EXPERIMENT 2

THE BALMER SERIES

AIM:

In this experiment the wavelengths of the first three lines of the **Balmer series** are determined and in extend **Rydberg's constant *R***.

APPARATUS:

Spectrum tube, hydrogen
Spectrum tube, mercury
Holders for spectral tubes, 1 pair
Cover tube for spectral tubes
Connecting cord, 30 kV, l = 1000 mm
Object holder, 55 cm 1
Diffraction grating, 600 lines/mm
High voltage supply unit, 0-10 kV
Insulating support
Tripod base -PASS-
Barrel base -PASS-
Support rod -PASS-, square, l = 400 mm
Right angle clamp -PASS-
Stand tube
Meter scale, demo, l = 1000 mm
Cursors, 1 pair
Measuring tape, l = 2 m

METHODOLOGY:

The spectrum of the radiation emitted by a hot body is continuous, because there are very many different kinds of oscillations in any real lump of matter, so that the precise quanta exist at all frequencies.

But there are discontinuous spectra called line spectra- the pattern of radiation emitted by pure elements, when they were heated or electrically disturbed. The spectral lines are images of the narrow slit that the light falls on in a spectrometer.

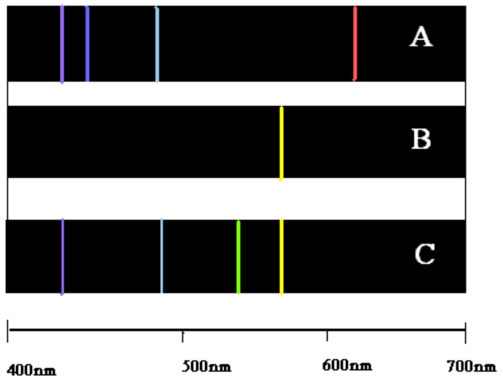

Figure 2.1: *The emission spectrum of* hydrogen (A), *sodium* (B) *and mercury* (C). *In the Balmer Series the spacing of lines decreases steadily as they proceed into the ultraviolet toward shorter wavelengths and their intensities fall rapidly.*

Each element has a unique emission spectrum. Spectra are usually produced by elements and mixtures in the gaseous form, i.e. hot gases. Solids can be vaporized in a hot flame (Bunsen Burner). Spectra can be also produced by electrically disturbing atoms, i.e. firing electrons and ions through a low pressure gas in a discharge tube.

The spectrum of the simplest atom **hydrogen** (1 proton, 1 electron) was found to have four visible lines and a large number of invisible in the ultraviolet and infrared. The total Balmer series of hydrogen (visible spectrum) is described by the following formula:

$$N = R\left(\frac{1}{4} - \frac{1}{n^2}\right) \quad , \quad n = 3,4,5,6 \qquad (2.1)$$

Where $R = 109677.567\ \text{cm}^{-1}$ is Rydberg's constant and $\text{N} = 1/\lambda$ is the wavenumber. There is a total of 4 spectral lines in the Balmer series. Nevertheless in this experiment we will see only visible lines are for n=3, 4, 5 as listed in the table below, since the fourth line weak and difficult to see.

Table 2.1

n=3	H_{α}	*Red*	*656.28nm*
n=4	H_{β}	*Turquoise*	*486.13nm*
n=5	H_{γ}	*Blue*	*434.0nm*

If parallel rays of light are incident perpendicularly to the plane of a diffraction grating, with uniform phase over the grating, then one will observe a diffraction pattern which will have a series of intensity maxima at angles θ satisfying the equation

$$k\,\lambda = g\,\sin\theta, \qquad k = 0, 1, 2\ \ldots \quad (2.2)$$

Where λ is the wavelength of the emitted light, *g* is the grating constant and *k* is the spectrum order (*k*=1 is the 1st order diffraction image). Thus the grating will allow a determination of an unknown wavelength if the positions of the intensity maxima are measured and if g is known.

