Experiment

G0-1

English (Official)

The experimental examination lasts **210 minutes** and is worth 40 points.

Before the exam

- Do not open the envelopes with tasks or the large box with secret equipment.
- It is not recommended to touch the equipment on the table before reading the instructions, as you may mess up its settings.
- The start and end of the exam are marked by an audible signal. The audible signal will sound every hour, as well as 15 minutes and 5 minutes before the end of the exam and at the end of the exam.

Spectrometer tutorial

- In the experimental task, the spectrometer is one of the most complex and probably unfamiliar devices.
- During the task, you will obtain spectra, and you will need to save the spectrum data in the "Results" folder on your desktop according to the instructions in the tasks.
- After reading these general instructions, you will need to perform practice spectrum measurements, save the spectrum file to the appropriate folder, and use the program to verify that you have saved the file with the correct name to the appropriate folder.
- The training period for working with the spectrometer is 30 minutes, and this time is not counted as part of the round. Therefore, take your time to learn how to measure spectra.

During the exam

- The envelope you will be given will contain the tasks (sheets marked Q), special answer sheets (marked A), and working sheets (marked W). You may only write on one side of the sheet, as indicated. If you have written something that you do not think needs to be checked, cross it out with an "X."
- Try to use as little text as possible in your answers. Use equations, logical operators, diagrams, and graphs to explain your solution.
- In this round, you do not need to evaluate errors anywhere. However, pay attention to the required number of significant digits when writing numerical answers.
- Please note that most of the tasks do not depend on the solutions to the previous ones. The tasks do not have to be solved sequentially.
- To plan your teamwork, the first page of the answer sheet contains a **summary plan of the experimental work**, which also indicates the connections between the items and the duration of their completion. First, read the tasks in full, and then, if necessary, distribute the items of the task among your teammates.
- Inside the large box with secret equipment, there is a yellow bag. Inside it, there are test tubes with orange caps. You will need to pour samples of the solutions you have prepared into these test tubes as you complete the task. The test tubes are labeled, so don't make a mistake!
- There are various signs in your cubicle; raise them if you encounter any problems:
  - WC, when you need to use the restroom;
  - WATER, when you need a bottle of drinking water;
  - EXTRA SHEETS, when you need additional answer sheets (new printed sheets are marked with a Z), you can request no more than 5 additional sheets at a time, but there is no limit to the number of requests;

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- SPECTROMETER HELP, when you think your spectrometer is not working;
- LAPTOP HELP, when you need help with your laptop;
- MICROSCOPE HELP, when you need help with the microscope;
- HELP in all other cases.

At the end of the exam

- The end of the exam is signaled by a triple sound signal.
- When you hear the triple signal, you must stop writing immediately. Put your pen aside and hand it to the assistant when he approaches. You must also stop touching the computer. If you are seen writing after the signal or working on the computer, your team will be disqualified.
- Collect the answer sheets (A) in the correct order, then place the solution sheets (W) and, if necessary, any additional sheets (Z). Place this stack of sheets in the "Marking envelope."
- Collect the remaining sheets of paper, including the tasks and instructions, and place them in the original envelope in which you received the tasks.
- Place both envelopes in a large kraft envelope.
- Check that you have placed all the tubes with orange caps (Answer tubes) in the yellow bag.
- Wait in your cubicle until the kraft envelope and yellow bag are collected.
- Wait in your cubicle until the assistant checks the files you are submitting (using the Validate saved files button) and downloads them.
- Wait in your cubicle until your supervisor comes to collect you. He or she will escort you out of the competition area. You are not allowed to take anything out of the cubicle or the competition area.

Tutorial assignment on working with a spectrometer

Read the instructions for using the spectrometer carefully. They are printed after the general instructions and are labeled G1. You will also find a video file named "G1.Spectrometer.mp4" on your desktop, which shows the sequence of actions.

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.01 You have two plastic cuvettes in your tripod. One contains water, the other contains a solution of a dye. You will need to measure the absorption spectrum of the dye. Throughout the entire experiment make sure to hold the cuvettes in such a manner that opaque sides are held between two fingers and transparent sides are not being touched. Otherwise, impurities on the transparent faces might skew the results. Nonept

Plug the spectrometer power supply into a power outlet.
Make sure that the spectrum measurement program is running on your computer.
Install a screen in the spectrometer that blocks the direct path of the lamp rays.
Press the "Background" button in the program.
Remove the screen from the spectrometer.
Install the cuvette with water in the spectrometer.
Press the "Baseline" button in the program.
Replace the cuvette with water with a cuvette with a dye (a cuvette with green liquid).
Write "01" in the field for the spectrum name.
Press the "Single spectrum" button. A curve of the measured spectrum will appear in the spectrum area.
Move the "Control spectrum" slider to the opposite position. The dye absorption spectrum measured by the Scientific Committee should be displayed in the spectrum area.
If the spectra are not similar at all, raise the "Spectrometer Help" sign, and someone will come to you and help you with the spectrum measurement.
If the spectra are similar or almost identical, click on the spectrum save button (2h in the interface description). Save the spectrum to a file named 01.txt in the Desktop > Results > 01 folder (i.e., the path to the file should be Desktop/Results/01/01.txt).
Click on the "Validate saved files" button. You should see a report with the first item checked (see figure below).
Lift the "Spectrometer Help" sign and show the assistant the spectra and the report with the successful check.

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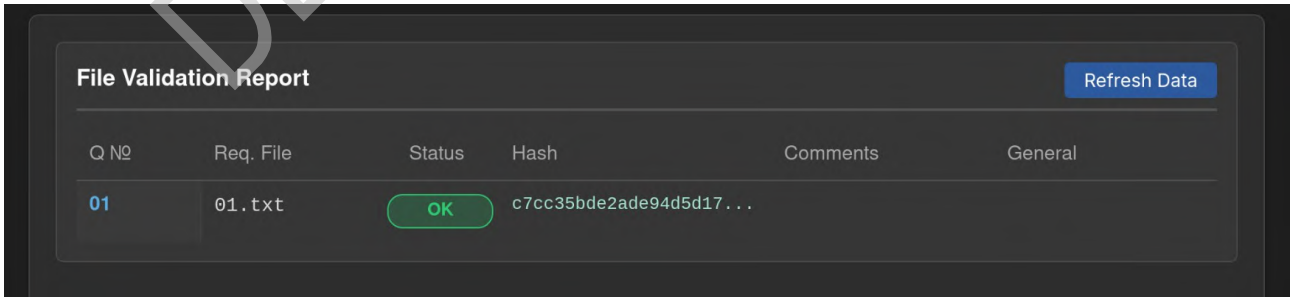
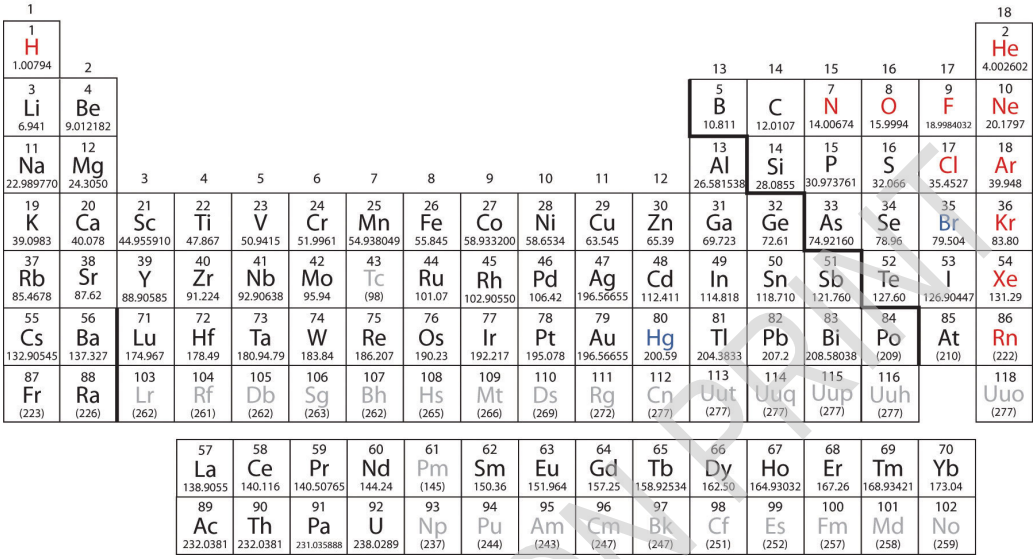


Experiment

G0-4

English (Official)

Periodic table of elements



1																	18
1 H 1.00794	2											13	14	15	16	17	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050	3	4	5	6	7	8	9	10	11	12	13 Al 26.581538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6534	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 196.56655	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	71 Lu 174.967	72 Hf 178.49	73 Ta 180.94.79	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.56655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Cn (277)	113 Uut (277)	114 Uuq (277)	115 Uup (277)	116 Uuh (277)		118 Uuo (277)

57 La 138.9055	58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04
89 Ac 232.0381	90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)

The reactivity series

Li	Cs	K	Mg	Al	Zn	Fe	Co	Pb	H_2	Cu	Pt	Au
-3.04	-3.01	-2.92	-2.36	-1.66	-0.76	-0.44	-0.28	-0.13	0.00	+0.34	+1.28	+1.50

Tabulated values and fundamental constants

Quantity	Value
Water density	$\rho = 1000$ kg/m^3
Elementary charge	$e = 1.6 \cdot 10^{-19}$ C
Avogadro's constant	$N_A = 6.02 \cdot 10^{23}$ mol^{-1}
Universal gas constant	$R = 8.31$ J/(mol·K)

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Experiment

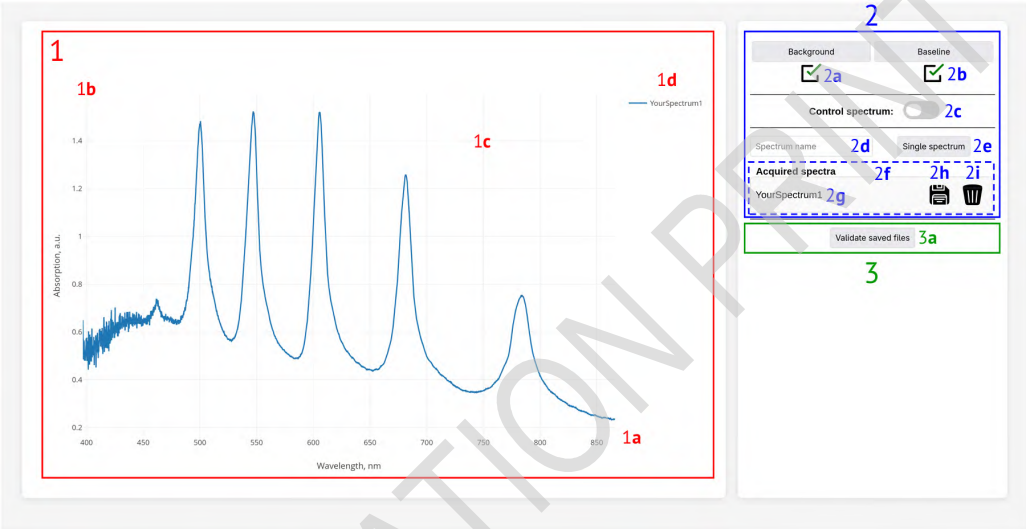
G1-1

English (Official)

Instructions for using the spectrometer (for parts 0, B, C, F)

Watch the video instruction “G1.Spectrometer.mp4”.

Software interface



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1. Spectrum area

   (a) Wavelength axis

   (b) Absorption axis

   (c) Spectral curve construction area (if you hover the cursor over the spectrum line, it will show the absorption values on the graphs)

   (d) List of displayed spectra (you can click on the spectrum name to hide or show it again)

2. Spectrometer control area

   (a) “Background” button and status (the button is used to measure the background when measuring the spectrum)

   (b) “Baseline” button and status (the button is used to measure the baseline)

   (c) “Control spectrum” slider (only needed in part 0, displays the control spectrum of the substance for tutorial)

   (d) Text field for entering the spectrum name (we recommend using it to name your spectra; you can write item numbers, solution compositions, and any other information there)

   (e) “Single spectrum” button (measures the spectrum)

   (f) “Acquired spectra” area (shows a list of the spectra you have measured)

   (g) Your names for the measured spectra

   (h) Save spectrum button (be sure to use it to save the spectra requested in the task)

(i) Delete spectrum button

3. Submitted file verification area

(a) The “Validate saved files” button verifies that you have saved and named the spectra correctly for each question where you need to save them. A new window will appear showing the verification results.

