PhysicsQuest [2025]: The Secret Glow of Nanobit from the Kitchen

| **Title:** The Secret Glow of ‘Nanobits’ from the Kitchen  **Subtitle:**  Developed by - Robert Ferrante, Ph.D., Ginger Chateauneuf, Ph.D - US Naval Academy | | |
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| **Total Time:** 1.0 - 1.5 hours  **Audience:** Middle School Science Teachers  **Education Level:** Grades 5 - 9 | | |
| **Content Area:** Physical science  **Educational topic:** Chemical Reactions; Interaction of light with matter  **Objectives:** Students will experiment with Cdots to understand how materials can be changed in a chemical reaction to fluoresce and how students can test the fluorescent properties in several applications.  **Key Question:** What are carbon quantum dots (Cdots)? Why do they behave so differently when exposed to different light sources? How can we observe or change their properties? | | |
| [**Next Generation Science Standards**](https://www.nextgenscience.org/sites/default/files/MSDCI.pdf)**:**  **MS-PS1-2.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.  **MS-PS4-2**. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. | | |
| **Materials** | **Provided in kit**   * 20 g Table sugar * Small square or rectangular sample holders like spectrophotometer cells * Ultraviolet (UV) flashlight or small blacklight * Red and green laser pointers * Filter papers (or coffee filters) * *Clear* PVA (polyvinyl alcohol) glue * Cotton swabs (we used Q-tips) * Clean glass microscope slides or small hand-held mirror * For extension: Tic-Tac® candies   Teacher must provide   * Water * Measuring equipment (e.g. 10 mL grad. cylinder & scale or eyedroppers & measuring spoons). *NOTE: 1 mL is about 20 drops with eye dropper* * Pyrex glass containers (250 mL beaker or 1 cup measuring cup) * Microwave oven * Hair dryer * For extension: Urea | |
| **Overview:** In this activity, students will utilize a chemical reaction to convert everyday items into “carbon quantum dots (Cdots)". These materials are fluorescent under ultraviolet light and upon exposure to certain wavelengths of lasers. Once formed, the materials can be used in some simple applications, e.g “secret” writing or capturing fingerprints. As an extension, other substances (urea, lemon juice, Tic-Tac® candies) can be used in the recipe to change the luminescent behavior of the Cdot products. | | |
| **Teacher Background:** Note: This lesson is good for physical science class in middle school, high school chemistry class, AP Chemistry class when using extensions provided.  **Some topics that can be discussed before these lessons are implemented:**   * the metric system * size scales * light, color, and the electromagnetic spectrum * absorption and emission of light   In this activity, students will utilize a chemical reaction, which can change one substance into a different one, to convert everyday items into “carbon quantum dots (Cdots)”. The new substance (Cdots) have interesting properties when they are exposed to light. Here, heating the samples in a microwave oven breaks down the carbon compounds, which re-form as very tiny carbon particles. These Cdots can absorb energy from an ultraviolet (UV) flashlight, green and red lasers, causing the particles to glow. But not just *any* wavelength of light will "excite" them enough to make this happen (think back to Activity 1 to understand why). By testing samples with different starting molecules, and using different light sources, we will try to find out how physicists first began to understand our quantum world. And, we can have some fun with simple applications of the Cdots as well!  More than any other element, carbon has the capability of forming bonds to itself, which can lead to very large molecules that are predominantly carbon, while the other elements tend to ‘boil’ away, typically as water molecules (H2O). In the case of carbon quantum dots (Cdots) the molecules can reach the nanoscale or larger. (Of course, carbon particles can be made to truly macroscopic scale, in the form of graphite or diamond.) But it is the “nanoparticle” quantum dots that behave in the most curious way.  