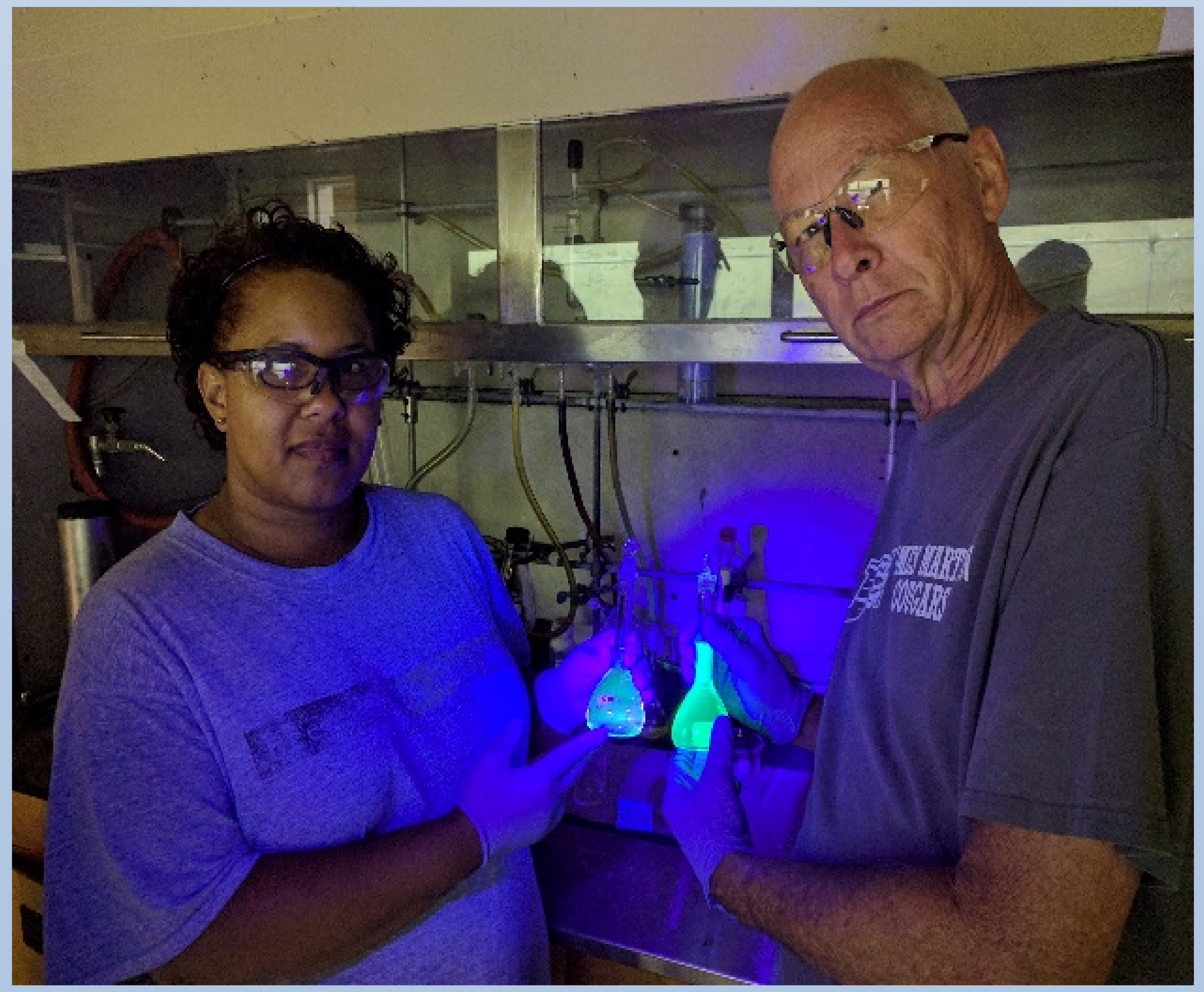
How you can use Fluorescence and Light to demonstrate Chemistry Concepts in your Classroom

Geneva Bell & Phil H Carver



CTI/SRET/UNCC

August 17, 2017

Research in the Lab

Expectations

- Hoping to gain experience in a University research lab
- Refine or update past experiences
- To share the gained knowledge with our classrooms

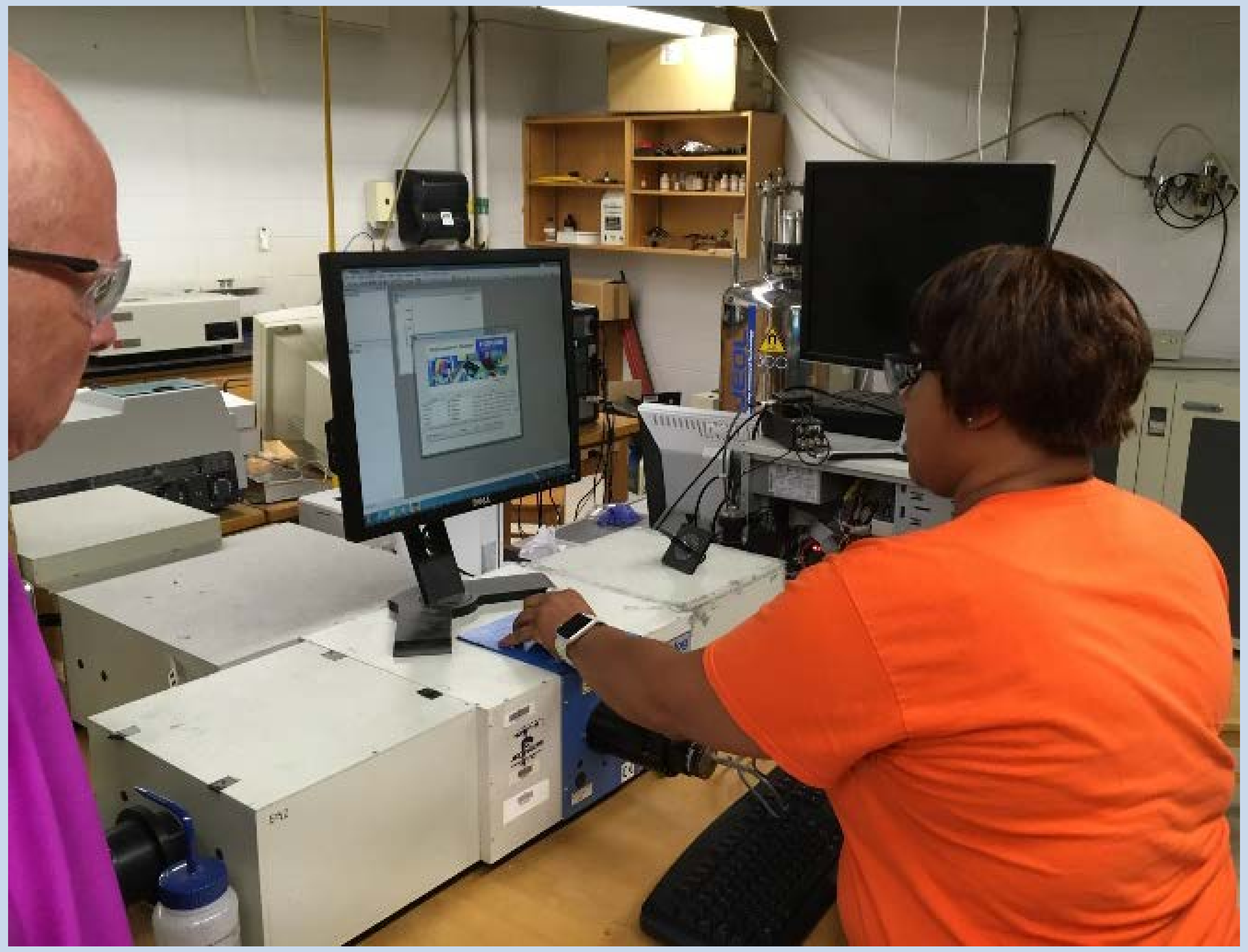
Reality

- Didn’t think about all hazardous material and safety training
- Huge gap in lab experiences and safety differences in level and equipment
- Posters are very detailed and presented as finale

