Atomic Spectra & Band Theory

Mark Scheme

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Quantum Physics
Sub Topic	Atomic Spectra & Band Theory
Paper Type	Theory
Booklet	Mark Scheme

Time Allowed: **76 minutes**

Score: **/63**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a** photon 'absorbed' by electron B1
photon has energy equal to difference in energy of two energy levels B1
electron de-excites emitting photon (of same energy) in any direction B1 [3]

(b) ($E = hc/\lambda$ C1
$= (6.63 \times 10^{-34} \times 3 \times 10^{8}) / (435 \times 10^{-9})$ C
$= 4.57 \times 10^{-19}$ J (*allow 2 s.f.*) C
$= (4.57 \times 10^{-19}) / (1.6 \times 10^{-19})$ (eV)
= 2.86 eV (*allow 2 s.f.*) A [4]

(ii) arrow pointing in either direction between –3.41 eV and –0.55 eV B [1]

2 **(a** each wavelength is associated with a discrete change in energy M1
discrete energy change / difference implies discrete levels A1 [2]

(b) **1.** arrow from –0.54 eV to –0.85 eV, labelled L B1 [1]

2. arrow from –0.54 eV to –3.4 eV , labelled S B1 [1]
(two correct arrows, but only one label – allow 2 marks)
(two correct arrows, but no labels – allow 1 mark)

(ii) $E = hc / \lambda$ C1
$(3.4 - 0.54) \times 1.6 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / \lambda$ C1
$\lambda = 4.35 \times 10^{-7}$ m A1 [3]

(c) –1.50 → –3.4 = 1.9 eV
–0.85 → –3.4 = 2.55 eV (allow 2.6 eV
–0.54 → –3.4 = 2.86 eV (allow 2.9 eV
3 correct, 2 marks with –1 mark for each additional energy
2 correct, 1 mark but no marks if any additional energy differences B2 [2]

3 **(a)** packet/quantum/discrete amount of energy M1
of electromagnetic radiation A1
(allow 1 mark for 'packet of electromagnetic radiation')
energy = Planck constant × frequency *(seen here or in **b**)* B1 [3]

(b) each (coloured) line corresponds to one wavelength/frequency B1
energy = Planck constant × frequency
implies specific energy change between energy levels B1
so discrete levels A0 [2]

4 **(a)** each line represents photon of specific energy M1
photon emitted as a result of energy change of electron M1
specific energy changes so discrete levels A1 [3]

(b) **(i)** arrow from –0.85 eV level to –1.5 eV level B1 [1]

(ii) $\Delta E = hc/\lambda$ C1
$= (1.5 - 0.85) \times 1.6 \times 10^{-19}$ C1
$= 1.04 \times 10^{-19}$ J
$\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(1.04 \times 10^{-19})$
$= 1.9 \times 10^{-6}$ m A1 [3]

(c) spectrum appears as continuous spectrum crossed by dark lines B1
two dark lines B1
electrons in gas absorb photons with energies equal to the excitation energies M1
light photons re-emitted in all directions A1 [4]

5 **(a)** **(i)** e.g. electron / particle diffraction B1 [1]

(ii) e.g. photoelectric effect B1 [1]

(b) **(i)** 6 A1 [1]

(ii) change in energy = 4.57×10^{-19} J
$\lambda = hc/E$ C1
$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (4.57 \times 10^{-19})$
$= 4.4 \times 10^{-7}$ m A1 [2]

6 **(a)** each line corresponds to a (specific) photon energy B1
photon emitted when electron changes its energy level B1
discrete energy changes so discrete levels ..... B1 [3]

(b) ($E = hc / \lambda$ …(*allow ratio ideas*) C1
$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (486 \times 10^{-9})$
$= 4.09 \times 10^{-19}$ J ..... A1 [2]

(ii) four transitions to/from -5.45×10^{-19} J level B1
all transitions shown from higher to lower energy (level) ..... B1 [2]

[Total: 7]

7 (a e.g. 'instantaneous' emission (of electrons)
threshold frequency below which no emission
(max) electron energy dependent on frequency
(max) electron energy not dependent on intensity
rate of emission (of electrons) depends on intensity
(*any three sensible suggestions, 1 each*) B3 [3]

(b) 'packet' / quantum of energy M1
of electromagnetic energy / radiation A1 [2]

(ii) discrete wavelengths mean photons have particular energies M1
energy of photon determined by energy change of (orbital) electron M1
so discrete energy levels A0 [2]

(c) (three energy changes shown correctly B1
arrows 'pointing' in correct direction B1
wavelengths correctly identified B1 [3]

(ii) chooses λ = 486 nm C1
$\Delta E = hc / \lambda$ C1
$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (4.86 \times 10^{-9})$
$= 4.09 \times 10^{-19}$ J (*allow 2 s.f.*) [3]

8 (a) $E = hc/\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (486 \times 10^{-9})$ C1
$= 4.09 \times 10^{-19}$ J ...(allow 2 sf)..... A1 [2]

(b) energy level drawn at 4.09×10^{-19} J ..... B 1
transition 4.09×10^{-19} to zero clear ..... B 1
transition 4.09×10^{-19} to 3.03×10^{-19} clear ..... B 1 [3]
(-1 for reversed arrows, -1 for extra level at 1.06)