Questions

Q1.

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

A radiation detector is placed near a radioactive source and measures the count rate from the source. Different absorbers are placed between the detector and the source. The results are shown in the table.

Absorber	Corrected count rate / s^{-1}
None	850
Paper	850
Aluminium foil	150
Lead sheet	20

Which of the following is emitted by the source?

☒ **A** α-radiation only

☒ **B** β-radiation only

☒ **C** α-radiation and β-radiation

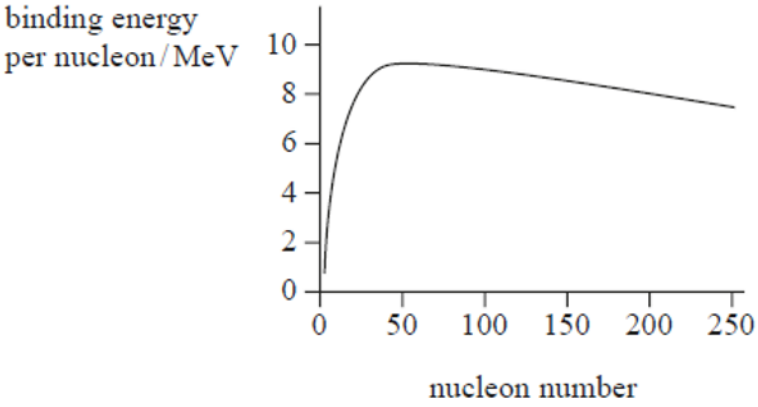
☒ **D** β-radiation and γ-radiation

(Total for question = 1 mark)

Q2.

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

The graph shows how the binding energy per nucleon varies with nucleon number.



Which of the following conclusions is supported by this graph?

☒ **A** The total energy released is greatest when two low mass nuclei fuse.

☒ **B** The total energy absorbed is greatest when two low mass nuclei fuse.

☒ **C** The total energy released is greatest when a massive nucleus undergoes fission.

☒ **D** The total energy absorbed is greatest when a massive nucleus undergoes fission.

(Total for question = 1 mark)

Q3.

Scientists have been working to achieve a practical nuclear fusion reactor for more than 70 years. So far, this has been with only limited success.

Explain the difficulties involved with fusion as a viable source of power on Earth.

You should include reference to the conditions necessary for fusion to occur.

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(Total for question = 4 marks)

Q4.

Oganesson (Og) can be produced by firing calcium (Ca) ions at a target of californium (Cf) atoms. Oganesson and a number of neutrons are produced in the nuclear reaction.

(a) Complete the equation for the reaction

(1)

$$^{48}_{20}\text{Ca} + ^{249}_{98}\text{Cf} \rightarrow ^{294}_{118}\text{Og} + \_\_\_\_ \times \_\_\_\_\text{n}$$

(b) The calcium ions were accelerated to an energy of 245 MeV.

(i) State how ions of this energy could be produced.

(1)

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(ii) It is claimed that calcium ions with an energy of 245 MeV are travelling at relativistic speeds.

Assess the validity of this claim.

mass of calcium ion = 47.95 u

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(c) The isotope Og-294 is extremely unstable and decays via alpha decay.

After 2.5 ms, a sample contains 500 atoms of Og-294.

Calculate the original number of Og-294 atoms in the sample.

half-life of Og-294 = 0.89 ms

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Original number of atoms = ...

(d) Explain a precaution necessary when handling a sample of an alpha emitting isotope.

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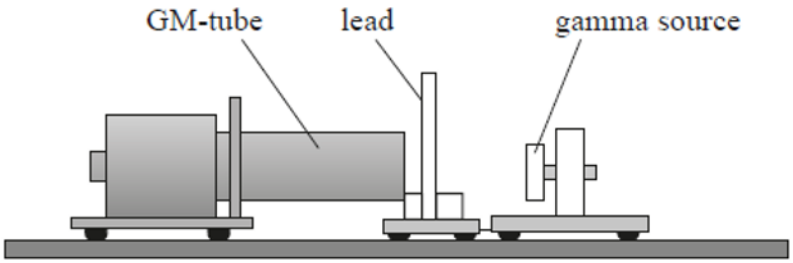
(Total for question = 12 marks)

Q5.

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

The student used a GM-tube to measure the background count for 10 minutes. She then used the apparatus below to measure the count for 2 minutes for different thicknesses of lead.



To correct the readings for the effect of background radiation she should

☒ **A** add the background count to each count.

☒ **B** add the background count rate to each count rate.

☒ **C** subtract the background count from each count.

☒ **D** subtract the background count rate from each count rate.

(Total for question = 1 mark)

Q6.

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

The student discovered that a thickness of 1.0 cm of lead reduced the corrected count rate to 50% of its initial value with no lead.

Which of the following statements is correct?

☒ **A** A thickness of 0.5 cm would reduce the corrected count rate to 75% of its initial value.

☒ **B** A thickness of 0.5 cm would reduce the corrected count rate to 25% of its initial value.

☒ **C** A thickness of 2.0 cm would reduce the corrected count rate to 25% of its initial value.

☒ **D** A thickness of 2.0 cm would reduce the corrected count rate to zero.

(Total for question = 1 mark)

Q7.

Potassium chloride may be used to flavour food. Potassium chloride contains trace amounts of a radioactive isotope of potassium (K). This decays into an isotope of calcium (Ca) by beta decay.

(a) (i) Complete the nuclear equation for this decay:

$$\text{\_\_\_\_}^{40}\text{K} \rightarrow \text{\_\_\_\_}_{20}\text{Ca} + \text{\_\_\_\_}\beta^{-} + {}^{0}_{0}\overline{\nu}_{e}$$

(2)

(ii) Calculate the energy, in MeV, released when a nucleus of potassium-40 decays into a nucleus of calcium.

	Mass / u
Potassium nucleus	39.963998
Calcium nucleus	39.962591
Electron	0.00054858
Electron neutrino ($\overline{\nu}_e$)	negligible

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Energy released = ... MeV

(iii) Explain why there is a range of energies for the beta particles emitted in the decay of a sample of potassium-40.

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(b) A sample of potassium chloride initially contains 1.10×10^{22} atoms of potassium-40.

half-life of potassium-40 = 1.25×10^{9} years
1 year = 3.15×10^{7} s

(i) Show that the activity of this sample is about 1.9×10^{5} Bq.

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(ii) It is claimed that after a period of 50 years, the activity of the sample would be less than the activity of a typical
school source.

Assess the validity of this claim. Your answer should include a calculation.

activity of a school source = 1.85×10^{5} Bq

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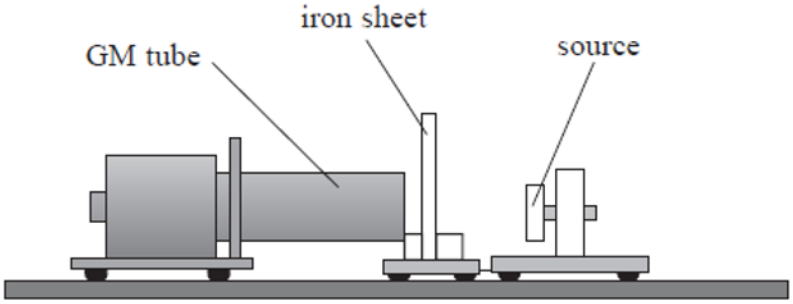
(Total for question = 14 marks)

Q8.

