50				
(a)(i)	r : radius of nucleus / nuclei r_0 : radius of nucleon / proton / neutron / hydrogen nucleus; A : number of nucleons / (protons + neutrons) / mass number;	1 1	[2]
(ii)	line curves in correct sense from origin but doesn't become horizontal; any part drawn with ruler loses this mark	1	[1]
(b)(i)	$r = r_0 A^{1/3} = 1.41 \times 10^{-15} \times 56^{1/3}$ $= 5.39 \times 10^{-15}$ m do not allow 5.4×10^{-15} m	1 1	[2]
(ii)	$m = V\rho$ allow $m = \frac{4}{3}\pi r^3 \rho$ $= \frac{4}{3}\pi (5.39 \times 10^{-15})^3 \times 1.44 \times 10^{17}$ (= 9.45×10^{-26} kg)	1 1	[2]
(c)(i)	protons: 26, neutrons: 30;	1	[1]
(ii)	mass = $26 \times 1.673 \times 10^{-27} + 30 \times 1.675 \times 10^{-27} = 9.37(48) \times 10^{-26}$ kg allow ecf from **(c)(i)** allow 2 sf	1	[1]
(d)	difference in mass = $0.08 \times 10^{-26} = 8 \times 10^{-28}$ (kg) accept $7 - 10 \times 10^{-28}$ (kg) wrong unit 0/1 allow ecf from **(b)(ii)** and **(c)(ii)**	1	[1]
(e)	$E = (\Delta)m c^2$ $= 8 \times 10^{-28} \times (3 \times 10^8)^2 = 7.2\ 10^{-11}$ J accept $6.3 - 9.0 \times 10^{-11}$ J allow ecf from **(d)** allow 1 sf	1 1	[2] **12**

51 **(a)**	similar mass means large momentum transfer (in collision); hence fewer collisions are needed; neutron colliding with heavy nucleus bounces off with similar speed / k.e. scores 1/2 max. neutron colliding with similar mass nucleus transfers large k.e. / speed scores 1/2 max.	1 1	[2]
(b)(i)	${}^{236}_{92}U \rightarrow {}^{110}_{45}Rh + {}^{121}_{47}Ag + 5\,{}^{1}_{0}n$ allow ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{110}_{45}Rh + {}^{121}_{47}Ag + 5\,{}^{1}_{0}n$ no neutrons 0/2, incorrect number of neutrons 1/2 $5\,{}^{1}_{0}N$ gets 1/2 max. ${}^{5}_{0}n$ gets 0/2 if ${}^{1}_{0}$ missing from neutron symbol, 1/2 max. ${}^{236}_{92}U + {}^{1}_{0}n \rightarrow {}^{110}_{45}Rh + {}^{121}_{47}Ag + 6\,{}^{1}_{0}n$ gets 1/2	2	[2]
(ii)	plots 5 or 6 points correctly 4 points plotted correctly gets 1/2 3 or less points correct gets 0/2 allow points using (relative yield)/2	2	[2]
(iii)	line passes through all 6 points; graph is sensibly symmetrical; uses only ruler allow 1/2 max. for symmetry if no points plotted allow 1/4 max. for parts **(ii)** and **(iii)**	1 1	[2]
(iv)	accept 0.01% □ yield □ 0.02% allow ecf for minimum greater than 0.02%	1	[1]
(c)(i)	${}^{121}_{47}Ag \rightarrow {}^{121}_{48}X + {}^{0}_{-1}\beta$ / ${}^{0}_{-1}e + {}^{(0)}_{(0)}\bar{\nu}$; omits ν–bar, 1/2 max. omits ${}^{0}_{-1}$ from β symbol, 1/2 max. if *A* or *Z* number incorrect, -1 each error	2	[2]
(ii)	protons: +1 neutrons: -1	1	[1]
			12

52 (a)	neutron is udd / proton is uud; quarks are: up down strange top bottom charm; *either* up / u has $Q = (+)2/3$, $B = (+)1/3$; *or* down / d has $Q = -1/3$, $B = (+)1/3$; quarks are fundamental particles; (1) for every quark there is an antiquark; (1) antiquarks have opposite values of *Q*, *B* and *S* (compared to quark) (1) quarks are held together by strong force / gluons (1) *Q*, *B* and *S* are conserved in (quark) reactions (1) any 2	1 1 1 2	 [5]
(b)(i)	charge: $1 + (-1) \rightarrow 0 + 0 + (-1) + X_Q$ so $X_Q = (+)1$ baryon number: $1 + 0 \rightarrow 1 + 0 + 0 + X_B$ so $X_B = 0$ strangeness: $0 + 0 \rightarrow 0 + 0 + 0 + X_S$ so $X_S = 0$ working need not be shown has NO strangeness gets 0/1 has NO baryon number gets 0/1	1 1 1	 [3]
(ii)	π^+ particle / antiparticle to π^- / meson with quark composition of (up + not-down) do not allow positron	1	[1] **9**

