QUANTUM PHYSICS I

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 Fig. 5.1 shows five energy levels for electrons in a mercury atom.

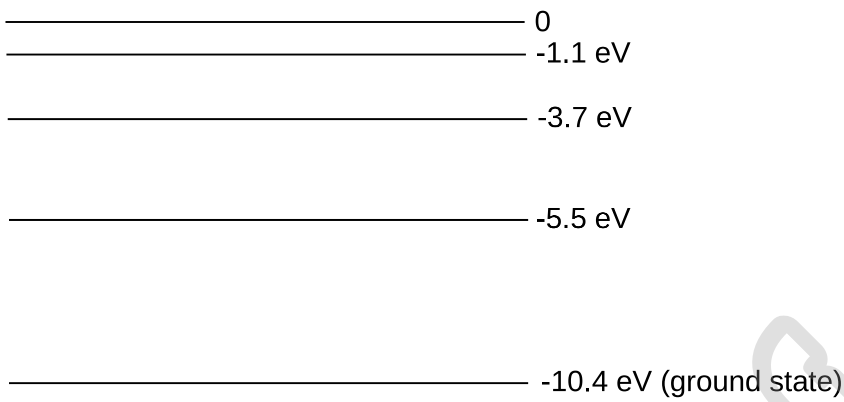

Fig. 5.1

(a) State the number of possible transitions between these five levels which result in photon emission.

number of transitions = ……………….. [1]

(b) Cool mercury vapour at low pressure is bombarded with electrons of kinetic energy **8.0 eV**.

(i) Calculate the shortest wavelength photon that could be emitted.

wavelength = ………….……..….. nm [2]

(ii) State the region of the electromagnetic spectrum in which the radiation in **(b)(i)** lies.

……………………………………………………………………………………...…. [1]

(iii) For the possible transitions, sketch the spectrum produced. [2]

(c) Explain how Fig. 5.1 can be used to account for absorption spectra.

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…………………………………………………………………………………………….. [2]

Ans **a** ${}^{5}_{2}C = 10$

b **(i)** For shortest wavelength, the atom is excited from the ground state to energy level -3.7 eV

From $E = \dfrac{hc}{\lambda}$,

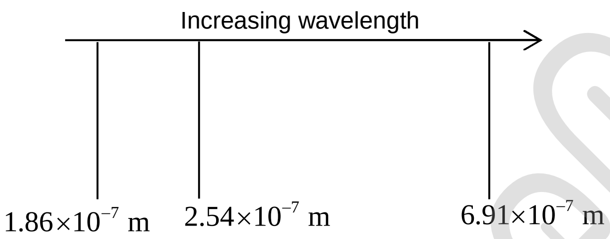
$$\lambda = \frac{(6.63\times10^{-34})(3\times10^{8})}{[-3.7-(-10.4)]\times1.6\times10^{-19}}$$

$$= 1.86\times10^{-7}\text{ m}$$

$$= 186\text{ nm}$$

(ii) Ultraviolet [10 nm to 400 nm]

(iii)



- 3 lines with 1.86×10^{-7} m labelled
- Increasing spacing between the lines

c From Fig. 5.1, when a photon with energy corresponding to the difference of 2 energy levels is absorbed by the atom, the electron moves from a lower energy level to a higher energy level.

2 **(a)** Outline and explain experimental observation(s) which provided evidence for the wave nature of light.

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……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………… [3]

(b) The photoelectric effect provides evidence for the particulate nature of electromagnetic radiation. State three experimental observations that support this conclusion.

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2. …………………………………………………………………………………………….....
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3. …………………………………………………………………………………………….....
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……………………………………………………………………………………………………[3]

Ans **a** **Diffraction**

Diagram (if drawn) must show light source (e.g. light, laser), object causing diffraction (e.g. single slit) and means of observation (e.g. screen)

For observable diffraction, the size of the slit should be of the same order as that of the wavelength.

OR Description of setup must mention the above items.

It was expected that the light on the screen would be the size of the slit but the width of the band of light seen on the screen is greater than the slit width. This demonstrates the spreading effect on a wave as it passes through an aperature.

OR

2-Source Interference

Diagram (if drawn) must show light source (e.g. light / laser), object causing interference (i.e. double slit) and means of observation (e.g. screen)

Light source must be monochromatic and coherent

OR Description of setup must mention the above items.

Instead of two bright fringes of the screen, a fringe pattern containing light and dark fringes is observed.

OR

Difraction grating

Diagram (if drawn) must show light source (e.g. light / laser), diffraction grating and means of observation (e.g. screen)

Light source must be monochromatic and coherent

OR Description of setup must mention the above items.