A student investigated the absorption of gamma radiation by iron. She placed a gamma source in a holder and set up a Geiger-Müller (GM) tube a short distance away. She placed thin sheets of iron between the GM tube and the source as shown.



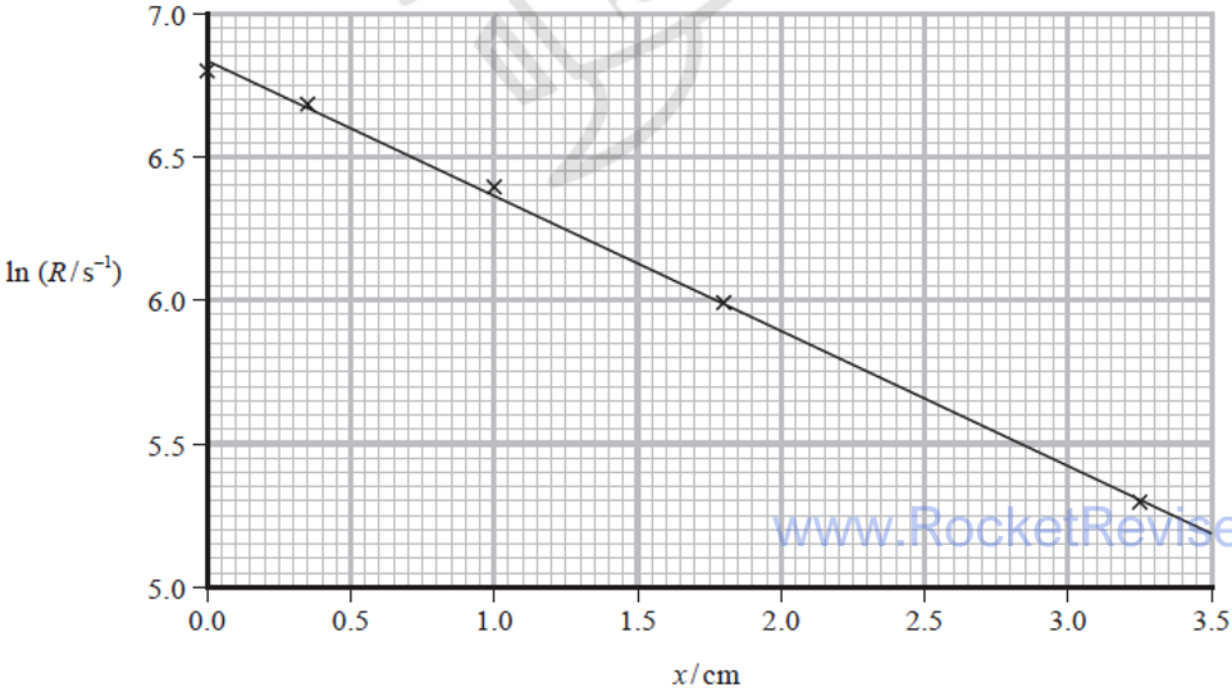
The student used five different thicknesses of iron and determined the count rate for each thickness.

The count rate with no iron sheet in place is R_0. After passing through an iron sheet of thickness x the count rate R is given by the equation

$$R = R_0 e^{-\mu x}$$

where μ is a constant.

The student used her data to plot a graph.



The student used the gradient of the graph to determine a value for μ and used this to estimate the half-value thickness for the iron. This is the thickness of iron that would reduce the count rate to R_0 / 2
The student used a source that emitted gamma rays of energy 1.1 MeV.

Deduce whether the data the student obtained confirms this energy value.

half-value thickness for 1.1 MeV gamma rays in iron = 1.5 cm

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(Total for question = 6 marks)

Q9.

* Nuclear fusion in the core of a star is the source of the star's power output.

Explain the conditions required to bring about and maintain nuclear fusion in stars.

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(Total for question = 6 marks)

Q10.

Polonium-218 is a naturally occurring radioactive isotope with a half-life of 185 s.
A sample of this isotope contains 2.75×10^{15} unstable nuclei.

Which of the following expressions can be used to determine the activity in Bq of the sample?

☒ **A** $\frac{185}{\ln 2} \times 2.75 \times 10^{15}$

☒ **B** $\frac{2.75 \times 10^{15}}{\ln 2 \times 185}$

☒ **C** $\frac{\ln 2}{185} \times 2.75 \times 10^{15}$

☒ **D** $\frac{\ln 2}{2.75 \times 10^{15}} \times 185$

(Total for question = 1 mark)

Q11.

The penetration of matter by radiation depends on the ionising power of the radiation.

Which of the following statements is correct?

☒ **A** α-particles are weakly ionising so they are stopped by thin paper.

☒ **B** α-particles are highly ionising so they only travel a few centimetres in air.

☒ **C** γ-radiation is highly ionising so it is highly penetrating.

☒ **D** γ-radiation is weakly ionising so it is not very penetrating.

(Total for question = 1 mark)

Q12.

Many countries use nuclear power stations to provide electrical power. Energy is released when nuclei undergo fission in the core of the reactor.

(a) State what is meant by nuclear fission.

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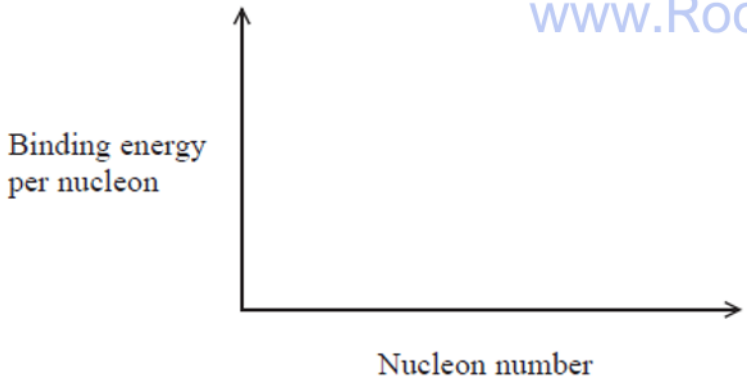
(b) (i) Sketch a graph to show how the binding energy per nucleon varies with nucleon number, for a wide range of isotopes.

(2)



(ii) Mark the position of iron-56 on your graph.

(1)

(c) Complete the nuclear equation below.

$$^{236}_{92}\mathrm{U} \rightarrow \ ^{\quad}_{38}\mathrm{Sr} + \ ^{141}\mathrm{Xe} + 2 \times \ ^{\quad}\mathrm{n}$$

(2)

(d) Calculate, in MeV, the binding energy per nucleon for a nucleus of $^{236}_{92}\mathrm{U}$.

	Mass / GeV/c²
$^{236}_{92}\mathrm{U}$	219.8750
n	0.93956
p	0.93827

(2)

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Binding energy per nucleon = ... MeV

*(e) Ultraviolet radiation (UV) is produced when alpha particles interact with air. This can be used to detect alpha particles when a nuclear reactor is decommissioned.

Explain how UV is produced by alpha particles in the air, and why detecting UV has advantages compared with detecting alpha particles directly.

