A large, semi-transparent watermark of the Hogwarts crest is centered on the page. The crest features a shield with a lion, a unicorn, a eagle, and a snake, surrounded by the text 'HOGWARTS' at the top and 'DORMIENS SUAVITER MORIANTUR' at the bottom. The background is a soft-focus image of the Hogwarts castle.

**PHYSICS & CHEMISTRY
VERSUS ALCHEMY**
**Under Harry Potter's
cloak**

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SCIENCE ON STAGE

SUMMARY MEMORY

INTRODUCTION:

My name is Nuria Muñoz. I'm a Physics and Chemistry teacher at The Inmaculada School in Algeciras, in southern Spain. I'd like to share the project that I've done with a group of my students.

The Project is called PHYSICS AND CHEMISTRY VERSUS ALCHEMY. UNDER HARRY POTTER'S CLOAK.

At the beginning of the course we decided to do some brain storming classes. The students suggested different ideas, those of which we could then develop and achieve together throughout the year.

As a result, a group of students, who are really keen on Harry Potter novels, thought that we should look into his amazing wizard world.

I'd never read any of his books before but as the idea sounded interesting, I borrowed one of their books and started to read it. As I was reading the first novel I realised that it had everything to do with Chemistry and Alchemy, but at the same time it was simply pure magic!!!!

Therefore it seemed to be a wonderful goal to try to achieve for many reasons:

- Firstly it would help develop my students pleasure of reading in general.
- It could also connect three subjects so different like Literature, Physics and Chemistry, that are complete worlds apart.
- At the same time I could help my students dive deep down into the ancestral tradition of Alchemy.
- And above all so that I could then create a special mysterious atmosphere like JK Rowling herself, whilst I could offer an original way of getting Chemistry across to my students and bewitching them at the same time.

So then we started preparing this fascinating and truly satisfying project. The students began to read the seven novels of the saga extremely carefully as they had to pick out all the paragraphs that had anything and everything to do with magic. When we finished the reading we decided to focus on the first three novels as more magical happenings appeared in them.

We split the project up into four different parts:

RESULTS:

FIRST PART: ALCHEMY.

We all know that Harry Potter's adventures belong to the science fiction world, but then slowly we started to discover that behind each character in the saga we could find alchemy symbols. The students then became even more intrigued when they found out that JK Rowling is a real enthusiast and expert on Alchemy and she used it as the main core throughout all her novels, as she rightly once said in an interview, in 1998.

Therefore firstly we had to ask ourselves 'What is Alchemy?'

So in a nutshell we could define Alchemy as being an ancient technique which on the one hand has an experimental side to it but on the other hand has a spiritual side to it as well. From the experimental point of view the alchemists' main aim was to discover a substance, the Philosopher's Stone, that could transform common metals into Gold. Whereas spiritually speaking they were striving to purify their souls searching for perfection and thus becoming immortal.

Therefore we could conclude that Alchemy without being a science is full to the brim of Chemistry. I'll just give you a brief outline of Alchemy related throughout Harry Potter novels.

Firstly there were four elements always present in Alchemy, such as Earth, Air, Fire and Water which are represented in the books by the four Hogwarts boarding houses. Including three basic chemical products like Mercury, Sulphur and Salt which represented Mind, Body and Soul and were acted out by the three main characters.

The seven basic steps in Alchemy are also related to physics and chemical processes and are represented individually in each book.

- Calcination → Harry Potter and The Philosopher's Stone.
- Solution → Harry Potter and The Chamber of Secrets.
- Separation → Harry Potter and The Prisoner of Azkaban
- Conjunction → Harry Potter and The Goblet of Fire.

- Fermentation → Harry Potter and The Order of the Phoenix.
- Distillation → Harry Potter and The Half-Blood Prince.
- Coagulation → Harry Potter and The Deathly Hallows.

Throughout the whole of our project, my students curiosity was highly stimulated both by the alchemists that they discovered in the novels like Paracelsus, Nicholas Flamel, Hermes Trimegisto... who really did exist!!! Together with other outstanding scientists like Isaac Newton, Robert Boyle, John Dalton, Ernest Rutherford, Antonie Lavoisier... who were also convinced alchemists but had to remain in absolute secrecy.

Of all the scientists previously mentioned, I'd like to add the fact that my students decided to analyse Sir Isaac Newton's biography because they were astonished when they found out that the majority of his scientific achievements were developed during his youth, even before he reached the age of twenty five. Those of which he did when he withdrew to Lincolnshire throughout the Great Plague from 1660 for almost one and a half years. Following that period he then dedicated all of his time to the world of Alchemy. According to his biographer he actually wrote more than one million words about Alchemy!!! Ironically it wasn't for his contribution to Science that awarded him the title of Sir in 1705 rather more for his dedication as a Master of the Royal Mint in London.