How to measure the spectrum?

You can watch the video instruction "G1.Spectrometer_pipette.mp4".

1. Prepare two cuvettes: one with water*, the other with the sample.
2. Plug the spectrometer power supply into a power outlet.
3. Make sure that the spectrum measurement program is running on the computer.
4. Install a screen in the spectrometer to block the direct path of the lamp rays.
5. Press the “Background” button. If everything is OK, the background measurement status will be marked with a green check mark.
6. Remove the screen from the spectrometer.
7. Place the cuvette with water in the spectrometer.
8. Press the “Baseline” button. If everything is OK, the baseline measurement status will be marked with a green check mark.
9. Replace the cuvette with water with a cuvette with a sample.
10. Enter the desired name in the spectrum name field.
11. Press the “Single spectrum” button. A curve of the measured spectrum will appear in the spectrum area.

* – strictly speaking, the first cuvette measured is the one with the solvent (usually water), and the second is the cuvette with the solvent + the substance being tested. If the solvent for the substance being tested is not water, but, for example, ehtanol, then ethanol should be poured into the first cuvette.

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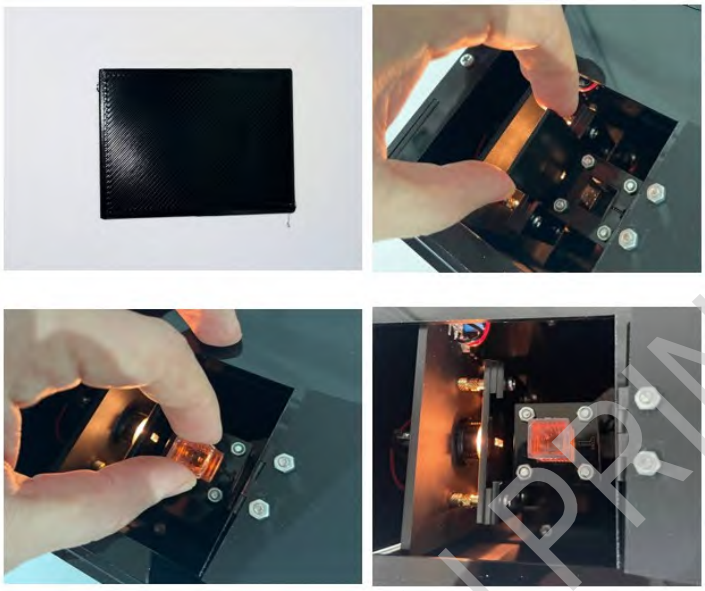

Use of a thin cuvette for measurements

Watch the video instruction "G1.Spectrometer_thin_cuvette.mp4".

Note: use thin cuvettes only if it is explicitly specified in the question.

1. To measure the absorption of concentrated solutions without dilution, you can use a thinner cuvette. Do this only at the tasks where it is specified.
2. Prepare about 500 μL of the test solution in a separate test tube.
3. Prepare about 500 μL of distilled water.
4. Take a thin cuvette in the adapter.
5. Carefully fill the cuvette with the water prepared in the step 2 using a micropipette.
6. Place the cuvette in the adapter in the spectrometer and press "Baseline".

Note: Make sure that the plain side of the cuvette is facing the light source

7. Remove the cuvette from the spectrometer and use a syringe with a needle to remove all the water from the cuvette.
8. Carefully fill the cuvette with the test solution.
9. Place the cuvette in the adapter in the spectrometer and press "Single spectrum".
10. Remove the cuvette from the spectrometer and use a syringe with a needle to remove all of the sample from the cuvette.
11. Pour and rinse the cuvette to remove any sample residue. Use a syringe with a needle to remove any water residue after rinsing.

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Experiment

G1-4

English (Official)

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Experiment

Q1-1

English (Official)

Electrolysis, photosynthesis and spectrometry (40 points)

This task will explore various chemical and biological processes, and one of the main physical research methods will be spectroscopy.

Spectroscopy can vary in terms of the technique used, and its capabilities range from determining the structure of substances to the movement of galaxies. As a rule, a spectrum refers to the dependence of a physical quantity (energy, radiation intensity, absorption, etc.) on the wavelength of light.

A real beam of light is always a composite object. It consists of several elementary beams of different colors—waves with different wavelengths. A real beam can be separated into elementary beams using a prism or a diffraction grating.

For example, we can use a prism to obtain a rainbow from sunlight. If we measure the intensity of different colors in the rainbow with a sensor and plot a graph of this intensity against wavelength, we get something similar to Fig. 1(upper left).

The resulting graph is called the spectrum of solar **emission** radiation in the visible range.

An incandescent lamp, a fluorescent lamp, and LEDs can be used as radiation sources. Using a prism or a diffraction grating, we can obtain rainbow-like images and measure the intensity for different colors in them (see the other graphs in Fig. 1). The graphs show the intensity with which the light source **emits** in a given wavelength range.

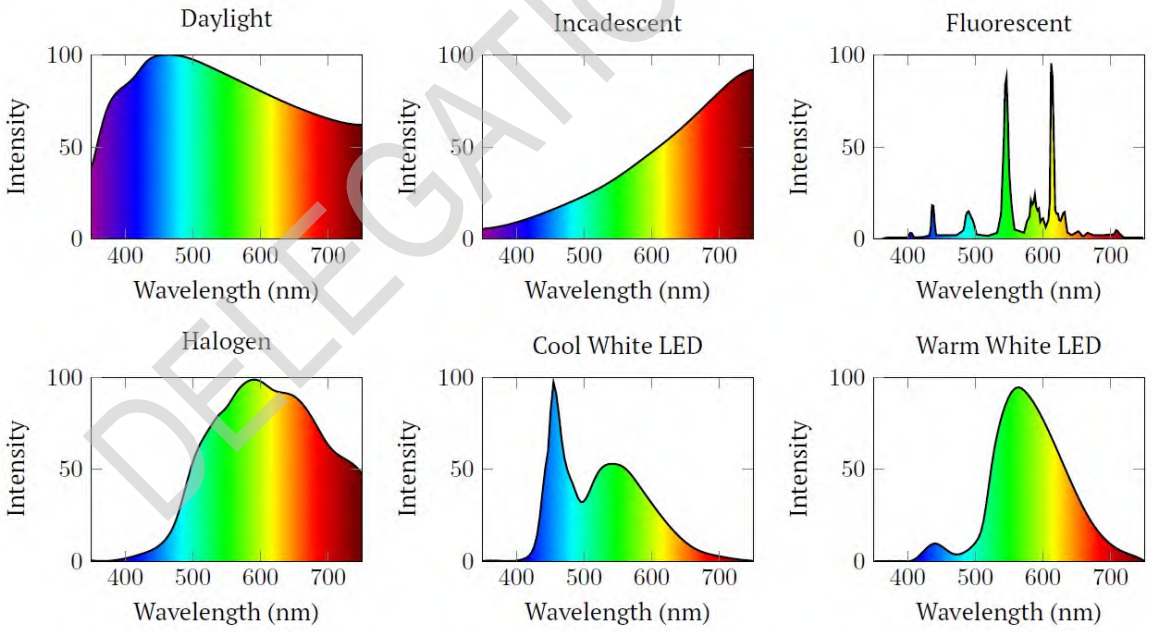

Fig. 1

Light interacts with the objects around us, and the nature of this interaction determines the visible color of the object. In this task, we will study the absorption of light by various solutions. For example, a solution of malachite green absorbs blue light (wavelength 450 nm) and red light (wavelength 600 nm), but does not absorb green light (wavelength 500 nm). Therefore, white light passing through the solution becomes green (Fig. 2).

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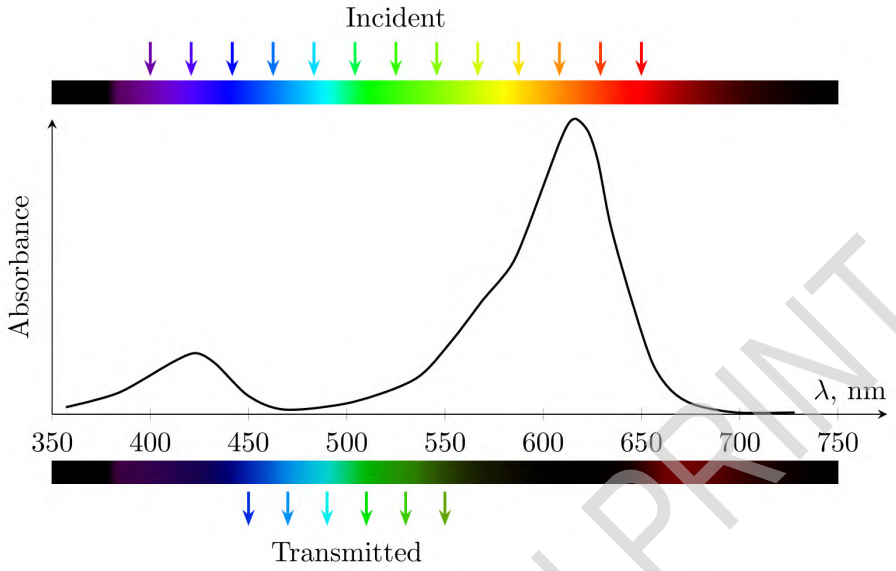

Fig. 2

Quantitatively, this absorption process is described by the ratio of the intensity of incident light I_0 to the intensity of transmitted light I:

$$A = \log_{10} \frac{I_0}{I}.$$

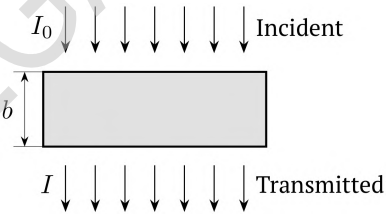

Fig. 3

Now let's imagine that we shine a beam of fixed color (laser) into a solution of malachite green. The green laser will pass through the solution with virtually no absorption ($I_{\text{gr}} \approx I_{0,\text{gr}}$), while the blue laser will be strongly absorbed ($I_{\text{bl}} \ll I_{0,\text{bl}}$).

Therefore, to describe the absorption process, we need to specify the wavelength λ we are working with:

$$A(\lambda) = \log_{10} \frac{I_0(\lambda)}{I(\lambda)}.$$

The dependence $A(\lambda)$ is called the absorption spectrum. Figure 2 shows the absorption spectrum of malachite green. The absorption spectrum $A(\lambda)$ is described by the Beer-Lambert law and depends on the substance of which the object is composed, the concentration of this substance n, and the thickness of the sample b:

$$A(\lambda) = cb \cdot \varepsilon(\lambda),$$

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where $\varepsilon(\lambda)$ is a coefficient unique to each substance. If the sample consists of substances A and B, their absorptions are added together:

$$A(\lambda) = b\,(c_A\,\varepsilon_A + c_B\,\varepsilon_B)\,.$$

If any substance that absorbs green light is added to a solution of malachite green, the solution will become very dark, as it will absorb almost all visible light passing through it.

To analyze the chemical processes occurring in this task, you will need to measure the absorption spectra of copper sulfate solutions and pH indicators in solutions of varying acidity. You will also obtain absorption spectra of photosynthetic pigments from two algae and use them to try to explain the efficiency of photosynthesis when microorganisms are illuminated with different colors.

Section I. Electrolysis of copper sulfate solution (25 points)

Part A. Oxygen generation during electrolysis (5 points)

In this part of the task, you will perform electrolysis of an aqueous solution of $CuSO_4$ and calculate with the charge that passed through the solution during electrolysis using various methods.During the electrolysis process, you will observe:

- the release of gaseous molecular oxygen at the anode,
- the deposition of metallic copper at the cathode,
- a decrease in the pH of the solution.

By analyzing the results of these observations, you will calculate the charge that contributed to a particular effect and compare it with the total charge that flowed through the solution, measured by the direct method $Q = I \cdot t$, where I is the current flowing through the solution and t is the time of electrolysis.

