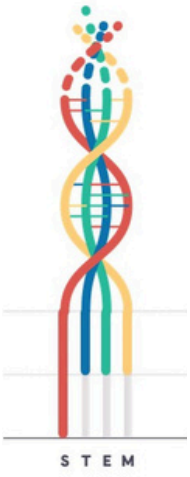
The amazing role of photocatalysis
Amase *Educational Card*

# The amazing role of photocatalysis





## Abstract

Contamination is huge problem for the health of the human kinds and all the planet. In this module we are going to learn how we can use some materials, known as photocatalysts, to clean water and air. Or even to produce new sources of green energy.

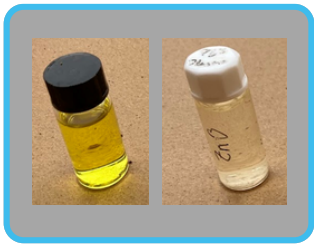


## Keywords

Sun, radiation, UV, health, oxidation, catalysis, ligth absorption


## For whom?

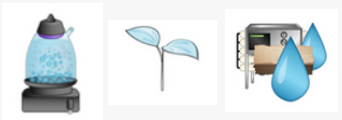
age: 12-16
This project aims mainly at
STEM-Literacy
STEM-Exploration
STEM-Focus





## Game module

Jar lamp reactor
SuperArtificial Leaf
Water



## Central Wondering

Can we clean our cities with the sun?

## Summary


What do we need to understand photocatalysis?

In this module we are going to understand the basic phenomena behing the photocatalytic processes. A photocatalyst is a semiconductor material that is able to absorb light and speed up chemical reactions. It is a complex but exciting topic that will help us to learn how advanced materials can be useful for the cleaning of air and water pollution in our cities. Through this module, we will cover the following units:

- Unit 1: pollution and health. We will describe what is pollution and how it affects human health. We will perform an experiment to show how contaminants can be detected and cleaned.
- Unit 2: a little bit of chemistry. We will get into the world of the oxidation and reduction reactions, which are around us in our day-life. These chemical reactions are very important to understand how a photocatalyst works.
- Unit 3: Electromagnetic spectrum. “Photo-” indicates that the photocatalyst interacts with light. We need to learn that light is a type of electromagnetic radiation.
- Unit 4: Using a photocatalyst. This unit is focused on making an experiment using a photocatalyst, and show that it really works!!!

# What do we need to understand photocatalysis?

## Table of Learning Activities

**Unit 1: pollution and health**

- Set the Scene: what is pollution?
- Get at work: sources of pollution in a city.
- Scientists speak: effects on health.
- Exploring activity: contamination around you:
  - Air pollution.
  - Water pollution.

**Unit 2: a little bit of chemistry**

- Set the Scene: what is oxidation and reduction?
- Scientifics speaks: oxidation and reduction reations.
- Get at work: glossary and crosswords.
- Exploring acitivity: redox reactions in your life.
- Scientists speak: make a redox reaction.

**Unit 3: Electromagnetic spectrum**

- Set the Scene: light and color.
- Scientists speak: electromagnetic radiation from sun.
- Get at work: fixing concepts
- Exploring activity: let's play with colors!

**Unit 4: Using a photocatalyst**

- Set the Scene: where can we use a photocatalytic materials.
- Scientists speak: how a photocatalyst works?
- Exploring activity: photocatalysis to clean water.

**Conclusion**

- Answering the central wondering

Add logos here.

This will be explained in the Pedogogical Guideline

## How?

### Pedagogy of Wonder

Set the scene

Philosophical dialogue

On discovery!!

Raising Wondering Questions

Wat does our scientist say?

Get to work!

Experience in the game

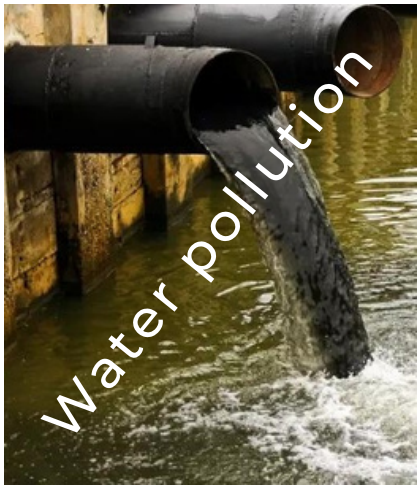
Module of the game
Add row, column of the matrix at stake


