Materials Science Mini Kit: Magic Color Beads and UV Light

Lesson Plan: Objective, Description, Materials List, and Safety Precautions

Lesson Objective

To demonstrate that there are forms of light which are not visible to the human eye but can be absorbed by a material, altering the material's properties.

Experiment Description

These special plastic beads contain a chemical substance or pigment that changes color when exposed to ultraviolet (UV) light. When exposed to UV light, the beads will become red, orange, yellow, blue, or purple. If the beads are removed from UV light, they will slowly return to their white color. The beads can change between white and the various colors thousands of times.

Materials List

Items provided in the kit

- 10 color-changing plastic beads
- 12-inch string
- UV flashlight (also used with the *What is Fluorescence?* experiment)

Items to be provided by the teacher/school

- opaque brown plastic bag

Optional items for extending the experiment

- other containers that can be found at home or school (transparent, translucent, and opaque, or even colored) ie. metal, paper, plastic, glass
- Sunscreen
- a pair of sunglasses or a filtered lens
- different light sources (i.e., fluorescent, incandescent, LED, blacklight, colored light)

Safety Precautions

The small plastic beads are a **choking hazard**

- Do not allow children to put the beads in their mouths or attempt to swallow them.

UV light can cause **eye damage**

- Do not shine the UV flashlight into anyone's eyes.
- Always point the flashlight downward and at the beads as directed in the experimental procedure.

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Lesson Plan: Background Information

Background Information

Light: More Than Meets the Eye

Light is produced by a particle called a photon that propagates through space by oscillating, or moving up and down, forming a path described as a wave, as shown in **Figure 1**. The distance between two adjacent crests (peaks) of a wave created by the oscillating photon is the wavelength of the light.

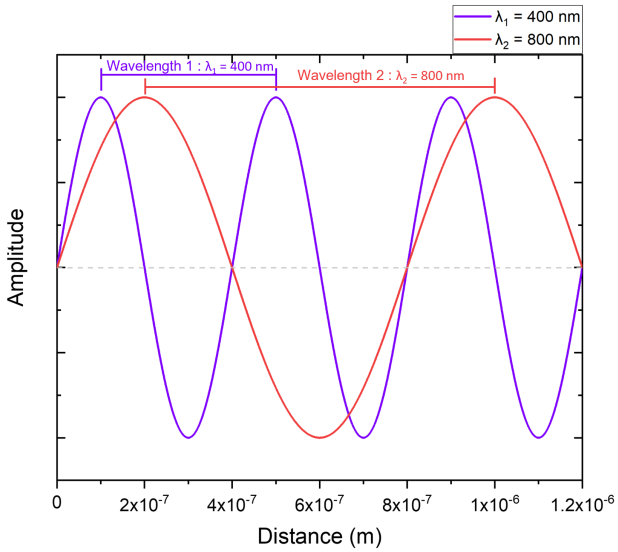

Figure 1. Two waves of different wavelengths.

There are several classifications of light based on the wavelength of the wave the photon follows. These include ultraviolet (UV) light, visible light, and infrared (IR) light, as shown in **Figure 2**. The wavelength of UV light is shorter than that of visible light, while infrared light has longer wavelengths than visible light. These classifications, and the wavelengths for each, are illustrated in the figure below.

So where do we find UV light? The sun gives off light we can see (visible light) and some that we cannot see (ultraviolet and infrared). Just as there are different colors or wavelengths in the visible light spectrum (such as red, yellow, green, and blue), there are different wavelengths of UV light. Long wave UV-A has wavelengths from 400-315 nm and is what is emitted from a "blacklight" that we use to make posters, paint, clothing, and other objects glow (fluoresce). UV-A is also needed by our bodies to synthesize vitamin D. Shorter wavelengths known as UV-B (315-280 nm) are the major cause of sunburn.

