TOPIC 10.A. Atomic Physics and Elements of Quantum Physics
Fundamentals of Atomic Physics and Quantum Mechanics. Radioactivity.

Today, the most common methods of qualitative substances analysis are *spectroscopic methods*, which are based on the ability of atoms and molecules to absorb, radiate and scatter electromagnetic radiation. Using these methods, it is possible to describe the electronic structure, spectra and other properties of atoms and molecules.

Atomic physics is the branch of physics that studies as the atoms structure and properties so as elementary processes at the atomic level.

Quantum mechanics is the theoretical base of atomic physics and studies the laws of molecules, atoms, atomic nuclei and elementary particles motion and interaction.

Exercise 10.1a. Supplement the definitions and write down the answers to the questions.

The first Bohr postulate (quantizing orbits conditions): ________________________________

____

____

$$L = mrv = n\frac{h}{2\pi}. \quad (10.1a)$$

When this condition is satisfied, the length of the Bohr orbit is:

$$r_n =$$

λ is de Broglie wavelength.

The second Bohr postulate (the frequency condition). ________________________________

____

____

This transition is described by the *Planck relation*:

(10.2a)

$\Delta E = \left|E_j - E_i\right|$ is ____

h is ____

ν is ____

c is ____

λ is ____

$\widetilde{\nu} = \frac{2\pi}{\lambda}$ is ____(10.3a)

Radiation (emission) of electromagnetic waves is possible when the molecule energy state changes from the upper levels to lower ones, the absorption occurs during passing from the lower levels to the upper ones (Fig 10.1a).

Then the radii of stationary circular orbits and the rate of electrons on these orbits are calculated by formulas:

$$r_n = \frac{\varepsilon_0 h^2}{\pi e^2 m Z} n^2 \qquad \text{and} \qquad v_n = \frac{Ze^2}{2nh\varepsilon_0},$$

where Z is ____

ε_0 is ____ *m* is ____

r is ____

e is ____

n is ____

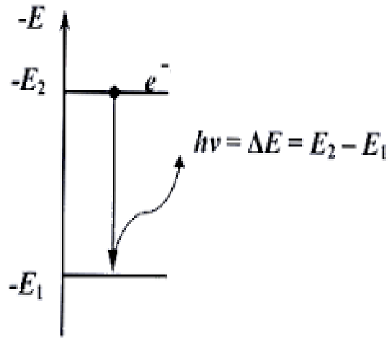


Fig. 10.1a. Schematic electrons transition from one energy level to another one

When electromagnetic radiation interacts with matter, atoms ionization is occurred and free electrons appear. This phenomenon is called the *photoelectric effect*.

The momentum of photon (the electromagnetic radiation quantum) is equal to:

$$p = \frac{h\nu}{c} = \frac{h}{\lambda}; \qquad (10.4a)$$

Photon mass is: $m = \frac{h\nu}{c^2}$. (10.5a)

Einstein's equation for the photoelectric effect:

(10.6a)

It means that photon energy $h\nu$ is expended for emission of an electron exiting from the irradiated matter, $W = eU_0$ (where U_0 is the inhibitory potential difference) and for kinetic energy of the emitting electron.

Extrinsic photoelectric effect appears when irradiation ν is $\nu_0 \geq \frac{W}{h}$. *The red photoelectric threshold* corresponds to the state when the kinetic energy is equal to zero.

According to the quantum theory, any part of a substance can be in only one definite stationary state, which has certain unique physical properties: electron density distribution, dipole moment, etc. This state is described by the *wave function* ψ. For each energy level it can be several values of ψ.

Exercise 10.2a. *The Schrodinger`s equation* in the one-dimensional case of the stationary states of particle motion has the form of:

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}[E - U(x)]\psi = 0, \qquad (10.7a)$$

E is ____

U is ____

m is ____

ψ is ____

ψ^2 is ____

Quantum numbers:

n is ____

l is ____ *m* is ____

s is ____

The *Pauli exclusion principle* ____

____

____

Exercise 10.3a. Supplement the definitions and write down the answers to the questions.