Research Goals

- To learn how to use the Flourolog Instrument for characterization of fluorescence properties of various dyes

- To characterize fluorescent dyes that can be used in Light Emitting Diodes (LED)



Vocabulary Words

Dye Characteristics

- Emission
- Excitation
- Lifetime
- Photon
- Solvents

Equipment and Chemicals

- Fluorolog (fluorescence spectrometer)
- Nitrogen
- Silicon based dye

Fluorescent Dyes Research

Research Investigations

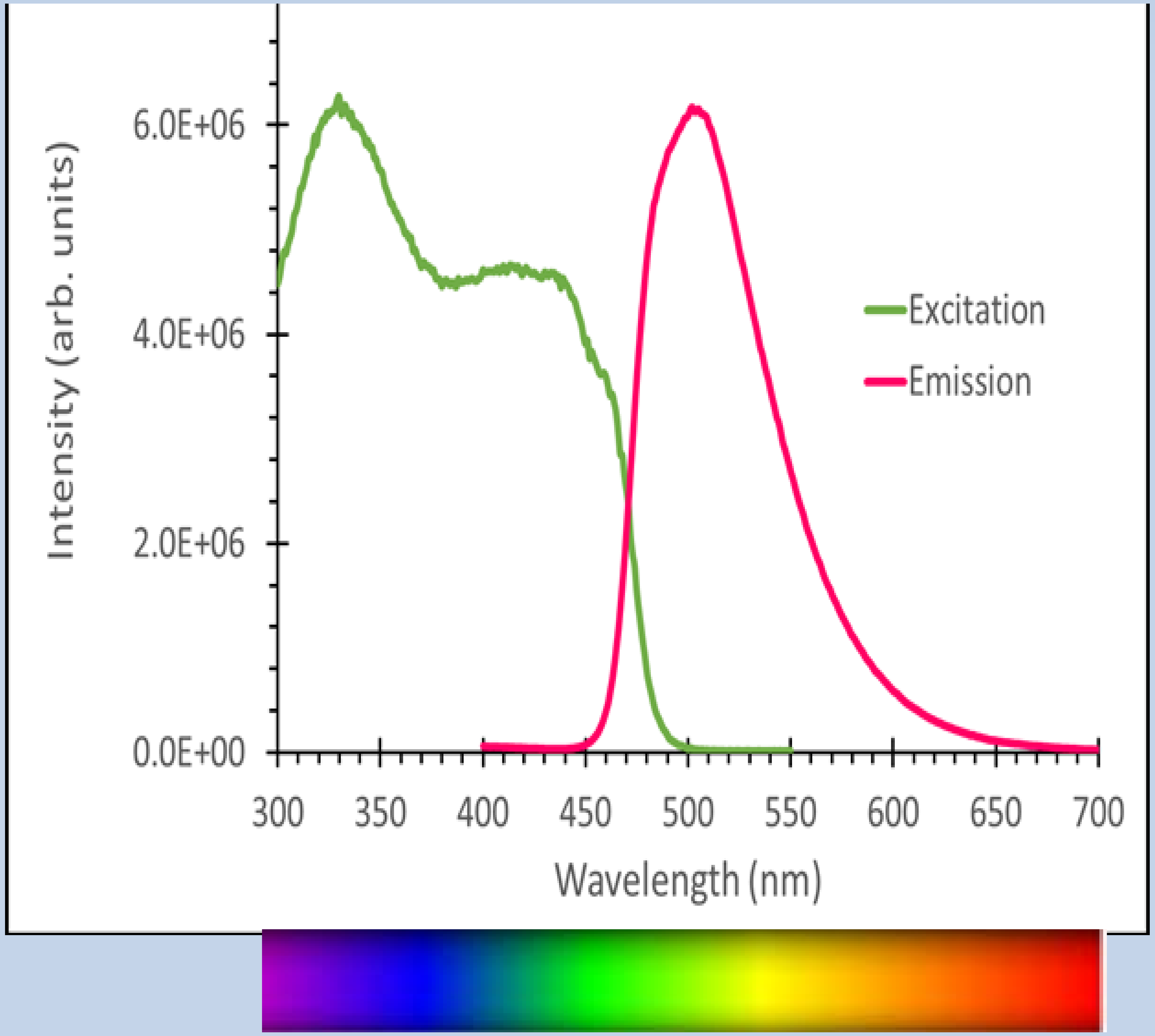
- Investigate 2 fluorescent dyes
- Use different solvents
- In air vs degassed solutions
- Emission: amount of light emitted
- Excitation: when light energy is applied to a molecule it is excited.
- Lifetime: length it takes to stop “glowing”

Poster and Curricula

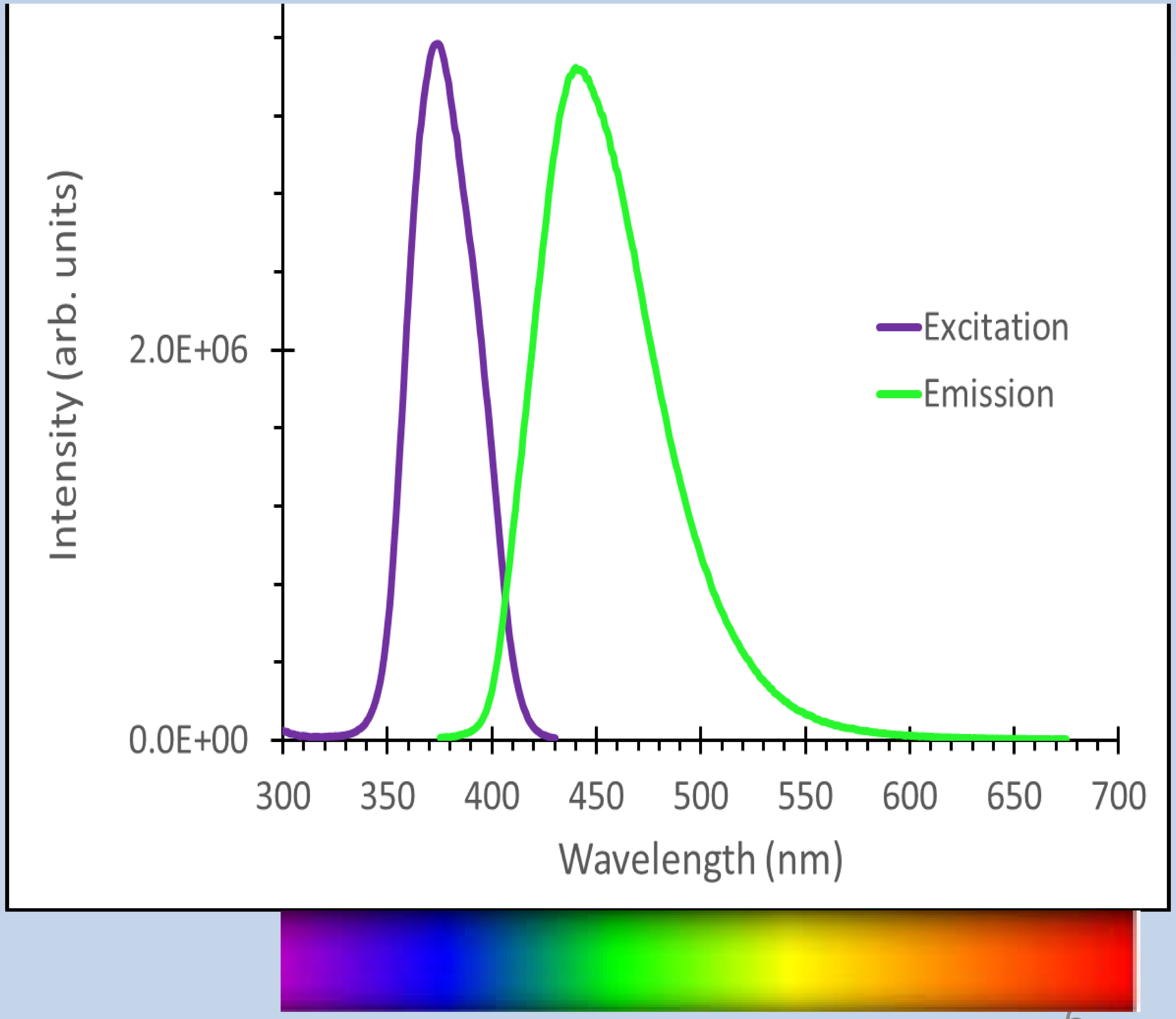
- Flow and content of scientific presentation
- Format of the poster
- Attended undergraduate research poster competition
- Application of novel research to 8th grade science

