Nuclear Fusion & Fission

Question Paper

Level	International A Level
Subject	Physics
Exam Board	Edexcel
Topic	Physics from Creation to Collaps
Sub Topic	Nuclear Fusion & Fission
Booklet	Question Paper

Time Allowed: **74 minutes**

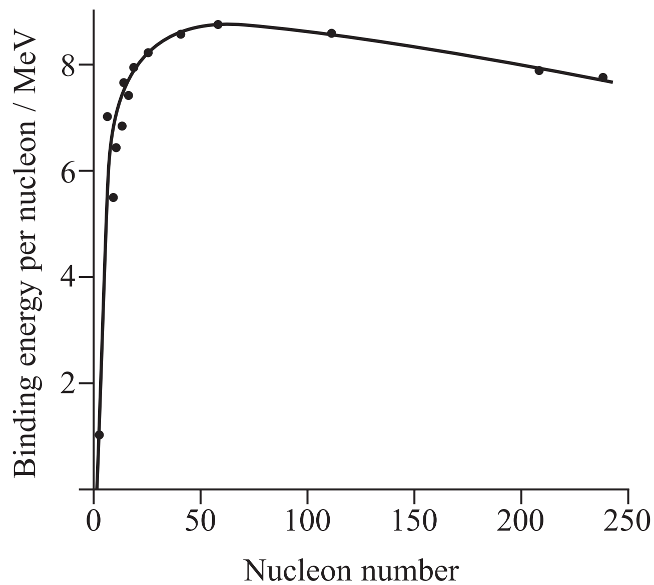
Score: **/61**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 The graph shows how the binding energy per nucleon varies with nucleon number for a range of nuclides.



(a) (i) State what is meant by the binding energy of a nucleus.

(1)

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(ii) Explain why nuclear fusion is only viable as an energy source if light nuclei are used.

(2)

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*(b) Outline the conditions necessary for viable fusion to occur and explain why the interiors of stars are ideal for this.

(4)

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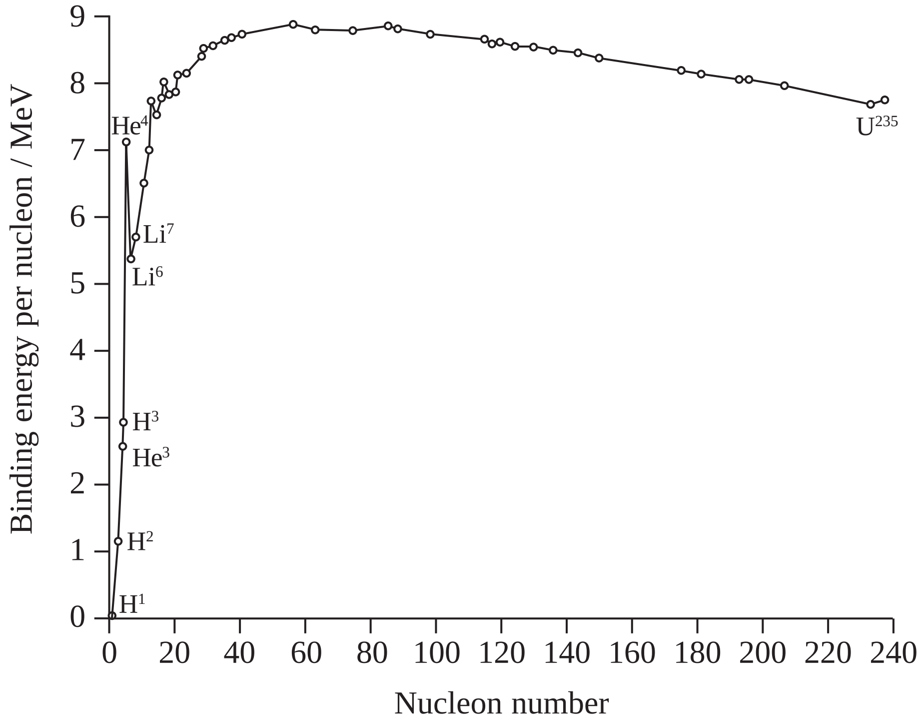
(Total for Question 1 = 7 marks)

2 The graph shows how the binding energy per nucleon varies with nucleon number for a range of isotopes.



(a) Explain why an alpha particle (He^4) is more likely than any other small nucleus to be emitted from a large unstable nucleus.

(2)

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(b) Explain why fission reactors use isotopes such as U-235 as fuel.

Your answer should include reference to the graph.

(3)

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(Total for Question 2 = 5 marks)

3 (a) Stars are formed from gas clouds within galaxies. As the gas cloud contracts, an extremely dense core at a very high temperature is formed. Within the core the hydrogen begins to fuse into helium.

(i) Explain why the core must be extremely dense and at a very high temperature for fusion to take place.

(2)

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(ii) As the gas cloud contracts the internal energy of the system increases.

Explain how energy conservation applies to the system during this period of contraction.

(2)

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(iii) Explain how the fusion of hydrogen into helium in the core enables large amounts of energy to be released.