What we don't know yet and is still in scientific debate

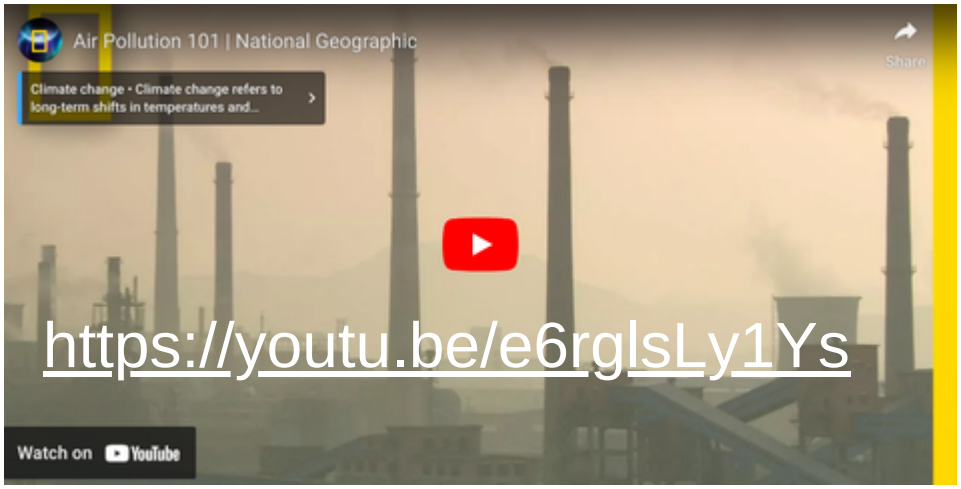
# Unit 1: pollution and healt

## Set the scene

Watch the videos






## Philosophical dialogue

Do a round table with you students. Debate about the questions

1. Do you think pollution is an important problem?
2. What can you do in your daylife to avoid pollution?
3. Do you know strategies to clean air or water?

# Unit 1: pollution and healt

## Get to work!

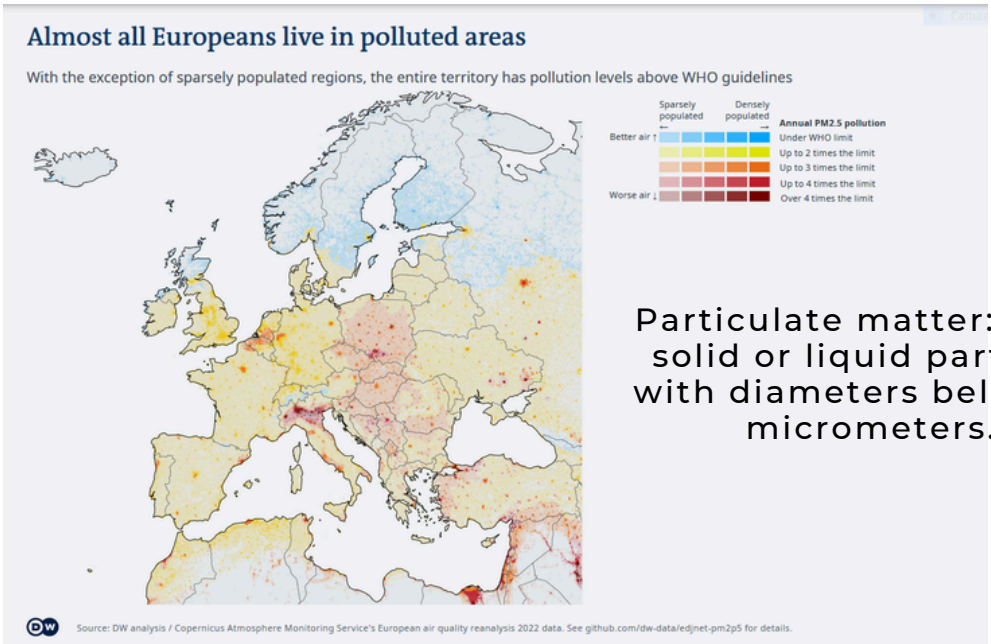
Can you list at least 4 sources of pollution in your city/town?:

- _____.
- _____.
- _____.
- _____.

## Wat does our scientist say?

According to World Health Organization (W.H.O.) webpage:

- "*Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.*"
  - Main contaminants: particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide.




Particulate matter: small solid or liquid particles with diameters below 2.5 micrometers.

- "*Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio. Absent, inadequate, or inappropriately managed water and sanitation services expose individuals to preventable health risks.* "
  - Main sources: urban wastewater, chemicals from industry, chemicals from agriculture.

