Q1.

A tube contains a vapour of mercury atoms at low pressure. In an experiment, the vapour is bombarded by a beam of electrons.

An electron in the beam gains 6.7 eV of kinetic energy by moving through a potential difference V.

(a) Deduce V.

V = ____________________ V

(1)

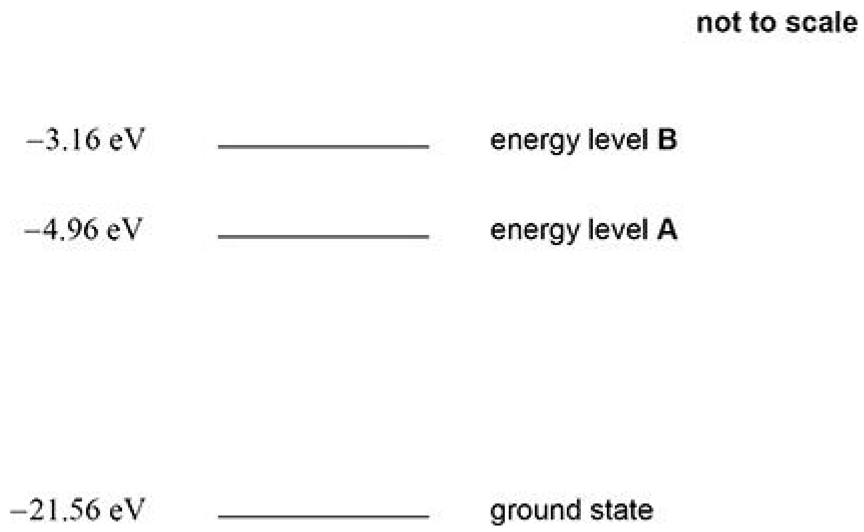
The electron collides with a mercury atom. The atom subsequently emits a photon of ultraviolet radiation with an energy of 6.7 eV.

(b) Calculate the wavelength of the emitted photon of this ultraviolet radiation.

wavelength = ____________________ m

(3)

(c) The experiment is repeated with a different gas.
The figure below shows the three lowest energy levels for an atom of the gas.



When an electron in the beam collides with the gas atom, 18.4 eV of energy is transferred to the atom.
The atom subsequently emits a photon of visible light.

State and explain the energy transitions that are involved.
Support your answer with appropriate calculations.

(4)
(Total 8 marks)

Q2.

A sample of bromine gas contains a mixture of two isotopes. An experiment is done to find the percentage of each isotope in this sample.

(a) In the experiment, the gas is ionised by a beam of electrons.

Explain how the beam of electrons causes a particle of the gas to have a charge of $+1e$.

____

____

____

____

____

____

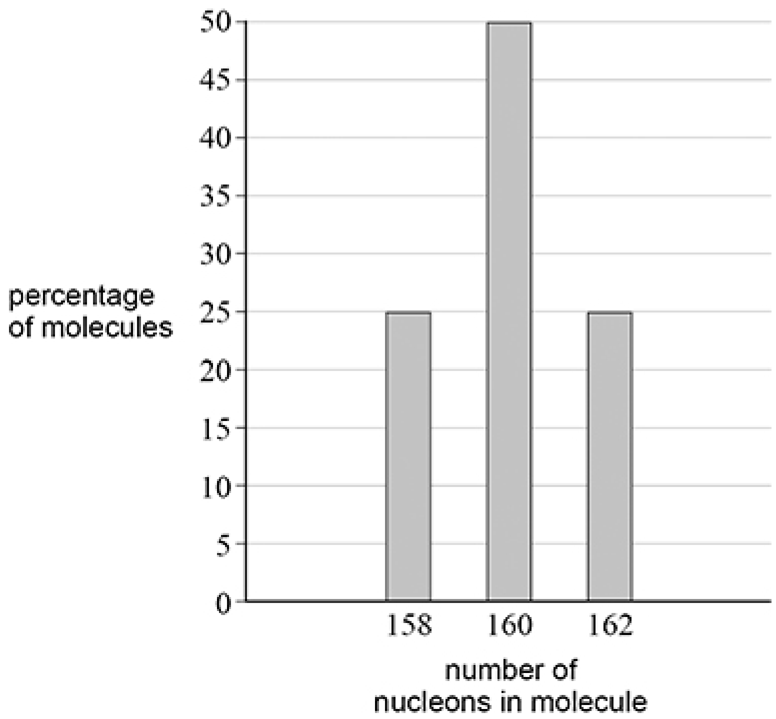
____

____

(2)

The gas consists of bromine molecules. Each molecule has two bromine atoms. The experiment finds that the bromine molecules contain 158, 160 or 162 nucleons.

The figure below shows the percentage of these different molecules in the sample.



(b) Bromine has a proton number of 35
The two isotopes in the sample have different nucleon numbers.

Calculate the number of neutrons for the isotope that has the greater nucleon number.

number of neutrons = _______________

(2)

(c) Deduce the percentage of each isotope in the gas.
Justify your conclusion.

____

____

____

____

____

____

(2)
(Total 6 marks)

Q3.

