DO NOT WRITE IN THIS AREA

3 The mass of a muon is 0.113 u.

Which of the following is equal to the equivalent mass-energy, in joules, of the muon?

☒ **A** $0.113 \times (3.0 \times 10^8)^2$

☒ **B** $\dfrac{0.113}{(3.0 \times 10^8)^2}$

☒ **C** $0.113 \times (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27}$

☒ **D** $0.113 \times (3.0 \times 10^8)^2 \times 1.67 \times 10^{-27}$

(Total for Question 3 = 1 mark)

7: A student used a detector to determine the intensity of radiation from a source of gamma radiation. After correcting for background, the intensity of radiation recorded by the detector was I_0.

A lead sheet of thickness 2.5 cm was placed between the source and the detector. The corrected intensity of radiation recorded by the detector was now $0.50\,I_0$.

The original lead sheet was replaced by a new lead sheet of thickness 7.5 cm.

Which of the following was the corrected intensity of gamma radiation recorded by the detector?

☒ **A** $0.33\,I_0$

☒ **B** $0.25\,I_0$

☒ **C** $0.13\,I_0$

☒ **D** $0.06\,I_0$

(Total for Question 7 = 1 mark)

1 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 = 1 mark)

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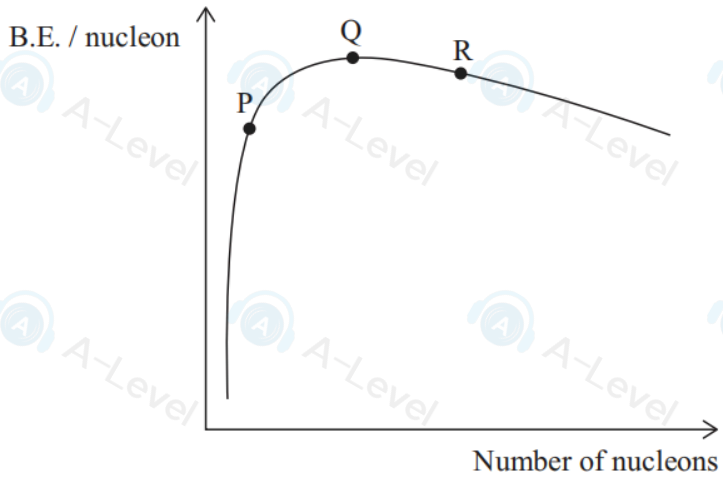
4 The graph shows how the binding energy (B.E.) per nucleon varies with the number of nucleons. The positions of three isotopes, P, Q and R, are marked on the curve.



Which row of the table lists the isotopes from least stable to most stable?

	Least stable ⟶		Most stable
☒ **A**	P	Q	R
☒ **B**	P	R	Q
☒ **C**	Q	R	P
☒ **D**	R	P	Q

(Total for Question 4 = 1 mark)

3: Energy is released when the fusion of low mass nuclei takes place.
Energy is also released when the fission of high mass nuclei takes place.

Which row of the table shows the change in binding energy per nucleon (B.E. / nucleon) for fusion and fission?

	Nuclear fusion	Nuclear fission
☒ **A**	B.E. / nucleon decreases	B.E. / nucleon decreases
☒ **B**	B.E. / nucleon decreases	B.E. / nucleon increases
☒ **C**	B.E. / nucleon increases	B.E. / nucleon decreases
☒ **D**	B.E. / nucleon increases	B.E. / nucleon increases

(Total for Question 3 = 1 mark)

DO NOT WRITE IN THIS AREA

7 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 7 = 1 mark)

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6: In a laboratory, the background count rate is 22 counts per minute.

A detector is placed 25 cm from a gamma source. The count rate recorded by the detector is 54 counts per minute.

The detector is then placed 50 cm from the source.

Which of the following is the expected number of counts per minute?

☒ **A** $\left(\frac{54 - 22}{2}\right) + 22$

☒ **B** $\left(\frac{54 - 22}{4}\right) + 22$

☒ **C** $\left(\frac{54 + 22}{2}\right) - 22$

☒ **D** $\left(\frac{54 + 22}{4}\right) - 22$

(Total for Question 6 = 1 mark)

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3 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 3 = 1 mark)

DO NOT WRITE IN THIS AREA

1 A radioactive source emits alpha radiation, beta radiation and gamma radiation.

Which of the following is correct?

