LABORATORY WORK

DETERMINATION OF LIQUID REFRACTIVE INDICATOR USING A REFRACTOMETER

PURPOSE:

Learn how a refractometer works.

Study the dependence of the refractive index of the solution on its concentration.

Determine the concentration of the unknown solution.

EQUIPMENT:

Refractometer, a set of solutions of various concentrations, pipette.

REFRACTOMETER OPERATING PRINCIPLE

A refractometer is used to determine the optical density of substances. The main element of the device is two rectangular glass prisms (n = 1.7), located with their bases to each other at a distance of 0.1 mm (Fig. 4). The space between the prisms is filled with the test fluid.

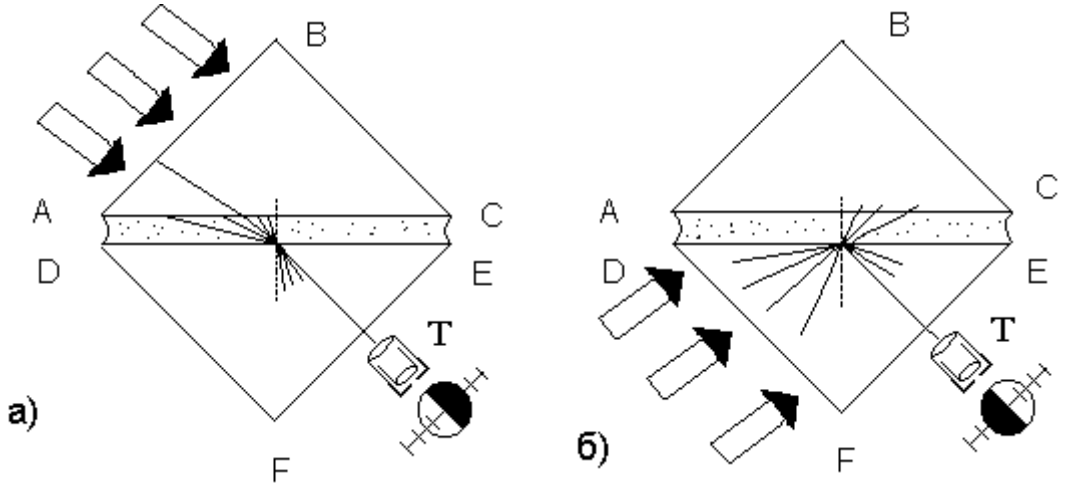


Fig.1. Path of rays in a refractometer in transmitted (a) and reflected (b) light.

The ABC prism is called the *lighting prism*, and the DEF prism is called the *measuring prism*. Measurements can be performed in both transmitted and reflected light. In the first case, the device implements the ray path of *limiting angle of refraction*. The rays from the light source fall (Fig. 1a) on the AB facet ABC, are refracted and hit the matt surface of the AC, on which the light flux is diffusely scattered. As a result, the rays will enter the liquid and reach the DE face at different angles (from 0 to 90°). Refracting at the edge DE, the rays inside the prism DEF pass

only in directions lying within the limiting angle β_{cr}. On the edge EF, these rays are refracted and come out at a certain angle β into the telescope T. The objective of the telescope focuses parallel rays coming from different points of the object on the edge EF at different angles. Therefore, if the axis of the telescope is set in the direction of the rays limiting the β_{cr}, then the field of view in the focal plane of the lens is divided into light and dark areas. In this case, the following condition is met:

$$\frac{\sin\alpha_{max}}{\sin\beta_{cr}} = \frac{n_{glass}}{n_{liq}}, \quad (1)$$

where $\alpha_{max} = 90°$; β_{cr} - limiting angle of refraction of light in liquid;

n_{glass} is the refractive index of the prism glass; n_{liq} is the refractive index of the liquid under study. Since sin 90° = 1, then from equation (1) it follows:

$$n_{liq} = n_{glass} \cdot \sin\beta_{cr}. \quad (2)$$

When examining the refractive index in reflected light, a refractometer creates the path of the rays according to *total internal reflection*. The rays from the light source are directed (Fig. 1b) onto the matte surface of the DF prism. As a result of diffuse scattering, rays enter the DEF prism at different angles (from 0 to 90°). Since the rays that have reached the edge DE pass from an optically denser medium (glass) to an optically less dense medium (liquid), the rays whose angle of incidence is greater than the limiting one will undergo total reflection. The rays, the direction of which corresponds to the value of the limiting angle of total reflection, and determine the border of light and shadow. In this case, the following condition is met:

$$\frac{\sin\alpha_{cr}}{\sin\beta_{max}} = \frac{n_{liq}}{n_{glass}}, \quad (3)$$

if sin 90° = 1, then

$$n_{liq} = n_{glass} \cdot \sin\alpha_{cr}. \quad (4)$$

Thus, in both cases there is a strict correspondence between the refractive indices of the liquid and the value of the limiting angle. The position of the interface between light and shadow is determined by the value of the limiting angle, and, consequently, by the value of the refractive index of the liquid. Therefore, in the field of view of the telescope on the scale of the refractometer, not the values of the angle are plotted, but the values of the refractive index. It is convenient to determine the refractive indices of transparent liquids in transmitted light, and those of intensely colored or turbid liquids in reflected light.

Note that when light passes through the interface between different media, white light decomposes into monochromatic waves. This phenomenon is called light dispersion and is caused

by the dependence of the refractive index of a substance on the frequency (length) of the light wave. As a result, the border between the illuminated and dark parts of the field of view will be spectrally colored. To obtain a sharp boundary between light and shadow, a dispersion compensator is used in the refractometer, which is a prism that selects only yellow rays corresponding to the middle of the visible spectral range.

Since the refractive index of a liquid depends on the concentration of a solute, then, by constructing a calibration graph, it is possible to determine the unknown concentration of a solution of a given substance from the known refractive index.

PRACTICAL PART

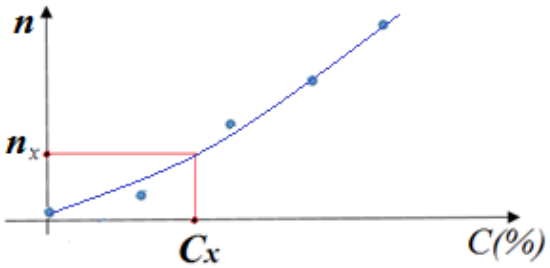
Become familiar with the refractometer device.

Determine the refractive index of distilled water (if the refractometer is adjusted correctly, then n = 1.333).

Determine the refractive index of solutions of known concentration. For each solution, repeat the measurements 4 times and find nav. Enter the results in the table.

No.	C,%	n_1	n_2	n_3	n_4	$n_{average}$
1						
2						
3						
4						
5						
6						

Plot the dependence n = f (C):



Determine the refractive index of a solution of unknown concentration.

Find the unknown concentration of the solution from the graph.

TEST QUESTIONS

What phenomenon is called refraction of light?

What is the physical meaning of absolute and relative refractive indices?

Formulate the laws of light refraction.

What is called the limiting angle of refraction?

Tell about the phenomenon of total internal reflection of light.

Tell us about the work of the refractometer (ray path in transmitted and reflected light).

Tell us about the use of refraction in biomedical research.

What is the purpose of fiber optics used in medicine?

SITUATIONAL TASKS

1. The absolute refractive index of the medium is 1.5. What is the speed of light in this environment?
2. The speed of light in a certain medium is 2.5 10^8m/s. What is the absolute refractive index of the medium?
3. The wavelength of violet light in a vacuum is 400 nm. Determine the wavelength of this radiation in topaz if its refractive index is 1.83.
4. A ray of light is incident on a glass plate with a refractive index of 1.5. Find the angle of incidence if the angle between the reflected and refracted rays is 90^0.
5. Find the angle of total incidence of the beam on the glass-water interface.
6. The limiting angle of incidence for a ray exiting the turpentine into the air is $42^0$23 '. Determine the speed of propagation of light in turpentine.