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(Total for question = 14 marks)

Q13.

Thorium is an unstable isotope that decays into radium as shown in the nuclear equation.

$$^{228}_{90}\text{Th} \rightarrow {}^{224}_{88}\text{Ra} + {}^{4}_{2}\alpha$$

The table below gives the masses of the nuclei.

Nucleus	Mass / u
^{228}Th	228.02873
^{224}Ra	224.02021
$^{4}\alpha$	4.00260

(a) Show that the energy released in the decay is about 5.5 MeV.

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(b) A textbook states that the kinetic energy gained by the alpha particle when a nucleus of thorium-228 decays is equal to 5.4 MeV.

Comment on this statement. Your answer should include a calculation.

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(Total for question = 8 marks)

Q14.

Cobalt-60 is a source of gamma radiation. Gamma radiation can be used to sterilise medical equipment.

(a) (i) Complete the nuclear equation for the decay of cobalt-60 to nickel.

$$^{60}_{27}\text{Co} \rightarrow \quad \text{Ni} + \quad \beta^- + \quad ^{0}_{0}\overline{\nu}_e$$

(2)

(ii) Suggest why the majority of the energy released is shared between the β^- particle and the antineutrino.

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(b) The activity of a cobalt-60 source is 4.07×10^{14} Bq initially.

When used for sterilising, the source is replaced when the activity drops below 1.85×10^{14} Bq.

Calculate the time in years until the source should be replaced.

half-life of cobalt-60 = 5.27 years
1 year = 3.16×10^{7} s

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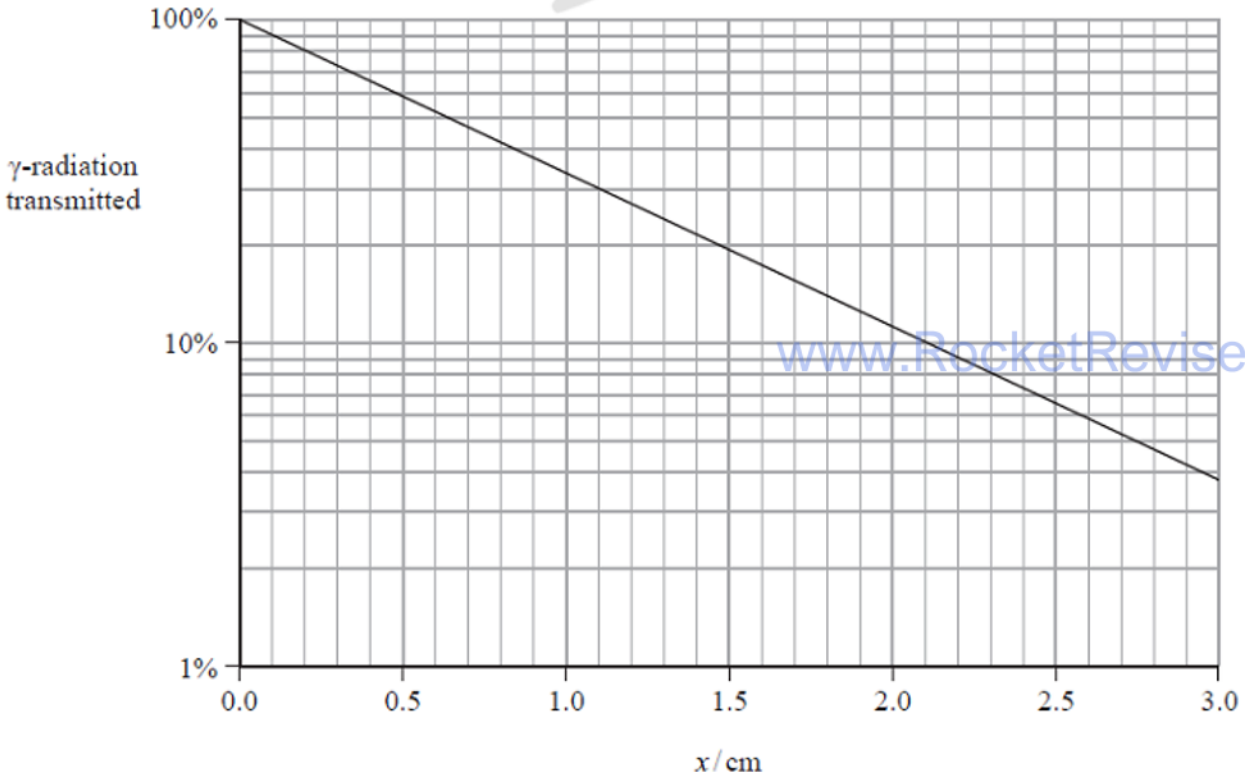
Time until source should be replaced = ... years

(c) When in use the cobalt-60 source is shielded with lead. The graph shows how the transmission of γ-radiation depends upon the thickness x of the lead shielding.



The count rate from a source must be reduced from 4.0×10^{14} Bq to 1.2×10^{14} Bq.

Deduce whether lead shielding of thickness 1.0 cm would be sufficient to achieve this.

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(Total for question = 9 marks)

Q15.

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

In the Sun, nuclear fusion occurs mainly in the core.

Which of the following is a reason for this?

☒ **A** Helium nuclei surround the core.

☒ **B** Most of the Sun's hydrogen is in the core.

☒ **C** The core contains most of the mass of the Sun.

☒ **D** The temperature is greatest in the core.

(Total for question = 1 mark)

Q16.

A pacemaker is a device used to regulate a person's heart rate.

Some of the first electronic pacemakers used an isotope of plutonium, Pu-238, as the power source.

(a) Pu-238 decays by alpha emission.

Show that the energy released when a nucleus of Pu-238 decays into a nucleus of uranium is about 5.6 MeV.

	Mass / u
Plutonium nucleus	237.999089
Uranium nucleus	233.991578
α-particle	4.001506

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(b) In one pacemaker, the activity of the plutonium source was measured to be 6.75×10^{10} Bq in 2020.

Calculate the power of the source, in W, when it was fitted 40 years ago.

