THE GREENHOUSE PROBLEM

Interaction between light and matter

Mr. Brown decided to build up a new greenhouse at his garden. His wife was very keen about it and because she was a very cheerful person she wanted their greenhouse to be colourful and so they both agreed on green colour.

Mr. Brown started building the greenhouse and soon, there was a green-glass greenhouse right in the middle of the garden. They planted all kinds of vegetables and enjoyed their unique greenhouse. But very soon, they discovered that plant don't grow and even turn yellow.

Dokážete Skleničkovým pomoci zjistit, čím to je a navrhnout jim řešení problému?

Try to help Browns to find out why plant didn't grow well in the green-glass greenhouse.

What you might need to know

The white light (e.g. the light coming from the sun or a bulb) consists of different colors. These colors are observable when the light passes through water droplets during rain and it is known as rainbow. More easily, we can observe the effect if the white light is passing through a special prism. Nevertheless, it is more complicated. The light is, in fact, a wave (from physics, it is known as an electromagnetic wave). And, every wave can be described by a parameter which is called wavelength (hence, length of a wave). It is not now necessary to understand, why the light is wave, nevertheless, important information is that some wavelengths corresponds to some color. For example, if the wavelength of a light is around 600 nm, the color is red. If some light consists of lights lines of all the wavelengths, we perceive it as white.

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The human eye is able to perceive (as colors) just wavelengths between 380 – 780 nm. This region of light is called visible light. The two main ways of interaction between light and a matter are absorption and emission. If the matter absorbs all the wavelength of the light, we perceive it as a black. It the matter passes all the wavelengths through, we perceive it as colorless. If some wavelength(s) is absorbed, we perceive the wavelengths which reach our eyes, it means the non-absorbed light and the matter is colorful.

It seems, if we want to help to Browns, we need to explore the emission and absorption phenomena and interpret the results. Let's go!

Explore the world around: simulate the process in laboratory

*What you need - **chemicals**:* Yellow, red, orange, blue food dyes and water, calcium carbonate powder or a fine powdered sand, green parts of plant (ivy is perfect, spinach), ethanol

*What you need – **equipment**:* 6 beakers or test-tubes with a holder, cuvettes, spectrophotometer, diodes of particular wavelengths (violet, blue, green, orange, red, yellow), battery or circuit needed to switch on the diodes, spatula, lab spoon, mortar and pestle, filtration apparatus

Procedure:

1. Prepare the spectrophotometer and switch it into the measurement in an emission mode. Measure the wavelengths of light of a respective color emitted by particular diodes and assign the colors (by the value of maximum of emission peak) to the wavelength region in the first column of the table below.

2. Prepare set of the food dye solutions into the 4 beakers (20 mL). Very small amount of solid dye is needed to prepare the mentioned volume, hence add few powder grain by tip if the spatula into 20 mL of water, the prepared solution must be transparent.

3. Switch the spectrometer into absorption mode (hence, you will measure, which wavelength is absorbed from the white light). Measure the spectra of all the dye solutions and assign the colors (by the value of maximum of absorption peak) to the wavelength region in the second column of the table below. If the absorption (value at *y*-axis is not between 0.5 – 1.5 or there are some artifacts (strange lines) on the spectrum, dilute the solution to get between these values.

Wavelengths (nm)	Colour of emitted light (1. task)	Colour of solution (3. task)
380 – 435		
436 – 490		
491 – 560		
561 – 610		
611 – 640		
641 – 760		

4. You can inquire other spectra: which emission (absorption) spectrum will you get when you put a colour filter in front of white light source? Where will you find the signals in spectrum? Next, you can simulate the conditions in greenhouse. Imagine, you put a coloured matter behind the coloured filter. Measure the spectra of different coloured solutions that are enlightened by light coming through different colour filters. Which solutions absorb which colour?

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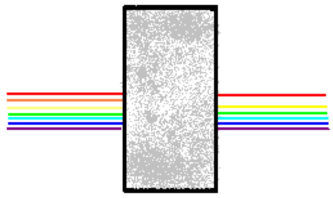
5. Prepare the chlorophyll solution into the last beaker. Cut the leaves or green parts of plants into small pieces, add into mortar and add 0.5 g of calcium carbonate (or the sand) and 10-15 mL of ethanol. Rub the mixture to prepare paste. Filter the mixture into a test-tube and pour a sample into cuvette.

6. Having the spectrometer in the absorption mode, measure the spectrum of the chlorophyll extract. Draw the measured spectrum bellow and fill in in the table the maxima of peaks in the spectrum. Again, the absorption value at *y*-axis must be between 0.5 – 1.5 and with no artefacts (strange lines) on the spectrum, dilute the solution to get between these values.

Spectrum of chlorophyll:
Maxima: ……………………………………………… and ………………………………………………

Evaluate the data



Try to explore the table you just filled in and try to find any relations between two columns. If you understand the relations between colors, you can answer the following question: What will be the color of the matter on the picture?

Now, you have enough information to help Browns. Try to clearly explain why the plants in green greenhouse grow badly. Which experiment should you perform to get the answer? Write down the procedure and the expected result.

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Show your results

Write Browns the result of your research: describe how you carried out the experiment and drawed your conclusions about why plants in green greenhouse turn yellow and fade. How should they solve the problem?

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Now, you have enough of experience and knowledge to answer the following questions:

1. What would happen if Browns use a black color glass?

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2. Can you recommend any glass-color that wouldn't affect growth of plants?

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3. Try to derive, what color have a solution, which absorbs blue color and a light of 610 nm.

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