

Question		Expected Answers	M	Additional Guidance
1				
	a	i light emitted from (excited isolated) atoms produces a line spectrum a series of (sharp/bright/coloured) lines against a dark background	B1 B1	max 2 marks from 3 marking points
		ii in an absorption spectrum a series of <u>dark</u> lines (appears against a bright background/within a continuous spectrum)	B1	accept black
	b	i $\epsilon = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.00 \times 10^8 / 436 \times 10^{-9}$ $= 4.56 \times 10^{-19}$ (J)	C1 C1 A1	apply SF error if all numbers not to 3+ figures 4.54 if use 6.6
		ii 3.64×10^{-19} (J)	A1	allow mark if repeated error from b(i)
	c	i correct vertical lines; correct labels arrow(s) downwards	B1 B1 B1	1 mark for 1 vertical line + correct label
		ii $- 8.86 + 4.56 = - 4.3 \times 10^{-19}$ (J) $- 7.94 + 3.64 = - 4.3 \times 10^{-19}$ (J)	B1 B1	ecf b(i) do calculation for one line only correctly scores 2 marks; give answer as 4.3×10^{-19} or -4.3 scores 1 mark do calculation for both lines and give answer as 4.3×10^{-19} or -4.3 scores both marks
<p>N.B. Before marking 7d check pages 18, 19 and 20 for additional answers by scrolling down. Extra answers MUST be annotated to show that they have been seen and credited back in the relevant question when appropriate.</p> <p>✓ = 1 extra mark x = incorrect; scores 0 NBOD = no added value or no further action needed; scores 0 CON = if reference is made to the additional answer in the main text and this answer contradicts the other then deduct the original mark; = if NO reference is made to the additional answer in the main text and this answer contradicts the other then do NOT change the original mark</p>				
	d	($d \sin \theta = \lambda$) $3.3 \times 10^{-6} \sin \theta = 546 \times 10^{-9}$ $\sin \theta = 0.165$ $\theta = 9.5^\circ$	C1 C1 A1	
Total question 7			15	

Question			Answer	Marks	Guidance
2	(a)	(i)	3 correct labels	B1	
		(ii)	the (three) colours add up/superpose to give white light or no dispersion/diffraction of incident white light/AW	B1	allow use of formula $d \sin \theta = n\lambda$ so constructive interference at $\theta = 0$ for all λ
		(iii)	select $\lambda = d \sin \theta$ $\lambda = 1.67 \times 10^{-6} \sin 19.1$ $\lambda = 546 \times 10^{-9}$ (m)	C1 C1 A1	allow 547×10^{-9} as answer is 546.46×10^{-9} do not allow 550×10^{-9} unless SF mark already deducted
	(b)		select $E = hc/\lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^8/436 \times 10^{-9}$ $E = 4.56 \times 10^{-19}$ (J)	C1 C1 A1	do not allow 4.6×10^{-19} unless SF mark already deducted
	(c)	(1 arrow correctly labelled 2 more arrows correctly labelled	B1 B1	
			Total	10	

Question			Answer	Marks	Guidance
3	(a)	(i)	emission of electron(s) from a <u>metal</u> (surface) when photon(s)/light/uv/em radiation are incident (on surface)	B1	allow singular electron and absorption of photon
		(ii)	energy to accelerate/move an electron through a p.d. of 1 V/AW	B1	not 1.6×10^{-19} J
		(iii)	$5.0 \times 1.6 \times 10^{-19} = 8.0 \times 10^{-19}$ J	B1	allow 8 for 8.0; no mark if unit incorrect
	(b)		the <u>minimum</u> energy required to release an electron from the <u>surface</u> of the metal	B1	
		(i)	$\phi = 8.0 \times 10^{-19} - 1.1 \times 10^{-19}$ $= 6.9 \times 10^{-19}$ J	B1	no mark if unit incorrect unless unit in a(iii) incorrect
		(ii)1	$\frac{1}{2}mv^2 = 1.1 \times 10^{-19}$ $v^2 = 2.2 \times 10^{-19}/9.11 \times 10^{-31}$ ($= 2.4 \times 10^{11}$) $v = 4.9 \times 10^5$ ($m\ s^{-1}$)	C1 M1 A0	accept ora substitute 5×10^5 to find $E = 1.1 \times 10^{-19}$
		(ii)2	$\lambda = h/mv$ $= 6.63 \times 10^{-34} / 9.11 \times 10^{-31} \times 4.9 \times 10^5$ $= 1.5 \times 10^{-9}$ (m)	C1 C1 A1	accept 1.46×10^{-9} if using $v = 5 \times 10^5$
A A A	(c)	(Electrons behave as waves/diffract (observable because) gaps/atoms are of similar wavelength to electrons <u>regular/ordered</u> pattern of atoms/atoms act as a grating/AW allowing interference to produce pattern on screen/AW rings occur because atomic 'crystals' at all possible orientations to beam/AW	B1 B1 B1 B1 B1	allow graphite for atoms max 3 from 5 marking points
		(ii)	wavelength is too large to produce a diffraction pattern/electrons not travelling fast enough/AW	B1	ecf (b)(ii)2 ; e.g. for AW: wavelength is about 10 times atomic spacing or wavelength is different to spacing
Total				14	

Question		Answer	Marks	Guidance
4	(a)	light from the two sources must be/slits is coherent only possible to produce constant phase difference using a single source	B1 B1	allow 'has a constant phase difference' for 'is coherent' allow separate light sources are not coherent/do not have a constant phase difference
	(b)	at D: 180° or π rad at B: 0 or 360° or 2π rad	B1 B1	max 1 out of 2 if unit omitted except on zero allow $^\circ$ as symbol for rad
	(c)	(2.0×10^{-3} (m)	B1	allow 1 SF and 2 mm; allow 1.8 or 1.9 mm, only 2 SF
	(ii)	$\lambda = ax/D$ $= 0.4 \times 10^{-3} \times 2.0 \times 10^{-3} / 1.5$ $= 5.3(3) \times 10^{-7}$ (m)	C1 C1 A1	select formula ecf c(i) ; substitute answer
	(d)	2λ 1060 (nm)	C1 A1	ecf c(ii) ; allow 1000 for 5×10^{-7} allow 1066, 1067, 1070, 1100
A A A	(e)	($E = (8.7 \times 10^{-19} - 5.0 \times 10^{-19}) = 3.7 \times 10^{-19}$ (J) select $E = hc/\lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / 5.3 \times 10^{-7}$ $= 3.73 \times 10^{-19}$ (J) [or 3.98×10^{-19} if using 5.0×10^{-7}]	B1 C1 M1 A1	readings from diagram must see substitution ora substitute for E and find λ calculation ora 5.4×10^{-7} (m) N.B. the B mark can be awarded inside the calculation only for the ora method
	(ii)	X in infra-red/ir Z in ultra-violet/uv	B1 B1	allow 1 mark for answers reversed
		Total	16	