Laboratory work 60

Studying of a atom spectrum of hydrogen

The purpose of work: research of a visible part of atom spectrum of hydrogen; definition of constant Rytberg and the ionization potential of hydrogen atom.

The spectrum of radiation is the major characteristic of matter. With its {his} help it is possible to establish {install} structure of substance, some characteristics of its{his} structure, property of atoms and molecules.

Researches of spectra of radiation of the rarefied gases have shown, that in each gas is inherent quite certain *линейчатый a spectrum,* i.e. a spectrum consisting of groups of separate spectral lines.

Position of lines in nuclear spectra can be explained only on the basis of quantum representations. In the quantum mechanics shows, that energy электронов in atom can accept not any, but only some certain values $E1, E2, E3..., En$. Conditions with various values of energy refer to *as levels of energy (power levels).*

Elementary of atoms - atom of hydrogen consists of a kernel positively charged in which electrostatic floor{field} one moves электрон. In the quantum mechanics the formula is received, allowing to calculate possible{probable} values of energy электрона

$$E_n = -Rhc/n^2, \qquad (1)$$

Where $R = m_e e^4/\left(8h^3\varepsilon_0^2 c\right)$. (2)

Here $those$ = 9,11·10-31 kg - weight of rest электрона, e = 1,60 10-19КЛ - its{his} charge, h = 6,63·10-34 *Дж·с* - Planck's constant, with = 3 108 i/with - speed of light in vacuum, $\varepsilon 0$ = 8,85·10-12 *õ/m* - an electric constant, n = 1,2,3... - the main quantum number (coincides with number of a power level).

From (2) follows, that *R*-a constant. It{her} name constant Ридберга.

In figure 1 levels of energy of atom of hydrogen are represented. The power condition corresponding{meeting} n = 1 refers to *as the basic* or *normal* (not raised){excited)} condition. Conditions with n> 1 refer to *raised{excited}.* At increase *n* power levels approach to border *(n* =). Thus the maximal value of energy is equal to zero (*E* = 0). It speaks that электрон in atom is connected by force of an attraction to a kernel $(E < 0)$. The more n, the above the power level, greater energy possesses that электрон. Электрон free atom of hydrogen (not подвергшегося to external influences) is in a normal condition (n = 1) and to it{him} there corresponds{meets} energy

$$E_1 = -Rhc. \qquad (3)$$

If to this atom to inform energy, greater{big} or equal (3) электрон will fall outside the limits atom - the atom is ionized. Therefore energy

$$E_i = -E_1 = Rhc$$

Name *energy of ionization,* and size

$$\varphi_1 = E_1/e = Rhc/e \qquad (4)$$

In potential of ionization.

If the atom of hydrogen has received energy, smaller $_{Ei}$ электрон can pass to any *m-th* level, i.e. in the raised{excited} condition. In this condition электрон is insignificant shares of second and passes to lower level. At such transitions energy is radiated, and there are *spectral lines of emission. Energy of quantum of radiation* is equal to a difference энергий these levels

$$h\nu_{mn} = E_m - E_n \qquad (5)$$

Where vmn-frequency of radiation.

In figure 1 transitions between the levels, emissions corresponding{meeting} spectral lines, are designated by arrows. Transition электронов with bottom on top level of energy is accompanied by absorption of quantum of light tone of frequency. Considering, that $\nu = c/\lambda$, from (1) and (5) follows

$$\frac{1}{\lambda_{mn}} = R\left(\frac{1}{n^2} - \frac{1}{m^2}\right). \qquad (6)$$

The parity{ratio} (6) has been received empirically and refers to as generalized formula Бальмера. It{she} allows to define{determine} *lengths of waves* λ_{mn} *of the spectral lines, let out (absorbed) by atom of hydrogen.*

Set of the lines having the general{common} bottom level, name *a spectral series.* From figure it is visible, that lines in a spectrum of hydrogen settle down series. For all lines of a series *n* remains to constants, and *m* can accept values: m = *n* + 1, n + 2, n + 3....

