A-Level Physics

Energy Levels and Photon Emission

Mark Scheme

Time available: 68 minutes
Marks available: 61 marks

1.

(a) λ = 656 nm ✓

Power of 10 error allow 2

Use of $E=hc/\lambda$ ✓ = 3.0 × 10^{-19} (J)

Allow ecf for wrong choice of wavelength

E/ 1.6 × 10^{-19}

= 1.9 (1.88) (allow 1sf if correct)

Treat as skill mark – allow conversion for any value of E

3

(b) They are (just) free ✓

Allow released from atom

1

(c) This is the ground state ✓

or

This is the lowest level an electron can occupy

Allow lowest energy state

Condone level for state

Allow description of ground state

1

(d) To become free / to remove an electron (reach zero energy) energy has to be supplied ✓

or

Energy decreases from 0 as electrons move to lower energy levels/relate to energy needed to move from that state to 0

Or

Electrons release energy as they move lower

Or

Zero is the maximum energy

1

(e) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question**

Mark	Criteria
6	All three aspects analysed. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all 3 aspects. If there are a couple of errors or missing parts then 5 marks should be awarded.
4	Two aspects successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	Two aspects discussed, or one discussed and two others covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one aspect discussed successfully, or makes a partial attempt at 2 or all 3.
1	None of the three aspects covered without significant error.
0	No relevant analysis.

The following statements are likely to be present.

A Reason for high potential difference

pd accelerates electrons/produces high speed / high energy electrons in the tube L1

electrons have to have sufficient energy to excite the atoms/raise electrons into higher levels L3

B Relation between spectrum and energy level diagram

Visible spectrum results from excited electrons moving into the lower level at -3.4 eV L3

Each transition results in a photon of light L2

Energy of photon is the difference in the energies of the two levels L2

Frequency of light in the spectrum given by $\Delta E = hf$ L1

C Relevant calculation clearly communicated

Gives an example: eg the lowest frequency is due to a transition from the -1.5 eV level to the -3.4 level L1

Uses an energy difference to deduce one of the wavelengths: eg energy difference in J = 3×10^{-19} L2

$\lambda = hc/E = 660$ nm L2

6

[12]

2. **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the '*Mark Scheme Instructions*' document should be used to assist in marking this question.**

Level	Criteria	QoWC
L3 5−6 marks	Good discussion of both elements in question with at least 4 points mentioned in each element	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3−4 marks	Good discussion with at least 3 points in one element and 2 points in the other element	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1 1−2 marks	Discussion of one element only incorporating at least two points.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0	Unsupported combination or no relevant analysis	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

Collisions

- *Energy from collision of charged particles transfers to electrons in gas molecules.*
- *Electrons excited to higher energy levels.*
- *The more energy the electrons absorb the higher the energy levels reached.*
- *Electrons are unstable at higher energy levels so will fall back down.*
- *When it falls down it will emit a photon.*

Formation of spectral lines

- *Photon energy = hf/ or photon energy proportional to frequency.*
- *Spectral lines are at specific wavelengths.*
- *Each spectral line corresponds to an electron falling down to a lower energy state.*
- *Energy gap, $\Delta E = hc/\lambda$*
- *Larger energy gap means higher energy photon is emitted so shorter wavelength or vice versa.*

Responses with no mention of photons are likely to receive zero marks.

6

[6]

3. (a) (i) electrons passing through tube collide with electrons in mercury atom ✓

Allow mercury atoms collide with each other

transferring energy / atom gains energy from a collision ✓

causing orbital electrons / electrons in mercury atom to move to higher energy level ✓

Atomic electrons move from ground state

3

(ii) (each) excited electron / atom relaxes to a lower (energy) level ✓

allow excited electron / atom de-excites / relaxes

Allow excited electron / atom relaxes to ground state

Condone moves for relaxes

emitting a photon of energy equal to the energy difference between the levels ✓

2

(b) coating absorb (uv) photons (causing excitation) / (uv)photons collide with electrons in the coating (causing excitation) / electrons in coating are excited

allow atoms in coating absorb (uv) photons (causing excitation)

