RECOGNISING ACHIEVEMENT

A2 NUCLEAR + PARTICLE

Mark Scheme 2825/4

January 2004

Question	Expected Answers	Marks
1 (a)	strong /force interaction is zero	1 [1]
(b)	$F_E = Q_1 Q_2/(4\pi\varepsilon_0 r^2)$; $= (1.6 \times 10^{-19})^2/[4\pi \times 8.85 \times 10^{-12} \times (0.82 \times 10^{-15})^2]$; $= 3.4 \times 10^2$ N ; ans.	1 1 1 [3]
(c)(i)	indicates slightly larger separation; explanation: protons repel; (1) because they have like charges; (1) hence strong force is attractive; (1) relates to graph eg below axis, *F* is attractive; (1) any 3	1 3 [4]
(ii)	(approx.) 3.4×10^2 N; reason: because strong force must balance electrostatic / repulsive force;	1 1 [2]

2(a)	nucleus absorbs / captures a neutron ;	1	
	meaning of thermal neutron ; (1)		
	new nucleus splits into two (roughly equal) parts ;	1	
	energy is released in fission ; (1)		
	new nuclei (are unstable and) emit neutrons ; (1)		
	but need moderating / slowing down ; (1)		
	emitted neutrons can cause further nuclear reactions, hence chain / self-sustaining reaction ;	1	
	suitable equations: eg $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U$		
	$^{236}_{92}U \rightarrow X + Y$		
	X (or Y) $\rightarrow$ W + neutrons		
	any equation; (1)	3	
	any 3		
(b) (i) 1	handling: use of protective clothing eg lead aprons etc (1)		
	use of protective screen eg work with material in a box (1)		
	keep materials at a distance eg use tongs (1)		
	any 1	1	
2	storage: high level waste kept under water (1)		
	use of lead (not 'metal') / concrete canisters (1)		
	warning signs / accurate record-keeping (1)		
	store in remote place ie where people won't go (1)		
	allow time for materials to decay (1)		
	any 1	1	
3	disposal: burial of material / storage underground (1)		
	vitrification or AW (1)		
	importance of site suitability eg no leaching / earthquakes (1)		
	storage in impervious / inert containers eg stainless steel (1)		
	any 1	1	[3
(ii) 1	3 justifications in terms of (as appropriate) (1):		
2	gamma radiation absorbed by lead / concrete (1)		
	either α–radiation absorbed by air/attenuated by effect of inverse square law *or* β–particlesabsorbed by (eg) several mm of metal (1)		
3	decay of radioisotopes over time *or* appropriate reference to half life (1)		
	(human) exposure is cumulative, so need to keep to a minimum (1)		
	3 appropriate reasons	3	[3

3(a)(i)	$E_k = 2.1 \times 10^{-23} \times 3 \times 10^8 n = 6.3 \times 10^{-15} n$ J so ke of one particle = 6.3×10^{-15} J	1	[1]
(ii)	(no) idea of random motion / spread of velocities / energies / this value is only an average value	1	[1]
(b)(i)	nuclei both have same (kind of) / positive charge ; so they repel	1 1	[2]
(ii)	graph: negative gradient throughout ; curved correctly and reaches zero ;	1 1	[2]
(iii)	adds ke's ; ke is <u>all</u> converted to pe / states law of energy / states no extra work done ;	1 1	[2]
(iv)	$r = Q_1 Q_2 / (4\pi\varepsilon_0 E_P) = (1.6 \times 10^{-19})^2 / (4\pi\, 8.85 \times 10^{-12} \times 1.3 \times 10^{-14})$; subs. $= 1.8 \times 10^{-14}$ m ; ans.	1 1	[2]
(c)	${}^2_1H + {}^2_1H \rightarrow {}^3_2He + {}^1_0n$ (+energy)	1	[1]

4(a)	two dees: correct shape and position (need not be labelled) ; connected to an alternating supply - clear on sketch or labelled ; magnetic field at right angles to sketch / stated in account; proton accelerated by E field between dees / attracted / repelled by negatively / positively charged dee ; polarity of dees changes every time particle emerges from a dee / crosses the gap ; (1) magnetic force on proton, perpendicular to motion ; (1) acts as centripetal force / has no component along direction of motion ; (1) hence (proton has) constant speed inside dee ; (1) spiral track consistent with B direction (1) any 3	1 1 1 1 3
(b) (i)	$T = s / v$ $= \pi R /(BQR/m) = \pi m / (BQ)$ or $2\pi R /(BQR/m) = 2\pi m / (BQ)$ $f = 1/2T$ or $f = 1 / T$ $(= BQ / (2\pi m))$ $(= BQ / (2\pi m))$ algebra	1 1 1
(ii)	$f = 1.2 \times 1.6 \times 10^{-19} / (2\pi \times 1.67 \times 10^{-27}) = 1.8(3) \times 10^{7}$ Hz ans.	1
(c)	*or* Q/m is constant / Q and m are both constant ;	1

