PEARSON EDEXCEL IAL PHYSICS · YPH11

PHYSICS



EXAM QUESTION PACK

UNIT 5: NUCLEAR DECAY

SCORE	PERCENTAGE
/38	%

STEMUP

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Q1.

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.

(3)

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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.

(2)

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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.

(2)

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(Total for question = 7 marks)

Q2.

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.

(4)

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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

(4)

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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

(4)

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Number of actinium atoms after 7.0 days = ...

(Total for question = 14 marks)

Q3.

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.

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

(2)

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

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

(2)

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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

(3)

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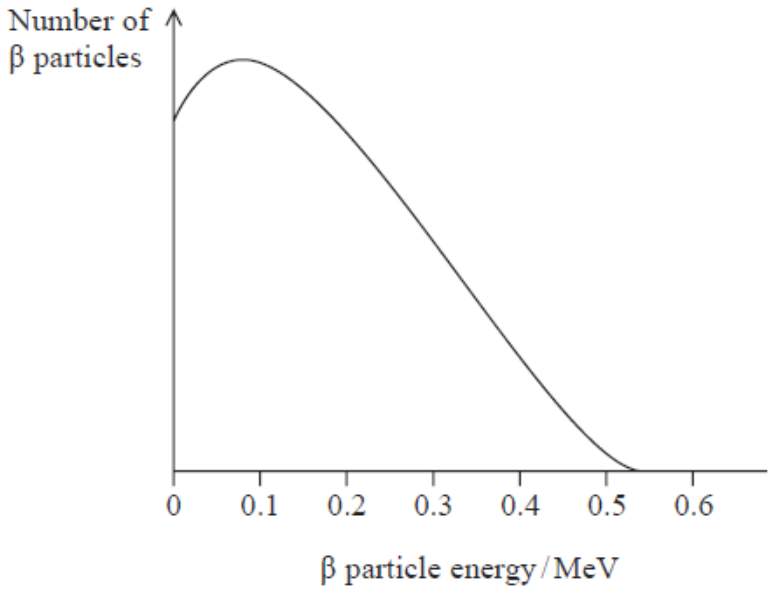
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(Total for question = 7 marks)

Q4.

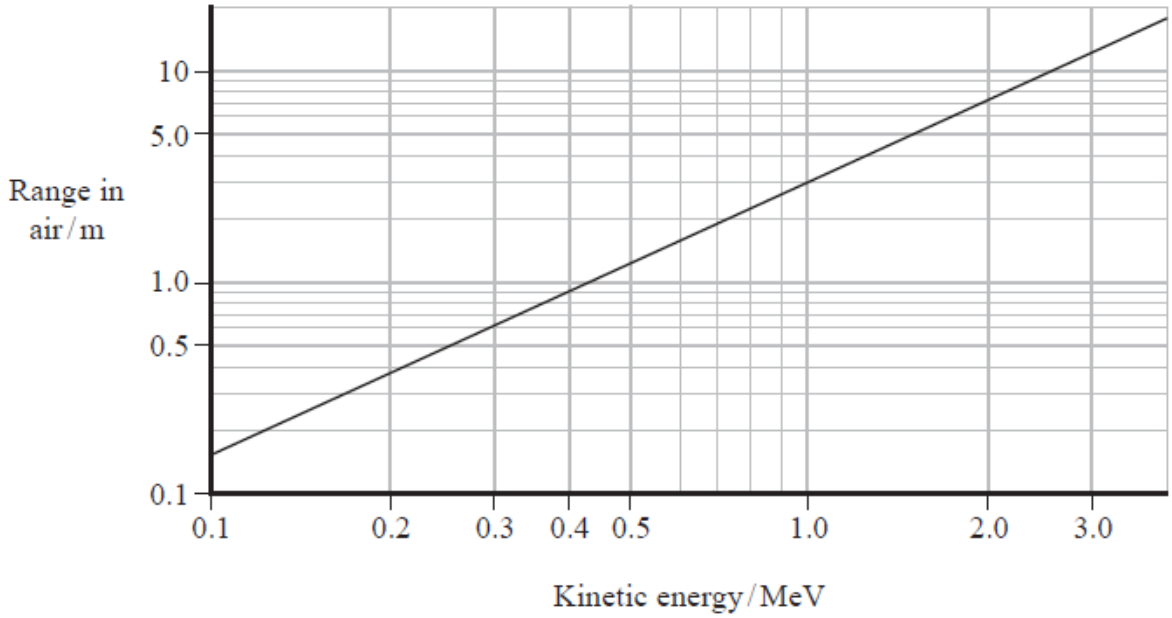
Strontium-90 is commonly used in schools to demonstrate the properties of β particles.

