

Mark Scheme

Q1.

Question Number	Answer	Mark
	C	1

Q2.

Question Number	Answer	Mark
	D	1
	Incorrect Answers: A – absorption of the longest wavelength B – emission with the longest wavelength C – absorption of the shortest wavelength	

Q3.

Question Number	Answer	Mark
	B ground state to level 2	1
	Incorrect Answers: A – incorrect change in energy C – incorrect change in energy and direction D – incorrect direction	

Q4.

Question Number	Answer	Mark
	B	1

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
	An explanation that makes reference to: - if photon energy equal to an energy level difference in the elements present (1) - then the photon can be absorbed by an electron and the electron is excited/moves to higher level (1) - so the absorption spectrum is created because the frequencies of the absorbed photons are missing from the continuous spectrum produced by the star (1)	Accept references to re-emission in all directions.	3

Q6.

Question Number	Acceptable Answers	Additional guidance	Mark
	- Use of $E = hf$ and $v = f\lambda$ (1) - Converts between eV to J (1) $\lambda = 2.0 \times 10^{-7}$ (m) and conclusion that superradiance can occur (1)	<u>Example of calculation</u> $E = 6.2 \text{ eV} \times 1.6 \times 10^{-19} \text{ C}$ $E = \frac{6.63 \times 10^{-34} \text{ Js} \times 3.0 \times 10^8 \text{ ms}^{-1}}{\lambda}$ $\lambda = 201 \text{ nm}$ so superradiance can occur	3

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	- Use of $E = hf$ (1) - Use of $c = f\lambda$ (1) - Apply conversion factor of 1.6×10^{-19} for photon energy from J to eV (1) - Level = -5.74 (eV) (1)	<u>Example of calculation</u> $f = 3.00 \times 10^8 \text{ m s}^{-1} / 6.1 \times 10^{-7} \text{ m}$ $= 4.91 \times 10^{14} \text{ Hz}$ $E = 6.63 \times 10^{-34} \text{ Js} \times 4.91 \times 10^{14} \text{ Hz}$ $= 3.26 \times 10^{-19} \text{ J}$ $3.26 \times 10^{-19} \text{ J} / 1.6 \times 10^{-19} \text{ C} = 2.04 \text{ eV}$ Level = -3.71 eV - 2.04 eV = -5.75 eV	4

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Use of $E = \frac{1}{2}mv^2$ (1) • Use of $E = hf$ and $c = f\lambda$ (1) • $\lambda = (2.4 - 2.5) \times 10^{-7}(\text{m})$ (1) • leading to a conclusion that radiation is ultraviolet Or conclusion consistent with their value for wavelength (1)	MP4 dependent on MP2 <u>Example of Calculation</u> $\Delta E_k = \frac{1}{2} \times 9.11 \times 10^{-31} \text{ kg} \times ((2.5 \times 10^6 \text{ m s}^{-1})^2 - (2.1 \times 10^6 \text{ m s}^{-1})^2)$ $\Delta E_k = 8.4 \times 10^{-19} \text{ (J)}$ $\lambda = \frac{6.63 \times 10^{-34} \text{ J s} \times 3 \times 10^8 \text{ m s}^{-1}}{8.4 \times 10^{-19} \text{ J}}$ $\lambda = 2.4 \times 10^{-7}(\text{m})$	4

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$ (1) • mean kinetic energy = $6.4 \times 10^{-20} \text{ J}$ (1)	<u>Example of calculation:</u> $\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$ $= \frac{3}{2} \times 1.38 \times 10^{-23} \text{ J K}^{-1} \times 3100 \text{ K} = 6.42 \times 10^{-20} \text{ J}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• There are electron transitions between energy levels in the atoms. (1) • When electrons return to a lower level they emit energy in the form of <u>photons</u> (1)		2

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Electrons are excited to higher energy states / levels (by incident electrons) (1) - An electron returns to the lower energy state / level resulting in the emission of a <u>photon</u> (1) - The energy of the photon is equal to the difference of the energy states / levels (1) - Large difference in energy states / levels so as $E = hf$, radiation is high frequency (1)	For MP1 and MP2 allow - Electrons knock electrons out of low energy levels - Electrons cascade down to fill up the levels	4

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	(Moving) electrons collide with lattice/ions (1) - Transfer of energy to (lattice) ions so they vibrate with larger amplitude/speed (and the temperature increases) (1)		2
(ii)	- Electrons/ions in the tube collide with mercury/phosphor atoms and excite electrons (in the mercury/phosphor atoms) (1) - Energy is released in the form of photons as the electrons move back down (to the ground state) (1)	Mention of work function scores 0 MP2 Allow de-excite for move back down	2

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- the atoms have discrete energy levels (1) - atoms gain energy and get excited / electrons move to higher energy levels (1) - atoms/electrons move to lower energy levels and emit energy as photons (1) <u>different</u> energy changes cause photons with <u>different</u> frequencies/wavelengths (1)		(4)