A.1 Balance the equations for the reactions occurring in the solution at the anode 0.4pt

$$H_2O - e^- \rightarrow H^+ + O_2\uparrow$$

and cathode:

$$Cu^{2+} + e^- \rightarrow Cu^0.$$

Assume that no other reactions occur at the anode and cathode.Write down and balance the overall equation for the electrolysis of an aqueous solution of $CuSO_4$.

$$CuSO_4 + H_2O \rightarrow$$

A.2 Prepare $V_0 = 150$ mL of copper sulfate with a molar concentration of $c_0 = 0.400$ M. You are given copper sulfate powder ($CuSO_4 \cdot 5H_2O$). How many grams m_{bs} of powder are needed to prepare the specified solution? It can be assumed that the volume of the resultant copper sulfate solution is the same as the volume of the added water. 1.0pt
We will call the resulting solution "solution **A2**." Pour 5 mL of solution **A2** into **Answer tube A2**.

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A.3	In accordance with instruction **G2**, perform electrolysis of 120 mL of solution **A2** for $t_0 = 1$ h at a current of $I = 1$ A. Record the dependence of the volume of oxygen released V_{O_2} on time t. Take at least 10 measurements. Plot the resulting dependence and draw an approximation curve.	2.5pt

A.4	After electrolysis, stir the solution remaining in the electrolyzer. In accordance with the **G2** instructions, filter approximately 20-25 mL of the stirred solution after electrolysis. We will refer to the filtered solution as "solution **A4**." Pour 5 ml of solution **A4** into **Answer tube A4**.	0.6pt

A.5	Calculate the charge Q that flowed during electrolysis based on the known value of the current.	0.2pt

A.6	The amount of oxygen released at point **A3** can be used to determine the charge flow during electrolysis. Write a formula that relates the total volume of oxygen released V_{O_2} to the charge flow Q_{O_2}. Calculate the numerical value of the charge Q_{O_2}. Assume that the experiment takes place at a pressure of $p_0 = 10^5$ Pa and a temperature of $T_0 = 298$ K.	0.3pt

Part B. Determination of copper concentration (7 points)

In this part, you need to determine the concentration of copper ions in solution **A4** based on how much it absorbs certain light. The blue color of the solutions under investigation is entirely determined by the concentration of Cu^{2+} ions.

Prepare five solutions of $CuSO_4$, each with a volume of 4 mL, in optical cuvettes.

Cuvette number	Molar concentration $[Cu^{2+}]$, M
1	0.0400
2	0.0350
3	0.0300
4	0.0250
5	0.0200

B.1	In the answer sheets, fill in the table showing what volume of solution **A2** ($V_{\mathbf{A2}}$) and water (V_{H_2O}) need to be mixed to obtain 4 mL of the required solutions. *Note that the initial solution **A2** has very strong absorption, so in this point you calculate its dilution by a factor of 10 or more.*	1.0pt

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B.2	Using the calculations made in the previous task, prepare five solutions in optical cuvettes. In accordance with instruction **G1**, measure the absorption spectrum of each of the five solutions. Save the measured spectra in the "**Results/B2**" folder on your desktop under the names "**B2.cuvette number.txt**" (for example, "B2.3.txt").	1.5pt

B.3	Specify the wavelength λ_0 of light that is most strongly absorbed by $CuSO_4$ solutions.	0.4pt

B.4	For each cuvette, record the absorption spectra and the determine the absorption coefficients A at the wavelength λ_0 that you have chosen. Plot a graph of the dependence of absorption A on the molar concentration of copper ions $[Cu^{2+}]$, draw a fitting straight line $A = s \cdot [Cu^{2+}]$ and determine its slope s.	2.0pt

In an optical cuvette, prepare 4 mL of a 10-fold diluted solution of **A4**.

B.5	Measure the absorption spectrum of a 10-fold diluted solution of **A4**.Save the measured spectrum in the "**Results/B4**" folder on your desktop under the name "**B4.txt**".	0.3pt

B.6	Determine the concentration of copper ions $[Cu^{2+}]_{\mathbf{A4}}$ in solution **A4**.	0.8pt

B.7	The decrease in copper ion concentration in the solution can also be used to determine the charge passed during electrolysis. Write a formula that relates the initial concentration of copper ions c_0, the final concentration of copper ions $[Cu^{2+}]_{\mathbf{A4}}$, and the charge flow Q_{Cu}. Calculate the numerical value of the charge Q_{Cu}. Assume the volume of the solution doesn't change throughout the electrolysis.	1.0pt

Part C. Determination of pH (12 points)

In this part of the problem, you need to determine the pH in solutions **A2** and **A4** using indicators that change color depending on the pH of the solution.You are familiar with and know how to work with colored pH indicators such as methyl orange or bromothymol blue. These indicators change color when the acid form transits to the base form. And typically by the color change one determines that the pH of the solution has changed to the desired degree. However, using a spectrometer, it is possible to determine the pH quantitatively (this is possible near the transition point).Let's consider how to determine the pH using the example of the cresol red indicator. Several cuvettes with different pH values (from 0.5 to 1.3) were prepared. The same amount of indicator was added to each cuvette. As a result, a color transition from red to orange/yellow is observed (Fig. 4).

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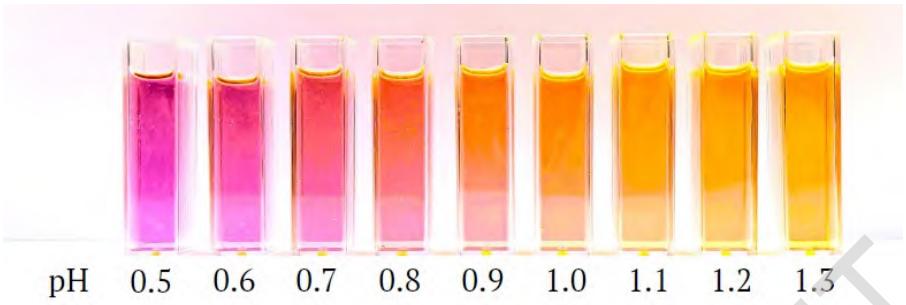

Fig. 4

Then, the absorption spectra for each of these cuvettes were measured and plotted together on a single graph (Fig. 5).

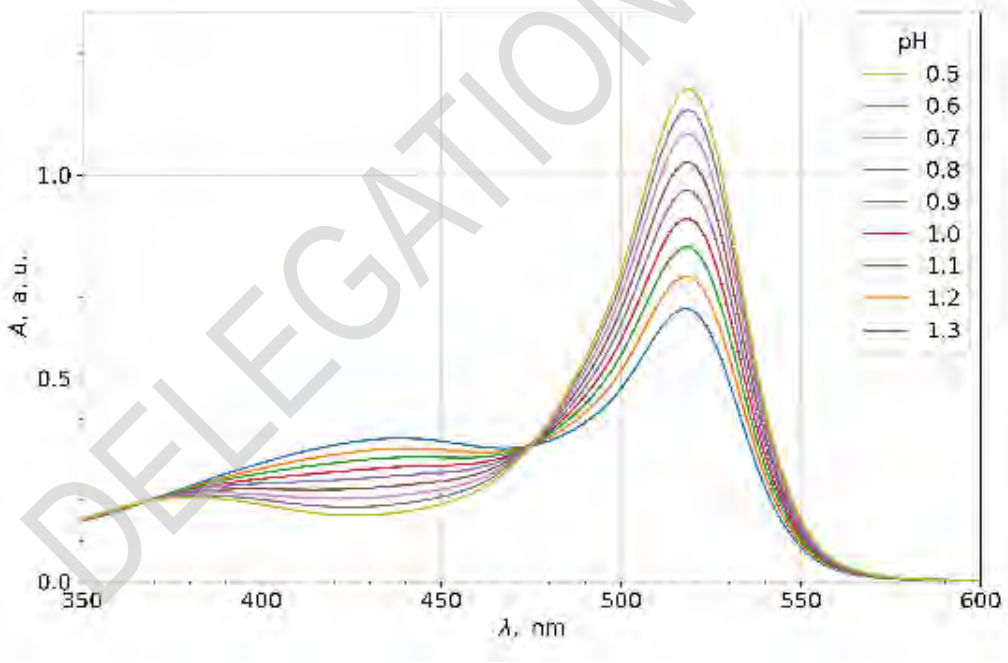

Fig. 5

What features can be observed in the graph:

absorption at $\lambda_{peak}^{CR} \approx 520$ nm, the value of which changes significantly with pH (this peak decreases with increasing pH);

absorption at 430 nm, the value of which changes much less significantly with pH changes (this peak increases as pH increases);

absorption at $\lambda_{iso}^{CR} = 475$ nm, the value of which remained constant with pH changes (all spectra intersected at this point, which is called the isosbestic point).

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Based on the absorption at the isosbestic point, it is possible to calculate the concentration of the indicator, since the absorption at this point does not depend on pH. It is clear that if the concentration of the indicator is doubled, for example, then all absorption values will also double, but the ratio A_{peak}/A_{iso} will remain constant and will correspond to a certain pH.

C.1	At the end of the exercises, there is an enlarged graph (Fig. 11). Determine the absorption values A_{peak} for each pH value on the graph. Determine the absorbance value A_{iso} at the isosbestic point. Calculate the ratios A_{peak}/A_{iso} for each pH value. For convenience, a table is provided on the answer sheet. Plot a graph of $A_{peak}/A_{iso}(\text{pH})$ and draw an approximating curve.	1.5pt

The resulting graph is universal and can be used as a calibration graph, since the values plotted on the axes do not depend on the initial concentration of the indicator. It can be used to determine the pH of solution **A4**.

Prepare 500 µL of undiluted solution **A4** in two 2 mL test tubes. Add 25 µL of cresol red solution to one of them. Mix the solution with the indicator thoroughly.

C.2	*This step uses a thin glass cuvette with an adapter.* Following the **G1** instructions for thin cuvettes, obtain the absorption spectrum of undiluted solution **A4** without indicator. Save the measured spectrum to the "**Results/C2**" folder on your desktop under the name "**C2.txt**".	0.3pt

C.3	*This step uses a thin glass cuvette with an adapter.* Following the **G1** instructions for thin cuvettes, obtain the absorption spectrum of the undiluted **A4** solution with the indicator. Save the measured spectrum to the "**Results/C3**" folder on your desktop under the name "**C3.txt**".	0.3pt

C.4	The introduction to the problem describes how absorption spectra are combined when there are several substances in solution. Based on measurements at points C2-C3, calculate the absorption A'_{peak} at wavelength λ^{CR}_{peak} caused ***only*** by the absorption of the indicator. What is the absorption A'_{iso} at a wavelength of $\lambda^{CR}_{iso} = 475$ nm caused ***only*** by the absorption of the indicator?	0.3pt

C.5	Based on the data in point C4, calculate the ratio A'_{peak}/A'_{iso}. Using the graph from point C1, determine the value of pH_{fin} in solution **A4**.	0.5pt

In the previous step, you determined the final pH, i.e., the concentration of hydrogen ions in the solution after electrolysis. Next, you need to determine the initial pH of the solution before electrolysis. The pH of solution **A2** is in the range from 3.00 to 5.00. In this range, the bromophenol blue indicator changes color well. Your task will be to obtain the same family of spectra for it as the authors did for cresol red (Fig. 5).

It would be possible to prepare solutions of different pH values, add the same amount of indicator, and measure their spectra. However, adding the same amount of indicator is difficult, and large errors will arise in the spectra. Therefore, you can choose the following approach:

take a cuvette and pour $V_0 = 4$ mL of solution with pH = 5.0 into it;

add 30 µL of bromophenol blue solution to the cuvette and mix well;

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measure the absorption spectrum of the indicator;

add a certain volume of ΔV of acid solution HCl to the cuvette and mix (you will be provided with 10 and 100 mM acid solutions), which will lower the pH;

measure the absorption spectrum of the modified solution;

continue adding concentrated acid and repeat steps 4 and 5 until we reach pH = 3.0 or lower.

The total volume of acid added will be small, so the change in the total volume of the solutions can be neglected.

To construct a graph similar to Fig. 5 and point C1, the pH values of the solution after each addition of concentrated acid are missing. The table on the answer sheets shows the initial concentration of HCl, the volume ΔV of concentrated acid added at each step, and the concentration C_{HCl} of the acid used. Your task is to calculate the pH values (*to two decimal places*) that the solution will have at each step of acid addition.