(3)

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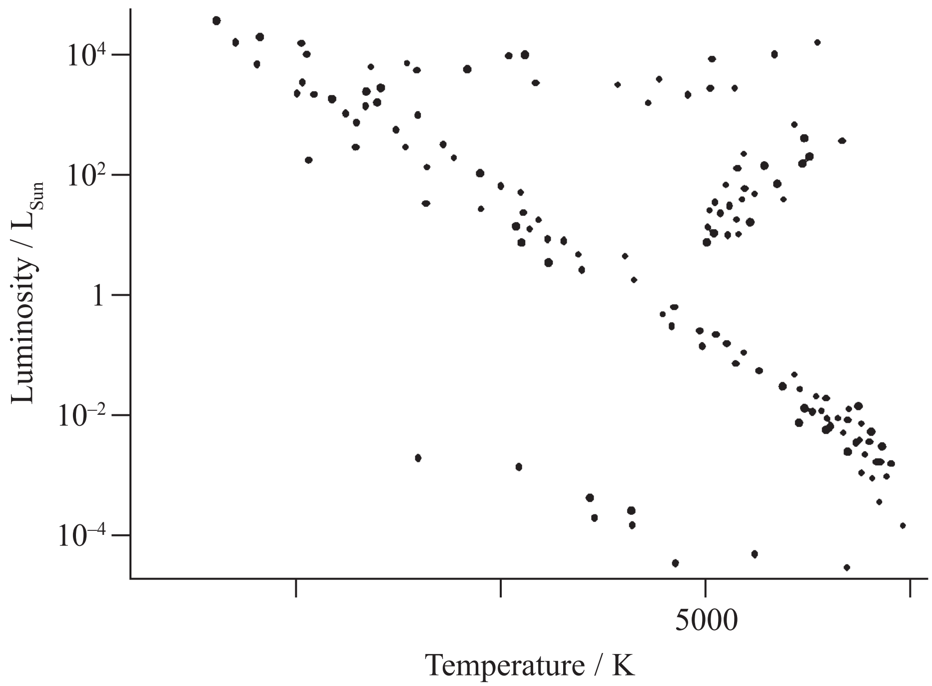
(b) The Hertzsprung-Russell diagram is used by astronomers to show the relationship between luminosity and temperature for stars.

(i) Complete the temperature scale on the Hertzsprung-Russell diagram.

(2)



(ii) The table shows the luminosity and temperature of a range of stars.

Star	Luminosity / L_{Sun}	Temperature / K	Star type
A	0.001	8 000	
B	0.1	4 400	main sequence
C	160	3 600	red giant
D	160	13 600	

Complete the table.

(2)

(iii) On the Hertzsprung-Russell diagram indicate where each of the stars A, B, C, and D is located.

(2)

(c) Polaris is the nearest variable star to the Earth and is an example of a standard candle.

(i) State what astronomers mean by a standard candle.

(1)

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*(ii) Recent measurements indicate that Polaris may be significantly closer to the Earth than previously thought.

Explain why this would have a significant impact on our estimation of the age of the universe.

(4)

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(Total for Question 3 = 18 marks)

4 In the early part of the 20th century the Nobel Prize winner George de Hevesy made the first use of a radioactive tracer. He studied the transportation of a small sample of the isotope lead-212 in a broad bean plant.

(a) Complete the nuclear equation for the decay of Pb-212.

(2)

$$^{212}_{82}\text{Pb} \rightarrow {}^{\dots}_{\dots}\text{Bi} + {}^{\dots}_{\dots}\beta^{-}$$

(b) The half life of ^{212}Pb is 3.83×10^4 s.

(i) State what is meant by the term half life.

(1)

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(ii) Show that the decay constant of ^{212}Pb is about 2×10^{-5} s^{-1} and hence calculate the fraction of the original sample that will remain after a time of 1 day (86 400 s).

(4)

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Fraction remaining = ...

(iii) The energy released in this decay is 9.12×10^{-14} J.

Calculate the decrease in mass in kg that occurs in the decay of one Pb-212 atom.

(2)

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Decrease in mass = ... kg

(c) The isotope of bismuth produced by the decay of Pb-212 is itself radioactive. It produces both alpha and beta particles with an overall half life which is much shorter than that of the lead.

Discuss how the decay of the bismuth isotope could affect the measurements made on the activity of the broad bean plant.

(2)

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(d) George de Hevesy also discovered the element hafnium, which is a good absorber of neutrons. Hafnium is sometimes used to control the rate of fission in a nuclear fission reactor.

Suggest why a material which is a good absorber of neutrons would enable the rate of fission to be controlled.

(1)

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(e) Fusion reactors could become a better alternative to fission reactors.

Explain why this is the case and give reasons why practical fusion reactors are still only at the experimental stage.

