Visual Physics Online

Module 8 From the Universe to the Atom

P81 001

(a) What is the Balmer Series?

(b) Outline Bohr's explanation of the Balmer Series.

Check your answer by reviewing the solution guidelines below.

Solution Guidelines
(The solution is more detailed than required in a real examination. The solution is designed to give your greater depth of knowledge in preparation of your formal examinations)

(a)

The simplest atom, hydrogen, produces the simplest emission line spectrum when the hydrogen atoms are excited. The spectral lines of hydrogen appear in the visible, near infrared and near ultraviolet regions. The spectral lines are closely spaced in the near ultraviolet region and converge towards a short wavelength limit. This is a feature of all atoms with the short wavelength limit dependent upon the type of atom (figures 1 & 2).

Many attempts were made to find a numerical relationship between the magnitudes of the wavelengths for the spectral lines for hydrogen. Eventually, in 1885 **Johann Jakob Balmer** (1825 - 1898) showed that the wavelength of each spectral line in the Balmer series to a high degree of accuracy for is given by equation (1)

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

λ wavelength of emitted electromagnetic radiation

R Rydberg constant $R = 1.097\times10^{7}$ m^{-1}

n_i quantum number for initial state (integer n_i = 3, 4, 5, …)

Equation (1) was only an empirical relationship and had no theoretical basis. The formula was simply one which defined the relationships between the observable spectral lines.

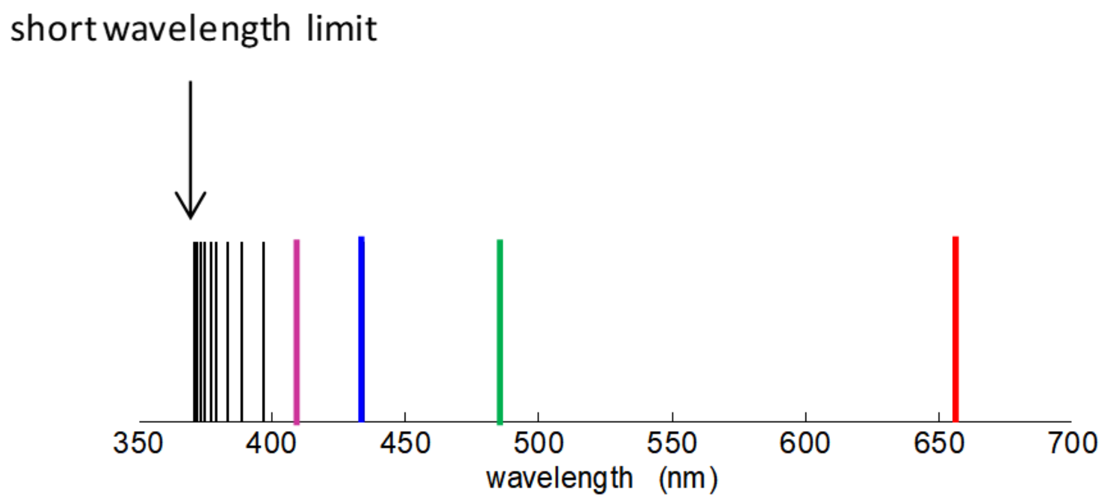

Fig 1. The emission spectrum of atomic hydrogen – Balmer series.

