Physics ATAR - Year 12 Particles Waves and Quanta 2016

Name:	Mark: / 60 = %

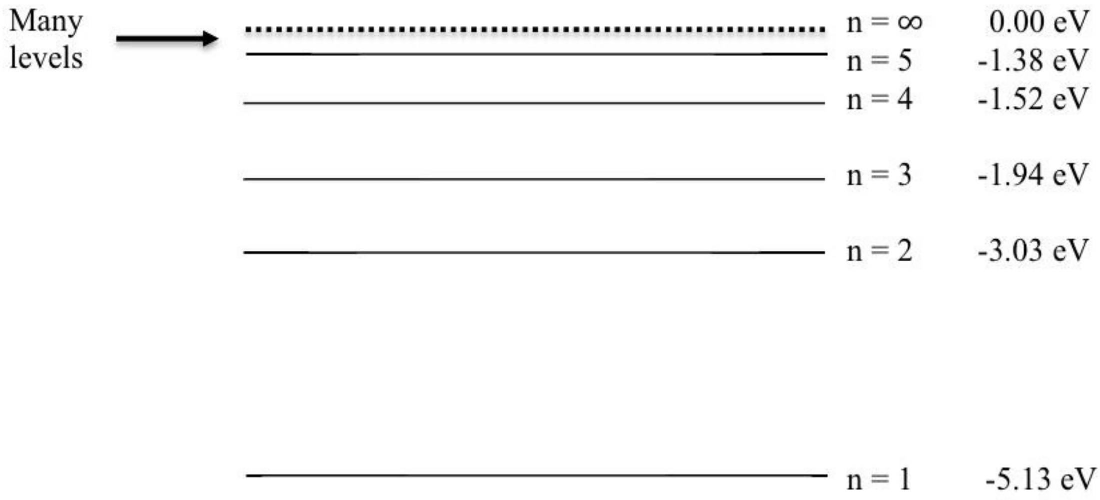
Time Allowed: 50 Minutes

Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(13 marks)**

The diagram below represents a simplified energy level diagram (not to scale) of a neutral sodium atom.



(a) Calculate the energy of the emitted photon when an excited electron decays from the n = 2 level to the n = 1 level.

(2 marks)

(b) Calculate the wavelength of this emitted photon.

(3 marks)

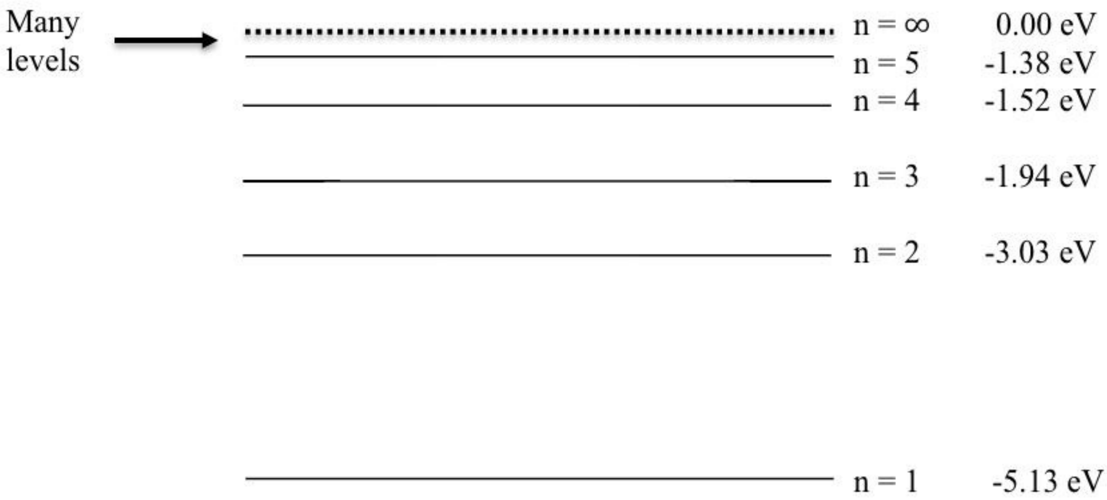
(c) Using the energy levels provided in the diagram above, show all of the possible transitions an excited electron could make to decay to the n = 3 energy level.

(2 marks)

(d) The sodium atom is bombarded with electrons, each having an energy of 3.50 eV. Calculate:

(i) the energies of the emitted photons when the bombarding electrons interact with atoms in their ground state. (Another diagram has been provided to assist you).