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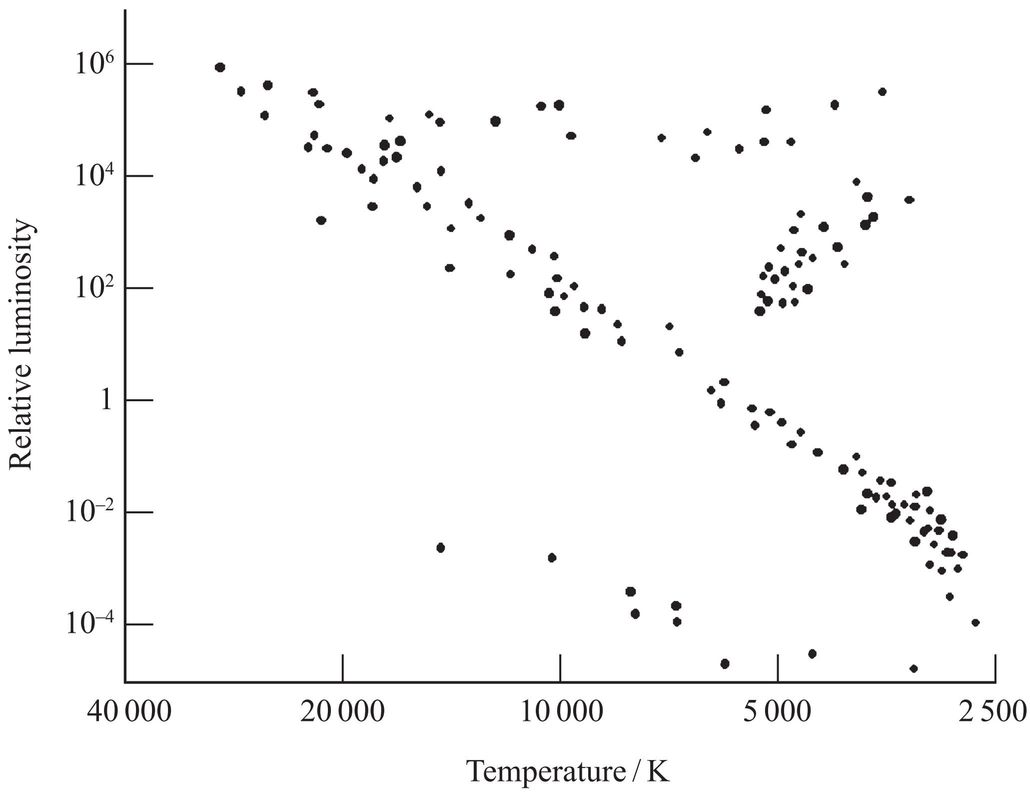
(Total for Question 4 = 17 marks)

5 Astronomers have been watching an old star suddenly stir back into new activity.

(a) They are studying a star known as "Sakurai's Object", an old white dwarf that has run out of hydrogen fuel for nuclear fusion reactions in its core. Astronomers now believe that some such stars can undergo a final burst of fusion.

Computer simulations indicate that convection would bring hydrogen in from the star's outer regions, causing a brief flash of new nuclear fusion. This produces a sudden increase in the size and brightness of the star.

The diagram below is a Hertzsprung-Russell diagram.



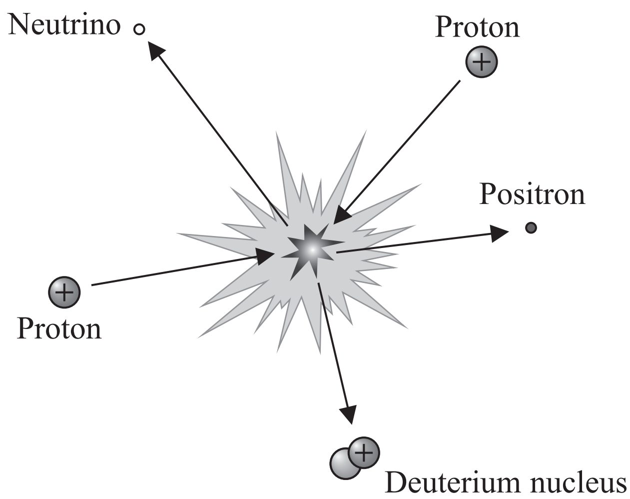
(i) On the diagram, mark a likely position for Sakurai's Object before the final burst of fusion took place. Label this X.

(1)

(ii) On the diagram, mark a likely position for Sakurai's Object during the final burst of fusion. Label this Y.

(1)

(b) During the hydrogen fusion process the first stage is the fusion of two protons to form a deuterium nucleus.



Particle	Mass / MeV/c^2
Deuterium nucleus	1875.62
Electron	0.51
Proton	938.27

(i) Complete the nuclear equation to represent the fusion of two protons to form a deuterium nucleus.

(1)

$$^{1}_{1}\text{p} + {}^{1}_{1}\text{p} \rightarrow$$

(ii) Calculate the energy, in joules, emitted in this first stage.

(3)

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Energy emitted = ... J

(c) For fusion to take place in the core of a star there must be a very high density of hydrogen at an extremely high temperature.

Explain why.

(3)

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*(d) The quest for a practical nuclear fusion reactor to contribute to our electrical power demands is hindered by the extreme conditions necessary. Nuclear fission already supplies a large fraction of this demand.

Discuss the potential advantages of nuclear fusion, compared with nuclear fission, as a means of supplying our power demands.

(5)

(Total for Question 5 = 14 marks)