Question			Answer	Marks	Guidance
1	(a)		force per unit (positive) charge	B1	**Allow**: $E = \frac{F}{Q}$, where F = force on (a positive) charge Q
	(b)	(i)	The direction is different (AW)	B1	
		(ii)	$E \propto 1/r^2$ or distance is doubled ∴ E decreases by a factor of 4 electric field strength = 2.0×10^5 (N C^{-1})	C1 A1	**Not**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ on its own **Allow** 1 sf answer
	(c)	(i)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F_E = \frac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(5.0\times10^{-11})^2}$ $F_E = 9.2 \times 10^{-8}$ (N)	C1 C1 A1	 **Allow**: 1 mark if $Q = q = 1$ giving an answer of 3.6×10^{30} (N)
		(ii)	$F_G = \frac{6.67\times10^{-11}\times1.67\times10^{-27}\times9.11\times10^{-31}}{(5.0\times10^{-11})^2}$ $F_G = 4.06 \times 10^{-47}$ (N) ratio = $9.2 \times 10^{-8}/4.06 \times 10^{-47}$ ratio = 2.3×10^{39}	C1 A1	 **Note**: Deduct 1 mark if mass of two electrons or two protons is used, then ecf Possible ecf from **(c)(i)**
		(iii)1	wavelength = 2.0×10^{-10} (m) $\lambda = h/mv$ $p = \frac{6.63\times10^{-34}}{2.0\times10^{-10}}$ $p = 3.3 \times 10^{-24}$ (kg m s^{-1})	C1 C1 A1	 Possible ecf for incorrect wavelength **Note**: Answer to 3 sf is 3.32×10^{-24} (kg m s^{-1}) **Allow**: 1 sf answer

Question			Answer	Marks	Guidance
		(iii)2			Possible ecf from **(iii)1**
			$v = \frac{3.32\times10^{-24}}{9.11\times10^{-31}}$ (= 3.64 × 10^{6} m s^{-1})	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			E_k = ½ × 9.11 × 10^{-31} × (3.64 × 10^{6})^2	C1	
			E_k = 6.0 × 10^{-18} (J)	A1	**Note**: Answer to 3 sf is 6.05 × 10^{-18} (J) **Allow**: 1 sf answer
			or		
			$E_k = ½ p^2/m$	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			E_k = ½ × (3.32 × 10^{-24})^2/9.11 × 10^{-31}	C1	
			E_k = 6.0 × 10^{-18} (J)	A1	
			Total	**15**	

Question			Answers	Marks	Guidance
2	(a)		electric field strength = force per unit (positive) charge	B1	**Allow**: force/charge **Not**: *F*/*Q*
	(b)	(i)	$E = V / d$ $3.0 \times 10^{6} = V / 1.3 \times 10^{-3}$ V = 3900 (V)	C1 A1	**Note**: This mark is for correct substitution **Allow**: 1 mark if answer is 3.9×10^{n} (V), n ≠3 – POT error
		(ii)	$Q = It$ $Q = 2.7 \times 10^{-9} \times 4.0 \times 10^{-2}$ charge = 1.1×10^{-10} (C) or 1.08×10^{-10} (C)	C1 A1	**Note**: This mark is for correct substitution
		(ii)	number = $1.08 \times 10^{-10} / 1.6 \times 10^{-19}$ number = 6.8×10^{8} or 6.75×10^{8}	B1	Possible ecf from **(b)(ii)1**
		(iii)	energy = *VQ* energy = $3900 \times 1.08 \times 10^{-10}$ energy = 4.2×10^{-7} (J)	C1 A1	**Note**: No credit for using ½ *QV* Possible ecf from **(b)(ii)1**
			Total	**8**	

Question			Expected Answer	Mark	Additional Guidance
3	(a)	(i)	$E = \frac{V}{d} = \frac{2400}{9.4\times10^{-3}}$ $E = 2.55 \times 10^{5}$ (V m^{-1}) force = $E \times Q = 2.55 \times 10^{5} \times 1.60 \times 10^{-19}$ force = 4.09×10^{-14} (N)	C1 A1	**Allow** 1 mark for 4.1×10^{-n}, $n \neq 14$ **Allow** 2sf answer of 4.1×10^{-14} (N) Alternative: $F = \frac{Ve}{d} = \frac{2400\times1.60\times10^{-19}}{9.4\times10^{-3}}$ C1 force = $4.08(5) \times 10^{-14}$ (N) [Allow: 4.08×10^{-14} (N)]
		(ii)	KE = $e \times V$ or KE = $F \times d$ KE = $1.6 \times 10^{-19} \times 2400$ or KE = $4.09 \times 10^{-14} \times 9.4 \times 10^{-3}$ KE = 3.84×10^{-16} (J)	C1 A1	**Allow** 2 sf answer Possible ecf if answer from **(a)(i)** is used
		(iii)	KE = $\frac{1}{2}mv^2$ $v = \sqrt{\frac{2\times3.84\times10^{-16}}{9.11\times10^{-31}}}$ speed = $2.9(0) \times 10^{7}$ (m s^{-1})	B1	Possible ecf if answer from **(a)(ii)** is used
	(b)		There is no change (to the gain in KE) work done or KE = Fd, F or E is halved <u>and</u> d is doubled or work done or KE = VQ and V is the same or work done or KE = VQ and this does not depend on distance	M1 A1	
			Total	7	

Question			Answer	Marks	Guidance
4	(a)		Observations: 1. Most of the alpha particles went straight / un-deflected through (the atom(s) / foil) (AW) 2. (Some of the) alpha particles were scattered / repelled / deflected through large angles (AW) Conclusions (QWC mark): • 1 showed that most of the atom is empty space **and** • 2 showed the existence of small / dense / positive nucleus	M1 M1 A1	**Not** 'reflected' **Allow**: The QWC mark even if 'alpha reflected at large angles' is mentioned in 2
	(b)	(i)	The aluminium nucleus has velocity / accelerates / moves to the right There is a repulsive force on the (aluminium) nucleus (to the right) / According to conservation of momentum the (aluminium) nucleus must move (to the right)	B1 B1	**Allow**: Moves away from the alpha particle
		(ii)	$8.0\times10^{6}\times1.6\times10^{-19}=\frac{1}{2}\times6.6\times10^{-27}\times v^{2}$ (Any subject) speed = 2.0×10^{7} (m s^{-1})	C1 A1	**Note**: Answer to 3 sf is 1.97×10^{7} (m s^{-1}) **Allow** 1 sf answer 2×10^{7} (m s^{-1})
		(iii)	Q = 13e or q = 2e or $F=\frac{Qq}{4\pi\varepsilon_0 r^2}$ $270=\frac{13\times1.6\times10^{-19}\times2\times1.6\times10^{-19}}{4\pi\times8.85\times10^{-12}\times r^{2}}$ (Any subject) distance = 4.7×10^{-15} (m)	C1 C1 A1	**Allow**: $F=k\frac{Qq}{r^2}$, where $k=9\times10^{9}$ **Note**: No credit for using Q and q as 13 and 2

Question			Answer	Marks	Guidance
		(iv)	The strong force is attractive Correct explanation of size / direction of resultant force	M1 A1	**Allow**: The strong force is repulsive M1 Correct explanation of size / direction of resultant force A1
			Total	**12**	