5(a)(i)	every particle has (corresponding) antiparticle ; (1) particle and antiparticle have opposite charges but sams mass ; (1) matter and antimatter annihilate one another (when they collide) ; (1) any 2	2	[2]
(ii)	positron e^+ *or* β^+ *or* ${}^0_1e$ or ${}^0_1\beta$	1	[1]
(b)(i)	$e^- + e^+ = 2\gamma$;	1	[1]
(ii)	$E = mc^2$; $= 2 \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2$ (= 1.64×10^{-13} J) $E = 2hf$; $f = 1.64 \times 10^{-13} / (2 \times 6.63 \times 10^{-34}) = 1.24 \times 10^{20}$ Hz ; ans.	1 1 1	[3]
(c)(i)	final energy = 2 + 5 x 3 = 17 MeV ans ; (allow 2 + 3 + 5 x 3 = 20) explanation: electron gains 3 MeV (of energy) between one cylinder / electrode and the next (and 3.0 MeV on entering first cylinder) ;	1 1	[2]
(ii)	sketch: two arrows, same length at equal angles, <90°, to forward direction (can be both along line of action) ; explanation: resultant mtm. must be along direction / path of original electron (*or* AW) ;	1 1	[2]
(iii)	electron accelerates / speed increases ; (electron) spends equal time in each electrode;	1 1	[2]

6(a)	proton numbers correct Se 34: Br 35: Kr 36 neutron numbers correct Se 45: Br 44: Kr 43 -1 any error	1
(b)	**1.** β^- / electron (and (electron) antineutrino) **2.** β^+ / positron (and (electron) neutrino) 1 and 2 answers reversed gets 1/2	1 1
(c)(i)	${}^{79}_{37}Rb \rightarrow {}^{79}_{36}Kr + {}^{0}_{1}e + {}^{(0)}_{(0)}\upsilon$ β^+ *or* e^+ gets 1/2 only omits ν, 1/2 only	2
(ii)	weak force / interaction	1
(iii)	78.9240 - 78.9201 = 0.0039 u allow 0.0039 - positron mass = 0.00335u	1
(iv)	energy = mc^2 $= 0.0039 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 5.8(3) \times 10^{-13}$ J (*or:* $E = 0.0039 \times 931$ MeV (= 3.63) = $3.63 \times 1.6 \times 10^{-13}$ J = 5.8×10^{-13} J)	1 1 1
(v)	most taken by neutrino / beta particle ; because these particle(s) much less massive / because of application of . mtm. law ;	1 1

7(a)(i)	Idea of zig-zag path 3-5 reflections, i = r, reflection at boundary Refractive index of light guide > air (allow denser) Provided $i \geq C$, TIR occurs.	Any 3	1 1 1	 [3]
(ii)	$\sin C = 1/n$ $C = \sin^{-1}(1/1.58) = 39.3°$.		1 1	 [2]
(b)(i) (ii)	$E = hc/\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8}/413 \times 10^{-9}$ $= 4.82 \times 10^{-19}/1.6 \times 10^{-19} = 3.01$ eV 10^4 photons = 3.01×10^4 eV % conversion $= 3.02 \times 10^4 \times 100\%/1.5 \times 10^6 = 2\%$	Photon energy eV conversion	1 1 1 1	 [2] [2]
(c)(i) (ii) (iii)	$hc/\lambda = 2.2 \times 1.6 \times 10^{-19}$ $\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8}/(2.2 \times 1.6 \times 10^{-19})$ = 566 nm the work function is greater than the photon energy / no photoelectron emission $hf = \phi + ½m_e v_{max}^2$ $hf - \phi = (3.02 - 2.2) \times 1.6 \times 10^{-19} = 1.31 \times 10^{-19}$ J $v_{max} = \sqrt{(2 \times 1.31 \times 10^{-19}/9.1 \times 10^{-31})} = (5.0\text{-}5.4) \times 10^5$ ms^{-1}	 560- 570 nm Or equivalent Or $hf = \phi$ + KE Omit eV conversion: 2/3 KE = 3eV or 2.2eV: 1/3	1 1 1 1 1 1	 [2] [1] [3]
(d)(i) (ii)	3^{12} = 531000 $Q = ne = 531000 \times 1.6 \times 10^{-19} = 8.5 \times 10^{-14}$ C $I = Q/t = 8.5 \times 10^{-14} / 3 \times 10^{-9}$ $= 2.8 \times 10^{-5}$ A	Allow 3^{13} = 1590000 Q=e: 1/3	1 1 1 1 1	 [2] [3]