The energy level is called *nondegenerated* if________________________________

____

The energy level is called *degenerated* if___________________________________

____

Energy levels are *splited* when____

____

A state is called *singlet* if ____

A state is called *triplet* if____

The emission spectrum is ____

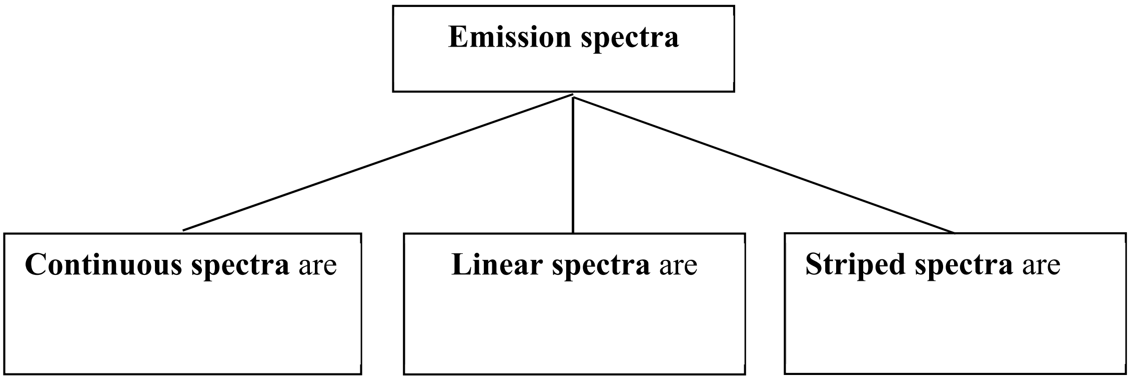
____

____

The absorption spectrum is ____

____

The emission spectra are divided into (give the examples):



The spectral line is the main tool for establishing the substance composition.

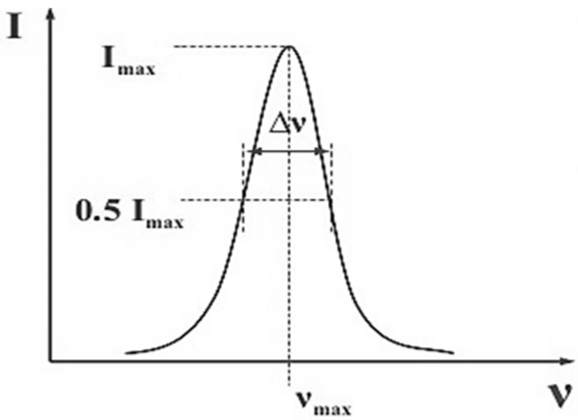


Fig. 10.2a. Spectral line image

The main characteristics of the spectral line: I is line intensity, ν is frequency, $0.5I_{max}$ is spectrum intensity at half-height, $\Delta\nu$ is line width at half-height, ν_{max} is the value of the frequency that corresponds to the maximum intensity of the spectral line I_{max}.

Example of problem solution

Determine the quantum energy of light with a wavelength 740 nm.

Data:	***Solution:***
$\lambda = 740\ nm$	$$E = \frac{hc}{\lambda},$$
	$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{740 \times 10^{-9}} = 2.7 \times 10^{-19}\ (J).$$
$E - ?$	$$[E] = \left[\frac{J \times s \times m}{m \times s}\right] = [J]$$

***Answer*:** the quantum energy of light with a wavelength 740 nm is $2.7 \times 10^{-19}\ J$.

Problem 10.4a. The position of the spectral line on the wavelength scale corresponds to 500 nm. What is the position of this spectral line on the wave numbers scale?

Data:	***Solution:***

***Answer*:**____

Problem 10.5a. Determine the photons energy that correspond to the longest (λ=0.76 μm) and the shortest (λ=0.4 μm) lengths of the spectrum visible part.

Data:	***Solution:***

***Answer*:**____

Problem 10.6a. Determine the momentum of a photon with energy 6×10^{-19} J.

Data: | ***Solution:***

Answer: ____

The Main Characteristics and Registration of Spectra

The energy of the photon absorbed determines the spectral line location on the frequency scale.

The population of energy levels is determined by the number of particles that are in the state E_i and E_j, i.e., respectively, values are N_i and N_j. The distribution of particles over the energy levels is determined by the *Boltzmann equation*:

$$\frac{N_i}{N_j} = exp\left(\frac{E_i - E_j}{kT}\right), \tag{10.8a}$$

where k – Boltzmann const.

Exercise 10.7a. Supplement the definitions and write down the answers to the questions.

The main condition for the absorption is ____

____

Exercise 10.8a. Supplement the definitions.