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	- Use of $E = hf$ and $c = f\lambda$ (1) - Convert J to eV (1) 2.1 eV (1) - Arrow drawn on diagram from -3.04 eV to -5.14 eV (1)	<u>Example of calculation</u> $E = 6.63 \times 10^{-34} \text{ Js} \times 3.00 \times 10^8 \text{ m s}^{-1} / 5.89 \times 10^{-7} \text{ m}$ $= 3.38 \times 10^{-19} \text{ J}$ $3.38 \times 10^{-19} \text{ J} / 1.60 \times 10^{-19} \text{ C} = 2.11 \text{ eV}$	4

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	μ read from graph (1) - Use of $I = I_0 e^{-\mu x}$ (1) $I = 1.5 \text{ W m}^{-2}$ (1)	Accept μ in the range $140 \text{ (m}^{-1}\text{)} - 160 \text{ (m}^{-1}\text{)}$ Accept answers that round to 1.4 W m^{-2} or 1.5 W m^{-2} dependent upon value of μ for MP3 <u>Example of calculation:</u> $I = 1.8 \text{ W m}^{-2}$ $\times e^{-150 \text{ m}^{-1} \times 1.4 \times 10^{-3} \text{ m}} = 1.46 \text{ W m}^{-2}$	3

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	- Electrons exist in discrete energy levels (1) (After the mercury atom is excited) electrons move back to a lower energy level (1) - Or (After the mercury atom is excited) electrons move back down from a higher energy level - Photons are emitted (1) - Frequency of emitted radiation / photons depends on the difference in energy between the energy levels (1) - Or reference to $\Delta E = hf$ - Since there are only certain energy changes possible, only certain frequencies are possible (1)	Accept excited state for higher energy level Accept ground state for lower energy state	5

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with	

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no
6	4	
5 - 4	3	
3 - 2	2	
1	1	
0	0	

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning	marks for linkages).	
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2		
Answer is partially structured with some linkages and lines of reasoning	1		
Answer has no linkages between points and is unstructured	0		
Indicative content - electrons/atoms move to higher energy levels Or electrons/atoms are excited - they then move to lower energy levels (accept ground state) and the energy (from the change) is given out in the form of a <u>photon</u>			(6)

- the energy levels are discrete Or only certain energy levels are possible - the energy of the photon is <u>equal</u> to the difference in energy levels Or $hf = E_2 - E_1$ Or $hc/\lambda = E_2 - E_1$ - there are only a limited number of energy differences and only a corresponding set of frequencies/wavelengths - different elements have different energy level (differences), so they will produce different frequencies/wavelengths	looking for energy differences /changes not energy levels	
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Question Number	Acceptable Answers	Additional Guidance	Mark
	- atoms/electrons have fixed/discrete/specific energy levels (1) - electrons get excited by absorbing <u>photons</u> (1) - energy of <u>photon</u> absorbed = difference in energy levels (1) - only certain transitions possible, so only certain <u>photon</u> energies absorbed so only certain frequencies missing (1) - the set of frequencies absorbed depends on the element (1)	Answers in terms of emission spectrum can be awarded MP1, 4 and 5	5

Q18.

Question Number	Acceptable Answers	Additional guidance	Mark
	Max 6 Similarities - An electron absorbs a photon Or electrons gain energy from a photon (1) - photons need a minimum amount of energy (1) - So light must be above a certain frequency (1) - increasing the light intensity increases the number of electrons (released per sec) (1) - Evidence for the particle model of light (1) Differences - In the photoelectric effect electrons are released from the surface (1) - But electrons remain within the LDR (1) - Photoelectric effect occurs in metals Or LDR is a semiconductor (1)		6

Q19.

Question Number	Acceptable Answers	Additional guidance	Mark
	- Atoms contain discrete energy levels (1) - The atom/electron loses energy and falls back down energy levels emitting a <u>photon</u> (1) - with energy equal to the difference in energy levels (1) - Energy (of photon) is proportional to frequency (1) - So emitted frequency of radiation corresponds to the difference in energy levels of a particular atom (1)		5

Q20.

Question Number	Answer		Mark
(a)(i)	4.0 Ω	(1)	1
(a)(ii)	Use of $V=IR$ $I = 0.75 \text{ A}$ (ecf) <u>Example of calculation</u> $I = 3 \text{ V} / 4 \Omega$ $I = 0.75 \text{ A}$	(1) (1)	2
(a)(iii)	Use of $P = I^2 R$ or $P = VI$ or $P = V^2/R$ Power = 2.0 W (ecf) <u>Example of calculation</u> $P = (0.75 \text{ A})^2 \times 3.6 \Omega$ $P = 2.0 \text{ W}$	(1) (1)	2
(b)	Total resistance (of circuit) will increase Current will decrease Reference to $P = I^2 R$ to explain power decreasing Or $P = VI$ to explain power decreasing Or Lost volts increases Or Ir increases V across element decreases Reference to $P = VI$ to explain power decreasing Or $P = V^2/R$ to explain power decreasing	(1) (1) (1) (1) (1) (1)	3

Q21.

