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Study of Properties of Light and Observations of Various Spectra with a Home-Made Spectroscope

Mireia Díaz-Lobo*, Josep M. Fernández-Novell

Department of Biochemistry and Molecular Biology, Faculty of Biology,
University of Barcelona, Barcelona, Spain
mireiadiaz02@yahoo.es

Abstract: *The article introduces didactic experiments related to light properties which could be easily adapted to any educational level, from school to University, and even explains how to make a spectroscope with enough revolving power to observe and deeply study spectra of various sources of light. Furthermore, through of these experiments, teachers could introduce different relevant concepts about flame and visible spectroscopy, which are included in the curriculum of physical chemistry subject, depend on the educational level. Moreover, each of these didactic experiments is about the most important properties of light such as reflection, refraction, diffraction and colours, and two relevant techniques in chemistry such as flame spectroscopy (concretely, atomic emission spectroscopy) and visible spectroscopy for studying some ionic salts and sources of light which are around us, respectively. In addition, all the activities, described in this work, could be performed in both university and school laboratories because they only need basic materials and common chemical compounds. An effective way to consolidate and integrate the knowledge that students receive in theoretical classes is that students perform educational practices such as didactic experiments during their school period and also University courses.*

Keywords: *Didactic experiments, educational tools, light properties and spectroscopy.*

1. INTRODUCTION

There is growing interest among most scientist, science educators and teacher community to include practical lessons and laboratory experiments as active learning approaches, which allow students to appreciate how primary evidence is used to construct scientific knowledge [1-4]. Additionally, our teaching experiences suggest that an effective way to consolidate and integrate the knowledge that students receive in theoretical classes is that students perform educational practices such as didactic experiments during their school period and also University courses [3-4]. Furthermore, our educational experiences also propose that didactic experiments are an effective pedagogical tool to offer evidence-based science instruction to students, and, at the same time, students could acquire a wide and profound theoretical knowledge base [3-4].

One of the most challenges in the education world is capture the attention of students during theoretical classrooms, specially, when they are not motivated [5-8] because they find that physical chemistry is one of the most boring and complex subjects in school and even at University [9-11]. An excellent way to motivate students and capture their attention is that they could perform practicals, appropriate to the educational level, since they could observe the chemical and physical concepts introduced in the classrooms by themselves [12-13]. Through laboratory experiments, students not only easily acquire basic science vocabulary but also learn to both interpret and discuss chemical phenomena at adequate and acceptable level [14-16]. When students do practicals in group they could discuss experimental procedures and results of experiments in a pleasant atmosphere and, simultaneously, learn how to communicate their ideas and doubts with other members of the group, focus on solving questions and develop social skills such as teamwork, tolerance and respect for the opinion of others [17-19].

The objective of the present contribution is to describe some laboratory experiments related to light properties using common chemical substances to offer teaching tools to science teachers that allow them to introduce their students, from all educational levels, into the world of physical chemistry and increase their interest in this science. Moreover, each of these didactic experiments is about the most important properties of light such as reflection, refraction, diffraction and colours, and two relevant techniques in chemistry such as flame spectroscopy (concretely, atomic emission spectroscopy) and visible spectroscopy for studying some ionic salts and sources of light, which are around us, respectively. Therefore, each didactic experiment introduces different relevant concepts which are included in the curriculum of physical chemistry subject in Spain [20]. Furthermore, these practicals present a high versatility because they could be adapted perfectly to science school students and University students depending on the depth of the concepts and explanation given to them and the chemicals used to perform the practicals. This work even explains how to make a spectroscope with enough revolving power to observe and deeply study spectra of various sources of light. On top of that, the experiments described in this work demand both common and basic material resources thus a broad spectrum of science teachers and academic institutions could perform them in school and University laboratories.

2. Light and its Properties

Light is a radiation that propagates in form of waves. More specifically, light is an electromagnetic radiation that propagates in the vacuum at a speed of 300,000 km/h, which is known as "the speed of light in vacuum" and symbolized by the letter c (c = 300000 km/h). In any other medium, the speed of light is lower than in vacuum. The energy carried by an electromagnetic wave is proportional to its frequency, so the higher is the frequency of the wave, the greater is its power. Therefore, electromagnetic waves are classified according to their frequencies (Fig. 1) [21].