53 (a)	(consists of) positive ions / nuclei and electrons; not just electrons stripped from nuclei	1	[1]
(b)	ions / nuclei / electrons are charged; moving charge / ions / electrons experience force in magnetic field; ions / nuclei / electrons spiral along field lines;	1 1 1	[3]
(c)(i)	calculates b.e. per *nucleus* : 1.11 x 2 (= 2.22) 2.57 x 3 (= 7.71) both expressions so energy released = 7.71 - 2 x 2.22 (= 3.27 MeV) = $3.27 \times 10^{6} \times 1.6 \times 10^{-19}$ = $5.2(3) \times 10^{-13}$ J omits multiplication by 2 and 3, 1/3 max.	1 1 1	[3]
(ii)	reaction 2 generates more energy (than reaction 1);	1	[1]
(d)	initial mtm. = final mtm. so 0 = $m_H v_H + m_n v_n$ 0 = $(4 m_n) v_H + m_n v_n$ so $v_n = 4 v_H$ k.e. of $^{4}_{2}He$ = $\frac{1}{2} m_H v_H^2$ k.e. equation applied (to n or He) = $\frac{1}{2}(4m_n) v_H^2 = 2 m_n v_H^2$ k.e. of $^{1}_{0}n$ = $\frac{1}{2} m_n v_n^2 = \frac{1}{2} m_n (4v_H)^2 = 8 m_n v_H^2$ alg. *either* k.e. of $^{1}_{0}n$ = 4 x (k.e. of He) *or* $^{1}_{0}n$ has 80% of total energy 80% unsupported scores 1/5 k.e. stated to be proportional to 1/(mass) scores 2/5 if correct answer obtained	1 1 1 1 1	[5]
54 (a)	Np graph: graph has exponential shape / there is exponential decay of Np nuclei / number (of Np nuclei) is halved in 2.3 days / constant time / in its half life; Pu graph: sum of Pu + Np nuclei = 3.0×10^{20} at all times; (1) *either* because <u>one</u> Np nucleus decays to <u>one</u> Pu nucleus *or* rate of decay of Np and formation of Pu are equal; (1) and half life of Pu >> / <u>much</u> bigger than half life of Np; (1) any 2	1 2	[3]

(b)	time required = time for Np nucleus to fall to 0.30×10^{20}; then *either* $N = N_0 (½)^{t/T½}$ so $N/N_0 = (½)^{t/T½}$ $\lg(N/N_0) = t/T_{½} (\lg 0.5)$ $\lg(0.1) = t/2.36 \lg(0.5)$ $t = 7.8$ days *or* uses $N = N_0 e^{-\lambda t}$ where $\lambda = \ln 2 / 2.36$ (= 0.294 day^{-1}) (1) so $0.1 = e^{-0.294\,t}$ (1) $\ln(0.1) = -0.294\,t$ $t = 7.8$ days (1) *or* $\lambda = \ln 2 / (2.36 \times 24 \times 3600) = 3.41 \times 10^{-6}\ s^{-1}$ $0.1 = e^{-3.41 \times 10exp(-6)\, t}$ $\ln(0.1) = -3.41 \times 10^{-6}\, t$ $t = 6.76 \times 10^5$ s $= 6.76 \times 10^5 / (24 \times 3600) = 7.8$ days	1 1 1 1	[4]
	calculates time for Np to fall to 2.7×10^{20} / Pu to rise to 0.3×10^{20} = 0.36 day gets 0 1 1 1 = 3/4 uses $T_{½}$ for plutonium can get 2/4 max. attempts to use repeated halving of *N* can get 2/4 max. if using 0.3 (not 2.7)		**7**