In the present{true} work spectral lines of series Бальмера *(n = 2)* are studied{investigated}. The Most intensive lines of this series are in visible area of a spectrum. They are designated by symbols

H_α - A red line (m = 3); H_γ - blue-violet (m = 5);
H_β - Green-blue (m = 4); H_δ - violet (m = 6).

Lines of series Лаймана are located in ultra-violet area, Пашена - in infra-red.

Devices and accessories{belongings}: стеклянно - prismatic монохроматор УМ-2, the gas-discharge laser (as a source линейчатого a spectrum), the Power unit.

For supervision of spectral lines and measurement of their lengths of waves in work it is used стеклянно - prismatic монохроматор УМ-2 which device and instructions for use are resulted{brought} by it{him} in the appendix.

Excitation of atoms occurs{happens} in the gas category. The pressure{voltage} enclosed to a gas-discharge tube, accelerates the charged particles which are being gas. Particles collide{face} with neutral atoms, transfer{transmit} them energy and translate them in the raised{excited} condition. Through time of the order 10-8 about atoms again pass to lower power level, letting out surplus of energy in the form of a spectrum which we and observe by means of монохроматора.

The task 1. *Graduation of a scale of drum{reel} УМ-2.*

Graduation of a scale of a drum{reel} монохроматора is made to express indications of a scale of a drum{reel} in lengths of waves.

1. A gas-discharge tube place in a support located on a rail of the device, and include in a network through a power unit. Adjusting{regulating} position of a tube, achieve full illumination{coverage} of a crack 1 монохроматора (figure 2).

2. Turning a drum{reel} 7, look through through an eyepiece all spectrum from violet up to red border. All lines should be equal and are brightly shined{covered}.

3. Include lighting bulbs of scales and an index 10. Combine consistently an index with lines of a spectrum of a neon and helium from red up to violet, specified by the teacher. Do{make} readout of corners on a drum{reel} 7, marking{celebrating} color of a line (not less than 10 lines). Then measurements repeat upside-down - from violet up to red border.

4. Calculate average value of readout <> on a drum{reel} for each spectral line. The table of lengths of waves of these lines is applied on the device.

5. Results of measurements and calculations bring in table 1.

6. Build градуировочный (калибровочный) the schedule on a millimetric paper. On an axis of ordinates postpone corners <>, and on an axis абсцисс - lengths of waves λ corresponding{meeting} them. The scale should be chosen such that the schedule was enough big and allowed to define{determine} precisely lengths of waves of a spectrum of a studied{an investigated} element. Градуировочный (калибровочный) the schedule (it{him} still name a dispersive curve) should represent a smooth curve. This curve build

by means of a curve a pencil. At construction of the schedule some experimental points sometimes appear displaced from a smooth curve. Such "emissions" testify more often to wrong decoding an observable picture of spectral lines. In this case it is necessary to compare more closely{attentively} with a picture to the table of lengths of waves and to make to the schedule of correction. Under this schedule it is possible to define{determine} length of a wave of any line of a spectrum if its{her} position on a scale of a drum{reel} 7 is known.

Table 1

Gas										
λ, *нм*										
$\psi_{K\to\Phi}$										
$\psi_{\Phi\to K}$										
$\langle\psi\rangle$										

The task 2. *Definition of constant Ридберга and potential of ionization of atom of hydrogen.*

5. Instead of the gas-discharge laser before a crack put the tubes filled by hydrogen, and in a spectrum of radiation find lines of atomic hydrogen $H_\alpha, H_\beta, H_\gamma, H_\delta$ of series Бальмера and remove for them readout of corners, acting similarly п.3 tasks 1. Knowing <> on a dispersive curve define{determine} lengths of waves of these lines λ_{mn}.