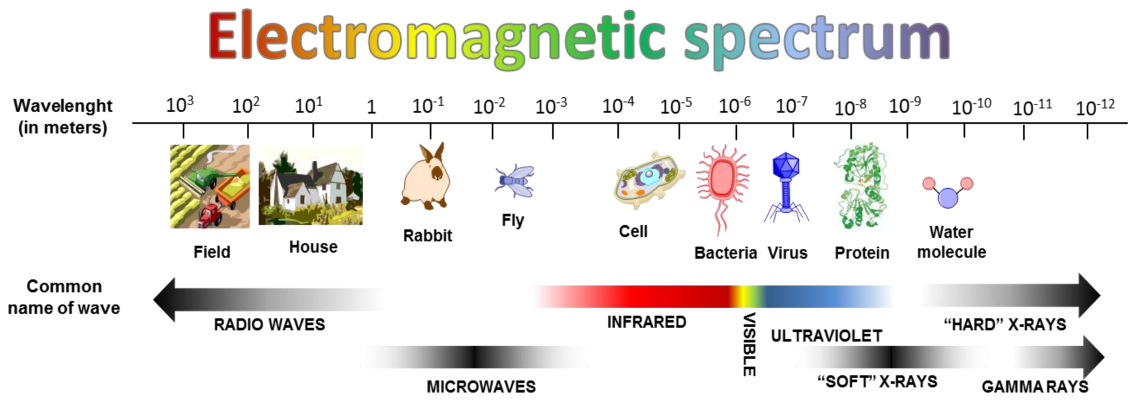

Fig1. *Classification of electromagnetic waves depending on their frequencies.*

Light could also be defined as the visible radiation of the electromagnetic spectrum that the human eye can capture. Light has three characteristic properties. Firstly, it propagates in a straight line (Fig. 2D). Secondly, it reflects when it reaches a reflective surface (reflection, Fig. 2A) and, thirdly, it changes its direction when it passes from a medium to another one (refraction, Fig. 3) [22].

2.1. Reflection

Reflection is the change of direction experienced by a light beam when it impacts on the surface of bodies [23-24]. The reflection of light is represented by two beams: the beam which reaches the surface, incident beam, and the beam which is "rebounded" after being reflected, reflected beam (Fig. 2A). Normal line is a straight line perpendicular to the surface. The incident beam forms an angle with the normal which is called angle of incidence. There are two laws of reflection. The first law is that the incident beam, reflected beam and the normal are in the same plane, and, the second law is that the angle of incidence and angle of reflection are equal (Fig. 2A) [23-24]. We can see objects around us because the light reflected in them are captured by our eyes. There are two types of light reflection: specular reflection and diffuse reflection. Specular reflection occurs when the surface is smooth and shiny (mirror, calm water) and all the reflected beams go in the same direction because of reflecting at the same angle. Diffuse reflection occurs when the surface is rough and reflected beams go in all directions [23-24]. We perceive objects and their shapes due to the diffuse reflection of light on their surfaces.

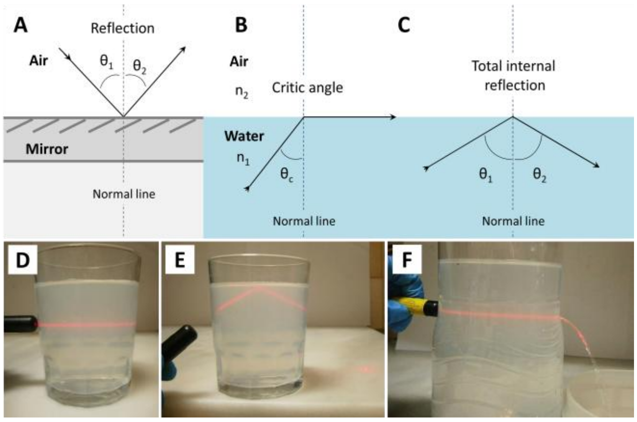

Fig2. *Scheme of the phenomena of (A) reflection of light, (B) critic angle and (C) total internal reflection. (D) Light propagates in straight line. (E) Laser beam that has a total internal reflection. (F) Laser beam suffers a total internal reflection inside of the stream of water and, consequently, it does not go outside.*

