Student's Card **Pyrotechnics lab experiences with CRMs**

Module 1

Objective: Luminescence colour effect

Introduction

Pyrotechnics is the science and craft of using materials capable of experiencing self-contained and self-sustaining exothermic chemical reactions to produce heat, light, gas, smoke and/or sound. The most important feature of this lab experience is the production of colour. It can be generated by two phenomena: luminescence and incandescence.

Pyrotechnics take place due to chemical reactions that occur inside the pyrotechnic devices. In most cases, they give rise to the following effects: flames, smoke and sparks. In certain pyrotechnic devices, there are also controlled explosive reactions that trigger another typical effect, the explosion.

Pyrotechnics are based on the chemical reactions of reduction and oxidation (redox reactions) produced between oxygen and fuels. A redox reaction consists of a chemical reaction in which there is an exchange of electrons. One substance loses electrons and is oxidized (in this case, fuel) and another substance gains electrons and is reduced (oxygen). For this reaction to take place, it requires four elements that are known as the tetrahedron of fire:

- Fuel (reducing agent): They represent the fuel of combustion and react with the oxygen released by oxidants, producing enormous amounts of gas at elevated temperatures.
- Oxidizer (oxidizing agent): Usually oxygen.
- Heat: Fuel activation energy.
- Chain reaction: the process that allows the progress of the mixture-fuel reaction.

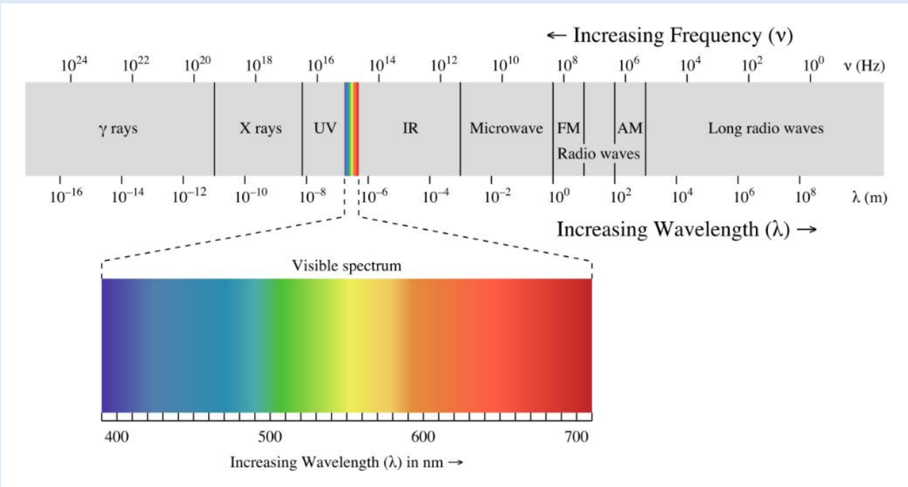
In the reduction and oxidation reactions, several levels are differentiated depending on the energy released and the speed of the reaction: combustion, deflagration and detonation.

Apart from these basic substances of pyrotechnic compositions, other complements that modify the characteristics of combustion are added to the mixtures. Focusing on visual effects, salts and metallic elements are the elements which, at a specific reaction temperature, will give rise to effects as striking as those that will be appreciated in lab practice. Depending on the element(s) added to the combustion reaction, a specific colour can be obtained.

The two phenomena that produce impressive visual effects in pyrotechnics are incandescence and luminescence.

- Incandescence: generation of coloured light due to the heat energy from the elements subjected to the reaction. When the emitting body reaches a certain temperature, it emits radiation that, within the visible spectrum and an adequate wavelength, gives rise to the emission of light of the desired colour. It starts with the red colour from the infrared range, and as the temperature rises, it adopts more yellowish colours, until it reaches white. This phenomenon only achieves warm colours. The rationale behind this is when the white colour is obtained due to the high temperatures, the compound starts disintegrating.

- Luminescence: A chemical process by which the electrons of heat-producing metal cations are excited by receiving a large amount of energy. These electrons reach a higher energy level. Since they are not stable at that energy level, they return to their ground state, emitting energy in the form of photons with a colour spectrum characteristic of each element called the emission spectrum. The larger the energy jump, the cooler the colours emitted. The phenomenon can emit coloured light at both high and low temperatures, thus achieving all the colours of the visible spectrum depending on the wavelength of the emitted radiation.



The previous theorical activity cannot be carried on a school laboratory because of the complexity of working with gunpowder, the equipment required and the high risk of deflagration. For this reason, the laboratory procedure will consist only in a more controlled combustion of solutions.