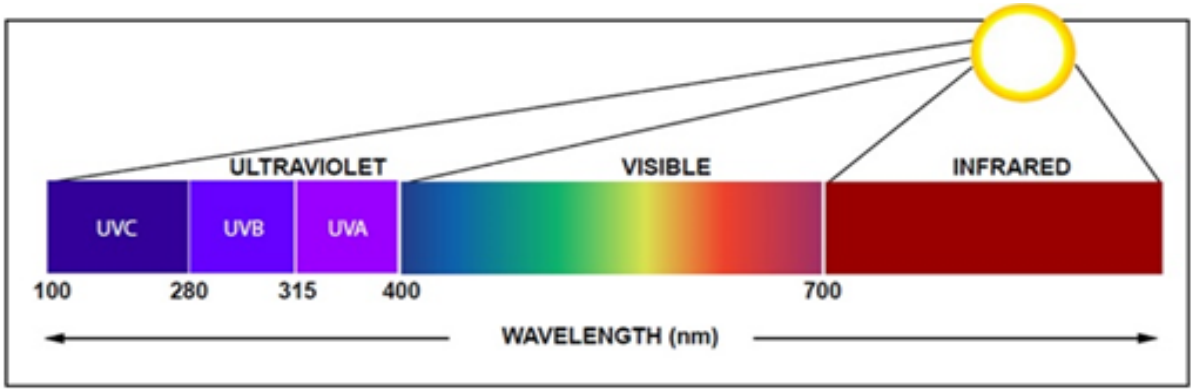

Figure 2. Wavelengths of ***electromagnetic radiation*** produced by the sun.

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Lesson Plan: Background Information

Objects appear in certain colors when they absorb certain wavelengths of visible light and reflect the other wavelengths. White objects do not absorb any visible light and reflect all visible wavelengths, which appear white when combined. Black objects absorb all the visible light and reflect none. Green objects absorb all visible light except green wavelengths (roughly ranging from 495 to 570 nm), which they reflect and human eyes can detect. Objects also absorb and reflect UV light, but humans cannot see this light. For example, the pigments used to color the beads for this experiment react to wavelengths from 360-300 nm, which human eyes cannot detect.

How do color-changing beads change color?

The key to why the beads change color lies in the molecule that makes up the dye within the bead. At the center of this molecule is a carbon atom, which is bonded to two planes (large flat sheets) of similar atoms, as visualized in **Figure 3**. The first plane can be called the "A" plane of atoms, say the plane on the right of the carbon atom. The other plane, to the left of the carbon atom, is the "B" plane of atoms. The "B" plane is oriented perpendicular to the "A" plane, so you can only see the thin side view.

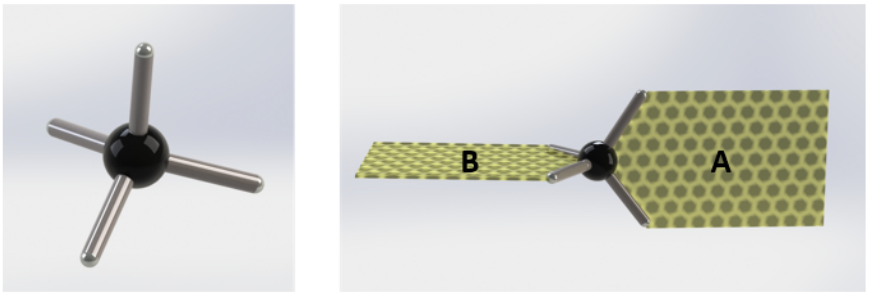

Figure 3. On the left, a carbon atom is shown with its four available bonds. On the right, the molecular structure arrangement is shown with the carbon atom at the center and two atomic planes labeled "B" and "A" to illustrate their perpendicular configuration.

Both individual "A" and "B" planes can only absorb short wavelength UV light and reflect all visible light, so the beads appear white when the planes are perpendicular to each other. When they are exposed to UV light (like from sunshine or a special lightbulb), and they absorb this UV light, the flat planes of atoms rotate to be in the same orientation, or parallel to each other, such as in **Figure 4**, so that they create one large, flat plane.When there is functionally one large plane of atoms (two smaller planes combined), larger wavelengths of light in the visible spectrum can be absorbed, leading to color. One can vary the sizes of these planes in the dye molecule to absorb different wavelengths, leading to a variety of colors being reflected for us to see.

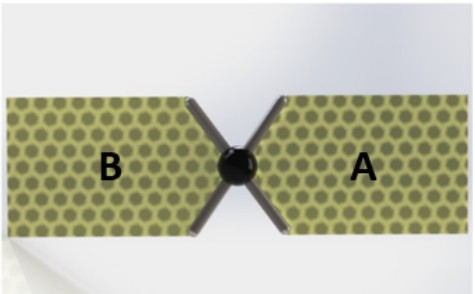

Figure 4. Planes "B" and "A" oriented to the parallel, flat configuration.

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Lesson Plan: Background Information

When there is no longer exposure to UV light, the individual planes rotate back to their original, perpendicular position. This breaks up the large plane. This removes the visible wavelength absorption and the appearance of color, turning the bead white again. This process of exposing UV light to rotate the individual planes to a parallel configuration, then removing the UV light to rotate them back to a perpendicular configuration can be infinitely repeated.