The spectral line intensity depends on: ____

____

The natural broadening of the spectral line is associated with the fulfillment of the Heisenberg-Bohr quantum-mechanical uncertainty ratio, according to which the natural width δE_i for each level is determined by the duration τ_i if the system is in the considering state:

$$\delta E_i \geq \frac{h}{2\pi\tau_i}. \tag{10.9a}$$

Doppler broadening is observed when the particle moves: when the particle moves toward the observer, its radiation frequency increases, when the particle moves away from him, it decreases. The spectral line expansion in this case will be determined by the formula:

$$\Delta \nu_D = \nu_0 \sqrt{\frac{2 \ln 2 kT}{Mc^2}} \tag{10.10a}$$

where T is ____

M is ____

ν_0 is ____

Problem 10.9a. Determine the natural broadening of the electronic spectral line, if the lifetime of the excited state is $\tau = 10^{-8} s$.

Data:	***Solution:***

Answer: ____

Problem 10.10a. Calculate the argon line Doppler broadening, if $\lambda_0 = 555$ nm at a temperature of 1500 K.

Data:	***Solution:***

Answer: ____

Exercise 10.11.a. Supplement the definitions:

The ground molecule state is ____

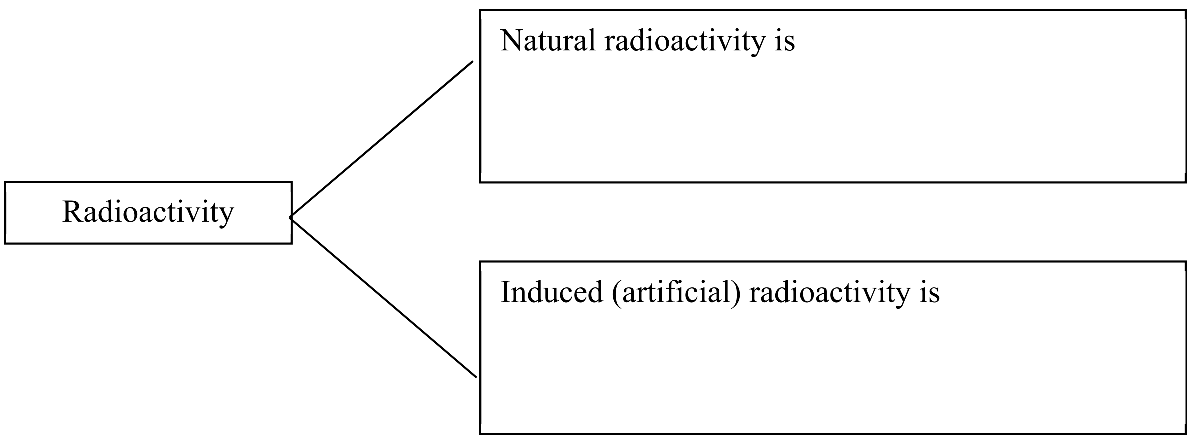
____

The excited molecule state is ____

Radiation Biophysics

The ability of some elements atomic nuclei to be spontaneously disintegrated with emission of other nuclei and elementary particles is called radioactivity. All types of radioactive decay obey the laws of conservation of mass, energy, and electric charge.

Exercise 10.12a. Fill in the scheme with kinds of radioactivity:



Exercise. 10.13a. Define the terms:

α-radiation is____

____

β-radiation is____

____

γ -radiation is____

____

Exercise 10.14a. In the scheme of decay the parent nucleus is.$_{Z}^{A}X$, where

Z is ____

A is____

Exercise 10.15a. Fill in the scheme of decay.

α-decay general scheme can be written in the following way:

(10.11a)

Scheme β^- -decay scheme looks like (fill): ...

$$_{6}^{14}C \rightarrow ?\_\_\_\_ + {}_{-1}^{0}\beta + ?\_\_\_. \quad (10.12a)$$

Scheme β_+ -decay scheme looks like (fill): ...

$$_{6}^{11}C \rightarrow ?\_\_\_\_ + {}_{+1}^{0}\beta + ?\_\_\_ \quad (10.13a)$$

Exercise 10.16a. Write down the law of radioactive decay:

- in differential form (10.14a)
- in integral form (10.15a)

Exercise 10.17a. Explain what means the sign "-" in the law of radioactive decay____________

____

Exercise 10.18a. Fill in the Table 10.1a.

Table 10.1a.

Basic parameters of the radioactive decay

Parameter	Parameter`s definition and its units of measurement
Radioactive decay constant, λ	(10.16a)
The half-life, $T_{1/2}$	(10.17a)
The activity if an isotope, *a*	(10.18a)

Problem 10.19a. How many atoms Po^{210} decays per day, if the initial mass of polonium is 10.6 kg? Po^{210} has a half-life of 138 *days*.

