1 *(a) In a demonstration, ultraviolet light is incident on a zinc plate and electrons are emitted.

The intensity of the ultraviolet light is increased.

Explain the following observations:

- the number of electrons emitted per second increases
- the maximum kinetic energy of an electron does not change.

(4)

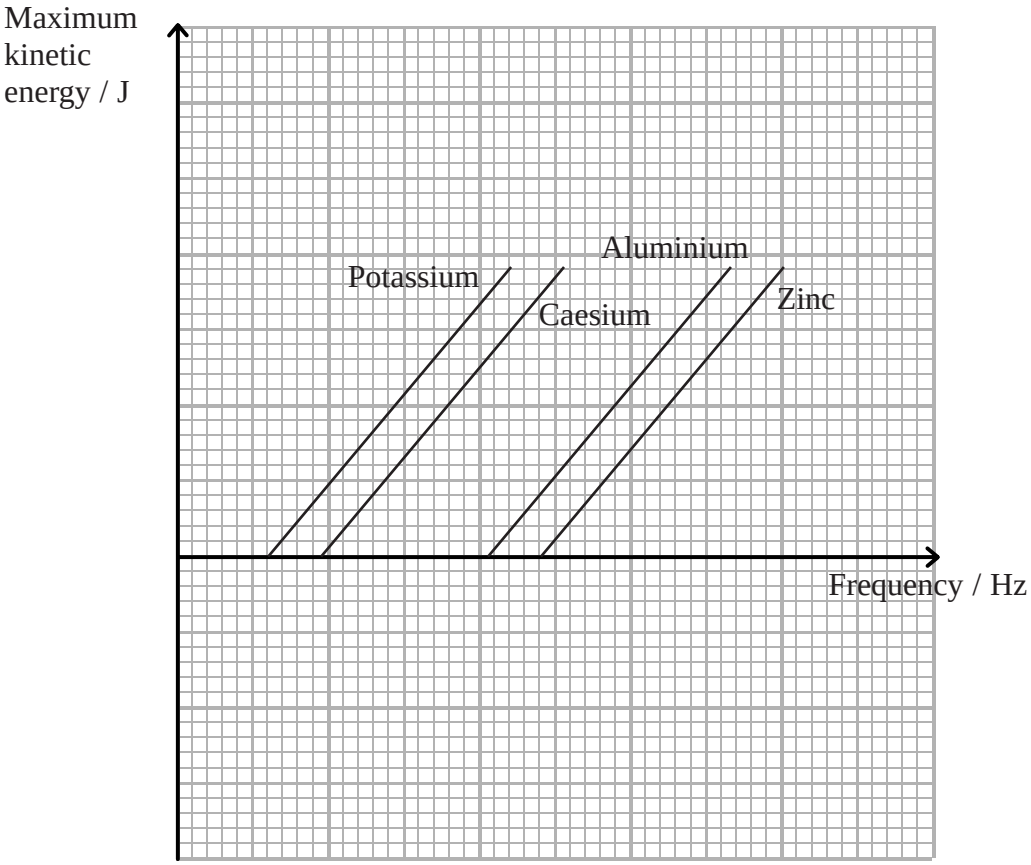
(b) The table shows the work functions of four metals.

Metal	**Work function / 10^{-19} J**
Aluminium	6.53
Caesium	3.36
Potassium	2.30
Zinc	6.88

(i) Determine which of these metals would emit electrons when illuminated with visible light of frequency 5.88×10^{14} Hz.

(3)

(ii) The graphs show how the maximum kinetic energy of the emitted electrons varies with the frequency of incident light for the four metals.



Use the relationship $hf = ½ mv^2 + \varphi$ to explain the relative positions of the graphs and why they are all parallel.

