ATOMS: SPECTRA QUESTIONS

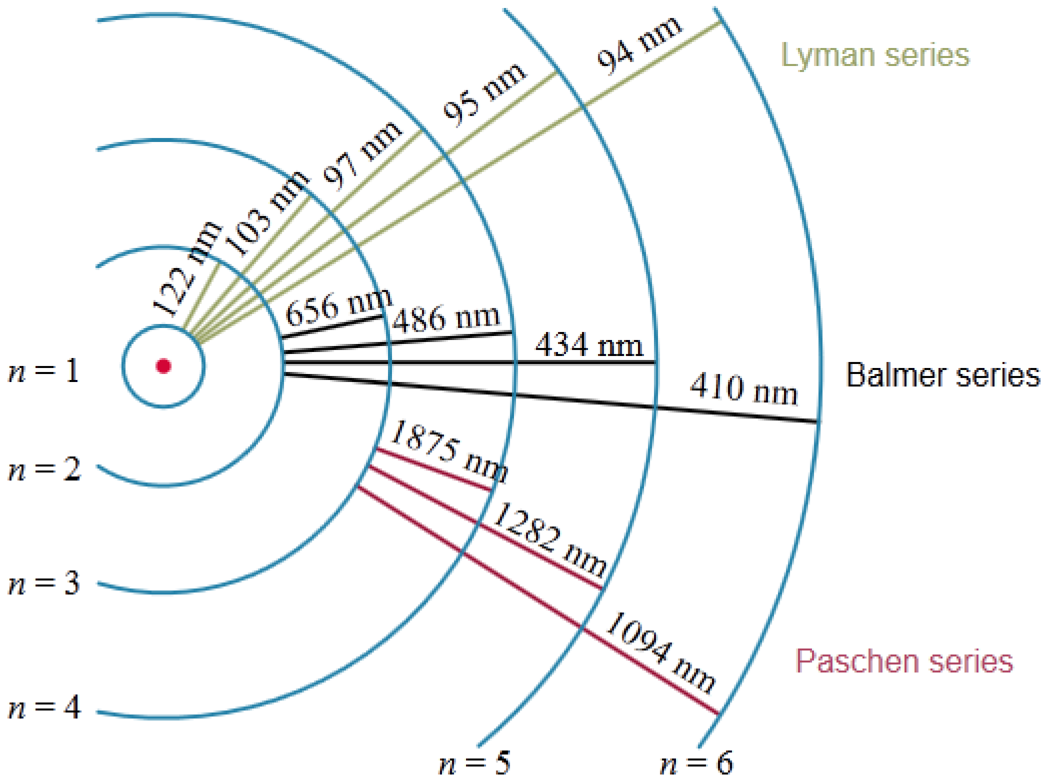
SODIUM LAMPS (2012;2)

(d) In 1802 William Wollaston noted the appearance of dark lines in the spectrum of sunlight. These lines are due to the presence of certain chemical elements in gases surrounding the Sun.

(i) Explain why sharp dark lines appear only at specific wavelengths.

(ii) Explain how a comparison between the spectrum of sunlight, with the dark lines, and the spectrum of light from a sodium lamp, can identify that sodium is one of the elements in the Sun's atmosphere.

ATOMIC SPECTRA (2010;1)



(a) The above diagram illustrates the Bohr model of the hydrogen atom.

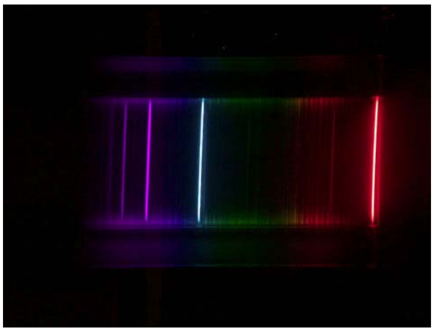
(a) Explain what the circles and lines represent.