(3 marks)

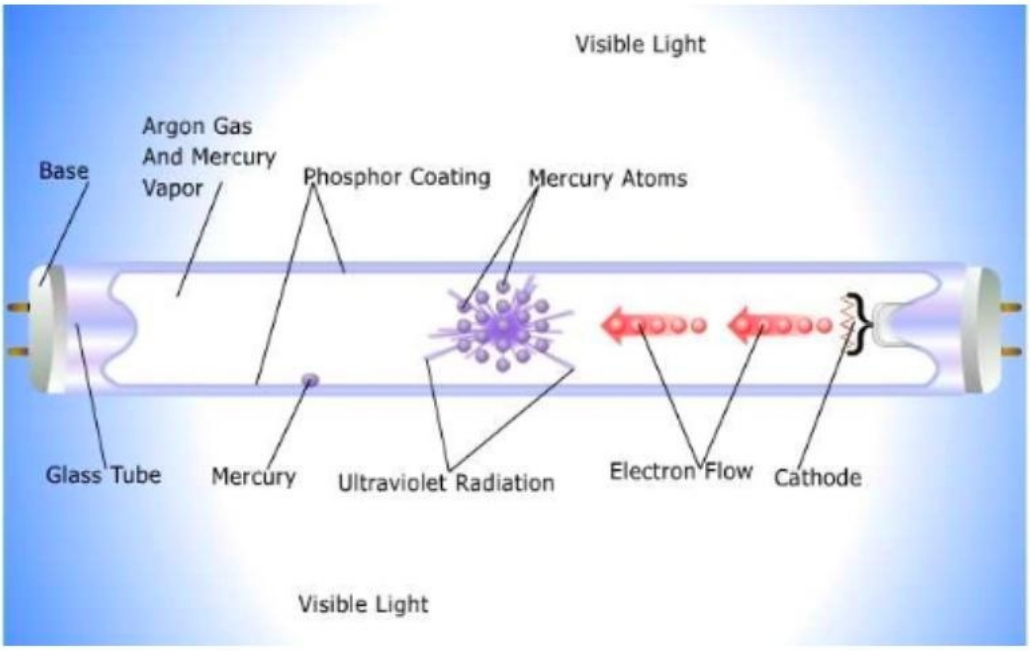


(ii) the energies of the scattered bombarding electrons if they interact with atoms in their ground state.

(3 marks)

Question 2 **(14 marks)**

A fluorescent tube is filled with low-pressure mercury vapour which, when excited by the electron flow, emits radiation in the ultra-violet region. The tube is coated in a phosphor coating that emits visible light.



(a) Explain, with the aid of a diagram, how the ultra-violet light is converted to visible light when it strikes the phosphor coating.

(4 marks)

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(b) Examining the spectral emission of a fluorescent tube reveals a prominent spectral line with energy 3.00 eV. Calculate the energy of these photons in Joules.

(2 marks)

(c) Calculate the wavelength of the 3.00 eV photon.

(3 marks)

(d) State the colour of these photons.

(1 mark)

(d) The Rutherford model of the atom described the electrons as analogous to planets that orbited the sun (the nucleus). Further experimental evidence contradicted this model resulting in acceptance of the Bohr model of the atom. Explain why the Rutherford model needed to be changed and how the Bohr model provides a better fit with the experimental evidence.

(4 marks)

Question 3 **(10 marks)**

A 1.50 x 10^2 m long spaceship rushes past a stationary observer at a speed of 2.70 x10^8 ms^{-1}.

(a) Calculate the length of the spaceship as it appears to the stationary observer as it rushes past.

(3 marks)

(b) The stationary observer and the pilot of the spaceship have a disagreement over the length of the spaceship, each arguing that their measurement of the spaceship is correct and the other person is wrong. Explain which person, if either, is correct.

(3 marks)

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(c) Explain, using the following equation from Einstein's theory of special relativity and one of Newton's laws, why a particle with mass will never reach the speed of light.

