Sleuthing, The Avengers and Chemistry

Lesson Plan for Grades: 9th grade
Length of Lesson: 50 minutes

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Date created: 04/26/2018

Subject area/course:
- Chemistry

Materials:
- access to internet (only for teacher use during Engage, optional for student use during Explore)
- For Jigsaw: 7 post it sheets, markers
- Handouts (class set): Student handouts 1-4
- Alternative to Student Internet Research: "Expert" Handouts

Safety:
- For the Explore: None

TEKS/SEs:
§112.35. Chemistry
(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:
- (B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(6) Science concepts. The student knows and understands the historical development of atomic theory. The student is expected to:
- (B) understand the electromagnetic spectrum and the mathematical relationships between energy, frequency, and wavelength of light;

Lesson objectives: SWBAT (Students Will Be Able To):
- Identify different types of radiation and how their energy relates to the frequency and wavelength.

Differentiation strategies to meet diverse learner needs:
- Provide detailed handouts with written instructions.
- For ELL students, provide sentence stems when needed and subtitles for video clips.

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ENGAGEMENT (7 minutes)

- Teacher asks students to share their experiences about the last fireworks show they saw (4th of July, New Years, special parade or at a theme park). What did you see? What did you notice?
- Teacher - "Let's look at something similar. Has anyone ever had a lifesaver?" Students -"Yes." Teacher - "Here's can be happening in your mouth as you're chewing a lifesaver. Please write down your observations."
- https://www.youtube.com/watch?v=tW8q_JfmcbU (Skip to 1:12 to save time)
- Students to think-pair-share the following question: "What did you notice? Why do you think this happened?" [Think (1 min) -pair (1 min)-share (1 min) should last a total of 3 minutes]
- Call on two different groups to share their thoughts. Explain that electrons from the sugar crystal are jumping to the Nitrogen in the air, exciting it, and producing blue and ultraviolet light.

TRANSITION: "This produces light in the visible and ultraviolet regions of the electromagnetic spectrum. Let's find out what that means."

EXPLORATION (15 minutes)

- The class will be split up into 7 groups. Each group will become the "expert" in Radio, Microwave, infrared, visible, ultraviolet, x-rays, and gamma rays. The class will participate in a jigsaw activity in which each group becomes the expert in their type of light and shares out to the class (as an alternative, students can be split up into home groups prior to their expert groups, one student from each is assigned to a specific expert group, and after the activity the students return to their home groups to share.)
- A brief introduction to wavelength and frequency may be necessary. Project or post a diagram of both as students work on their projects.
- Assign each group member one or two of four responsibilities: Leader, Scribe, Timekeeper, and Reporter.
- Students should include energy, wavelength, frequency, and uses on their posters.
- Teacher should monitor as students work, ensuring that they are including the necessary information.
- For the poster, it is suggested that you make an example in advance so that teacher and students know what is expected.

TRANSITION: Now we'll share our findings to our classmates. Reporters, please speak loudly and clearly so that it is clear what your classmates should be writing.

EXPLANATION (10 minutes)

- Reporters will come up group by group to present their findings to the class. While groups are presenting, the audience should be filling out their EM spectrum worksheets with the appropriate information.
- Teacher should show the completed EM spectrum worksheet on the doc cam or projector to provide a clear visual aid for students to refer to during their discussion and to ensure that students have written the information correctly. Teacher can also list out important points students make in the discussion (for students to use as supplementary notes).

TRANSITION: Now that we've come to a consensus on the wavelengths, frequencies, and energy for each type of radiation, let's find out how they relate to one another.

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ELABORATION (15 minutes)

- With completed EM spectrum on the board, have students think-pair-share the relationship between energy, wavelength, and frequency. Students should think for 3 minutes, pair for a minute or two, and share during a whole-class discussion.
- Students should be given extra time to think here. The exponential notation might make it difficult for students to recognize a relationship.
- If students struggle with this activity, have them answer questions 1-3 on Teacher Handout 1.
- The teacher should monitor closely during pairing to select students to share. The class discussion should be an opportunity to correct alternative conceptions and arrive at the correct relationship: Wavelength is inversely related to frequency, energy is directly related to frequency and inversely related to wavelength.
- Teacher should write student ideas on the board, leading students to the equations ***E* = h *f*** where h is the **Planck's Constant**, h = 6.626×10^{-34} J s.and ***f* = cλ** where c is the speed of light (3×10^8 metres per second).
- If there is time, teacher can refer back to the Lifesaver discussion and show the diagram of how an electron gets excited and when it returns to ground state, releases the energy in the form of light. Teacher can connect this back to the **E = hf** and **f = cλ** for the blue light.
- Teacher should make sure to reiterate which end of the spectrum is least/highest energy and frequency. These often get mixed up for students.