half-life of Pu-238 = 87.7 years

energy of α-particle = 5.6 MeV

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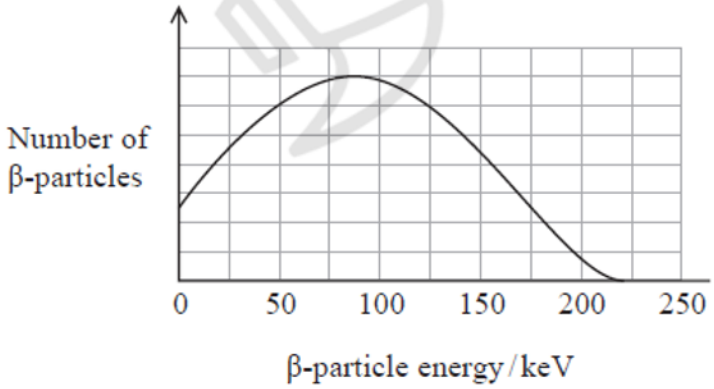
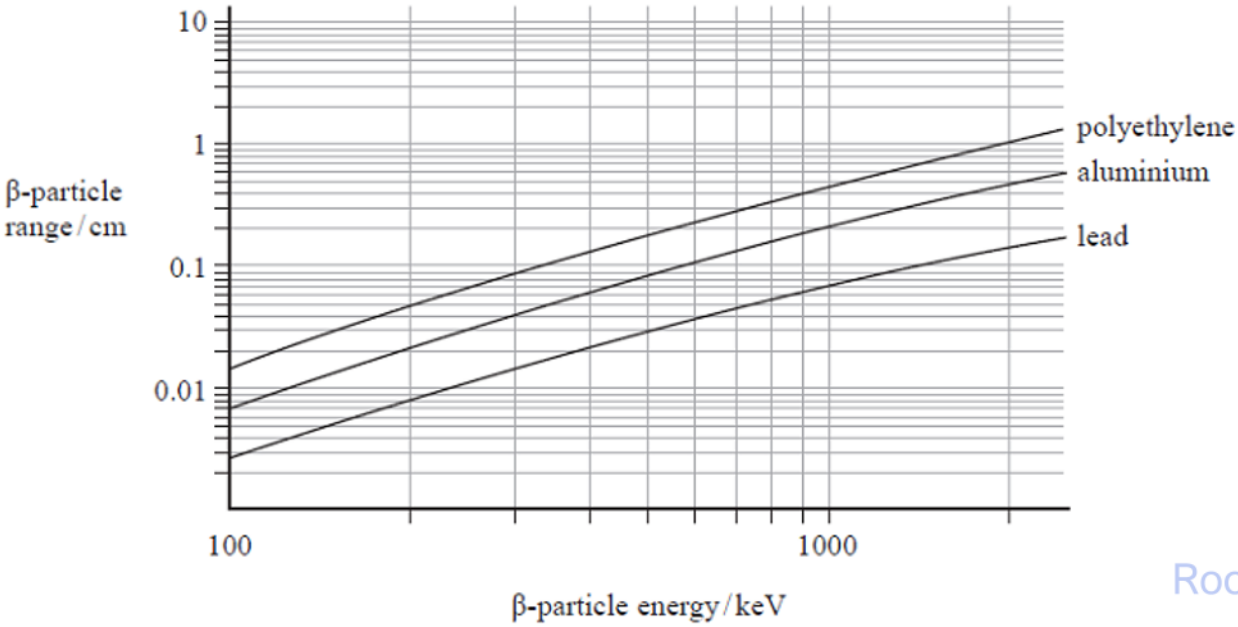
Power of source = ... W

(c) Another source that was used in early pacemakers was promethium-147. This emits β-particles. The energy spectrum for the β-particles is shown.



The graphs below show how the range of beta particles depends on the beta particle energy, for different materials.



It is suggested that a layer of polyethylene, of thickness 0.5 cm, would be able to absorb all the beta particles emitted from a promethium-147 source.

Comment on this suggestion.

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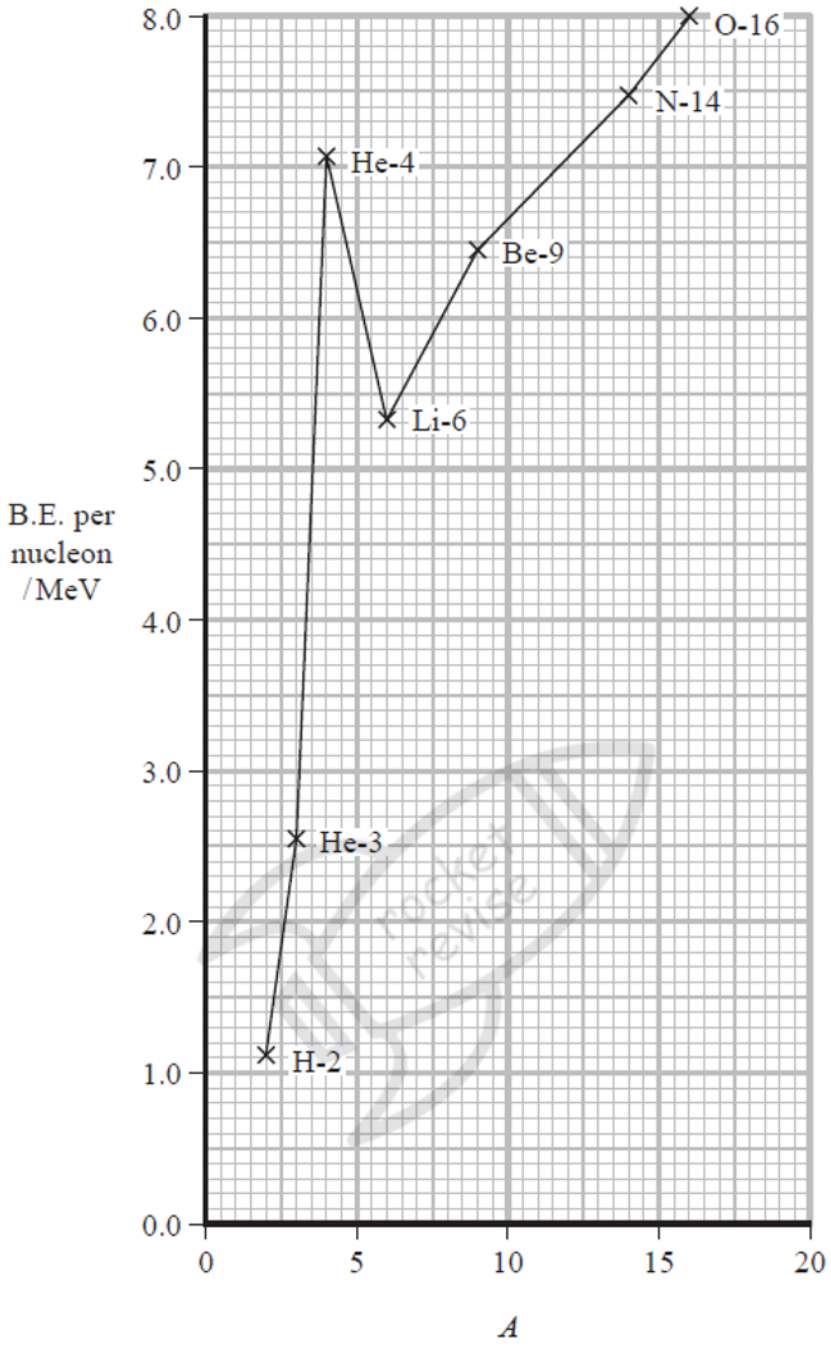
(Total for question = 13 marks)

Q17.

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

The graph shows how the binding energy (B.E.) per nucleon varies with nucleon number *A* for low mass nuclei.



Which of the following is the energy required to split a He-4 nucleus into 2 protons and 2 neutrons?

☒ **A** 2.6 MeV

☒ **B** 7.1 MeV

☒ **C** 14.2 MeV

☒ **D** 28.4 MeV

(Total for question = 1 mark)

Q18.

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

A detector and counter were placed near a radium source. A student measured the count for one minute. He used this value to calculate the count rate in Bq from the source.

Which of the following would increase the accuracy of the student's value for the count rate?

☒ **A** Adding the background count rate to the measured count rate.

☒ **B** Increasing the counting time to 10 minutes.

☒ **C** Repeating the count with a different detector and calculating a mean value.