A didactic experiment, that allows us to study the different properties of light, could be performed using a glass filled of water with a few drops of milk and a laser. The drops of milk permit to observe the beam of the laser in the liquid. When the beam of the laser is into the liquid, it is easy to see that it propagates in a straight line (Fig. 2D). If the beam laser is pointed from one of the lateral wall of glass (in a level lower than the level of the liquid) to up, it is possible to observe the phenomenon of total internal reflection of the beam (Fig. 2E). This phenomenon occurs when the incident angle of a light beam, which reaches the surface of separation of two mediums of different values of refractive index, is higher than a certain value, called critic angle (θ_c, Fig 2B), and if the light beams pass from a medium with a high refractive index (such as water) to a medium with a low reflective index (such as air) (Fig. 2C). In that experiment it could be seen how the beam of the laser is reflected on the surface of the liquid and goes again into the liquid (Fig. 2E). Changing the orientation of the laser, it could observe that the angle of the incident beam with the surface of the liquid is equal than the angle of the reflected beam with the same surface (Fig. 2C).

The following didactic experiment is also related to the phenomenon of total internal reflexion and helps to explain, at the same time, the fundamental principle of the optic fibre (Fig. 2F). A hole of 2 mm of diameter is done, in a lateral of a plastic bottle, with a needle to 10.5 cm of the base. The bottle is filled with water and few drops of milk. Next to the bottle, a recipient is placed to collect the stream of water that goes outside from the hole. The laser beam is pointed to the opposite extreme of the hole, at the same level of it, because the laser beam passes through the hole. The laser beam follows the way of the stream of water instead of going in a straight direction. Laser beam has a total internal reflection inside of the stream of water and, consequently, it rebounds in water and does not go outside (Fig. 2F). Total internal reflection is a curious phenomenon that occurs when light travels from a dense medium to a less dense one, for instance, from water to air. Rays of light at angles of incidence larger than the critical angle do not transmitted to air at all, but reflected back into the first medium, water (Fig. 2C) [25-26]. This is the fundamental principle of the optic fibre. When light traveling in an optically dense medium (optic fibre) hits a boundary at a steep angle (an angle larger than the critical angle for the boundary), the light is completely reflected (total internal reflection phenomenon). This effect is used in optical fibers to confine light in the core and transmit light waves undiminished over large distances [27].

2.2. Refraction

Refraction is the change of direction experienced by a light beam when it passes from one medium to another medium in which propagates with different speed (Fig. 3A) [23-24]. For example, when light passes from air to water, light is deflected. A clear example of refraction can be observed by placing a pencil in a glass of water. It seems that the pencil (Fig. 3B and 3C) is broken, but it is clearly known that does not happen. This phenomenon is produced by the reflection of light passing from a gaseous medium to a liquid medium. There are two fundamental laws of refraction. The first law is that the refracted beam, the incident beam and normal line are in the same plane. The second law is the refracted beam approaches normal line when it passes from a medium in which propagates faster to another in which propagates slower. Conversely, it departs from the normal line when it moves to a medium in which it propagates faster [23-24]. The relationship between the speed of light in vacuum and in a medium which can be propagated is called the refractive index of this medium [27].

An educational experiment that helps explain the phenomenon of refraction is both a trick and an optical illusion. A coin is put on a flat surface. On top of this coin, a vessel is placed on it (Fig. 3F). The coin is still watching. If the vessel is filled with water, and we look from one side of the vessel, we could not see the coin, giving the optical illusion that the coin has disappeared (Figure 3G). In fact, the light reflected on the surface of this coin is deviated every time it changes the environment. Therefore, in this case, the light refracts two times because it pass from the glass to the water and, later, from the water to the air. Therefore, light beams from the coin suffer two successive refractions and they are not able to reach our eyes creating the optical illusion that the coin disappears when we look from one side of the vessel (Fig. 3G), but if we look from the top, we can see the coin without any difficulty since the light that incidents perpendicular to the surface of separation of two media does not suffer deviation.

However, if the coin is placed inside the vessel (Fig. 3H) and we fill the vessel with water we continue watching the coin (Fig. 3I). The light reflected in the coin deviates when it passes from water to air (there is one refraction), but it is able to reach our eyes and we can still see the coin.

Finally, a sophisticate experiment about diffraction could be done only with a laser, a one-slit and two-slit diffraction grating. Fig. 3D and Fig. 3E show a single-slit diffraction and a double-slit diffraction, respectively. This experiment allows students to observe that an inverse relation exists between the separation of the points of diffraction and the distance between the slits of the diffraction grating. The largest is the distance between the slits of the diffraction grating, the closer appear the points of diffraction (Experiment of the double-slit diffraction grating of Young) [28].

