Modeling Light Interactions with Matter (liquid solutions)

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Subject: Physics

Grade Level: High School

Standards: Next Generation Science Standards (www.nextgenscience.org)

HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy

Schedule: Two 45 minute periods

CCMR Lending Library Connected Activities:
Diffraction
DNA and the Diffraction of Light (CIPT)
The Phantastic Photon and LEDs (CIPT)

Objectives:	**Vocabulary:**
Laser pointers of several frequencies, index cards, and a small transparent container of extra virgin olive oil can be used to investigate the interaction of light with particles in solution. One can describe the observed phenomena operationally in terms of brightness, color, and direction or from a photon – particle perspective.	· transmission · scattering · absorption · fluorescence · Stokes Shift
Students Will: 1. Operationally define scattering, transmission, absorption, and fluorescence. 2. Develop a photon/energy level model for absorption and fluorescence. 3. Interpret absorption and emission spectra and define the Stokes Shift	**Materials:** - Two plain white index cards - One small, transparent container of extra virgin olive oil - Laser pointers (green, red, blue/violet)
Safety	The laser pointers used can damage tissue, especially in the eye. Care must be taken to assure that laser light is aimed only at the targets intended in this activity

Science Content for the Teacher:

When light encounters matter (such as particles in a solution), there are several phenomena which may occur. Light may pass through the material without any color or direction change, in which case it has transmitted through the material. If charges within the particle begin to vibrate with the same frequency (color) as the incident light and that light now heads off in all directions, then scattering has occurred. When light scatters, its direction may change but its color, wavelength, and frequency will not. Absorption stands as another possible phenomenon. During absorption, the light energy of the incident photon is converted into other forms of energy, such as rotational or vibrational energy. The intensity of the incident light diminishes, possibly too low to see. Finally, an absorbed photon may force the particle into an excited state. When the electron returns to a lower energy level, the particle emits a photon which may move in any direction and have a different color from the incident photon. In this case, fluorescence has occurred.

Careful study of these phenomena occurs via spectroscopy: The intensity of absorption or emission over a range of the electromagnetic spectrum (such as visible, infrared, ultraviolet, microwave, or x-ray wavelengths) Absorbance and emission spectroscopy can be used to detect the presence of particles in solution, even if the solution is rather dilute.

Fluorescence is a relatively rare, but interesting phenomenon. In most cases, the incident photon has a greater energy (and hence greater frequency or smaller wavelength) than the emitted photon. The difference in energy, known as a "Stokes Shift," happens because some of the energy of the incident photon converts to other forms of energy (e.g. vibrational or rotational). Careful analysis of fluorescence can allow for the determination of the size distribution and/or speed of the particles in a solution. Fluorescent particles form the basis of several forms of medical imaging.

Classroom Procedure:

1. Print appropriate numbers of copies.
2. Students obtain two index cards, one green laser pointer, and one small, transparent container of extra virgin olive oil. Each group will later need a red laser pointer and a blue/violet laser pointer.
3. Student groups complete exercises and experiments outlined on the student handout.
4. The teacher monitors group and individual progress on the experiments and exercises. Monitoring will include reading students' notebooks, encouraging group discussions, and "checking out" groups who complete each part.
5. Students complete an exit ticket.

Assessment:

Students will answer questions as they complete each exercise. Students will also complete a an exit ticket.

Resources:

Gore, Gordon R., "Fun with fluorescence in olive oil," *The Physics Teacher*, 50, 377-378, (2012)

Wahab, M. Farooq, and Gore, Gordon R., "Deeper insight into Fluorescence—Excitation of Molecules by Light," *The Physics Teacher,* 51, 306-308, (2013)

Extra Activities:

- Those outlined in: Wahab, M. Farooq, "Fluorescence Spectroscopy in a Shoebox," *Journal of Chemical Education,* 84 (8), 1308 (2007)
- Those outlined in: Albert, Daniel R., Todt, Michael A., and Davis, H. Floyd, "A Low-Cost Absorption Spectrophotometer," *Journal of Chemical Education,* 89, 1432-1435 (2012)

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