

Mark Scheme

Q1.

Question Number	Answer	Mark
	A is the correct answer B is not the correct answer as this transition would result in the emission of a photon with the shortest wavelength. C is not the correct answer as the arrow direction indicates absorption rather than emission. D is not the correct answer as the arrow direction indicates absorption rather than emission.	(1)

Q2.

Question Number	Answer	Mark
	The only correct answer is A $\left(\frac{f}{8}\right)$ B is not correct because this is the energy for transition $n = 4$ to 3 or $n = 2$ to 1 C is not correct because this is the energy for transition $n = 3$ to $n = 2$ D is not correct because this is the energy for transition $n = 4$ to 1	1

Q3.

Question Number	Answer	Mark
	A is the correct answer as a photon cannot be partially absorbed by an atom. B is not the correct answer as a photon of 10.2eV would use all of its energy to transfer an electron from the -13.6eV level to the -3.4eV level. C is not the correct answer as an electron of 13.6eV would use 10.2eV to transfer the electron and retain 3.4eV as its own kinetic energy. D is not the correct answer as an electron of 10.2eV could give all its energy to transfer an electron from the -13.6eV level to the -3.4eV level.	(1)

Q4.

Question Number	Answer	Mark
	B is the correct answer A is not correct because E_1 should be added to the energy of the photon. C is not correct because the speed of light should be part of the numerator and wavelength should be the denominator and E_1 should be added to the energy of the photon. D is not correct because the speed of light should be part of the numerator and wavelength should be the denominator.	1

Q5.

Question Number	Answer	Mark
	C is the correct answer as the possible jumps in energy levels are from $n=3$ to $n=2$, $n=3$ to $n=1$ and $n=2$ to $n=1$. A is not the correct answer as there is more than one possible energy level jump. B is not the correct answer as there are more than two possible energy level jumps. D is not the correct answer as there are less than four possible energy level jumps.	(1)

Q6.

Question Number	Answer	Mark
	The only correct answer is B - 3 A is not correct because the energy transferred to the electron is not 4.91 eV C is not correct because the energy transferred to the electron is not 6.70 eV D is not correct because the energy transferred to the electron is not 7.73 eV	1

Q7.

Question Number	Answer	Mark
	B is the correct answer as there is no downwards jump of energy levels equivalent to 0.54eV when falling from the -0.54eV level A is not the correct answer as this difference in energy levels is produced when an electron falls from the -0.54 eV level to the -0.85 eV level C is not the correct answer as this difference in energy levels is produced when an electron falls from the -1.51eV level to the -13.60 eV level D is not the correct answer as this difference in energy levels is produced when an electron falls from the -0.54 eV level to the -13.60 eV level	(1)

Q8.

Question Number	Answer	Mark
	The only correct answer is A (9.8 eV) B is not correct because this would be a transition between the ground state and $n = 1$ C is not correct because this would be a transition between the ground state and $n = 2$ D is not correct because this would be a transition between the ground state and $n = 3$	1

Q9.

Question Number	Answer	Mark
	D is the correct answer A is not the correct answer as this corresponds to the smallest energy change B is not the correct answer as this corresponds to the smallest energy change C is not the correct answer as this corresponds to the smallest energy change	1

Q10.

Question Number	Answer	Mark
	The only correct answer is A (A because this emits a photon with the highest frequency) B is not correct as a photon would be absorbed C is not correct because the frequency would be smaller so wavelength larger D is not correct as a photon would be absorbed	1

Q11.

Question Number	Answer	Mark
	Use of $E = hf$ (1) Converts J to eV (1) Transition from $(-) 0.54\text{eV}$ to $(-) 0.85\text{eV}$ (1) Example of calculation $E = hf = (6.63 \times 10^{-34} \text{ Js}) \times (7.48 \times 10^{13} \text{ Hz}) = 4.96 \times 10^{-20} \text{ J}$ $4.96 \times 10^{-20} \text{ J} / (1.60 \times 10^{-19} \text{ J eV}^{-1}) = 0.31 \text{ eV}$	(3)
	Total for question	3

Q12.