Data:	***Solution:***

Answer: ____

Problem 10.20a. The human body, on average, contains radioactive $^{226}_{88}Ra$ with a mass equal to $m = 6 \cdot 10^{-9}$ g. Determine the activity of $^{226}_{88}Ra$ in the human`s body if its half-life is $T_{1/2} = 1622$ years.

Data:	***Solution:***

Answer: ____

The Effect of Ionizing Radiation on a Living Organism

Exercise 10.21a. Define the following terms and write down the answer.

What is ionizing radiation?____

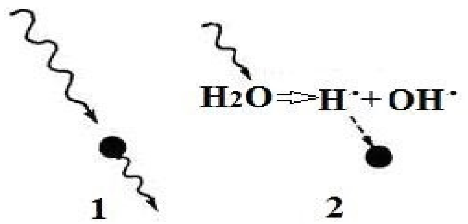
____

Water radiolysis is____

____

____

In analyzing the mechanisms of action of ionizing radiation on living organisms are distinguished direct and indirect effects of radiation on the structure of the cell. Specify the number of each effect:



Mechanism of action of radiation

1 - ______________________________

2 - ______________________________

Exercise 10.22a. Specify arrows the accordance between the physical quantity and the formula for its calculation:

1) The exposure dose	a) $D = k \cdot X$
2) The relationship between exposure and absorbed dose	b) $D = \frac{dW}{dm}$
3) The absorbed dose	c) $X = \frac{dq}{dm}$
4) The attenuation law	d) $I = I_0 \cdot e^{-\mu x}$

Exercise 10.23a. Define the following terms:

Radiosensitizers are ____

____

Radioprotectors are ____

____

Exercise 10.24a. Fill in the Table 10.2a.

Table 10.2a.

Relationship between miscellaneous and system units

Physical quantity	Miscellaneous unit	System unit	The conversion from miscellaneous to the system units
Activity of an isotope			1Ci = ... Bq
The exposure dose			1R = ... $C \cdot kg^{-1}$
The absorbed dose			1rad = ...Gy
The equivalent dose			1rem = ... Sv

Problem 10.14b. The thickness of half-value layer for γ-rays of cobalt-60 in *Pb* is 0.99 cm. Determine the linear coefficient of attenuation and the thickness of *Pb* layer, in which the intensity of narrow beam decreases in 8 times.

Data:

Solution:

Answer: ____

Control questions

1. Wave function. The wave function physical sense.
2. Energy levels: degenerate and nondegenerate.
3. The main spectra characteristics.
4. Atom planetary model.
5. Population of energy levels.
6. Compare ionizing radiation types.
7. What is the phenomenon of radioactive decay?
8. Where radioisotopes are used?
9. What external factors may change the radioactive decay rate?
10. Radioprotectors. Radiosensitizers. Radioresistance.
11. Describe the main hazards effects of radioactive isotopes of iodine and cesium that were found after the Chernobyl accident.

Individual assignments

1. Particle charged accelerated by a potential difference $U = 200$ V, has the de Broglie wavelength 2.02 pm. Find the particle mass *m* if its charge is numerically equal to the electron charge.
2. Determine the photon energy *E* (in electron-volts), which corresponds to the wavelength $\lambda = 380$ nm (purple threshold of visible spectrum).
3. Determine the photon mass *m* the wavelength of which corresponds to $\lambda = 380$ nm (purple threshold of visible spectrum).
4. Determine the photon momentum which energy is $E = 1$ MeV.
5. Determine the electron de Broglie wavelength λ, if its kinetic energy is K = 1 keV.
6. The cells of a biological object contain 5×10^{-7} mol of radioactive $^{60}_{27}Co$. How many nuclei of $^{60}_{27}Co$ decays in 1 year, if its half-life is $T_{1/2} = 5.27$ years?
7. Activity of radioactive $^{45}_{20}Ca$ is $a = 2\times10^{9}$ Bq. Find the mass of the radioactive drug, if $T_{1/2} = 165$ days.
8. The decay of $N = 10^{6}$ nuclei of radon-222 with a half-life $T_{1/2} = 3.82$ days is studied. How many nuclei of radon disintegrates in 24 hours and 91.68 hours?
9. The initial activity of 1 g of the isotope $^{226}_{88}Ra$ is 1 Ci. Determine the half-life $T_{1/2}$ of this isotope.
10. In nutrient mixture introduced 1 mg of radioactive isotope $^{32}_{15}P$, which has the half-life $T_{1/2} = 14.3$ days. Determine the radioactive decay constant and activity of phosphorus.
11. In process of radiometric studies of the sample strontium isotope $^{90}_{38}Sr$ was found. Its activity is 107 Bq. Calculate the mass of strontium in the sample? The half-life is $T_{1/2} = 28.5$ years.
12. The activity of seeds, soaked in a solution of sodium nitrate containing radioactive isotope $^{24}_{11}Na$, is 6.02×10^{-16} Ci. Calculate the weight of absorbed by grains radioactive isotope? The half-life is $T_{1/2} = 14.96$ h.

