Nuclear Physics

Mark Scheme 4

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Particle & Nuclear Physics
Sub Topic	Nuclear Physics
Paper Type	Theory
Booklet	Mark Scheme 4

Time Allowed: **71 minutes**

Score: **/59**

Percentage: **/100**

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

1	(a (i)	Fe shown near peak	A1	[1]
	(ii)	Zr shown about half-way along plateau	A1	[1]
	(iii)	H shown at less than 0.4 of maximum height	A1	[1]
	(b) (i)	heavy / large nucleus breaks up / splits	M1	
		into two nuclei / fragments of approximately equal mass	A1	[2]
	(ii)	binding energy of nucleus = $B_E \times A$	B1	
		binding energy of parent nucleus is less than sum of binding energies of fragments	B1	[2]
2	(a)	energy required to separate nucleons in a <u>nucleus</u>	M1	
		to infinity	A1	[2]
	(b)	1u = 1.66×10^{-27} kg		
		$E = mc^2$	C1	
		$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$	M1	
		$= 1.49 \times 10^{-10}$ J		
		$= (1.49 \times 10^{-10}) / (1.6 \times 10^{-13})$	M1	
		= 930 MeV	A0	[3]
	(c) (i)	Δm = 2.0141u – (1.0073 + 1.0087)u		
		$= -1.9 \times 10^{-3}$ u	C1	
		binding energy $= 1.9 \times 10^{-3} \times 930$		
		=1.8 MeV	A1	[2]
	(ii)	Δm = (57 × 1.0087u) + (40 × 1.0073u) – 97.0980u	C1	
		= (–)0.69 u		
		binding energy per nucleon = (0.69 × 930) / 97	C1	
		= 6.61 MeV	A1	[3]
3	(a)	splitting of a heavy nucleus (*not atom/nuclide*)	M1	
		into two (lighter) nuclei of <u>approximately same mass</u>	A1	[2]
	(b)	$^{1}_{0}n$		
		$^{4}_{2}He$ (*allow* $^{4}_{2}\alpha$)	M2	
		$^{7}_{3}Li$	A1	[3]
	(c)	emitted particles have kinetic energy	B1	
		range of particles in the control rods is short / particles stopped in rods / lose kinetic energy in rods	B1	
		kinetic energy of particles converted to thermal energy	B1	[3]

4	**(a)**	ability to do work	B1	
		as a result of the position/shape, etc. of an object	B1	[2]
	(b) (i) 1	$\Delta E_{gpe} = GMm / r$	C1	
		$= (6.67 \times 10^{-11} \times \{2 \times 1.66 \times 10^{-27}\}^2) / (3.8 \times 10^{-15})$	C	
		$= 1.93 \times 10^{-49}$ J	A1	[3]
	2	$\Delta E_{epe} = Qq / 4\pi\varepsilon_0 r$	C1	
		$= (1.6 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} \times 3.8 \times 10^{-15})$	C	
		$= 6.06 \times 10^{-14}$ J	A1	[3]
	(ii)	idea that $2E_K = \Delta E_{epe} - \Delta E_{gpe}$	B1	
		$E_K = 3.03 \times 10^{-14}$ J		
		$= (3.03 \times 10^{-14}) / 1.6 \times 10^{-13}$	M1	
		$= 0.19$ MeV	A0	[2]
	(iii)	fusion may occur / may break into sub-nuclear particles	B1	[1]
5	**(a)**	momentum conservation hence momenta of photons are equal (but opposite)	M1	
		same momentum so same energy	A1	[2]
	(b) (i)	$(\Delta)E = (\Delta)mc^2$	C1	
		$= 1.2 \times 10^{-28} \times (3.0 \times 10^8)^2$		
		$= 1.08 \times 10^{-11}$ J	A1	[2]
	(ii)	$E = hc / \lambda$		
		$\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^8) / (1.08 \times 10^{-11})$	C	
		$= 1.84 \times 10^{-14}$ m	A1	[2]
	(iii)	$\lambda = h / p$		
		$p = (6.63 \times 10^{-34}) / (1.84 \times 10^{-14})$	C	
		$= 3.6 \times 10^{-20}$ N s	A1	[2]

6 **(a (i)** number = $(5.1 \times 10^{-6} \times 6.02 \times 10^{23}) / 241$ C1
= 1.27×10^{16} A1 [2]

(ii) $A = \lambda N$ C1
$5.9 \times 10^{5} = \lambda \times 1.27 \times 10^{16}$
$\lambda = 4.65 \times 10^{-11}\ s^{-1}$ A1 [2]

(iii) $4.65 \times 10^{-11} \times t_{½} = \ln 2$ C1
$t_{½} = 1.49 \times 10^{10}$ s
= 470 years A1 [2]

(b) sample / activity would decay appreciably whilst measurements are being made B1 [1]

7 **(a)** neutron is a single nucleon / particle ..... B1 [1]

(b) binding energy = $4 \times 7.07 \times 1.6 \times 10^{-13}$ C1
= 4.52×10^{-12} J
binding energy = $c^2 \Delta m$ C1
$4.52 \times 10^{-12} = (3.0 \times 10^{8})^2 \times \Delta m$
$\Delta m = 5.03 \times 10^{-29}$ kg ..... A1 [3]

(c) (fusion *do not allow fussion*) ..... B1 [1]

(ii) $(2 \times 1.12) + 3x = 28.28$ C1
…... –17.7 ..... C1
x = 2.78 MeV per nucleon ..... A1 [3]
(*use of +17.7 gives x = 14.6 MeV, allow 1 mark only*)

[Total: 8]

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