Step	V_0, mL	C_{HCl}, mM	ΔV, μL
0	4.0	-	-
1	4.0	10	+4.0
2	4.0	10	+8.0
3	4.0	10	+16.0
4	4.0	10	+30.0
5	4.0	100	+6.0
6	4.0	100	+12.0
7	4.0	100	+25.0

C.6	Fill in the remaining fields in the table on the answer sheets.	1.4pt

C.7	Perform the experiment described above, adding the specified amount ΔV of acid with concentration C_{HCl} at each step. Measure and save the absorption spectrum at each step according to instruction **G1**. Save the measured spectra in the folder on your desktop named "**Results/C7**" under the names "**C7.step number.txt**" (for example, "C7.2.txt"). You should end up with 8 spectra. Pour the remaining solution after obtaining all spectra into **Answer tube C7**.	3.0pt

C.8	Display all spectra from item C7 in the program's working area. Determine the wavelength λ_{peak}^{BB} at which absorption changes most significantly with pH changes. Determine the wavelength of the isosbestic point λ_{iso}^{BB}.	0.8pt

C.9	Plot the graph of the dependence of the absorption ratio at wavelengths λ_{peak}^{BB} and λ_{iso}^{BB} on pH (i.e., the graph $A_{peak}/A_{iso}(\text{pH})$ for bromophenol blue).	1.5pt

Next, do the same as in steps C2 and C3, but with a different indicator. Pour 500 µL of undiluted solution **A2** in two 2 mL test tubes. Add 20 µL of bromophenol blue solution to one of them. Mix the solution with the dye thoroughly.

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C.10	*This step uses a thin glass cuvette with an adapter.* Following the **G1** instructions for thin cuvettes, obtain the absorption spectrum of the undiluted **A2** solution without indicator. Save the measured spectrum to the "**Results/C10**" folder on your desktop under the name "**C10.txt**".	0.3pt
C.11	*This step uses a thin glass cuvette with an adapter.* Following the **G1** instructions for thin cuvettes, obtain the absorption spectrum of the undiluted **A2** solution with indicator. Save the measured spectrum to the "**Results/C11**" folder on your desktop under the name "**C11.txt**".	0.3pt
C.12	Based on the measurements in questions C10-C11, calculate the absorption A'_{peak} at wavelength λ^{BB}_{peak} caused ***only*** by the absorption of the indicator. What is the absorption A'_{iso} at a wavelength of λ^{BB}_{iso} nm caused ***only*** by the absorption of the indicator?	0.3pt
C.13	Based on the data in point C12, calculate the ratio A'_{peak}/A'_{iso}. Using the graph from point C9, determine the value of pH_{ini} in solution **A2**.	0.5pt
C.14	By increasing the concentration of hydrogen ions in the solution (i.e., decreasing the pH), it is also possible to determine the charge passed during electrolysis. Write a formula that relates the initial pH_{ini} of the solution, the final pH_{fin} of the solution, and the charge Q_{pH} that has passed through. Calculate the numerical value of the charge Q_{pH}.	1.0pt

Part D. Summary of results (1 point)

D.1	Based on the laws you know, fill in the table on the answer sheet, checking only one of the options for each statement: true/false.	0.7pt
D.2	Select and mark with a check mark on the answer sheet the most reliable value of the leaked charge.	0.3pt

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Section II. Study of photosynthetic organisms (15 points)

Photosynthesis is a key process occurring in our planet's biosphere, allowing organisms to use the energy of sunlight to sustain life. Due to photosynthesis, more than 99% of organic substances are formed, which are used to feed organisms at all levels of the food chain. However, there are many different types of metabolism based on the use of light energy. If carbon dioxide is the source of carbon in photosynthesis, i.e., it is fixed with the subsequent formation of organic matter, this is referred to as carbon dioxide fixation, and such organisms are called photoautotrophs. Photosynthesis can also occur without carbon dioxide fixation, using various organic substances instead of carbon dioxide; such organisms are called photoheterotrophs.

Water can be used as an electron donor for the electron transport chain in photosynthetic membranes. In this case, one of the products of photosynthesis is oxygen, and this type of photosynthesis is called

oxygenic. Organic or reduced inorganic compounds can also be electron donors. In this case, the products of photosynthesis will not be gaseous, and this type of photosynthesis is called anoxygenic.

Phototrophic organisms are extremely diverse: they differ in cell structure, types of photosynthetic pigments, and many other characteristics. Phototrophic organisms often form complex communities where they occupy different niches. In this task, you are asked to study the characteristics of photosynthesis in two microorganisms, A and B, and draw conclusions about their physiology and ecology.

Part E. Determination of spectral efficiency of photosynthesis in cultures of two microorganisms (6.4 points)

In this task, you will determine the presence and effectiveness of oxygen release by cultures of two microorganisms, A and B, when illuminated with light of different wavelengths. Three LED arrays serve as the light source: blue, green, and red. Each array consists of three LEDs connected in series (Fig. 6).

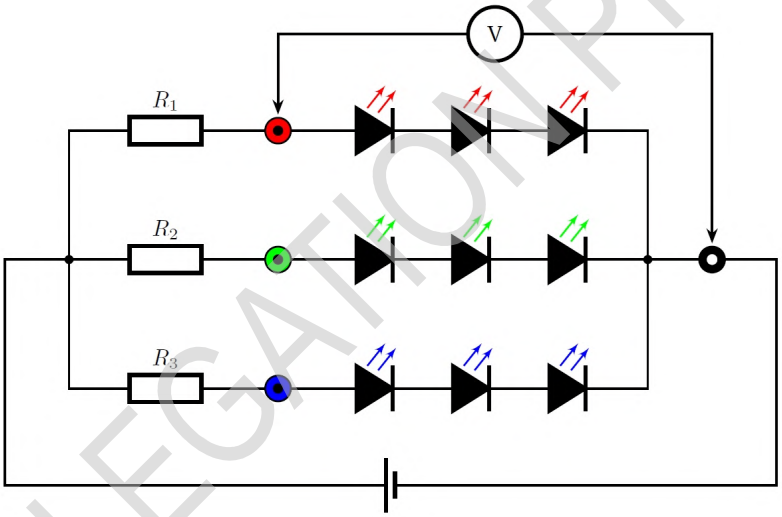

Fig. 6. Scheme of the electric curcuit of LED-arrays

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E.1	For each LED battery, measure the voltage across the 3 LEDs connected in series and calculate the voltage across **single** LED when the power source is turned on. Fill in the table in the answer sheets.	0.6pt

The figure below shows the volt-ampere characteristics of LEDs.

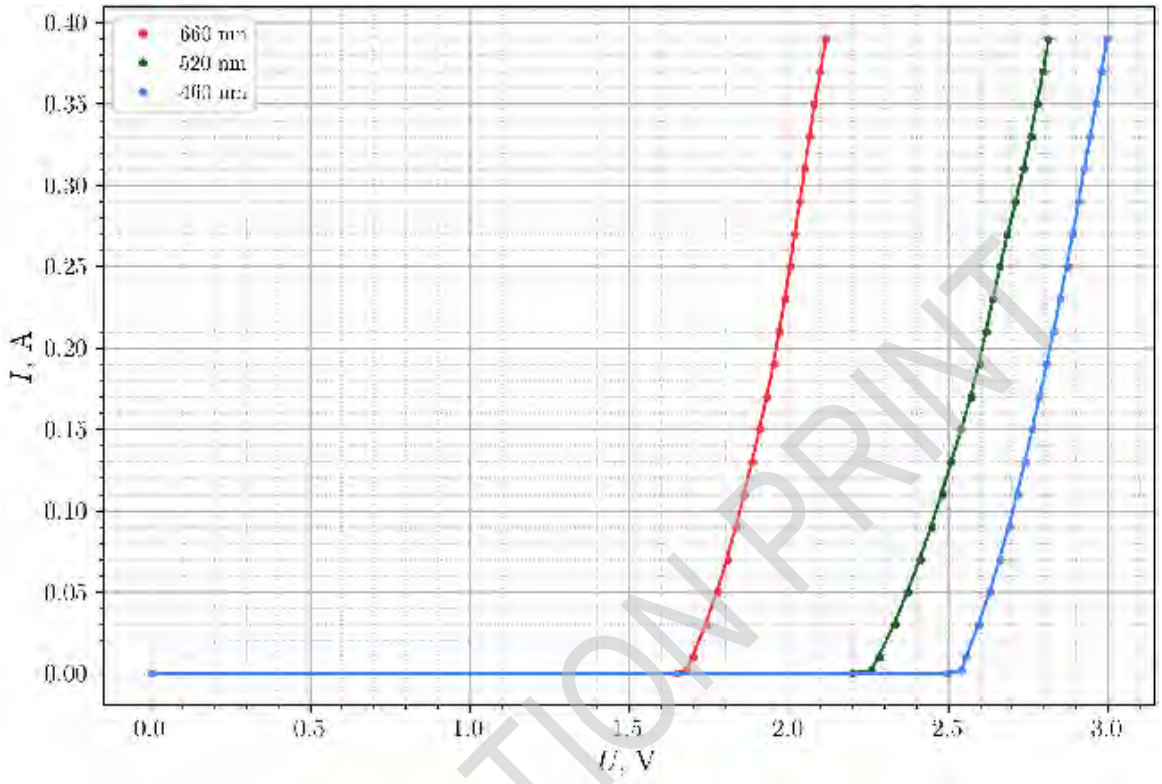

Fig. 7. Volt-ampere (IV) characteristics of light-emitting diodes

E.2	Find the current I flowing through the LEDs of each color. Fill in the table in the answer sheets.	0.3pt

The figure below shows the dependence of the light power P emitted by LEDs on the current I flowing through them.

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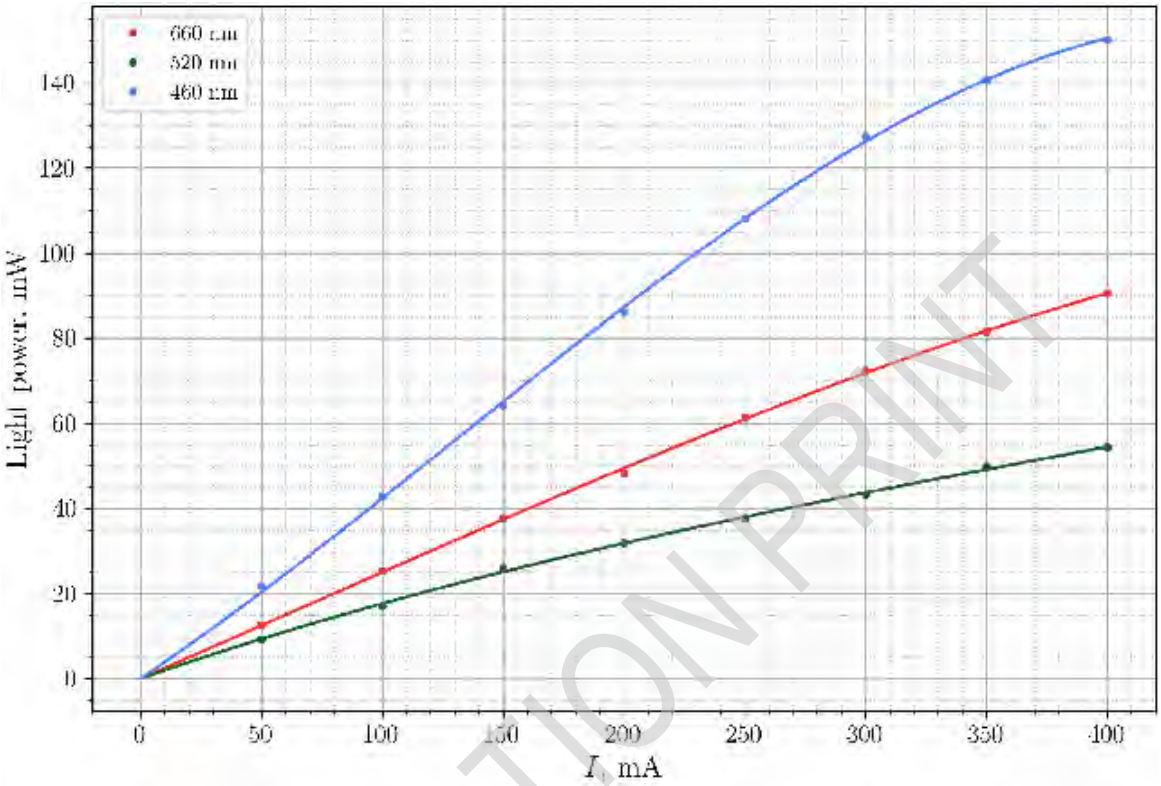

Fig. 8. Dependence of LED radiation power on current strength

E.3	Find the power of light P emitted by each of the LED. Fill in the table in the answer sheets.	0.3pt

The internal cross-sectional area of the tubes is $S_0 = 1.77$ mm². Using the setup for studying the spectral sensitivity of photosynthesis one may measure the volume of oxygen V, which is released by microorganisms when exposed to light of different colors.