☒ **D** Subtracting the background count from the measured count.

(Total for question = 1 mark)

Q19.

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

Cancer cells inside the body can be killed by directing narrow beams of radiation from different directions onto the cells. The source of radiation is outside the body.

Which radiation would be the most suitable to use?

☒ **A** alpha radiation because it is very ionising

☒ **B** alpha radiation because it is very penetrating

☒ **C** gamma radiation because it is very ionising

☒ **D** gamma radiation because it is very penetrating

(Total for question = 1 mark)

Q20.

A nucleus of polonium-210 decays to lead-206 by emitting an alpha particle.
The masses of the particles are shown in the table.

	Mass / kg
Polonium-210	3.48572×10^{-25}
Lead-206	3.41918×10^{-25}
Alpha particle	6.64437×10^{-27}

(a)(i) Show that the energy released in the decay is about 9×10^{-13} J.

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(ii) 98% of the energy from the decay is released as kinetic energy of the alpha particle.

Calculate the velocity of the alpha particle immediately after the decay.

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Velocity of alpha particle = ...

(b) Explain why not all of the energy from the decay is released as kinetic energy of the alpha particle.

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(Total for question = 7 marks)

Q21.

Actinium-225 is a radioactive isotope. It decays to francium by emitting alpha particles. Actinium-225 has a short half-life, which makes it suitable for medical applications.

(a) Complete the nuclear equation for this decay.

$$^{225}_{89}\text{Ac} \rightarrow \text{\_\_\_\_} \text{Fr} + \text{\_\_\_\_} \alpha$$

(2)

(b) In a radioactive decay, energy is released and the total mass decreases.

Show that the energy released if the mass decreases by 1 u is about 930 MeV.

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(c) The francium nucleus and the alpha particle move away from each other after the decay.

Explain why the kinetic energy given to the alpha particle is just less than 5.9 MeV.

mass decrease for the decay = 6.35×10^{-3}u

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(d) The activity of a sample of actinium-225 is 7.4×10^{7} Bq when it is prepared.

Calculate the number of actinium atoms in the sample 7.0 days later.

half-life of actinium-225 = 9.9 days

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Number of actinium atoms after 7.0 days = ...

(Total for question = 14 marks)

Q22.

Potassium-40 (^{40}K) is a radioactive isotope. ^{40}K can decay by β^- emission.

(a) Complete the nuclear equation for the decay of ^{40}K by β^- emission.

$$\_\_\_\_^{40}K \rightarrow \_\_\_\_^{\ldots\ldots}_{20}Ca + \_\_\_\_^{\ldots\ldots}\beta^- + {}^{0}_{0}\bar{\nu}$$

(2)

(b) Occasionally ^{40}K decays by emitting a β^+ particle.

Give two similarities between a β^+ particle and a β^- particle.

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(c) A fertiliser contains potassium chloride. The activity of a sample of the fertiliser due to radioactive
potassium was 48.6 Bq.

It is claimed that the time *t* taken for the activity of the sample to fall below the background count rate would be more than 9×10^9 years.

Deduce whether this claim is correct.

background count rate = 0.42 Bq
half-life of $^{40}K = 1.25 \times 10^9$ years

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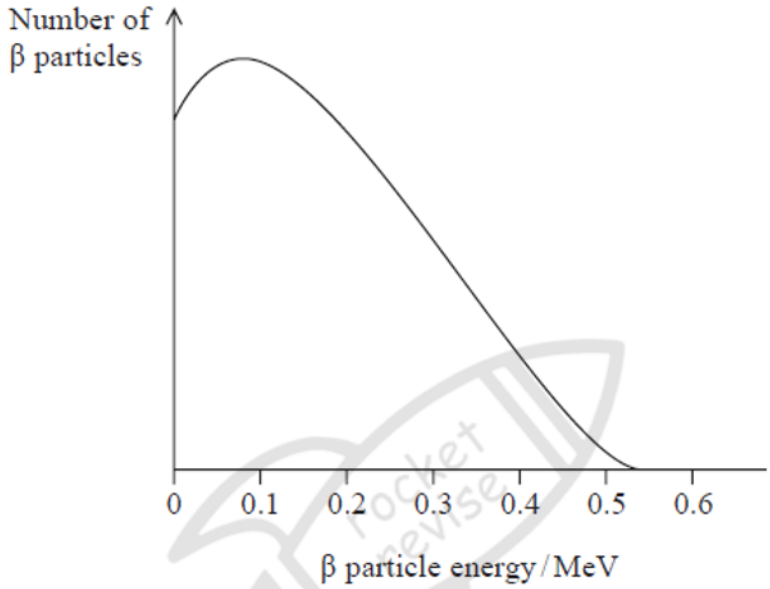
(Total for question = 7 marks)

Q23.

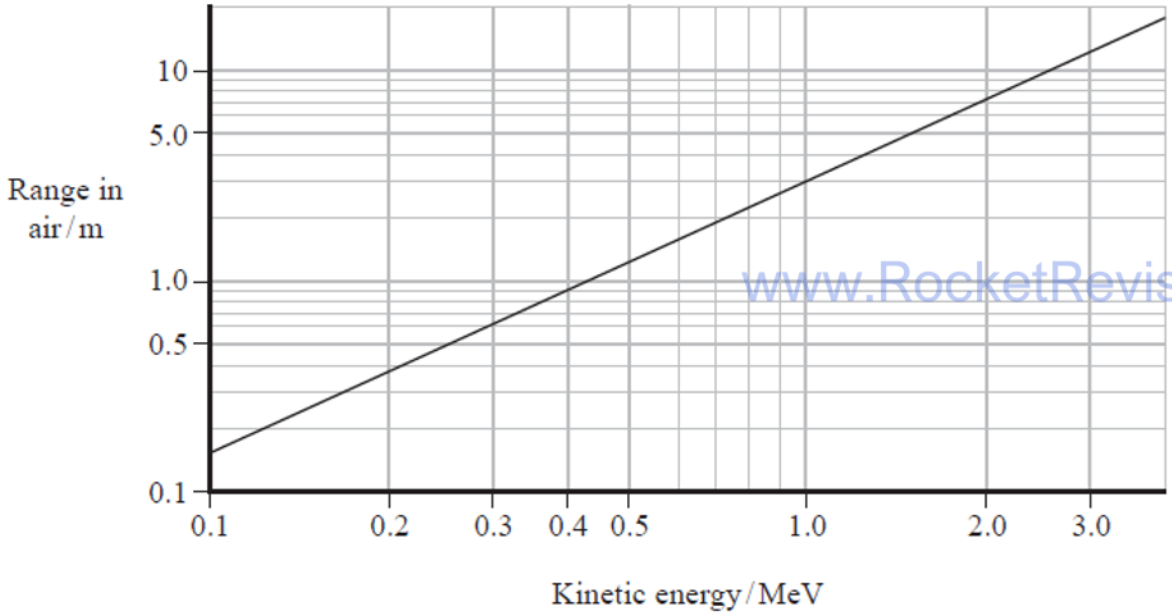
Strontium-90 is commonly used in schools to demonstrate the properties of β particles.

The range of energies of β particles emitted from a source of strontium-90 is shown below.



When β particles travel through air they ionise air molecules, which limits how far they travel. The range of the β particles depends upon their kinetic energy when released from the nucleus.

