Mark schemes

1. (a) substitution into $E = hc/\lambda$ ✓

multiplies E by 3.0×10^{16} to give 0.0136 (W)✓

Condone POT error on MP1

2

(b) considers the effect of wavelength on power or emission rate ✓

Red photon energy calculated (3.0×10^{-19} J) and used with $P = E_{photon} \times$ rate of emission

Alternative for MP1: red photon energy is $\frac{440}{660}$ times smaller (than blue photon energy)

considers the maximum possible, or required, emission rate ✓

<u>maximum</u> emission rate is 6.9×10^{16} s^{-1}

OR

evaluates required emission rate as 9.0×10^{16} s^{-1}

combining MP1 and MP2 with reference to graph to reach the conclusion that it is not possible ✓

not possible as:

max emission rate is 6.9×10^{16} s^{-1}, and required is 9.0×10^{16} s^{-1}

max power is 0.021 W, and required is 0.028 W

max current is 60 mA, and required is > 60 mA

3

(c) The mark scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.

Mark	**Criteria**	**QWC**
6	All 3 areas A, B and C covered Only allow minor omissions	The student presents the relevant information coherently, employing structure, style and SP&G to render meaning clear. The text is legible.
5	2 complete descriptions with one partial from A, B and C.	
4	Full description of one area, with partial description of two other. OR Full description of two areas with very little on third or nothing at all.	The student presents relevant information in a way which assists the communication of meaning. The text is legible. SP&G are sufficiently accurate not to obscure meaning.
3	A full description of one area and a partial description of one area. OR A partial discussion of all three areas.	
2	A full description of one area. OR A partial discussion of two areas.	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.
1	Only one area covered, and that partially.	
0	No relevant information	

Area A - Wavelength comparison:
• Red LED will emit longer wavelengths than 660 nm (accept "longer than red light).
• Blue LED will emit wavelengths longer than 440 nm (accept "longer than blue light).
• Blue LED will emit visible light. Accept named colours.

Area B - Excitation process:
• Excitation mentioned (as first step of fluoresence)
• Photons are absorbed by atoms in coating
• Atoms are excited/gain energy;
• Atomic electrons move to higher energy levels (than n = 2)
• Photons have sufficient energy to promote electrons to high enough levels

Area C - De-excitation process:
• De-excitation or relaxation mentioned (as subsequent step)
• Photons are emitted by atoms in coating
• Atoms de-excite/lose energy
• Atomic electrons move to lower energy levels
• Electrons move to ground state via other energy levels
• Emitted radiation consists of (a range of) lower photon energies/frequencies or longer wavelengths

6

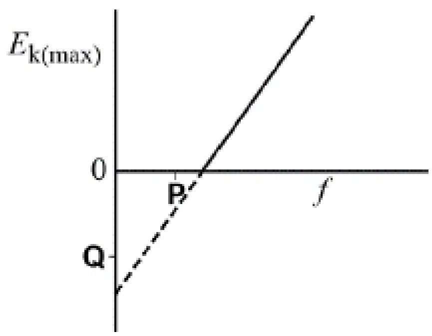
[11]

2. A

0.3×10^{-19} J

[1]

3. C



[1]

4. B

3.3×10^{-19} J

[1]

5. D

It emits photons of UV light following ionisation or excitation.

[1]

6. C

1.6×10^{-18} J

[1]

7. B

muon electron

[1]

8. (a) Idea that atoms gains energy (from beta particle) eg atoms excited or atoms/electrons moved to higher energy levels ✓

Idea that atom loses energy by emission of light/photons eg atoms de-excite or electrons move to lower energy levels ✓

Allow ionisation as named process

2

(b) Use of $E = \frac{hc}{\lambda}$ **OR** use of $c = f\lambda$ and $E = hf$ ✓

Condone POT error for λ

3.2×10^{-19} (J) ✓

Allow 3.1×10^{-19} (J) if 6.6×10^{-34} used

2

(c) Use of $W = QV$ **OR** determines pd = 750 V ✓

1.2×10^{-16} (J) ✓

2

(d) Max 3 from: ✓ ✓ ✓

Attempt to count squares **OR** calculate unit area **OR** Statement that area under curve = charge flow

