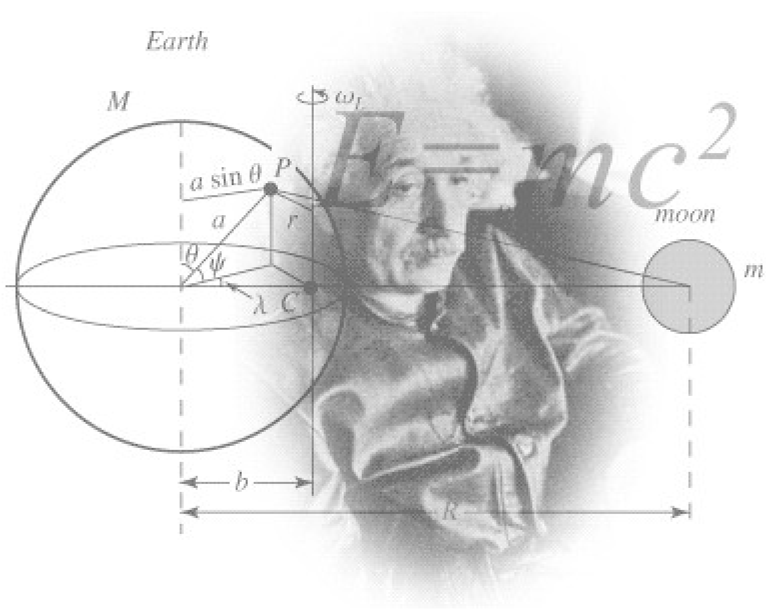
Y12 Physics

Section 2: Problem Solving

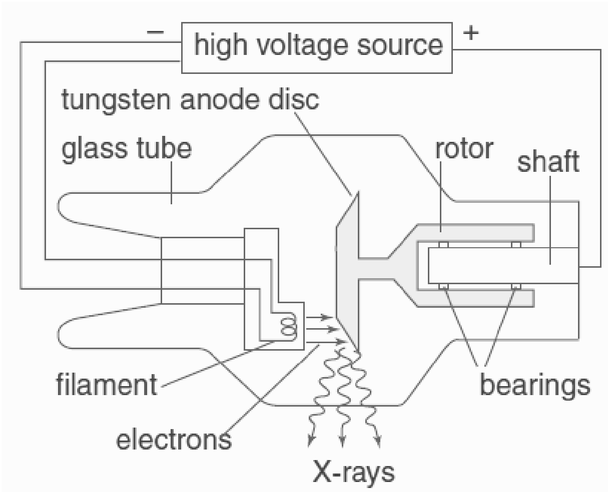
3: Wave Particle Duality

& Quantum Theory



Question 16 **(12 marks)**

The diagram below shows an X-ray tube.



(a) Explain how the tube produces x-rays when in operation.

(3 marks)

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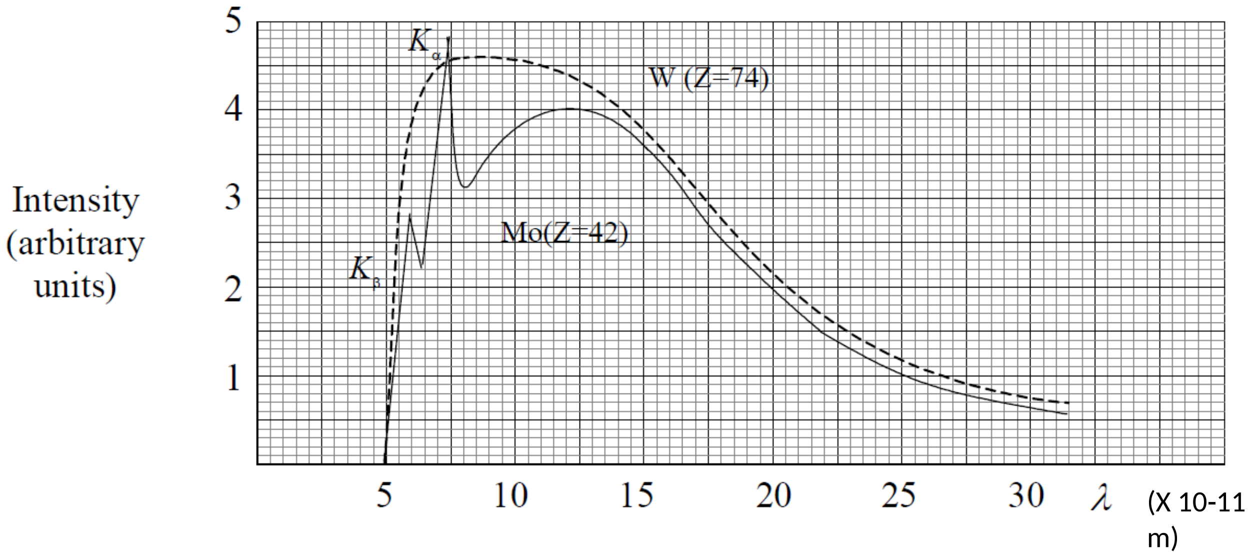
A particular X-ray tube uses molybdenum (Mo) as the target element and another uses tungsten (W). The atomic number = of molybdenum is 42 while that of tungsten is 74.
Recall: Atomic number = number of protons = number of electrons in a neutral atom.