6. By means of the formula (6) on the received values λ_{mn} calculate four values of constant Ридберга *R.* Define{determine} average value <R> and estimate{appreciate} an error of result by a standard technique. The value received experimentally <*R*> compare to its{her} theoretical value calculated from a parity{ratio} (2).

7. Under the formula (4) calculate potential of ionization of atom of hydrogen in вольтах, using average value of constant Ридберга.

8. Data of measurements and calculations bring in table 2.

Table 2

Line of hydrogen	<ψ>	λ, м	R_i, $м^{-1}$	<R>, $м^{-1}$	ΔR_i, $м^{-1}$	ΔR, $м^{-1}$	E,%	R, $м^{-1}$	φ, эВ
H_α									
H_β									
H_γ									
H_δ									

9. Final result write down in the form of $R = \langle R \rangle \pm \Delta R$

Control questions

1. What spectra give the rarefied gases?
2. What series the spectrum of hydrogen has? In what areas of a spectrum they are located? Write down their formulas.

3.What sense quantum numbers *m* and *n* have*?* Find the least and greatest lengths of waves of spectral lines in visible area of a spectrum of hydrogen.

4.What least energy should have электроны that at excitation of atoms of hydrogen by their impacts there were all lines of all series of hydrogen?

5.What refers to as potential of excitation? In potential of ionization?

6.How to construct a dispersive curve of the device?

The appendix

The description монохроматора УМ-2

In work it is used стеклянно - prismatic монохроматор УМ-2, intended for spectral research in a range of lengths of waves from 380 up to 1000 nanometers. The structure of the device includes following basic parts (figure 2).

1. An entrance crack 1. The micrometric screw 9 allows to open a crack for the necessary width. Usually working width of a crack is equal 0.02 - 0.03 mm.

2. Коллиматор 2. The micrometric screw 8 allows to displace an objective concerning a crack at focusing different spectral lines.

3. A complex{difficult} spectral prism. It{she} is established{installed} on a rotary little table 6 which rotates about a vertical axis the screw 7 together with отсчетним a drum{reel}. The screw path is put{rendered} on a drum{reel} with градусными divisions. Along a path the index of turn of a drum{reel} slides. At rotation of a drum{reel} the prism turns and in a midfield of sight there are various sites of a spectrum. Turn of a drum{reel} on one division 2 corresponds{meets} to turn of system of prisms on 20 '.

4. The Telescope. Consists of an objective 4 and an eyepiece 5. The objective gives the image of an entrance crack 1 in the focal plane in which the index 10 in the form of a triangle is located. It{he} is shined{covered} with a bulb and considered{examined} in an eyepiece 5. Under a bulb the disk with a set of optical filters is located. Turning a disk, it is possible to shine{cover} an index with the necessary color. The eyepiece is established{installed} on sharpness of the image of an index and spectral lines by rotation of a frame.

5. The case 11 is strengthened on a rail. On a rail the light source is placed also.

6. The lighting system joins in a jack 3,5 In on the board of a power unit. The toggle-switches located on the basis of монохроматора, allow to include bulbs of gaffers of scales and an index.

Focusing монохроматора УМ-2. Before the beginning of supervision the

device follows carefully отфокусировать so that an index 10 and spectral lines had precise, clear borders. For this purpose, moving an eyepiece, it is necessary to receive the sharp image of an edge of an index 10. Then, having shined{covered} an entrance crack of the device to find a yellow line of a spectrum and to receive its{her} clear image by means of the screw 8. For readout of position of a spectral line its{her} center combine with an edge of an index and on divisions of a drum{reel} make readout. For reduction of a mistake{an error} width of an entrance crack do{make} whenever possible small (0.02 - 0.03 mm). For supervision of the weakest lines in extreme violet area, a crack it is necessary to expand till 0.05 - 0.06 mm. The eye notices weak lines in movement is better, therefore at supervision it is useful to turn slightly a drum{reel} in both parties{sides} from average position.

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