M1.(a) (i) ultraviolet / UV / UV light / ultra(-)violet ✓

1

(ii) <u>electron</u>(in ground state) has moved / in to higher (energy) level / shell / orbital / state OR up level / shell / orbital / state ✓

Ignore reference to photons

1

(iii) (free) electrons collide with orbital electrons / mercury electrons / electrons in atom ✓

transferring energy ✓

Ignore any reference to photons

2

(iv) (mercury) atoms have discrete / fixed / specific energy levels ✓

when electrons change levels they lose an exact / fixed / specific / discrete / set amount of energy OR photons emitted with exact / fixed / specific / discrete / set amount of energy ✓

(leading to photons of) fixed / particular / certain / discrete / specific / unique frequencies ✓

Each mark independent

Don't accept characteristic for 3rd mark

3

(b) (i) (*use of* $\lambda = c / f$)

$f = 3 \times 10^{8} / (254 \times 10^{-9})$ ✓

$f = 1.18 \times 10^{15}$ (Hz) ✓

AE penalty if give answer to 1 sig fig

2

(ii) (*use of* $E = hf$)

$E = 6.63 \times 10^{-34} \times 1.18 \times 10^{15} = 7.82 \times 10^{-19}$J ✓

$E = 7.82 \times 10^{-19} / 1.6 \times 10^{-19}$ ✓ = 4.9 (4.875) eV

CE part (i)

Range 4.8 − 5.0 acceptable

2

(c) coating <u>absorbs</u> photons / uv light ✓
and re-emits (photons) of low(er) energy / long(er) wavelength / low(er) frequency ✓

Ignore any description of mechanism

2

[13]

M2. (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]

M3. (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]

M4. (a) lowest energy state/level that the electron can occupy

or state in which electron needs most energy to be released

B1

1

or the level of an unexcited electron (not lowest orbit)

(b) (i) force = mv^2/r or $mr\omega^2$ and $v = r\omega$

B1

$8.1 \times 10^{-8} = 9.1 \times 10^{-31} \times v^2/5.3 \times 10^{-11}$
or (v^2 =) 4.72×10^{12} seen

B1

2.17 × 106 (m s^{-1})

B1

(ii) $\lambda = h/mv$ or $6.6 \times 10^{-34}/9.1 \times 10^{-31} \times 2.2 \times 10^6$

C1

7

3.3×10^{-10} m

A1

(iii) circumference = $2\pi 5.3 \times 10^{-11} = 3.3 \times 10^{-10}$ m

M1

1 (allow e.c.f. from (ii))

A1

(c) (i) $1.9(4) \times 10^{-18}$ J

B1

(ii) 5.6×10^{-19} J (e.c.f. 2.5×10^{-18} − their (i))

B1

(iii) energy difference $E = 3 \times 10^{-19}$ J
(condone any difference)

C1

$E = hc/\lambda$ *or* $E = hf$ *and* $c = f\lambda$

or their $E = 6.6 \times 10^{-34} \times 3.0 \times 108/\lambda$

C1

6.6 or 6.7×10^{-7} m

A1

5

[13]

M5.A

[1]