55

a	**i**	212; β	**2**	
	ii	208; α	**2**	**4**
b		range/penetration/absorption experiment:		
		α place detector very close/ 2cm from source; measure count rate,	**1**	
		use paper screen or move back to 10 cm or more; contrast to	**1**	
		background count level/ other emissions from same source	**1**	
		β place detector eg 10 cm from source; measure count rate, add	**1**	
		thin sheets of Al until count drops to very low or almost constant value	**1**	
		aliter deflection experiment:		
		needs vacuum for α experiment;	**1**	
		source for radiation passes through region of E- or B- field;	**1**	
		deflection of particles detected by detector to distinguish emissions;	**1**	
		detection method *max 4 marks*	**1**	**4**
c	**i**	$A = \lambda N ;= \lambda m N_A/M ;= 0.0115 \times 6.02 \times 10^{23} \times 1 \times 10^{-9}/212 = 3.27 \times 10^{10}$ min^{-1}	**3**	
	ii	$T_{1/2} = 0.693/\lambda = 60.3$ (min)	**1**	
	iii	Curve passing through (0,32) (60, 16) (120,8) *ecfs from (i) & (ii)*	**1**	**5**
		Total		**13**

56 **(a)** **(i)**	general shape: crosses axis, reaches turning point; then hits distance axis (not asymptotic);	**1** **1**	 **[2]**
(ii)	marks sections as 'repulsive' and 'attractive', consistent with graph;	**1**	**[1]**
(iii)	marks crossing point 'X'	**1**	**[1]**
(b)	at smaller separation / to left of X, force is repulsive; at larger separation / to right of X, force is attractive; either so force always returns neutrons to original separation / is a restoring force **or** at equilibrium separation strong force is zero;	**1** **1** **1**	 **[3]**
(c)	acts only on nearest neighbour / when nuclei are 1 diameter apart; **either** so force holding nucleons/ neutrons together independent of size of nucleus **or** reference to b so distance apart (of nucleons) must be constant; so density of nucleus is independent of size;	**1** 1 **1**	 **[3]** **10**
57 **(a)**	23992U -> 23993Np + 0-1β / 0-1e + $\bar{\nu}$ allow 23892U + 10n on LHS 23993Np -> 23994Pu + 0-1β / 0-1e + + $\bar{\nu}$ allow neutrino instead of antineutrino omits neutrino altogether - gets 1/2	**1** **1**	 **[2]**
(b)	straight line starts from zero and reaches 1.08 x 1013 at t = 6.0 x 105 s or equivalent	**1**	**[1]**
(c) **(i)**	rate of decay increases with time; because rate of decay increases with / is proportional to number of nuclei;	**1** **1**	 **[2]**
(ii)	(eventually) rate of decay (of $^{239}_{93}$Np) = rate of formation	**1**	**[1]**
(iii)	$dN/dt = (-)\lambda N$ equation $\lambda = 0.693 / T_{½}$ so $N = (dN/dt) / \lambda = 1.8 \times 10^7 / (0.693 / [2.04 \times 10^5])$ subs. $= 5.3 \times 10^{12}$ ans. calculation of λ gets 1/3	**1** **1** **1**	 **[3]**
(iv)	correctly curved from zero to (5.3×10^{12}) or less	**1**	**[1]**
(d) **(i)**	24 000 year remembers $= 24000 \times 3.16 \times 10^7 = 7.58 \times 10^{11}$ s answer	**1** **1**	 **[2]**
(ii)	starts from origin with zero gradient; approaches line parallel with Np production line, X;	**1** **1**	 **[2]** **14**