Emission and Excitation Graphs

Fluorescence Spectra of $Si(Bzimpy)_2$ in CH_2Cl_2

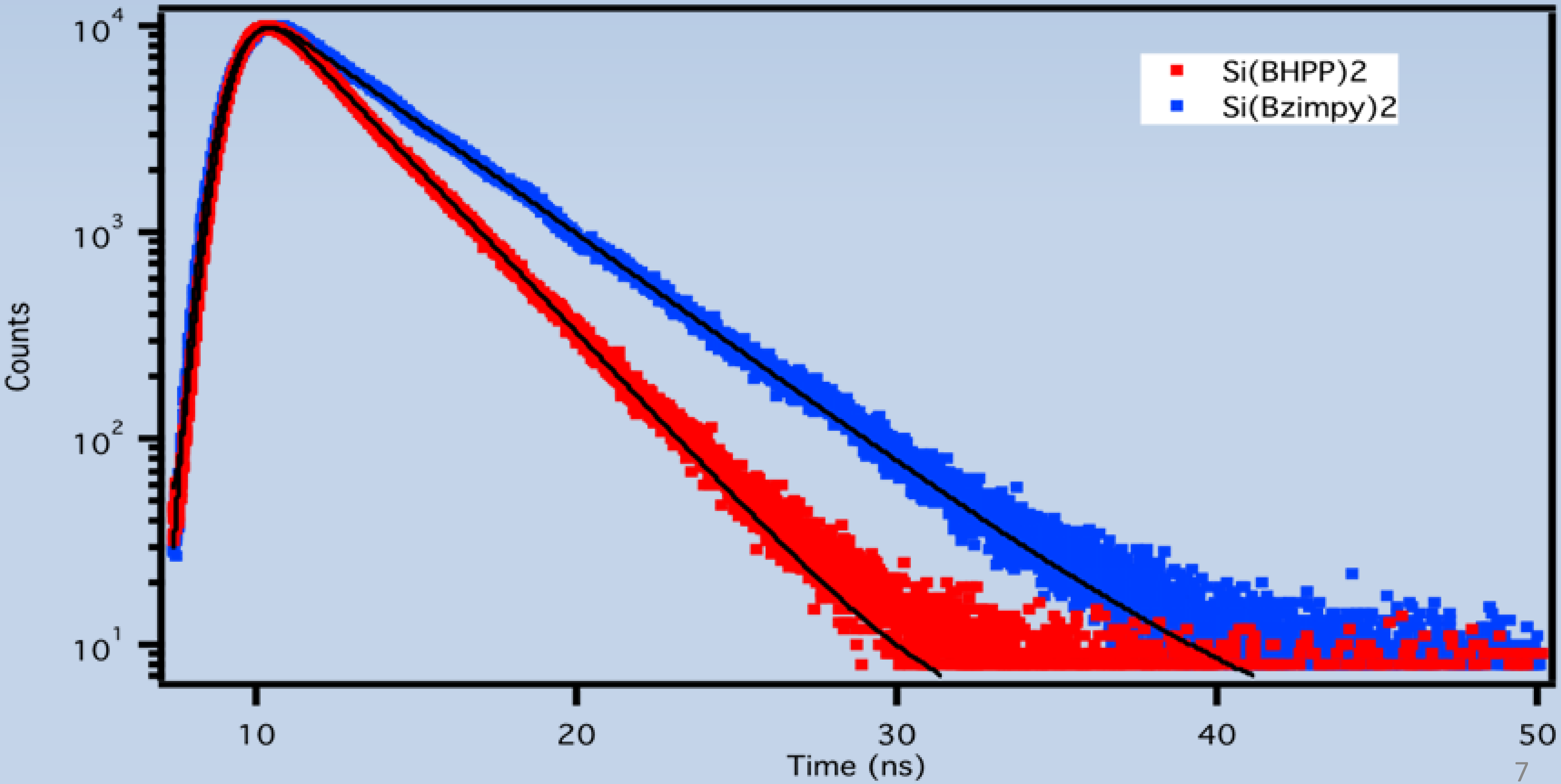


Fluorescence Spectra of $Si(BHPP)_2$ in CH_2Cl_2



Lifetime Decay Graph

Decay of $Si(Bzimpy)_2$ **Decay of $Si(BHPP)_2$**



Essential Standards

- 6.P.1.2 Explain the relationship among visible light, the electromagnetic spectrum, and sight.
- 6.P.3.2 Explain the effects of electromagnetic waves on various materials to include absorption, scattering, and change in temperature.
- 8.P.1.1. Classify elements, compounds and mixtures based on atom arrangement.
- 8.P.1.2. Use the periodic table to identify elements based on information about physical properties.
- 8.P.1.2. Use the periodic table to predict chemical reactions.
- 8.P.1.3 Identify the properties of matter.
- 8.p.1.4. Explain how a balanced equation demonstrates the Law of Conservation of Mass

Chemical vs. Physical Changes

- One evidence of a chemical change is the production of a new substance.
- The quinine is still quinine when it changes color to blue in sunlight.
- How do we know it's a physical change?
- Because color changes back to clear when removed to sunlight.

Chemical vs. Physical Changes

- Objective: To demonstrate the color change in quinine in tonic water when exposed to sunlight is a physical change.

- Standard 8.P.1.3 Physical changes do not change the composition of a substance, only the physical properties.

- Example: Quinine color change will reverse when removed from sunlight.

