

## EXPERIMENT 2: ATOMIC SPECTRA OF He & Hg

### Related Topics

Rydberg series, Forbidden transitions, metastable state, energy level, excitation energy. photon emitting

### Principle

The spectral lines of He and Hg are examined by means of a diffraction grating. The wavelengths of the lines are determined from the geometrical arrangement and the diffraction grating constants.

### Tasks

1. Determination of the wavelengths of the most intense spectral lines of He.
2. Determination of the wavelengths of the most intense spectral lines of Hg.
3. Determination of Rydberg constant by estimating the energy-level transitions of spectral lines.

### Theory and Evaluation

#### Geometrical Approach to the experiment:

If light of wavelength  $\lambda$  falls on a grating having a grating constant  $k$ , it is diffracted. Intensity maxima occur if the angle of diffraction which satisfies the condition:

$$n \cdot \lambda = k \cdot \sin\phi; \quad n = 0, 1, 2 \dots$$

From Fig.2. we have:

$$\sin\phi = \frac{1}{\sqrt{d^2 + l^2}}$$

and hence

$$\lambda = \frac{k \cdot l}{\sqrt{d^2 + l^2}}$$

for the first-order diffraction.

Grating constant ( $k$ ) is the separation of the lines. In order to determine grating constant, you must find the number of lines ( $N$ ) per meter on grating. Then you can simply calculate  $1/N$  to obtain  $k$ .

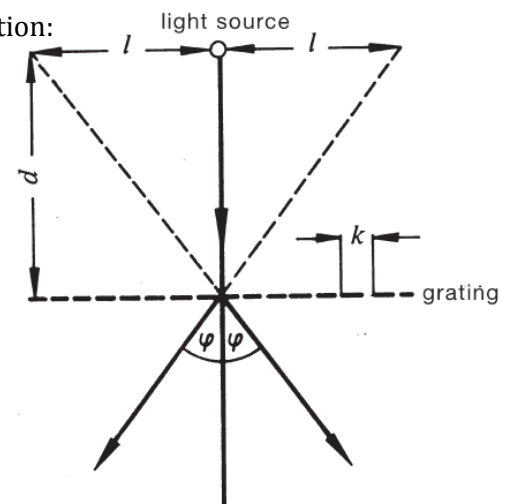


Fig. 2: Diffraction of light of wavelength  $\lambda$  at the grating.

When atoms of a gas are excited (by high voltage, for instance) they will give off light. Each element (in fact, each isotope) gives off a characteristic atomic spectrum, a set of particular wavelengths. One of the great early triumphs of quantum theory was in explaining these spectra.

Quantum theory tells us that electrons can only occupy particular energy levels. The energy levels are quantized, in other words. To conserve energy when an electron makes a transition from a higher-energy state to a lower-energy state, a photon, with an energy corresponding to the energy difference between the electron energies, is emitted.

The following table gives the measured lines:

Colour	$\lambda/\text{nm}$	Transition
red	$665 \pm 2$	$3\ ^1\text{D} \rightarrow 2\ ^1\text{P}$
yellow-orange	$586 \pm 2$	$3\ ^3\text{D} \rightarrow 2\ ^3\text{P}$
green	$501 \pm 2$	$3\ ^1\text{D} \rightarrow 2\ ^1\text{P}$
blue-green	$490 \pm 2$	$4\ ^1\text{D} \rightarrow 2\ ^1\text{P}$
blue	$470 \pm 3$	$4\ ^3\text{S} \rightarrow 2\ ^3\text{P}$
violet	$445 \pm 1$	$4\ ^3\text{D} \rightarrow 2\ ^3\text{P}$

Table 1: Measured spectral lines of He and the corresponding energy-level transitions.

The table below gives the lines obtained by experiment:

Colour	$\lambda/\text{nm}$	Transition
yellow	$581 \pm 1$	$\left\{ \begin{array}{l} 6\ ^1\text{D1} \rightarrow 6\ ^1\text{P1} \\ 6\ ^3\text{D1} \rightarrow 6\ ^1\text{P1} \end{array} \right.$
green	$550 \pm 1$	$7\ ^3\text{S1} \rightarrow 6\ ^3\text{P1}$
green	$494 \pm 2$	$8\ ^1\text{S1} \rightarrow 6\ ^1\text{P1}$
blue	$437 \pm 2$	$7\ ^1\text{S} \rightarrow 6\ ^1\text{P1}$

Table 2: Measured spectral lines of Hg and the corresponding energy-level transitions.

The Danish physicist Neils Bohr presented a solar-system model of the atom, in which the electrons occupy particular circular orbits centered on the nucleus. It is important to understand that the Bohr model is not a true picture of how the electrons behave in an atom, but we use the Bohr model because it is a good starting point in understanding how to determine the energies of the energy levels.

Using his model Bohr predicted that wavelength of the light emitting by the energy-level transitions of atoms:

$$\frac{1}{\lambda} = \frac{2\pi^2 m e^4}{c h^3} \left( \frac{1}{n_s^2} - \frac{1}{n_i^2} \right)$$

where  $\frac{2\pi^2 m e^4}{c h^3}$  is called as Rydberg constant (R) and is equal to **109677,581 cm<sup>-1</sup>**.

## Equipment

Spectrum tubes(helium,mercury), Diffraction grating(600 lines/mm), Power suppliers, Digital Multimeters, Insulators



**Fig.1:** Experimental set-up for measuring the spectra of He and Hg.

## Set-up and Procedure

The experimental set-up is shown in Fig. 1. Helium 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. The room is darkened to the point where it is still possible to read the scale. The distance  $2l$  between spectral lines of the same color in the right and left first order spectra are read without moving one's head. The distance  $d$  between the scale and the grating is also measured. The individual lines (first order) of the spectral lamp are observed by means of the grating and the distance  $2l$  between equal lines is determined with the metre scale. Then wavelength of spectral lines must be determined. Predictions about energy-level transitions can be obtained by using Table 1. and Table 2. Finally, you have to calculate Rydberg constant for every energy-level transition.