(b) Explain how this model explains emission line spectra **and** absorption line spectra caused by hydrogen.

(b) The line between $n = 5$ and $n = 2$ is labelled 434 nm (4.34×10^{-7} m). Show that this is correct for a hydrogen atom.

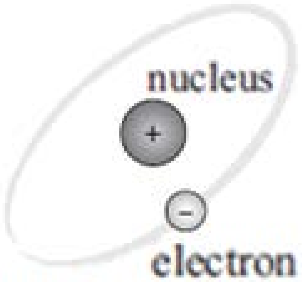
(c) Calculate the energy of a hydrogen atom in its ground state. Express your answer in eV.

THE HYDROGEN SPECTRUM (2009;1)



(a) Briefly describe how the light that formed the hydrogen line spectrum illustrated could be produced experimentally.

(b) Rutherford's model pictured an atom with 'electrons orbiting a solar nucleus', as illustrated below. The Bohr model was proposed to explain the line spectra of hydrogen, something that the Rutherford model could not explain.

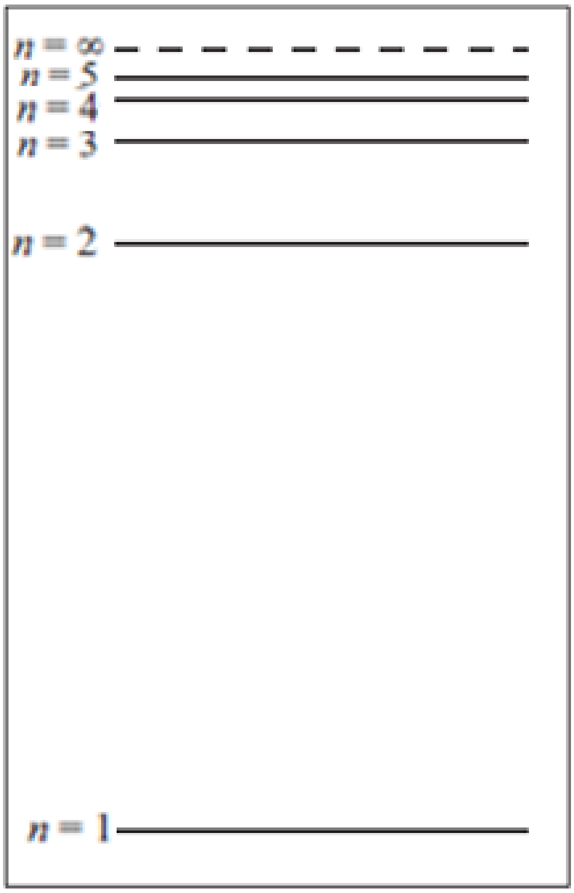


The Rutherford model for a hydrogen atom.

Discuss how the Bohr model was able to explain the line spectrum that the Rutherford model could not.

(c) The hydrogen spectrum in the visible region is part of the Balmer series. Energy transitions that give rise to this series are to the n = 2 level (emission) and from the n = 2 level (absorption). Calculate the energy of the n = 2 level.

(d) The diagram shows energy levels in a hydrogen atom. A continuous spectrum from a star shows absorption lines in the visible part of the spectrum. One dark line indicates the absorption of photons with an energy of 2.86 eV. An astronomer believes that this is due to the presence of hydrogen atoms surrounding the star. Calculate the final energy level, n, when a photon of light of this frequency is absorbed by an atom of hydrogen.