Question Number	Answer	Mark
(a)	Quantum of ... Or (discrete) packet of ... Or discrete quantity of ... (To score the mark must refer to something relevant e.g. light / energy) Of <u>electromagnetic</u> radiation/energy	(1) (1) 2
* (b)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) describe relevant interaction between single photon and single electron photon energy depends on frequency Or reference to $E = hf$ (must be link to photons/light) if photon energy greater than work function, electron emitted (immediately) whereas for waves energy could build up Or with waves that the electron can absorb energy continuously or over time so any frequency should work Or but this build up doesn't happen	(1) (1) (1) (1) (1) 5
(c)(i)	Use of $4.3 \times 1.6 \times 10^{-19}$ Use of $E = hf$ $f = 1.0 \times 10^{15}$ Hz <u>Example of calculation</u> $E = 4.3 \text{ V} \times 1.6 \times 10^{-19} \text{ C}$ $= 6.9 \times 10^{-19} \text{ J}$ $6.9 \times 10^{-19} \text{ J} = 6.63 \times 10^{-34} \text{ Js} \times f$ $f = 1.0 \times 10^{15} \text{ Hz}$	(1) (1) (1) 3
(c)(ii)	Ultraviolet Accept ultraviolet even if frequency in c(i) is incorrect, but allow ecf from candidate's value of frequency to appropriate part of electromagnetic spectrum	(1) 1
Total for question		11

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	- The electrons/atoms can only exist in discrete/specific energy levels (in the sodium atoms) (1) - Electrons/atoms become excited Or Electrons/atoms move to higher energy levels (1) - The electrons/atoms then move to lower energy levels, giving out energy in the form of <u>photons</u> (1) - The energy of the photon is equal to the energy difference between the energy levels (1) $E = hf$ and $\lambda = c/f$ so wavelength depends on the photon energy (1) - There are only certain energy transitions possible (between discrete levels) so only certain frequencies/wavelengths are visible. (1)	accept $E = hc / \lambda$ MP6 – Allow reference to few or limited number for ‘certain’. Allow reference to discrete differences in energy levels.	6

(ii)	- Use of $n\lambda = d \sin \theta$ (1) $d = 1.77 \times 10^{-6} \text{ m}$ (1) - Choose $d = 2.0 \times 10^{-6} \text{ m}$ as a smaller value than $d = 1.77 \times 10^{-6} \text{ m}$ would cause greater diffraction angles so the third order would not be seen, but $3.3 \times 10^{-6} \text{ m}$ would produce smaller angles than $2.0 \times 10^{-6} \text{ m}$, causing larger relative uncertainty in measurement (1) - Or - Use of $n\lambda = d \sin \theta$ - A correct value of $\sin \theta$ or θ $d = 1.0 \times 10^{-6} \text{ m} \rightarrow 1.77$ $d = 1.7 \times 10^{-6} \text{ m} \rightarrow 1.04$ $d = 2.0 \times 10^{-6} \text{ m} \rightarrow 0.88 \quad 62.^\circ$ $d = 3.3 \times 10^{-6} \text{ m} \rightarrow 0.535 \quad 32.^\circ$ (1) - Choose $d = 2.0 \times 10^{-6} \text{ m}$. $1.7 \times 10^{-6} \text{ m}$ would give a sine value greater than 1, so no 3rd order is visible, and $3.3 \times 10^{-6} \text{ m}$ would produce smaller angles than $2.0 \times 10^{-6} \text{ m}$, causing larger relative uncertainty in measurement (1)	<u>Example of calculation</u> $3 \times 5.89 \times 10^{-7} \text{ m} = d \sin 90^\circ$ $d = 1.77 \times 10^{-6} \text{ m}$	3
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Q23.

Question Number	Answer	Mark
(a)	Photon – quantum/packet of something relevant e.g. light, radiation, any other named e-m radiation, energy (1) (quantum/packet) of <u>electromagnetic</u> energy/radiation/waves (1) (dependent mark)	2
(b)	Use of $(20.66 - 18.70) \times 1.6 \times 10^{-19}$ (1) Use of $E = hf$ (with energy in eV or J) (1) $f = 4.7 \times 10^{14}$ Hz (1) <u>Example of calculation</u> $f = (20.66 - 18.70) \times 1.6 \times 10^{-19} / 6.63 \times 10^{-34}$ $f = 4.73 \times 10^{14}$ Hz	3
(c)	From kinetic energy of atoms (1)	1
(d)	Diffraction (1) Light spreads (sideways) as it passes through the slit (1) Narrower slit causes more diffraction/spreading Or diffraction increasing as gap width gets closer to wavelength (1)	3
Total for question		9