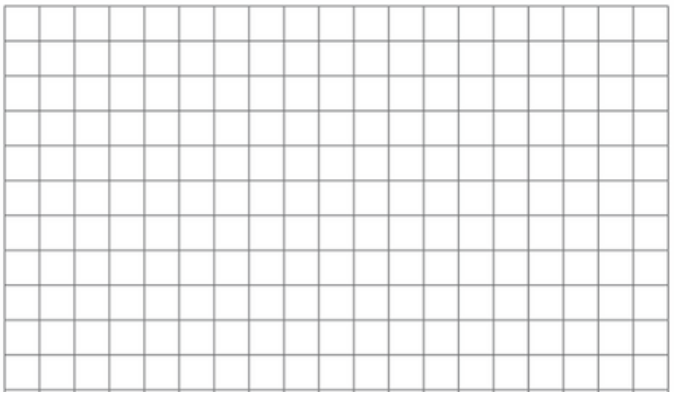
Can you identify the position of big cities?
Has you hometown good or bad air quality?

# Unit 1: pollution and healt

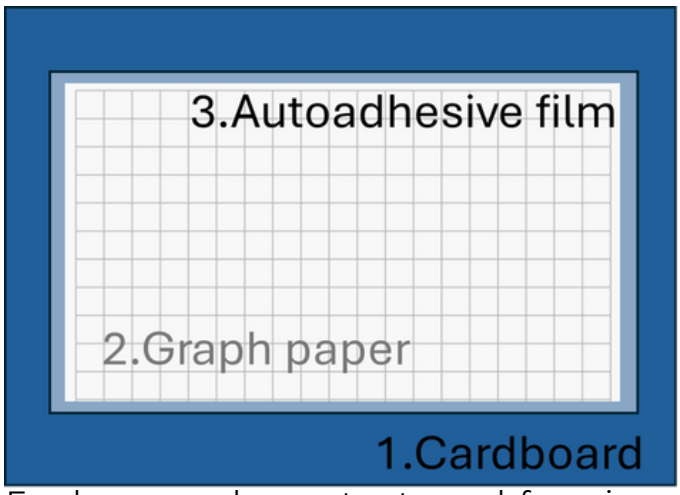
## On discovery!! Air pollution

### What materials do you need?

- Autoadhesive book cover film.
- Graph paper.
- Cardboard.
- Scissors.
- Glue stick.
- Magnifying glass and/or microscope.



You can use this as your graph paper.




Each group has a test card for air pollution

Divide your class into small groups.

Each group will cut the graph paper and glue it on a cardboard.

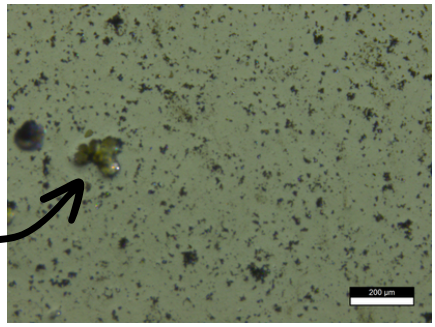
Then, take the autoadhesive cove film, cut a piece of the same size of the graph paper and glue to it the non-sticky part. Then, remove the cover of the sticky part.

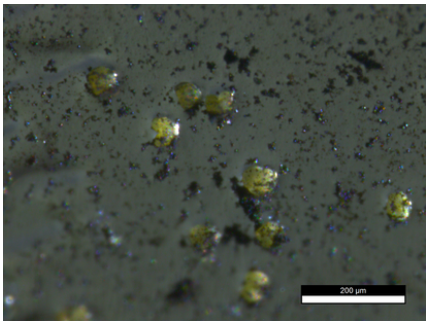
Choose different localizations, (indoor, outdoor, city center, park, small village...) to leave the test card for 24 h. After that time, count the number of particulates in each square of the graph paper, and record them in a table laid out with the same number of squares as the graph paper. You can use magnifying glass.

? Calculate the average number of particulates per square to be used while comparing pollution with other groups. Where do you have more air pollution?

If you can have a microscope, check for:

- Particulate matter.
- Pollen particles.