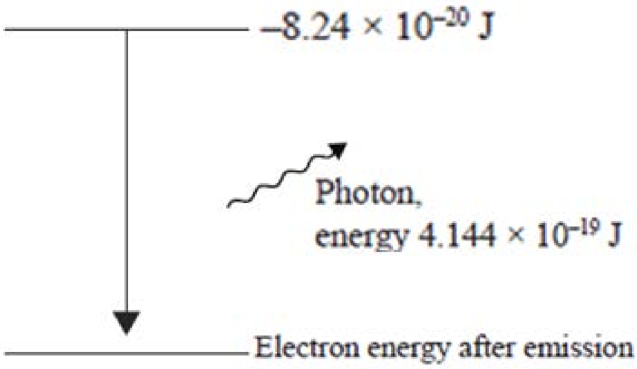
ENERGY LEVELS (2008;2)

Planck's constant $= 6.63 \times 10^{-34}$ J s
Speed of light $= 3.00 \times 10^{8}$ m s^{-1}

A 'black' lamp produces photons that are in the ultraviolet (UV) part of the electromagnetic spectrum. When UV is absorbed by some materials, it makes them glow in the dark. These materials are called phosphors. The white T-shirt in the photo glows because the detergent it was washed in contains phosphors that remain in the fabric after laundering. When an electron in a phosphor is excited by a UV photon, it comes down from its excited state by emitting a visible photon. Some of the original UV energy is retained in the phosphor as thermal energy.
An electron is excited by a UV photon, causing a visible photon of frequency 6.250×10^{14} Hz and energy 4.144×10^{-19} J to be emitted.

(a) Calculate the wavelength of the light photon. Round your answer to the correct number of significant figures.

(b) Suggest a reason why the photons emitted from the phosphor are in the visible region of the electromagnetic spectrum but not in the X-ray region.



(c) The visible photon is emitted when the excited electron drops to a lower energy level. If the excited electron has energy of -8.24×10^{-20} J, calculate the energy of the electron after the photon has been emitted.

(d) The UV photon whose energy was used to excite the electron has a frequency of 3.86×10^{15} Hz. Calculate the amount of heat energy gained by the phosphor after one absorption-emission event.

(e) The colour of the T-shirt under the 'black lamp' light is white. White light is seen when light of many different wavelengths is present. Explain what this tells you about the energy levels in the phosphor material.

HYDROGEN SPECTRUM (2007;2)

Speed of light	$= 3.00 \times 10^8 \text{ m s}^{-1}$
Charge on the electron	$= 1.6 \times 10^{-19}$ C
Planck's Constant	$= 6.63 \times 10^{-34}$ J s
Rydberg Constant	$= 1.097 \times 10^7 \text{ m}^{-1}$

The electron in the hydrogen atom emits or absorbs electromagnetic radiation when it moves between different energy levels. The visible part of the spectrum emitted by hydrogen can be seen in the laboratory by applying a high voltage to a hydrogen discharge tube. The diagram below represents some of the electron energy levels in the hydrogen atom.

(a) To which energy level does the electron drop when it emits visible light?

(b) The absorption spectrum for hydrogen gas consists of a series of dark lines within the full spectrum of colours. Explain clearly how the dark line in the red part of the spectrum is produced.

(c) Calculate the frequency of the photon produced when an electron drops from the second excited state (n = 3) to the ground state (n = 1).

An electron in energy level 4 jumps to a higher energy level, and then drops down to the ground state, releasing a photon of frequency 3.200 x 10^{15} Hz.

(d) Calculate the frequency of the photon required for the first jump.

SOLAR POWER (2006;2)

Rydberg's constant $= 1.097 \times 10^7\ \mathrm{m^{-1}}$
Planck's constant $= 6.63 \times 10^{-34}\ \mathrm{J\,s}$
Speed of light $= 3.00 \times 10^8\ \mathrm{m\,s^{-1}}$

Nuclear reactions in the Sun produce light. The main element in the Sun is hydrogen. The spectrum of hydrogen can be observed in the laboratory with a hydrogen discharge tube. The visible lines in the hydrogen spectrum are called the Balmer series and are described by the formula:

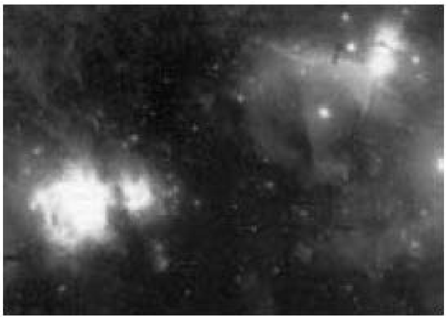
$$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$$

where S =2.