- ☒ **A** Alpha radiation is the most ionising.
- ☒ **B** Beta radiation is the least penetrating.
- ☒ **C** Beta radiation is the most ionising.
- ☒ **D** Gamma radiation is the least penetrating.

(Total for Question 1 = 1 mark)

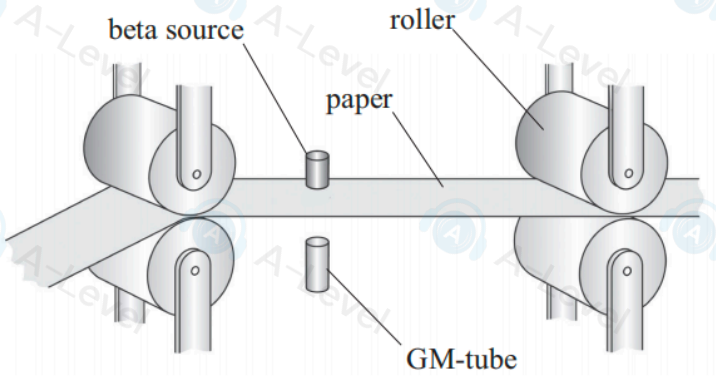
8 Which row of the table gives the relative ionising power and penetration of gamma radiation?

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

(Total for Question 8 = 1 mark)

21 Promethium is produced as a byproduct of nuclear fission. An isotope of promethium, Pm-147, decays by beta emission.

(a) The thickness of paper produced in a paper mill can be monitored using beta radiation, as shown.



(Source: SCIENCE PHOTO LIBRARY)

The count rate recorded by the GM-tube is a measure of the thickness of the paper.

(i) Explain why a source of beta radiation is suitable to monitor the thickness of the paper.

(2)

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(ii) Pm-147 decays by beta decay to an isotope of samarium, Sm.

Complete the decay equation.

(2)

$$^{147}_{61}\text{Pm} \rightarrow \text{.....}\ \text{Sm} + \text{.....}\ \beta^{-} + {}^{0}_{0}\overline{\nu}_{e}$$

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DO NOT WRITE IN THIS AREA

(iii) In a particular paper mill, the Pm source was replaced when the activity of the source had decreased to 0.75% of its initial activity.

Calculate the time that the source had been in use.

half-life of Pm-147 = 2.62 years

(4)

Time source had been in use = ...

(b) The most stable isotope of promethium is Pm-145.

Calculate the binding energy per nucleon for nucleons in a nucleus of Pm-145.
Give your answer in MeV.

mass of a Pm-145 nucleus = 144.913 u
neutron mass = 1.00867 u

(4)

Binding energy per nucleon = ... MeV

(Total for Question 21 = 12 marks)

20: The space probe Galileo was sent into space to study the planet Jupiter. The space probe was powered using plutonium-238.

Plutonium-238 decays to an isotope of uranium by emitting an alpha particle.

(a) Complete the nuclear equation for the decay of plutonium-238.

(2)

$$^{238}_{\ldots\ldots}\mathrm{Pu} \rightarrow {}^{\ldots\ldots}_{92}\mathrm{U} + {}^{\ldots\ldots}_{\ldots\ldots}\alpha$$

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(b) The space probe was powered by the energy released in the decay of plutonium-238.

(i) Show that the energy released in the decay of one nucleus of plutonium-238 is about 5.7 MeV.

mass of plutonium nucleus = 3.9516×10^{-25} kg
mass of uranium nucleus = 3.8851×10^{-25} kg
mass of alpha particle = 6.6399×10^{-27} kg

(4)

(ii) When the space probe was launched, the decay of plutonium-238 produced a power of 550 W.

A website states that there was 1.00 kg of plutonium-238 when the space probe was launched.

Deduce whether the website statement is accurate.

number of atoms in 0.238 kg of plutonium = 6.00×10^{23}
half-life of plutonium-238 = 87.7 years
1 year = 3.15×10^{7} s

(5)

(iii) The space probe took 74 months to travel to Jupiter.

Calculate the power produced when the space probe arrived at Jupiter, due to the decay of plutonium-238.

1 month = 2.63×10^{6} s

(2)

Power produced = ...