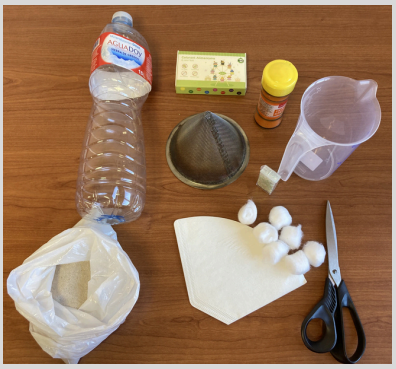


# Unit 1: pollution and healt

## On discovery!! Water pollution

### What materials do you need?

- One clear plastic bottle (1-liter size) or
- A sieve and a container (optional)
- A Coffee filter.
- Cotton balls.
- Fine sand.
- Dirty water: add soil, oil, alcohol, purpurine, pieces of paper, etc. to clean water.
- Food coloring (any color).
- A container to prepare the dirty water.



**Cut the plastic bottle in half. The top half will be used as the filter column (you can use also a sieve), and the bottom half will be used to collect the filtered water.**
**Turn the top half of the bottle upside down, so the neck is pointing downwards**

Prepare the filter: Place the coffee filter inside the neck of the bottle. Place a layer of cotton balls over the coffee filter. Add a layer of fine sand on top of the cotton

Prepare the dirty water: mix with clean water the soil, oil, purpurine, pieces of paper and a few drops of food coloring.

Filter the dirty water: Pour the dirty water with food coloring slowly into the top of the filter column. The water will pass through the layers of sand, cotton and coffee filter, with each layer removing different types of impurities

Analyze results: Compare the filtered to the original dirty water. Note the clarity and color of the filtered water. Discuss how the layers of the filter helped to clean the water and whether the food coloring (representing difficult-to-remove contaminants) was filtered out.

## What contaminants have been removed by the filter? What contaminants have not been removed?

Discussion points

- Water treatment plants use multiple stages of filtration and additinal chemical processes to remove the different contaminants.
- Even water that look clean may still contain dissolved contaminants (represented by the food coloring and alcohol) that are not visible to the naked eye: drugs, microplastics, virus and bacterias, etc.

You can also see the experiment here.

# Unit 2: a little bit of chemistry

## Set the scene

Describe what you see in the images



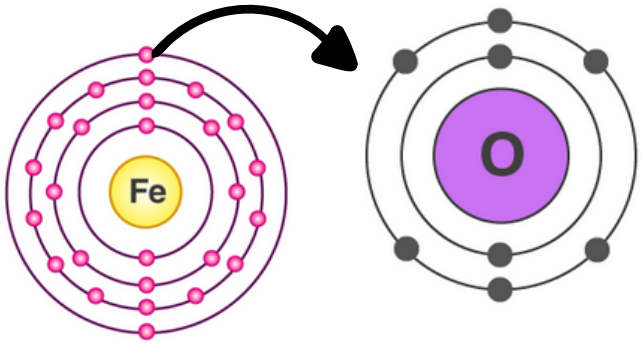
**What is the name of this process?: _____**

## Wat does our scientist say?

Atoms are formed by electrons, protons and neutrons. Play at: Built an atom

When iron reachs with the oxygen in the air, a chemical reaction is produced. This chemical reaction is called oxidation. The reaction produces a compoun named iron oxide (also rust).

Iron atoms loss some electrons. It is oxidated.




**Oxygen atoms gain some electrons. It is reduced**

**In chemical reactions, if an element/compound losses electrons, another element/compound gain them. Oxidation and reduction go on at the same time, so we termed them as redox reactions.**

Although historically this process is related with the combination of oxygen with a metal, in Chemistry, a reaction that involves a loss of electrons is called oxidation; whereas a reaction that implies a gain of electrons is called reduction.

You can play with redox reactions: chemistry lab simulator.

# Unit 2: a little bit of chemistry

## Glossary

**Atom**: smallest unit into which matter can be divided without the release of electrically charged particles.
**Electron:** subatomic particle with a negative one elementary electric charge.
**Element:** any substance that cannot be decomposed into simpler substances by ordinary chemical processes.
**Compound:** any substance composed of identical molecules consisting of atoms of two or more chemical elements.
**Chemical reaction:** a process in which one or more substances, the reactants, are converted to one or more different substances, the products.
**Oxidation:** a chemical process that occurs when atoms lose electrons. It as also been seeing as the process when elements or compounds gain oxygen.
**Reduction:** a chemical process that occurs when atoms gain electrons. It as also been seeing as the process when elements or compounds gain hydrogen.
**Catalysis:** acceleration of a chemical reaction by addition of a substance not consumed during the reaction.