(4 marks)

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

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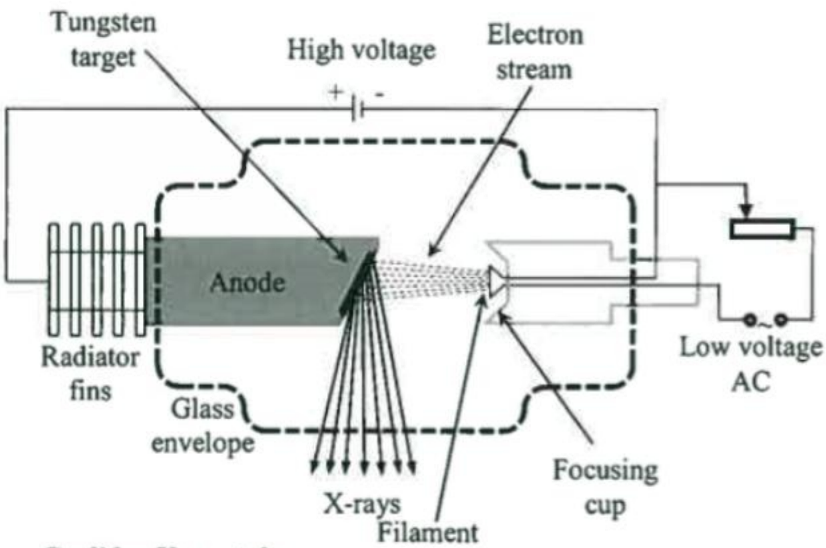
Question 4 **(12 marks)**

The following diagram shows a simple type of X-ray tube. It can be used to produce either hard X-rays (with short wavelengths) or less penetrating soft X-rays (with longer wavelengths).



Coolidge X-ray tube

(a) State what adjustment could be made to the X-ray tube to vary the wavelength of the X-rays it produces.

(1 mark)

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(b) A proportion of the X-ray photons produced will be characteristic of the tungsten target anode. Explain, with the inclusion of a diagram, how these photons are related to the structure of the tungsten atoms.

(3 marks)

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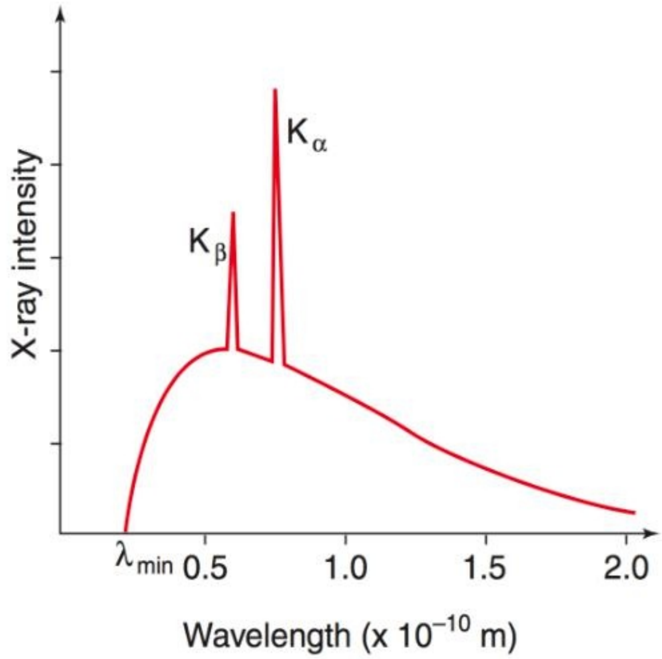
The following X-ray spectrum was produced using a 50.0 kV tube with a tungsten target anode.



(c) Making use of the diagram, calculate the energy, in eV, of the photons emitted in the K_β peak.

(4 marks)

(d) Explain, using an appropriate calculation, why no X-rays with a wavelength less than 0.25 x 10^{-10} m are produced.

(4 marks)

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Question 5 **(11 marks)**

A sub-atomic particle called a Kaon (K^-) can be created in high energy particle accelerators before decaying into 3 smaller sub-atomic particle called 'pions'. The mean life-time (the time before it decays) of a Kaon at rest is 1.24×10^{-8} s and, in a series of experiments, is emitted at a speed of 95% the speed of light. Classical mechanics suggests that the Kaon can only travel 3.53 m, however, in experiment, the Kaon is detected to have travelled much further before decaying.

(a) Explain why the Kaon is detected to have travelled further.

(3 marks)

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(b) Calculate the distance the Kaon travels when relativistic effects are to be considered.

(4 marks)

(c) During an experiment, two Kaons are fired towards each other, each with a speed of 0.90 c with respect to a stationary observer positioned at a detector between the two Kaons. Calculate the magnitude of the speed of one Kaon from the reference frame of the other.

(4 marks)

END OF TEST