TOPIC 10B. Physical Methods of Analysis

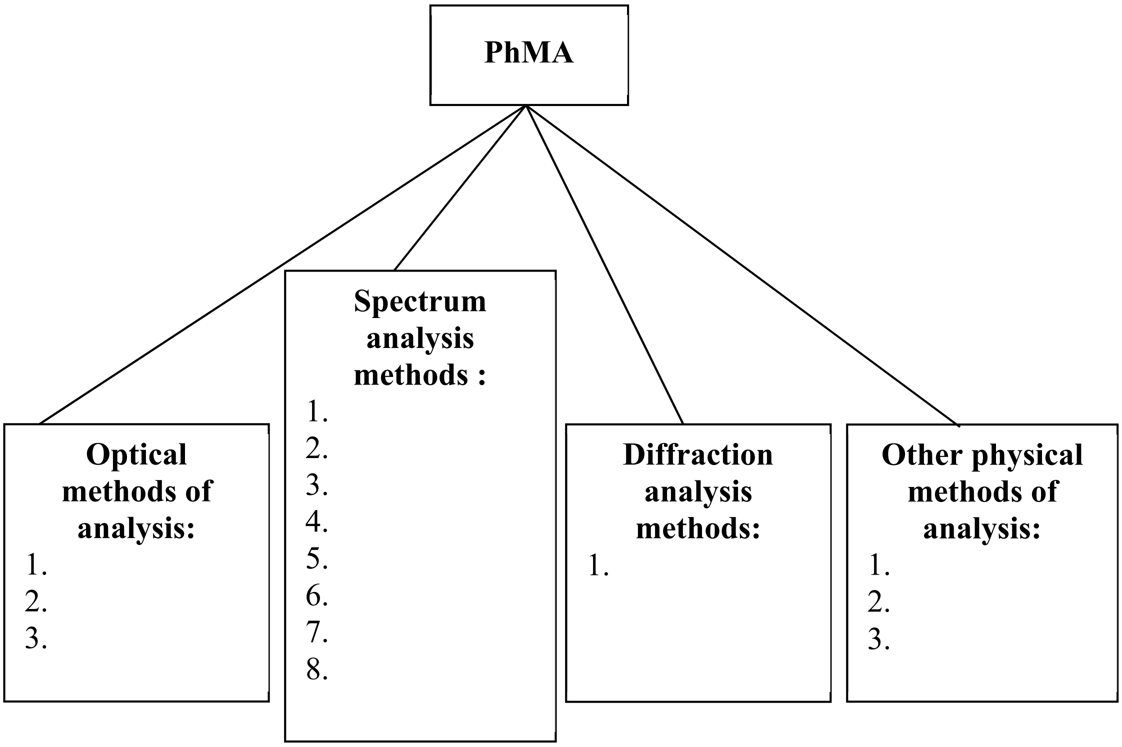
Physical methods of analysis are methods based on the interaction of the radiation, the field or the particles flux with the substance. The results of this interaction provide useful information about the object. Each method has a direct and inverse task.

Direct task of the method is the determination of the result of interaction of the radiation, the field or the particles flux with the substance that has a certain set of physical properties. The method theory development is based on the implementation of direct task.

The inverse task of the method is the interpretation of experimental results that obtained by this method. According to the ability of solving the inverse task we can evaluate characteristics of the method such as sensitivity, accuracy, availability, usability, etc.

Physical methods can be classified by the nature of the interaction of the radiation, the field or the particles flux with the substance and the properties of the substance that can be determined by these methods.

Fill in the scheme with physical analysis techniques available to pharmacists:



Optical Methods

Optical methods of analysis based on measurement of parameters that characterize the interaction of electromagnetic radiation with matter: radiation intensity of excited atoms, the absorption of monochromatic radiation, the refractive index, faraday rotation angle, etc. All these parameters depend on the concentration of the substance in the test object.

1. ***Refractometry*** is optic research method, based on the phenomenon of light refraction at the interface between two media, and measurement of the refractive index, which is specific characteristic of the substance.

