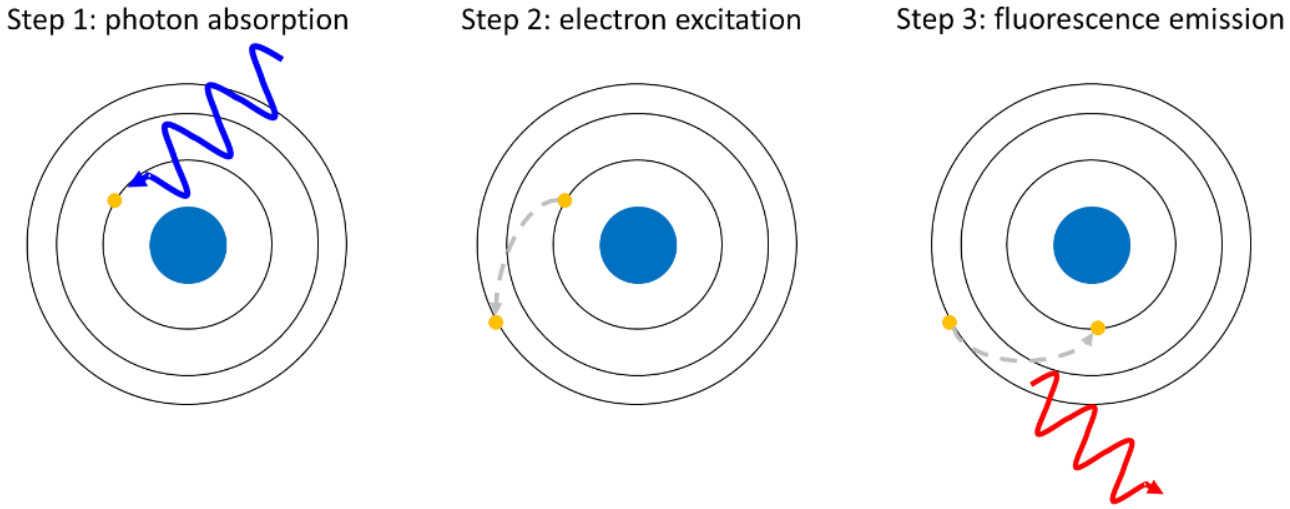
Different types of Luminescence



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Appropriate for students aged between 15-18

Length 60 min

Preparation and introduction: 15-20 minutes

Implementation: 15-20 minutes

Closing: discussion 10-15 minutes

Hypothesis

In nature there are different ways that light can be emitted. There are substances that can emit light chemically, mechanically or by light excitation. If for example we shine light to a chemical substance we can observe its emittance, because its chemical structure changes.

Key vocabulary

Luminescence, photoluminescence, fluorescence emission, inner-filter effect, chemiluminescence, triboluminescence.

Objectives

- ✓ *Identify the different kinds of Luminescence*
- ✓ *Differentiate between the various kinds of Luminescence*
- ✓ *Understand fluorescence emission and inner filter effect*

Equipment and material

No	Material/equipment	Quantity	Role in the experiment	Cost
1	Green laser pointer	1	Light source	10-20€
2	Dye (Coumarin 153 and/or Rhodamine 6G)	50-60μg	Photoluminescence dye	5g Rhodamine 6G = 20-30€ 100mg Coumarin 156 = 40-50€
3	PMMA or polystyrene 1mm cuvetes	2	Containers for the solution	100 cuvettes = 10-15€ Sigma Aldrich price
4	ETOH (ethanol)	4-5 ml	Solvent	200ml of ethanol = 5-10€
5	Glass cup	1	Mechanical tension	
6	Lifesavers mints Wint o green	1	Triboluminescence media	5-10€
7	Glowsticks	1	Chemiluminescence	2-5€
8	syringe	1	Photoluminescence	
9	small spatula	1		
10	10 ml or more flask	1		
Total Cost				50-80€

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Introduction

In nature, we can find various objects that can emit light such as: the sun, different dyes, and other chemicals like luminol, living organisms (fireflies, the fishes in the deep sea and algae) as well as sugar and different ores. During this experience, we will discuss three types of luminesce: photoluminescence, chemiluminescence and triboluminescence.

Photoluminescence is when light energy, or photons, stimulate the emission of a photon and it can be divided into two categories phosphorescence and fluorescence.