E.4	For this task, use microorganism A. Prepare the setup for measurements according to the **G3** instructions. Turn on the light source and start timing. If **no oxygen release is observed** 30 minutes after the start of the experiment, record zero values for V_{O_2} in the table in the answer sheets. If oxygen release is observed 30 minutes after the start of the experiment, continue the experiment for another 1.5 hours. Record the volume of oxygen V_{O_2} released when illuminated by different colors of light in the table on the answer sheet.	1.0pt

E.5	For microorganism B, repeat the procedure described in the previous question. Fill in the table in the answer sheets.	1.0pt

To compare the photosynthetic efficiency E of different microorganisms, it is necessary to obtain the average efficiency per cell and per incident radiation power:

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$$E = \frac{V_{O_2}}{N \cdot P},$$

where V_{O_2} is the volume of oxygen released during exposure to light, N is the number of cells exposed to light, and P is the radiation power.

E.6	According to instruction G4 get the image of the cells in Goryaev's chamber for both microorganisms A and B. Save the acquired images to the "**Results/E6**" folder on your desktop under the name "**E6.A.txt**" and "**E6.B.txt**" respectively.According to instruction **G4**, use Goryaev's chamber to count the number of cells in the four small squares n_A and n_B of microorganisms A and B.The edge of the large square of the Goryaev chamber is 0.2 mm, the depth of the chamber is 0.1 mm, and the large square consists of 16 small squares. Count the total number of cells N_A and N_B of microorganisms A and B inside a 20 ml syringe. Write down the calculation formula showing how n_A and N_A are related.	1.0pt

E.7	Using the data obtained in points **E4**, **E5**, and **E6**, calculate the photosynthetic efficiency E for both microorganisms and all colors of light. Fill in the table in the answer sheets.	1.2pt

E.8	Using the data obtained in questions **E3** and **E7**, fill in the table in the answer sheets.	1.0pt

Part F. Determination of the pigment composition of the microorganisms (5.2 points)

The pigment composition largely determines the ability of photosynthetic organisms to absorb different spectral intervals of solar radiation. Pigment composition may vary among organisms of different systematic groups. The main photosynthetic pigments are chlorophylls and carotenoids. They differ in chemical structure and physical properties. The physical properties of the most important pigments, such as absorption maxima and retention factor, are shown in the table below.

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Pigments	Absorption maxima, nm	R_f
Chlorophyll a	430, 660	0.48
Chlorophyll b	450, 660	0.38
Bacteriochlorophyll	605, 780	0.42
Bacteriofeofetin	550, 750	0.45

Characteristics of absorption spectra and retention factor (R_f) of chlorophyll pigments on a chromatogram

Pigment	Absorption maxima, nm	R_f
Beta-carotene	430, 460, 490	0.98
Lutein	420, 450, 480	0.35
Carotenoid 1	480, 500, 520	0.83
Carotenoid 2	480, 500, 520	0.62
Carotenoid 3	480, 500, 520	0.54

Characteristics of absorption spectra and retention factor (R_f) of carotenoid pigments on a chromatogram

The retention factor value is calculated using the formula:

$$R_f = Z_x/Z_f,$$

where Z_x is the distance between the start line and the center of the pigment spot, and Z_f is the distance between the start line and the solvent front.

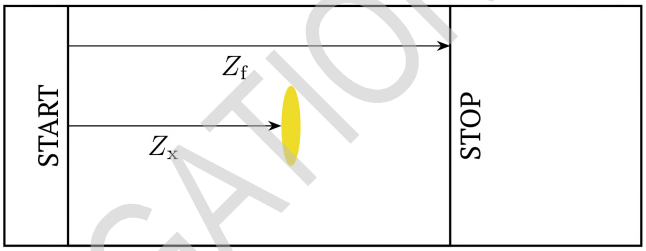

Fig. 9

The microbial culture box contains concentrated extracts of these microorganisms in small test tubes. These will be needed for chromatography and absorption spectral measurements. The volume of the extracts provided in the test tubes is approximately 150 µL. Therefore, before opening them, shake the liquid down.

F.1	According to instruction **G5**, perform thin-layer chromatography of extracts of microorganisms A and B.Immediately after completing the chromatography and drying the plate, analyze the table and carefully mark the spots corresponding to chlorophylls with an “X” and the spots corresponding to carotenoids with an “O” on the plate with a pencil.Raise the HELP sign so that an assistant can come to you and photograph the plate.Place the marked plate in **Answer tube F1**.	2.0pt

Take three plastic cuvettes. Pour 3 mL of ethanol into each of them. Use one of the cuvettes to establish the baseline, and add 50 µL of extracts of microorganisms A and B to the others. Mix the diluted extracts thoroughly.

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F.2	In accordance with instruction **G1**, obtain the absorption spectrum of extracts from microorganisms A and B. Save the measured spectra in the folder on the desktop "**Results/F2**" under the names "**F2.A.txt**" and "**F2.B.txt**" for microorganisms A and B, respectively. Pour 3 mL of the microorganism extract solutions you measured into **Answer tube F2.A and Answer tube F2.B**.	1.0pt

F.3	Based on the chromatograms you have obtained, as well as the absorption spectra, mark whether the statements are true or false on the answer sheet.	1.4pt

F.4	What conclusions can be drawn from the results of thin-layer chromatography and absorption spectrum analysis? Mark whether the statements are true or false on the answer sheet.	0.8pt

Part H. Study of Microorganism Ecology (3.4 points)

In small water bodies, the community of microorganisms is distributed according to physiological characteristics. In small water bodies with poor water mixing, a zone of oxygen concentration shift is formed, when anaerobic conditions are created in the deep layers. In the absence of oxygen, phototrophic organisms can use compounds other than water as electron donors. In this case oxygen is not released and this type of photosynthesis is called anoxygenic, unlike the oxygenic photosynthesis of cyanobacteria and green algae.

In the water column, phototrophic microorganisms are distributed according to their relationship to oxygen (aerobic and anaerobic) and their ability to absorb light in different parts of the spectrum.

It is known, for example, that among anoxygenic phototrophic bacteria, green bacteria are anaerobic and many of them are well adapted to using low-intensity light, while purple bacteria are resistant to oxygen.

H.1	Select the correct statements about microorganisms.	0.8pt

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H.2 The figure shows a diagram of a small pond with poor water circulation. Identify the zones of the pond (A-D) where the following microorganisms will live. 0.8pt

1. cyanobacteria and green algae
2. anaerobic decomposers of organic matter
3. green bacteria
4. purple bacteria

Write the numbers of the organisms in the table on the answer sheet.

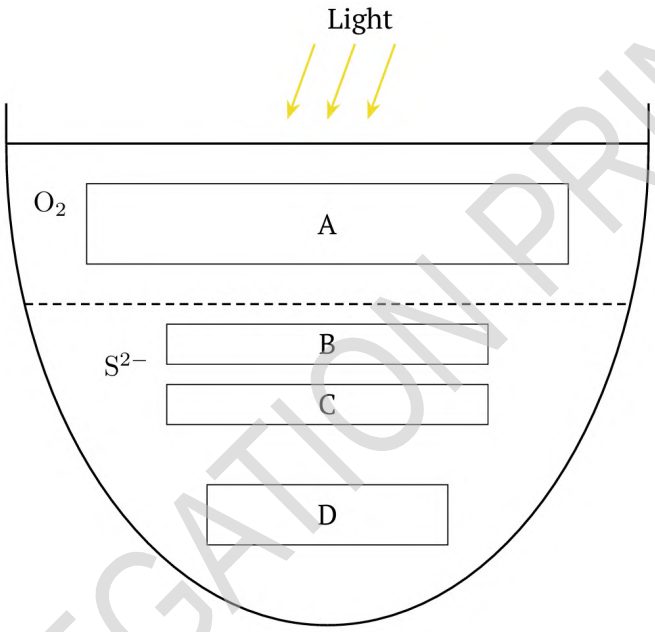

Fig. 10

H.3 Based on the information about microorganisms A and B that you obtained during your research, determine in which pond zone (A-D from task H2) each of the microorganisms is most likely to live. 0.8pt

H.4 Cyanobacterial mat consists of many phototrophic and non-phototrophic microorganisms that are arranged in layers one below the other. Indicate whether the following statements are true or false. 1.0pt

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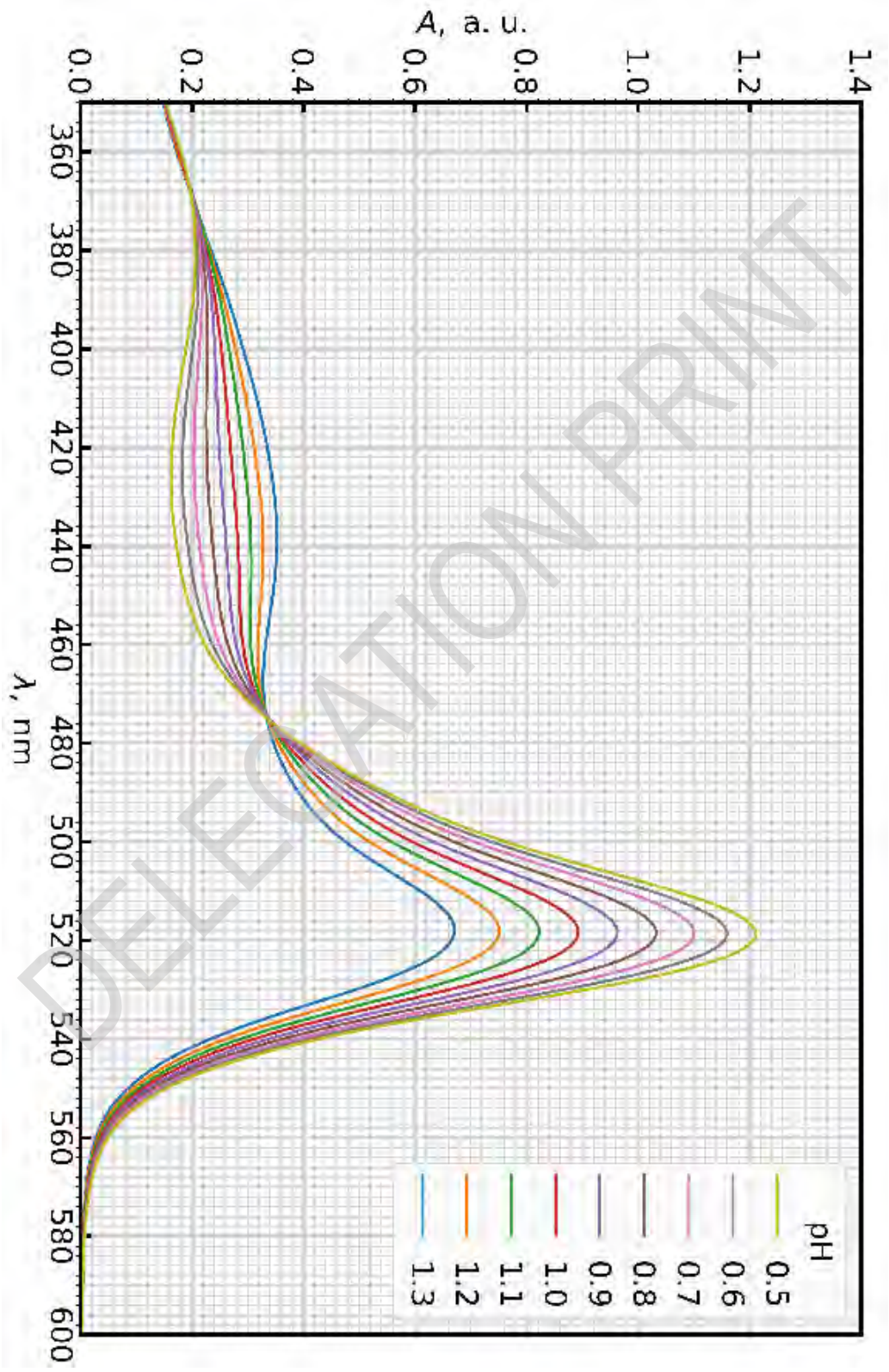