As the name suggests, nanomaterials are very small particles, characterized by a size less than 100 nm in diameter. They can assume a variety of shapes such as sheets, tubes, fibers and spheres. They are relatively non-toxic, able to be produced using inexpensive raw materials, and they are fairly easy to synthesize. They were discovered in the early 2000s as a by-product of the purification of carbon nano-tubes4. Many synthetic methods and various carbon sources (even fresh plant leaves!) can be used to make Cdots. The negative aspect of that ubiquity is that the resultant particles are not very well characterized at all. A generic representation of Cdots involves an aromatic carbon core surrounded by an outer skin including functional groups left over from the starting material, or formed during the reaction process. The presence of some functional groups in the starting material (e.g., amines) has been shown to change the luminescent yield of the particles, but the theory is not as well-developed.  **Luminescent Properties in Quantum Dots:**  A unique aspect of quantum dots is that their fluorescent emission can be “tuned” simply by changing the size of the particle, or its chemical composition. Larger particles emit at longer (redder) wavelengths, while smaller particles emit at shorter (bluer) wavelengths. A crude picture of this is that because the particle size is roughly comparable to the size of the wavelength of light. Providing energy to the particle can “excite” an electron from the ground state to an excited state, much as providing electricity to a neon light can excite the neon atoms in the tube. For the Cdots in this exercise, we provide the energy in the form of light from a UV flashlight or green laser. A red laser does not have sufficient energy to cause the excitation. Once excited, the or Cdot particles can glow. Nature in general dictates that systems prefer to be at their lowest energy level (think water running downhill). The Cdot particles can de-energize to emit their excess energy as light. Neon tubes glow red because the energy of red light corresponds to the energy *difference* between the excited state energy level and the lower (ground) state level.  In this activity we find that de-excitation of the Cdots leads to broad emission across the blue-green part of the spectrum, and in some cases, includes red emission as well. And, just as changing gases in neon lamps alters the emitted colors, incorporating other atoms in the Cdots can change the absorption and emission characteristics. It is worth noting that the energy of the light emitted will always be equal to or less than the energy of excitation – that is, the emission will be at longer wavelengths (blue, green or red) than the ultraviolet originally absorbed. One further point to note is that some excited molecules may not emit visible light at all, or emit light for a very long time after the excitation is turned off. In the former case, energy could be emitted as heat (i.e., infrared light which we cannot see.) The latter case will be familiar to almost all children, since most have seen or played with “glow-in-the-dark” toys. Laundry “brighteners” work by this process – the UV we are exposed to all the time keeps them glowing, at least while in the light. Remove the exciting ultraviolet light and the brightening effect on the clothes goes away. But glow-in-the-dark toys work by “phosphorescence”, where the energy gets trapped in the molecule, and only ‘leaks’ out slowly (i.e. glow-sticks). The specific energy level structure of the molecules causes the difference.  The Cdots made from sucrose or Tic-Tac® candies cannot be easily distinguished in terms of intensity or color of emission under UV light. However, subtle differences in response to a green laser beam can be distinguished, in some samples. For example, Cdot suspensions made from table sugar show a red-orange color where illuminated by a green laser beam, while Cdots from Tic-Tacs® show no change from the green beam. Note that the structures of the starting materials in these cases are quite similar (mostly sucrose), but Tic-Tacs® also include sugar polymers, coloring and flavoring agents, etc. If you use Urea to make a sample, you will see difference in color emitted as well.  **References**:   1. United States Naval Academy Chemistry Department, Experiment #490: Synthesis and Properties of Quantum Dots. 2024. https://intranet.usna.edu/ChemDept/\_files/documents/integrated-labs/SC364/2024\_Documents/S24\_SC364\_EXP\_490\_Quantum\_Dots\_FV9.pdf (accessed September 20, 2024). 2. Liu, J.; Li, R.; Yang, B. Carbon Dots: A New Type of Carbon-Based Nanomaterial with Wide Applications. *ACS Cent. Sci.* **2020**, *6*, 2179-2195. 3. Application of Nanotechnology. https://www.nano.gov/about-nanotechnology/applications-nanotechnology (accessed February 25, 2024). 4. The Role of Nanotechnology in a Forensic Investigation. https://www.azonano.com/article.aspx?ArticleID =5521 (accessed February 25, 2024).   **Additional References**:   * Xu, H; Yang, X; Li, G.; Zhao, C.; Liao, X. Green Synthesis of Fluorescent Carbon Dots for Selective Detection of Tartrazine in Food Samples. *J. Agric. Food Chem.* **2015**, *63*, 6707-6714. * Xu, X.; Ray, R.; Gu, Y.; Ploehn, H.J.; Gearheart, L.; Raker, K.; Scrivens, W.A.. Eletrophoretic Analysis and Purification of Fluorescent Single-Walled Carbon Nanotube Fragments. *J. Am.Chem. Soc.* **2004**, *126*, 12736-12737 * Chen, C.Y.; Tsai, Y.H.; Chang, C.W. Evaluation of the dialysis time required for carbon dots by HPLC and the properties of carbon dots after HPLC fractionation. *New J. Chem.* **2019**, *43*, 6153. * Nkeumaleu, A.T.; Benetti, D.; Haddadou, I.; DiMare, M.; Ouellet-Plamodon, C.M.; Rosei, F. Brewery Spent Grain Derived Carbon Dots for Metal Sensing. *RSC Adv.* **2022**, *12*, 11621. * Wang, Q.; Liu, X.; Zhang, L.; Lv, Y. Microwave-assisted Synthesis of Carbon Nanodots Through an Eggshell Membrane and their Fluorescent Application. *Analyst*, **2012**, *137*, 5392.  **Teacher Tips:**  1. Suggested [STEP UP Everyday Actions](https://engage.aps.org/stepup/curriculum/everyday) to incorporate into activity    1. When pairing students, try to have male/female partners and invite female students to share their ideas first    2. As you put students into groups, consider having female or minority students take the leadership role.    3. Take note of female participation. If they seem to be taking direction and following along, elevate their voice by asking them a question about their experiment. 2. Consider using white boards so students have time to work through their ideas and brainstorms before saying them out loud. 3. As students experiment, roam around the room to listen in on discussion and notice experiment techniques. If needed, stop the class and call over to a certain group that has hit on an important concept. 4. Consider [culturally responsive tools and strategies](https://www.nciea.org/blog/a-culturally-responsive-classroom-assessment-framework/) and/or [open ended reflection questions](https://www.cde.state.co.us/standardsandinstruction/es-student-reflections-mc) to help push student thinking, have students track their thinking during the activity, connect to their lives, and create opportunities to develop STEM identity. 5. Allow the work of physicists to come alive by signing up for a virtual visit from a working physicist using [APS’s Physicist To-Go](https://www.aps.org/initiatives/physics-education/k-12/physicists-to-go) program. You can request a plasma scientist to talk about the concepts students learned in this activity! | | |
| **Key Terms (used or presented after the activities - see Forward for details)**  Nanoparticles: carbon dots as an example, are in the range of 2 – 100 nanometers in diameter. For comparison a piece of paper is about 100,000 nm thick.  fluorescence: an example of general photoluminescence – light emitted by an excited state particle. Whether the light emitted is characterized as “fluorescence” depends on how long the emission lasts. Due to the path that the excited state molecule takes to the ground state, fluorescence can last on the order of nano to micro seconds. Phosphorescence can last much longer, as long as a tenth of a second. For C-dots it’s difficult to determine the exact time-scale of emission due to the large mixture of particle sizes.  ultraviolet (UV) light: in the range 390-405 nm. The light source we use to excite the C-dots (photoluminescent nanoparticles), to see if they will “glow”. That is, when the solution is observed under “room light” they will look clear. Turn out the light and apply a UV source and they will look cloudy and greenish. This is the “glow” and it is particularly illustrative when writing secret messages on paper. | | |
| **Teacher’s Guide**   1. We invite you to watch a [brief video demonstration](https://www.youtube.com/watch?v=jYG5279Cmx0&list=PLgxD9DiwxLGp_3vj3biSPG88gIyU6Vzpz&index=10) of the developer conducting the experiment you’ll be facilitating with your students.     **Some photos of results**  Sugar Cdots - under room lights versus UV illumination    Comparison of Cdots from Tic-Tacs® (LEFT) and table sugar (RIGHT) under room light, UV (405 nm) and green laser (532 nm) illumination.  https://lh6.googleusercontent.com/EOio51XPMp-hXHj9sK2zzDy5uBFpzXdvxY4TZjN3vcKglbEmxghJ4ht6fAca2aEs5BYUhqB0XQwa-jmKNWjw_3DCyCRBBMfJ-FcPUMyXfpKCzt2RgZQUztAHlEozZvTb6mj--9w6M6Vpxgc=nw      Fingerprint trap Secret message (invisible except under UV light) | | |