We also studied the symbology and alchemistic meanings portayed by all the Harry Potter's characters, but I'm only going to mention a few of them right now.

- Harry Potter represents the metal that he's trying to change into Gold to reach total liberation of his mind, body and soul.
- Herminone represents the new mind through the search of the alchemist's transformation. She's mercury.
- Ron symbolizes the human soul. He's sulphur.
- Dumbledore represents the driving force that guides the alchemist to achieve the elixir of life.
- Voldemort symbolizes Lucifer, the devil, who tries to kill Harry Potter's new soul but he's not powerful enough.

During the process of Alchemy, sulphur and mercury purify metals, so Ron and Hermione help Harry to transform himself into Gold.

Finally we discovered that the Philosopher's Stone not only represents the ability to change lead into Gold and to obtain eternal life but also symbolizes our own process of personal evolution in life that we have to strive to change the 'lead' of our faults into the 'Gold' of our virtues.

This total transformation comes about in all of the seven books of Harry Potter's saga as are the seven steps also needed by the alchemists to create the Philosopher's Stone.

So having anxiously lapped up the whole philosophy on this matter I decided to transform the highlights of Harry Potter's adventures into seven unforgettable Chemistry lessons!!!

SECOND PART: CHEMISTRY

Having selected the principal magical events in the books, we then started to investigate just how we could reproduce them in our Chemistry lab.

Our top priority was to discover the chemical reaction or physical process that were actually happening behind the magical effects and on what scientific basis they were founded.

Once we finished this phase we then set about the objective of including it in our Chemistry syllabus for the academic year, in order to achieve our 'alchemistic' goal, which was to transform the subject of Chemistry taught by Mrs. Nuria Muñoz into the Transformation classes given by Professor Minerva McGonagall.

It was extremely important to recreate a real life atmosphere so I completely changed the lab at our school into the one like the Hogwarts boarding school. I didn't doubt not even for a moment to dress up in a green velvet cloak and a witch's pointed hat to keep my students attention.

The expectation was therefore tremendously high amongst my students and every single day they were waiting anxiously for our Chemistry class, sorry I mean Transformation class to start again.

I'm now going to show you all, the exact paragraphs taken out of the novels and how we made them come alive in the lab.

LESSON 1: PHYSICS PROPERTIES AND STATE CHANGES OF THE MATTER

IN THE NOVEL:

Book 2: Harry Potter and the Chamber of Secrets.

Chapter 12: The Polyjuice Potion. Page 183.

*'The Great Hall looked magnificent. Not only were there a dozen frost-covered Christmas trees..... but **enchanted snow was falling, warm and dry**, from the ceiling...'*

IN THE LABORATORY:

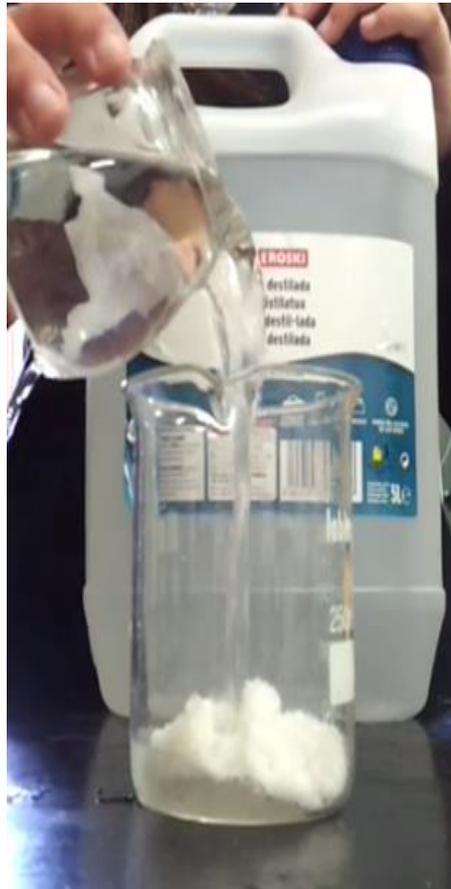
ARTIFICIAL SNOW: SODIUM POLYACRYLATE

Materials used in this experiment:

- Sodium polyacrilate.
- Distilled water.
- Glass container.

Procedure:

- We extract the polyacrilate out of babies nappies.
- We put it in a container and fill it with water.
- After a few seconds we can see ***how enchanted warm and dry snow is made.***



Explanation:

This experiment is used to explain that there are some substances called hydroscopic products like polyacrilate that can absorb up to twenty times its own weight in water. Creating a new white substance which is like a real life snow flake.

Another similarity to real snow is that if we add salt to it then it will melt, so we can use it to explain the freezing point depression.



IN THE NOVEL:

Book 2: Harry Potter and the Chamber of Secrets.

Chapter 4: At Flourish and Blotts- Page 58.