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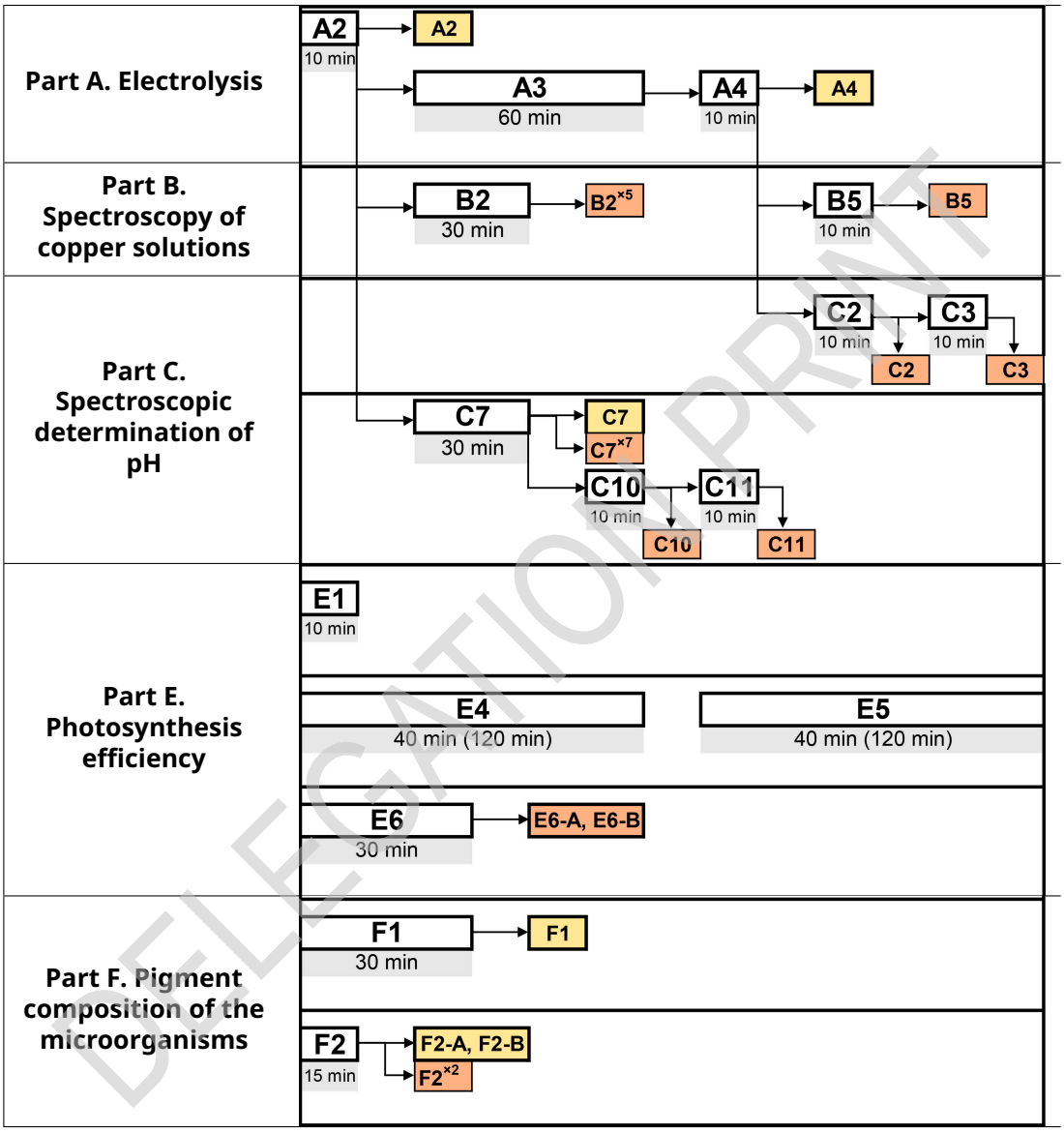
Fig. 11. Enlarged graph for C1

A1-1

English (Official)



Results should be poured into the **Answer Tube**

Files should be saved and uploaded to the test system

DELEGATION PRINT

Part D. Summary of results (1 point)

D.1 (0.7pt)

No.	Statement	True	False
1	Some of the oxygen produced escapes through the open surface of the solution.		
2	During electrolysis, molecular oxygen can form at the cathode.		
3	The oxygen formed at the anode can react with the graphite electrode.		
4	During the experiment, other gases besides oxygen may form on the electrodes.		
5	A significant portion of copper sulfate does not dissociate in solution.		
6	Replacing the graphite cathode with a copper one will not allow the charge to be correctly determined by the change in pHof the solution.		
7	Replacing the graphite anode with a copper one will make it impossible to correctly determine the charge by the concentration of copper ions.		

D.2 (0.3pt)

Q_{O_2}	Q_{Cu}	Q_{pH}

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E.6 (1.0pt)

$n_A =$

$n_B =$

$N_A =$

$N_B =$

E.7 (1.2pt)

Microorganism	Red	Green	Blue
A			
B			

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E.8 (1.0pt)

	True	False	It cannot be concluded from the experiment
Organism A is unable to perform photosynthesis when illuminated by green light.			
Organism B is capable of moving toward more optimal conditions for photosynthesis.			
Organisms A and B perform the same type of photosynthesis.			
Organism B performs photosynthesis more efficiently when illuminated with red light.			
Organism B performs anoxygenic photosynthesis.			

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Part F. Determination of the pigment composition of the microorganisms (5.2 points)

F.1 (2.0pt)
Answer tube F1 and photo

F.2 (1.0pt)
Saved spectra
Answer tubes F2.A and F2.B

F.3 (1.4pt)

	True	False
Chlorophylls will have two maxima in the red and blue regions of the absorption spectrum.		
Carotenoids can be found on the chromatogram of organism B.		
Carotenoids are more polar than chlorophylls.		
Carotenoids in this experiment can be clearly identified only by their mobility, since their absorption spectra are similar.		
On the chromatogram of organism A extract, chlorophylls have the highest mobility.		
Bacteriochlorophyll absorbs the longer wavelength part of the spectrum than chlorophylls.		
Carotenoids participate in electron transfer along the photosynthetic electron transport chain.		

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F.4 (0.8pt)

	True	False
Organism B can use the longer wavelength part of the spectrum for photosynthesis.		
The pigment compositions of organisms $A$and B are identical.		
In mixed communities, organism B is found in deeper layers than organism A.		
The carotenoid sets of both organisms are identical.		

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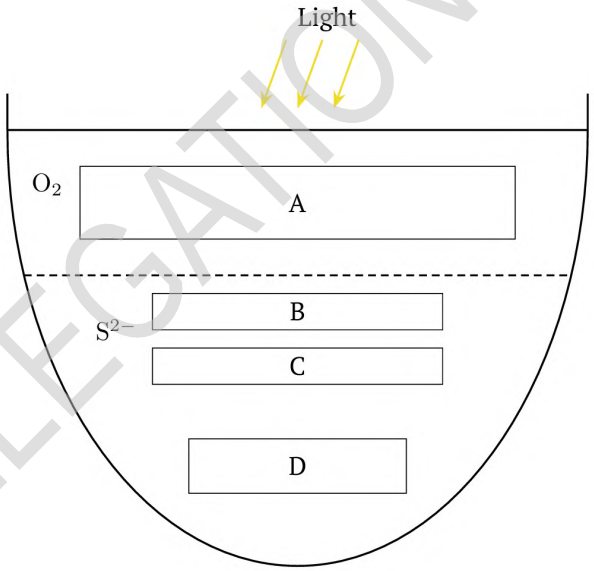
Part H. Study of Microorganism Ecology (3.4 points)

H.1 (0.8pt)

	True	False
Green algae are aerobic microorganisms.		
Purple and green bacteria perform oxygenic photosynthesis.		
Phototrophic bacteria can use reduced sulfur compounds as electron donors in anoxygenic photosynthesis.		
Cyanobacteria mainly live in anaerobic conditions.		

H.2 (0.8pt)



Pond zone	Microorganisms
A	
B	
C	
D	

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H.3 (0.8pt)

Microorganism	Pond zone
Microorganism A	
Microorganism B	

H.4 (1.0pt)

	True	False
Microorganisms can move within the microbial mat.		
In the upper layer of the cyanobacterial mat, bright light increases the risk of photodamage to the photosynthetic apparatus of cells.		
Non-phototrophic microorganisms can only exist deep within the cyanobacterial mat.		
Phototrophic microorganisms with different sets of pigments can change position in microbial mat depending on changes in the wavelength range of sunlight.		
At sunrise and sunset, bacteria capable of absorbing light in the shorter wavelength region of the spectrum will photosynthesize most actively.		

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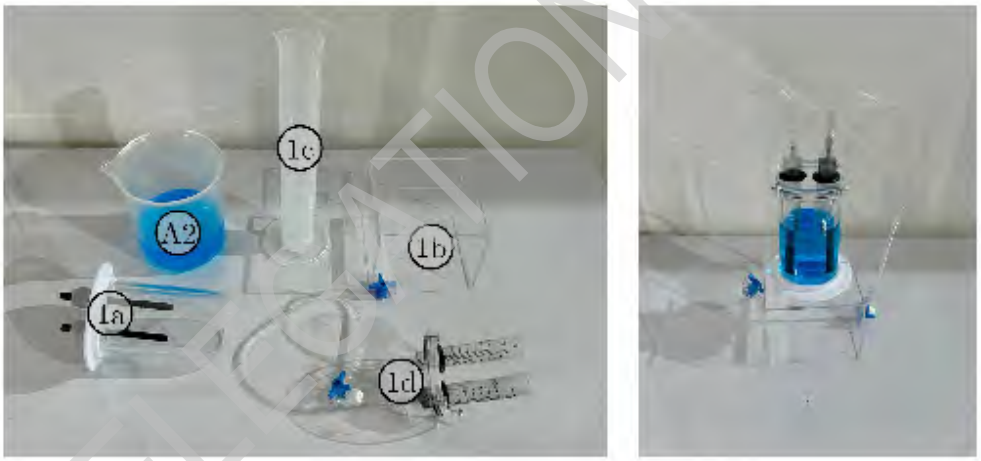
Instructions for using the electrolyzer (for part A)

Watch the video instruction "G2.Electrolysis.mp4".

Instructions for conducting electrolysis

I. Preparing the electrolysis chamber

1. Place the electrolysis chamber (1a) on the stand (1b), Fig. G2-1.
2. Using the measuring cylinder (1c), pour 120 mL of "solution **A2**" into the electrolysis chamber.
3. Firmly attach the gas collection system (1d) to the electrolysis chamber such that the gas doesn't leak. Note that the electrodes must be inside the gas collection system syringes. Be careful during this attachment such that the electrodes do not break.
4. The assembled setup should look like the one in Figure G2-2.