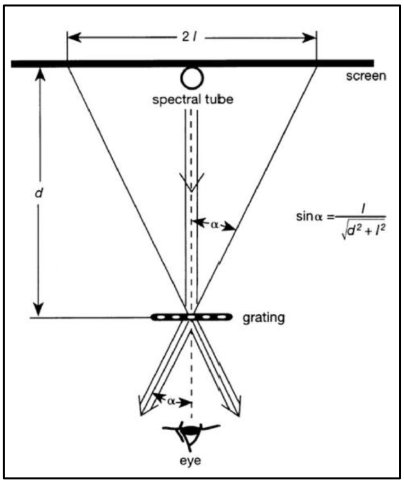

Figure 2.2: Wavelength determination using a diffraction grating. g: grating constant, d: distance from grating to screen, The distance 2 l between spectral lines of the same colour in the right and left first order spectra are read through the grating

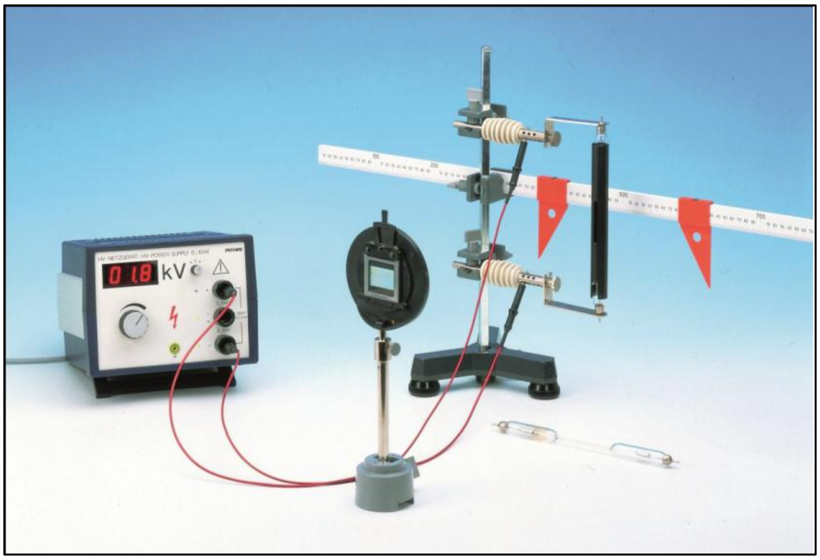

Figure (2.3): Set-up of experiment

PROCEDURE

The experimental set-up is shown in Figure (2.3). Hydrogen or mercury spectral tubes connected to the high voltage power supply unit are used as a source of radiation. The power supply is adjusted to about 5 kV. The scale is attached directly behind the spectral tube in order to minimize parallax errors. The diffraction grating should be set up at about 50 cm and at the same height as the spectral tube. The grating must be aligned so as to be parallel to the scale. The luminous capillary tube is observed through the grating (see Fig 2.2). The room is darkened to the point where it is still possible to read the scale. The distance 2 l between spectral lines of the same color in the right and left first order spectra are read through the grating. The distance between the grating and the eye should be so short, that both lines are visible at the same time without moving the head. The distance d between the scale and the grating is also measured. Three lines are clearly visible in the Hg spectrum. The grating constant g is determined by means of the wavelengths given in Table 2.1. Rydberg's constant, and thus the energy levels in hydrogen, are determined from the measured wavelengths by means of Balmer's formula.

1. Determine the distance 2l.
2. Taking into account that the grating constant is $g = \frac{1}{600} mm$, determine the different angles corresponding to the different spectral lines. Using equation (2.2) you should be able to work out their corresponding wavelengths.
3. Using equation (2.1), plot $1/\lambda$ for all 3 values obtained against $\left(\frac{1}{4} - \frac{1}{n^2}\right)$ and determine a value for Rydberg's constant R.

RESULTS TABLE d ……………………

n	l (cm)	θ= $\tan^{-1}$(l/d) (degree)	sin θ	λ (cm)	1/λ (cm^{-1})	$\left(\frac{1}{4} - \frac{1}{n^2}\right)$
3 RED						
4 TURQOISE						
5 BLUE						