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)

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 ☒.

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

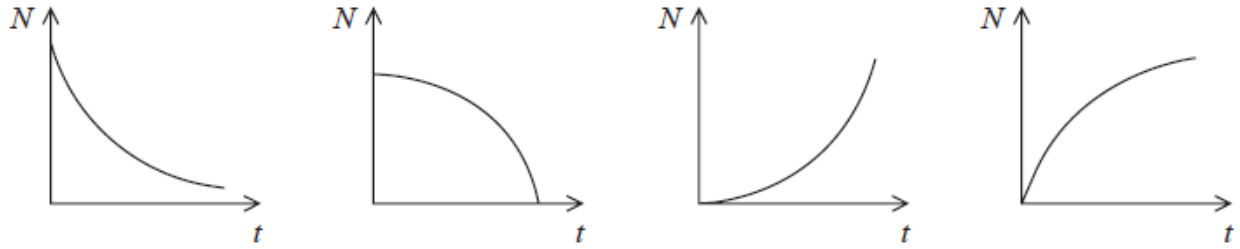
(Total for question = 1 mark)

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 ☒.

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**

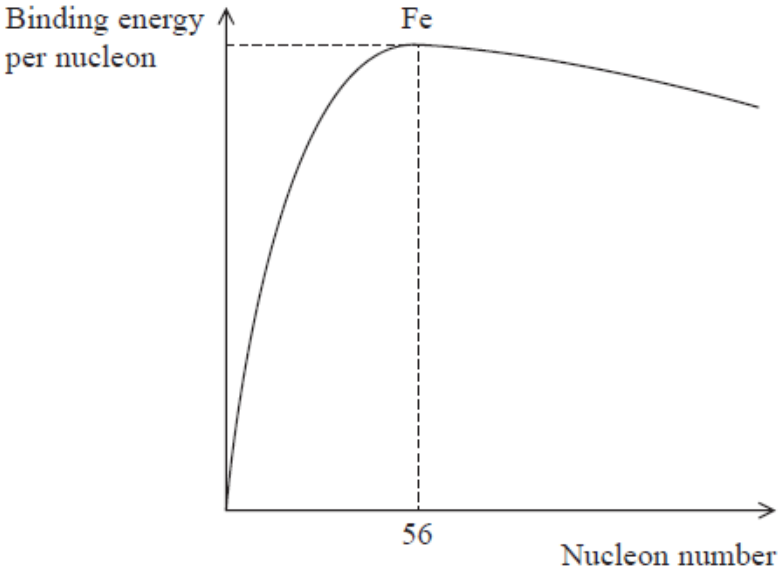
☒ **D**

(Total for question = 1 mark)

Q7.

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)

Q8.

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)

Q9.

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)

Mark Scheme

Q1.

