RECOGNISING ACHIEVEMENT

A2 Nuclear + Particle

Mark Scheme 2825/04
June 2004

Question	Expected Answers	Marks
1 (a)	number of nucleons (in nucleus) / nucleon number / number of neutrons and protons / mass number NOT atomic number	1 [1]
(b)	one axis labelled, curved in correct sense and passes through origin; curve continues with positive gradient; (mark lost if line becomes horizontal or negative gradient) allow graph of r *vs* $A^{1/3}$ straight line through origin for 2/2 unlabelled / wrong axes gets 0/2	1 1 [2]
(c)(i)	cubes both sides of equation to get $r^3 = r_0^{\,3}A$; multiplies both sides by $4\pi/3$; allow reverse argument: divides by $4\pi/3$ then takes cube root	1 1 [2]
(ii)	volume of nucleus volume of a nucleon / proton / neutron / hydrogen nucleus	1 1 [2]
(d)	$m = Am_0$ *or* $m = Am_0$ - mass defect or equivalent	1 [1]
(e)	density of nucleus *independent* of A ; (1) because mass and volume both increase by same factor / A *or* writes expression for density of each, so it is clear that A cancels; (1) spacing (of nucleons) always the same ; allow comment: density of many-nucleon nucleus < density of single neutron/proton/nucleon (because spherical nucleons have spaces between); (1) any 2	1 2 [3] 11
2(a)	*either* decay: means loss of / alpha, beta particles/ electrons from nucleus / gamma radiation ; fission: means splitting of nucleus into two (roughly equal) parts / nuclei; *or* decay is spontaneous (1) but fission is <u>neutron</u>-induced (1) NOT natural or random	1 1 [2]
(b)	${}^{238}_{92}U + {}^{1}_{0}n$ -> ${}^{239}_{92}U$	1 [1]
(c)	${}^{239}_{92}U$ -> ${}^{239}_{93}Np + {}^{0}_{-1}e$ + ν-bar / ν ${}^{239}_{93}Np$ -> ${}^{239}_{94}Pu + {}^{0}_{-1}e$ + ν-bar / ν if neutrino missing, 1/2 max. allow β^- for e^- in both for 1/2 max.	1 1 [2]

(d)(i)	alpha (particles) / α / $^{4}_{2}He$ / helium nucleus;	1	[1]
(ii)	$\lambda = 0.693 / t_{½}$ $\lambda = 0.693/(24100 \times 365 \times 24 \times 3600)$ subs. (= $9.1(2) \times 10^{-13} s^{-1}$)	1 1	[2]
(iii)	$A = \lambda N$ $N = (0.25/0.239) \times 6.02 \times 10^{23}$ (= 6.3×10^{23}) *or* $0.25/(1.67 \times 10^{-27} \times 239)$ both subs. so $A = 9.1(2) \times 10^{-13} \times 6.30 \times 10^{23}$ = $5.7(4) \times 10^{11}$ Bq ans. + unit: Bq or s^{-1}	1 1 1+ 1	[4] 12
3(a)	reaction: $^{2}_{1}H$ / $^{2}_{1}D$ + $^{3}_{1}H$ / $^{3}_{1}T$ -> $^{4}_{2}He$ + $^{1}_{0}n$ (+ energy); raise temperature (of gases) / high temperature / gives example, not less than 10^{6} K / hot; (gas) becomes plasma / electrons stripped from nuclei; plasma confined by magnetic field / 'bottle' ; (materials contained in) toroidal / doughnut-shaped vessel / Tokamak ; (1) how: ohmic heating (or AW) / large current causes heating ; (1) plasma forms 1-turn transformer secondary coil / low turns ratio; (1) neutral beam injection heating ; (1) radio frequency / RF heating ; (1) self-heating by alpha particles ; (1) detail: eg ions spiral along *B* lines ; (1) high density (of plasma) ; (1) energy / k.e. / fast enough to overcome Coulomb barrier (1) any 2	1 1 1 1 2	[6]
(b)	nuclear equation: *either* $^{1}_{0}n + ^{6}_{3}Li \rightarrow ^{3}_{1}H + ^{4}_{2}He$ *or* $^{1}_{0}n + ^{7}_{3}Li \rightarrow ^{3}_{1}H + ^{4}_{2}He + ^{1}_{0}n$ (1) lithium layer surrounds reactor vessel, or simply lithium 'blanket' ; (1) ('lithium' alone does not score) neutron k.e./ energy transferred to lithium causes heating; (1) circulate coolant through lithium / blanket ; (1) any 2 (coolant) heats water and converts it to steam which drives turbines and turns (electrical) generators ;	2 1	[3]
(c)	little / not much / no radioactive waste / short half life; (1) small volume / amount of waste; (1) no greenhouse gas emission / no CO_2 emission / acid rain; (1) (almost) unlimited stocks of raw materials (Li) / fuel / deuterium; (1) no chance of runaway / meltdown; (1) energy per unit mass of fuel is greater; (1) any 2	2	[2] 11
4(a)	gravitational pressure / gravitational confinement / gravity pulls material inwards; describes plasma state: mixture of electrons and nuclei / becomes a plasma because electrons stripped from nuclei;	1 1	