58	**(a) (i)**	to come to rest simultaneously, total mtm. = 0 *or* AW (but initial mtm. not zero)	**1**	**[1]**
	(ii)	initial mtm. = $3mu - 2mu = mu$ when closest, mtm. = $(3m + 2m)v$ so $5mv = mu$ (and $v = u/5$)	**1** **1**	**[2]**
	(b) (i)	initial k.e. = final k.e. + (gain of) p.e.	**1**	**[1]**
	(ii)	k.e. = $\frac{1}{2}mv^2$ total k.e. = $\frac{1}{2} \times 3mu^2 + \frac{1}{2} \times 2mu^2$ (= $2.5mu^2$) = $2.5 \times 1.67 \times 10^{-27} u^2$ (= $4.18 \times 10^{-27} u^2$) allow $m = 1.66 \times 10^{-27}$ kg for full credit	**1** **1** **1**	**[3]**
	(iii)	gain of p.e. = initial k.e. - final k.e. $\frac{(1.6 \times 10^{-19})^2}{(4\pi \times 8.85 \times 10^{-12} \times 1.5 \times 10^{-15})} = 4.18 \times 10^{-27} u^2 - 4.18 \times 10^{-27} (u/5)^2$ $1.53 \times 10^{-13} = 4.01 \times 10^{-27} u^2$ algebra $u = 6.18 \times 10^6$ m s^{-1} omits $- 4.18 \times 10^{-27} (u/5)^2$, gets $u = 6.06 \times 10^6$ m s^{-1} : 1/2, 1, 1 = 3/4	**2** **1** **1**	**[4]** **11**
59	**(a)**	$^{236}_{92}U \rightarrow {}^{100}_{40}Zr + {}^{131}_{52}Te + 5\,{}^{1}_{0}n$	**1**	**[1]**
	(b) (i)	nucleon number: no change proton number: increases by 1	**1**	**[1]**
	(ii)	nucleon number: 100 proton number: 44	**1**	**[1]**
	(iii)	5 correct points 4 correct arrows	**1** **1**	**[2]**
	(iv)	straight line through / close to 56 / 44 of $1 \le$ gradient < 2 if curved, correct sense	**1**	**[1]**
	(c) (i)	reactant mass = 99.895 808 u product mass = 99.891 679 + 0.000 549 (= 99.892 228 u) mass defect = 0.003 580 u	**1** **1**	**[2]**
	(ii)	$\Delta m = 0.003\,580 \times 1.66 \times 10^{-27}$ (= 5.943×10^{-30} kg) $E = (\Delta)mc^2$ = $5.943 \times 10^{-30} \times (3.0 \times 10^8)^2$ (= 5.35×10^{-13} J) *or* uses 1u = 931 MeV so 0.00358 = 931 × 0.00358 (= 3.33 MeV) (1) = $3.33 \times 1.6 \times 10^{-13}$ (= 5.33×10^{-12} J) (1)	**1** **1**	**[2]**
	(iii)	(anti-)neutrino is also emitted (1) (anti-)neutrino has (some) energy (1) recoiling (niobium) nucleus has (kinetic) energy (1) any 2	**2**	**[2]** **12**

60	a		A: the number of (undecayed) nuclei which decay per second/rate of decay of nuclei	1	
			λ: the probability of a given nucleus decaying in the next second or in unit time/the (decay) constant relates the activity to the number of undecayed nuclei	1	
			N: the number of undecayed nuclei/nuclei of the original nuclide (remaining)	1	3
	b	i	90 and 234	1	
		ii	$2 \times 10^{-6} \times 7.0 \times 10^{6} = 14$ (kg)	1	
		iii	$N = (m/M) N_A = 14 \times 10^{3} \times 6 \times 10^{23}/238$ ($= 3.5 \times 10^{25}$)	1	
		iv	$\lambda = 0.69/T = 0.69/4.5 \times 10^{9} \times 3.2 \times 10^{7} = 4.8 \times 10^{-18}$ (s^{-1})	1	
			$A = \lambda N = 4.9 \times 10^{-18} \times 3.5 \times 10^{25} = 1.7 \times 10^{8}$; s^{-1} or Bq	2	6
	c		change of state/water changes to steam; requiring latent heat;	2	
			for heating steam, calculation requires a different specific heat capacity;	1	
			energy/heat losses to surroundings not included/AW *max 3 marks*	1	3
			give 1 mark for **formula only gives energy needed to heat water to 100°C**		
			Total		**12**

61 (a) (i)	gradient = 2.7×10^{-45} (m^3) ans. (1); accept values between 2.7 and 2.8 $\times 10^{-45}$	1	[1]
(ii)	quotes $r^3 = A r_0{}^3$ *or* $r = A^{1/3} r_0$ deduces $r_0 = \sqrt[3]{\text{(gradient)}}$ calculates $r_0 = 1.4 \times 10^{-15}$ m allow 1.39 to 1.41 $\times 10^{-15}$ m if values from graph used, max 2/3 answer without working scores 2/3 allow ecf from **(i)**	1 1 1	 [3]
(b)	$\rho = m / V$ *or* $\rho = m / [(^4/_3)\pi r^3]$ equation *either* $= \dfrac{12 \times 1.67 \times 10^{-27}}{12 \times {}^4/_3 \pi (1.4 \times 10^{-15})^3}$ subs. $= 1.45 \times 10^{17}$ kg m^{-3} ans. allow ecf for r_0 from **(a)(ii)** omission of one 12 factor can score max 2/3 omission of conversion factor from u to kg can score max 1/3 *or* reads off $12r^3$ where A = 12 from graph then $\rho = \dfrac{12 \times 1.67 \times 10^{-27}}{{}^4/_3 \pi \times 3.28 \times 10^{-44}}$ (1) $= 1.46 \times 10^{17}$ kg m^{-3} (1)	1 1 1	 [3]
(c)(i)	ratio = $\dfrac{1.45 \times 10^{17}}{3530} = 4.12 \times 10^{13}$	1	[1]
(ii)	mass of nucleus is about the same as mass of atom *either* most of atom is empty space or AW *or* nucleus occupies only (very) small part of volume of atom; *or* link betwen mass and volume e.g. same mass in larger / smaller volume;	1 1	 [2] **10**
62 (a)(i)	(neutrons) having energies comparable with thermal energies / slow moving / low kinetic energy / energy in range 6 - 100 eV / energy similar to (energy of) atoms of surroundings ;	1	[1]
(ii)	*either* thermal neutrons will be captured / absorbed (by U-235 nuclei) *or* higher energy neutrons do not get absorbed;	1	[1]