(c) Jupiter is much further away from the Sun than Mars is. A space probe to Mars was powered by solar cells.

Suggest why solar cells were **not** suitable for a space probe travelling to Jupiter.

(2)

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(Total for Question 20 = 15 marks)

11 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)

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

(b) The energy released in the decay is 2.6 keV. You may assume that, in this case, the beta particle receives all the emitted energy.

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

(3)

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Speed of β^- particle = ...

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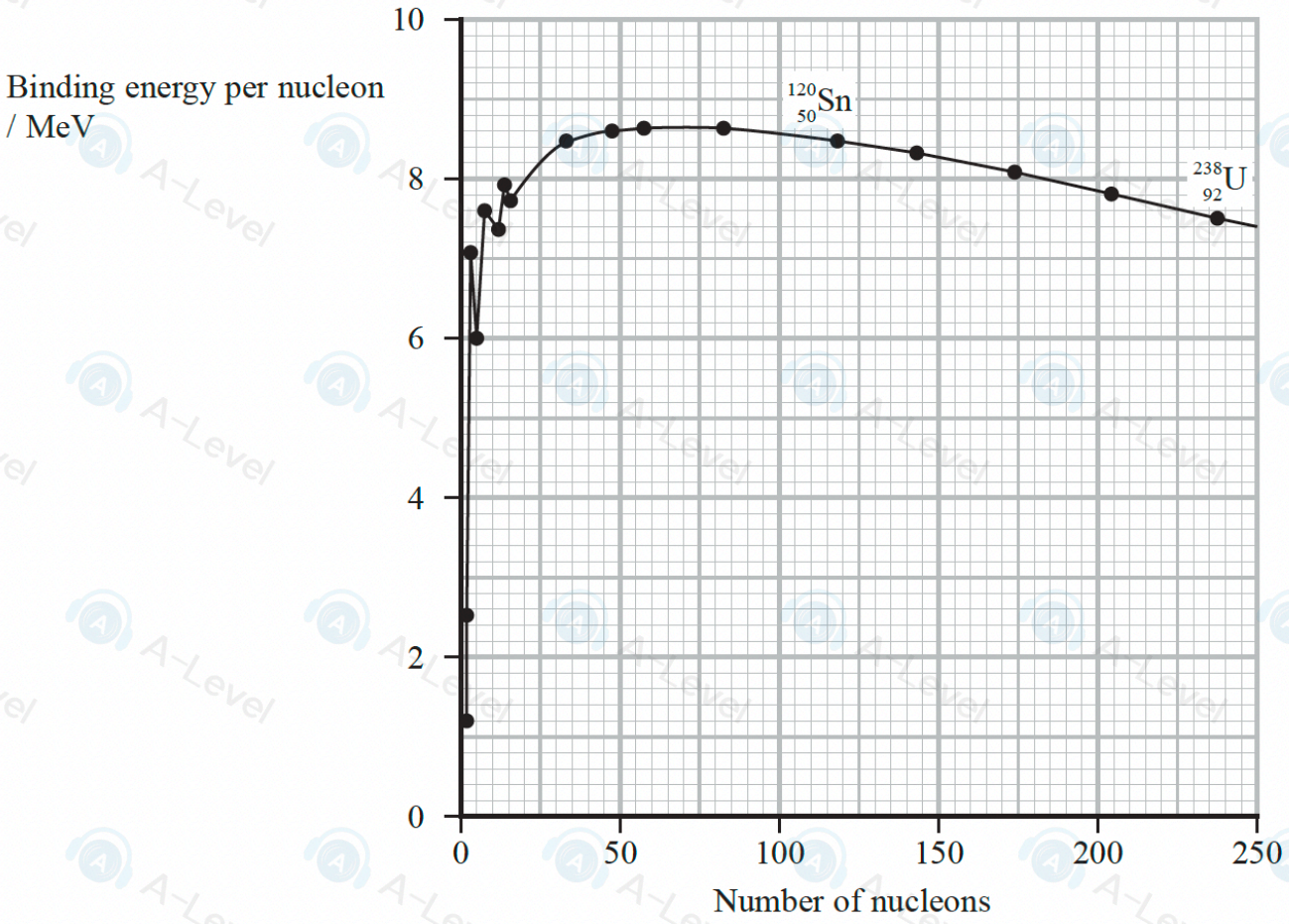
DO NOT WRITE IN THIS AREA

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



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(a) Explain why energy is released when a nucleus undergoes fission.

