Mark Scheme 2825/04
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NUCLEAR + PARTICLE

Question	Expected Answers	Marks
1 (a)	forces F_S and F_G acting inwards, force F_E acting outwards - all through centre of proton; 3 forces 2/2, 2 forces 1/2, marked and labelled	2 [2]
(b)	$F_E = F_S + F_G$; accept $F_E + F_S + F_G = 0$ allow ecf from **(a)**	1 [1]
(c)(i)	$F_E = Q^2/(4\pi\varepsilon_0 r^2)$ $= (1.6\times10^{-19})^2/[4\pi\times8.85\times10^{-12}(2.8\times10^{-15})^2] = 29\text{ N}$ use of $r = 1.4\times10^{-15}$ m (-1) once only	1 1
(ii)	$F_G = m^2G/r^2$ $= (1.67\times10^{-27})^2\times6.67\times10^{-11}/(2.8\times10^{-15})^2 = 2.4\times10^{-35}\text{ N}$	1 1
(iii)	$F_S = 29$ N / same as F_E allow ecf	1 [5]
(d)	$F_E >> F_G$ so F_G negligible / insignificant / can be ignored or AW	1 [1]
(e)(i)	$F_E = 0$ (1)	
(ii)	$F_G = 2.4\times10^{-35}$ N (approx.) allow ecf (1)	
(iii)	$F_S = 2.4\times10^{-35}$ N (approx.) (1) comment: F_S now repulsive (not attractive) or AW *or* indicated by minus sign with F_S; (1) any 3	3 [3] **12**
2(a)(i)	${}^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{239}_{92}\text{U}$	1
(ii)		2
(iii)	${}^{239}_{92}\text{U} \rightarrow {}^{239}_{93}\text{X} + {}^{0}_{-1}\text{e} + {}^{(0)}_{(0)}\nu$(–bar) ${}^{239}_{93}\text{X} \rightarrow {}^{239}_{94}\text{Pu} + {}^{0}_{-1}\text{e} + {}^{(0)}_{(0)}\nu$(–bar) omits any neutrino (-1) once only electron incorrectly represented (-1) once only	1 [4]

(b)(i)	24 000 year / >24 000 year	1	[1]
(ii)	$\lambda = \ln 2 / T_{½} = \ln 2 / (24000 \times 365 \times 24 \times 3600)$ subs. $= 9.16 \times 10^{-13}\,s^{-1}$ *or* $< 9.16 \times 10^{-13}\,s^{-1}$ ans. failure to convert years to s, giving 2.89×10^{-5}, gets 1/2	1 1	 [2]
(c)(i)	239 g of Pu contain 6.02×10^{23} atoms *or* alternative correct use of N_A $N = (0.05 \times 4.4 / 0.239) \times 6.02 \times 10^{23}$ ie applies % and units correctly (= 5.54×10^{23} (atoms))	1 1	 [2]
(ii)	activity $= \lambda N$ $= 9.16 \times 10^{-13} \times 5.54 \times 10^{23}$ allow ecf $= 5.08 \times 10^{11}$ Bq / s^{-1} ans. + unit	1 2	 [3] **12**
3(a)	p.e. increases k.e. decreases *or* k.e. is converted to p.e. gets 2/2 eventually <u>all</u> k.e. is changed to p.e.	1 1 1	 [3]
(b)	$E_P = (1.6 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} \times 2.1 \times 10^{-15})$ (= 1.1×10^{-13} J) so k.e. of <u>each</u> proton = $½ \times 1.1 \times 10^{-13} = 5.5 \times 10^{-14}$ J	1 1	 [2]
(c)	$5.5 \times 10^{-14} = 2.07 \times 10^{-23}\,T$ so $T = 2.7 \times 10^{9}$ K ans. accept 2.6×10^{9} K	1	[1]
(d)	*either:* E_K is the *mean* k.e. of protons (1) protons (in plasma) have a range of k.e.s (1) any 1 so (at any instant) some protons have much greater k.e. than average *or:* protons can fuse for separations > 2.1 fm (1) because of (quantum) tunnelling (effects) (1)	 1 1	 [2]