## Get to work! Find glossary words.

A W K G Y T V C C X F E M N J U V X U U L C C
S Q U R X F F Q D G O A M V T E C G L I L H I
Z W S S J Y D H M U K M T M R Y F Y Z Q S E R
D P I M M S G I P J K S B O I Z D M J C B M K
A N S U P K Y D Y J U X P J M S O M R E D I L
T W Y S X N X L H O W M V Q D H W O C O D C A
D Z L C W F F O I O G E D E L E M E N T F A J
N M A X S P I E A E L E C T R O N C M Z A L T
U P T R S J H R Q F V F O X I D A T I O N R E
O H A G M M C U O D Y G V Y D F L L N B D E R
P A C Q C U G F H W C M O P T Z C B G X V A A
M R E R E D U C T I O N D B I M M Q I V K C N
O I O V C H X V C B E I S Q R G X E H H C T V
C Z H C A V K R A I C I P R M Z T E E D I I T
Q N W P E R Y M B J Q Q N E L Q W Q O X Y O Y
D X Q C N L O O C G C Z H B C P I L I E A N X

# Unit 2: a little bit of chemistry

## On discovery!!

Find redox reactions in your real life: can you provide more examples/photos?





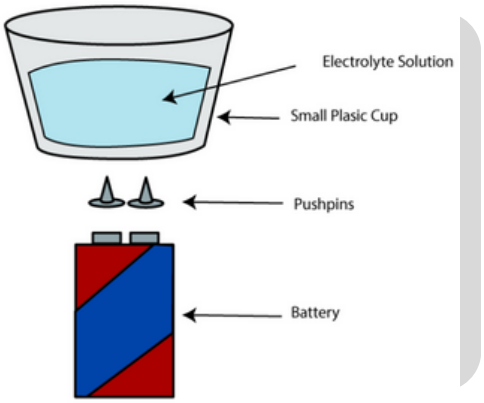
Detailed explanation here.

## On discovery!!: make a redox reaction.

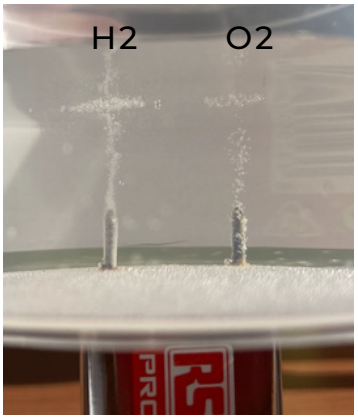
### What materials do you need?

- 9V battery
- Plastic container (small, clear works best)
- Two pushpins.
- Electrolyte: baking soda, salt...

Follow the image to mount you experiment




You should observe the formation of bubbles at the tip of the pins!!




- Electrolyte is necessary to allow electricity to pass thorugh the water.
- Water molecules (H2O) are dissociated into H+ and OH-.
- The electrolyte increase the electrical conductivity of water.
- Hydrogen gas is produced when hydrogen ions H+ are reduced (gain electrons) at the cathode (the negative pin, with is the positive terminal of the battery).
- Oxygen and carbon dioxide gas are produced when OH- and CO3- are oxidized (loss electrons) at the anode (the positive pin, with is the negative terminal of the battery).

- (Optional, do with caution): To test for the presence of hydrogen, carefully collect the gas in a small container (like a test tube) inverted over the cathode pin. After a couple of minutes, remove the container and bring it near a lighter. Hydrogen gas will combust with a small "pop" sound, indicating its presence.