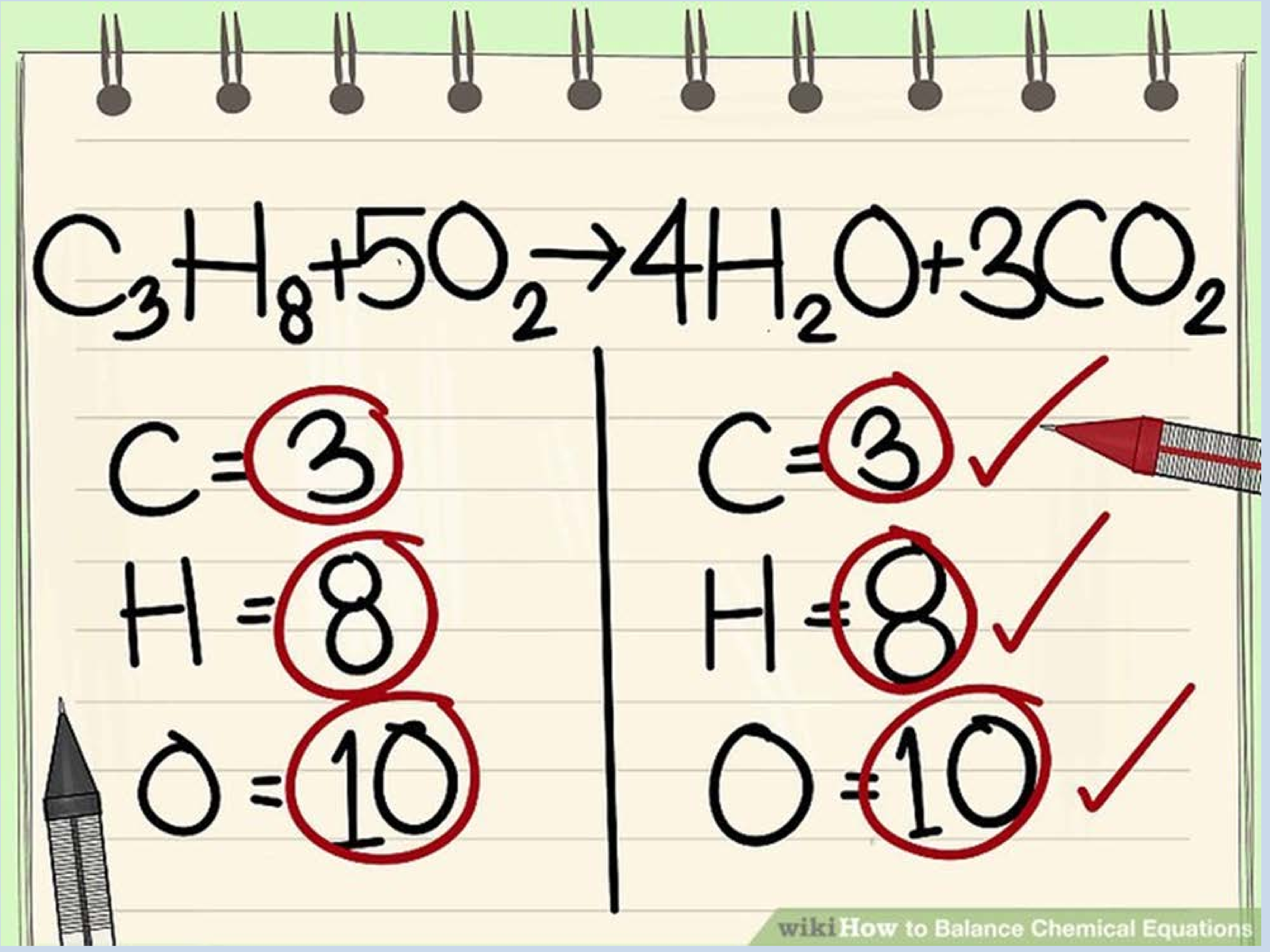
Balancing Equations Activity
T Chart with Math

$$2\,C_{19}H_{13}N_5 + 4\,C_6H_{15}N + SiCl_4 \longrightarrow C_{38}H_{22}N_{10}Si + 4\,C_6H_{16}NCl$$

Si(Bzimpy)$_2$

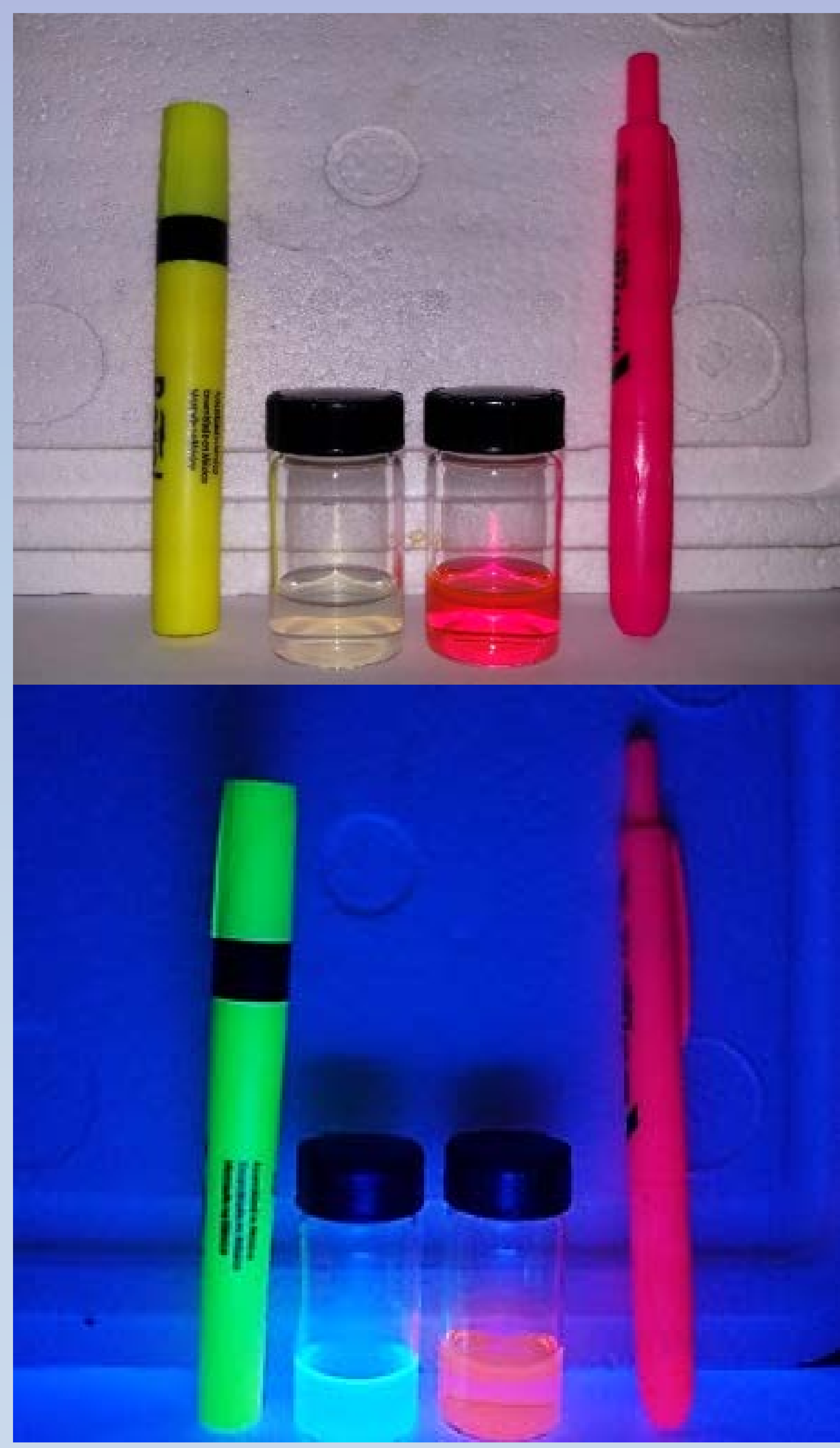
$$2\,C_{17}H_{13}NO_2 + 4\,C_6H_{15}N + SiCl_4 \longrightarrow C_{34}H_{22}N_2O_4Si + 4\,C_6H_{16}NCl$$