The graph below shows the x-ray spectra (x 10^{-11} m) produced by the two tubes when the accelerating potential is the same for both tubes.



(b) Explain, with reference to the mechanism of x-ray production, why the minimum wavelength produced is the same for both target elements.

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(2 marks)

(c) Use data from the graph to calculate the accelerating potential used in the x-ray tubes.

(3 marks)

The graph shows that characteristic peaks K_α and K_β occur for molybdenum, but not for tungsten. In order to obtain characteristic spectra for tungsten, the accelerating potential has to be increased beyond a certain value.

(d) Explain the formation of the characteristic peaks for molybdenum.

(2 marks)

(e) Suggest why characteristic tungsten spectra only appear when the accelerating potential is greater than that necessary to produce molybdenum characteristic spectra.

(2 marks)

Question 21 **(11 marks)**

Diagram 1 below shows part of the emission spectrum of atomic hydrogen. The wavelengths of the main emission lines are also shown. Diagram 2 shows the principal energy levels of atomic hydrogen in electron volts.

Diagram 1

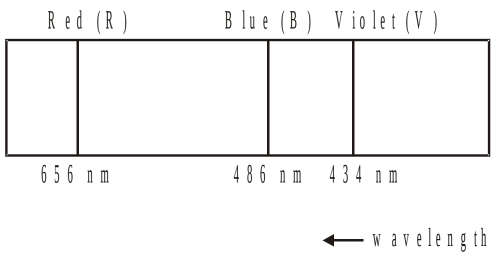
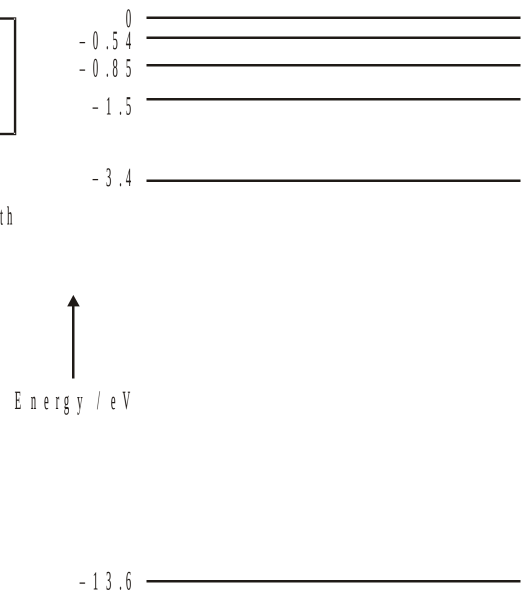


Diagram 2



(a) Find the energy of a photon of violet light.

(2 marks)

(b) On diagram 2, show an arrow to represent the electron transition that gives rise to the red line. Label this arrow “R”. (2 marks)

(c) On diagram 2, show an arrow to represent the electron transition that gives rise to the blue line. Label this arrow “B”.

(2 marks)

Note: Working to identify the transitions should be shown below and this could result in part marks for an incorrect arrow being drawn.

(d) State two physical processes by which an electron in the ground state to move to a higher level.

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(2 marks)

(e) When white light is transmitted through a cold sample of hydrogen gas and analysed, it is found that the intensity of light of wavelength 103 nm is greatly reduced. Carefully explain this observation.

(3 marks)

Question 20 **(12 marks)**

The energy levels of atomic sodium are shown below:

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                      0  ---------------------------------------- n = ∞
                                                                    }Many levels
                  -1.38  -------------------------------------- n = 5

Energy            -1.52  -------------------------------------- n = 4
 (eV)

                  -1.94  -------------------------------------- n = 3



                  -3.03  -------------------------------------- n = 2




                  -5.13  -------------------------------------- n = 1
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(a) What is the ionisation energy of a sodium atom? (1 mark)

Sodium atoms with electrons in the ground state are bombarded with electrons of energy 3.50 eV.

(b) What is the highest energy level that an atom of this element could be excited to when bombarded by this electron beam? (1 mark)

(c) On the energy level diagram above, show all the possible electron transitions when excited atoms return to the ground state after bombardment by this electron beam. What will be the energy or energies of the photons emitted?
(3 marks)