(b)(i)	3 points plotted; any point incorrect loses this mark	1	
(ii)	curve through 3 points and heads down towards zero; line peaks between Br and origin;	1 1	[3]
(iii)	BE per *nucleus* of $^{235}_{92}U$ = 7.60 x 235 (= 1786 MeV) BE of products = 8.20 x 146 + 8.60 x 87 both lines (= 1197 + 748 MeV) so energy released = (1197 + 748) - 1786 = 159 MeV omits multiplication by nucleon number to get 9.2 MeV gets 0,1,0 = 1	1 1 1	 [3]
(iv)	graph: 2 humps; sensibly symmetrical with minimum between 110 and 125;	1 1	 [2]
(v)	on Fig. 2.1 two labels **F** near to Br and La; two regions shaded / marked / ringed around Br and La with gap between; labels etc. on Fig. 2.2 scores zero	1 1	 [2]
(c)(i)	speed after collision = 0.93 x speed before collision so after 120 collisions, final speed = $(0.93)^{120}$ x speed before collision = 2.48×10^{3} m s^{-1}	 1 1	 [2]
(ii)	this is collision is head-on but other collisions may not be;	1	[1]
			15
63 **(a)**	confines / pulls together plasma / nuclei / ions / nucleons / protons; (1) so increases density/ concentration / number per unit volume; (1) and increases frequency / number of collisions among nuclei; (1) gravitational attraction heats plasma / gravitational p.e. changed to heat; (1) any 3	3	[3]
(b)	*either* area is potential / stored energy / work done / energy to overcome coulomb barrier *or* minimum k.e. at infinity or AW; it is (minimum) energy needed for fusion;	 1 1	 [2]
(c)	E_k = $2.07 \times 10^{-23} \times 15 \times 10^{6}$ (= 3.1×10^{-16} J) so for two nuclei, E_k = 6.2×10^{-16} J	1	[1]

(d)	combined (mean) k.e. << required p.e. / energy needed for fusion; (1) aware there is a range / spread of (nuclear) k.e.s; (1) (very) small proportion of $^1_1$H nuclei have enough energy to cause fusion;(1) aware (quantum) tunnelling can occur so fusion at distances > x_0 or AW;(1) any 3	3	[3]
(e)(i) **(ii)**	reactant mass = 2 x 1.007 276 = 2.014 552 u product mass = 2.013 553 + 0.000 549 = 2.014 102 u so Δm = 4.5×10^{-4} u E = $\Delta m\, c^2$ = $4.5 \times 10^{-4} \times (1.66 \times 10^{-27}) \times (3.0 \times 10^8)^2$ = 6.7×10^{-14} J allow conversion using 1 u = 931 MeV positron and electron annihilate	 1 1 1 1	 [3] [1] **13**
64 **(a)**	number of *decayed* U-238 nuclei = ½ x number of *undecayed* U-238 nuclei; so $^1/_3$ of U-238 has decayed and $^2/_3$ of U-238 has not decayed; (so ratio = $^2/_3$)	1 1	 [2]
(b)	*either* $\lambda = 0.693 / T_{½} = 0.693 / (4.47 \times 10^9)$ (= 1.55×10^{-10} y^{-1}) subs. $N = N_0 e^{-\lambda t}$ so $N / N_0 = e^{-\lambda t}$ and $\ln (N / N_0) = -\lambda t$ $\ln (0.667) = -1.55 \times 10^{-10}\, t$ alg. / arith. so $t = 2.61 \times 10^9$ y ans. *or* $N / N_0 = (½)^x$ so $0.667 = (½)^x$ and $\ln (0.667) = x \ln(0.5)$ and $x = 0.584$ then $t = x T_{½} = 0.584 \times 4.47 \times 10^9 = 2.61 \times 10^9$ y	1 1 1	 [3]
(c)	*either* $N_0 = (5.00 / 238) \times 6.02 \times 10^{23}$ subs. = 1.26×10^{22} atoms ans. *or* $N_0 = (5.00 \times 10^{-3}) / (1.67 \times 10^{-27} \times 238)$ (1) = 1.26×10^{22} atoms (1)	1 1	 [2]
(d)	exponential decay graph for U: starts from N_0 and approaches t axis; exponential growth of Pb from zero: approaches a constant value of N_0 ; lines sensibly 'mirror images';	1 1 1	 [3] **10**