Question Number	Answer	Mark
	For the electron (in the atom) to move from -13.6eV to -1.5eV requires 12.1eV (1)	
	0.2eV / remaining (kinetic) energy left for the (incoming) electron (1)	
	Idea that <u>energy</u> of a photon is transferred to a single electron Or Idea that photon can only excite an electron if it matches the energy difference between levels Or Idea that photons give all of their energy (or none at all) (1)	
	Photon energy is not exactly 12.1eV so electron/atom remains at the -13.6eV level Or There is no transition equivalent to 12.3eV Or There is no -1.3eV energy level (1)	4
	(Ignore references to work function or photons being emitted) (MP1 – award this mark if 12.1eV is seen) (MP3 – do not award simply for saying “one photon interacts with one electron”) (MP4 – Award if candidates make it clear that 12.1eV is not equal to 12.3eV in an argument to explain why photons cannot produce the change in energy levels for the electron)	
	Total for Question	4

Q13.

Question Number	Answer	Mark																																								
* a	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. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	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	
IC points	IC mark	Max linkage mark	Max final mark																																							
6	4	2	6																																							
5	3	2	5																																							
4	3	1	4																																							
3	2	1	3																																							
2	2	0	2																																							
1	1	0	1																																							
0	0	0	0																																							
	Number of marks awarded for structure of answer and sustained line of reasoning																																									
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 • Atoms/electrons absorb energy/photons • Electrons move to higher energy levels • Then drop down energy levels, releasing <u>photons</u> • Energy levels are discrete • For hydrogen atoms, there are only a small number of possible energy level differences (that can occur to produce visible light) • Since $E = hf$ and $v = f\lambda$, only certain wavelengths are emitted (For IC1, do not allow 'gain energy') (For IC2 and IC3, allow electrons excited and de-excited) (IC4, allow 'atoms only have certain/specific energy levels')	6
--	--	---

b	Air contains different gases/molecules/elements/atoms (1) Each (different) gas has its own energy levels (so light with a large number of wavelengths/frequencies are released) (1) (MP1 – do not accept 'air is a mixture of different particles')	2
Total for question		8

Q14.

Question Number	Answer	Mark
a	(Sodium) electrons/atoms gain/absorb energy (1) And electrons move to higher energy levels (1) (Sodium) electrons drop to lower energy levels, releasing <u>photons</u> (1) (For MP2 & MP3, allow excited and de-excited) (For MP2 & MP3, do not allow “atoms” for “electrons”) (For “levels” accept shells, orbitals, states)	3
b	Use of $c = f\lambda$ and Use of $E = hf$ (1) Converts J to eV (1) Energy = 2.11eV (1) <u>Example of calculation</u> $f = (3.00 \times 10^8 \text{ m s}^{-1}) / (589 \times 10^{-9} \text{ m}) = 5.09 \times 10^{14} \text{ Hz}$ $E = (6.63 \times 10^{-34} \text{ Js}) \times (5.09 \times 10^{14} \text{ Hz}) = 3.38 \times 10^{-19} \text{ J}$ $E \text{ (in eV)} = (3.38 \times 10^{-19} \text{ J}) / (1.60 \times 10^{-19} \text{ J eV}^{-1}) = 2.11 \text{ eV}$	3
c	Uses $\tan\theta = s / D$ (1) Use of $n\lambda = d\sin\theta$ with $n = 1$ (1) Grating has 301 lines / mm, so the label is correct. (1) OR Uses $\sin\theta = \frac{s}{\sqrt{s^2 + D^2}}$ (1) Use of $n\lambda = d\sin\theta$ with $n = 1$ (1) Grating has 301 lines / mm, so the label is correct. (1) (Use of double slit or single slit equations does not gain any credit) (Allow reverse calculation to show that 300 lines per mm leads to a value of λ that is close to the given value or that 300 lines per mm leads to a value of d or θ that is close to a value calculated). <u>Example of calculation</u> $\tan\theta = 0.234 \text{ m} / 1.30 \text{ m} = 0.18$ $\theta = 10.2^\circ$ $n\lambda = d\sin\theta$, so $d = 589 \times 10^{-9} \text{ m} / \sin 10.2^\circ = 3.33 \times 10^{-6} \text{ m}$ lines per mm = $1 / 3.33 \times 10^{-3} \text{ m} = 301$.	3
Total for question		9

Q15.