*"A...man was...taking photographs with a large black camera that emitted **puffs of purple smoke** with every blinding flash..."*

IN THE LABORATORY:

PUFF OF PURPLE SMOKE: SUBLIMATION OF IODINE

Materials used in this experiment:

- Iodine solid.
- Small spoon.
- Camera.
- Lighter.

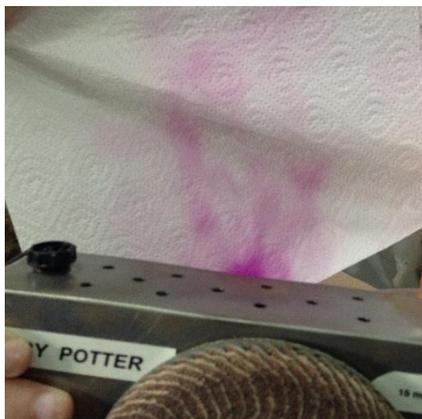


Procedure:

- We designed and made our own camera especially with an opening at the back.

- We added a bit of Iodine on the spoon and put it inside the camera.
- We heated it with the lighter and **puffs of purple smoke** started to appear.

Explanation: This 'magical effect' is useful to explain the process of sublimation of Iodine.



LESSON 2: ATOMIC STRUCTURE OF THE MATTER

IN THE NOVEL:

Book 1: Harry Potter and The Philosopher's Stone.

Chapter 15: The Forbidden Forest. Page 208.

*"So me, Harry an' Hermione'll go one way an' Draco. Neville an' Fang'll go the other. Now, if any of us finds the unicorn, **we'll send up green sparks**, right?... – an' if anyone gets in trouble, **send up red sparks**, an' we'll all come an' find yeh – so, be careful – let's go..."*

Book 2: Harry Potter and the Chamber of Secrets.

Chapter 4: At Flourish and Blotts. Page 48.

*"He took **a pinch of glittering powder** out of the flowerpot... and threw the powder into the flames... **the fire turned emerald Green...**"*

IN THE LABORATORY:

COLOURED FLAMES. FLAME COLORATION TEST

Although we would have liked to make real fireworks in the lab for safety reasons we decided to do the flame coloration test instead to make the Harry Potter's scenes come alive.

Materials used in this experiment:

- Test tubes.
- Rack.
- Droppers.

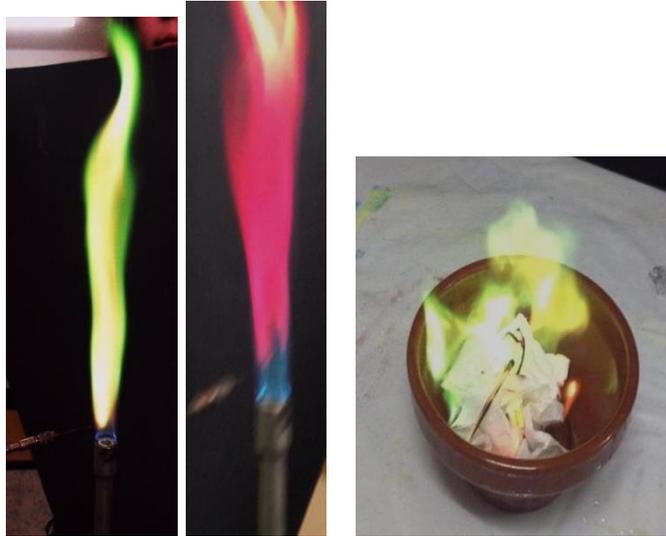
- Glass rod.
- Beaker.
- Loopful.
- Loopful handle.
- Spatula.
- Bunsen burner.
- Distilled water.
- Hydrochloric acid.
- Lithium chloride.
- Copper dichloride.



Procedure:

- We label the three test tubes with the names of the salts that we are going to use.
- We prepare a saturated solution of each type of salt in distilled water in separate test tubes.

- We submerge the loopful, which represents our own magic wand, in Copper dichloride solution, trying to collect a bit of salt deposited at the bottom of the tube and then we put it right into the Bunsen burner flame.
- We can observe that the flame changes its color ,” **we’ll send up green sparks”**
- After that we clean the loopful in a test tube with hydrochloric acid and put it back into the flame to make sure that it’s completely clean.
- Then we repeat the same experiment with Lithium chloride solution and we’ll **“ , send up red sparks”**



Explanation:

We use this experiment to explain:

- The internal structure of an atom and its elementary particles.
- The energy levels in its shell and jumping electrons.
- The atomic spectrum.
- The physical phenomenon of colour.

IN THE NOVEL:

Book 1: Harry Potter and the Philosopher’s Stone.

Chapter 11: Quidditch. Page 155.

