Exercise 9
Energy levels of hydrogen atom. Rydberg constant.

Aim

Spectra analyses of light emitted by hydrogen atoms, determining of ionization energy of hydrogen atom and Rydberg constant on the basis of electron transitions observation between energy levels.

Required theoretical knowledge

Emission spectrum of hydrogen atom in visible light, Balmer series, Rydberg formula. Bohr model of the atom, energy states, Rydberg constant, spectral series Lyman (ultraviolet), Paschen, Brackett, Pfund (infrared). Ionization energy of hydrogen atom. Diffraction grating, diffraction grating equation. Emission and absorption spectra, continuous spectrum, linear spectrum. Dependence of the energy of light on the wavelength.

Equipment

Spectroscopic lamps: helium and hydrogen, handle for lamps, power supply adapter 0 – 10 kV, stand, diffraction grating, micro spectrometer with optical waveguide, computer.

Measurement plan:

A. Diffraction grating:

1. Carefully set a helium lamp in a stand and connect to the power supply.
2. Carry out observations of a spectrum emitted by the lamp; observe the discharge lamp through a diffracting grating.

Problems for discussion:

Starting from the equation of the diffraction grating, indicate in the observed spectrum zero, first and second line position. What is the order of the spectrum?
Using the equation of the diffraction grating indicate, which the lines correspond to a longer wavelength and which to the shorter ones.

B. Transmission between energy levels

1. Turn on the power supply of the spectrometer – red diode should be lighting.
2. Insert an optical waveguide terminal into a hole in a lamp shield.
3. Launch the computer program „SPM" for the spectrometer. In „settings" („Ustawienia") assume: averaging 30 and the time at least 500 millisecond.
4. Start measurements with "Pomiar". During the measurements the computer mouse is not active. After the measurements, record the wavelengths corresponding to the maxima of the spectrum. Position of a cursor is displayed in the right-hand top corner of the computer screen. Write down the value to Table 2.
5. Note: especially low intensity is observed for lines with the shortest wavelengths. In the case of the noisy spectrum, or a small number of measured line (4, or at least 3 lines should be measured), repeat the measurement in a normalization mode:
   a. Firstly, carry out the measurement when the lamp, is off
   b. when the message SPM "fiber cover your face" - to measure the dark current of the detector with the power off discharge lamp.

6. Identify colors of lines responsible for each wavelengths emitted by the excited atoms.
7. Turn off the hydrogen lamp.

Problems for discussion:

How the wavelength of light depends on its energy? Show on the measured spectral lines with blue and red color. What series of the hydrogen spectrum is observed? Identify the specific spectral lines with the corresponding transitions between energy levels of a hydrogen atom and indicate the transition. Attributed to each line the principal quantum number n, corresponding to the number of energy levels, from which the transition is initiated.

8. Fill in the Table 2 with n values corresponding to the energy levels, from which the transition observed in the Balmer series is initiated.

C. Rydberg constant and ionization energy

Problems for discussion:

On the basis of theoretical sketch Rydberg formula inverse wavelength dependence of 1 / n2.
Give way to determine the Rydberg constant and its uncertainty.
How to calculate the ionization energy of the hydrogen atom?
Give the definition of the unit of energy [eV].

1. Reciprocals of the measured (and corrected) wavelengths write down in Table 2.
2. Make a graph of the inverse of the wavelength vs. inverse of the square of the quantum number.
3. To the above graph fit a line using regression method, and on that basis determine the Rydberg constant and its uncertainty.
4. Calculate the ionization energy of hydrogen.

Literature

1. Halliday, Resnick "Fundamentals of Physics - 8th edition", John Wiley 2007,
2. J.R.Rydberg, *Phil. Mag.* **29**, 331 (1890)
3. N. Bohr, *Phil. Mag.* **26**, 151 (1913)