Si(BHPP)$_2$

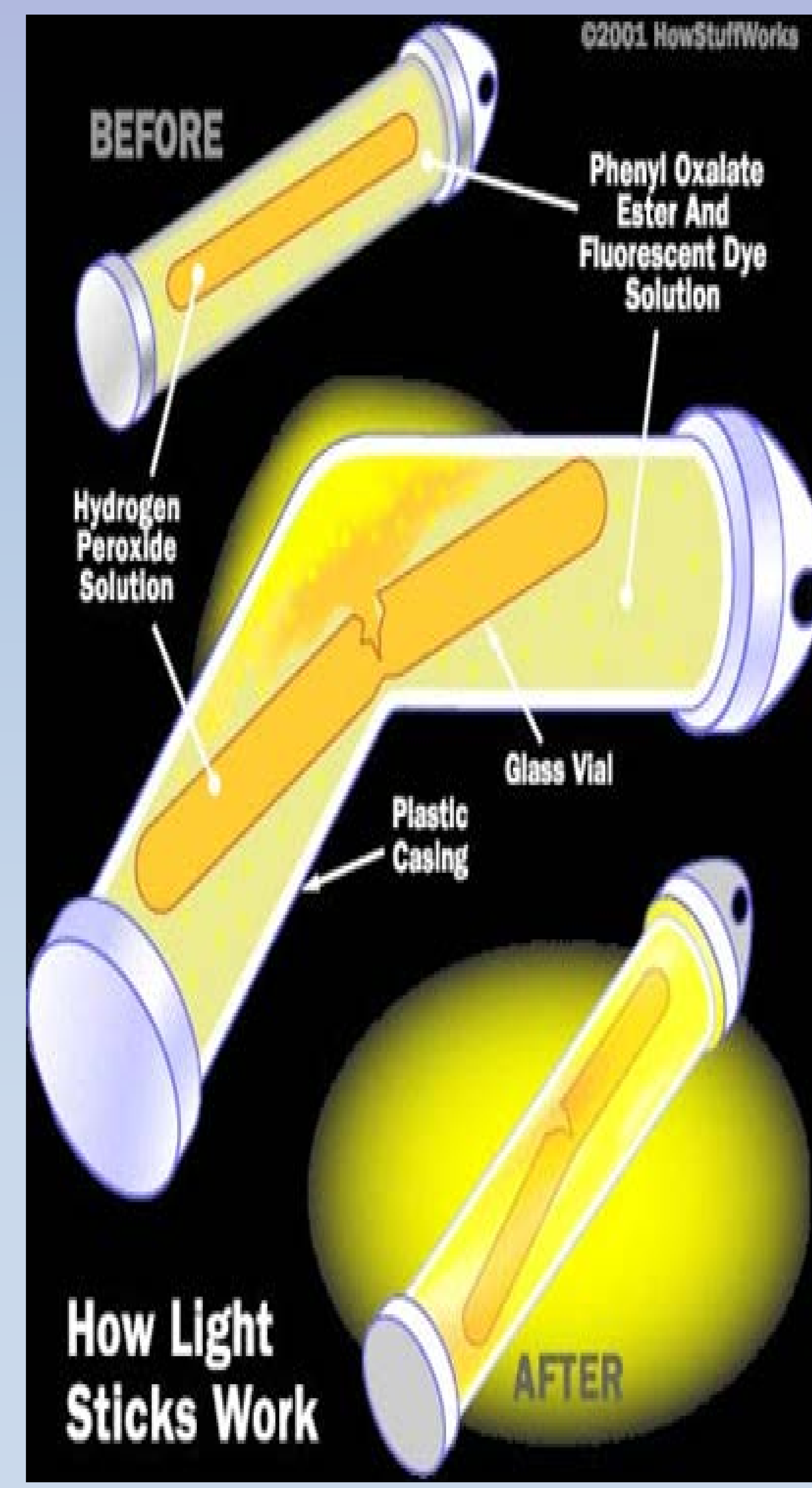


Mixtures & Compounds

Markers Lab



Glow Sticks



$$C_{14}H_{10}O_4 + H_2O_2 + dye_{(relaxed)} \longrightarrow$$

$$\longrightarrow 2C_6H_6O + C_2O_4 + dye_{(excited)}$$

Research Experience for Teachers (SRET)

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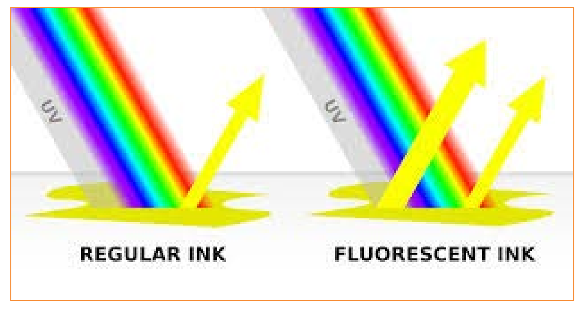
Introduction

Human eyes can interpret only a narrow range of wavelengths of electromagnetic waves known as visible light (390 nm – 700 nm). Different of wavelength within that range are perceived as different colors. Light is a form of energy emitted by the sun as well as light-producing objects on Earth. Light can be absorbed, transmitted, refracted, and/or reflected (scattered) by objects depending on their properties, the type and angle of light that hits the object. Some materials can absorb high energy light (ultraviolet light) known as visible light and emit lower energy light (visible light) such as when your neon clothes "glow" under black light. "

In the case of this research experience the fluorescence properties were explored using a particular wavelength (365 nm) of light that is being absorbed and the visible light that is being emitted.

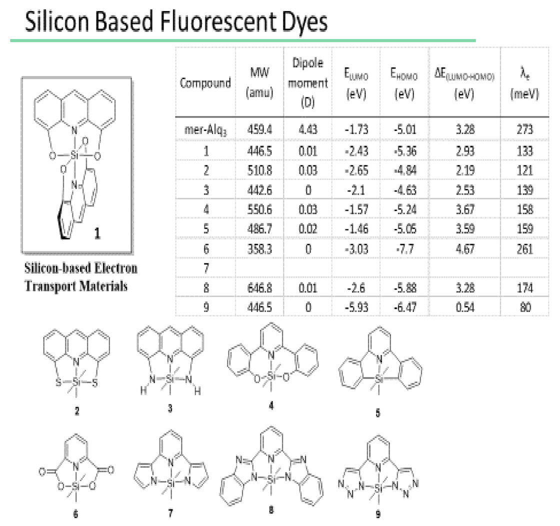


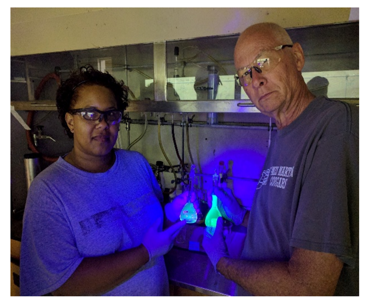
$$2\ C_{19}H_{13}N_5 + 4\ C_6H_{15}N + SiCl_4 \longrightarrow \underset{Si(Bzimpy)_2}{C_{38}H_{22}N_{10}Si} + 4\ C_6H_{16}NCl$$

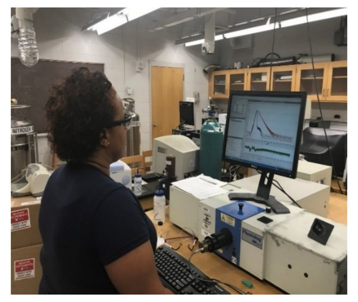
$$2\ C_{17}H_{13}NO_2 + 4\ C_6H_{15}N + SiCl_4 \longrightarrow \underset{Si(BHPP)_2}{C_{34}H_{22}N_2O_4Si} + 4\ C_6H_{16}NCl$$

Research Goals

- To characterize fluorescent dyes that can be used in Light Emitting Diodes (LED)
- To learn how to use the Flourolog Instrument for characterization of fluorescence properties of various dyes





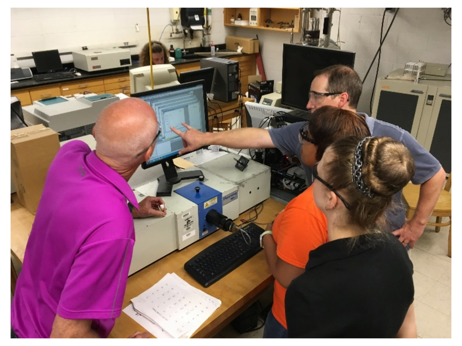


- **Nanometers** and **Nanoseconds** are tiny measurements that scientist use.
- **Nao** means 1 billionth of a meter or second, which written in exponents is $1{\times}10^{-9}$ m or s.
- **Absorption**: how much light a substance takes in (Absorb)
- **Emissions**: how much light a substance gives off (Emit)
- **Excitation**: when light energy is applied to a molecule it is excited
- **Photons**: light
- **Lifetime**: A measure of the time a fluorophore spends in the excited state before falling back to the ground state by **emitting** a **photon**. The **lifetime** of fluorophores are measured in units ranging from picoseconds to of **nano**seconds.