The graph below shows how the range of a β particle in air depends upon its kinetic energy.



It is estimated that the most energetic β particles from strontium-90 will ionise 250 nitrogen molecules per cm of air that they pass through.

15.6 eV is required to ionise a nitrogen molecule.

Assess whether this estimate is consistent with the range of these β particles in air.

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(Total for question = 5 marks)

Q24.

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

A radioactive source is placed a few centimetres away from a detector.

When a sheet of paper is placed between the source and the detector there is no change in the count rate.

When a lead sheet of thickness 0.5 cm is placed between the source and the detector the count rate is reduced to the background rate.

Which of the following is emitted by the source?

☒ **A** alpha and gamma radiation

☒ **B** beta and gamma radiation

☒ **C** beta radiation only

☒

D gamma radiation only

(Total for question = 1 mark)

Q25.

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

Fission and fusion are both nuclear processes.

Which of the following statements is correct for both processes?

☒ **A** No harmful radiation is produced.

☒ **B** Nuclear binding energy increases.

☒ **C** Very high temperatures are required.

☒ **D** The process can occur spontaneously.

(Total for question = 1 mark)

Q26.

Caesium-137 is a radioactive isotope produced during the fission of uranium.

(a) State what is meant by fission.

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(1)

(b) (i) Caesium-137 decays by emitting beta radiation.

Complete the nuclear equation for the decay of caesium-137.

$$^{137}_{55}Cs \rightarrow \text{\_\_\_\_}Ba + \text{\_\_\_\_}\beta^{-} + {}^{0}_{0}\overline{\nu}$$

(2)

(ii) Explain why the emission of an antineutrino in the decay leads to a range of energies for the β^- particles.

(2)

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(c) Caesium-137 is a major source of radiation from radioactive waste.

(i) A nuclear fission reactor produces about 24 kg of caesium-137 each year.

A website states that 24 kg of caesium-137 has the same activity as 2000 kg of radium-226.

Assess whether this statement is correct.

half-life of caesium-137 = 30.2 years
mass of a caesium atom = 136.9 u
activity of 2000 kg of radium-226 = 7.33×10^{16} Bq
1 year = 3.15×10^{7} s

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(ii) Caesium-137 may enter plants grown in a contaminated area.

The radiation from 100 g of plant material grown in a contaminated area can have a count rate

as high as 500 Bq. A count rate of 150 min^{-1} is considered safe.

Determine the time taken for the count rate from 25 g of plant material grown in a contaminated area to fall to a safe level.

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Time taken = ...

(Total for question = 14 marks)

Q27.

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

Which row of the table gives the conditions required in the core of a star for fusion to be sustained?

		Density	Temperature
☒	**A**	moderate	moderate
☒	**B**	moderate	very high
☒	**C**	very high	moderate
☒	**D**	very high	very high

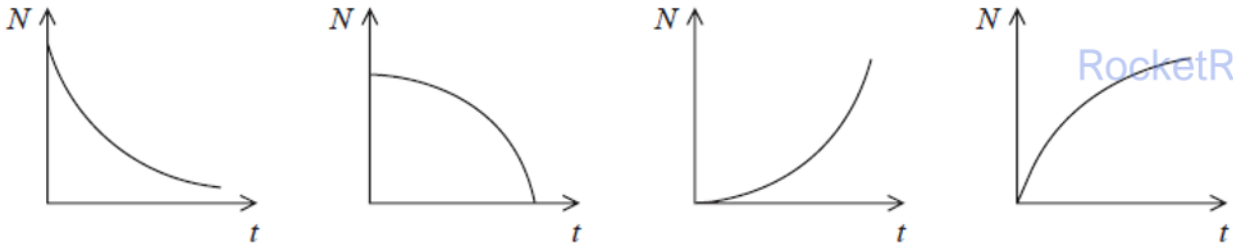
(Total for question = 1 mark)

Q28.

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

Bismuth decays to form a stable isotope of thallium.

Which graph shows how the number *N* of thallium atoms in a sample of bismuth varies with time *t*?



A **B** **C** **D**

☒ **A**

☒ **B**

☒ **C**

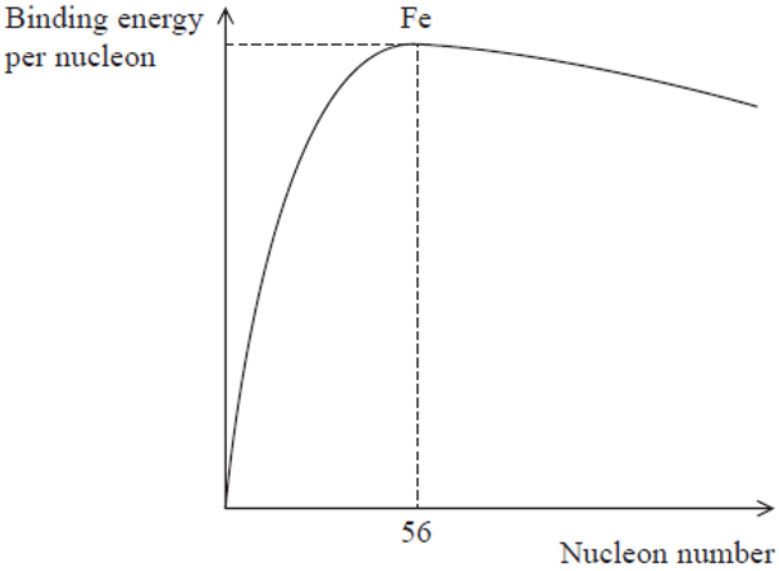
☒ **D**

(Total for question = 1 mark)

Q29.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The graph shows how the binding energy per nucleon depends upon nucleon number for a range of naturally occurring nuclides.



Which of the following can be deduced from the graph?

☒ **A** ^{56}Fe readily undergoes fission.

☒ **B** Fission releases less energy than fusion.

☒ **C** High mass nuclei cannot undergo fusion.

☒ **D** Low mass nuclei release energy during fusion.

(Total for question = 1 mark)

Q30.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Tritium is a radioactive isotope. Wine may contain traces of tritium. One 25-year-old bottle of wine was found to have an unusually high activity of 22 Bq.

half-life of tritium = 12.5 years

Which of the following gives the activity of this wine when it was bottled?

☒ **A** 44 Bq

☒ **B** 66 Bq

☒ **C** 88 Bq

☒ **D** 110 Bq

(Total for question = 1 mark)

Q31.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A student investigates the absorption of gamma radiation by lead. She determines the background radiation count rate before she starts the investigation.

Which of the following would **not** affect her value for the background count rate?

☒ **A** the place where she made the measurement

☒ **B** the temperature of the surroundings

☒ **C** the time interval for the background count

☒ **D** the type of radiation detector she used

(Total for question = 1 mark)

Q32.

In 1935 Irène and Frédéric Joliot-Curie were awarded a Nobel Prize for the discovery of artificial radioactivity.

They bombarded an aluminium sheet with alpha particles to produce a radioactive isotope of phosphorus as in the nuclear equation below.

$$^{27}_{13}\text{Al} + ^{4}_{2}\alpha \rightarrow ^{30}_{15}\text{P} + ^{1}_{0}\text{X}$$

(a) (i) Identify particle X.