(2)

(b) A nucleus of ^{238}U undergoes fission. One of the fission products is Sn.

Estimate the energy, in MeV, released in the fission.

You should use values from the graph.

(3)

Energy released = ... MeV

(c) One fission product is strontium–90.

(i) Complete the nuclear equation for the decay of strontium–90.

(2)

$$^{90}_{38}\text{Sr} \rightarrow \text{.....Y} + \text{.....}\beta^- + {}^{0}_{0}\bar{\nu}_e$$

(ii) In Georgia, in December 2001, some men discovered two small canisters in a forest. The canisters were hot and had melted surrounding snow. The canisters were later identified as containing ^{90}Sr.

The activity due to the ^{90}Sr in one canister was measured as 1.295×10^{15} Bq.

Calculate the rate of energy release, in watts, due to the ^{90}Sr in this canister.

energy released in each decay = 0.546 MeV

(3)

Rate of energy release in this canister = ... W

(iii) The authorities claimed that the canisters were 50 years old. The activity of each canister when new was 3.700×10^{15} Bq.

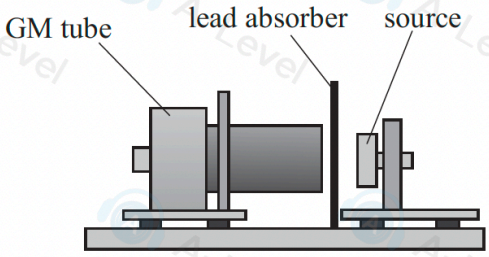
Assess the accuracy of the claim.

half-life of $^{90}Sr = 28.8$ years

(3)

(Total for Question 19 = 13 marks)

14 A student investigated the absorption of gamma radiation by lead, as shown. She used an americium source.



She placed sheets of lead absorber between the source and the GM tube. She recorded the count for 2 minutes for each thickness of absorber.

(a) Americium emits alpha radiation as well as gamma radiation.

State why alpha radiation will not affect the recorded count rate.

(1)

DO NOT WRITE IN THIS AREA

(b) Explain **one** modification to her method that would give a more accurate value for the count rate.

(2)

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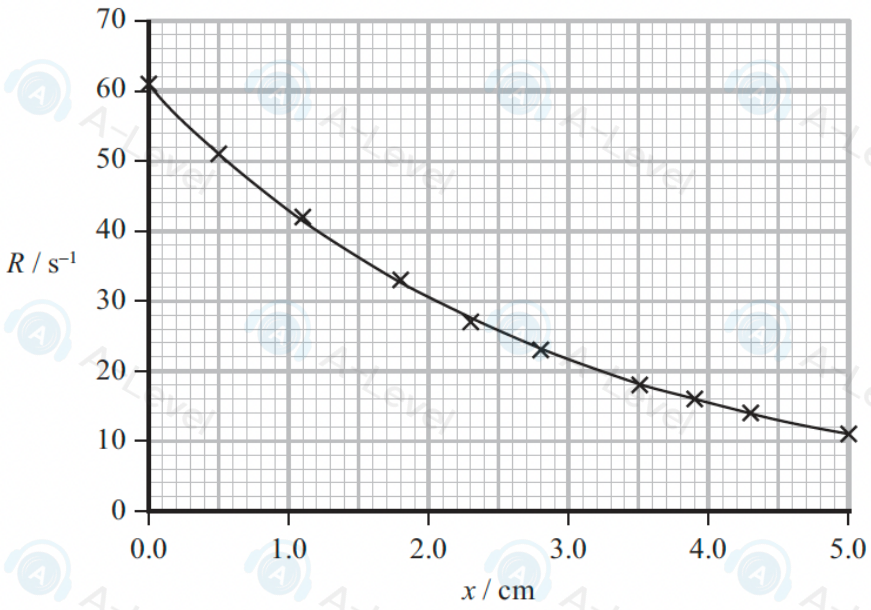
(c) The student plotted a graph of count rate R against thickness x of absorber.
Her graph is shown below.



R varies with x according to the equation

$$R = 60e^{-\mu x}$$

where μ is a constant.

Determine a value for μ.

(3)

μ = ...

(Total for Question 14 = 6 marks)