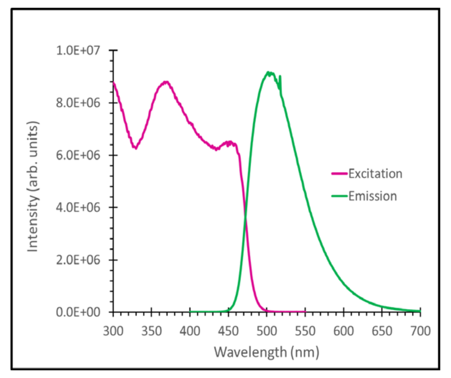
Data

Fluorescence occurs when a source of energy excites **molecules**, making them release packets of light called **photons**. When **ultraviolet light** is absorbed into the sample solution the absorbed energy causes the **molecules** to become excited. When energy is being released in the form of visible light, the **molecules** return to their initial relaxed state.

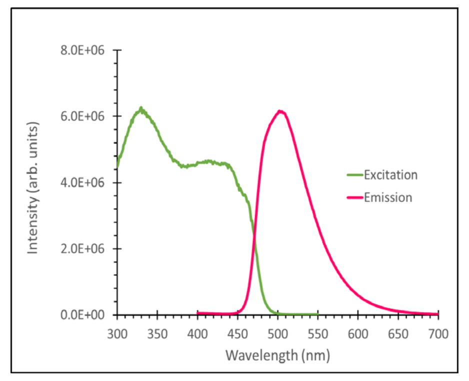
In the case stated above, the **molecules** are excited via light but there are other ways to excite molecules. For example via heat such as burning fire wood or fireworks or as a result of a **chemical reaction** like breaking a glow stick.



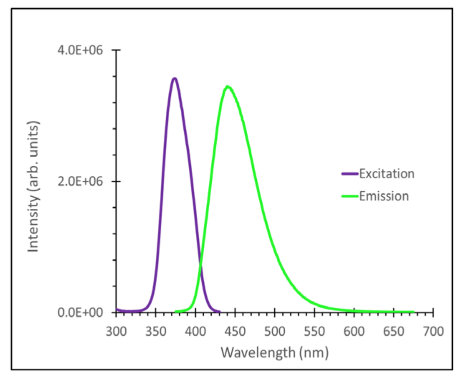
Fluorescence Spectra of Si(Bzimpy)$_2$ in $CHCl_3$



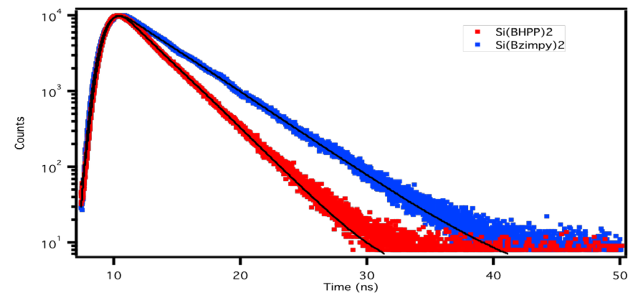
Fluorescence Spectra of Si(Bzimpy)$_2$ in CH_2Cl_2

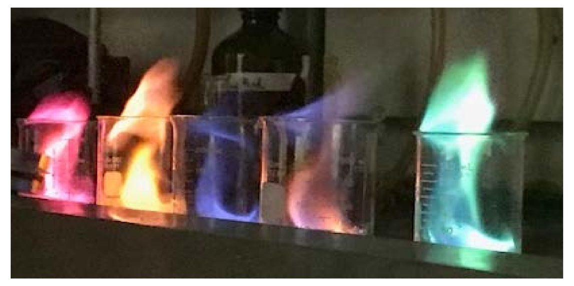


Fluorescence Spectra of Si(BHPP)$_2$ in CH2Cl$_2$



Time-resolved Fluorescence Spectra





Standards

6.P.1.2 Explain the relationship among visible light, the electromagnetic spectrum, and sight.
6.P.3.2 Explain the effects of electromagnetic waves on various materials to include absorption, scattering, and change in temperature.
8.P.1.1. Classify elements, compounds and mixtures based on atom arrangement.
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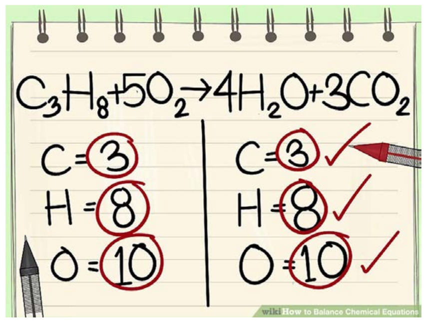

Acknowledgments

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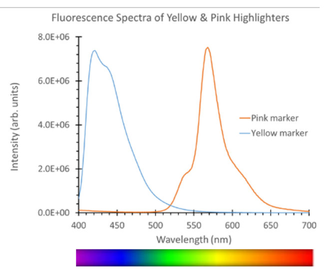
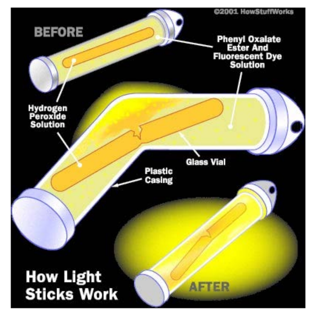
Labs

Mixtures & Pure Compounds





$$C_{14}H_{10}O_4 + H_2O_2 + dye_{(relaxed)} \longrightarrow 2C_6H_6O + C_2O_4 + dye_{(excited)}$$

Mixtures

- **Mixtures** are physical combinations of two or more different substances that retain their own individual properties and are combined physically (mixed together).
- **Mixtures** can be separated by physical means (filtration, sifting, or evaporation). Characteristic properties can be used to identify different materials and to separate a mixture into its components.
- **Mixtures** may be heterogeneous or homogeneous.
  - In a heterogeneous mixture, which is not uniform throughout, the component substances can be visibly distinguished. Tossed salad, granite, and iced tea are examples of heterogeneous mixtures.
  - In a homogeneous mixture, which is uniform throughout, the substances are evenly mixed and cannot be visibly distinguished. Air, steel, clear salt-water are examples of homogeneous mixtures.

Compounds

- **Compounds** are pure substances that are composed of two or more types of elements that are chemically combined.
- **Compounds** can only be changed into simpler substances called elements through chemical changes.

Physical vs Chemical Changes

Physical properties can be observed and measured without changing the kind of matter being studied. The following **physical properties** can be used to help identify a substance:

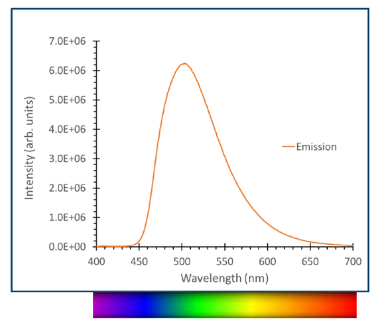
Boiling Point
Melting Point
Density
Color

Chemical Properties can also be used to help identify a substance. **Chemical properties** can be recognized only when substances react or do not react chemically with one another, that is, when they undergo a change in composition.

How to differentiate between physical and chemical changes?

