Mark schemes

1

(i) electrons [or ions] present **(1)**
electrons/ions accelerated by electric field
[or electrons and ions collide] **(1)**
excitation/ionisation of gas atoms/ions/molecules/particles occur **(1)**
photons emitted on return to lower energy or ground state **(1)**

(ii) electrons/ions do not gain enough kinetic energy
(to produce ionisation) **(1)**
because too many atoms/ions/molecules/particles present **(1)**

max 4
QWC 1

[4]

2

(a) (i) unit A: supplies current/power/energy to the filament or heats the filament **(1)**
0 – 50 V **(1)**

(ii) unit B: to make the anode positive w.r.t. the filament, so that electrons are attracted/accelerated to the anode **(1)**
> 250 V **(1)**

max 3

(b) (i) beam current or intensity is reduced **(1)**
(because) fewer electrons are emitted (per sec) from the filament **(1)**
[or no beam as no electrons emitted if voltage of A
reduced enough **(1)**
(only)]

(ii) electrons travel faster [or more kinetic energy] **(1)**
(because the force of) attraction to the anode is greater **(1)**

4

[7]

3

(a) (i) electrons pulled out of (gas) atoms so (gas) atoms become (+) ions
OR
ionisation by collision (also) occurs
OR
(+) ions (that) hit cathode causing it to release electrons ✓
conduction due to electrons and positive ions ✓

; Allow 'electrons ionise atoms' as compensation mark (if no marks elsewhere)

2

(ii) ions and electrons (moving in opposite directions) collide (with each other) and recombine and emit photons ✓

Owtte

electrons excite gas atoms (by collision)
and photons are emitted when de-excitation occurs ✓

If light not photons given in 1st 2 mark points, 1 max for 1st two mark points

gas needs to be at sufficiently low pressure in order that the particles (or uncharged gas atoms / ions / electrons) in the gas are widely spaced ✓

Owtte

otherwise (+) ions and / or electrons / particles would be stopped by gas atoms OR so that ions / electrons are accelerated (or gain enough ke) to cause excitation ✓

3max

(b) Specific charge = charge / mass (and
charge(s) of ion does not depend on the type of gas) ✓

Mass of ion depends on the type of gas ✓

Accept Q / m in symbols Q / m but not e / m if e / m is specifically stated as specific charge

2

[7]

4

(a) (i) current heats the wire **(1)**
electrons (in filament) gain (sufficient) k.e. (to leave the filament) **(1)**

(ii) electrons would collide with gas atoms / molecules **(1)**

3

(b) (i) k.e. = (eV = $1.6 \times 10^{-19} \times 3600$) = 5.8×10^{-16} (J) **(1)**

(ii) $\frac{1}{2} mv^2 = eV$ **(1)**

$$v = \left(\sqrt{\frac{2eV}{m}}\right) = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 3600}{9.1 \times 10^{-21}}}$$ **(1)** = 3.6×10^7 m s^{-1} **(1)**

4

[7]

5 (a) (i) The number of electrons (per second) in the beam will increase **(1)** because the filament will become hotter and will emit more electrons (per 2 second) **(1)**

2

(ii) the speed (or kinetic energy) of the electrons will increase **(1)**

because the electrons (from the filament) are attracted towards the anode with a greater acceleration (or force) **(1)**

(or gain more kinetic energy in crossing a greater pd)

2

(b) (i) (magnetic) force on each electron in the beam is perpendicular to velocity **(1)**

no work is done on each electron by (magnetic) force so ke (or speed) is constant **(1)**

magnitude of (magnetic) force is constant because speed is constant **(1)**

(magnetic) force is always perpendicular to velocity so is centripetal **(1)**

max 3

(ii) rearranging $r = \frac{mv}{Be}$ gives $\frac{e}{m} = \frac{v}{Br}$ **(1)**

$\frac{e}{m} = \frac{7.4 \times 10^{6}}{6.0 \times 10^{-4} \times 68 \times 10^{-3}} = 1.81 \times 10^{11}$ **(1)** C kg^{-1} **(1)**

for correct answer to 2 sf **(1)**

4

(iii) specific charge for the electron ≈ 2000 × specific charge of H^+ **(1)**

(accept = and accept any value between 1800 and 2000)

which was the largest known specific charge before the specific charge of the electron was determined/measured **(1)**

(or which could be due to a much greater charge or a much smaller mass of the electron)

2

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6 (a) k.e. (= work done = qV [or $1.6 \times 10^{-19} \times 2200$]) = 3.5×10^{-16} J **(1)**

$\frac{1}{2} mv^2 = 3.5 \times 10^{-16}$ J

hence $v \left(= \sqrt{\frac{2 \times 3.5 \times 10^{-16}}{9.1 \times 10^{-31}}} \right) = 2.8 \times 10^{7}$ m s^{-1} **(1)**

(2)

(b) (i) all the k.e. goes to one photon **(1)**
hf = k.e. [or 3.5×10^{-16} J] **(1)**

$\lambda = \frac{c}{f}$ **(1)**

$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{3.5 \times 10^{-16}}$ **(1)**

$= 5.7 \times 10^{-10}$ m **(1)**

(ii) $\lambda = \frac{h}{mv}$ **(1)**

$= \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 2.8 \times 10^{7}} = 2.6 \times 10^{-11}$ m **(1)**

(7)

[9]

7 (a) (i) $V \left(= \frac{W}{Q} \right) = \frac{6.0 \times 10^{-16}}{1.60 \times 10^{-19}}$ **(1)** = 3750 V **(1)**

(ii) heats the filament [or cathode or wire] **(1)**
to enable electrons to gain (sufficient) k.e. to leave filament
[or cause thermionic emission] **(1)**

(4)

(b) (i) electron moves towards positive plate
curve in field **(1)**
and straight beyond **(1)**

(ii) $t \left(= \frac{l}{v} = \frac{0.060}{3.6 \times 10^{7}} \right) = 1.67$ ns **(1)**

(iii) $y = -\frac{1}{2} at^2$ **(1)**

$a = \frac{eV_p}{md}$ **(1)**

combine to give $\frac{e}{m} = \frac{2yd}{V_p t^2}$ **(1)** $= \frac{2 \times 12.5 \times 10^{-3} \times 25 \times 10^{-3}}{1250 \times (1.67 \times 10^{-9})^2}$ **(1)**

$= 1.8 \times 10^{11}$ C kg^{-1} **(1)**

(max 8)

[12]

8 (a) current heats the wire ✓

1

electrons (in filament) gain sufficient KE (to leave the filament) ✓

1

(b) electrons would collide (or be absorbed or scattered) by gas atoms (or molecules) ✓

1

(c) Rearrange ½ $m v^2 = eV$ to give $v = (2eV/m)^{1/2}$

1

or correct substitution in equation.

1

$v = \left(\frac{2 \times 1.6 \times 10^{-19} \times 4800}{9.1 \times 10^{-31}}\right)^{\frac{1}{2}} = 4.1 \times 10^7$ m s^{-1}

1

$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 4.1 \times 10^7}$ ✓ $= 1.8 \times 10^{-11}$m✓

1

(d) Increasing the pd increases the speed (or kinetic energy or momentum) of the electrons ✓

1

which decreases their de Broglie wavelength ✓

1

so they are diffracted less so the rings become smaller ✓

1

[10]