An isolated metal plate is given a negative charge. Electromagnetic radiation is incident on the plate. The plate loses its charge due to the photoelectric effect.

(a) Discuss how the rate of loss of charge from the plate depends on the frequency and intensity of the incident radiation.

In your answer you should explain why:

- the plate loses its charge
- the photoelectric effect occurs only for frequencies greater than a particular value
- the rate of loss of charge increases with intensity for radiation above that particular value of frequency.

(6)

(b) Charged particles are emitted from the metal plate with a maximum kinetic energy of 1.1 eV when radiation of frequency 1.2×10^{15} Hz is incident on the plate.

Calculate, in eV, the work function of the metal.

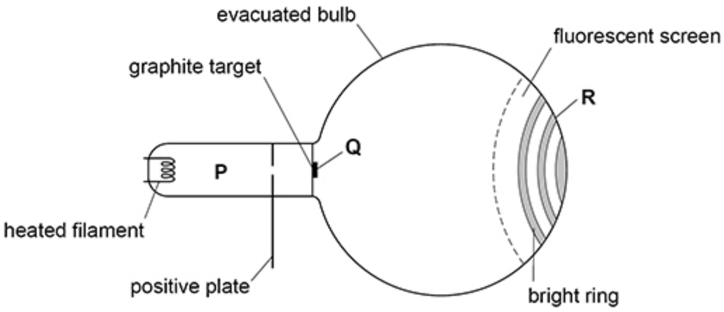
work function = _______________ eV

(3)

(Total 9 marks)

Q4.

The figure below shows apparatus used to demonstrate the wave–particle duality of electrons.



The heated filament emits slow-moving electrons.

In region **P**, the electrons are accelerated to a high speed.
At **Q**, the fast-moving electrons are incident on the graphite target.
R is a point on one of the bright rings that are formed where the electrons strike the fluorescent screen.

(a) The electrons demonstrate wave-like and particle-like behaviour as they travel from the filament to the screen.

State and explain at which of **P**, **Q** or **R** the electrons are demonstrating wave-like behaviour.

___

___

___

(2)

(b) The apparatus is adjusted so that the electrons are incident on the graphite target with a greater speed.

Explain why the bright rings formed on the screen now have a smaller diameter.

___

___

___

___

___

___

(3)

(Total 5 marks)

Q5.

Two stable isotopes of helium are $^{4}_{2}\mathrm{He}$ and $^{3}_{2}\mathrm{He}$.

(a) An atom of $^{4}_{2}\mathrm{He}$ is produced in a rock that contains uranium. It is produced following the radioactive decay of a $^{238}_{92}\mathrm{U}$ atom. The decay also creates an atom of thorium (Th).

Write an equation for the decay of $^{238}_{92}\mathrm{U}$.

$^{238}_{92}\mathrm{U} \rightarrow$

(2)

(b) A $^{3}_{2}\mathrm{He}$ nucleus can be produced by the decay of a tritium nucleus $^{3}_{1}\mathrm{H}$.

State and explain which exchange particle is responsible for this decay.

___

___

___

___

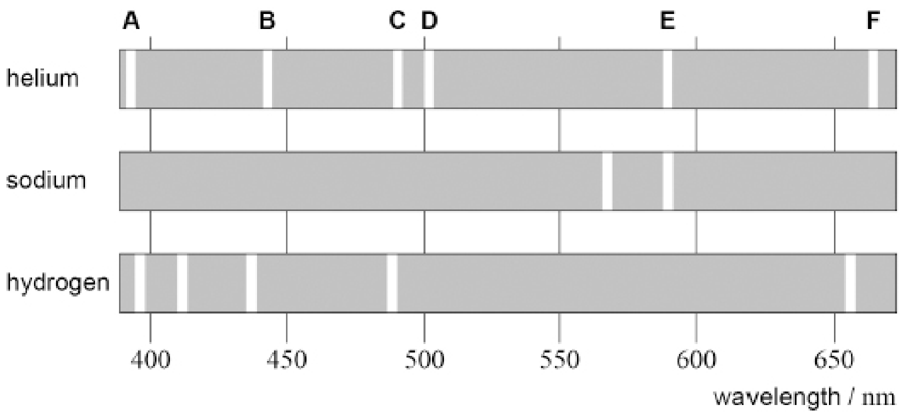
___

___

(2)

Helium was discovered by analysing the light in the **absorption** spectrum of the Sun.

The figure below shows the positions of the brightest lines, labelled **A** to **F**, in the **emission** spectrum of helium. The brightest lines in the emission spectra of sodium and hydrogen are also shown.



(c) Before helium was identified, some scientists suggested that the lines of the helium spectrum seen in the absorption spectrum of the Sun were due to the presence of sodium and hydrogen.

Discuss, with reference to the lines **A** to **F** in the figure above, the evidence for and against this suggestion.

____

____

____

____

____

____

____

____

(2)

(d) Calculate, in eV, the change in energy level responsible for the spectral line labelled **E** in the diagram above.

change in energy level = _______________ eV

(3)

(e) Explain, with reference to the processes within an atom, the difference between an emission spectrum and an absorption spectrum.

(3)

(Total 12 marks)