| **Objectives:**  \*In this activity, students will utilize a chemical reaction to convert everyday items into “carbon quantum dots (Cdots)". These materials are fluorescent under ultraviolet light and on exposure to certain wavelengths of lasers. Once formed, the materials can be used in some simple applications, e.g “secret” writing or capturing fingerprints. As an extension, other substances (urea, lemon juice, Tic-Tac® candies) can be used in the recipe to change the luminescent behavior of the Cdot products.  \*It is important to understand that student goals may be different and unique from the lesson goals. We recommend leaving room for students to set their own goals for each activity. | | |
| **Before the Experiment:** | | 1. We invite you to watch a [brief video demonstration](https://www.youtube.com/watch?v=jYG5279Cmx0&list=PLgxD9DiwxLGp_3vj3biSPG88gIyU6Vzpz&index=9) of the developer conducting the experiment you’ll be facilitating with your students. 2. Consider exploring XXX’s narrative using the lessons ideas detailed on the Introduction found in your materials kits. 3. Determine if you will use just the sugar Cdot solution or sugar, Tic-Tac®, lemon juice, urea preparations (only sugar and Tic-Tac® provided. Other materials are easily sourced by teachers).   a. to determine which to use, consider time, level of students, and lab technique of students.  b. for older students, high school chemistry or AP chemistry preparing all solutions for students to compare results may be appropriate. Guides will have to be updated to reflect this.  c. for younger students or general education classes, or physics classes, the sugar Cdots alone should be enough to show the concepts of florescence due to energy being absorbed and released at specific quanta.  2. Prepare the chosen solutions as shown below. |
| **Setting Up** | | Note: Amounts listed below were for one group of 4-5 students making one batch of Cdots. Generally, none of those quantities is critical. Amounts are also scalable if larger batches are desired. Microwave times will increase with the amount of water, and may even vary for small batches depending on the oven and where the sample is placed. Heating times WILL vary with ingredients, so careful observation is again important.  Note: Teachers might consider having all three ‘recipes’ run at the same time, with different student groups performing the various measuring and synthesis steps. Teachers can also prepare solutions of UNcooked samples, so they can be contrasted/compared in a darkened room to the Cdot behavior under UV and laser excitation.   1. Before students walk in, record yourself preparing the solution (again this is for one group, scale up as needed)    1. Make sure to wear safety goggles and a lab coat    2. Measure 1 g (~1/4 tsp) of table sugar    3. Place in Pyrex container or 250 mL Erlenmeyer flask    4. Add 10 g of water (10 mL, 2 tsp) to the container. Stir until the sugar is dissolved    5. Place in the microwave at 40% power for about 10 min. You want to make sure the final product is dark orange in color and a "sap" like consistency.    6. Also prepare a mixture of sugar water without microwave steps for students to compare with the prepared solution. They can complete all tests with both to see the special “quantum” nature of the Cdots vs. the control solution. 2. If it makes sense for your class, you can start the microwave right as they walk in and discuss what you are heating in the microwave, and show the video of what your prepared. **Make sure students wear goggles if the solution is still heating with them present.** If you need to monitor students as they come in, continue filming next section and show students when class starts 3. As the solution is in the microwave    1. Pay careful attention to your experiment!    2. After a few minutes check the sample (pause and restart heating if necessary)    3. Mixture will begin to smell like burnt sugar    4. **Stop heating when the mixture is syrupy and orange in appearance.** 4. **The glass will be very hot! Use potholders to remove from the oven.** 5. Add about 50 ml (1/4 cup) of water and swirl until the material is fully dissolved/suspended. 6. Solution should be dark orange (lighter than iced-tea, if darker, add a bit more water)   The container now contains a “suspension” of *very* tiny carbon particles called “carbon dots” or “Cdots”. *(Image above: clusters of Cdots made from an aloe plant.)