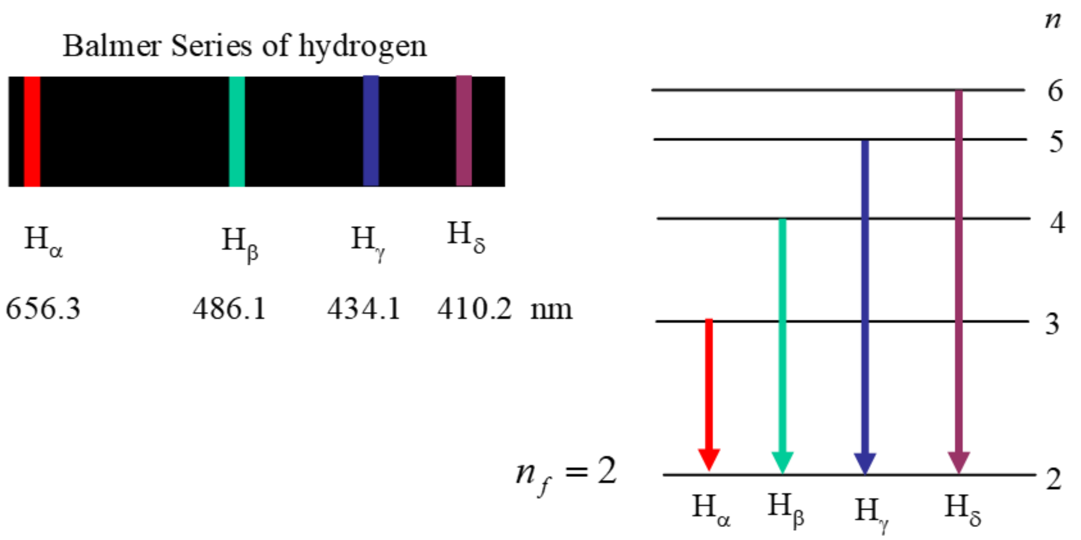

Fig. 2. Balmer series for hydrogen.

(b)

Bohr Model

An atom emits or absorbs energy only when an electron moves from one stable state to another. In a transition from its initial state to its final state, a photon is either emitted or absorbed and the energy of the photon is equal to the difference in the energy of the two states (equation 2)

(2) $$\Delta E = \left| E_f - E_i \right| = h\,f$$

ΔE energy lost or gained by atom

$h\,f$ energy of emitted or absorbed photon

h Planck's constant h = 6.63x10^{-34} J.s *f* frequency of electromagnetic radiation (photon)

E_i total energy of electron in initial state n_i

E_f total energy of electron in final state n_f

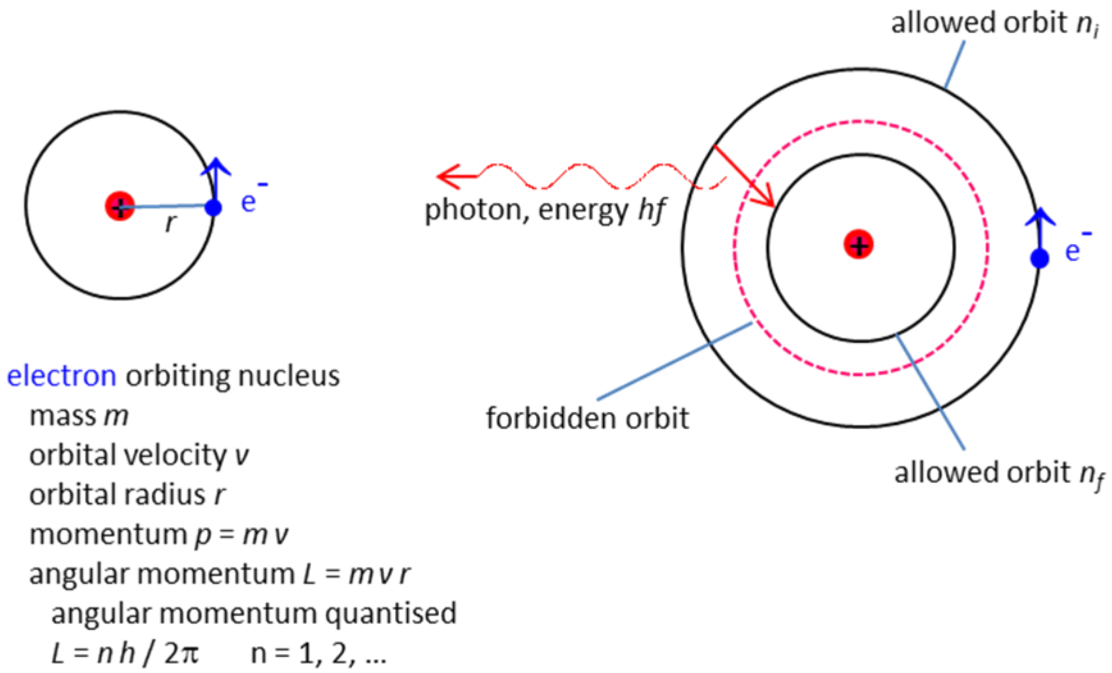

Fig. 3. Bohr's model of the atom.

Bohr's model explains the Balmer Series – transitions were made from allowed initial states where $n_i > 2$ to the final state described by $n_f = 2$. The Bohr's predictions for the wavelength of the radiation emitted in these transitions agreed with the measured values for the Balmer Series. The Balmer equation (equation 1) can be derived from the Rutherford-Bohr model of the atom.