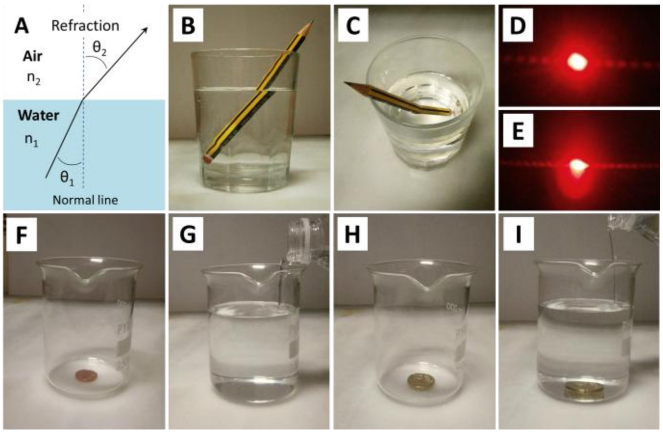

Fig3. *(A) Scheme of the phenomena of refraction of light. (B and C) If a pencil is placed in a glass of water, the pencil seems to be broken. (D) Single-slit diffraction of a laser beam. (E) Double-slit diffraction of a laser beam. (F) A vessel is placed on the top of the coin. (G) When the vessel is filled with water, the light reflected on the surface of the coin suffers two successive refractions and it does not reach our eyes, creating the optical illusion that the coin disappears. (H) A coin is placed inside a vessel. (I) If the vessel is full of water, the light from the coin suffers only one refraction and it is able to reach our eyes.*

3. SPECTROSCOPY

Spectroscopy is a field of science which studies the interactions of electromagnetic radiation (light) with the matter. Among the phenomena that occur in these interactions are the absorption, emission and scattering of light by matter [28]. Historically, spectroscopy originated through the study of visible light dispersed according to its wavelength, by a prism. White light is a mixture of colours, if a beam of white light passes through a scattering medium, such as a prism, the colours are separated because they have different refractive indexes, different wavelengths. Therefore, white light is split into beams of different colours that deviate differently when they refracted. The least deviates from the incident angle is red, followed by orange, then yellow, green, blue and finally violet, which is the most commonly diverted. In this way, a set of colours called optical spectrum is obtained. This phenomenon shows that white light is composed of all colours of the spectrum. Later the concept of spectroscopy was expanded greatly to comprise any interaction with radiative energy as a function of its wavelength or frequency. Spectroscopy is a sufficiently broad field that many sub-disciplines exist, each with numerous implementations of specific spectroscopic techniques. Some of the most important spectroscopy types are absorption, fluorescence, X-ray, flame (atomic emission and atomic absorption), visible, ultraviolet, infrared, Raman and resonance magnetic nuclear spectroscopy [29].

Spectroscopy has applications in all fields of chemistry. It allows the determination of angles, length of bonds, conformations and vibrational frequencies of molecules. Organic chemistry uses magnetic resonance spectroscopy to determine the structure of organic compounds. Kinetic spectroscopic methods are used in order to know the variation of reagent or product in time. Analytical chemistry uses spectroscopy to determine the composition of a sample. Even it is possible to know the composition of distant stars and planets by studying the light that reaches to us [28].

3.1. Flame Spectroscopy

Both atomic absorption spectroscopy and atomic emission spectroscopy involve visible and ultraviolet light. These absorptions and emissions, often referred to as atomic spectral lines, are due to electronic transitions of outer shell electrons as they rise and fall from one electron orbit to another. Flame spectroscopy, also known as atomic spectroscopy, was the first application of spectroscopy developed [30].

An excellent experiment related to the emission of colours is the flame spectroscopy. This method uses flame excitation; atoms are excited from the heat of the flame to emit light. The flame spectroscopy can be carried out in the laboratory relative easy, just having a Bunsen burner or an alcohol lamp and different aqueous solutions of various metals. When a solution of $FeCl_3$ is burn, an orange flame with sparks is obtained (Fig 4A). A solution of CuCl generates an intense green flame (Fig. 4B); a LiCl solution, a reddish flame (Fig. 4C); a NaCl solution, an orange flame (Fig. 4D); a $MgCl_2$ solution, a flame red with sparks (Fig. 4E) and an H_3BO_3 solution, a flame with blue base because of Boron (Fig. 4F).

