Marks
2 (a) i)	C - 14		1
(ii)	B - 8		1
(iii)	A - 6		1
(b)	A - An electron		1
(c)	A - 1.5 g		1
(d)	Atoms/nuclei with same number of protons / same atomic number / same element; Different numbers of neutrons / different mass number / different atomic mass;	ALLOW 'different mass' for second mark if it's clear they are comparing atoms within the same element rather than different elements IGNORE references to electrons if possible, but if candidates makes an incorrect reference to electrons then list principle applies for that mark (e.g 'same number of protons but different number of neutrons and electrons' = 1)	1 1
		Total	**7**

Question number	Answer	Notes	Marks
3 (a)	(nuclear) fission;	DO NOT ALLOW fusion	1
(b)	Nucleus splits; Releasing neutrons; Which (hit / are absorbed by) different (uranium) nuclei;	PENALISE ONCE if 'atom' used for 'nucleus'	3
(c)	Kinetic (energy of particles) Of (fission) products / (daughter) nuclei / neutrons	DO NOT ALLOW 'movement' for kinetic	1 1
(d) (i)	Slow down neutrons;	DO NOT ALLOW 'movement' for kinetic	1
(ii)	Kinetic/heat/thermal; Kinetic; Kinetic/electrical; Electrical;	ALLOW 'electric' for 'electrical'	4
		Total	**11**

Question number	Answer	Notes	Marks
4 (a) (i)	rocks / radon (gas) / space / cosmic / Sun / medical sources / from carbon atoms in living things	REJECT named radiation e.g. gamma	1
(ii)	Any three from Remove source / with no source present; measure background / count; repeat / find mean / average value; subtract (background value) from experimental values (with source);	ACCEPT take readings (of background) / read background	Max 3
(b) (i)	GRAPH S A P P L	Orientation unimportant Quantity and unit on both axes Single smooth curve	5
(ii)	value consistent with graph (should be 0.9 – 1.4 minutes)		1
(c)	(gamma) can be detected outside the body /can pass through; half life related to use – long enough to get around the body (for use as tracer); half life related to patient safety - falls to low levels soon after use;	Ignore ionising ability Reject "cause less damage" without reference to activity or time	3

Question number	Answer	Notes	Marks
5 (a) (i)	 any one correct; all 3 correct;;		2
(ii)	(different surfaces) emit heat at different rates/eq;	allow emit different amounts of heat / radiation	1

Question number	Answer	Notes	Marks
5 (b) (i)	P = ρ x g x h ;	do not accept: • gravity for g • 10 for g • d for density accept: • word equations and rearrangements • for h allow height depth height difference	1
(ii)	sub into eqn for P; evaluation; unit; e.g. (P=) 1260x10x0.25 3150 Pa	no POT error as 'g' used allow 9.8(1) for g 1260x9.8x0.25 3090 allow • N/m^2 • matching unit e.g. 3.15 kPa	3

(iii)	any THREE from: MP1. black absorbs IR/heat; MP2. black heats up more than shiny; MP3. gas particles on black side move faster/get hotter/have more KE/move apart; MP4. pressure on left/black side increases;	Allow RA where appropriate allow gas expands allow force(/area) for pressure ignore: ideas of collisions	3
(iv)	difference in liquid height is less; more difficult/harder to move ;	height goes down less /decrease in h is less allow: argument in terms force /pressure	2

(v)	MP1 it will give a bigger temperature (range)/eq; AND DOP a suitable comment e.g. MP2 a larger difference in water level; MP3 a larger difference in air volume; MP4 a larger difference in (kinetic) energy of air/gas molecules/particles; MP5 idea of upper limit to range;	Allow the girl is right amount of water for water level amount of air for air volume speed of molecules /particles water would reach the bulb if the second statement is chosen, no marks	2

(Total for Question 5 = 14 marks)