(3)

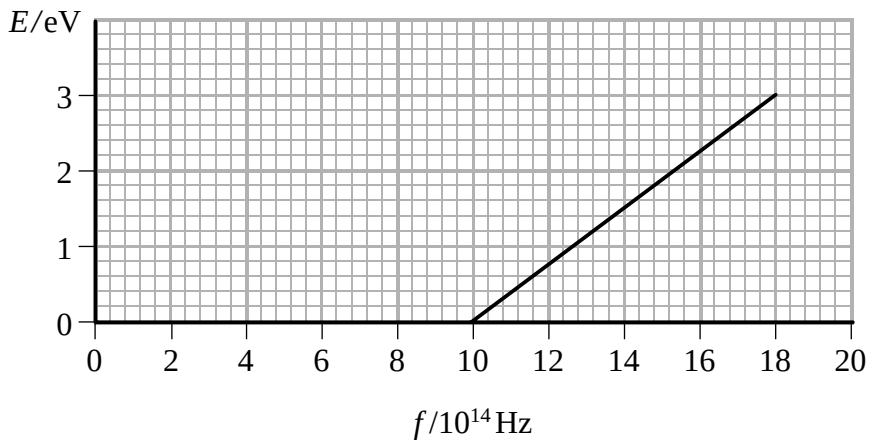
(iii) A school laboratory has a photoelectric cell for student use. The metal plate in the photoelectric cell is made of caesium and it can be used with a set of filters to obtain a graph similar to the one in (ii).

Explain why the metal plate is made of caesium rather than zinc.

(2)

(Total for Question = 12 marks)

2 The graph shows how the maximum kinetic energy E of photoelectrons emitted from the surface of aluminium varies with the frequency f of the incident radiation.



(a) Explain why no photoelectrons are emitted below a frequency of 10×10^{14} Hz.

(1)

(b) Calculate the work function of aluminium in electron volts.

(3)

Work function =

(c) State the quantity represented by the gradient of the graph.

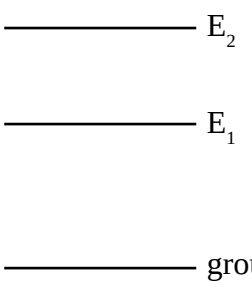
(1)

(d) Add a second line to the graph to show how E varies with f for a metal which has a work function less than aluminium.

(2)

(Total for Question = 7 marks)

3 The energy level diagram shows the ground state and two excited states E_1 and E_2 of a neon atom.



In a helium neon laser, collisions occur between helium atoms and neon atoms. This results in the helium neon atoms being excited from the ground state to level E_2. They then emit photons and move to level E_1.

(a) What is meant by 'energy level'?

(1)

(b) What is a photon?

(1)

(c) Write a formula in terms of E_1 and E_2 for the energy of an emitted photon.

(1)

(d) The wavelength of an emitted photon is 6.33×10^{-7}m.

Calculate the energy of this photon.

(3)

Energy =

(Total for Question = 6 marks)

4 The following passage describes some important aspects of the photoelectric effect. Insert the missing words.

In the photoelectric effect, a single ..... interacts with a single electron at the surface of a ..... In this interaction ..... is conserved. This was summarised by Albert Einstein in the following equation

$$hf = \Phi + \tfrac{1}{2}mv^2$$

where $\tfrac{1}{2}mv^2$ is the maximum kinetic energy of the .....

and Φ is the .....

(Total for Question = 5 marks)

5 (a) Explain what is meant by the work function of a metal.

(1)

.....

.....

.....

*(b) Observations of the photoelectric effect support the particle theory of light.

State **one** such observation and explain how it supports the particle theory of light.

(3)

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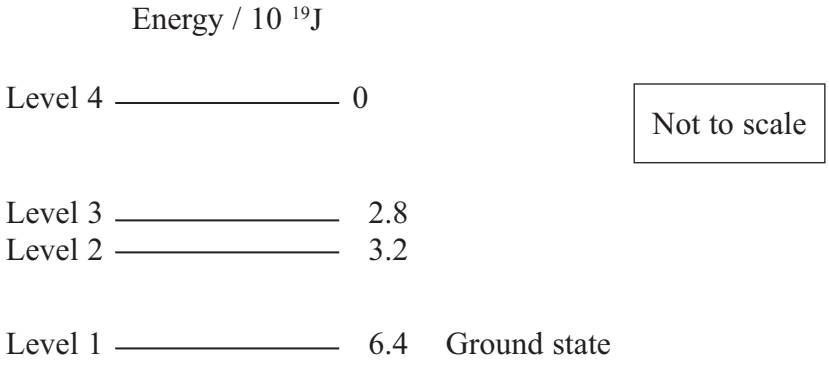
(Total for Question 4 marks)

6 The diagram shows four energy levels for an electron in a particular atom.



(a) State what is meant by an energy level.