TRANSITION:

EVALUATION (throughout entire lesson)

- Teacher will observe students formatively during the Explore. Teacher should observe how students are conceptualizing wavelength, frequency, and energy.
- Teacher will guide students in Explain discussion and formatively assess students for comprehension and connections built between concepts and content from the jigsaw activity.
- This should be embedded throughout the lesson as well as at the end of the lesson.

SOURCES AND RESOURCES

- **Dr. Raychelle Burke's *Hot Science – Cool Talks #112,* "Sleuthing, The Avengers, and Chemistry",** http://www.esi.utexas.edu/talk/crime-solving-avengers-chemistry/
- PBS LearningMedia - Making Waves with the Electromagnetic Spectrum, https://www.pbslearningmedia.org/resource/phy03.sci.phys.energy.lp_emspect/making-waves-with-the-electromagnetic-spectrum
- Wikipedia - Sunscreen. https://en.wikipedia.org/wiki/Sunscreen
- Lumen Learning - Photon Energies and the Electromagnetic Spectrum. https://courses.lumenlearning.com/physics/chapter/29-3-photon-energies-and-the-electromagnetic-spectrum/
- Healthline - What is a PET scan? https://www.healthline.com/health/pet-scan#pet-scan-vs-other-tests
- Ducksters - Types of Electromagnetic Waves. https://www.ducksters.com/science/physics/types_of_electromagnetic_waves.php
- Live Science - Infrared Radiation, https://www.livescience.com/50260-infrared-radiation.html
- Britannica - Forgery. https://www.britannica.com/art/forgery-art#ref584758
- Academia - L.A.M. Technique. http://www.academia.edu/8611306/L.A.M._Technique_Layer_Amplification_Method_-_Principe
- Business Insider - How Do Microwaves Cook Food? https://www.businessinsider.com/how-do-microwaves-work-2014-6
- NASA Science - Radio Waves. https://science.nasa.gov/ems/05_radiowaves

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STUDENT HANDOUT 1: ENGAGE

Name:_____________ Period:____ Date:_________
Group Members:_________________

My Observations	My Partner's Observations

What I think is occurring:

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STUDENT HANDOUT 2: EXPLORE

Name:______________ Period:____ Date:__________

Group Members:_____________________________

Expert Group Activity
Our Region ______________

For this activity, you and your group members will become the experts in radio, microwaves, infrared, visible, ultraviolet, x-ray, or gamma-ray. You will make a poster and share this out to the class. Your poster should include: radiation type, wavelength, frequency, energy, and uses.

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STUDENT HANDOUT 3: EXPLORE (ALTERNATIVE TO INTERNET ACCESS)

Of all the forms of electromagnetic radiation, gamma rays have the highest photon energy at greater than 10^5 eV and less than $3x10^{19}$ Hz frequency. Because they have so much energy, they easily produce ionization in the materials that absorb them. This means that they can be very dangerous to humans since they can damage tissue and interrupt cellular reproduction. However, this also means that they can be useful in cancer treatment as they have ample opportunity to disrupt these rapidly reproducing cells. These $<10^6$ cm wavelength of light also allow doctors to use PET scans for finding diseases such as cancer, heart problems and brain disorders.

At a lower frequency than gamma rays at 3×10^6 - 3×10^{19} Hz, x-rays have the ability to produce large amounts of ionization but are less hazardous. This makes them common for use in hospitals and doctors' offices. If you have ever been to the dentist, it is likely you are familiar with x-rays. These x-rays can help identify a range of dental problems from abnormal changes in the root canal as a result of infection to impacted wisdom teeth. They help dentists make informed decisions about what treatment a patient needs. You've probably also had experience with the heavy vests that accompany the imaging. These lead aprons limit exposure to the ionizing radiation at 10^3 - 10^5 eV per photon, protecting your organs from damage. This radiation in the 10^{-7} - 10^{-9} cm wavelength range is also used in airport security, allowing TSA to take a peek inside your bag for contraband. X-rays make it possible for security to see inside your bag without actually opening them, saving us the headache of longer security lines and upholding the safety of the inspector.