Q	Part	Answer	Marks	Total
65	(a)(i)	leptons;	1	[1]
	(ii)	neutrino / muon / tau(on);	1	[1]
	(b)(i)	up down down / udd;	1	[1]
	(ii)	*Q* *B* *S* u (+)$^2/_3$ (+)$^1/_3$ 0 — u values d -$^1/_3$ (+)$^1/_3$ 0 — d values	1 1	
	(iii)	so for neutron *Q* = 0 *B* = 1 *S* = 0	1	[3]
	(c)	*either* express in quarks: u + u-bar τ d + u u d s-bar d d d	1	
		compares quarks: (u: u + u + u-bar τ u u's cancel, so balances) *either* d: d + d τ d + d + d no balance *or* s: 0 τ s-bar so no balance concludes reaction not possible	1 1 1	
		or (*Q*: 1 - 1 τ 0 + 0 *B*: 1 + 0 τ 0 + 1) *S*: 0 + 0 τ 1 + 0 correct *S* equation gets 2, 0 + 0 = -1 + 0 gets 1 ; (2) not possible because *S* does not balance; (2) 'not possible' unsupported gets zero	[4]	
				10

Q	Part	Answer	Marks	Total
66	**a**	39; number of protons (in Y-90 nucleus)/atomic no. (of Y)	**2**	
		81; number of neutrons (in the Ba-137 nucleus)	**2**	**4**
	b i	the number of <u>atoms/nuclei</u> which decay per second or number of <u>atomic/nuclear</u> decays per second	**1**	
	ii	$0.693/(30 \times 3.15 \times 10^7)$	**1**	
		$= 7.3(3) \times 10^{-10}$ (s^{-1})	**1**	**3**
	c i	($A = \lambda N$)= $7.33 \times 10^{-10} \times 3.525 \times 10^{15}$ *ecf b(ii)*	**1**	
		or can take the gradient of the tangent to the curve at (15,3.525)		
		$= 2.58 \times 10^6$ Bq or 2.60 MBq	**1**	
	ii	e.g. take N at t = 15 y then $N = N_o \sqrt{}2$ giving $3.525 \times 10^{15} = 0.707\ N_o$ hence $N_o = 4.99 \times 10^{15}$ or use $N = N_o e^{-\lambda t}$ with appropriate substitution for N and t		
		award marks as follows: viable method; suitable substitutions; achieving	**2**	
		correct solution	**1**	
	iii	$N = (m/M)N_A$ or $4.99 \times 10^{15} = (m/137) \times 6.02 \times 10^{23}$	**1**	
		hence $m = 1.14 \times 10^{-6}$ g *ecf c(ii)*	**1**	**7**
		Total		**14**

67	b	ratio of atom to nuclear diameter/radius: about 10^4 or 10^5;	1	
		atomic or nuclear diameter given, i.e 10^{-10} m or 10^{-14} m or 10^{-15} m *do not score twice if mark already given in (a) for atomic diameter*	1	
		or giving both atomic and nuclear diameters can score both marks above		
		electrons can be accelerated to give speeds where wavelength is of order of	1	
		nuclear radius/diameter; so that diffraction effects are observable	1	
		statement that hard X-rays are still at atomic size wavelengths	1	
		energy of X-rays required well above electron transition energies to achieve such	1	
		small wavelengths/some calculation using $c = f\lambda$ and energy = hf to show energy	1	
		of X-rays required *up to 3 marks*	1	4
		pattern/size of ring enables radius of the nucleus to be found *max 4*	1	
		Total		**11**
		Quality of Written Communication (see separate sheet)		4