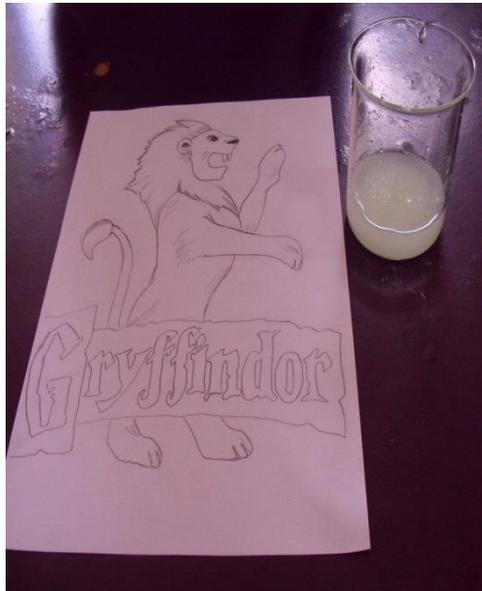
*“... they had painted a large **banner** on one of the sheets... and Dean... had done a large **Gryffindor lion** underneath. Then Hermione had performed a tricky little charm so that **the paint flashed different colours...**’*

IN THE LABORATORY:

QUIDDITCH BANNER: FLUORESCENT INK

Materials used in this experiment:

- Tonic water.
- Fluorescein.
- UV lamp.
- Beaker.
- Brush.



Procedure:

- We draw a Gryffindor lion on a white sheet of paper like a banner used for Quidditch.
- We wet the brush in tonic water and paint over the lion. Then we put it under the UV lamp and we can see how the paint has now become fluorescent.
- After that we paint it with fluorescein and observe how the **the paint flashed different colours** .



Explanation:

This experiment is useful to explain a form of luminescence, the fluorescence, the emission of light by a substance that has absorbed light or other electromagnetic radiation.

We can explain that the emitted light has a longer wavelength and therefore lower energy than the absorbed radiation.

We can use our example to demonstrate that the substances we used for painting the banner absorbed radiation in the ultraviolet region of the spectrum, and thus invisible to the human eye, and they emitted light in the visible zone.

LESSON 3: CHEMICAL KINETICS.

IN THE NOVEL:

Book 2: Harry Potter and the Chamber of Secrets.

Chapter 12: The Polyjuice Potion. Page 186.

'Hermione ladled large dollops of the Potion into each of the glasses....

*The Potion hissed loudly like a boiling kettle and frothed madly. A second later, **it had turned a sick sort of yellow...***

IN THE LABORATORY:

THE POLYJUICE POTION: DECOMPOSITION REACTION OF HYDROGEN PEROXIDE

Materials used in this experiment:

- 2 Graduated cylinders 100 mL and 10 mL.
- Scales.
- Beaker.
- Spatula.
- Large serving tray.
- Hydrogen peroxide.
- Potassium Iodide.
- Distilled water.
- Washing up liquid.

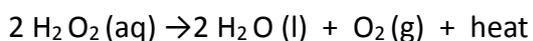
Procedure:

- Safety goggles and gloves should be worn during the demonstration.
- Then we prepare a saturated solution of Potassium Iodide, dissolving 8 g of iodide in 10 mL of distilled water.
- In a 100 mL cylinder, we add 10 mL of hydrogen peroxide and 5 mL of washing up liquid.
- So we touch the cylinder to check that the temperature is rising during the reaction.
- Soon after we add 5 mL of Potassium Iodide solution and we stand back and see what happens... Remember **“ a second later it had turned a sick sort of yellow...”**

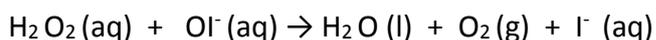
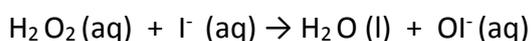


Explanation:

The rapid evolution of oxygen gas is produced by the following reaction:



The decomposition of hydrogen peroxide in the presence of iodide ion occurs in two steps:



This experiment is useful to present an example of a catalyzed reaction. At room temperature hydrogen peroxide decomposes very slowly. The presence of a catalyst may cause it to decompose more quickly.

Therefore we can use it to introduce the concept of a catalyst: a substance that increases the rate of a chemical reaction without being consumed at the same time.

The study of the reaction mechanism leads you towards the activation energy involved.

From that point on, you can start studying the energy involved in a reaction, noting that steam may be seen emerging from the cylinder at the same time which can be used to explain the exothermic and endothermic reactions.

LESSON 4: STUDY OF THE SYNTHESIS REACTIONS

IN THE NOVEL:

Book 1: Harry Potter and the Philosopher's Stone.

Chapter 7: The Sorting Hat. Page 101.

"What's that?"

*He gasped. So did the people around him. About twenty ghosts had just streamed through the back wall. **Pearly – white and slightly transparent...***

IN THE LABORATORY:

THE HOGWARTS' GHOSTS: SYNTHESIS REACTION OF AMMONIUM CHLORIDE.