Question Number	Answer		Mark
(a)(i)	Mass difference calculation	(1)	3
	Use of $\Delta E = c^2 \Delta m$	(1)	
	$\Delta E = 8.7 \times 10^{-13}$ (J)	(1)	
	Example of calculation $\Delta m = (3.48572 - 3.41918 - 0.0664437) \times 10^{-25}\ \text{kg} = 9.63 \times 10^{-30}\text{kg}$ $\Delta E = (3.00 \times 10^8\ \text{m s}^{-1})^2 \times 9.63 \times 10^{-30}\ \text{kg} = 8.67 \times 10^{-1}\ \text{J}$		
(a)(ii)	Use of $E_k = \frac{1}{2}mv^2$	(1)	2
	$v = 1.6 \times 10^7\ \text{m s}^{-1}$ (allow ecf from (a)(i))	(1)	
	Example of calculation $0.98 \times 8.67 \times 10^{-1}\ \text{J} = \frac{1}{2} \times 6.64437 \times 10^{-27}\ \text{kg} \times v^2$ $\therefore v = \sqrt{\frac{2 \times 0.98 \times 8.67 \times 10^{-13}\ \text{J}}{6.64437 \times 10^{-27}\ \text{kg}}} = 1.60 \times 10^7\ \text{m s}^{-1}$		
(b)	Momentum must be conserved (in the decay)	(1)	2
	The lead nucleus must recoil after the decay **Or** the lead nucleus moves in the opposite direction to the alpha particle	(1)	
	Total for question		7

Q2.

Question Number	Answer		Mark
(a)	Top row correct	(1)	
	Bottom row correct	(1)	2
	Example of calculation		
	$^{225}_{89}\text{Ac} \rightarrow {}^{221}_{87}\text{Fr} + {}^{4}_{2}\alpha$		
(b)	Use of 1 u = 1.66×10^{-27} kg	(1)	
	Use of $\Delta E = c^2 \Delta m$	(1)	
	Use of 1 J = 1.6×10^{-19} eV	(1)	
	1 u = 934 (MeV)	(1)	4
	Example of calculation		
	$\Delta E = (3.0 \times 10^8 \text{ m s}^{-1})^2 \times 1.66 \times 10^{-27} \text{ kg} = 1.494 \times 10^{-10} \text{ J}$		
	$\therefore \Delta E = \frac{1.494 \times 10^{-10} \text{ J}}{1.6 \times 10^{-13} \text{ J MeV}^{-1}} = 934 \text{ MeV}$		
(c)	Use of 1 u = 934 MeV (ecf from (b) [Accept calculation from first principles]	(1)	
	The mass of the Fr nucleus is much greater than the mass of the α	(1)	
	Momentum is conserved so (recoil) velocity of Fr nucleus is much less than the velocity of the α	(1)	
	So the kinetic energy of the α is much greater than the kinetic energy of the Fr **Or** (after the decay) the α has most of the kinetic energy [MP4 dependent upon MP2 or MP3]	(1)	
	OR		
	Use of 1 u = 934 MeV (ecf from (b) [Accept calculation from first principles]	(1)	
	Mathematical statement of momentum conservation	(1)	
	Use of $E_k = \frac{p^2}{2m}$ **Or** use of $E_k = \frac{1}{2}mv^2$ **and** $p = mv$	(1)	
	E_k calculated and statement that E_k is just less than 5.9 MeV **Or** E_k calculated and statement that α has most of the kinetic energy	(1)	4
	Example of calculation		
	$\Delta E = 6.35 \times 10^{-3}$ u × 934 MeV u^{-1} = 5.93 MeV		
	[5.91 MeV if "show that" value used]		

(d)	Use of $\lambda\, t_{1/2} = \ln 2$	(1)	
	Use of $A = -\lambda N$	(1)	
	Use of $N = N_0 e^{-\lambda t}$	(1)	
	$N = 5.6 \times 10^{13}$	(1)	**4**
	Example of calculation $\lambda = \frac{\ln 2}{9.9 \times 24 \times 3600\ \text{s}} = 8.10 \times 10^{-7}\text{s}^{-1}$ $N = \frac{7.4 \times 10^{7}\text{s}^{-1}}{8.10 \times 10^{-7}\text{s}^{-1}} = 9.13 \times 10^{13}$ $N = 9.13 \times 10^{13} \times e^{-8.10\times10^{-7}\text{s}^{-1}\times7.0\times24\times3600\ s} = 5.59 \times 10^{13}$		
	Total for question		**14**

Q3.