- **Physical changes** do not change the composition of a substance, only the physical properties. Evidences of a physical change include:
  - Change in state of matter
  - Change in size or shape
- **Chemical changes** result in the formation of one or more new substances with new chemical and physical properties. Evidences that a chemical change may have occurred include:
  - Color change
  - Temperature change
  - Formation of a precipitate
  - Formation of a gas

Fluorescence Spectra of Tonic Water



Research Experiences with Fluorescent Dyes for Teachers

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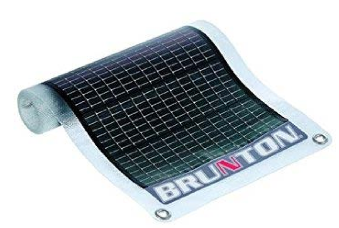
[b]Dept. of Chemistry, UNC Charlotte, 9201 University City Blvd., Charlotte, NC 28223

Background Information and Applications of Fluorescent Dyes

The sunlight that reaches earth is enough to power the world's energy usage. However, only about 25% of the sun's energy reaches the Earth's surface. And most of that limited solar energy cannot be utilized effectively, as most solar cells have efficiency rating of less than 20%. Also, the wavelengths used by solar panels are restricted to wavelengths between 300 and 700 nanometers (nm) that can be absorbed by silicon solar cells and wavelengths under 400 nm are often wasted as heat inside the solar or photovoltaic cell.



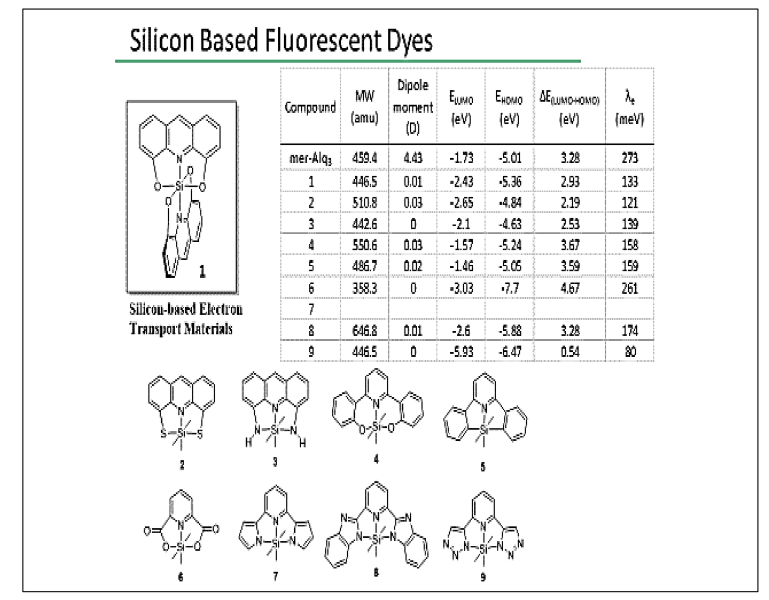
Fluorescent dyes can be used for converting light, as they have the ability to convert one high energy photon into two or more low energy photons. Electrons are excited by the photons and when they fall back down, they release two photons that have lower energy. With using fluorescent dyes, wavelengths under 400 nm can be converted to about 600 nm, which is visible light, and the silicon wafers can use more efficiently. In other words, research on fluorescent dyes can help make solar panels more efficient.

Research Goals

- To characterize fluorescent dyes that can be used in Light Emitting Diodes (LED)
- To learn how to use the Flourolog Instrument for characterization of fluorescence properties of various dyes




Vocabulary and Reference Data

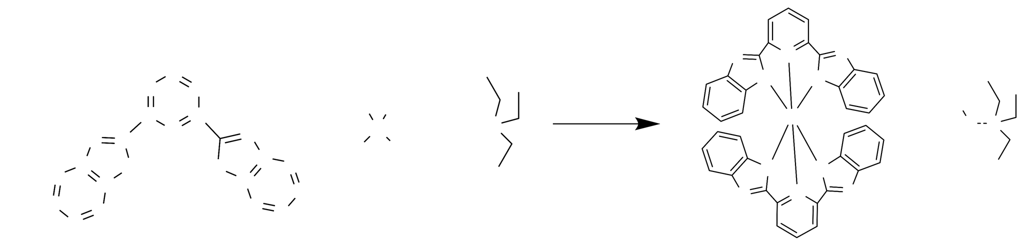


Compound	MW (amu)	Dipole moment (D)	E_{LUMO} (eV)	E_{HOMO} (eV)	$\Delta E_{(LUMO-HOMO)}$ (eV)	λ_t (meV)
mer-Alq_3	459.4	4.43	-1.73	-5.01	3.28	273
1	446.5	0.01	-2.43	-5.36	2.93	133
2	510.8	0.03	-2.65	-4.84	2.19	121
3	442.6	0	-2.1	-4.63	2.53	139
4	550.6	0.03	-1.57	-5.24	3.67	158
5	486.7	0.02	-1.46	-5.05	3.59	159
6	358.3	0	-3.03	-7.7	4.67	261
7						
8	646.8	0.01	-2.6	-5.88	3.28	174
9	446.5	0	-5.93	-6.47	0.54	80

-Nanometers and Nanoseconds are tiny measurements that scientist use.
-Nao means 1 billionth of a meter or second, which written in exponents is 1×10^{-9} m or s.
-Absorption: How much light a substance takes in (Absorb).
-Emissions: How much light a substance gives off (Emit).
-Compounds: 2 or more elements chemically combined.
-Excitation: when light energy is applied to a molecule it is excited.
-Photons: light.
-Lifetime: A measure of the time a fluorophore spends in the excited state before falling back to the ground state by emitting a photon. The lifetimes of fluorophores are measured in units ranging from picoseconds to of nanoseconds.
Bioluminescence: the production and emission of light by a living organism.

Obtained Data

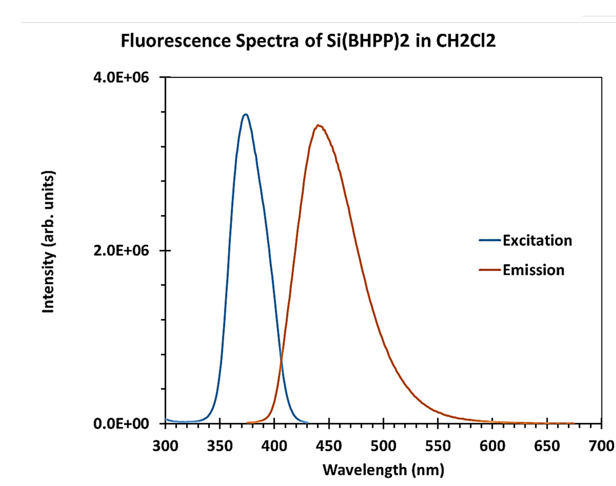
Reaction Equation Using Structural Formulas

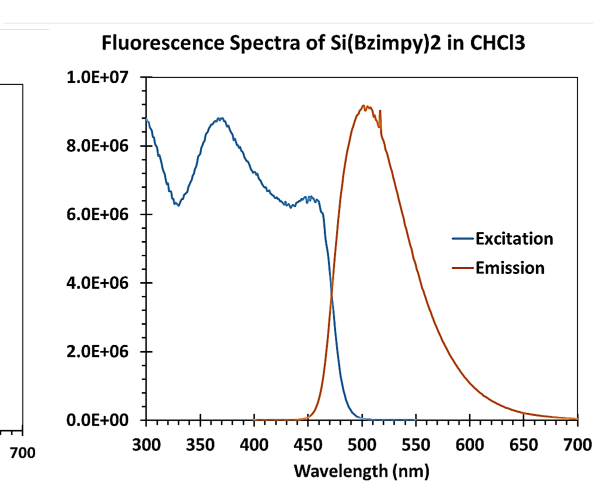


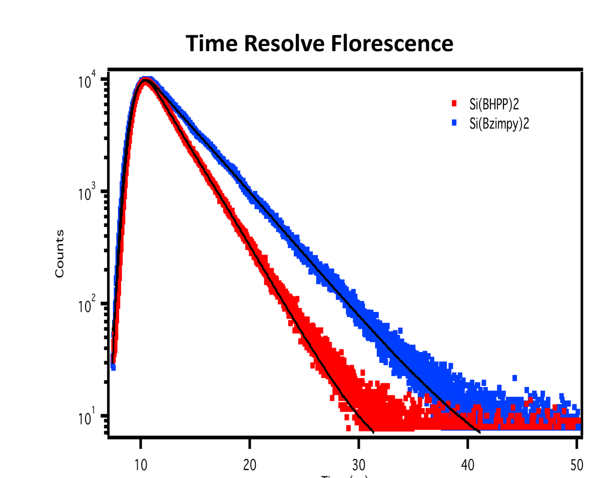
Reaction Equations Using Molecular Formulas