A pattern of bright narrow lines/spots with dark regions between them are observed on the screen. The spacing between the lines/spots are not equal.

Note: drawing of wavefronts / ripples is not accepted as there are multiple planes for light waves.

b

1. For a given metal, there is a threshold frequency below which no emission of photoelectrons occurs regardless of the intensity of radiation.
2. Emission of photoelectrons occurs with no observable time lag at frequencies of greater than threshold frequency, even at very low intensity.
3. Increasing the intensity of the radiation has no effect on the maximum energy of the electrons
4. The rate at which electrons are emitted increases proportionally with the intensity of the radiation.
5. The maximum kinetic energy (not kinetic energy) of the emitted photoelectron is dependent on / increases linearly (not proportional) with the frequency of the incident radiation (above threshold frequency), even with low intensity.

Any 3 from the above.

3 **(a)** X-rays are produced when electrons are accelerated through a potential difference towards a metal target such as tungsten. Fig. 7.1 shows a typical X-ray intensity spectrum that can be produced from an X-ray tube.

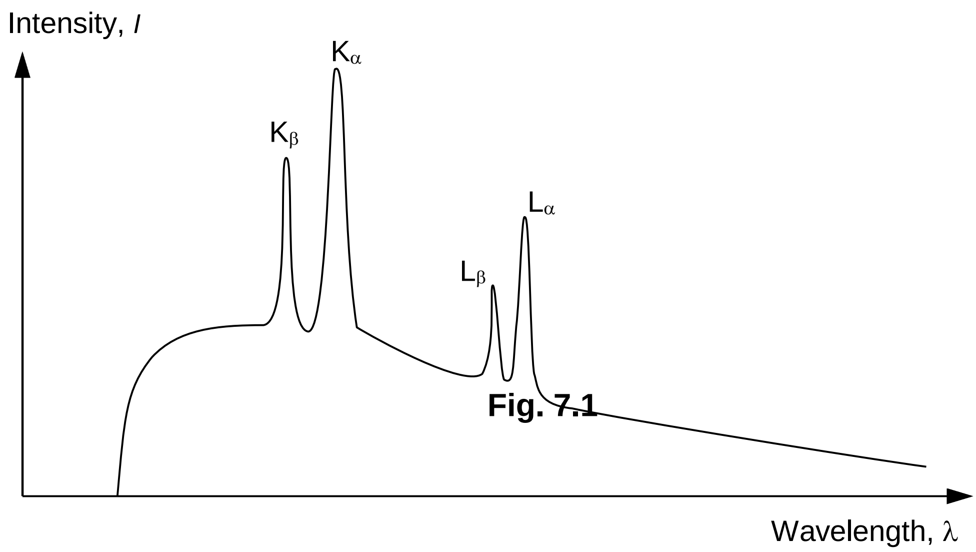

Fig. 7.1

Using conservation of energy, explain why there is a minimum wavelength for the emitted X-rays.

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…………………………………………………………………………………………………..[1]

(b) In a chest X-ray, a photographic film receives photons which have travelled through flesh and bone from a source.

(i) Estimate the area of a film which covers the chest of an adult.

area = …………………… m^2 [1]

(ii) Assume that on average, **10** x-ray photons fall on each grain of the photographic film and the grains are about **1.0 μm** apart.

Use your estimate in **(b)(i)** to calculate the total x-ray energy falling on the film. Each x-ray photon has a quantum energy of 10^{-15} J.

total energy = …………………….…. J [3]

(c) When all possible photon paths are summed, the amplitude of the wave function for paths travelling through flesh is four times the size of the amplitude for paths travelling through bone.

Calculate the ratio

$$\frac{\text{probability of photon arrival though flesh}}{\text{probability of photon arrival through bone}}.$$

ratio = …………………. [1]

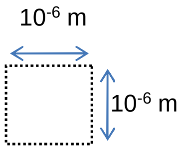
Ans **(a)** The cut-off wavelength corresponds to the most energetic photon that can be produced. That happens <u>when **all the kinetic energy** of an accelerated electron is lost in a single collision/interaction with the target atom in producing one photon.</u>

(b) **(i)** area = 0.200 m x 0.300 m = 0.0600 m^2

Accept a range of 0.0300 $m^2 \leq$ area $\leq$ 0.120 m^2

(ii)

Area of a graph:



no of grains = $\dfrac{0.0600}{10^{-6}\times 10^{-6}} = 6.00\times 10^{10}$

no of photons = $6.00\times 10^{10} \times 10 = 6.00\times 10^{11}$

energy = $6.00\times 10^{11} \times 10^{-15} = 6.00 \times 10^{-4}$ J

(c) implied probability of arrival proportional to square of amplitude

ratio = $4^2 = 16$