Ultraviolet light has yet less energy per photon at 3 - 10^3 eV. This means that though it is still high enough energy to ionize atoms, it takes several photons to disrupt cell reproduction. This 7.5×10^{14} - 3×10^{17} Hz frequency of light is emitted by the Sun. You have probably heard of sunscreen and sunglasses that block UVA and UVB rays. Sunscreen does this by either reflecting or absorbing UV rays to protect the skin from overexposure which can cause sunburn and in extreme cases, cancer. However, UV radiation is essential to the functioning of bodily processes. UV has enough energy per photon to trigger production of Vitamin D in the skin. Without 4×10^{-5} - 10 cm wavelength radiation, we would not be able to produce Vitamin D in the skin which would inhibit our ability to take up calcium. This could lead to diseases associated with soft bones and deformed skeletal systems, and can increase risk for cardiovascular disease, cognitive impairment, asthma, and cancer.

Visible light, also given off by the Sun, at 2-3 eV of energy per photon, does not have enough energy to trigger production of Vitamin D in the skin. Visible light is responsible for everything you see. An apple is red because it reflects red light and absorbs all other colors. The colors of light, ranging from least energetic to most are red, orange, yellow, green, blue, indigo, and violet. Since photons of violet light have the highest energy, molecules that absorb this light are more easily damaged. This is why red and green are the first to fade on posters, while blue and violet dyes stick around. Light in the wavelength range of 7×10^{-5} - 4×10^{-5} cm is responsible for everything that you see. Visible light occupies frequencies of 4.3×10^{14} - 7.5×10^{14} Hz, and the varying frequencies within this range are responsible for the range of colors we see in our world. The words on this page are black because they absorb all light in this wavelength and frequency and reflect none.

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Infrared radiation, from 0.01 - 7×10^{-5} cm in wavelength, has yet even lower energy per photon than visible light. Near infrared radiation, that on the higher end of the 3×10^{12} - 4.3×10^{14} Hz frequency range, are used in TV remotes to change channels. Far infrared, that on the lower end of the frequency range, give off heat. Infrared radiation is emitted by the Sun and is partially responsible for sustaining life on earth. Infrared radiation is also emitted from radiators and fires, making it especially useful in the winter and for cooking food. Everything with a temperature above 5 degrees Celsius emits this 0.01-2 eV radiation, meaning that your own body emits IR! Infrared rays can also be used in detection of fraudulent paints because they can penetrate thin oil paint layers to reveal earlier paintings underneath. Sometimes, this will reveal previous signatures from the true artist or, as in the case of the Mona Lisa, revealing previous versions of a work hidden underneath using the Layer Amplification Method.

Microwaves have a lower energy in the range of 10^{-5} - 0.01 eV. Microwaves, like radio waves, are used to transmit data. However, because they are higher in frequency in the range of 3×10^{9} - 3×10^{12} Hz, they can penetrate clouds, smoke and rain. For this reason, they are used for carrying phone calls, computer data and radar. Because of microwaves, meteorologists can use radars to make weather predictions. In a world without microwaves, you wouldn't know when to pack your umbrella! Waves 10 - 0.01 cm wavelength are also responsible for heating your food quickly. Microwaves at a certain frequency within this range are absorbed by water, fat, and sugar. The reversing of the electric field in the microwave oven causes polar water molecules to flip back and forth, causing friction by rubbing against other water molecules and producing heat as a result.

Radio

Radio waves have the least amount of photon energy at less than 10^{-5} eV. These 10 cm and above waves are used to carry signals across large distances for AM radio, aircraft communication, and are emitted by stars and gases in space. They are also the lowest frequency wave at less than 3×10^{9} Hz. Changing the channel on your radio tunes the radio to a specific frequency, allowing you to receive a different frequency of radio wave and thus receive different information. According to NASA, you can learn a lot about the composition, structure, and motion of planets, comets, clouds of gas and dust, stars and galaxies by studying the radio waves they emit.

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<u>STUDENT HANDOUT 3: EXPLAIN/ELABORATE</u>

	Radio	Microwave	Infrared	Visible	Ultraviolet	X-rays	Gamma
Wavelength (cm)							
Frequency (Hz)							
Energy per photon (eV)							

As other groups present, fill in the blanks on your EM spectrum chart.

Think-Pair-Share
What relationship do you see between wavelength and frequency? Energy and frequency? Energy and Wavelength?

Make your notes here and then share with your shoulder partner.