Question Number	Answer	Mark
a	Conversion of eV into J (1) Use of $E = hf$ (1) Use of $v = f\lambda$ with $v = 3.00 \times 10^8 \text{ ms}^{-1}$ (1) $\lambda = 654 \text{ (nm)}$, so light (for this transition) is red (1) <u>Example of calculation</u> $1.9 \text{ eV} \times (1.60 \times 10^{-19} \text{ J eV}^{-1}) = 3.04 \times 10^{-19} \text{ J}$ $f = \frac{E}{h} = \frac{3.04 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ Js}} = 4.59 \times 10^{14} \text{ Hz}$ $\lambda = \frac{v}{f} = \frac{3.00 \times 10^8 \text{ ms}^{-1}}{4.59 \times 10^{14} \text{ Hz}} = 6.54 \times 10^{-7} \text{ m}$	4
b	Converts 8.60 light years into metres (1) Use of $I = P/A$ (1) Use of $A = 4\pi r^2$ (1) Power of Sirius A = $9.73 \times 10^{27} \text{ W}$ (1) <u>Example of calculation</u> $8.60 \times 365 \times 24 \times 60 \times 60 \times (3.00 \times 10^8 \text{ ms}^{-1}) = 8.14 \times 10^{16} \text{ m}$ $P = I \times A = (1.17 \times 10^{-7} \text{ W m}^{-2}) (4\pi) (8.14 \times 10^{16} \text{ m})^2 = 9.73 \times 10^{27} \text{ W}$	4
c	Atoms have fixed/certain/discrete energy levels (1) Or Emitted photons have discrete energy (1) Only certain transitions are possible (in a hydrogen atom) (1) Or Some transitions are not possible (in a hydrogen atom) (For MP2, allow “differences in energy (levels)” for “transitions”)	2
Total for question		10

Q16.

Question Number	Answer	Mark																																								
(a)(i)	Use of $E = hf$ (1) $f = 5.19 \times 10^{14} \text{ Hz}$ (1) <u>Example of calculation</u> $f = \frac{3.44 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ J s}} = 5.189 \times 10^{14} \text{ Hz}$	2																																								
* (a)(ii)	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. <table border="1"> <thead> <tr> <th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr> </thead> <tbody> <tr><td>6</td><td>4</td><td>2</td><td>6</td></tr> <tr><td>5</td><td>3</td><td>2</td><td>5</td></tr> <tr><td>4</td><td>3</td><td>1</td><td>4</td></tr> <tr><td>3</td><td>2</td><td>1</td><td>3</td></tr> <tr><td>2</td><td>2</td><td>0</td><td>2</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>1</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>0</td></tr> </tbody> </table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table border="1"> <thead> <tr> <th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr> </thead> <tbody> <tr> <td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr> <tr> <td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr> <tr> <td>Answer has no linkages between points and is unstructured</td><td>0</td></tr> </tbody> </table> IC1 The potential difference causes a current in the gas / tube IC2 So energy is transferred to the gas atoms IC3 Electron/atom gains (sufficient) energy to move up energy levels IC4 An (excited) electron (is unstable and) falls back down emitting a photon IC5 With a wavelength/frequency corresponding to the difference in the energy levels Or reference to $E = hf$ or $E \propto f$ IC6 Electrons/atoms exist in discrete/fixed/certain energy levels so only certain frequencies / wavelengths are emitted	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	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	6
IC points	IC mark	Max linkage mark	Max final mark																																							
6	4	2	6																																							
5	3	2	5																																							
4	3	1	4																																							
3	2	1	3																																							
2	2	0	2																																							
1	1	0	1																																							
0	0	0	0																																							
	Number of marks awarded for structure of answer and sustained line of reasoning																																									
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																																									

(b)(i)	Use of $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$ (1) Use of $hf = \phi + \frac{1}{2}mv_{\text{max}}^2$ (1) $v_{\text{max}} = 5.34 \times 10^5 \text{ m s}^{-1}$ (1) <u>Example of calculation</u> $4.75 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 7.6 \times 10^{-19} \text{ J}$ $7.6 \times 10^{-19} \text{ J} = 6.3 \times 10^{-19} \text{ J} + \frac{1}{2} \times 9.11 \times 10^{-31} \text{ kg} \times v_{\text{max}}^2$ $v_{\text{max}} = 534\,000 \text{ m s}^{-1}$	3
(b)(ii)	Use of $p = mv$ and $\lambda = \frac{h}{p}$ (1) $\lambda = 1.4 \times 10^{-9} \text{ m}$ (1) <u>Example of calculation</u> $\lambda = \frac{6.63 \times 10^{-34} \text{ J s}}{9.11 \times 10^{-31} \text{ kg} \times 5.3 \times 10^5 \text{ m s}^{-1}} = 1.37 \times 10^{-9} \text{ m}$	2
Total for question		13