(1)

(b) Draw on the diagram **two** arrows to indicate two different transitions that would result in emitted radiation of the same frequency.

(2)

(c) A gas consisting of these atoms can emit a line spectrum.

Explain how this happens.

(3)

(d) One of these atoms in its ground state absorbs 3.6×10^{19} J of energy from a collision with an electron.

Calculate the smallest frequency of radiation that the atom may subsequently emit.

(3)

Smallest frequency .....

(e) Calculate how much energy in eV would be required to ionise the atom in its ground state.

(2)

Energy .....

(Total for Question 11 marks)

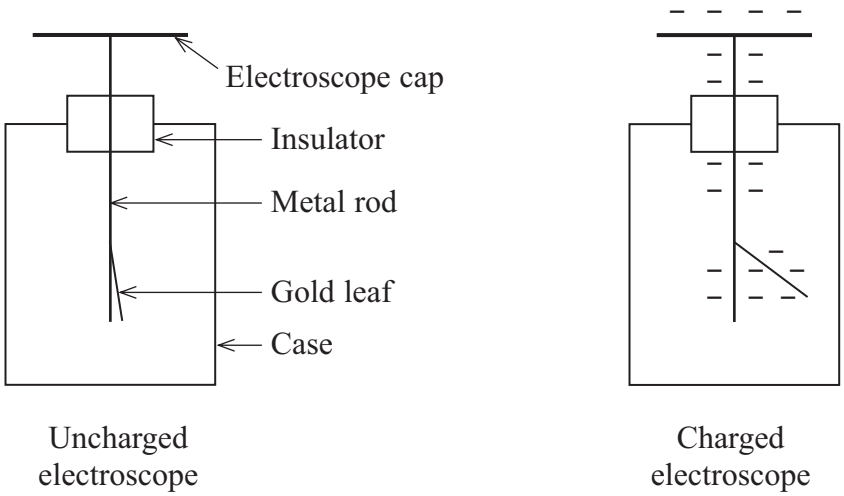
*7 In a fluorescent lighting tube, electrons with a range of kinetic energies collide with atoms of mercury vapour. These atoms are initially in their ground state. As a result of these collisions, some of the atoms emit photons.

Explain what is meant by the ground state of an atom and why photons are emitted.

(6)

(Total for Question 6 marks)

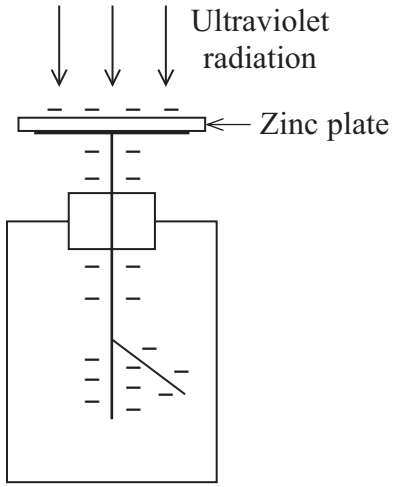
8 A gold leaf electroscope is used to detect very small amounts of charge. When the electroscope cap is negatively charged, electrons spread along the metal rod and the gold leaf so they both become negatively charged. The rod and leaf repel each other, so the gold leaf rises up.



Uncharged electroscope

Charged electroscope

A gold leaf electroscope can be used to demonstrate the photoelectric effect. A clean zinc plate is placed onto the cap of the electroscope and the plate and electroscope are charged negatively. Ultraviolet radiation is shone onto the zinc plate.



*(a) The gold leaf slowly falls.

Explain, with reference to the work function of zinc, why this happens.

(4)

(b) Why is the effect not observed if the ultraviolet radiation is replaced by visible light?

(1)

(c) Ultraviolet radiation of wavelength 2.00×10^{-7} m is shone onto the zinc plate.
Calculate the maximum speed of the electrons emitted from the plate.

work function of zinc 6.88×10^{-19} J

(4)

Maximum speed of electrons .....

(d) The source of ultraviolet radiation is moved further away from the zinc plate.

State what will happen to the maximum speed of the electrons emitted from the plate. Justify your answer.

(2)

(Total for Question 11 marks)