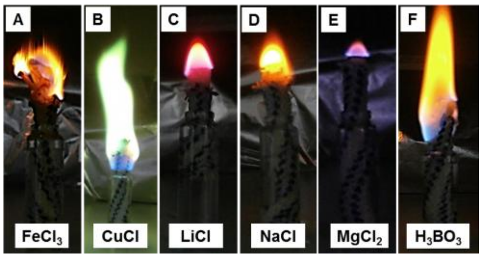

Fig4. *Emission spectra of aqueous solutions of $FeCl_3$ (A),CuCl (B), LiCl (C), NaCl (D), $MgCl_2$ (E) , H_3BO_3 (F).*

3.2. Visible Spectroscopy

Visible spectroscopy studies the decomposition of visible light into beams of different colours, in other words, into beams of different wavelengths. This technique is used in physical and analytical chemistry because each type of atom and molecule has unique spectrum. As a result, these spectra can be used to detect, identify and quantify the amount of atoms and molecules which are presented in samples. Visible spectroscopy is also used in astronomy and remote sensing on earth. Most research telescopes have spectrographs. The measured spectra are used to determine the chemical composition and physical properties of astronomical objects (such as their temperature and velocity) [28-29].

An exelent educational practical is building a home-made diffraction spectroscope which allows studying flame emissions of ionic compounds and sources of light which are around us. This work explains how a simple diffraction spectroscope by transmission could be built from a CD and a box (Fig. 5). It is a simple spectroscope for its optics because it does not have collimator lens and a focus ring. Although this spectroscope is not strictly a scientific instrument because we could not be able to measure the angles of diffraction with it, this home-made spectroscope is effective enough to observe the Fraunhofer absorption lines of sunlight, the emission lines of various light sources that are surround us in our day to day, such as the spectrum of a halogen bulb, a blue halogen bulb which is used to study in libraries, an energy-saving bulb, a fluorescent lamp, a TV screen and a LED screen of a laptop and the light emitted by some of the ionic salts mentioned before like NaCl, LiCl and CuCl. Obviously, the educational power of this spectroscope goes beyond a simple practical realization. The home-made spectroscope is formed by three parts: the network of diffraction, the mask with a narrow slit (diffraction grating) and the body (admission and ocular tubes) (Fig. 5A). The diffraction network is obtained from a CD (Fig. 5G). A CD is engraved with a spiral groove of 0.6 microns wide with a groove and groove spacing of 1.6 microns. The presence of the spiral groove makes the CD an excellent diffraction network readily available. To obtain a good direction network, firstly, the platinum layer of the CD should be removed trying to not scratch the surface of the transparent polycarbonate layer. A square of 33 x 33 mm is cut from the CD (Fig. 5H).

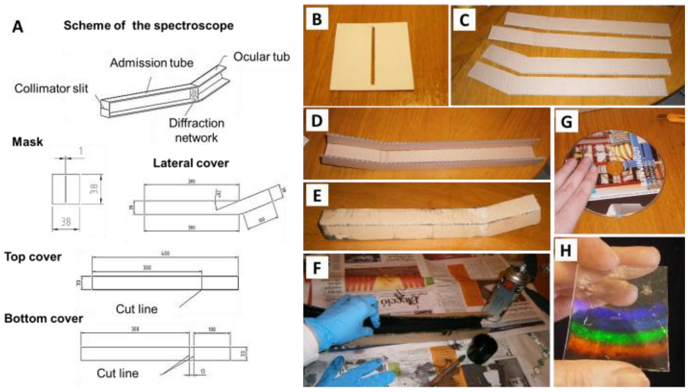

Fig5. *Home-made spectroscope made from a CD. (A) Scheme of the various components that make up the body of the spectroscope. (B) Mask with a narrow slit (diffraction grating). (C) Top cover, bottom cover and lateral covers. (D) Assembling the lateral covers to the bottom cover. (E) Mounting the top cover. (F) To avoid internal reflections in the admission and ocular tubes, the interior walls are painted in black colour. (G) Diffraction network is obtained from a CD. (H) Part of a CD, without the platinum layer, that shows some coloured bands in form of a fan due to the circular scratch (spiral) of the CD.*

