[redacted]

9 When a clean zinc plate is illuminated by electromagnetic radiation of variable frequency, photoelectrons are emitted from the plate. The following observations about the emitted photoelectrons are made:

1. For a constant frequency above a minimum value, the maximum kinetic energy of the emitted photoelectrons is independent of the intensity of the incident radiation.

2. Below a certain frequency, there is no emission of photoelectrons regardless of the intensity of the radiation.

(a) Explain how these observations provide evidence for the particulate (photon) nature, and **not** the wave nature, of electromagnetic radiation.

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.... [4]

(b) State the name of the frequency described in observation 2.

.... [1]

(c) The zinc plate has a work function energy of 4.33 eV. Electromagnetic radiation of wavelength 210 nm is incident on the plate.

Calculate the maximum kinetic energy of the emitted photoelectrons.

maximum kinetic energy = ... J [3]

(d) In order to measure the maximum kinetic energy of the emitted photoelectrons in **(c)**, the zinc plate is placed in the apparatus shown in Fig. 9.1.

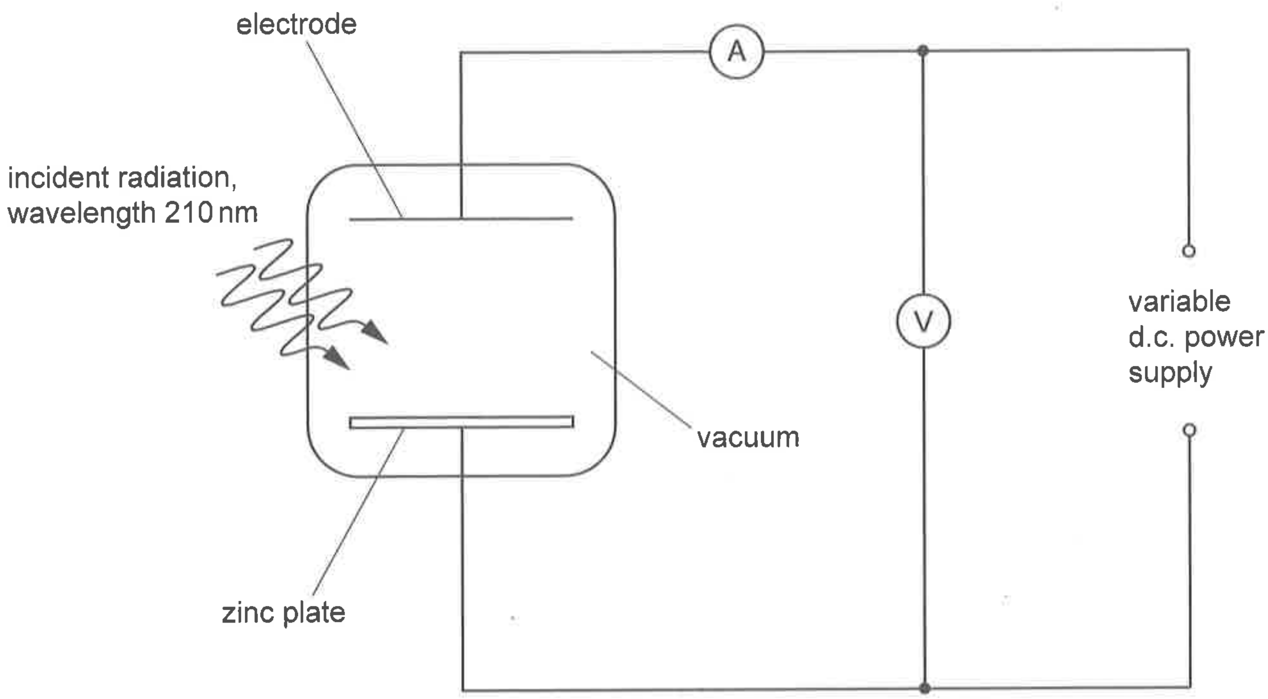

Fig. 9.1

The potential difference between the electrode and the zinc plate is gradually increased from zero until the current reading on the ammeter just decreases to zero. The potential of the electrode is negative with respect to the zinc plate.