(1)

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(ii) Calculate the energy released, in joules, in this nuclear reaction.

Particle	Mass / GeV / c^2
^{1}X	0.9396
$^{4}\alpha$	3.7274
^{27}Al	25.1333
^{30}P	27.9206

(4)

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Energy released = ... J

(b) Radioactive phosphorus was one of the first artificially produced isotopes to be used in the diagnosis of cancerous tumours.

The isotope ^{32}P is injected into a person and collects in the tumour. Radiation is detected outside the person's body. ^{32}P is a positron emitter with a half-life of almost fifteen days.

Explain why ^{32}P is suitable for this procedure.

(4)

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(Total for question = 9 marks)

Q33.

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

The radioactive decay of a nucleus is described as a random process.

Which of the following is a reason for this?

☒ **A** There are a number of different decay paths.

☒ **B** The nucleus will probably decay after one half-life.

☒ **C** The nucleus will decay without any external stimulus.

☒ **D** There is a fixed probability of the nucleus decaying in the next second.

(Total for question = 1 mark)

Q34.

Caesium-137, ^{137}Cs, is a common product of uranium fission.
Very small samples of ^{137}Cs can be used to calibrate radiation detector equipment.

(a) ^{137}Cs decays to an isotope of barium by emitting a β^- particle.

Complete the nuclear equation for the decay of ^{137}Cs.

(2)

$$\text{.....}^{137}Cs \rightarrow \text{.....}_{56}Ba + \text{.....}\beta^- + {}^{0}_{0}\overline{\nu}_e$$

(b) A sample of pure ^{137}Cs has an activity of 7400 Bq.

Calculate the mass, in kg, of the sample.

half-life of ^{137}Cs = 30.2 years
mass of ^{137}Cs atom = 137 u
1 year = 3.15×10^7 s

(4)

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Mass of sample = ... kg

(Total for question = 6 marks)

Q35.

A nucleus of rhenium-187 decays to a nucleus of osmium by emitting a β^- particle.

(a) Complete the nuclear equation for the decay of rhenium-187.

(2)

$$^{187}_{75}\text{Re} \rightarrow \text{.....Os} + \text{.....}\beta^- + {}^{0}_{0}\overline{\nu}$$

Calculate the speed of a β^- particle emitted in this decay.

(3)

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Speed of β^- particle = ...

(Total for question = 5 marks)

Q36.

In the early part of the 20th century, Rutherford made the first observation of an element being changed into a different element.

Alpha particles were fired at nitrogen atoms.

The nuclear equation for this reaction is:

$$^{4}_{2}\mathrm{He} + {}^{14}_{7}\mathrm{N} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$$

(a) Calculate the minimum energy, in MeV, required for the reaction to take place.

(4)

Nuclide	Mass / 10^{-27} kg
^{17}O	28.2185
^{14}N	23.2451
^{4}He	6.64432
^{1}H	1.67299

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Minimum energy = ... MeV

(b) Explain why the alpha particle must have an energy greater than the minimum energy for the reaction to take place.

(2)

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(Total for question = 6 marks)

Q37.

In 2023, a small capsule of caesium-137 was lost when being transported from a mine in Western Australia.

The activity of the caesium in the capsule was 19 GBq.

(a) (i) Show that the decay constant for caesium-137 is about 7.3×10^{-10} s^{-1}.

half-life of caesium-137 = 30.1 years
1 year = 3.15×10^{7} s

(2)

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(ii) Calculate the mass of caesium in the capsule.

(3)

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Mass of caesium = ...

(iii) Calculate the activity of the caesium in the capsule after 2 years.

(2)

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Activity after 2 years = ...

(b) The capsule was found after 14 days.

Calculate the total energy, in J, released from the capsule in 14 days.

activity of caesium in capsule = 19 GBq
energy released in each decay of caesium-137 = 1.17 MeV
1 day = 86 400 s

(3)

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Total energy released in 14 days = ... J

(Total for question = 10 marks)

Q38.

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

Fusion reactions are the primary energy source of stars.

Which row of the table gives the conditions necessary for fusion in stars?

		Density	Temperature
☒	**A**	high	high
☒	**B**	high	low
☒	**C**	low	high
☒	**D**	low	low

(Total for question = 1 mark)

Q39.

A nucleus of thorium-230 is unstable and decays to a nucleus of radium-226 by emitting an alpha particle.

The table shows the masses of the particles involved.

	Mass / u
Thorium-230 nucleus	230.0331
Radium-226 nucleus	226.0254
Alpha particle	4.0026

(a) Determine the energy, in J, released when a nucleus of thorium-230 emits an alpha particle.

(4)

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Energy released = ... J

(b) Determine the time taken, in years, for 90% of the thorium-230 in a sample to decay to radium-226.

half-life of thorium-230 = 75 400 years

(4)

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Time taken = ... years

(Total for question = 8 marks)

Q40.

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

A student is investigating the absorption of gamma radiation by lead. Before starting the investigation, she determines the background count.

Which of the following does **not** affect the background count?

☒ **A** the count time

☒ **B** the location

☒ **C** the temperature

☒ **D** the type of detector

(Total for question = 1 mark)

Q41.

In France, scientists from many countries are working together to build the International Thermonuclear Experimental Reactor (ITER).

(a) On the ITER website it states:

"Fusion is the energy source of the Sun and stars. In the core of these stellar bodies, hydrogen nuclei fuse into helium nuclei and release tremendous amounts of energy."

Explain why energy is released when hydrogen nuclei fuse to form helium nuclei.

(2)

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(b) It is hoped that the ITER will be the first fusion device on Earth to maintain nuclear fusion for long periods of time.

To achieve fusion in the ITER, a hot plasma is used.

The plasma must

- be at an extremely high temperature
- have sufficient density for fusion.

Explain why each of these two conditions must be met.

(4)

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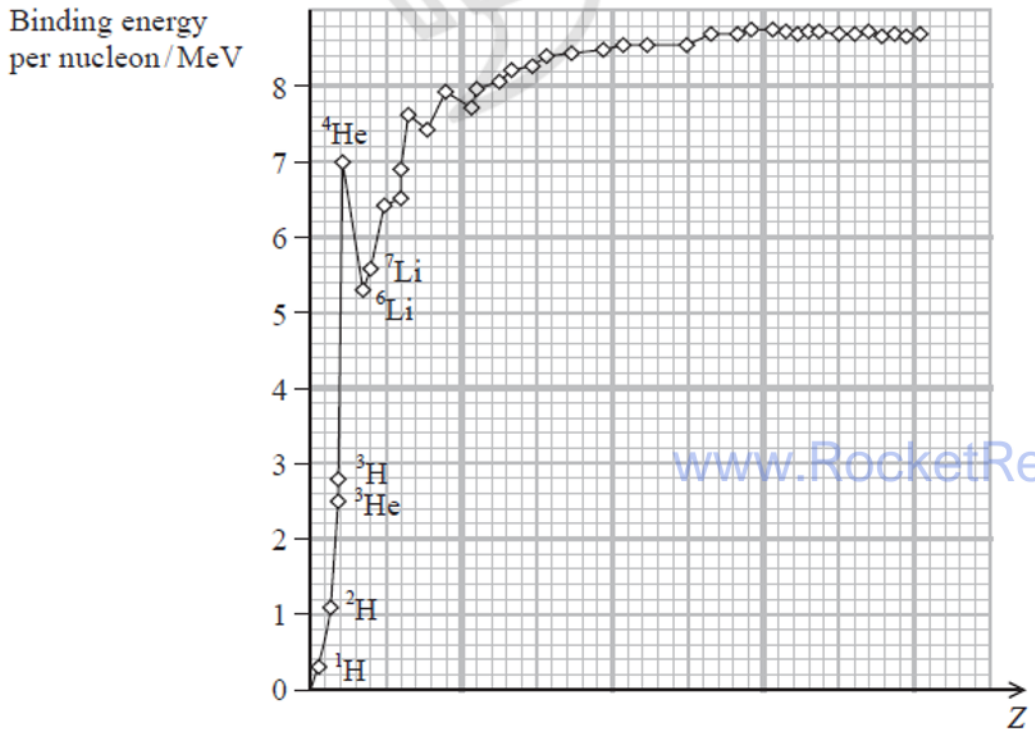
(c) The graph shows the variation of binding energy per nucleon with proton number Z.