The mask with a narrow slit (diffraction grating) is a square of 38 x 38 mm and the slit is 1 x 33 mm (Fig. 5A and 5B). The mask is made with a cardboard of 1 mm of thick. The collimator slit has to be parallel to the spiral groove of the CD. This gives a long rainbow instead of a narrow one. The diffraction network shows bands in form of a fan due to the circular scratch (spiral) of the CD (Fig 5H). Moreover, the diffraction network should be placed in the spectroscope with the widest part of the fan down in order to see the largest rainbow that it could generate. The purpose of the mask with the slit is to avoid diffuse light and permit passage a narrow beam of light parallel to the diffraction network, therefore, the mask with the slit acts as a collimator (collimator slit). This greatly improves the spectrum produced by the network diffraction. The distance between the collimator slit and the diffraction network is 300 mm, which is the focal length of a normal eye (Fig 5A). This distance determines the length of the admission tube.

The body of the spectroscope (admission and ocular tubes) is made with cardboard of 2 mm of thick. To determine the angle of the ocular tube with respect to the admission tube, it is necessary to use the mathematic formulas of the phenomenon of diffraction, wherein the diffraction angle is determined by the average value of the angles of diffraction of the wavelengths at the ends of the visible spectrum. The Equation 1 defines the diffraction angle (θ) that suffers a beam of light passing through a diffraction grating:

$$Sin\ (\theta) = m \times \lambda / d \qquad (1)$$

Where θ is the angle of diffraction with respect to the optical axis, λ is the wavelength radiation (light), d is the constant grating (spacing between line and line of the network) and m is the order of diffraction. In that case, it is the first order, $m = 1$, to obtain a bright spectrum instead of resolution. The visible spectrum is between the wavelengths of 0.4 µm (for purple colour) to 0.7 µm (for red colour).The diffraction network fabricated from a CD has a constant grating of 1.6 microns, which correspond to 625 lines per millimetre. With these values of wavelength, constant of the diffraction network and the diffraction order is the first order, it could determine the angles of diffraction for the two colours of the extremes of the rainbow. For the purple colour the θ is 14.5° and for the red colour the θ is 25.9°. The average angle between the two colours determines the inclination or angle of the ocular tube with respect to the admission tube. The average angle is 20.2°, this corresponds approximately to the angle of the yellow colour. The length of the ocular tube is determined by the width of the rainbow to be achieved. In this spectroscope, the width of the rainbow observed is 20 mm. The value of dispersion that allows the diffraction network for both extremes of the visible spectrum is 11.4° (angle of the red colour minus the angle of the purple colour). Therefore, the length of the ocular tube is 100 mm (Fig. 5A). With all this information, templates for each part of the spectroscope could be made. The lines specified as "cut lines" in the scheme of Fig. 5 indicates the places where it has to make a shallow cut, without cross the board, of 1mm of depth to allow folding top cover and bottom cover according the contour of the lateral covers. Fig. 5 shows the procedure of assembling the home-made spectroscope. In order to avoid internal reflections in both the admission and ocular tubes, the interior walls are painted in black colour.

3.2.1 Study of the solar spectrum

The solar spectrum is not continuous and has some dark bands, called Fraunhofer bands (Fig. 6). It is possible to count 6 defined lines and 8 weak lines because of the moderate resolving power of the home-made spectroscope. The Fraunhofer bands, which are perfectly defined and could be observed, are the C band in dark red (H-alpha, 656 nm), 'a' in red (molecular oxygen in Earth atmosphere), D in orange (Na, 589 nm), E in green (Fe, 527 nm), b1 and b2 also in green (Mg, 518 nm), F in blue (H-beta, 486 nm) and G in purple (Fe and Ca, 431 nm) (Fig. 6A) [31]. H-alpha and H-beta are a specific deep-red line and a blue visible spectral line, respectively, created by hydrogen, which occurs when a hydrogen electron falls from its third to second lowest energy level (H-alpha) or its fourth to second lowest energy level (H-beta). The Sun is composed mainly of hydrogen. So it might think that the light that comes from the Sun would be formed by very few types of photons (the characteristic photons of the emission spectrum of hydrogen). But in fact, the spectrum of sunlight is almost continuous. Its continuity is because very hot bodies, such as Sun, usually produce all types of radiation. The fact that the solar spectrum is nearly continuous and not completely continuous has also another explanation. In the solar and the Earth atmosphere there are chemical compounds, even in small concentrations, that absorb part of the radiation from the Sun. These elements are the O_2, H_2, Na, Fe, Ca and Mg. They act as a filter. For this reason, when the spectrum of sunlight is registered at high resolution, numerous black lines (hundreds of them) are observed [31]. As mentioned above, these lines are called Fraunhofer in honour of the scientist Joseph Fraunhofer (1787-1826) that investigated them in depth for the first time two hundred years ago [32].

