6 **(a)** In the fluorescent tube shown in Fig 6.1, electrons are accelerated from the filament and collide with a mercury atom, which is at its ground state.

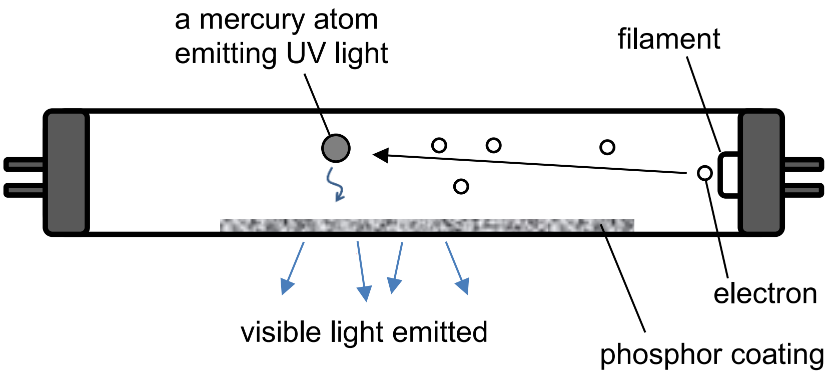


Fig. 6.1

Some of the energy levels of a mercury atom are represented in Fig. 6.2.

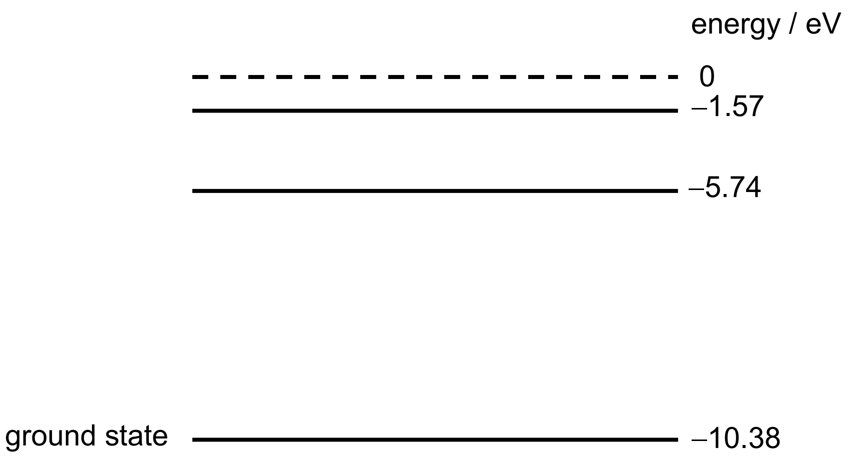


Fig. 6.2 (not to scale)

(i) In one particular interaction, an electron with kinetic energy 10.0 eV collides with a mercury atom at its ground state.

Determine the longest wavelength of UV radiation that can be emitted due to this interaction.

wavelength =……………………………….m [2]

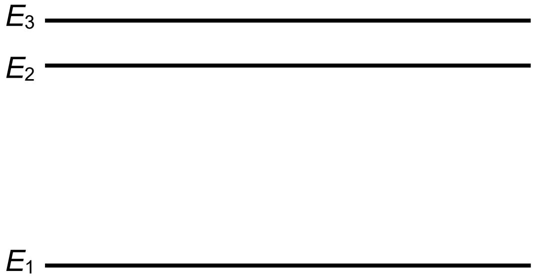
(ii) The UV photons emitted by the mercury atoms strike the phosphor coating on the inside of the fluorescent tube. The phosphor absorbs the UV photons and emits visible light by fluorescence.

Fig. 6.3 shows three energy levels E_1, E_2 and E_3 of an atom in the phosphor that are involved in the absorption of UV and emission of infrared and visible light.

On Fig. 6.3, draw arrows to indicate the following transitions:

(1) absorption of a UV photon
(2) emission of a red light photon
(3) emission of an infrared photon

Label the transitions clearly.



[1]

Fig. 6.3

(iii) Explain why the light emitted by the phosphor is of a longer wavelength than the UV light absorbed.

……………………………………………………………………………………………

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

(b) In an experiment to demonstrate the wave-particle duality of matter, UV light of wavelength 310 nm is incident on a polished sodium metal plate in a vacuum. The work function of sodium is 2.28 eV.

(i) Explain the energy transformation that occurs during photoelectric emission.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) Calculate the maximum kinetic energy of the photoelectrons emitted from the sodium plate.

maximum kinetic energy = ……………………… J [2]

(c) The emitted photoelectrons are directed as a beam towards a thin, polycrystalline graphite film. The electrons pass through the film and strike a fluorescent screen, producing a diffraction pattern as shown in Fig. 6.4 due to the wave-like properties of electron.

Assume that this diffraction pattern is formed only by the electrons possessing the maximum kinetic energy calculated in **(b)(ii)**.

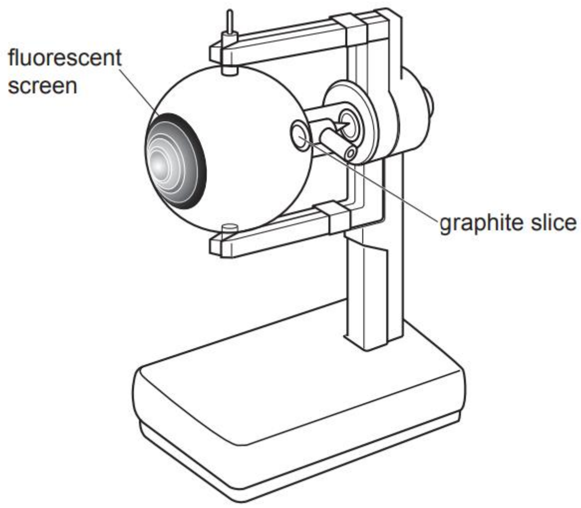


Fig. 6.4

(i) Determine the de Broglie wavelength of an electron with this maximum kinetic energy.

de Broglie wavelength = ………………………….. m [2]

(ii) Hence, explain why an observable diffraction pattern is formed.

……………………………………………………………………………………………

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

(iii) In reality, photoelectrons are emitted with a range of kinetic energies, from the maximum value calculated in **(b)(ii)** down to zero.

Explain how this range of energies affects the appearance of the diffraction pattern compared to the ideal one discussed in **(c)**.

……………………………………………………………………………………………

……………………………………………………………………………………………

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