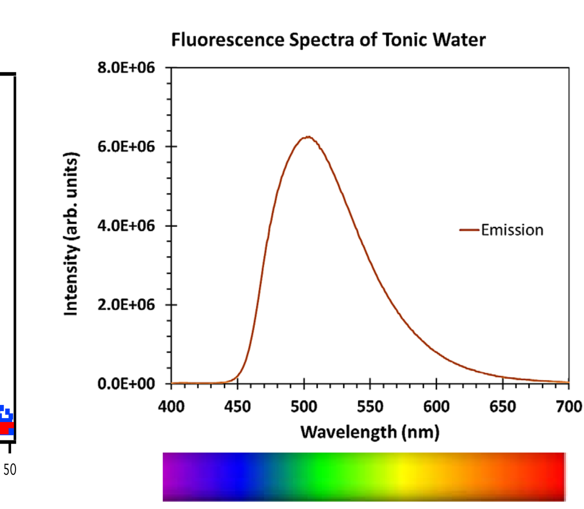
$$2\,C_{19}H_{13}N_5 + 4\,C_6H_{15}N + SiCl_4 \longrightarrow \underset{Si(Bzimpy)_2}{C_{38}H_{22}N_{10}Si} + 4\,C_6H_{16}NCl$$

$$2\,C_{17}H_{13}NO_2 + 4\,C_6H_{15}N + SiCl_4 \longrightarrow \underset{Si(BHPP)_2}{C_{34}H_{22}N_2O_4Si} + 4\,C_6H_{16}NCl$$



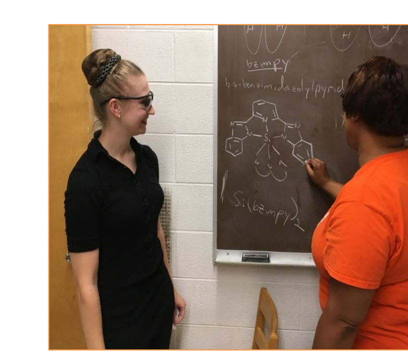






Fluorescence occurs when a source of energy excites molecules, making them release packets of light called photons. When you burn wood, you create light and heat energy. The heat energy causes light energy and the heat energy causes the molecules that make up the wood to speed up. When the molecules speed up, they hit each other with more frequency. If the molecules are excited enough, the heat will transfer energy to some of the molecule's electrons.

When this happens, an electron will be boosted to a higher energy level (This is the excited state). When the electron's energy level eventually falls back down to its original level (This is the relaxed state) it gives up some of its energy in a form of light. A glow stick does the same thing, but it uses a chemical reaction to excite the fluorescent dye. And, we can apply ultra-violet light to a dye which can be converted to visible light

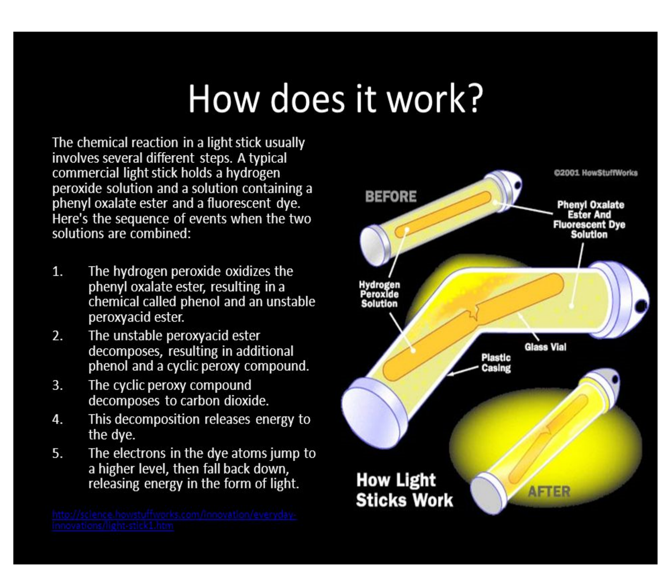


NC Standards

Standards included in this Curriculum Unit include:
8.P.2.2 Explain the implications of the depletion of renewable and nonrenewable energy resources and the importance of conservation.
8.P.1.1 Classify matter as elements, compounds, or mixtures based on how the atoms are packed together in arrangements.
8.P.1.2 Explain how the physical properties of elements and their reactivity have been used to produce the current model of the Periodic Table of elements.
8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.
8.P.1.4 Explain how the idea of atoms and a balanced chemical equation support the law of conservation of mass.

Lab Activities and Materials

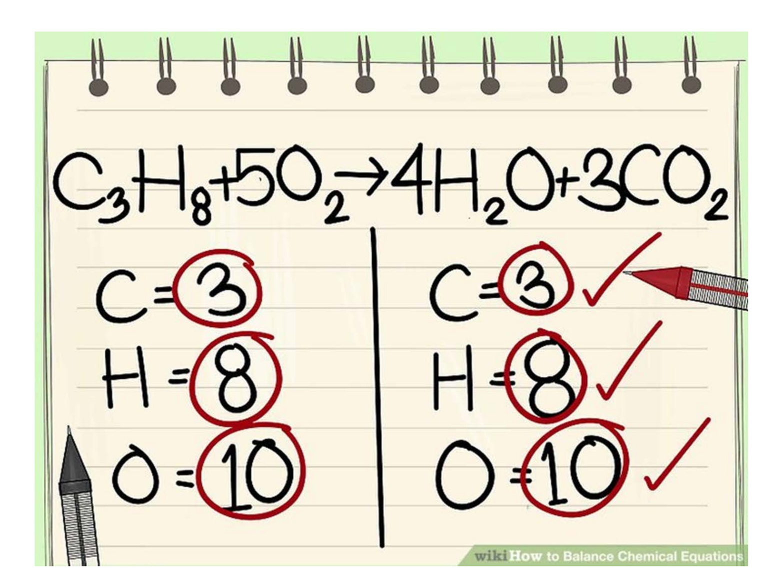
Glow Stick Lab



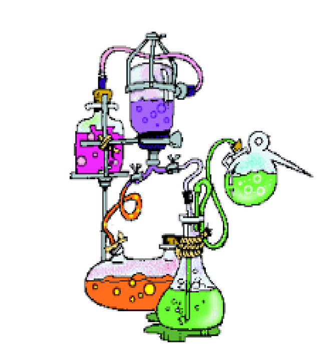
Tonic Water with Quinine Lab

These labs are related to the NC 8th Grade Science Standard 8.P.1.4, in which students compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.
The glow stick activity demonstrates the release of energy and proves that a chemical reaction occurs. The quinine in the tonic water, which turns blue when observed under sunlight or UV light, however, proves that a physical change occurred when it is removed from the sunlight and UV light.

Balancing Equations Lab



The Balancing Equations Lab is related to the NC 8th Grade Science Standards 8.P.1.4, as students are expected to explain how the idea of atoms and a balanced chemical equation support the Law of Conservation of Mass (LCM).
The reaction, shown in the form of an equation above, demonstrates The LCM and can be used in a lesson plan to identify elements and prove that the equation is balanced, thus proving the LCM.




Acknowledgements

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- Phil Carver, James Martin Middle
- Scott Gartlan, CTI
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- CTI support

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