Materials used in this experiment:

- 2 Glass jars of the same size.
- 2 Brushes.
- A pair of rubber gloves.
- 2 Droppers.
- 2 Beakers.
- Concentrated ammonia solution.
- Concentrated hydrochloric acid solution.



Procedure:

- We use the droppers to put 2 or 3 mL of hydrochloric acid in one glass jar and the same amount of ammonia solution in the other.
- We wet the inside of each glass jar, one with HCl and the other with NH_3 .
- And then we put one jar right on top of the other and lo and behold!!!! That ***“pearly white and slightly transparent ghost appears!!!!”***



Explanation:

This experiment is useful to introduce the classification of the chemical reactions into synthesis, displacement, double displacement and decomposition. And focus our

attention on the synthesis reaction. We can also refer to the experiment we did before, in lesson 3, as an example of a decomposition reaction.

LESSON 5: INTRODUCTION TO ORGANIC CHEMISTRY

IN THE NOVEL:

Book 3: Harry Potter and the Prisoner of Azkaban.

Chapter 10: The Marauder's Map. Pages 164 & 165.

«It was a **map** showing every detail of the Howarts castle...But the truly remarkable thing was the tiny ink dots moving around it..... 'Right', said George briskly, '**don't forget to wipe it.....'Just tap it..... And it'll go blank'**...»

IN THE LABORATORY:

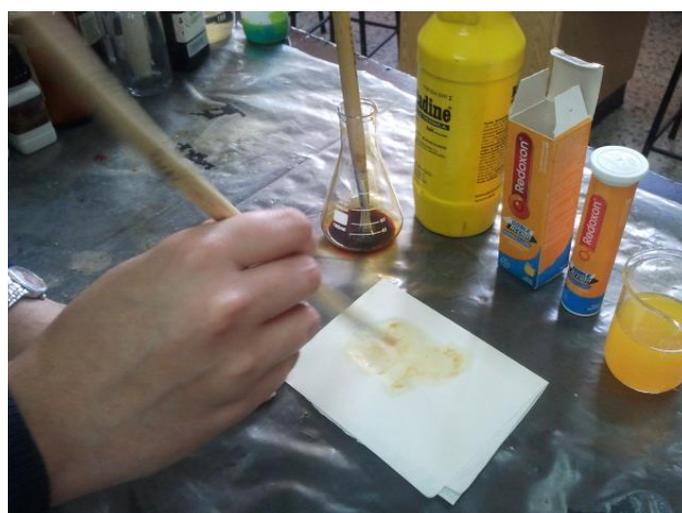
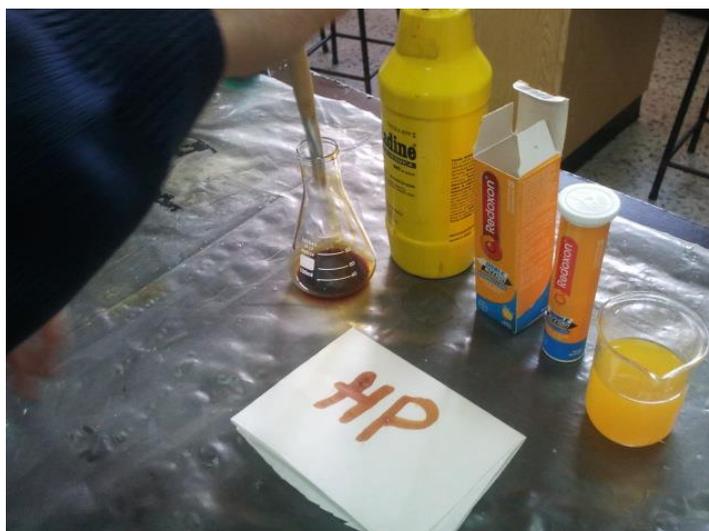
THE MARAUDER'S MAP: REACTION BETWEEN IODINE AND ASCORBIC ACID.

Materials used in this experiment:

- 2 Brushes.
- The Marauder's map.
- 2 Beakers.
- Iodine solution form the Chemist's.
- Vitamin C.
- Water.

Procedure:

- We wet the brush in the Iodine solution and write a message on the Marauder's map.
- We dissolve a vitamin C tablet.
- We wet another brush in the vitamin C solution and write on top of the same message... '**don't forget to wipe it.....'Just tap it..... And it'll go blank'**...»



Explanation:

It's the first time that an organic compound appears in our project so we take advantage of the chance to start with Organic chemistry, especially concerning the antioxidant properties of this important organic acid.

We can explain that vitamin C dissolves well in water and when it reacts with iodine, it destroys the complex between iodine and the cellulose of the sheet of paper.

LESSON 6: PROTON – TRANSFER REACTIONS. ACID – BASE.

IN THE NOVEL:

Book 2: Harry Potter and the Chamber of Secrets.