Question Number	Answer		Mark
(a)	Top line correct	(1)	
	Bottom line correct	(1)	**2**
	Example of calculation $^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}$		
(b)	**Any TWO from:**		
	Both have the same mass	(1)	
	Both are leptons	(1)	
	Both are fundamental particles	(1)	
	Both have the same magnitude charge	(1)	
	Both are deflected in electric/magnetic fields	(1)	
	Both are (weakly) ionising	(1)	**2**

(c)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$	(1)	**3**
	Use of $A = A_0 e^{-\lambda t}$ to find time for activity to fall to background level	(1)	
	$t = 8.6 \times 10^9$ years, so claim is incorrect	(1)	
	OR		
	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$	(1)	
	Use of $A = A_0 e^{-\lambda t}$ to find activity after 9×10^9 years	(1)	
	$A = 0.33$ Bq so claim is incorrect	(1)	
	<u>Example of calculation</u> $\lambda = \frac{\ln 2}{1.25 \times 10^9 \text{ years}} = 5.55 \times 10^{-10} \text{ year}^{-1}$ $\ln\left(\frac{0.42 \text{ Bq}}{48.6 \text{ Bq}}\right) = -5.55 \times 10^{-10} \text{ years}^{-1} \times t$ $\therefore t = \frac{-4.75}{5.55 \times 10^{-10} \text{ years}^{-1}} = 8.56 \times 10^9 \text{ years}$		
	Total for question		**7**

Q4.

Question Number	Answer		Mark
	Max kinetic energy read from graph	(1)	
	Use of 15.6 eV to calculate number of nitrogen molecules ionised	(1)	
	Use of 250 to calculate range of β particle	(1)	
	Range of β particle read from graph	(1)	
	Comparison of their two ranges with conclusion	(1)	
	OR		
	Max kinetic energy read from graph	(1)	
	Use of 15.6 eV to calculate number of nitrogen molecules ionised	(1)	
	Range of β particle read from graph	(1)	
	Use of range to calculate number of molecules ionised	(1)	
	Comparison of their two numbers of molecules with conclusion	(1)	**5**
	<u>Example of calculation</u> Maximum E_k = 0.52 MeV→ 0.55 MeV $N = \frac{5.3 \times 10^5 \text{eV}}{15.6 \text{ eV}} = 3.40 \times 10^4$ $\text{Range} = \frac{3.40 \times 10^4}{250 \text{ cm}^{-1}} = 136 \text{ cm} = 1.36 \text{ m}$ Range of β particle = 1.2 m → 1.4 m		
	Total for question		**5**

Q5.

Question Number	Answer	Mark
	D is the correct answer, as the temperature must be very high for the nuclei to come close enough for fusion and the density must be very high for the rate of collision of nuclei to be sufficient to sustain fusion.	**(1)**

Q6.

Question Number	Answer	Mark
	D is the correct answer A is not the correct answer, as this graph shows N decreasing with t B is not the correct answer, as this graph shows N decreasing with t C is not the correct answer, as this graph shows an increasing rate of change of N	**(1)**

Q7.

Question Number	Answer	Mark
	D is the correct answer, A is incorrect, as 56Fe is the most stable isotope B is incorrect, as the graph shows the binding energy per nucleon C is incorrect, as high mass nuclei could be fused as long as energy is supplied	**(1)**

Q8.

Question Number	Answer	Mark
	C is the correct answer, as the activity halves in each half-life period	**(1)**

Q9.

Question Number	Answer	Mark
	B is the correct answer A is incorrect, as background count rate varies from place to place C is incorrect, as the background count is not constant D is incorrect, as some detector are more sensitive than others	(1)