In one possible fusion reaction, a nucleus of ^{2}H fuses with a nucleus of ^{3}H.

A nucleus of ^{4}He and a free neutron are produced as shown in the following nuclear equation.

$$^2\text{H} \quad + \quad ^3\text{H} \quad \rightarrow \quad ^4\text{He} \quad + \quad ^1\text{n}$$

Determine the energy, in MeV, released when a nucleus of ^{2}H fuses with a nucleus of ^{3}H.

(3)

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Energy released = ... MeV

(Total for question = 9 marks)

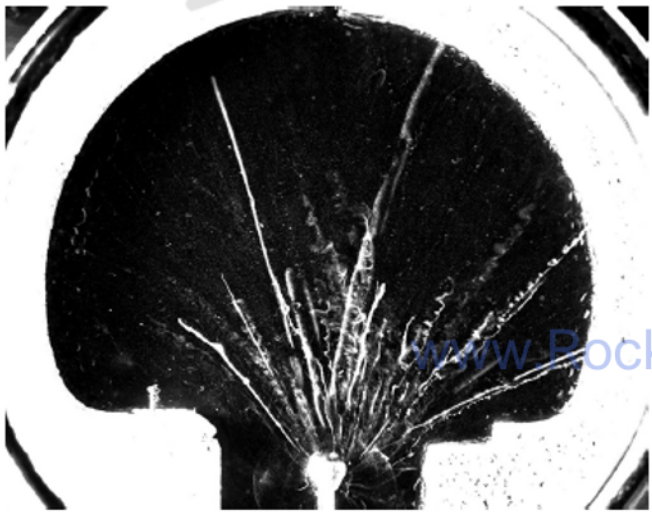
Q42.

A cloud chamber is used to show the tracks of alpha particles and beta particles.

These particles ionise the air as they pass through the chamber.

Liquid droplets form around the ions. The droplets form visible tracks, as shown.

View from above



(Source: © sciencephotos/Alamy Stock Photo)

A student makes the following observations:

- the alpha particle tracks are thick and straight
- the beta particle tracks are thin and twisted.

Explain these observations.

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(Total for question = 4 marks)

Q43.

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

Which of the following statements about nuclear binding energy (B.E.) is correct?

☒ **A** B.E. per nucleon increases steadily as proton number increases.

☒ **B** B.E. per nucleon decreases steadily as proton number increases.

☒ **C** B.E. per nucleon is approximately constant for all elements.

☒ **D** B.E. per nucleon increases to a maximum and then decreases as proton number increases.

(Total for question = 1 mark)

Q44.

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

Which row of the table gives the relative ionising power and penetration of gamma radiation?

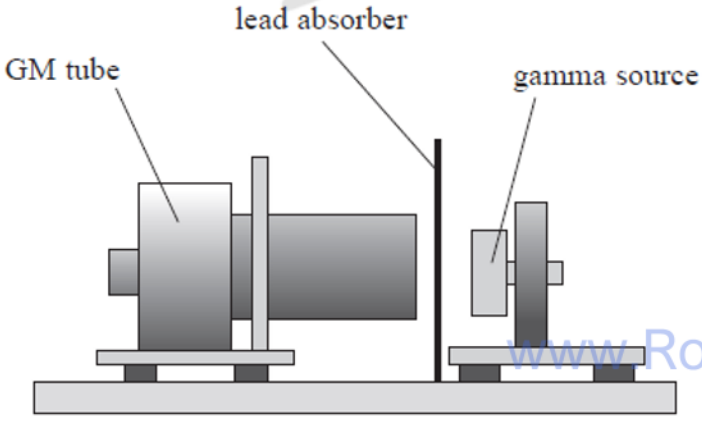
		Ionising power	Penetration
☒	**A**	low	low
☒	**B**	low	high
☒	**C**	high	low
☒	**D**	high	high

(Total for question = 1 mark)

Q45.

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

A student investigated the absorption of gamma radiation by lead, as shown.



With no absorber the intensity of radiation was I_o. With an absorber of thickness 0.8 cm the intensity was 0.25 I_o.

What thickness of absorber would give an intensity of 0.5 I_o?

☒ **A** 0.2 cm

☒ **B** 0.4 cm

☒ **C** 1.6 cm

☒ **D** 3.2 cm

(Total for question = 1 mark)

Q46.

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

When a nucleus of americium emits an alpha particle the energy released is 5.64 MeV.

Which of the following expressions gives the decrease in mass in kg of the nucleus when it emits the alpha particle?

☒ **A** $\frac{5.64 \times 1.60 \times 10^{-13}}{(3.0 \times 10^{8})^{2}}$

☒ **B** $\frac{5.64}{1.60 \times 10^{-13} \times (3.0 \times 10^{8})^{2}}$

☒ **C** $\frac{5.64 \times 1.60 \times 10^{-13}}{1.66 \times 10^{-27} \times (3.0 \times 10^{8})^{2}}$

☒ **D** $\frac{5.64 \times 1.66 \times 10^{-27}}{1.60 \times 10^{-13} \times (3.0 \times 10^{8})^{2}}$

(Total for question = 1 mark)

Q47.

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

The fusion of nuclei of ^{56}Fe in a star does not release energy.

Which of the following is a reason for this?

☒ **A** The magnitude of nuclear binding energy is the least for ^{56}Fe.

☒ **B** The magnitude of nuclear binding energy is the greatest for ^{56}Fe.

☒ **C** The magnitude of binding energy per nucleon is the least for ^{56}Fe.

☒ **D** The magnitude of binding energy per nucleon is the greatest for ^{56}Fe.

(Total for question = 1 mark)

Q48.

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

A student used a detector and counter to measure the background radiation count for five minutes. He used this value to calculate the background count rate.

Which of the following would increase the accuracy of the student's value for the background count rate?

☒ **A** Decrease the counting time to 1 minute.

☒ **B** Increase the counting time to 10 minutes.

☒ **C** Repeat the count with a different detector and calculate a mean value.

☒ **D** Repeat the count in a different location and calculate a mean value.

(Total for question = 1 mark)