1 small square = 2×10^{-12} (C) ; 1 large square = 5×10^{-11} (C)

Counts number of squares/Determines area

Converts number of squares to charge

Accept 140 to 180 small or 5.5–7 large squares

Accept $\frac{1}{2}$ base × height for triangle of base 12–16 ns and height 50 mA

Divides their total charge by 1.60×10^{-19}

2×10^{9} ✓

Allow 1 sf answer

4

[10]

9. **A**

[1]

10. **A**

[1]

11. (a) Frequency related to energy (of photon) /$E = hf$ ✓

MP1 is for linking photon energy to frequency

There is a minimum energy (of a photon) required to remove photoelectron; (minimum energy relates to minimum frequency). ✓

MP2 is for explaining what is meant by the work function.

If no other mark awarded, one mark can be given for relevant mention of work function.

Do not credit mention of threshold frequency unless explained

If no mention of a photon, 1 max.

Ignore references to energy levels.

2

(b) Evidence of use of maximum current ÷ charge on electron ✓

1.9×10^{14} (electrons per second) ✓

Expect to see $30 \times 10^{-6} \div 1.6 \times 10^{-19}$

Condone e for $1.6\text{x}10^{-19}$ *in MP1*

Allow POT error for current in MP1

Correct answer only for MP2

2

(c) Number of photoelectrons released (per second) depends on intensity of em radiation/number of (incident) photons (per second) (not pd.) ✓

MP1 is for relating the intensity to either the no. of incident photons or released photoelectrons per second

Constant current reached when <u>all</u> photoelectrons released (each second) reach anode (due to anode pd). ✓

MP2 is for linking constant current to all photoelectrons being detected.

Condone 'go round the circuit' for 'reach anode'.

2

(d) MP1 is for range of KE ✓

MP2 for what happens when V is negative in terms of kinetic energy or potential energy or work done on/by electron ✓

MP3 is for link to fewer photoelectrons having necessary KE. ✓

Example statements:

MP1: photoelectrons are released with a range of KE.

MP2: (When V *negative) photoelectrons lose KE/gain (E)PE crossing to anode.*

MP3: (As V *is increasingly negative) fewer of the photoelectrons (released per second) have sufficient (initial) KE to cross to anode (so current decreases).*

3

(e) Award each mark independently

If no mention of maximum KE do not award MP1.

Stopping potential related to maximum kinetic energy of photoelectrons/ $KE_{max} = eV_s$ ✓

(Max) KE = energy of photon – work function/ ϕ.

OR (max) KE increases as (work function is lower and) radiation same ✓

(max) KE increases, so stopping potential increases. ✓

Alternative

Reference to Einstein equation in the form: $hf = \phi + eV_s$ ✓

rearranged to

$$V_s = \frac{hf - \phi}{e}$$ ✓

So lower work function,(with hf and e constant,) gives higher Vs. ✓

3

[12]

12. **B**

[1]

13. **D**

[1]

14. **A**

[1]

15. (a) Particle with equal (rest) mass/energy ✓

but opposite charge/baryon number/lepton number ✓

2

(b) Antiproton ✓

Positron ✓

Do not accept antielectron for positron

2

(c) Rest energy of positron (0.510999) and antiproton (938.257) quoted, or 938.768 (MeV) seen ✓

Multiplies by 1.6 ✓

1.5×10^{-10} (J) ✓

Allow valid use of $E=mc^2$.