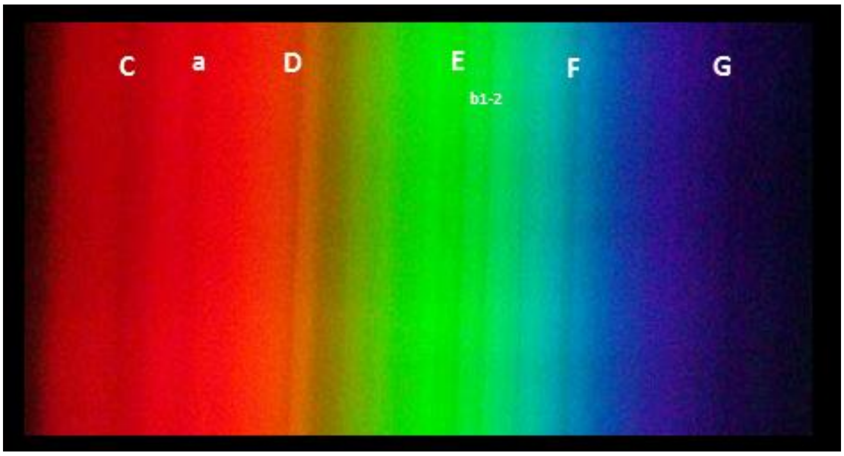

Fig6. *Photograph of the spectrum of sunlight*

3.2.2 Study of spectra of various sources of light

The spectrum of an incandescent bulb is continuous because it is a heated solid (a tungsten filament). The incandescent solids always have a continuous spectrum without emission and absorption bands (Fig. 7A). The spectrum of a blue incandescent bulb has two very intense blue bands and at the back there is a continuous spectrum because of the incandescent material which is formed (Fig. 7B). Candle light has as well a continuous spectrum (Fig. 7C). In the first few seconds after a candle (or a match) is lit, there is also the yellow sodium lines which disappears thereafter. If table salt is burnt, the two yellow sodium lines become prominent. This is a famous sodium doublet, two closely located lines, which comes from sodium (Na) emission. When a solution of LiCl is burnt with a candle, its emission spectrum presents an intense yellow band and bright red band (Fig. 7E) on a continuous background due to the candle light. However, if a solution of CuCl is burnt with a candle, the emission espectrum of CuCl is enoght intense to observe different bands in the blue, green and red region, but not the continuous spectrum of the candle light (Fig. 7F).The spectrum of an energy-saving bulb presents four bright bands. Concretely, it emits a purple (in the picture it is blue), an indigo, a green and a red line. In principle depend on the emission bands we could tell of which gas is made an energy-saving bulb (Fig. 7G). Fluorescent light has mercury gas emitting mostly ultraviolet light, which activates phosphor. The latter of the fluorescent emits broad band visible light. Therefore the spectrum of a fluorescent has bright mercury spectrum lines, most obviously green 546 nm, on a continuous background (Fig. 7H). It should be point out that the spectrum of an energy-saving bulb and fluorescent lamp are similar and the mixture of colours gives a sense that they emit white light. The spectrum of a white screen of TV (Fig. 7I) and computer display (Fig. 7J) have three bright bands in blue, green and red. The monitors of televisions and computers form colours combining three emitters that emit red, green and blue colours. It could easily check looking the screen with a magnifying glass and observe three small red, green and blue lights for each pixel of the screen. While red LED emits continuous spectrum in red (Fig. 7K), neon bulb has many red and orange discrete bright spectrum lines (Fig. 7L).

Human eye has two types of stem cells sensitive to light (called photoreceptors): rods and cones. Cones are responsible for providing information about colour. To find out how colour is perceived, it has to take account that there are three types of cones with different frequency responses, which have maximum sensitivity to red, green and blue colour. The cones that perceive green and red colour have a similar sensitivity curve, however, the response to blue colour is 20-fold lower than the response for the other two colours. The sensation of colour could be defined as the response of each curves of sensitivity in front of a spectrum radiated by the object observed. Therefore, human eye has three different answers, one for each colour. Combining these three colours, human brain assigns the whole rainbow.