Chapter 13: The very Secret Diary. Page 206.

*'Harry... flicked through the **blank pages not one of which had a trace of scarlet ink on it.** Then he pulled **a new bottle... dipped his quill into it, and dropped a blot onto the first page of the diary.***

The ink shone brightly on the paper... as though it was being sucked into the page, vanished...'

IN THE LABORATORY:

TOM RIDDLE'S DIARY: AMMONIA AND PHENOLFTALEIN.

Materials used in this experiment:

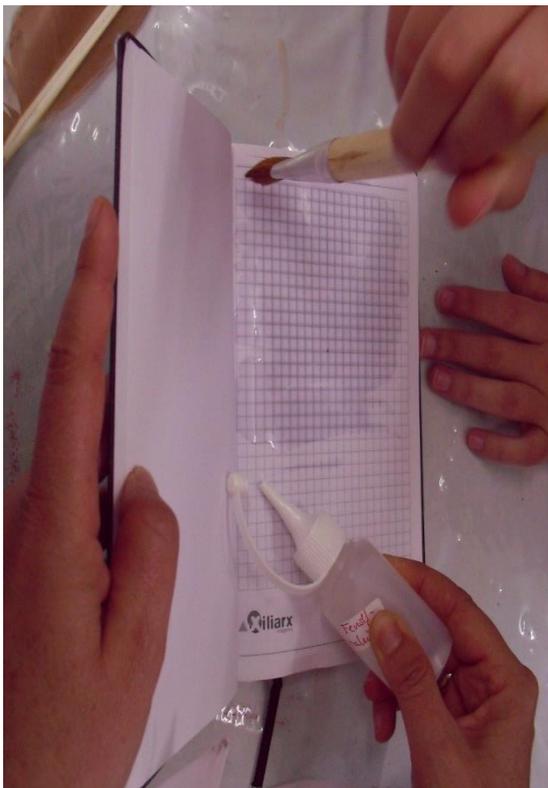
- Tom Riddle's diary.
- 2 Brushes.
- Ammonia solution.
- Phenolftalein.



Procedure:

- First of all we soak the pages of Tom Riddle's diary with phenolftalein and let them dry.
- We wet the brush in the ammonia solution and write a message on a page of the diary.

- People will notice that the liquid is transparent but then the message appears in a scarlet colour... ***The ink shone brightly on the paper... as though it was being sucked into the page, vanished...!***



Explanation:

We use this experiment to introduce a chemical description of acidic and basic solutions by Arrhenius.

The concepts of proton donors (acids) and proton acceptors (bases) by Brønsted – Lowry Theory.

The strength and weaknesses of acid-base pairs.

The water equilibrium: pH and pOH, and the equilibrium constant.

The indicators and how they change colour depend on the pH balance, as phenolphthalein for example.

So last but not least now we've finally reached the 7 th phase of our alchemistic journey together. I'd like to finish off by explaining our most exciting experiment.

LESSON 7: ELECTRON TRANSFER REACTIONS: OXIDATION – REDUCTION.

IN THE NOVEL:

Book 1: Harry Potter and the Philosopher's Stone.

Chapter 13: Nicholas Flamel. Page 183.

"She pushed the book towards them, and Harry and Ron read:

*The ancient study of alchemy is concerned with making the Philosopher's Stone.... **The Stone will transform any metal into pure gold**. It also produces the Elixir of Life, which will make the drinker immortal..."*

IN THE LABORATORY:

THE ALCHEMIST'S DREAM: FROM COPPER TO GOLD.

The alchemist's dream was to transform common metals into Gold in order to achieve eternal life.

Materials used in this experiment:

- A beaker.
- A Bunsen burner.
- A pair of tongs.
- A scale.
- Zinc powder.
- Sodium hydroxide.
- Distilled water.
- Ammonia solution.
- Washing up liquid.
- Copper coins.



Procedure:

- We prepare a solution dissolving 12 g of sodium hydroxide in 50 mL of distilled water. After that we add 2'5 g of zinc and we heat the solution until it's boiling.
- Beware!!! Sodium hydroxide is corrosive and the solution is exothermic.
- We clean 2 copper coins until they are shiny by submerging them into a mixture of ammonia and washing up liquid. After a few seconds we take them out and rinse them in water.
- We put the coins into the zinc solution that has to boil for 2 or 3 minutes.

- Then we take them out and we can see the coins have turned silver. We rinse them in water again.
- So we heat one of them in the blue flame and guess what? All of a sudden our copper coin transforms into a gold one!!!!!!..." **The Stone will transform any metal into pure gold...**"

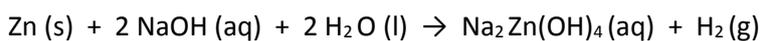




Explanation:

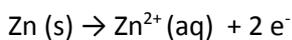
We can use this surprising experiment to help explain the electron – transfer reactions.

