

1

- (a) The mercury atoms in a fluorescent tube are excited and then emit photons in the ultraviolet region of the electromagnetic spectrum.

- (i) Explain how the mercury atoms become excited.

(3)

- (ii) Explain how the excited mercury atoms emit photons.

(2)

- (b) Explain how the ultraviolet photons in the tube are converted into photons in the visible part of the electromagnetic spectrum.

(2)

(Total 7 marks)

2

- (a) A fluorescent tube is filled with mercury vapour at low pressure. In order to emit electromagnetic radiation the mercury atoms must first be *excited*.

- (i) What is meant by an excited atom?

(1)

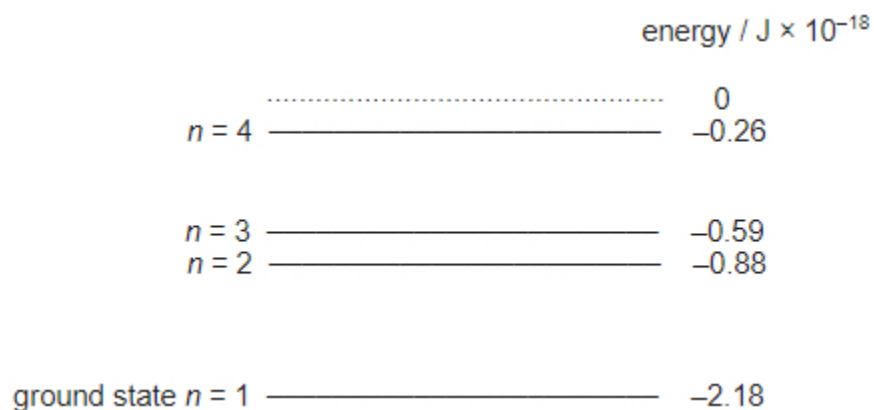
- (ii) Describe the process by which mercury atoms become excited in a fluorescent tube.

(3)

- (iii) What is the purpose of the coating on the inside surface of the glass in a fluorescent tube?

(3)

- (b) The lowest energy levels of a mercury atom are shown in the diagram below. The diagram is **not** to scale.



- (i) Calculate the frequency of an emitted photon due to the transition level $n = 4$ to level $n = 3$.

answer = _____ Hz

(3)

- (ii) Draw an arrow on the diagram above to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

(2)

(Total 12 marks)

3

- (a) A fluorescent tube is filled with mercury vapour at low pressure. After mercury atoms have been excited they emit photons.

- (i) In which part of the electromagnetic spectrum are these photons?

(1)

- (ii) What is meant by an excited mercury atom?

(1)

- (iii) How do the mercury atoms in the fluorescent tube become excited?

(2)

(iv) Why do the excited mercury atoms emit photons of characteristic frequencies?

(3)

(b) The wavelength of some of the photons emitted by excited mercury atoms is 254 nm.

(i) Calculate the frequency of the photons.

frequency _____ Hz

(2)

(ii) Calculate the energy of the photons in electron volts (eV).

energy _____ eV

(2)

(c) Explain how the coating on the inside of a fluorescent tube emits visible light.

(2)

(Total 13 marks)

4

An electron initially at rest is accelerated through a potential difference. It is then brought to rest in a collision, and all of its kinetic energy is converted into a single photon of electromagnetic radiation. Which one of the following quantities is **not** required to find a value for the wavelength of the photon?

- A The mass of the electron
- B The charge on the electron
- C The velocity of electromagnetic waves
- D The value of the potential difference

(Total 1 mark)

5

(a) When free electrons collide with atoms in their *ground state*, the atoms can be excited or ionised.

(i) State what is meant by ground state.

(1)

(ii) Explain the difference between excitation and ionisation.

(3)

- (b) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

(4)

- (c) The ionisation energy of hydrogen is 13.6 eV. Calculate the minimum frequency necessary for a photon to cause the ionisation of a hydrogen atom. Give your answer to an appropriate number of significant figures.

answer _____ Hz

(4)

(Total 12 marks)

Mark schemes

1

- (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
- (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 ✓
- (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

3

2

2

[7]

2

- (a) (i) an electron/atom is at a higher level than the ground state **(1)**
or electron jumped/moved up to another/higher level
- (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)**
- (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)**

1

3

max 3

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

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

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

3

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

2

[12]

3

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

1

- (ii) electron(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 $\lambda = c / f$)

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

$$f = 1.18 \times 10^{15} \text{ (Hz)} \checkmark$$

AE penalty if give answer to 1 sig fig

2

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

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

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

CE part (i)

Range 4.8 – 5.0 acceptable

2

- (c) coating absorbs photons / uv light ✓
and re-emits (photons) of low(er) energy / long(er) wavelength / low(er) frequency ✓
Ignore any description of mechanism

2

[13]

4

A

[1]

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 electrons** ✓

4

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

$$hf = 2.176 \times 10^{-18} \text{ ✓}$$

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

4

[12]