<u>*Theoretical questions:*</u>

1. On what physical principle the operation of the refractometer is based?

2. What is absolute and relative refractive index?
3. The physical sense of the absolute refractive index is ....
4. Wavelength dependence of the refractive index.
5. Does the absolute refractive index depend on the characteristics of environment?
6. Critical angle of refraction….
7. Total internal reflection…
8. Concentration dependence of the refractive index of the solution. How unknown concentration can be determined?
9. Draw the general scheme of the refractometer
10. Explain the structure and working principles of the refractometer.
11. Application of refractometers in the pharmaceutical industry.

2. ***Polarimetry*** is optical method for the study of optically active substances, which is based on measurement of the angle of rotation of polarization plane of the plane-polarized light that passed through the investigated substance. The method is widely used to determine the concentration of optically active substances in the solution, and to assessment of their purity. Specific rotation angle of the polarization plane is a constant that characterized the substance and it can be used for identification of the substance, including to determine the drugs.

Theoretical questions:

1. On what physical principle the operation of the polarimeter is based?
2. What is the optical activity? What are optically active substances?
3. What is the main condition for optical activity of the substance? Give examples.
4. What kind of light is called linearly polarized?
5. The angle of optical rotation and its relationship with the concentration of optically active substance in the solution.
6. Describe the wavelength dependence of the rotation of the polarization plane.
7. Polarized light can be obtained from natural using...
8. Not all organic compounds are optically active. In organic compounds optical activity appears if ...
9. Give examples of optically active substances that are a part of the biological tissues.
10. Explain the structure and working principles of the polarimeter.
11. Application of polarimetry method in the pharmaceutical industry.
12. Describe the phenomenon of birefringence.

3. ***Microscopy*** or ***microscopic analysis*** is the common name of methods for studying small objects (bacteria, cells, macromolecules, crystal structure etc.) by observation under a microscope.

Theoretical questions:

1. How does the method of microscopic analysis is used in verification of starting materials of herbal origin?
2. What types of electron microscopes do you know? Give a short description of them.
3. What is the linear magnification of microscope? What does it depend on?
4. What is the resolution limit, useful magnification of microscope and aperture angle?

5. Describe a typical scheme of optical microscope.
6. List the characteristics microscope.
7. Describe the mechanism of image formation in the microscope?
8. Using the microscope we can determine ....
9. Describe the microscopic analysis application in pharmacy?

Spectroscopic Methods

Spectroscopic methods based on the study of the intensity of absorption, emission or scattering of radiation dependence on frequency or wavelength, i.e. based on measuring the absorption or emission spectra. These methods determine the function of the intensity of the absorbed or emitted radiation:

$$I = f(v) \text{ or } I = f(\lambda).$$

Spectroscopic methods allow to study the energy states of atoms and molecules, determine the transition frequencies i.e. energy levels structure. These methods make it possible to estimate the transition probability by measuring bands intensity, and on this basis compute other characteristics of molecules (symmetry, geometric structure, electrical properties etc.). The combination of spectroscopic measurement techniques covers a wide frequency range and therefore energy range.

4. ***Colorimetry*** is photometric method used to determine the concentration of colored compounds in solution. A colorimeter is a device used to test the concentration of a solution by measuring its absorbance of a specific wavelength of light.

Theoretical questions:

1. What is the main idea of the colorimetric method?
2. Application of the colorimetry method in the pharmacy.
3. What is the mechanism of light absorption?
4. List the conditions of applicability of the Bouguer-Lambert-Beer law.
5. What is the monochromatic natural absorption coefficient?
6. What is the optical density? What factors does it depend on?
7. What is the transmittance?
8. Explain the structure and working principles of the colorimeter.
9. Explain the appointment and the rule of choosing of color-filters.

5. ***UV absorption spectroscopy*** is a section of optical spectroscopy based on obtaining and study of the absorption spectra in the UV area of the spectrum (wavelength range $\Delta\lambda$: 190 - 400 nm; λ<190 nm - vacuum ultraviolet range is used a little because of the strong absorption this radiation in the air). The absorption of UV radiation caused by electronic transitions in atoms and molecules from ground energy state to a higher (excited) states.
6. ***Optical spectroscopy*** (visible range $\Delta\lambda$: 400-700 nm) is based on the similar mechanism of quantum transitions between electronic energy levels of atoms and molecules.

Theoretical questions:

1. What is the molecular mechanism of absorption of electro-magnetic waves in visible and UV range?
2. Write down the formula of energy level population.

