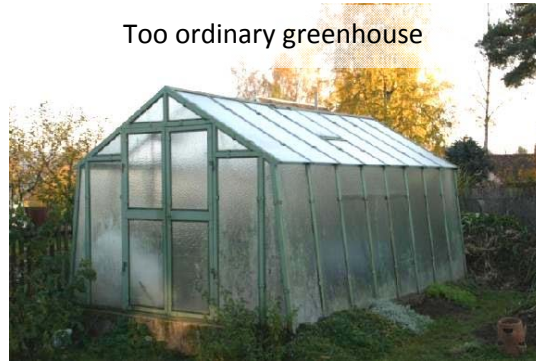


The greenhouse problem

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 plants don't grow and even turn yellow. Can you help Mr. And Mrs. Brown and explain them what the problem is?

All green plants' cells contain chlorophyll. This and light are indispensable for plants' growing. Why do you think that?

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Do you know why chlorophyll is green? Explain your idea.

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What do you think: does it matter which light arrives to plants? Why?

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Are there any differences in the light that arrives to the plants if the glass is green? Which? Why?

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Warming up

Learn more about light and the interaction with matter with the help of a spectrophotometer.

A spectrophotometer is a device that records the intensity of emission of a light source and also allows us to record the absorbance or the % transmittance of a solution, which allows to know the characteristics of light absorbed by a substance.

Experience 1. Capture the spectrum of white light. (Emitted light.)

Make a prediction of what the spectrum of white light will be like (you can draw the spectrum expected before recording the spectrum).

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Connect the spectrophotometer to LabQuest2 and choose the option that measures the intensity of light emitted.
Place the fiber optic connection and focus on your white light source (don't approach more than 4 cm) and start recording data.

Describe how the shape of the spectrum and note the range of wavelengths and the wavelengths corresponding to the maximum intensities.

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What can you say about white light?

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Experience 2. Black ink absorbance. (Absorbed light.)

Make a prediction of what the absorption spectrum of a black ink solution will be like (you can draw the expected spectrum before recording the spectrum).

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Select the option that measures the absorbance inside the cuvette.
Place the empty cuvette and calibrate the spectrophotometer following the instructions on the screen until the process is completed.
Introduce black ink (water with a few drops of ink) into the cuvette and cover it.
Start data capture, a new series in the absorbance mode and switch it off during a few seconds.
If the absorption values (ordinate axis) are not between 0.5 and 1.5 or there are some artifacts (nonexplicable lines) in the spectrum, dilute the solution in order to obtain absorption values between 0.5 and 1.5 or to make artifacts disappear.
Observe the graph obtained, called the visible absorption spectrum of the substance or substances in solution.

What magnitudes and units are represented on the axes of the recorded spectrum?
Compare it with previous measurement.

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Describe the absorption spectrum of the black ink. At what wavelength intervals does it absorb light?

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What type of light is necessary to record an absorption spectrum in the visible light?

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What could you explain about the light absorbed by the black solution?

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What you might need to know – information for curious students

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

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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 about 600 nm, its color is red. If some light is a mixture of wavelengths from the region 400 nm to 800 nm, we perceive it as white – noncolour to be precise.

If you want to understand the phenomenon of light and its properties such as energy and wavelength more deeply, you can look up relevant material in internet, such as <https://eee.uci.edu/programs/gchem/RDGVISSpec.pdf>

or <http://www.chemguide.co.uk/analysis/uvvisible/theory.html>

or <http://www.rsc.org/learn-chemistry/collections/spectroscopy/introduction#UVspectroscopy>

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 wavelengths of the light, we perceive it as a black. If the matter passes all the wavelengths through, we perceive it as colorless. If just some wavelength(s) from the range of visible light is absorbed, we perceive the wavelengths which reach our eyes, it means the non-absorbed light and the matter is colorful. The colour that we see is so called complementary to colour that is absorbed.

Explore the world around

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

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

Emitted light vs. absorbed light

You have explored there is a difference between emitted light and absorbed light. To find out why plants grow badly in a green greenhouse, you should know the wavelengths of different emitted colourlights and which wavelengths do colour solutions absorb.

Here you have some tips for measuring with spectrometer:

- if you want to know the wavelength of each light, you have to set up spectrometer in to measure emitted light, it means *intensity* depending on wavelength

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- if you want to measure what wavelength does the substance absorb, set up an absorption spectrum
- measured solutions must be transparent, not even translucent – check carefully, if the solution does not contain bubbles or some little objects. Mind the wall of cuvette – it has to be placed into spectrometer in a proper way.
- If intensity/absorption spectra contains some artefacts (lines), dilute the solution to get between these values. Value on y-axes has to be between 0.5 and 1.5.
- Food dyes are quite strong, you can use very little amount of it, few crystals – concentrated solutions shows lots of artifacts.

Measure the data and fill in the table below.

Wavelength region (nm)	Color of emitted light (1. Task)	Color of solution (3. Task)
380 – 435	Violet	Yellow
436 – 490	Blue	Orange
491 – 560	Green	Red
561 – 610	Yellow	Violet
611 – 640	Orange	Blue
641 – 760	Red	Green

1. You can inquire more spectra: try to measure emission spectra when you put colour filter in front of the white light source. Where are the signals in spectrum? Next you can simulate the options in greenhouse. Imagine you put some colourful matter behind the glass of different colour: measure absorption spectra of various colourful solutions that are enlightened by light that goes through different colour filter. Which solution absorbs which light?

Measuring sample

To answer the question about greenhouse, it is recommended to measure the spectra of chlorophyll. Prepare a transparent solution of it, measure the spectrum and put it down.

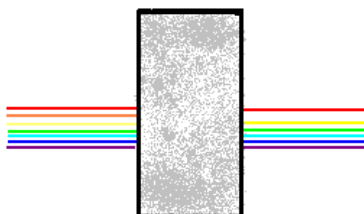
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Chlorophyll spectrum:

Maxima: and

Evaluate your data

Try to explore the table you just filled in and try to find any relations between two columns. If you understand the relationship between colours, you can easily answer following question: What will be colour of the solution on the figure below? (The incoming orange wavelength on the left is missing on the right.)



Hint 1: What does it mean, if we tell, that the colors are complementary?

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Hint 2: Try to derive, what color (wavelength) of emitted light is absorbed, if the solution has a yellow color.

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Now, you have enough information to help Browns. To clearly state your explanation why plants in green greenhouse do not grow, what experiment should you perform? Write down the procedure and the result.

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Show your results

Please, describe why plants of Mr. and Mrs. Brown turn to yellow and why do they die and how to solve the problem:

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Please, answer the following questions (now, you have enough of experience and knowledge to do that).

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

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

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3. If a solution absorbs green color and light of the wavelength of 610 nm, what is the color of the solution?

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4. Try to derive, what color have a solution, which absorb light of 900 nm.

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