## Wat does our scientist say?: hydrogen can be used as a source of clean energy!!

# Unit 3: Electromagnetic spectrum

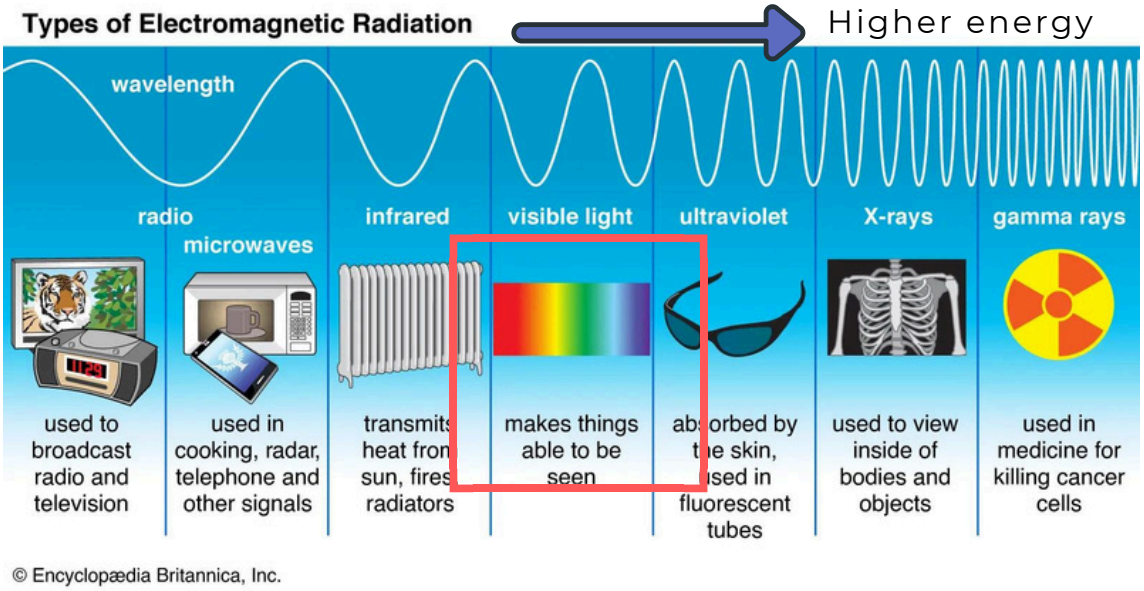
## Set the scene


https://www.youtube.com/watch?v=9Vsl0Iom3S0

We get light and energy from the sun. Today we are going to understand how some materials can absorb that light.

## Wat does our scientist say?

Solar radiation is the energy emitted by the sun in the form of Electromagnetic waves....




....But only a small part of the electromagnetic spectrum is part of solar radiation

# Unit 3: Electromagnetic spectrum

## Get to work!

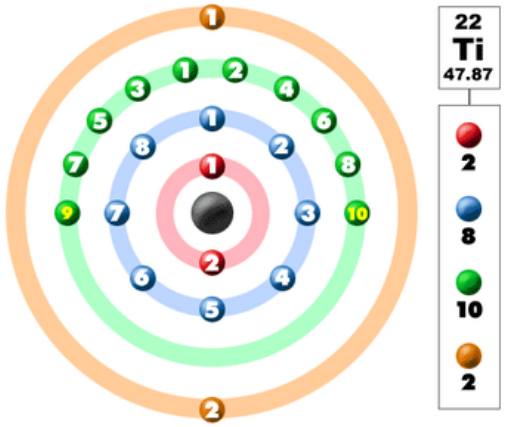
Define:

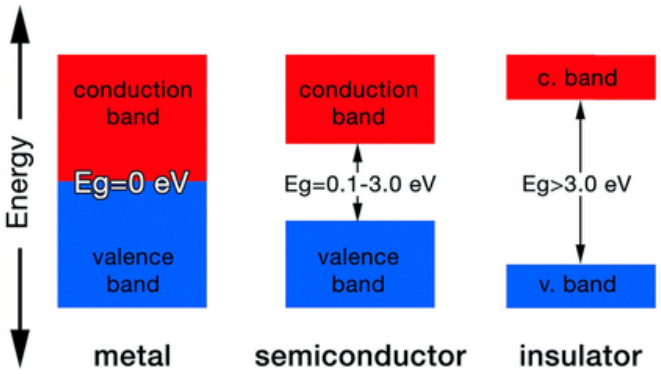
- Visible light is the part of the electromagnetic radiation that _____.
- Violet color has _____ wavelength and _____ energy.
- Red color has _____ wavelength and _____ energy.
- The electromagnetic radiations that come from sun are:
  - _____
  - _____
  - _____

## Wat does our scientist say?

We have seen that atoms are composed by protons, neutrons and electrons. The electons “live” in different energy levels, as different floors in a building.

Although electrons are lazy and they whan to be in the lowset energy posible, not all the electrons can be in the ground floor!




When we have a material, we have a lot of atoms togehter, and then a lot of electrons. Now we need bigger apartments for our electrons, which we call bands.

Some materials have all the apartments available for electrons (metals) and they can move to one apartment to another using low amount of energy.

On the other hand, there are materials (semiconductors and insulators) were we have stairs between apartments at different floors (energy gap Eg) and electrons need energy to climb the stair and reach the upper floors (conduction band, red). Again, they are more confortable in the low energy apartments at the ground floor (valence band, blue).

If we give electrons some energy, they can visit the upper floors. Of coruse, we know that they cannot live in the stairs!! So we have to give them enough energy.