Atomic electrons de-excite indirectly to previous lower level (and in doing so emit lower energy photons) ✓

Owtte (must convey smaller difference between energy levels in a transition) cascade

2

[7]

4. (a) (i) absorbs enough energy (from the incident) electron(by collision) OR incident electron loses energy (to orbital electron) ✓

exact energy / 10.1((eV) needed to make the transition / move up to level 2 ✓

For second mark must imply exact energy

2

(ii) *(use of $E_2 - E_1$) = hf*

$-3.41 - -13.6 = 10.19$ ✓

energy of photon = $10.19 \times 1.6 \times 10^{-19} = 1.63 \times 10^{-18}$ (J) ✓

$6.63 \times 10^{-34} \times f = 1.63 \times 10^{-18}$

$f = 2.46 \times 10^{15}$(Hz) ✓

(accept 2.5 but not 2.4)

CE from energy difference but not from energy conversion

3

(iii) $Ek = 1.7 \times 10^{-18} - 1.63 \times 10^{-18}$ ✓ $= 7.0 \times 10^{-20}$ J ✓

2

(iv) energy required is 12.09 eV / 1.9×10^{-18} ✓

energy of incident electron is only 10.63 eV / energy of electron less than this (1.7×10^{-18} J) ✓

State and explain must have consistent units i.e. eV or J

2

(b) (i) Electrons return to lower levels by different routes / cascade / not straight to ground state ✓

1

(ii) 3 ✓
n=3 to n=1 or n=3 to n=2 and n=2 to n=1 ✓
no CE from first mark

2

[12]

5.

(a) (i) when electrons/atoms are in their lowest/minimum energy (state) **or** most stable (state) they (are in their ground state) ✓

1

(ii) in either case an electron receives (exactly the right amount of) energy ✓

excitation promotes an (orbital) electron to **a higher energy/up a** level ✓

ionisation occurs (when an electron receives enough energy) **to leave** the atom ✓

3

(b) electrons occupy discrete energy levels ✓

and need to absorb an exact amount of/enough energy to move to a higher level ✓

photons need to have certain frequency to provide this energy **or** e = hf ✓

energy required is the same for a particular atom or have different energy levels ✓

all energy of photon absorbed ✓

in 1 to 1 interaction or clear **a/the photon** and **an/the electron**s ✓

4

(c) energy = $13.6 \times 1.60 \times 10^{-19} = 2.176 \times 10^{-18}$ (J) ✓

$hf = 2.176 \times 10^{-18}$ ✓

$f = 2.176 \times 10^{-18} \div 6.63 \times 10^{-34} = 3.28 \times 10^{15}$ Hz ✓ 3 sfs ✓

4

[12]

6.

(a) (i) an electron/atom is at a higher level than the ground state **(1)**

or electron jumped/moved up to another/higher level

1

(ii) electrons (or electric current) flow through the tube **(1)**

and collide with orbiting/atomic electrons or mercury atoms **(1)**

raising the electrons to a higher level (in the mercury atoms) **(1)**

3

(iii) photons emitted from mercury atoms are in the **ultra violet** (spectrum) **or** high energy photons **(1)**

these photons are absorbed by the powder **or** powder changes frequency/wavelength **(1)**

and the powder emits photons in the visible spectrum **(1)**

incident photons have a variety of different wavelengths **(1)**

max 3

(b) (i) (use of $E = hf$)

$-0.26 \times 10^{-18} - 0.59 \times 10^{-18}$ **(1)** $= 6.63 \times 10^{-34} \times f$ **(1)**

$f = 0.33 \times 10^{-18}/(6.63 \times 10^{-34}) = 5.0 \times 10^{14}$ (Hz) **(1)**

3

(ii) **one** arrow between n = 3 and n = 2 **(1)** in correct direction **(1)**

2

[12]