Q1. (a) A fluorescent tube is filled with mercury vapour at low pressure. After mercury atoms have been excited they emit photons.

(i) In which part of the electromagnetic spectrum are these photons?

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(1)

(ii) What is meant by an excited mercury atom?

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(1)

(iii) How do the mercury atoms in the fluorescent tube become excited?

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(2)

(iv) Why do the excited mercury atoms emit photons of characteristic frequencies?

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(3)

(b) The wavelength of some of the photons emitted by excited mercury atoms is 254 nm.

   (i)   Calculate the frequency of the photons.

                              frequency .... Hz

(2)

   (ii) Calculate the energy of the photons in electron volts (eV).

                              energy .... eV

(2)

(c) Explain how the coating on the inside of a fluorescent tube emits visible light.

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(2)
(Total 13 marks)

Q2.   (a)   When free electrons collide with atoms in their *ground state*, the atoms can be excited or ionised.

   (i)   State what is meant by ground state.

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(1)

(ii)   Explain the difference between excitation and ionisation.

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(3)

(b)   An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

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(4)

(c)   The ionisation energy of hydrogen is 13.6 eV. Calculate the minimum frequency necessary for a photon to cause the ionisation of a hydrogen atom. Give your answer to an appropriate number of significant figures.

answer ....Hz

(4)
(Total 12 marks)

Q3.   (a)   A fluorescent tube is filled with mercury vapour at low pressure. In order to emit electromagnetic radiation the mercury atoms must first be *excited*.

      (i)   What is meant by an excited atom?

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(1)

      (ii)   Describe the process by which mercury atoms become excited in a fluorescent tube.

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(3)

      (iii)   What is the purpose of the coating on the inside surface of the glass in a fluorescent tube?

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(3)

(b) The lowest energy levels of a mercury atom are shown in the diagram below. The diagram is **not** to scale.

energy / J × 10^{-18}

.... 0

$n = 4$ _____ −0.26

$n = 3$ _____ −0.59
$n = 2$ _____ −0.88

ground state $n = 1$ _____ −2.18
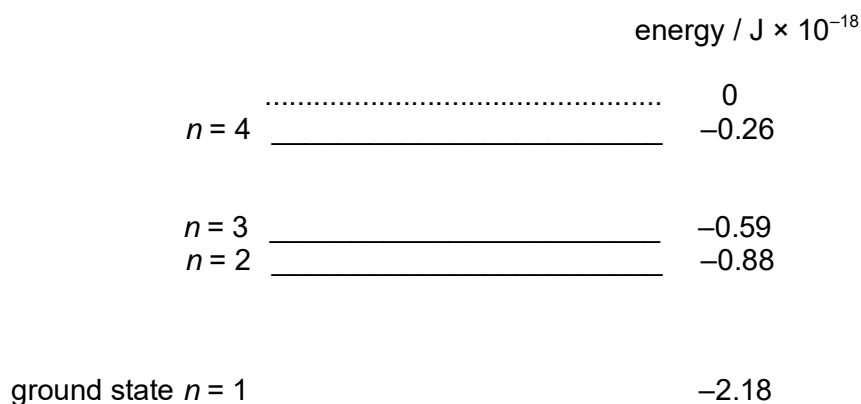
(i) Calculate the frequency of an emitted photon due to the transition level $n = 4$ to level $n = 3$.

answer = ... Hz

(3)

(ii) Draw an arrow on the diagram above to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

(2)
(Total 12 marks)

Q4. The Bohr model of a hydrogen atom assumes that an electron **e** is in a circular orbit around a proton **P**. The model is shown schematically in **Figure 1**.

Figure 1
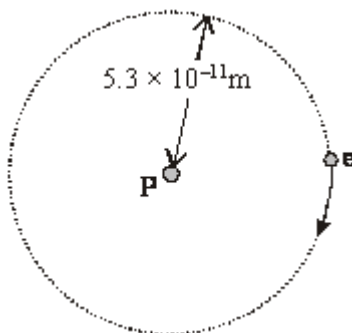
5.3×10^{-11}m

In the ground state the orbit has a radius of 5.3×10^{-11} m. At this separation the electron is attracted to the proton by a force of 8.1×10^{-8} N.

(a) State what is meant by <u>the ground state</u>.

....

....

(1)

(b) (i) Show that the speed of the electron in this orbit is about 2.2×10^6 m s⁻¹.
mass of an electron = 9.1×10^{-31} k g

(ii) Calculate the de Broglie wavelength of an electron travelling at this speed.
Planck constant = 6.6×10^{-34} J s

(iii) How many waves of this wavelength fit the circumference of the electron orbit? Show your reasoning.

(7)

(c) The quantum theory suggests that the electron in a hydrogen atom can only exist in certain well-defined energy states. Some of these are shown in **Figure 2**.

Figure 2

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                                          energy/10⁻¹⁹J
n = ∞ ────────────────────────── 0
n = 4 ──────────────────────── −1.4
n = 3 ──────────────────────── −2.4

n = 2 ──────────────────────── −5.4




n = 1 ──────────────────────── −21.8
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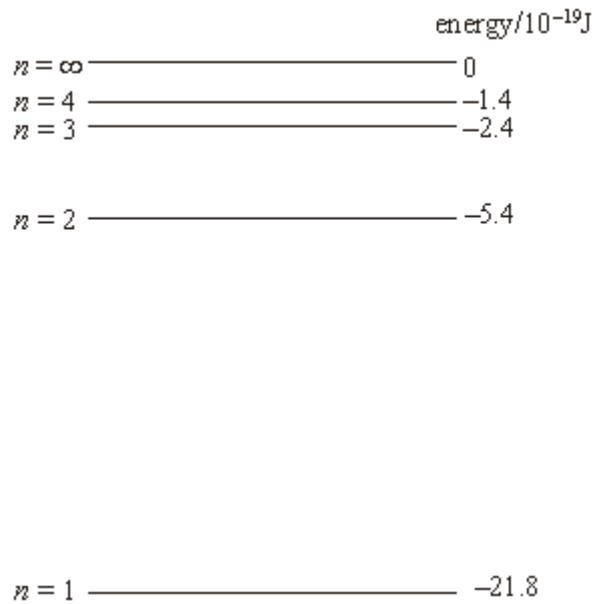
An electron **E** of energy 2.5×10^{-18} J collides with a hydrogen atom that is in its ground state and excites the electron in the hydrogen atom to the $n = 3$ level.

Calculate

(i)   the energy that is needed to excite an electron in the hydrogen atom from the ground state to the $n = 3$ level,

(ii)   the kinetic energy of the incident electron **E** after the collision,

(iii)   the wavelength of the lowest energy photon that could be emitted as the excited electron returns to the ground state.
        speed of electromagnetic radiation = 3.0×10^{8} m s⁻¹

(5)
(Total 13 marks)

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Q5. An electron initially at rest is accelerated through a potential difference. It is then brought to rest in a collision, and all of its kinetic energy is converted into a single photon of electromagnetic radiation. Which one of the following quantities is **not** required to find a value for the wavelength of the photon?

    A   The mass of the electron

    B   The charge on the electron

    C   The velocity of electromagnetic waves

    D   The value of the potential difference

(Total 1 mark)