# Unit 3: Electromagnetic spectrum

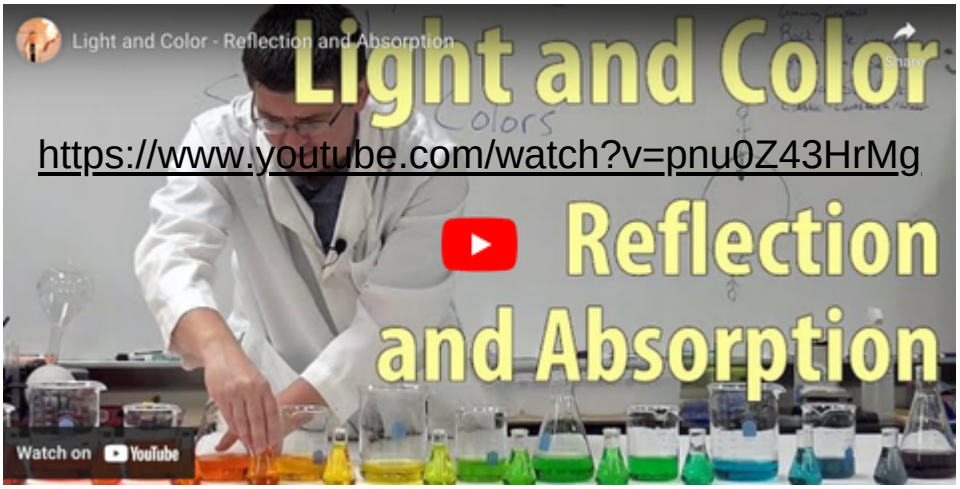
## Get to work!

Organize the sun radiations from the most to the less energetic:

- _____.
- _____.
- _____.
- _____.

Which one is the most effective to move electrons to the conduction band? _____.

## On discovery!!: let's play with colors!

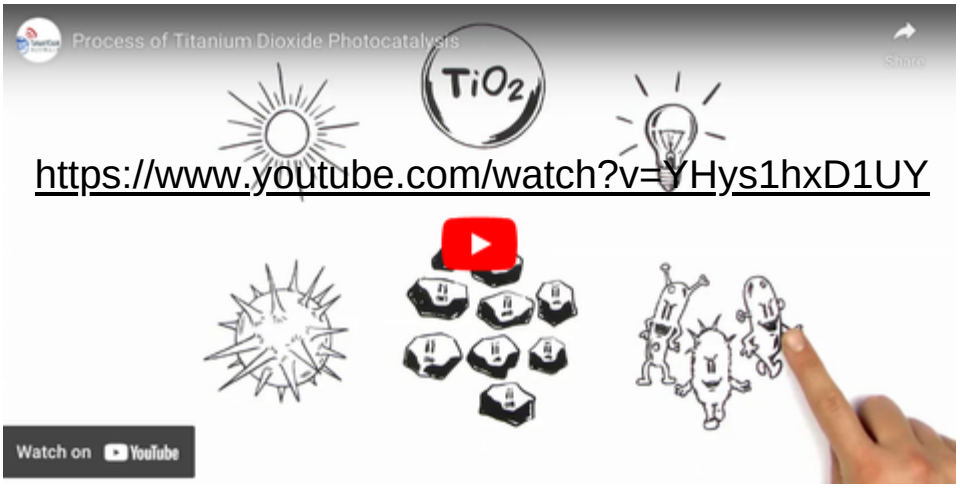




Experiment with food dyes

## What will be the color of semiconductor and isulator materials?

# Unit 4: Using a photocatalyst

## Set the scene

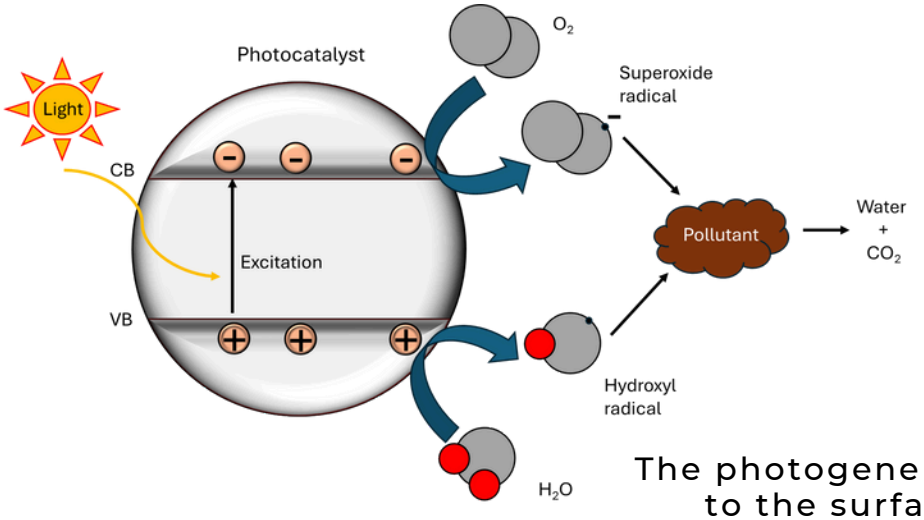



A photocatalytic material can help us to:

- Clean pollutants from air and water.
- Eliminate bacterias and other dangerous microorganisms.
- Produce green fuel(hydrogen)

## Wat does our scientist say?

A photocatalyst is a **semiconductor material** that is able to **absorb light** and speed up chemical reactions.




Redox reactions can be induced through the light absorption on a photocatalyst.

When photocatalyst particles absorb light, electrons jumps into higher energy level. This leaves an empty space in the low energy level (called hole).

The photogenerated electrons and holes go to the surface and reacts with water (oxidation) and oxygen (reduction) to produce radicals. Radicals are used to break pollutant molecules by redox reactions.

Most common photocatalysts are TiO2 and ZnO (semiconductor materials).

# Unit 4: Using a photocatalyst

## On discovery!! Cleaning water with a photocatalyst.

### What materials do you need?

- Food dye wich contains tartrazine (found in the supermarket, for paella). It gives orange color.
- Small glass jars (5 ml).
- Plastic beakers (50 ml).
- Laboratory spoons.
- Powders of a photocatalytic material (TiO2 or ZnO). The most easy to find is ZnO powders for cosmetic use.
- A nice sunny day :)

The food coloring is going to be used to simulate a pollutant in water. It represents the disolved compounds in water that cannot be filtered (remember unit 1)


We start checking the ingredients of our food coloring


- Cornflour.
- Tartrazine (E-102)
- Allura red AC (E-129)
- Salt.

Both E-102 and E-129 are colorants may have adverse effects on children's activity and attention.

Put some of the powders of the food coloring in a beaker and add water. Mix the colorant and the water with an spoon.

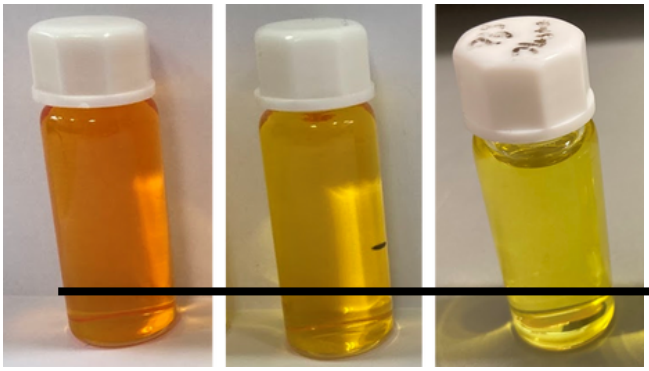
Leave the beaker at rest for a few minutes, until you see that the cornflour is deposited at the bottom.



You can also try with the filtered water from the experiment of unit 1

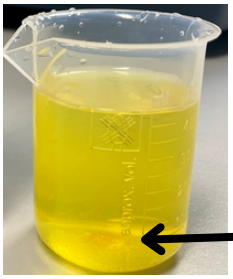
# Unit 4: Using a photocatalyst

**You can check that the more food coloring you add, the stronger the orange color you get.**



Less concentration (less ppm)

If you want your experiment to success, follow this recepy: in a beaker of 50 ml of water, add half spoon of food coloring.



Cornflour

The color you should get is more yellowish, which means that you have a concentration of hundreds of parts per million (ppm). This inidicates the number of parts of a the colorant per one million parts of the solution.

Fill three small glass jars with the colored water you have prepared. One is going to be your reference.

Take the photocatalyst powders and add half spoon to two of the glass jars.

Put the reference and photocatalyst glass jars in direct sunlight and wait. Leave the third jar in the dark. Check them one hour later.

Photocatalyst under sunlight has degradated the colorant!

**You can do a competition in your classroom: each group can try different concentrations of food coloring and photocatalyst, let's see what group wins!!!**

# Conclusion



The design of new photocatalytic materials that absorbs light in the visible region of the electromagnetic spectrum will help us to have clean cities:

- Photocatalytic materials can clean pollutants in air and water.
- Photocatalytic materials can produce green hydrogen, which avoids the generation of more pollutans.