Allow any power of ten

Allow credit for 3.0×10^{-10} (J) for proton–antiproton and electron–positron production

3

(d) Max 3 ✓ ✓ ✓

Idea that (atomic) energy levels/states are discrete, or (emitted) photon energy is discrete

Idea that a photon is produced by electrons/atoms moving to <u>lower</u> energy levels/states

Allow light/radiation for "photon"

Idea that wavelength/frequency relates to photon energy/ΔE

May see equation relating ΔE to f or λ

Idea that different wavelengths/frequencies are produced

3

[10]

16. D

[1]

17. C

[1]

18. C

[1]

19. D

[1]

20. (a) Clear indication of correct process

two correct values for λv from working plus conclusion

(7.35; 7.25; 7.35) ✓

three correct values plus conclusion ✓

Condone no or misuse of powers of 10

Allow use of value of h as the constant to show that v values in table are consistent with the λ values

1

....

ratio approach $v_1/v_2 = \lambda_2/\lambda_1$ shown for 2 sets of data ✓

shown for two other sets of data + conclusion ✓

May predict one of the values assuming inverse proportionality and compare with table value

(once for 1 mark; twice for 2 marks)

1

(b) $h = \lambda mv$ or substitution of correct data in any form ✓

May determine average value using mean constant from 2.1 or average 3 calculations in this part

1

6.7(0) × 10^{-34} from first and third data set; 6.6(0) × 10^{-34} from second ✓

1

(c) Particle behaviour would only produce a patch/circle of light /small spot of light or Particles would scatter randomly ✓

Wave property shown by diffraction/ interference ✓

Graphite causes (electron)waves/beam to spread out /electrons to travel in particular directions ✓

Bright rings/maximum intensity occurs where waves

interfere constructively/ are in phase ✓

for a diffraction grating maxima when sinθ = $n\lambda/d$ ✓

Marks are essentially for

1. Explaining appearance of screen if particle

2. Identifying explicitly a wave property

3. Explaining what happens when diffraction occurs

4. Explaining cause of bright rings

5. Similar to diffraction grating formula (although not same)

NB Not expected: For graphite target maxima occur when sinθ =$\lambda/2d$ (d =spacing of atomic layers in crystal)

1
1
1

(d) Electrons must provide enough (kinetic) energy

'instantly' to cause the excitation

OR

the atom or energy transfer in 1 to 1 interaction

OR

electron can provide the energy in discrete amounts

OR

energy cannot be provided over time as it would be in a wave

Description of Photoelectric effect = 0

Not allowed: any idea that wave cannot pass on energy, e.g. waves pass through the screen

1

Any 2 from

Idea of light emission due to excitation and de-excitation of electrons/atoms ✓

Idea of collisions by incident electrons moving electrons in atoms between energy levels/shells/orbits ✓

Light/photon emitted when atoms de-excite or electrons move to lower energy levels ✓

1

1

[10]

21. **A**

[1]

22. (a) λ = 656 nm ✓

Power of 10 error allow 2

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

Allow ecf for wrong <u>choice</u> 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]

23. **C**

[1]

24. **A**

[1]

25. (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]

26. (a) (i) Energy required to remove an electron
Minimum energy required to remove an electron from a (metal) surface

2

(ii) Read off λ = 550 (nm)
Use of $E = hc / \lambda$ or $E = hf$ and $c = f\lambda$
3.6×10^{-19}
or
Reads st of coordinates correctly
Use of $hc/\lambda = \Phi + E_{k(max)}$
3.6×10^{-19}(J)

3

(b) $E_k = 9.6 \times 10^{-20}$
J converted to eV / 0.6 eV
4.35 to 4.40×10^{-7} (m), using graph
OR

$E_k = 9.6 \times 10^{-20}$ or $\Phi = 6.4 \times 10^{-19}$(J)

$hc/\lambda = 4.96 \times 10^{-19}$ (using given value in (aii))
or 4.6×10^{-19} using calculated value
or $f = 7.5 \times 10^{14}$(Hz)

4×10^{-7} to 4.4×10^{-7} (m)

Allow ecf for second mark only (i.e. for adding incorrect KE to work function)

3

[8]