	high density / particles close together /high collision rate among nuclei; (1) high temperature / hot / example not less than 10^6 K; (1) (high temperature means) particles have enough energy to overcome repulsion between nuclei / Coulomb barrier; (1) much hydrogen present in Sun / refers to proton-proton reaction / 10^{56} protons ; (1) any 3	3	[5]
(b)(i)	because carbon / ${}^{12}_{6}C$ is regenerated at end or AW ;	1	[1]
(ii)	arrives at correct equation: $4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e$ (+ $2\,{}^{0}_{0}\nu$–bar); ${}^{12}_{6}C$ on both sides scores 1/2	2	[2]
(iii)	energy released $= 4 \times 7.1 \times 10^6 \times 1.6 \times 10^{-19}$ subs. $= 4.5(4) \times 10^{-12}$ J (omits 4 gives 1.1×10^{-12}; omits 10^6 gives $4.5 \times x10^{-18}$ omits 1.6×10^{-19} gives 28(.4) any one of these 1/2)	2	[2]
	binding energy involves ${}^{4}_{2}He$ splitting / fusing to protons and neutrons - not to protons and positrons (1) protons have initial ke (so energy release is greater) (1) electrons / positrons are generated / created , using some mass-energy (1) (k.e. of products does not score) any 1	1	[1]
(c)	total power $= 4.5 \times 10^{-12} \times 8 \times 10^{37}$ subs. $= 3.6 \times 10^{26}$ W ans. accept 4×10^{26}	1 1	[2] 13
5(a)	$E = ½mv^2$ *or* clear from substitution equation $20 \times 1.6 \times 10^{-19} \times 10^6 = ½ \times 1.67 \times 10^{-27} v^2$ so $v = 6.2 \times 10^7$ (m s^{-1}) ans. 6.1×10^7 (ms^{-1}) scores 1/2	1 1	[2]
(b) (i)	correct polarity: + on inner electrode, - on outer electrode	1	[1]
(ii)	$t = 2\pi R/v$ equation $= 2\pi \times 800/(6.2 \times 10^7) = 8.1 \times 10^{-5}$ (s) allow 1 s.f. ans. allow ecf from **(a)**	1 1	[2]
(c)(i)	*B* direction: out of paper / circle plus dot symbol / upwards *F* direction: towards centre	1 1	[2]
(ii)	$mv^2/R = Bqv$ 1 mark each side correct (so $R = mv/(Bq)$) $F = mv^2/R$ or $F = Bqv$ scores 1/2 assumption: magnetic field uniform / constant round whole of circular path ;	2 1	[3]
(iii)	can use weaker magnetic field / smaller / cheaper electromagnets / no need		

	for superconducting electromagnets (1) acceleration is less (for large *R*) so less radiation is emitted; (1) any 1	1	[1]
(d)	antiprotons have same mass as protons / electrons have different / smaller mass ; so antiprotons follow path of same radius in same field / electrons follow path of different / smaller radius / need different / smaller field ;	1 1	[2] **13**
6(a)1. **2.**	baryon hadron ; (either order) (allow nucleon)	1	[1]
(b)	$p^+ \rightarrow n^0 + e^+ + \nu$ *or* $^1_1p \rightarrow {}^1_0n + {}^0_1e + \nu$ equation name: (electron) neutrino	1 1	[2]
(c)	when inside / forming part of a (stable) nucleus	1	[1]
(d)(i)	proton: uud ; neutron: udd ;	1 1	[2]
(ii)	$p^+ \rightarrow n^0 + \pi^+$ ie cancels p^+ *or* cancels quarks	1	
	valid quark equation, eg (u u d) -> (u d d) $+ \pi^+$	1	
(iii)	π^+ must be (d-bar + u) π^+ contains d-bar *or* u scores 1	2	[4] **10**

7 (a) (i)	Mass	$= 0.15 \times 5 \times 60$	1
		$= 45$ kg	1
(ii)	Energy required	$= 45 \times 4200 \times (38 - 8)$ Must have temperature difference	1
		$= 5.67 \times 10^6$ J	1
(b) (i)	Work done	= Force $\times$ distance turned (Allow F.d)	1
		$= 80 \times 2\pi \times 0.2$	1
		$= 100$ J	
(ii)	Power produced	= Energy per rev. $\times$ Number of rev. per second	
		$= 100 \times 1.3$	
		$= 130$ W	1
(iii)	Total number of revolutions	$= 5.67 \times 10^6 / 100$	
		$= 56700$	1
(iv)	Time for pedalling	$= 56700 / 1.3$	1
		$= 43615$ secs	
		$= 12.1$ hours	1
c (i)	Total resistance in heater circuit = *EMF* / current Must see some evidence of equation used and physics of problem other than V = IR eg $R_{total} = R_1 + R_2$		1
		$= 24 / 5$	
		$= 4.8\ \Omega$	1
	Resistance of element	$= 4.8 - 1.2$	1
		$= 3.6\ \Omega$	
(ii)	Length or wire	$= RA / \rho$	1
		$= 3.6 \times 0.32 \times 10^{-6} / 1.5 \times 10^{-7}$	1
		$= 7.68$ m	1

d	Discussion on energy losses	*Work done against friction in bearings etc*	1
		Power loss from resistance of generator and connecting wires	1
		Heat radiated from tank	1

In one second student outputs 130 J of which only 120 J to generator and only 90J to tank

Thus pedalling time will be longer by factor 130 / 90 giving a new time of 17.5 hours. 2

(Any explained energy loss plus extra time calculations scores up to 2 marks)
(Any correct calculation of extra time scores 1 mark)

Maximum 4 marks for question

Up to 3 marks for intelligent discussion (but ignore sound)
Up to 2 marks for calculation **Max 4**