G2-1, 2

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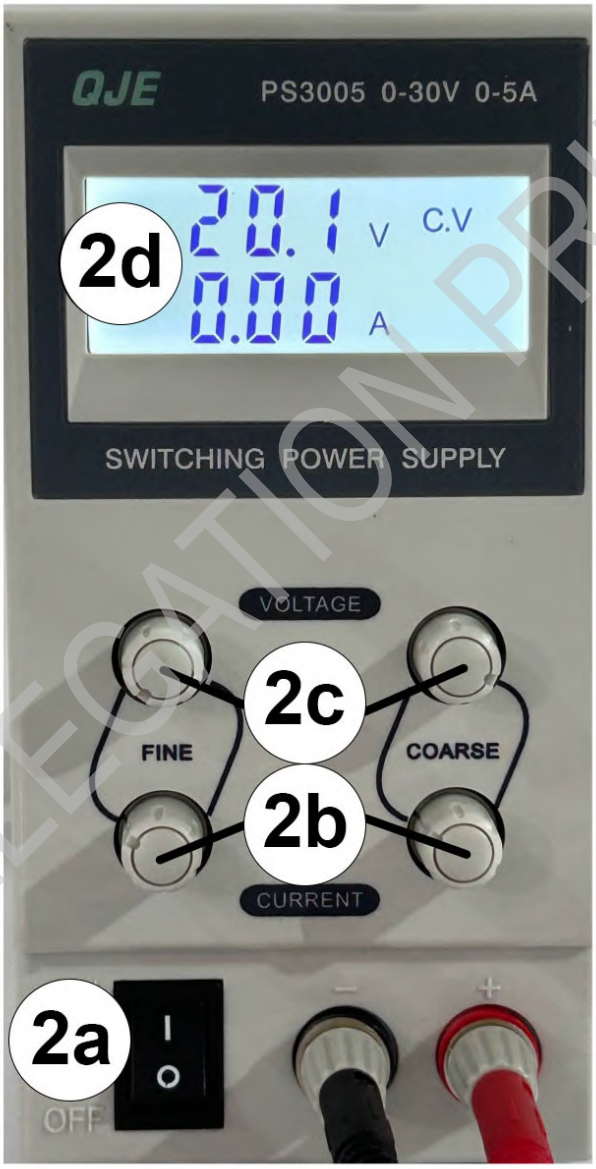
II. Preparing the power supply for electrolysis

1. Check that the adjustable power supply is switched off.
2. On the power supply, turn the "Current" and "Voltage" knobs (both 'Coarse' and "Fine") to the minimum setting (counterclockwise).
3. Make sure that the connecting wires are already inserted into the power supply unit.Power supply unit components are depicted in the Figure G2-3. On/off switch (2a). Current adjustment knobs (2b). On the right is the coarse adjustment knob (one full turn covers the entire available current range). On the left is the fine adjustment knob (full turn ~20% of the value set by the coarse adjustment). Voltage adjustment knobs (2c). Similarly, on the left is the fine adjustment, on the right is the coarse adjustment. Readings of the voltmeter and ammeter built into the power supply unit (2d).
4. Turn all the knobs on the power supply counterclockwise as far as they will go. Turn on the power supply. Turn the coarse current adjustment knob slightly clockwise (just enough so that the cur-

rent remains approximately 0 A, but when the voltage adjustment knobs are turned, the voltage readings change).

5. Use the “Voltage” knob on the power supply to set the voltage to “20.0” V.
6. Connect the crocodile clips (Fig. G2-4, 3c) to the electrodes of the electrolysis chamber.



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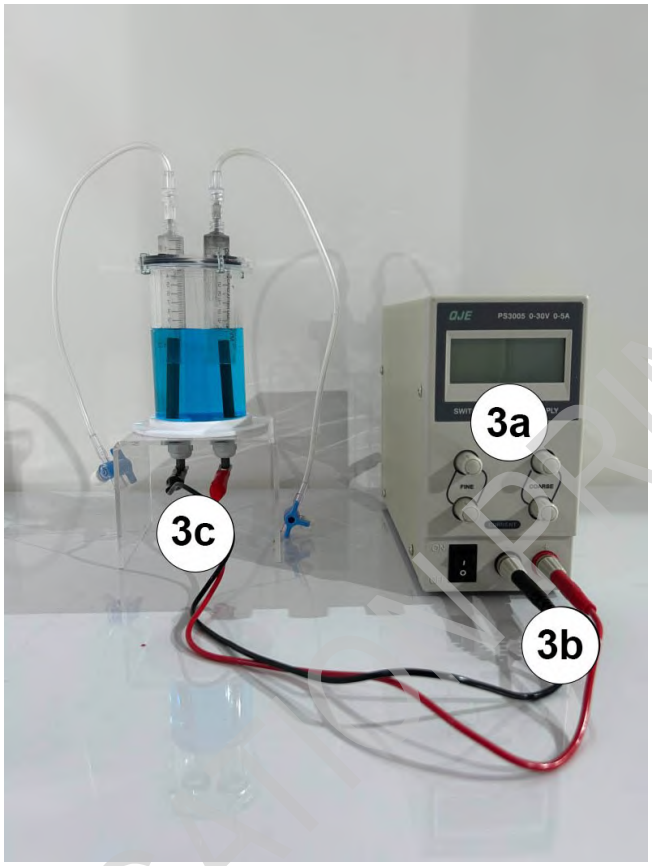

G2-4

III. Preparing the oxygen collection system

Note: screw the white cap onto the valve if not already installed.

1. Turn the tap to the “closed” position (Fig. G2-5).
2. Move the syringe plunger to the “0 mL” position.
3. Turn the tap to the “open” position.
4. Suck the air out of the syringe in the electrolysis chamber so that the solution level rises to the base of the syringe.
5. **Attention!** Solution should not enter the tube and the tip of the syringe.
6. Then turn the tap to the “closed” position.
7. Unscrew the syringe. Push the plunger to empty the syringe. Throughout the experiment you can empty the syringe whenever you want.
8. Repeat the preparation on the second electrode.

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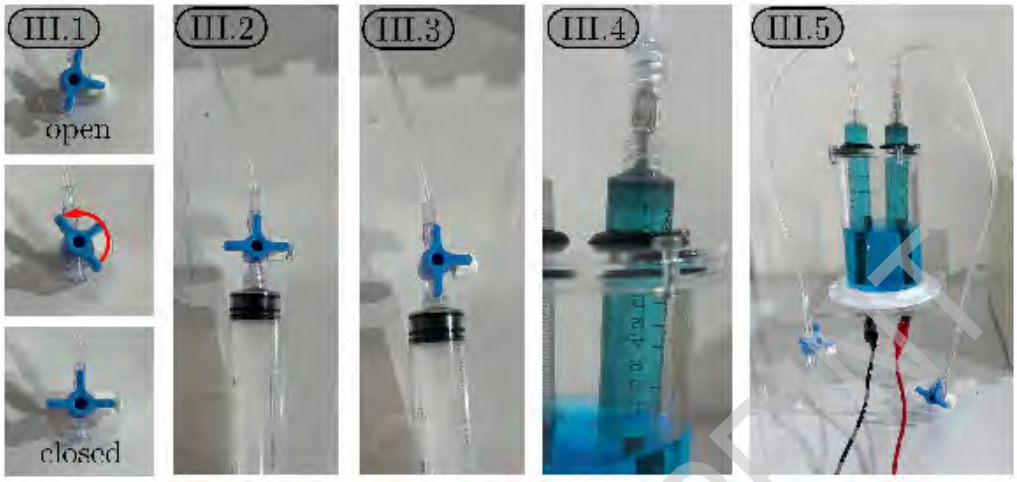

G2-5

IV. Checking the electrolysis operation

Set the power supply to a current of “1.0” A.

At the beginning of the main experiment make sure that gas begins to be released in the system. *Gas should begin to be released inside the electrolysis chamber and enter the chamber syringes. It occupies the space between the syringes and the solution, and the solution level in the chamber syringe gradually decreases. (Fig. G2-6).*

V. Starting the experiment:

1. Turn on the power supply and start the stopwatch.
2. As the syringe fills with gas, you will need to suck the gas out of the chamber syringe as described in step III above.

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G2-6

DELEGATION PRINT

Electrolysis process

Throughout the electrolysis process, you need to suck the gas collected in the syringe out, thereby measuring its volume.

To do this, follow the instructions below, filling in the answer sheet for question A3 as you go:

1. Turn the tap to the “open” position.
2. Push the plunger back until the solution level inside the vessel reaches the base of the syringe.
3. Turn the tap to the “closed” position.
4. Wait until the solution level inside the vessel drops, then repeat the above steps.

Suck the air our throughout the entire electrolysis process and record the volume sucked out!

End of electrolysis

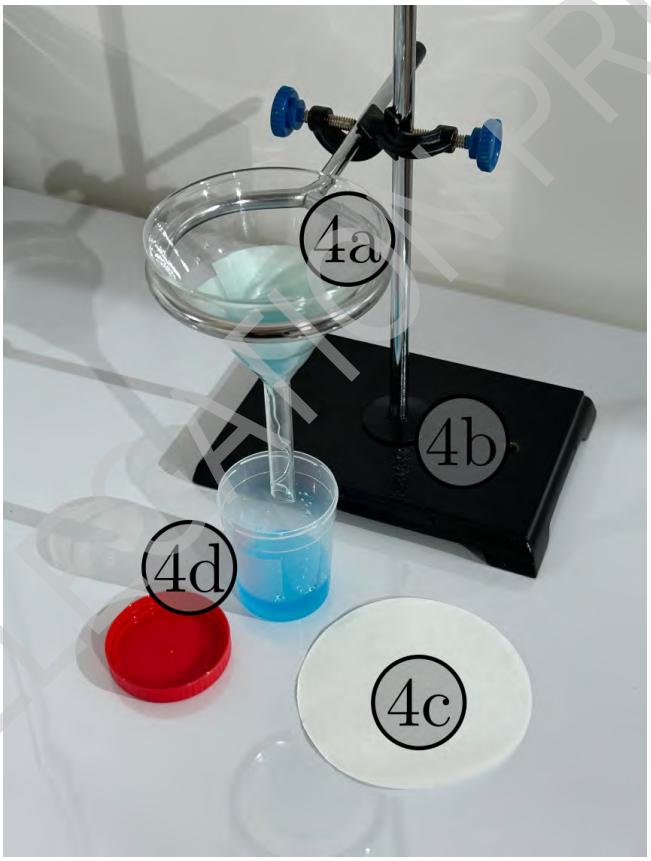
After the time specified in the conditions has elapsed, stop the electrolysis:

1. Turn off the power supply.
2. Disconnect the crocodile clips from the electrolysis chamber.
3. Remove the oxygen collection system and stir the solution in the chamber with a spoon.

For further research, you will need the solution obtained after electrolysis.

Filtration of the solution after electrolysis

1. Place the glass funnel (4a) in the stand (4b) (Fig. G2-7).
2. Fold the filter paper (4c) into a cone shape and place it in the funnel.
3. Place a laboratory container (4d) under the funnel.
4. Pour the solution from the electrolysis chamber into the funnel. The solution will be filtered and will flow into the container. Filter 20-25 mL of solution in this way. Solution **A4** will be obtained in the container.



G2-7

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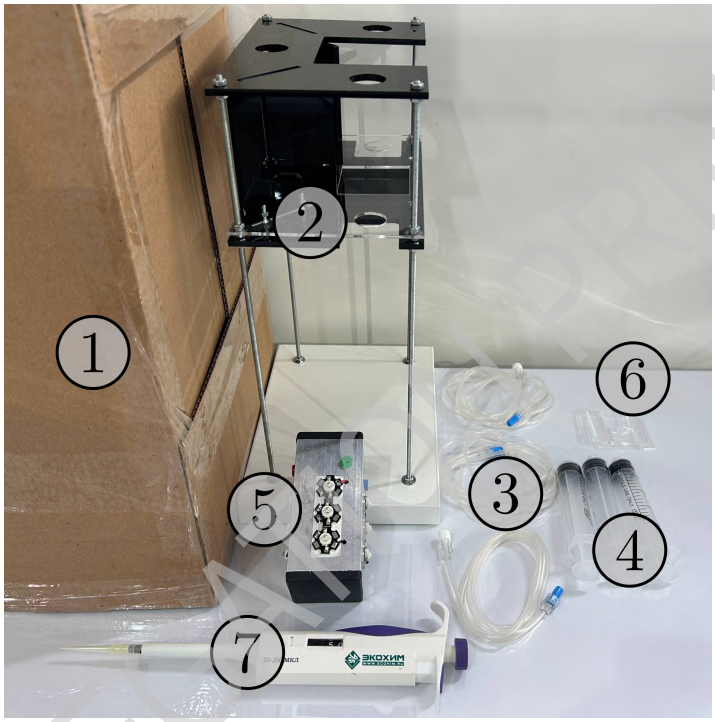
Instructions for photosynthesis setup (for part E)

Equipment



G3-1. Equipment

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1. Take the microbial culture box and shake it vigorously 20 times to mix.
2. Draw 20 mL of the same culture into each of the three syringes (4) for testing.
3. Pull the syringe plunger further out so that approximately 1 mL of air comes into each syringe.
4. Place the syringes in a special stand (2) for photosynthesis testing.
5. Secure the syringes in the stand by placing plates (6) under the “wings” of the syringes (see figure G3-2).
6. Take a long thin tube (3) and find the end that screws into the syringe tip (see figure G3-3, left).
7. Draw up 50 μL of distilled water by pipette (7) and inject it into the tube from the end you selected in the previous step (see figure G3-3, right).
8. Hold the opposite end of the tube with your finger (so that the drop inside does not move) and screw the first end of the tube into the syringe. Remove your finger from the opposite end of the tube. The drop may shift slightly.
9. Mark the position of either edge of the drop with a marker.
10. Attach the thin tubes to the other syringes in the same way (i.e., repeat steps 5-8).
11. Take the three-color illuminator (5) and plug its power supply into a power outlet.