The minimum potential difference for zero current is called the stopping potential.

Use your answer in **(c)** to calculate the stopping potential for the emitted photoelectrons.

stopping potential = ... V [2]

(e) The potential of the electrode in Fig. 9.1 is varied from –5.0 V to +5.0 V with respect to the zinc plate.

The variation of the current I with the potential difference V is shown in Fig. 9.2.

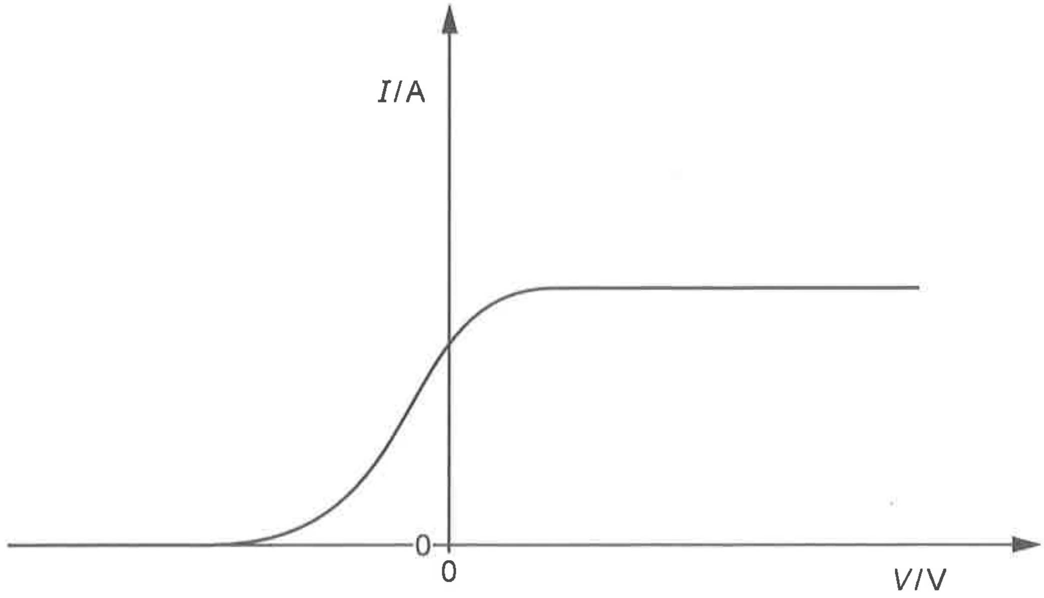

Fig. 9.2

(i) On Fig. 9.2, mark with the letter S, the stopping potential. [1]

(ii) The zinc plate is now illuminated with radiation of a shorter wavelength but the same intensity as in **(c)**.

On Fig. 9.2, draw the variation of I with V for the new wavelength. Label this line A. [2]

(iii) The wavelength of the incident radiation is returned to 210 nm. The intensity remains the same as in **(c)**.

The zinc plate is replaced with a metal plate that has a greater value of work function energy. Photoelectrons are still emitted.

On Fig. 9.2, draw the variation of I with V for the new plate. Label this line B. [1]

(iv) By reference to the photoelectrons explain why, for certain values of V, the current I is zero.

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.... [2]

(f) The electromagnetic radiation in **(c)** comprises photons which are emitted from an atom when electrons change energy levels within the atom.

A representation of some energy levels and their associated energies is shown in Fig. 9.3.

Fig. 9.3

(i) On Fig. 9.3, draw an arrow to show the electron transition between energy levels that causes the emission of the photons in **(c)**. [2]

(ii) Calculate the wavelength of the photon with the longest wavelength that can be emitted by the transition of an electron between the energy levels shown in Fig. 9.3.

Explain your working.

wavelength = ... m [2]

[Total: 20]

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