(a) Calculate the wavelength of the lowest frequency line in the Balmer series (L = 3). Give the answer to the correct number of significant figures.
(b) Explain how light of this particular frequency is produced in the hydrogen atom.
(c) An electron in the 6th excited state (L = 7) returns to the ground state in two jumps. It releases one photon with a wavelength of 2.165×10^{-6} m. What is the wavelength of the second photon?
(d) The Sun emits all wavelengths. However, when a solar spectrum is observed on Earth, it contains black lines that correspond to missing wavelengths. Give an explanation, in terms of energy absorption by electrons, for why some of the wavelengths of light in the solar spectrum are missing when the light reaches Earth.

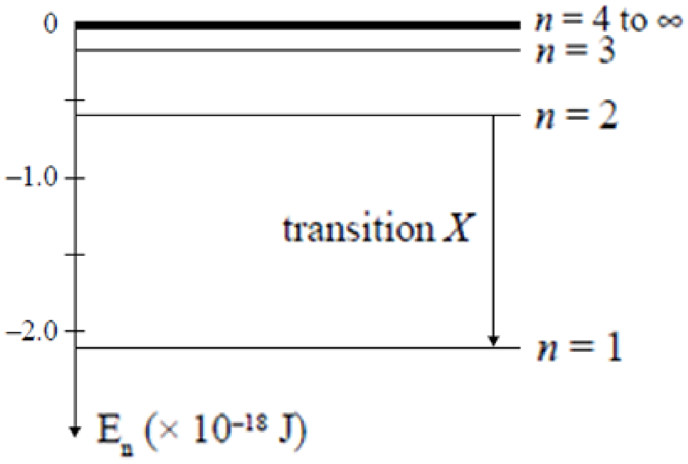
LIGHT EMITTED FROM A STAR (2005;2)

Light from stars is photons of electromagnetic radiation created by electron transitions between energy states. These photons produce spectra that identify the atoms that are producing the light. A common element that produces light from a star is hydrogen.



The Horsehead Nebula has a pink glow that comes from ionised hydrogen gas.

The possible energy states (levels) of the hydrogen atom electron are shown in the diagram below.



(a) In which part of the electromagnetic spectrum is the radiation emitted by transition X?

(b) Calculate the wavelength of the photons emitted by transition X.
(c) Explain which transition produces the red line in the visible part of the hydrogen atom
(d) Calculate the value of the ground state energy of the hydrogen electron. Give your answer to the correct number of significant figures.
(e) In order for an electron in a hydrogen atom to move from the third energy level to the fifth energy level, a photon of electromagnetic radiation must be absorbed. Calculate the energy of this photon.

QUESTION TWO (2004;1)

Use the following information when answering this question:

Speed of light = 3.00×10^{8} m s^{-1}
Planck's constant = 6.63×10^{-34} J s
Rydberg's constant = 1.10×10^{7} m^{-1}

Light energy is produced when the excited electrons of atoms drop from higher energy levels to lower energy levels.

(a) The electron in a hydrogen atom falls from the 5th energy level to the 2nd energy level.
  (i) Calculate the energy of the electron at the 2nd energy level. Give your answer to an appropriate number of significant figures.
  (ii) Calculate the wavelength of the light emitted by this electron transition.

The hydrogen atom, whose electron is in the 2nd energy level, is now ionised.

(b) Calculate the minimum frequency of the photon that can ionise the hydrogen atom.

In a hydrogen atom, electron transitions to the 2nd energy level produce visible light.

(c) Which transition will produce visible light of the lowest frequency? Explain your answer.