A-Level Physics

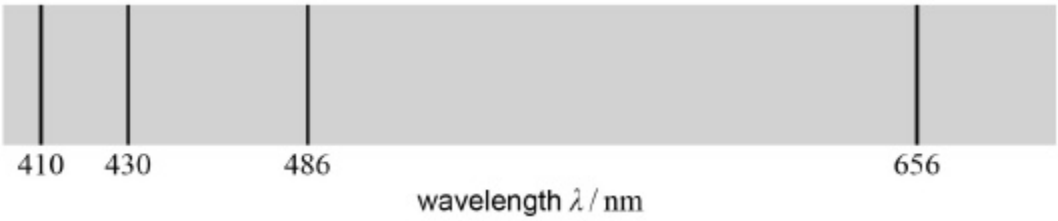
Energy Levels and Photon Emission

Question Paper

Time available: 68 minutes
Marks available: 61 marks

1. In a discharge tube a high potential difference is applied across hydrogen gas contained in the tube. This causes the hydrogen gas to emit light that can be used to produce the visible line spectrum shown in **Figure 1**.

Figure 1

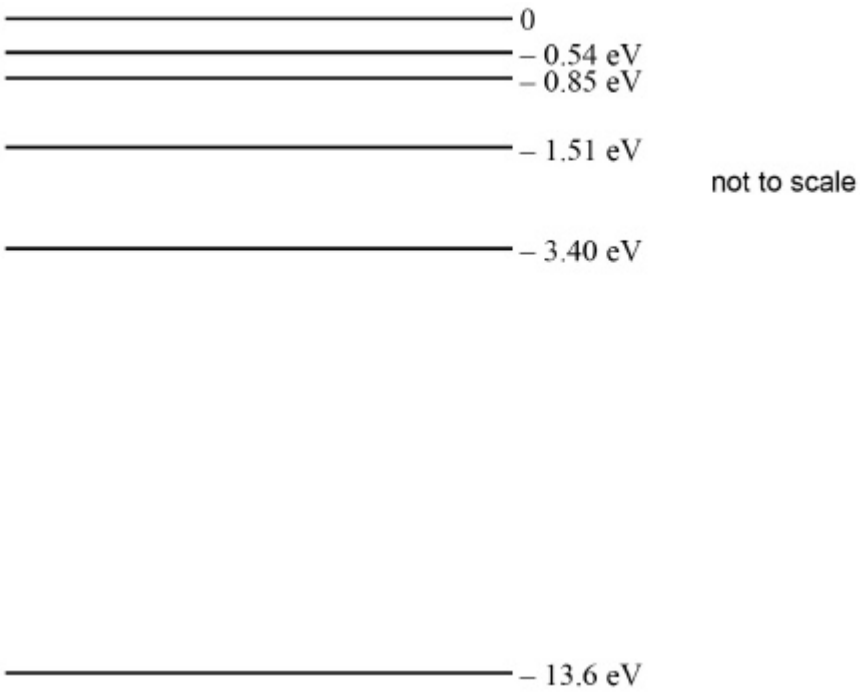


The visible line spectrum in **Figure 1** has been used to predict some of the electron energy levels in a hydrogen atom.

The energy levels predicted from the visible line spectrum are those between 0 and −3.40 eV in the energy level diagram.

Some of the predicted energy levels are shown in **Figure 2**.

Figure 2



(a) Calculate the energy, in eV, of a photon of light that has the lowest frequency in the visible hydrogen spectrum shown in **Figure 1**.

energy of photon = _____ eV

(3)

(b) Identify the state of an electron in the energy level labelled 0.

_____

_____

(1)

(c) Identify the state of an electron that is in the energy level labelled –13.6 eV.

_____

_____

_____

(1)

(d) Explain why the energy levels are negative.

_____

_____

_____

(1)

(e) Discuss how the discharge tube is made to emit electromagnetic radiation of specific frequencies.

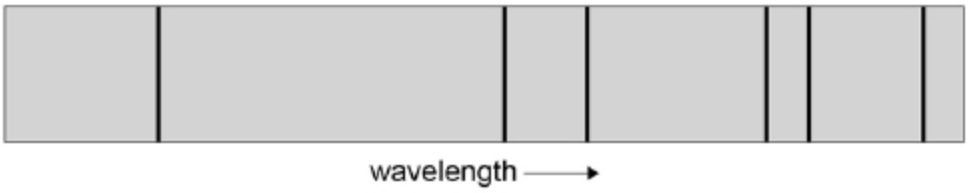
In your answer you should:

- explain why there must be a high potential difference across the tube
- discuss how the energy level diagram in **Figure 2** predicts the spectrum shown in **Figure 1**
- show how one of the wavelengths of light is related to two of the energy levels in the energy level diagram.