Sodium zincate is produced by the following reaction:

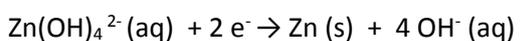


The silver aspect is produced by an oxidation-reduction between copper and zinc.

The following reaction is the oxidation of zinc:



Zinc ions gain a more complex structure in order to get zincate ions that when they are reduced they change into zinc that recoats the coin.



As the coin is heated by the flame, brass is formed thus giving it its final golden appearance.

At long last we've finally got the Philosopher's Stone!!!!!! Which is what we've been striving for throughout and I seriously do believe that I've managed to make Chemistry more exciting for my students. And this has become my personal Philosopher's Stone!!!!!!

THIRD PART: PHYSICS

While we were investigating all about Chemistry, we realised that HP's invisible cloak was an essential part of every single successful mission, so we started to delve deep down into Physics, too.

As you can imagine we haven't been able to create our own invisible cloak, otherwise today it would be a case of now you read it, now you don't.

Therefore we have tried to see how light really works, looking into phenomena like reflection and refraction managing to make effects very similar to invisibility.

All the physics experiments that we did throughout our project I can show you right now. For example:

1. Invisibility with baby oil

So a beaker disappears in baby oil or sunflower oil, because Pyrex glass has the same refraction index as these oils have.



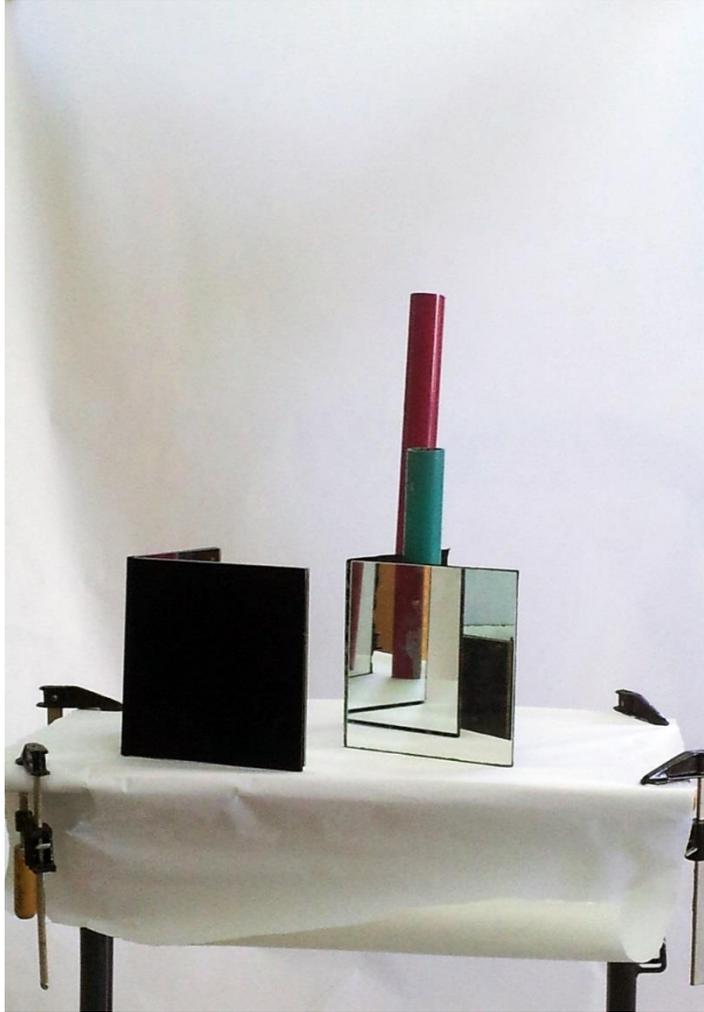
2. Fresnel lenses

As you can see we are able to conduct the light so that two shadowed areas are formed.



3. Playing with mirrors

As you can see we've got two pairs of mirrors. The first pair reflects light onto the second set of mirrors creating an optical illusion.



4. Disappearing coin trick

Watch where I put the coins and now if you crouch down a bit, as you are at a different angle apparently one of the coins vanishes while I'm pouring water in. Due to refraction.





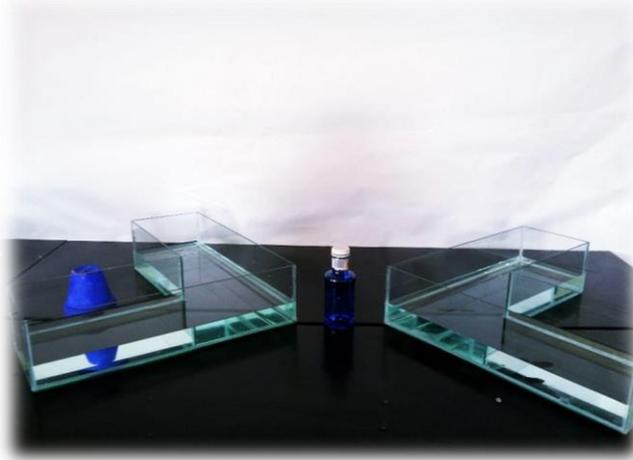
5. Red photographic filter

As you well know a red filter only lets in light of 700 nm wave length. So if we put the filter on top of this material you will see how the white, green and blue colours disappear, only red remains.

