	Question		Answer	Marks	Guidance
1 **A** **A** **A**	(a)	(i)	(atom releases energy when) electron moves from <u>high to low level</u> energy released is in form of a <u>photon</u> possible transitions are between n = 3 and n = 1, n = 3 and n = 2, n = 2 and n= 1	**B1** **B1** **B1**	can be illustrated on diagram by downward arrow connecting levels can be illustrated on diagram
	(a)	(ii)1	$\varepsilon = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 6.56 \times 10^{-7}$ $= 3.0(3) \times 10^{-19}$ (J)	 **C1** **A1**	choosing formula and substitution answer accept 3×10^{-19} (J) (no SF error)
	(a)	(ii)2	from n = 3 to n = 2	**B1**	**allow** between n = 3 and n = 2 **allow** n = 2 to n = 3 or between n = 2 and n = 3 **if** there is no contradiction with answer given in 7ai
	(b)	(i)	$d \sin \theta = \lambda \qquad d \sin 11.4^{o} = 6.56 \times 10^{-7}$ $d = 6.56 \times 10^{-7}/0.198$ $d = 3.3 \times 10^{-6}$ (m)	**C1** **C1** **A1**	choosing formula and substitution manipulation and $\sin 11.4^{o} = 0.198$
	(b)	(i)	$1/d = 3 \times 10^{5}$ m^{-1} = 300 mm^{-1}	**A1**	**ecf b(i)1**; allow 301 or 302 as data given to 3 sig figs
	(b)	(ii)	**2** rays, one either side of normal to grating at about 8°, say	**B1**	**accept** any sensible angle
			Total	**11**	

Question			Expected Answers	M	Additional Guidance
2					
	a	**i**	photoelectric effect/emission	B1	
		ii1	the <u>minimum</u> energy (required) to release an electron (from the surface of the metal)	B1	
		ii2	$3.5 \times 10^{-19} = 6.6 \times 10^{-34}$ f	C1	
			f = 5.3×10^{14} (Hz)	A1	
		iii	$\varepsilon = hc/\lambda = 6.6 \times 10^{-34} \times 3.0 \times 10^{8}/ 4.2 \times 10^{-7}$	C1	no second mark unless there is evidence of the
			= 4.7×10^{-19} (J)	A1	calculation being done
		iv	$\frac{1}{2}mv^2 = 4.7 \times 10^{-19} - 3.5 \times 10^{-19}$	C1	mark for using the p.e. equation
			= 1.2×10^{-19} (J)	A1	**accept** 1.5×10^{-19} from those using 5×10^{-19} J
	b	**i1**	12 (eV)	B1	
		ii2	$\varepsilon = eV = 12 \times 1.6 \times 10^{-19} = 1.92 \times 10^{-18}$ (J)	A1	**ecf(b)(i)1**
		ii	$\frac{1}{2}mv^2 = 2.0 \times 10^{-18}$	C1	$\frac{1}{2}mv^2 = 12$ scores 0/3
			$v^2 = 2 \times 2.0 \times 10^{-18}/9.1 \times 10^{-31} = 4.4 \times 10^{12}$	C1	**accept** 1.9×10^{-18} from **(b)(i)2**
			v = 2.1×10^{6} (m s⁻¹)	A1	giving v = $2.0(5) \times 10^{6}$
	c		e's emitted/s = $1.2 \times 10^{-8}/5 \times 10^{-19} = 2.4 \times 10^{10}$	C1	using 4.7×10^{-19} gives 2.55×10^{10}
			current = $2.4 \times 10^{10} \times 1.6 \times 10^{-19}$	C1	omitting 1% scores as a POT error
			= 3.8×10^{-9} (A) to 4.1×10^{-9} (A)	A1	allow 4 nA as the question states 'estimate'
			Total question 4	**16**	

Question			Expected Answers	Marks	Additional Guidance
3	(a)	(i)	line spacing d = 1/(300 x 1000) (= 3.3 x 10^{-6} (m))	B1	look for clear reasoning to award mark
		(ii)	$\sin \theta = \lambda/d$ = 6.3 x 10^{-7}/3.3 x 10^{-6} = 0.19 θ = 11 degrees	C1 C1 A1	rounding error of 0.2 here gives 11.9^{o} 11.9^{o} gets 2 marks
		(iii)	spots can be seen where n = d $\sin \theta/\lambda$ maximum n when $\sin \theta$ = 1 (giving n = 5.3) so n =5 can be seen thus 5 spots on either side of straight through + straight through = 11	B1 B1 B1	**accept** basic idea of orders for first mark N.B. calculation not necessary
	(b)	(i) (ii)	ε = hc/λ = 6.6 x 10^{-34} x 3.0 x 10^{8}/6.3 x 10^{-7} = 3.14 x 10^{-19} (J) 5.0 x 10^{-4}/3.14 x 10^{-19} = 1.6 x 10^{15}	C1 A1 C1 A1	**accept** 3.2 x 10^{-19} (J) **ecf** from **b(i)1**
	(c)	(i)	Electrons behave as waves/have a wavelength diffraction observable because gaps/atoms are similar to wavelength of electrons regular pattern of atoms acts as a grating allowing constructive interference to produce pattern on screen/AW rings occur because atomic 'crystals' at all possible orientations to beam/AW	B1 B1 B1 B1 B1	max 2 out of next 4 marking points **can** gain first 'waves' mark here as well as second mark if first line not written explicitly
		(ii) 1 2	λ = h/mv = 6.63 x 10^{-34}/9.1 x 10^{-31}v v = 6.63 x 10^{-34}/9.1 x 10^{-31} x 5.0 x 10^{-11} v = 1.5 x 10^{7} (m s^{-1}) $\frac{1}{2}mv^{2}$ = eV $\frac{1}{2}$ x 9.1 x 10^{-31} x 2.25 x 10^{14} = 1.6 x 10^{-19}V V = 6.4 x 10^{2} (V)	C1 A1 C1 C1 A1	using 6.6 instead of 6.63 gives 1.45 x 10^{7} using v =1.45 x 10^{7} gives 600 V
			Total question 6	**19**	