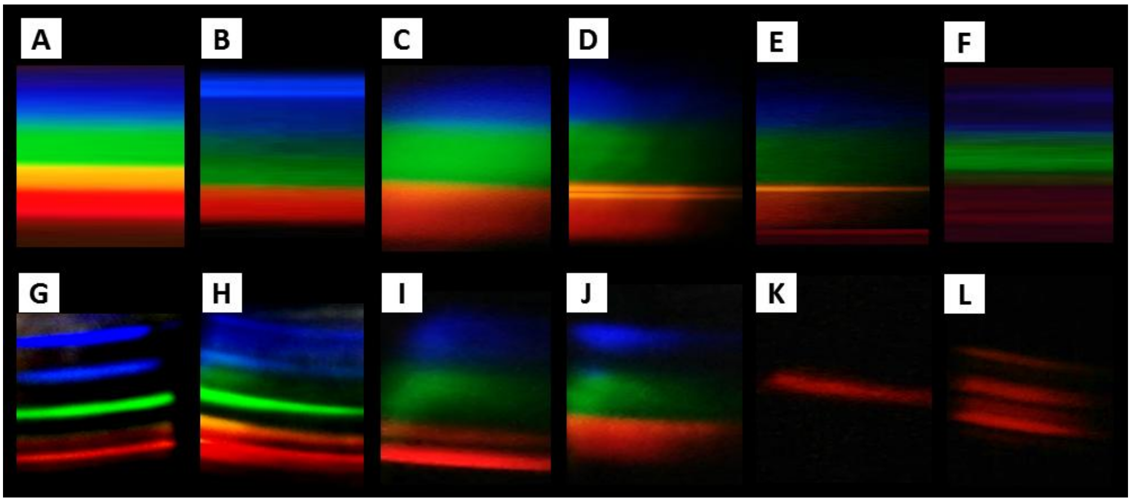

Fig7. *Photographs of the spectrum of an incandescent bulb (A), a blue incandescent bulb (B),a candle (C), a candle with table salt (NaCl) (D), a LiCl aqueous solution (E), a CuCl aqueous solution (F), an energy-saving bulb (G), a fluorescent lamp (H), a white screen on a TV monitor (I), a white screen on a laptop display (J), a red LED (K) and a neon bulb (L).*

4. Conclusions

There are a number of practical benefits of using educational experiments as didactic tools. Firstly, when science teacher explain experiments step by step and help students to perform them, these experiments become clear to the students because scientific concepts and techniques are gradually introduced. Therefore, students improve their understanding of theoretical knowledge through experimentation [33-35]. Secondly, after performing the practicals, students gain confidence in their ability and are also capable of arguing the experiments rationally, creating valid conclusions, and also employing the scientific techniques and methods they study to hypothetical situations involving scientific research. Finally, if students do experiments in groups, they could develop soft skills such as teamwork, problem solving and communications, which are essential skills in the students' future [36-38].

Moreover, most of these experiments can be performed using both basic equipment and chemicals, helping science teachers implement practicals that have all the characteristics of excellent classroom demonstrations because of their high degree of safety, visual interest, relative simplicity and ready availability of materials. Besides, these experiments can be related, according to educational level, with: the principle properties of light such as reflection, refraction, diffraction and colours, and two relevant techniques in chemistry such as flame spectroscopy (concretely, atomic emission spectroscopy) and visible spectroscopy for studying some essential salts and sources of light which are around us, respectively.

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AUTHOR'S BIOGRAPHY

Mireia Díaz-Lobo received her B.S. degree in Chemistry from Faculty of Chemistry at University of Barcelona and Ph. D. degree in Biochemistry from Faculty of Biology at University of Barcelona. She is currently working on chemical research. She is involved in the divulgation of chemistry among both young and adult people performing didactic experiments.

Josep Maria Fernández-Novell received his B.S degree and Ph. D. degree from Faculty of Chemistry at University of Barcelona. He is professor at the Dept. of Biochemistry and Molecular Biology of University of Barcelona. One of his priorities is the divulgation of chemistry and science in general, through didactic experiments.