4 (a) A beam of white light passes through a cloud of gas. The spectrum of the light emerging from the gas is viewed using a diffraction grating.

(i) Explain why the spectrum observed contains a number of dark lines.

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…………………………………………………………………………………………………… [4]

(ii) Some of the electron energy levels of the atoms in the cloud of the gas are represented in Fig. 4.1.

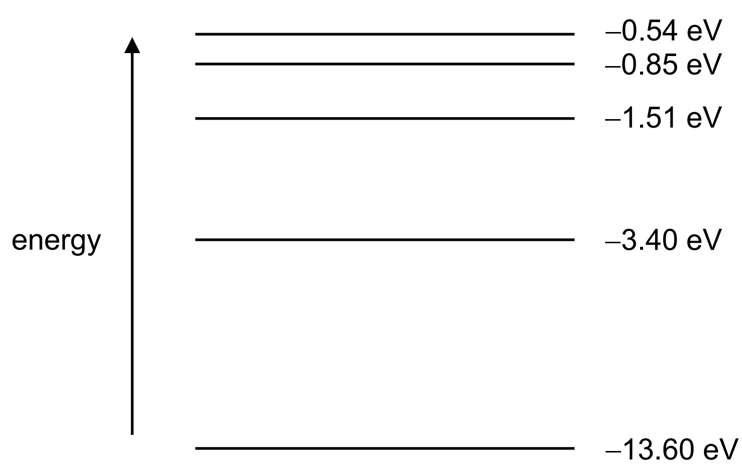


Fig. 4.1 (not to scale)

The photons of light have energies ranging from 1.60 eV to 2.60 eV.

On Fig. 4.1, draw arrows to show the electron transitions between energy levels that could give rise to dark lines in the absorption spectrum.

[1]

(b) A metal surface with a threshold frequency f_o is placed in an evacuated tube and illuminated with monochromatic light. The photoelectrons emitted are collected at an adjacent electrode of the same metal. The photoelectric current I depends on the frequency f of the incident light, and potential difference V between collector and emitter, and the incident power P.

In Fig. 4.2 to 4.4, sketch graphs to show the variation of I with

(i) f, while V and P remain constant.

Fig. 4.2

[2]

(ii) V, while f and P remain constant.

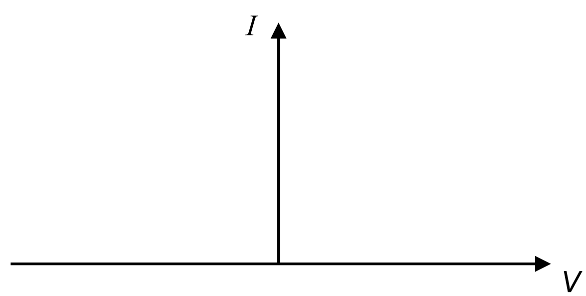


Fig. 4.3

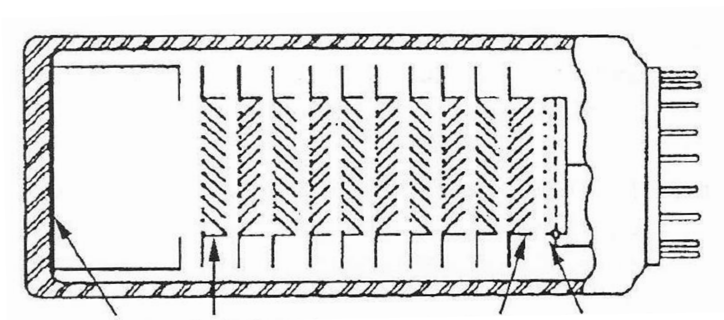
[1]

(iii) P, while f and V remain constant.

Fig. 4.4

[1]

(c) A very weak beam of light ray may be detected using a device known as a photo-multiplier, as shown in Fig. 4.5.



cathode first dynode tenth dynode anode

Fig. 4.5

The incident light causes photoelectrons to be emitted from the cathode. These photoelectrons are accelerated and strike a target electrode, called the first dynode. For each electron incident, six leave the dynode. These six are accelerated to the second dynode, which emits 36 electrons, which are all accelerated to the third dynode, and so on. The photomultiplier contains a series of ten dynodes in all.

(i) Calculate the number of electrons emitted by the tenth dynode for each electron striking the first dynode.

no. of electrons = ……………………………….. [1]

(ii) The electrons emitted from the tenth dynode are collected and constitute a current of 9.2 μA.

Determine the rate at which the photoelectrons are being emitted from the cathode.

rate = ……………………………….. s^{-1} [2]

(iii) The incident light has a wavelength of 361 nm. At this wavelength, one in three of the incident photons causes an emission of photoelectron from the cathode.

Determine the power of the incident light.

power = ……………………………….. W [2]

(iv) The electrons emitted by a dynode have negligible initial energy, and are accelerated through a potential difference of 50 V before striking the next dynode.

Determine the de Broglie wavelength of these electrons right before they strike the next dynode.

wavelength = ……………………………….. m [3]

[Total: 17]