(6)

(Total 12 marks)

2. The diagram below shows the line spectrum of a gas.



Explain how line spectra are produced. In your answer you should describe:

- how the collisions of charged particles with gas atoms can cause the atoms to emit photons.
- how spectral lines are explained by the concept of discrete energy levels.

(Total 6 marks)

3. (a) The mercury atoms in a fluorescent tube are excited and then emit photons in the ultraviolet region of the electromagnetic spectrum.

(i) Explain how the mercury atoms become excited.

(3)

(ii) Explain how the excited mercury atoms emit photons.

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(2)

(b) Explain how the ultraviolet photons in the tube are converted into photons in the visible part of the electromagnetic spectrum.

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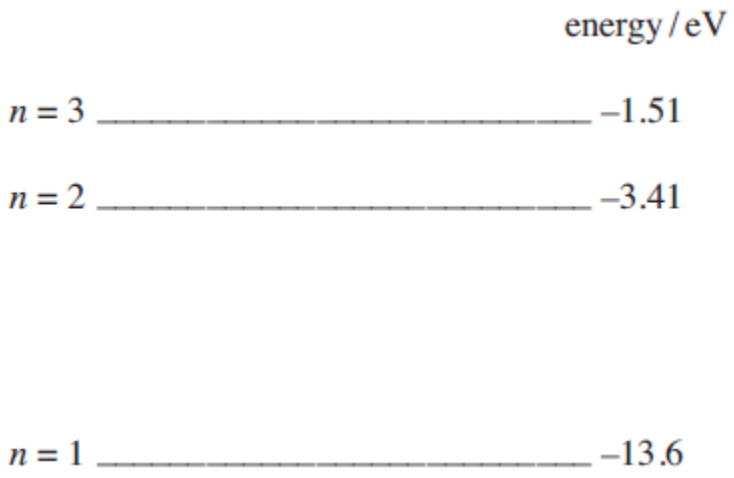
(2)

(Total 7 marks)

4. The diagram below shows the lowest three energy levels of a hydrogen atom.



(a) An electron is incident on a hydrogen atom. As a result an electron in the ground state of the hydrogen atom is excited to the $n = 2$ energy level. The atom then emits a photon of a characteristic frequency.

(i) Explain why the electron in the ground state becomes excited to the $n = 2$ energy level.

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_____

_____

_____

(2)

(ii) Calculate the frequency of the photon.

frequency = _____ Hz

(3)

(iii) The initial kinetic energy of the incident electron is 1.70×10^{-18} J.

Calculate its kinetic energy after the collision.

kinetic energy = _____ J

(2)

(iv) Show that the incident electron cannot excite the electron in the ground state to the $n = 3$ energy level.

(2)

(b) When electrons in the ground state of hydrogen atoms are excited to the $n = 3$ energy level, photons of more than one frequency are subsequently released.

(i) Explain why different frequencies are possible.

_____

_____

(1)

(ii) State and explain how many possible frequencies could be produced.

_____

_____

_____

_____

_____

(2)

(Total 12 marks)

5. (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.

_____

_____

_____

(1)

(ii) Explain the difference between excitation and ionisation.

_____

_____

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_____

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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)

6. (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?

_____

_____

(1)

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

_____

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_____

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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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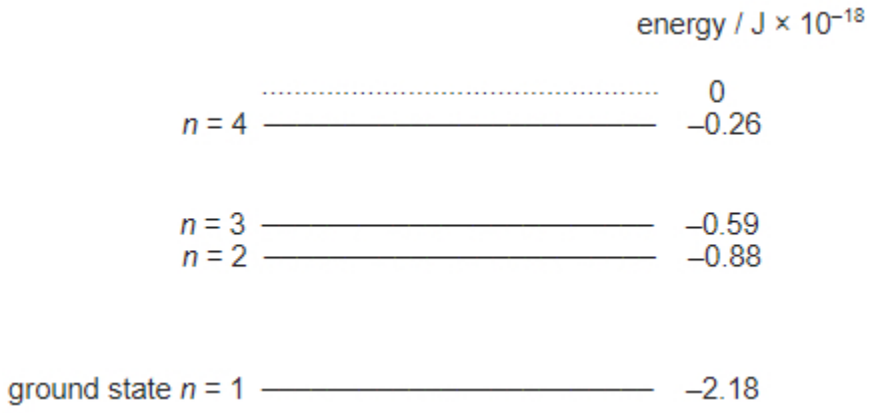
(3)

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



(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)