3. Draw the general scheme of the device for recording spectra and name all elements.
4. What is the absorption spectrum?
5. List the main characteristic absorption spectrum.
6. What is the emission spectrum?
7. Write down the relationship between the energy of electronic E_e, vibrational E_{vib} and rotational E_{rot} states of molecules.
8. Chromophores are …

7. ***IR spectroscopy*** is a section of optical spectroscopy based on obtaining and study of the absorption spectra in the infrared area of the spectrum (Δλ: 1 - 2.5 µm is near, Δλ: 2.5 - 50 µm is medium and Δλ: 50-300 µm is far infrared area of the spectrum). The absorption in IR area caused by transitions in quantum oscillatory system of atoms in the molecule (mostly medium IR band) and quantum transitions between rotational energy levels of molecule (far IR band).

Theoretical questions:

1. What is the molecular mechanism of absorption of electro-magnetic waves in IR range?
2. What is the analytic abilities of the IR spectroscopy method?
3. The characteristic frequencies are …
4. Explain the applicability of the Bouguer-Lambert-Beer law in IR spectroscopy method.
5. What is the fingerprint of compound in meaning of the IR spectroscopy method?

8. ***Raman scattering*** is effect of detection in the scattered by molecule radiation photons with a frequency of incident radiation and frequencies different from the frequency of the incident one. The phenomenon is due to Raman transitions between vibrational or rotational energy levels of the molecule.

Theoretical questions:

1. What is Stokes-shift (conditions)?
2. What is anti-Stokes-shift (conditions)?
3. Place different types of lines in the spectrum of the scattered radiation in order of decreasing intensity (for room temperature) and draw a spectrum.
4. What is the analytic abilities of the Raman scattering spectroscopy method?
5. Draw the scheme of Raman scattering.

9. ***Luminescence*** is nonequilibrium emission of radiation by a substance, excess of equilibrium (heat). It is not resulting from heat. Not all substances could luminesce. Substances that be able to luminesce called phosphors or luminophors.

Theoretical questions:

1. What is the fluorescence?
2. What is the phosphorescence?
3. Formulate Stokes' law.
4. What is the quantum and energy yields of luminescence?
5. What is the difference between absorption and emission spectrum of luminescence?
6. List the conditions for the luminescence analysis.

10. ***Nuclear magnetic resonance*** (NMR) is a selective (resonance) absorption of radiofrequency range electromagnetic waves, which is associated with transitions between energy levels that characterize the state of nuclear spins in a strong magnetic field. NMR is widely used in the study of water-containing compounds. It is determined by the fact that many substances, primarily organic compounds containing hydrogen atoms, nuclei which give powerful characteristic resonance peaks.

Theoretical questions:

1. Write down the condition of NMR.
2. What is the magnetic moment of the nucleus?
3. Write down the gyromagnetic ratio.
4. What is the chemical shift?
5. Define the spin-spin relaxation.
6. Spin-lattice relaxation is …
7. List the advantages and disadvantages of the NMR method.
8. Explain the application of the NMR method in modern medicine.

11. ***Mass spectroscopy*** (mass spectrometry, mass spectral analysis, mass spectrometry) is a method of analysis based on the separation of ionized particles by their masses (specifically in relation ion mass m to its charge q) by the action of magnetic and electric fields.

Theoretical questions:

1. What is the mass spectrum?
2. What is the analytic abilities of the mass spectroscopy method?
3. List the methods of ionization used in mass spectroscopy.
4. Draw the scheme of mass spectrometer.
5. Explain the interaction of charged particles with electric and magnetic fields.
6. Write down the Lorentz force.
7. What is the cyclotron frequency? Write down its formula.

Diffraction Methods

Diffraction methods based on the scattering of radiation or particles flux as a result of its interaction with the investigated object. Scattering in this case is elastic, and it is not accompanied by energy changes in the flux of particles or waves.

X-ray analysis based on diffraction of X-rays and used for medical research and biologically active substances. The main condition for diffraction is that λ should be about or less than the distance between the atoms of the object studied:

$$\lambda \leq r.$$

In diffraction methods measure the intensity of scattered light dependence on the scattering angle θ, i.e. as a function $I(\theta)$. The diffraction patterns are result of interference (superposition of waves) of scattered light.

12. ***X-ray structure analysis*** is a technique used for determining the atomic and molecular structure of a crystal (such as salts, metals, minerals, semiconductors, as well as various inorganic, organic, and biological molecules), in which the crystalline structure causes a beam of incident X-rays to diffract into many specific directions.