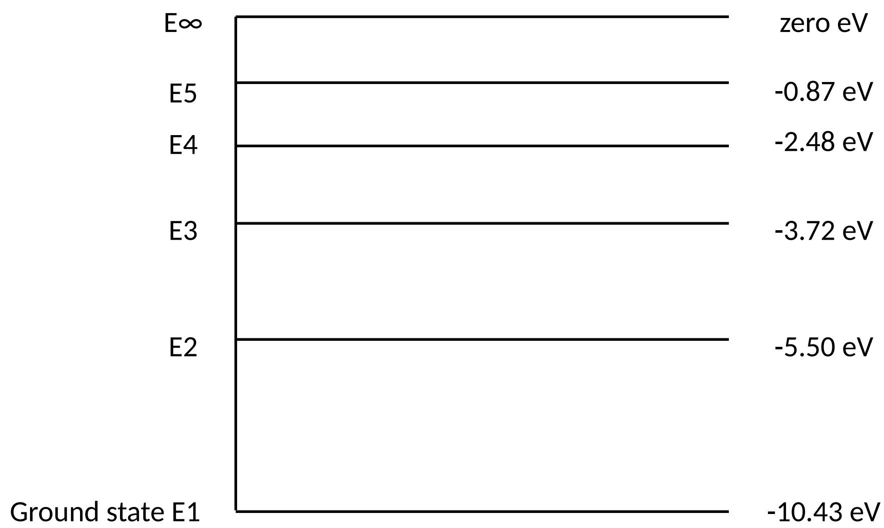
(d) What will be the energy or energies of the scattered electrons? (3 marks)

(e) Which transition accounts for the characteristic flame colour of sodium, which has a wavelength of 589 nm. Show working to justify your answer. (3 marks)

(f) What type of electromagnetic radiation is emitted by an electron transition from the third energy level to the second energy level? (1 mark)

Question 15 **(16 marks)**

A fluorescent light contains low pressure mercury vapour. When atoms of mercury are bombarded by high speed electrons they emit Ultraviolet photons. These UV photons strike a coating on the inside of the lamp causing it to fluoresce and emit visible light. The diagram below details some of the energy levels for Mercury.



a. Calculate the minimum speed of a bombarding electron that could ionise a ground state mercury atom.

(4)

b. Is it possible for a mercury atom to absorb a 10.5 eV photon? Explain briefly.

(2)

c. Explain why the mercury atom can emit several photon wavelengths but not a continuous emission spectrum.

(3)

d. The mercury atom can also emit a visible 772 nm photon. Identify the transition on the diagram with an arrow and label the transition “772 nm photon”. You must provide supporting calculations to justify your answer.

(4)

e. When UV photons strike the phosphor coating on the inside of the lamp the coating “fluoresces”. Explain this process with reference to a simple energy level diagram.

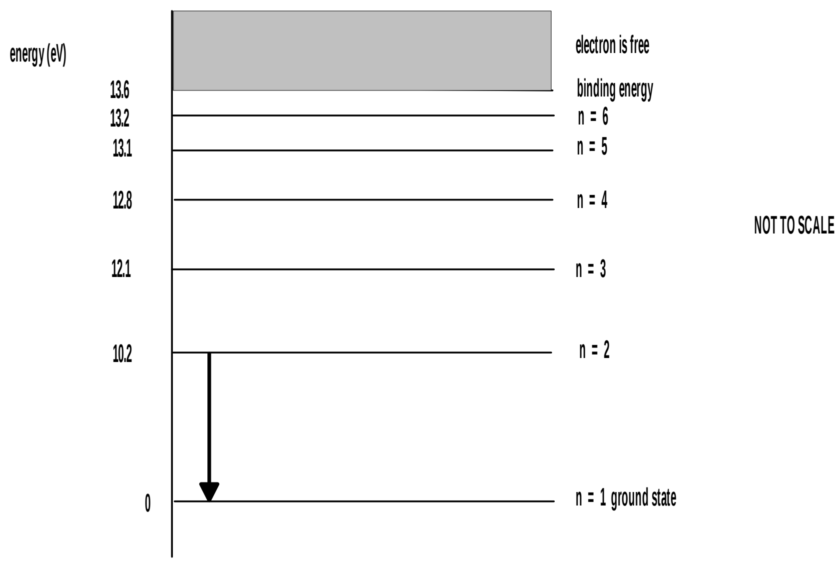
(3)

5 The emission spectra from excited hydrogen gas contain three distinct lines of wavelength 431.1 nm, 486.1 nm and 656.3 nm respectively.

(a) Perform as many calculations as necessary to demonstrate that the radiation with the shortest wavelength of those detected, has the largest energy. (2 marks)

(b) In which region of the electromagnetic spectrum do the three spectral lines appear? (1 mark)

The diagram below is an energy level diagram for the hydrogen atom. Use the diagram to answer questions (c) and (d) below.



(c) Calculate the amount of energy, in joules required to ionise an electron from the ground state. (3 marks)

(d) Draw arrows on the diagram to show all the possible energy transitions that may occur in the hydrogen atom. (one transition is already shown).
(3 marks)

The emission spectrum of light from the sun is continuous with colours ranging from red to violet. Some black lines can be seen amongst the coloured spectrum.

(e) What is the name given to this type of spectrum? (1 mark)

(f) Explain why these dark lines are present in the spectrum from the sun.
(2 marks)

(g) Would you expect to see similar black lines on a continuous emission spectrum produced by light from an incandescent globe? Explain your answer.
(2 marks)