(e)(i)	$2 \times (2.3 \times 10^{-13}) + 2 \times (8.8 \times 10^{-13}) + (20.6 \times 10^{-13}) = 42.8 \times 10^{-13}$ J adds energies, without x 2 gives 31.7×10^{-13} J for 1/2	2	[2]
(ii)	(2) neutrinos escape from the Sun (and carry away energy)	1	[1]
(f)	*either* T ($\propto E_K$) $\propto Q_1 Q_2$ and $Q_1 Q_2$ is greater for reactions in carbon cycle (eg 1 x 12 > 1 x 1); *or* verbally: repulsion is greater between nuclei in carbon cycle;	1	
	greater repulsion / Coulomb barrier means more energy needed (so higher temp.)	1	[2] **13**
4(a)	fixed target: accelerate one beam of particles / use high velocity / high energy particles;	1	
	collide with stationary particles / nuclei;	1	
	colliding beam: accelerate two beams of particles / use high velocity / high energy particles;	1	
	collide them head-on / from opposite directions; 'fired at' / 'aimed at' / 'directed at' instead of accelerated etc, (-1) once	1	
	Advantages: fixed target: no steering problems; (1) high probability of collision / many collisions; (1) because high density of particles in fixed target; (1) no problems of recoil in target; (1) any 1	1	
	colliding beam: (total) initial mtm. (can be) zero so final (overall) mtm. (can be) zero;	1	
	either so <u>all</u> k.e. can contribute to making new particles *or* two beams means twice as much energy available;	1	[7]
	allow any other relevant point up to appropriate max.		

(b)(i)	$m_e c \approx m_Z c$	1	
	so $m_e \approx m_Z$	1	[2]
(ii)	ratio = $(1.6 \times 10^{-25})/(9.11 \times 10^{-31}) = 1.8 \times 10^{5}$	1	[1]
(iii)	mass increases with speed	1	
	positron and ${}^{(0)}_{(0)}Z$ have different speeds (so masses have changed by different amounts)	1	[2]
(c)	much / most of input energy goes into k.e. of ${}^{(0)}_{(0)}Z$ particle (so less energy available to create ${}^{(0)}_{(0)}Z$)	1	[1] **13**
5(a)	β^{+} : ${}^{192}_{79}Au \to {}^{0}_{1}e + {}^{192}_{78}Pt + {}^{0}_{0}\nu$	1	
	β^{-} : ${}^{192}_{79}Au \to {}^{0}_{-1}e + {}^{192}_{80}Hg + {}^{0}_{0}\nu$ (-bar)	1	[2]
	omits both neutrinos gets 1/2 max.		
(b)	β^{+} decay: reactant mass = 191.921 47 u	1	
	product mass = 191.918 24 + 0.000 55 = 191.918 79 u	1	
	products mass < reactant mass so reaction can occur	1	
	β^{-} decay: (reactant mass = 191.921 47 u)		
	product mass = 191.921 41 + 0.000 55 = 191.921 96 u	1	
	products mass > reactant mass so reaction cannot occur	1	[5]

(c)	β^+ mass defect / mass loss = 191.921 47 - 191.918 79	1	
	(= 0.002 68 u)		
	then *either*: mass loss in kg = $0.002\,68 \times 1.66 \times 10^{-27}$	1	
	(= 4.45×10^{-30} kg)		
	so energy loss = $\Delta m\, c^2$	1	
	$4.45 \times 10^{-30} \times (3.0 \times 10^8)^2$		
	= 4.00×10^{-13} J	1	[4]
	or : 0.002 68u = $0.002\,68 \times 932$ MeV (2)		
	= (2.50 MeV)		
	= $2.50 \times 10^6 \times 1.6 \times 10^{-19}$ (1)		
	= 4.00×10^{-13} J (1)		
	accept 930 - 934 MeV u^{-1} giving 3.99 - 4.00(5) x 10^{-13} J		
			11
6(a)	all free hadrons (thought to be) (somewhat) unstable; (1) protons and neutrons are (both) hadrons; (1) + (1) protons and neutrons inside a nucleus are stable; (1) free neutrons have half life of 10 - 15 minutes; (1) free protons are stable / have half life of about 10^{32} year; (1) any 5	5	[5]
	allow equivalent marks for other hadrons and / or other relevant points		
(b)(i)	weak (force / interaction);	1	[1]
(ii)	${}^3_1H \rightarrow {}^3_2He + {}^{0}_{-1}e + \bar{\nu}$;	1	[1]
(iii)	$d \rightarrow u + e + \bar{\nu}$;	2	[2]
	$d \rightarrow u$ gets 1/2		
	u $d \rightarrow u + e / \beta + \bar{\nu}$ is not in simplest form, so gets 1/2 d		
	baryon reaction ${}^1_0n \rightarrow {}^1_1p + {}^{0}_{-1}e + \bar{\nu}$ gets 1/2		
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