Theoretical questions:

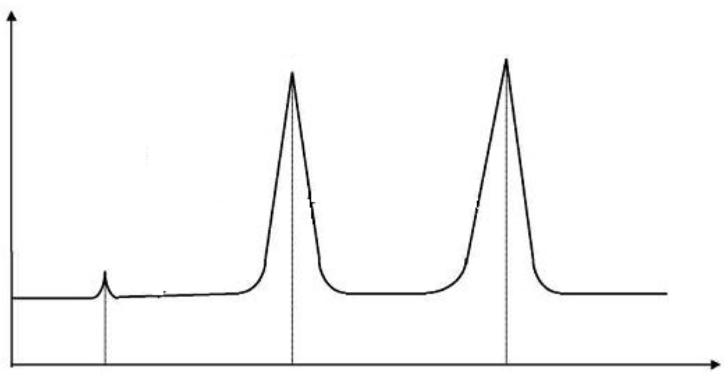
1. What is the main problem of X-ray structure analysis?
2. X-ray production.
3. X-ray spectrum.
4. X-ray-matter interaction.
5. Write down the Wulff-Bragg equation. Express its physical sense.
6. Write down Moseley`s Law.
7. Principles and specifics of high-energy electron diffraction.

Other Methods

13. ***Chromatography*** is the method of separation, analysis, physical and chemical investigation of materials. More detail it is the method of separating mixture into individual components. The basis of separation is the separation between the two phases of matter (mobile and stationary).

Theoretical questions:

1. Classify chromatographic methods of analysis.
2. What is the chromatogram?
3. What parameters must be specified to analyze the results of chromatograms (list)?
4. What is the analytic abilities of the chromatography method?
5. Is the chromatography method the method of qualitative or quantitative analysis?
6. What is the difference between gas-phase and liquid chromatography?
7. Analyze the chromatogram.



14. ***Thermal analysis*** is method that allows to investigate the composition and properties of substance, based on the registration of the transformation of the substance at a given changing of temperature. Recorded curve any changes in the properties of matter under the influence of temperature shift called a thermogram. Various thermal analysis methods applied to the study of phase transitions and phase equilibrium.

Theoretical questions:

1. Characterize thermal analysis methods.

2. Name the differences between thermal analysis (TA) and differential thermal analysis (DTA).
3. Name the features of DTA.
4. What is the analytic abilities of the thermal analysis method?
5. What is the phase transition?
6. What is the phase diagram?
7. What is the thermocouple element?
8. The graphical presentation of DTA results.

Individual assignments

1. Determine the refractive index and the speed of light in the media, if it is known that at the incidence angle of 35 ° the refraction angle is equal to 20 °.

2. Sodium yellow line matches the wavelength of 589 nm in the air. Determine the wavelength of that light in cedar oil, which refractive index is 1.52.

3. The relative refractive index on the interface air / water is equal to 1.333. Find the speed of electromagnetic waves in water?

4. A beam of monochromatic light passes through the glass plate with thickness l = 1 cm. It absorbs 0.1 of incident light intensity. Determine the monochromatic natural absorption coefficient of glass at this wavelength.

5. The absorption coefficient of blood plasma is 0.836 cm-1. The light intensity decreases 4 times. Find the thickness of the blood plasma layer.

6. The transmittance of the solution T =0.5. Find its optical density.Microscope lens focal length of 0.1 cm, focal length eyepiece 3 cm. The distance between the lens focus, and eyepiece (tube length) 20 cm. Determine the magnification.

7. Microscope lens focal length of 0.2 cm, focal length eyepiece 5 cm. The distance between the lens focus, and eyepiece (tube length) 30 cm. Determine the magnification.

8. Determine the threshold of resolution of dry and immersion microscope objective (n = 1.33) lens with an aperture angle u = 75 °. Accept that the wavelength is λ = 500 μm.

9. Find the refractive index of immersion liquid that should be used for microscopic analysis of sub-cellular elements with diameter of 0.25 μm observed through orange colored glass with wavelength of 600 nm. Microscope aperture angle is 70 °.

10. Find the angle of rotation, the polarization plane of the diabetic patient urine if the concentration of sugar in it C = 0.05 g·cm-3. The length of the tube l = 20 cm, specific rotation angle of sugar at the given wavelength [α0] = 6.67 deg·cm2·g-1.

11. Find the refractive index n of diamond if the reflected ray from its surface is maximally polarized at the refraction angle r equal to 22.5 degrees.

12. Find the angle between polarizer and analyzer of polarimeter, if the intensity of unpolarized light, that has passed through the polarimeter, reduced by 4 times?