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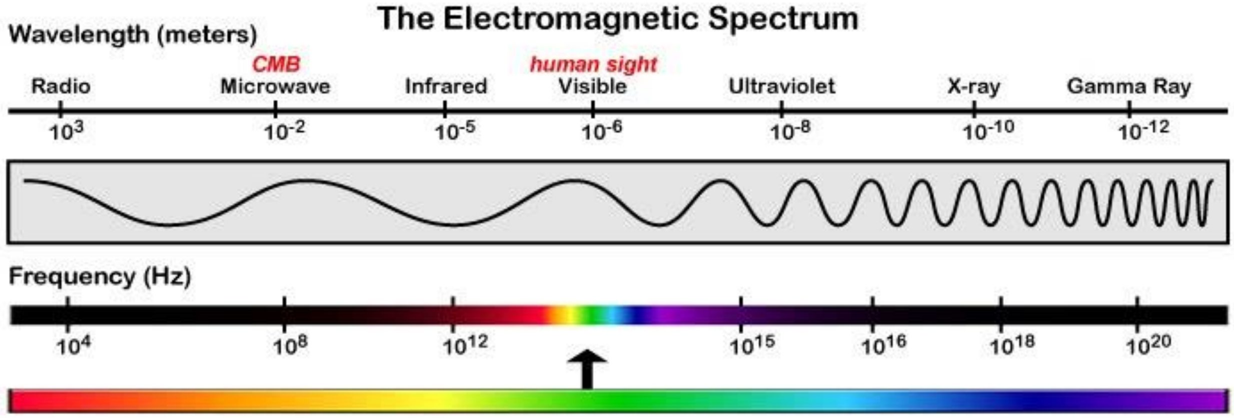
STUDENT HANDOUT 4: ELABORATE



Background Information:
About 300 years ago, Sir Isaac Newton saw a beam of sunlight through a glass prism. He discovered that light is made up of a spectrum of seven distinct visible colors. This spectrum of colors always appears in the same order. You can see this color spectrum (Red, Orange, Yellow, Green, Blue, Indigo, Violet and all the colors in between) when you look through a diffraction grating. There are two color ranges that are not visible to our eyes in this spectrum: below red is infra-red and above violet is ultra-violet. In a rainbow after a rainstorm this same color spectrum appears in the same order. Rainbows are created when sunlight passes through raindrops that act as millions of tiny prisms.

The color of a solid object depends on the colors of light that it reflects. A red object looks red because it reflects red light and absorbs all other colors. A blue object looks blue because it reflects blue light and absorbs all other colors. A white object reflects all colors of light equally and appears white. A black object absorbs all colors and reflects no visible light and appears black. Just like when you color with too many colors in one area with crayons or markers, all colors are absorbed, none are reflected and it appears black!

Explanation of visible light at the electronic level:
What do fireworks, lasers, and neon signs have in common? In each case, we see the brilliant colors because the atoms and molecules are emitting energy in the form of visible light. The chemistry of an element strongly depends on the arrangement of the electrons. Electrons in an atom are normally found in the lowest energy level called the ground state. However, they can be "excited" to a higher energy level if given the right amount of energy, usually in the form of heat or electricity. Once the electron is excited to a higher energy level, it quickly loses the energy and "relaxes" back to a more stable, lower energy level. If the energy released is the same amount as the energy that makes up visible light, the element produces a color. The visible spectrum, showing the wavelengths corresponding to each color, is shown below:

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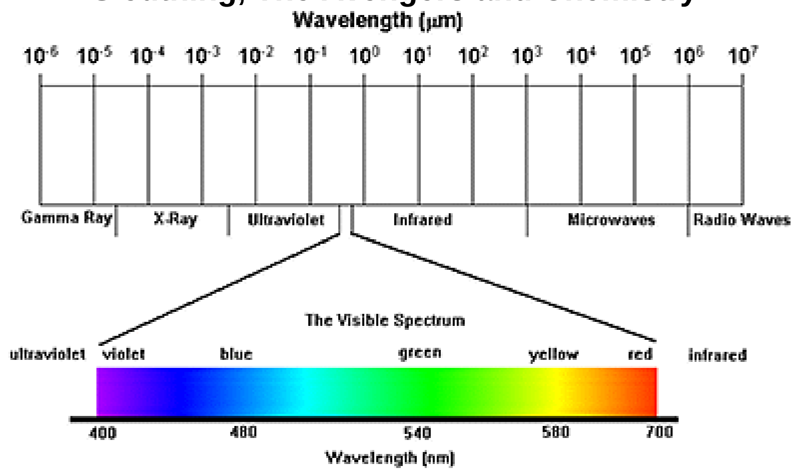

A wave of light has a wavelength, defined as the distance from one crest of the wave to the next, and written using the symbol. The wavelengths of visible light are quite small: between 400 mm and 650 nm, where 1 nm = 10^{-9} m is a ``nanometer'' - one billionth of a meter. Red light has long wavelengths, while blue light has short wavelengths.