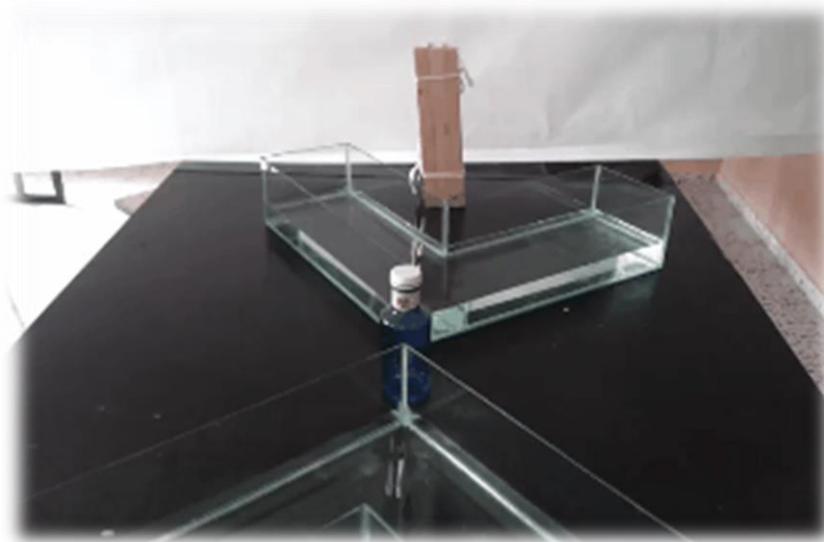


6. V shaped containers

Firstly look at the way the containers are positioned. Then using Snell's law, watch carefully how the light changes its direction. Again we get a shadowed zone



which hides the part of the object that is below water level.

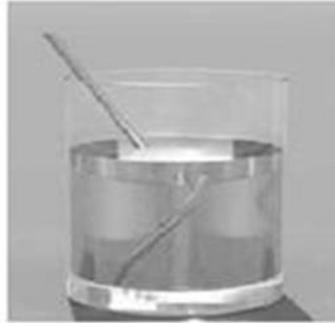
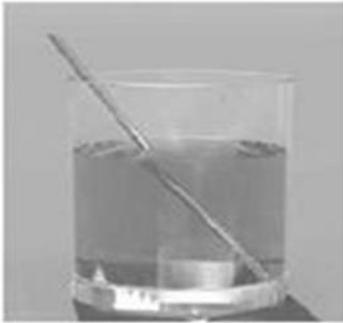
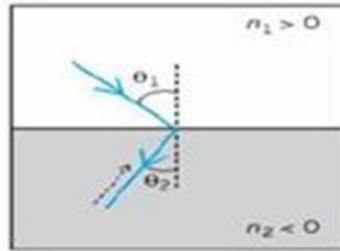
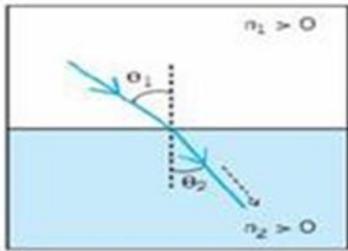


FOURTH PART: METAMATERIALS

Finally we investigated the most updated Engineering materials because actually there's been a very exciting recent discovery regarding the creation of a new fabric which has the same qualities as Harry Potter's invisible cloak.

This fabric is called metamaterial and has completely different properties that have got nothing to do with what we've seen until now. Also its refraction index is the opposite!!! It's negative instead of positive, so the Snell's law would now be transform into

$$n_i \sin \alpha_i = - n_r \sin \alpha_r$$



Refraction in an usual way

Refraction in a Metamaterial

Therefore if we place any object under a piece of this material it becomes totally invisible, just like Harry Potter's cloak!!!!

CONCLUSIONS:

- Alchemy is a lot more than simply magic, it's a philosophy of life.
- Throughout History many famous scientists that have made extremely important discoveries, have also dedicated a life time to Alchemy.
- JK Rowling is also a great expert on the matter.
- Each and every character in the saga oozes Alchemy.
- Behind every magical phenomenon in all the novels, a chemical reaction lies underneath.
- With Metamaterials Science fiction becomes Reality!!!
- Literature, Physics and Chemistry bubble all together...making classes come alive!!!
- But anyway, apart from all that magic!!!, **Science** really does Appear all over the Place!!

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