In contrast to photoluminescence where the excitation comes from outside media, like a light source in Chemiluminescence the emission comes from electrons that were excited by chemical reactions. Another form of chemiluminescence is bioluminescence and it occurs in living organisms, such as fireflies, some fungi, many marine animals, and bacteria.

Triboluminescence is a phenomenon in which light is generated when a material is mechanically pulled apart, ripped, scratched, crushed, or rubbed. The phenomenon appears to be caused by the separation and reunification of static electrical charges.

For more information about the above processes, read "Introduction to different types of luminescence".

Experiment instructions

General

- Begin the lesson by explaining the purpose of the experiment and the materials that will be used.
- Explain the fundamental theory of Photoluminescence, Chemiluminescence and Triboluminescence
- Proceed to the respective experiments described below.

Steps to follow

Photoluminescence

1	Use the small spatula to collect approx. 10μg of the dye	Prepare the stoke solution for the experiment. Due to the high fluorescence emission, the needed portion of the dye is very low. For safety reasons, gloves are needed.
2	Stock solution preparation	In a flask with 4 ml of ETOH add the dye and mix them until they homogenize to prepare the stoke solution. With the help of a syringe divide the stoke solution into 2 different tubes containing 2ml each. Label the cuvettes as a concentrated diluted and diluted solution.
3	Preparation of concentrated sample	Take the tube labeled as "concentrated" and add 3-5 times the initial amount to create an over-concentrated solution.
4	Laser excitation and fluorescence emission of the diluted sample	With the laser shine the diluted solution to observe the emission and write down your observations.

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5	Laser excitation and fluorescence emission of the concentrated sample	Use the laser and shine the concentrated solution to observe the emission and write down your observations.

Triboluminescence

1	Triboluminescence of the Wint-o Green candy	In a dark room place the Wint-o Green candy on a table and use the glass cup to apply force to it. Capture the light using a cell phone that works well in low light and write down your observation.

Chemiluminescence

1	Break the glowstick	Break down the Glowsticks and write down your observations.

Safety measures

No	Risk	Safety measure
1	Hand protection	Normal latex gloves
2	laser	Avoid eye contact
3	Fluorescence dye	Avoid eye contact and use gloves

Evaluation

- Prepare a lab report making an introduction by explaining the three phenomena of luminescence and describing the experimental steps that were followed.
- Include questions to a short test:
  - On the photoluminescence experiments, what was your observation for the concentrated solution and what was for the diluted solution? What is the phenomenon that describes this outcome?
  - What would you observe if you add NaI or KI on the diluted solution and then shine it with a laser?
  - What is the reason for the triboluminescence of the mint o green candy?
  - What kind of luminescence do you observe from the glowsticks (is it mechanical or chemical)?

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Introduction to different types of luminescence

Introduction

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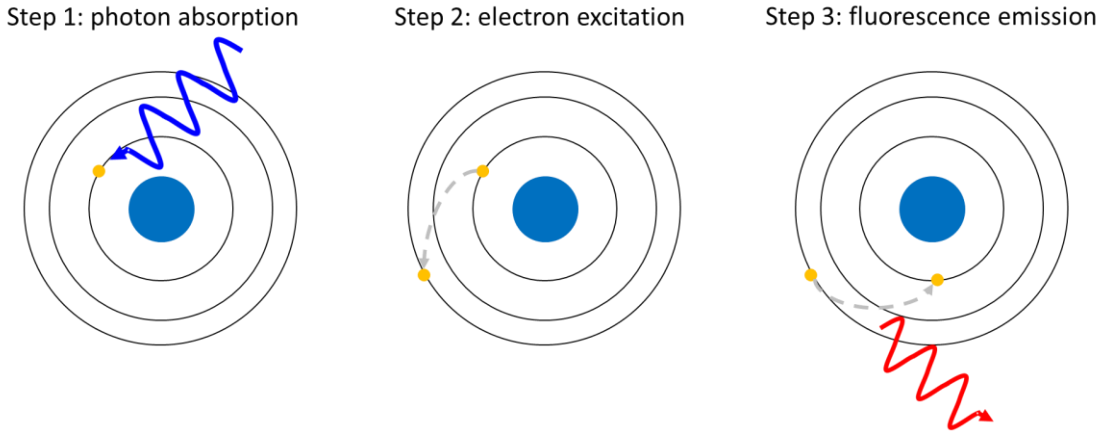

Figure 1. Schematic representation of the fluorescence emission. In the first step, an electron (yellow circle) absorbs a photon (blue arrow), in the second step the electron jumps to a higher energy level and in the third step the electron returns to its initial state by a photon emission (red arrow)

Photoluminescence

Photoluminescence can be divided into two categories phosphorescence and fluorescence. A simplified way to understand the fluorescence, emitted by an object, is to think of it as a three-step process (Figure 1). In the first step a photon is absorbed by an electron of the molecule. This electron becomes excited and jumps into a higher energy level. After some time, the electron falls back to its initial state by emitting a photon, which is the fluorescence. The fluorescence emission is fast and temporary. In contrast, phosphorescence has a similar mechanism, but the emission time is longer; spanning from a few seconds up to a few hours.