A particle of light, known as a photon, has an energy *E*. The energy of a single photon of visible light is tiny, barely enough to disturb one atom; we use units of "electron-volts", abbreviated as eV, to measure the energy of photons. Photons of red light have low energies, while photons of blue light have high energies.

The energy *E* of a photon is proportional to the wave frequency *f*,

$E = h f$ where the constant of proportionality h is the **Planck's Constant**, h = 6.626 x 10^{-34} J s.

Also, the relationship between frequency and wavelength can be defined as:

$f = \underline{c}\lambda$ where c is the speed of light (3×10^{8} meters per second).

So photons still have a wavelength. The longer the wavelength, the smaller the energy. For instance, ultraviolet photons have shorter wavelengths than visible photons, and thus more energy. This is why they can give you sunburn, while ordinary light cannot.

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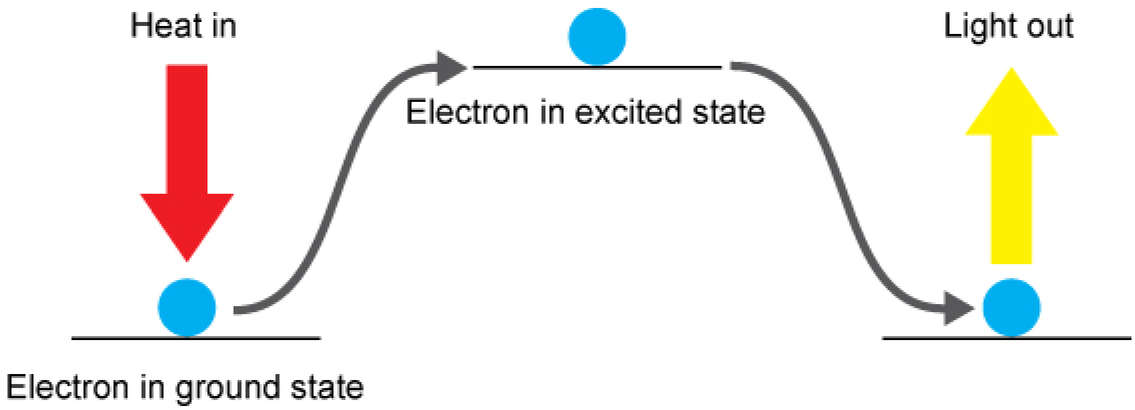
TEACHER HANDOUT 1:

EXAMPLE OF DRAWING/TYPE OF DISCUSSION TO BE HELD DURING ELABORATE:



1. List the colors observed in this lab from the highest energy to the lowest energy.
2. List the colors observed in this lab from the highest frequency to the lowest frequency.
3. List the colors observed in this lab from the shortest wavelength to the longest wavelength.

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TEACHER HANDOUT 2: EXPLAIN/ELABORATE

Electromagnetic Spectrum Data Table Source:
https://www.pbslearningmedia.org/resource/phy03.sci.phys.energy.lp_emspect/making-waves-with-the-electromagnetic-spectrum

	Radio	Microwave	Infrared	Visible	Ultraviolet	X-rays	Gamma
Wavelength (cm)	>10	10 - 0.01	0.01 - 7×10^{-5}	7×10^{-5} - 4×10^{-5}	4×10^{-5} - 10^{-7}	10^{-7} - 10^{-9}	< 10^{-9}
Frequency (Hz)	< 3×10^{9}	3×10^{9} - 3×10^{12}	3×10^{12} - 4.3×10^{14}	4.3×10^{14} - 7.5×10^{14}	7.5×10^{14} - 3×10^{17}	3×10^{17} - 3×10^{19}	> 3×10^{19}
Energy per photon (eV)	< 10^{-5}	10^{-5} - 0.01	0.01 - 2	2 - 3	3 - 10^{3}	10^{3} - 10^{5}	> 10^{5}