SSM-0032 : Particles and Fields of Modern Physics

Practical Session 2, 17th November 2005

Name of Student : ....

Ask a demonstrator if you are unsure how to use the apparatus.

Hand in answers to Dr.Waters at the end of the session.

The Rydberg Constant

Principle :

The figure below shows the energy level diagram for hydrogen. The electron in the hydrogen atom can make transitions between the different energy levels and, since the total energy must be conserved, the energy of the emitted light photon is equal to the difference between the electron energy levels. If the electron falls from energy level k to energy level j :

$$E_\gamma = \frac{hc}{\lambda} = E_k - E_j$$

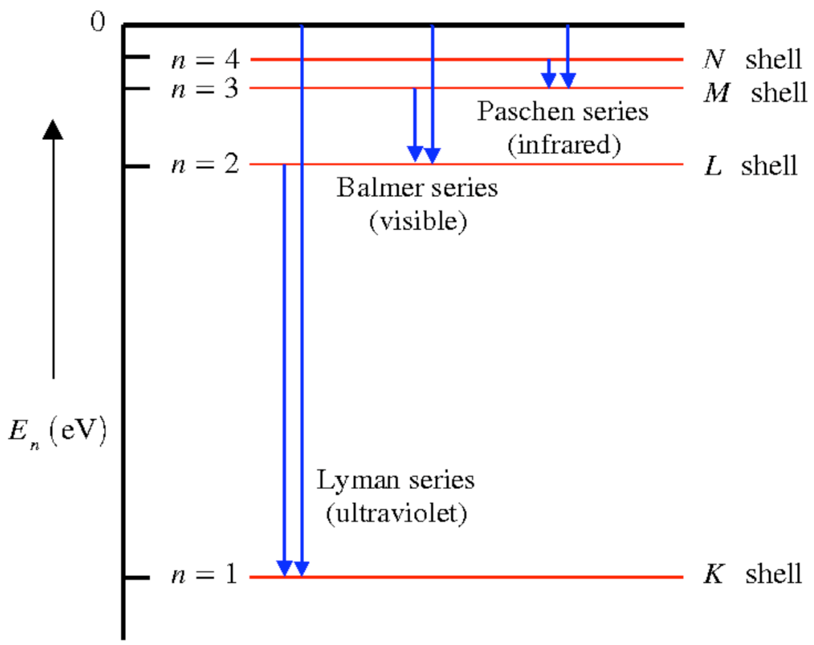
If the hydrogen atom is treated quantum mechanically (for example, in Bohr's model of the hydrogen atom or, equivalently, by solving the Schrödinger equation for the electron in the electric field of the nucleus), the prediction for the spacing of the energy levels is :

$$E_k - E_j \propto \left(\frac{1}{j^2} - \frac{1}{k^2}\right)$$

Hence,

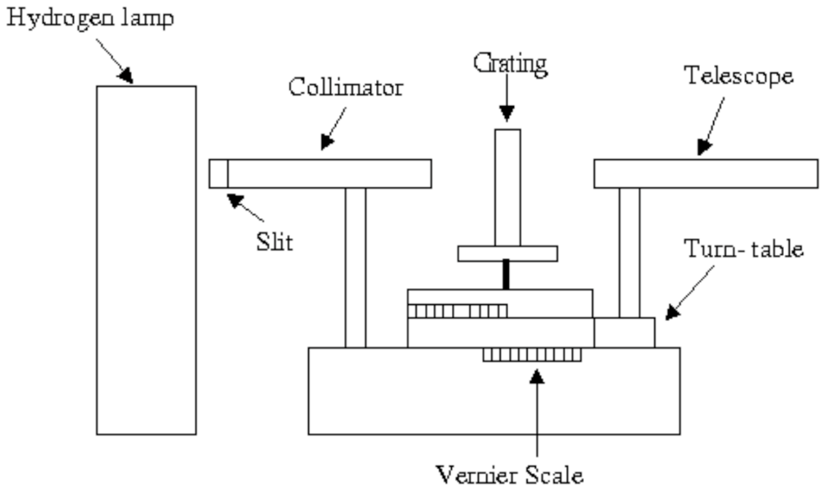
$$\frac{1}{\lambda} = R\left(\frac{1}{j^2} - \frac{1}{k^2}\right)$$

where R is known as the Rydberg constant.



As indicated in the energy level diagram, transitions to the $n = 2$ energy level give light frequencies in the visible region. In particular, the transition $3 \rightarrow 2$ gives rise to easily identifiable red light, the wavelength of which can be measured using a diffraction grating.

Apparatus :



A hydrogen discharge lamp maintains a population of excited hydrogen atoms that emit light as they return to their ground state. Light from the lamp is collimated, such that parallel rays are at normal incidence to the diffraction grating positioned at the centre of the apparatus. A viewing telescope on a turn-table is used to measure the angular positions of the diffraction fringes.

Procedure :

The apparatus should already have been calibrated and setup such that the grating is normal to the light from the collimator. View the grating at normal incidence using the telescope. A bright red line should be visible.

(1)Note the position of the viewing telescope on the Vernier scale when the line is in the centre of the telescope cross-hairs (the "straight-through" position). You should write down all your angle measurements in degrees and minutes. Ask a demonstrator if you are unsure how to read a Vernier scale.

(2)Turn the telescope away from normal incidence. Note the angular positions of the first few red lines. Repeat the measurements with the telescope on the other side of the straight-through positions.

The data will be analysed using the following formula for the angular positions of bright fringes from a diffraction grating with line spacing d :

$$d\sin\vartheta = n\lambda$$

The angle ϑ is measured with respect to the normal to the grating and n is the order of the fringe. The diffraction grating used in this experiment has 300 lines per mm.

Q1 Extract values of $\sin\vartheta_1, \sin\vartheta_2, \ldots$ from your data.

Q2 Make a graph of $\sin\vartheta$ vs. n using your data. Use the graph to extract a value for the wavelength λ.

Q3 From the measured wavelength, extract a value for the Rydberg contstant.

Q4 From your value for the Rydberg constant, derive a value for the ionisation energy of ground state hydrogen. How does this compare with the true value ?