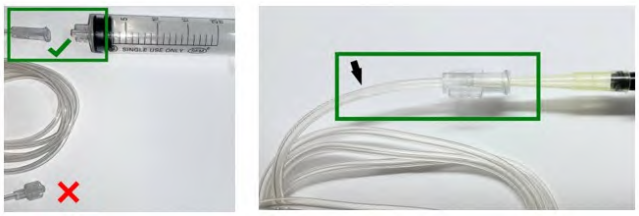
Note: long-term exposure to bright light might be a health risk. Avoid looking at the LEDs for too long.

12. Place the three-color illuminator in the stand (2) for studying photosynthesis so that each syringe is illuminated by its own color.

13. Cover the stand with the illuminator with a cardboard box (1) to eliminate the influence of background lighting.

14. Start the stopwatch and follow the further instructions in the tasks.

G3-2. Setting up the syringe with the culture.



G3-3. Selecting the end of the tube (left), filling the tube with a drop of water (right)

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Experiment

G4-1

English (Official)

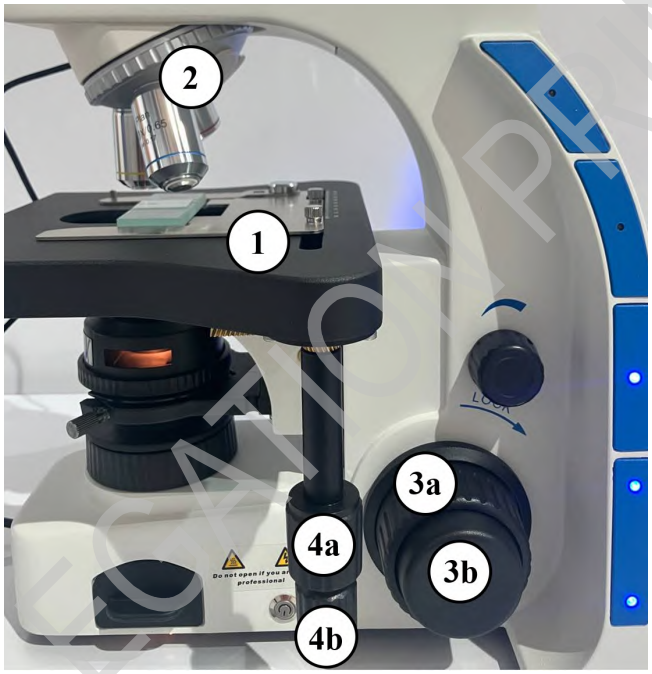
Instructions for working with microscope and Goryaev's chamber (for part E)

Object stage (1)

Revolving nosepiece (2)

Knob (3a) for coarse focus adjustment, knob (3b) for fine adjustment

Knobs (4a), (4b) for horizontal movement of the stage.



The Goryaev's chamber is a thick slide and has two counting chambers.

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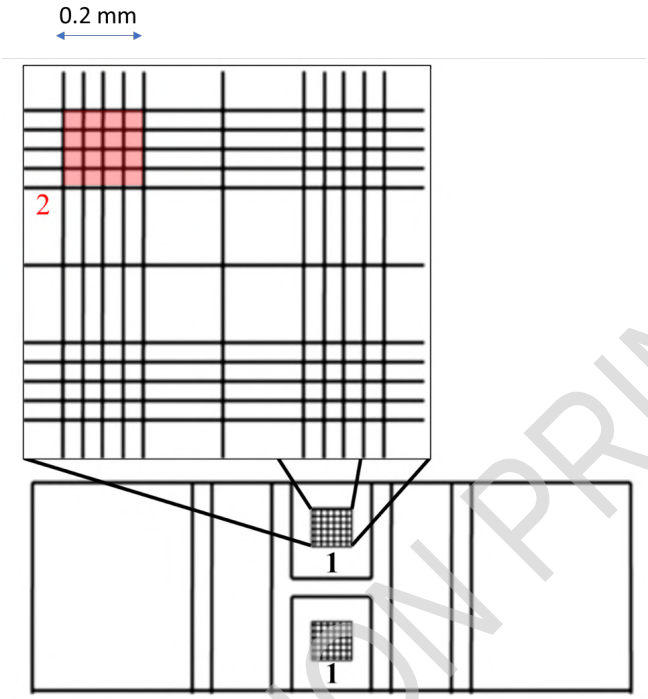
Experiment

G4-2

English (Official)



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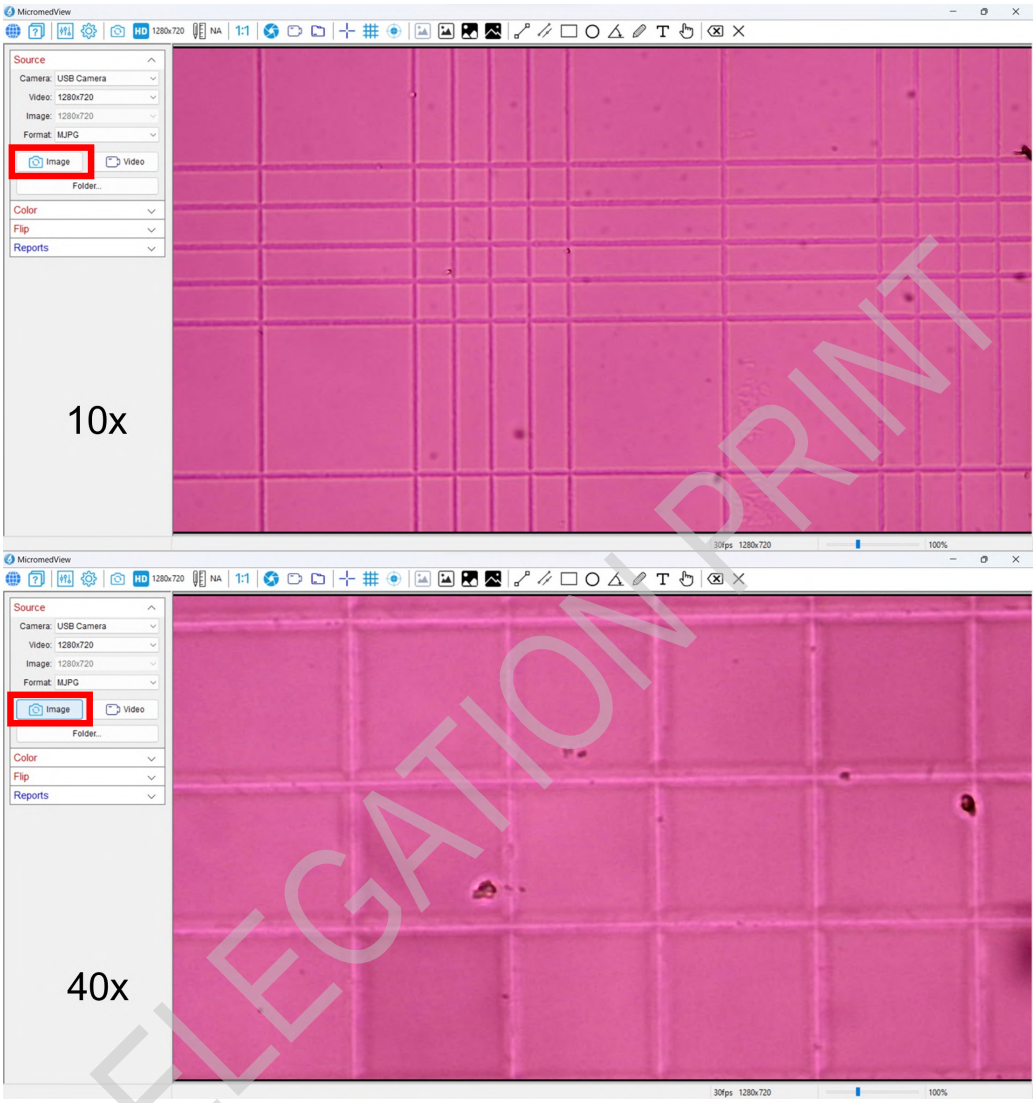
1. Take the microorganism culture containers and shake it vigorously to mix.
2. Using an automatic pipette, take 10 μL of culture of microorganism A and apply to the upper counting chamber, repeat for microorganism B and the lower chamber.
3. Cover the Goryaev's chamber with a coverslip and leave for 10 minutes to allow the cells to settle.
4. Open the “MicromedView" program.
5. Place the Goryaev's chamber on the objective stage. Select the 10x objective (1). Use knobs (4a) and (4b) to move the slide so that the counting chamber is in the field of view. Use knobs (3a) and (3b) to adjust the focus so that you can see the cells and cells of the counting chamber.
6. Use knobs (4a) and (4b) to move the slide so that one of the large squares (number 2 in the figure) of the chamber is in the center of the field of view.
7. Change the objective lens to 40x (1). Use the focus fine adjustment knob (3b) to adjust the focus. Use knobs (4a) and (4b) to adjust the position of the slide so that one of the large camera squares is in the center of the field of view.
8. Take a photograph of the field of view. When you press the button to save the photograph, a label appears indicating where in the file system the file is located. Copy **one photograph** of the microorganism under study into the "**Results/E6"** folder and rename it.
9. After finishing the work, the desktop folder "**Results/E6**" should contain photos with the names "**A.jpg**" and "**B.jpg**" for microorganisms A and B, respectively.

Experiment

G4-3

English (Official)



Overall view of the Goreyev's chamber at 10x and 40x. "Image" button marked by red frame. Press this button to save the image.

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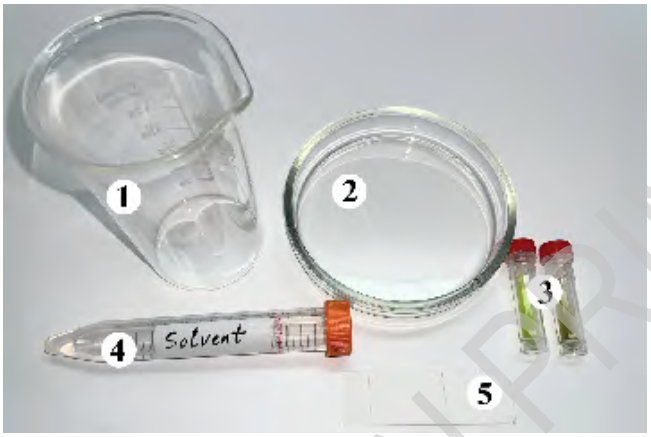
Experiment

G5-1

English (Official)

Instructions for thin-layer chromatography (for part F)



1. Take the chromatography plate (5) out of the bag. *Note: White coating of chromatography plate is fragile and can be damaged easily with force.* The plate has markings as shown in the task.
2. At the start line, carefully mark two dots with a pencil so that they divide it into three roughly equal segments. You will apply pigments to these dots.
3. Using an automatic pipette, apply two pigment extracts (3) to the marked points. Apply 0.5 µl of extract, waiting for the spot to dry (about 30 seconds) each time. Repeat the operation 5 times. After application, allow the chromatography plate to dry completely for 10 minutes.
4. Prepare a glass laboratory beaker (1) and a glass lid (2).
5. Pour the solvent mixture from the plastic test tube (4) into the glass beaker and cover with the glass lid. Wait 10 minutes.
6. Open the glass beaker. Place the chromatography plate vertically in the beaker so that the starting line is at the bottom, leaning the metal side of the plate against the beaker.
7. Cover the glass beaker with a glass lid and set it aside. Do not inhale the vapors contained in the beaker, do not leave the beaker open.
8. Leave the chromatography plate in the beaker until the liquid front reaches the stop line. This usually takes 5-10 minutes.
9. Carefully remove the plate from the glass. Cover the glass with a lid.
10. Mark the position of the liquid front with a pencil if it does not coincide with the stop line.
11. Leave the plate to dry on the table.
12. Use the dry plate for further tasks.

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