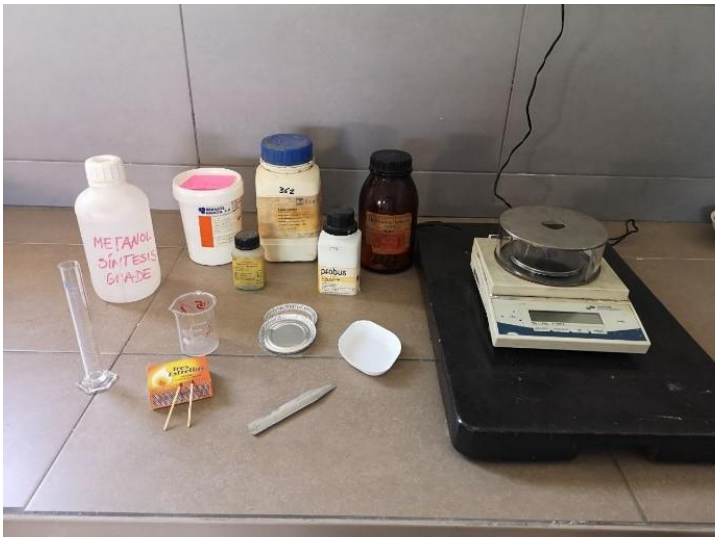
Student's Card **Pyrotechnics lab experiences with CRMs**

Necessities

Reagents	Formula		Quantity
Boric acid	H_3BO_3		2 g
Potassium hydroxide	KOH		3 g
Copper(II) chloride	$CuCl_2$		2.5 g
Lithium chloride	LiCl		2 g
Sodium bicarbonate	$NaHCO_3$		3.5 g
Methanol (methyl alcohol)	CH_3OH		5 x 8 mL

List of materials/tools

- Latex and fire-resistant gloves, safety glasses, lab coat
- Weighing scale
- Spatula
- Test tube
- Beaker
- Aluminium container
- Matches



Student's Card Pyrotechnics lab experiences with CRMs

Procedure

- First, get and measure each element on the weighing scale, using separate containers for each substance, as it is shown in the photo. For this step, tare the weighing scale with a plastic container. Then, with a spatula, pour the approximate amount of the solutes indicated in the initial table.

- For safety reasons, the following steps must be done only for one substance and then repeat the procedure for the other ones.
  - Get 8 mL of methanol measured in a test tube for each substance.
  - Once the solute and solvent are prepared with the required amount, both must be blended in a beaker. The solution will not be completely homogenous, except for copper chloride and the sodium bicarbonate solutions.
  - Afterwards, fill the aluminium container with the solution and move it to a fire-resistant surface.
  - Light the solution with a match and record the colour observed.

Student's Card **Pyrotechnics lab experiences with CRMs**

Additional Safety Notes

- All experiments must be performed by and under the supervision of an adult.
- Use appropriate protective clothing: safety glasses, lab coat, latex gloves during the solutions preparation and fire-resistant gloves during ignition and combustion.
- Methanol is very flammable and toxic, so avoid contact (skin, eyes and clothes) and do not inhale it. The solution should always be ignited on a fire-resistant surface.
- It is safer to burn each substance solution individually, rather than all of them at once.

Conclusions

These experiments demonstrate the capacity of the valence electrons of atoms to absorb energy and emit it in the form of electromagnetic radiation when they return to their ground state, at wavelengths (colours) specific to each element, corresponding to their electromagnetic emission spectra.

The different colours obtained in fireworks are based on the same principle, although using a different ignition source, as well as emergency flares.

Similarly, in astronomy, the colours of the stars also indicate the elements in their photosphere, which are classified according to their spectrum into seven different types.

Questions/Quiz

Q1) Can an incandescent phenomenon generate cold colours?

Q2) What is the difference between deflagration and combustion?

Student's Card Pyrotechnics lab experiences with CRMs

Q3) Which is the main element of the black powder?

Q4) Which four elements are needed to make a pyrotechnic reaction?

Q5) What colour is the most difficult to produce in a pyrotechnic reaction?

Q6) Why do we use methanol?

Q7) What colour produces copper chloride?

Q8) Match the element with the colour that produces.

1. Boric acid	a. Blue
2. Copper chloride	b. Pink
3. Lithium chloride	c. Orange
4. Sodium bicarbonate	d. Magenta
5. Potassium hydroxide	e. Green

EIT RawMaterials is supported by the EIT, a body of the European Union