Fluorescence emission is an interesting concept in science as it gives a lot of information in many different domains, such as biology and chemistry (in biological or chemical sensors), as well as in industry for the production of LED and fluorescent lamps. When working with fluorescent dyes scientists have to take into account several parameters that can affect the emission; for instance, the concentration of the different compounds can play a significant role.

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Let's take as an example the Rhodamine 6G, which is used in microscopy (fluorescence microscopy, flow cytometry, fluorescence correlation spectroscopy) as a tracer dye. By diluting the Rhodamine 6G into ethanol and using a green laser as an excitation source, a yellow fluorescence emission can be observed. By adding more compounds, thus increasing the concentration the fluorescence becomes higher. This can be seen easily as the emission becomes brighter. However, there is a point when the concentration becomes so high that the molecules of the Rhodamine 6G start to act as a filter and the fluorescence decreases. This kind of situation is the inner-filter effect.

Figure 2. Experimental demonstration of Luminol into hydroperoxide the blue colour comes from the intermediate that emits light in order to stabilize. Taken from Wikipedia

Chemiluminescence

In contrast to photoluminescence where the excitation comes from outside media, like a light source in Chemiluminescence the emission comes from electrons that were excited by chemical reactions. These are usually oxidation–reduction reactions, where a chemical substance interacts with an oxidant creating a radiative reaction intermediate. The latter undergoes into a more stable state by light emission. The general reaction equation is the following:

$$[\mathbf{A}] + [\mathbf{B}] \rightarrow [\text{reaction intermediate}] \rightarrow [\textit{Products}] + \underline{\text{light}}$$

A well-known example is the luminol reaction which is a classic chemistry demonstration of chemiluminescence. In this reaction, luminol reacts with hydrogen peroxide and releases blue light, which can be observed in Figure 2.

Bioluminescence is also a form of chemiluminescence that occurs in living organisms, such as fireflies, some fungi, many marine animals, and bacteria. Most bioluminescence is a result of a chemical reaction between the enzyme luciferase and the luminescent pigment luciferin, which gives a green colour. Organisms use

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bioluminescent reactions for a variety of purposes, including prey luring, warning, mate attraction, camouflage, and illuminating their environment.

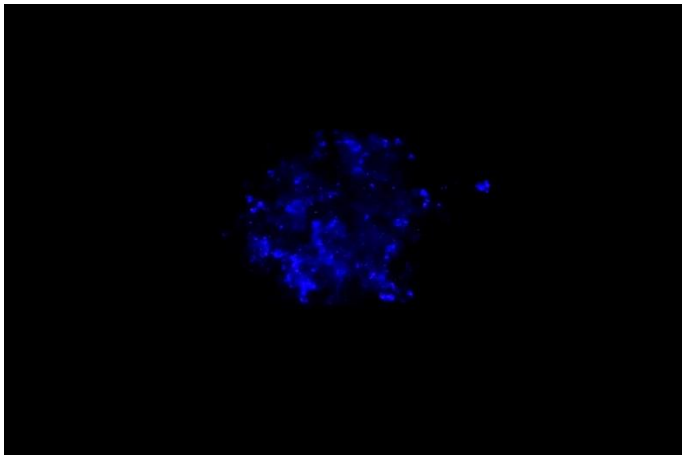

Figure 3. Triboluminescence coming from L-Nicotinsalicylat. *Taken by Wikipedia*

Triboluminescence

Finally, Triboluminescence is a phenomenon in which light is generated when a material is mechanically pulled apart, ripped, scratched, crushed, or rubbed. The phenomenon appears to be caused by the separation and reunification of static electrical charges. Some of the well-known experiments demonstrating this phenomenon can be observed when breaking sugar crystals or peeling adhesive tapes. It is also believed that the light results from the recombination of electrical charges after the fraction of the crystal structure. When the charges get back together, the air is ionized, producing a flash of light.

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