M1. Correct substitution ignoring powers of 10 in hc / λ

C1

Photon energy = 3.0(3) × 10^{-19} J

Photon energy in eV = 1.9 eV gets 3 marks

A1

Conversion of −3.4 eV to J (5.44 × 10^{-19} seen)

C1

Answer −2.4 × 10^{-19} J (must have negative sign)

−8.4(8.5) × 10^{-19} J gets 3 marks

A1

[4]

M2. (a) Peak power = 107 / 108 mW and load resistance = 290 / 310 Ω ✓

1

Use of power = I^2R with candidate values ✓

1

0.0186 – 0.0193 A ✓

1

(b) Area of cell = 36 x 10^{-4} m^2 and solar power arriving = 730 × (an area) ✓

1

$\frac{0.108}{2.63}$ seen ✓

1

0.041 (correct answer only; lose if ratio given unit) ✓ 1

(c) energy of one photon = $\frac{hc}{\lambda}$ = 4.0 ×10^{-19}J ✓ 1

Number of photons = $\frac{730 \times 36 \times 10^{-4}}{4.0 \times 10^{-19}}$ = 6.6 × 10^{18} s^{-1} ✓ 1

(d) **Two** from

Intensity of the sun at the Earth's surface
Average position of the sun
Efficiency of the panel
Power output of 1 panel
Weather conditions at the installation=
✓✓

Allow other valid physics answers=

2

[10]

M3.(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 × 1.6 × 10^{-19} = 1.63 × 10^{-18} (J) ✓
6.63 × 10^{-34} × f = 1.63 × 10^{-18}
f = 2.46 × 10^{15}(Hz) ✓
(accept 2.5 but not 2.4)

CE from energy difference but not from energy conversion

3

(iii) Ek = 1.7 × 10^{-18} − 1.63 × 10^{-18} ✓ = 7.0 × 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]

M4. (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]

M5. (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]