Deep Dive

The "planes" of atoms have a conjugated carbon backbone. Conjugated means that they alternate between single and double bonds, as shown here:

–C=C–C=C–C=C–C=

Conjugated molecules are known to be light absorbing. The longer the molecule is, the larger the absorbable wavelength.

Keywords

photon: a particle of light.

electromagnetic radiation: the flow of invisible energy through space in the form of electric and magnetic fields that make up electronic waves. Electromagnetic radiation is what makes the sun warm, and it's also how music is sent to your radio.

absorption: when photons (light particles) are trapped by a material.

light: tiny particles called photons moving in a wavelike manner.

molecule: a group of two or more atoms that are chemically bonded together. A molecule is the smallest unit of a substance that has all the properties of that substance.

reflection: when photons (light particles) are rejected by a material.

wavelength: the distance between two crests of a wave.

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Lesson Plan: Background Information

Experimental Procedure

1. Place five beads in the opaque brown plastic bag included in this package. Leave the other five beads in the clear bag and expose both bags to the sunlight. What happens to each group of beads?
2. Try placing the beads in other containers you find at home or school, including metal, paper, plastic, glass, clear, opaque, and colored.
3. Place some beads in direct sunlight and others in the shade. Where is the UV light the strongest?
4. Cover some beads with a pair of sunglasses and then expose them to sunlight. Try different sunglasses. What happens?
5. Expose the beads to different kinds of light sources: fluorescent, incandescent, colored, LED, blacklight, etc. Do the beads respond to any of these artificial lights?
6. Coat the beads with different SPF sunscreens (keep two beads without) then expose them to sunlight. How do they compare?

Cleanup and Resupply

- Beads can be reused.
- Rinse off sunscreen with water if necessary.

Tips for Success and Troubleshooting

- This activity can be done in small groups or together as a class.

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Lesson Plan: Discussion Prompts

Before the Experiment

Where does color come from?

Refer to information provided in the Background Information section of this document for discussions before beginning the experiment. Students may have prior knowledge on light classified in the visible range, discuss how each color has a characteristic wavelength within this range. To discuss further, explain that there are wavelength classifications above and below the visible spectrum (ultraviolet and infrared) that we cannot see.

Why are different objects different colors?

Continue to give students information stated in the Background Information section. Make sure students understand that objects will absorb certain wavelengths of visible light, and reflect the rest. With the exception of white objects (reflect all visible wavelengths and absorb none) and black objects (absorb all visible wavelengths and reflect none), an object will reflect the wavelength of its respective color, and absorb the rest.

During the Experiment

How can the beads change color?

State that the color is ultimately controlled by the molecule that makes up the dye within the bead. Discuss the geometry of the molecule, as provided in the Background Information section. When the beads are exposed to UV light, the flat planes of the atoms rotate to be in the same orientation, or parallel to each other. In this "flat" orientation, larger wavelengths of light in the visible spectrum can be absorbed, leading to color. When there is no further exposure to UV light, the plans of the molecule rotate back to their original, perpendicular position. This removes the visible wavelength absorption, turning the bead white again.

Why do the beads absorb some wavelengths of light in certain conditions but not in others?

Emphasize that UV light conditions are needed to rotate the flat planes of the molecules within the dye to the same orientation, so that they are parallel. In this parallel configuration, both UV light and visible light can be absorbed, which allows for visible colors to be reflected. Without the UV light conditions to rotate the perpendicular planes to a parallel orientation, all light within the visible wavelength is reflected.

After the Experiment

Which conditions made the beads change color? What did they have in common?

Have students list the conditions in which the beads changed color. In conditions where there was exposure to UV light (either unobstructed or conditions of mild opacity), the beads were able to change color.

Which light sources provide UV light?

Sources that provide UV light that of either real (sunlight), or artificial UV sources.

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Lesson Plan: Discussion Prompts

How effective are different types of sunscreens at blocking UV light?

Compare the different types of sunscreen (if multiple types were used) and their effectiveness in prohibiting the color change of the beads. Include SPF levels of each sunscreen in the discussion.

How effective are different types of sunglasses at blocking UV light?

Compare the different types of sunglasses (if multiple types were used) and their effectiveness in prohibiting the color change of the beads.

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Student Handout

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1. Which setups made the beads change color? What did these setups have in common?

2. Which light sources provide UV light?

3. How effective are different types of sunscreens at blocking UV light?

4. How effective are different types of sunglasses at blocking UV light?