*   1. Depending on the size of the class and the time available, it may be advantageous to set up several stations for various parts of the activity. Stations can include the following. Details on Station set up found in “During the Experiment” section below.    1. UV & Laser station    2. Secret Messages    3. Fingerprint trap activity.    4. Sample prep area 2. If time allows, prepare a comparison sample as described below. Have students repeat all station steps with additional sample and record in their table appropriately.  * Repeat the experiment using Tic-Tac® candies in place of table sugar. It turns out that Tic-Tac®s make great Cdots. Does the color or flavor of the candy matter? There is really only one way to find out – do the experiment! You can use the same basic recipe, although you probably will have to make some adjustments. That’s all part of experimental science. A single Tic-Tac® weighs about one-half gram, so 3 candies should work in about 10 grams or milliliters (or 1 Tbs) of water. ‘Cooking’ time may also vary – but you can still look for the yellow-orange syrupy appearance as a marker that it is done. * Repeat the experiment, using fresh lemon juice. Try about 10 g (3 tsp) lemon juice in place of the sugar solution in the original procedure. Heat carefully – this may take less time than the sugar did. Stop if it gets syrupy and dark, then add water (50 mL or ¼ cup). Try to write a secret message on a coffee filter, as before. * Repeat the experiment, using a mixture of sugar and urea. Try about 1 g sugar plus 1 g urea and 10 mL water. |
| **Before the Experiment** | | Cover or review any of these topics as you see fit:   * the metric system * size scales * light, color, and the electromagnetic spectrum * absorption and emission of light   Have students watch the video of you preparing the Cdot solution and let them view the results.   * Have studentsdescribe the materials you started with. How do they compare to the final product? |
| **During the Experiment** | | **-Collecting Data**  1. Make sure all students are wearing safety goggles (whether you made the solution before they arrive or not)  2. Make sure all students are aware of the dangers of using laser pointers or UV-A flashlights.  3. If you create a dark environment to view the Cdots, fix the laser/flashlight to a table so students don’t have the ability to move it.  **Procedure**   1. Have students read the following:   Cdots are “nanoparticles”, which can be billions of times smaller than the diameter of a hair. Nanoparticles are of great interest to scientists because they “fluoresce” (or glow) under ultraviolet light (like a blacklight). The color of the glow can be changed by making the particle larger or smaller.   1. Provide each student some of the Cdot suspension in the spectrometer cell. They will use this at all stations so make sure they use accordingly and don’t contaminate it. 2. Break students into 3 or 4 groups depending on the stations you are completing (see below).   **Station 1: Darkroom station**  Teacher Note: Affix the UV light to one place and the red and green lasers next to each other in another place. Aim the beams away from students, and keep them below eye level.  1.In a darkened room, use the UV light   * 1. Have an uncooked sample of sugar water at this station. In a table, have students do the following steps with the uncooked and cooked (Cdot) sample and compare   i. Have students bring their Cdot sample and non-Cdot sample up to the UV light  ii. Record observations of the sample before, during, and after being exposed to UV light  2.In a darkened room, use the Red and Green lasers   * 1. Have students bring their Cdot sample and non-Cdot sample up to the red laser      1. Record observations of the sample before, during, and after being exposed to red laser   2. Have students bring their Cdot sample and non-Cdot sample up to the green laser  1. Record observations of the sample before, during, and after being exposed to green laser    1. Were the results of the red and green laser the same or different. Why do you think this happened?   **Station 2: Secret Messages**  1.Have students saturate a cotton swab with their Cdot suspension. Use it to write their initials (or a secret message) on a coffee filter or notebook paper.   * 1. Allow the marks to dry (use the hair dryer if available).   2. When dry, see if you can find the marks in room light.   3. In a darkened room, use the UV flashlight to look for your marks.   4. Can you see them now?   5. Have students record their findings   **Station 3: Fingerprint trap**  1.In a small disposable container (plastic weigh boat) add:  a. ~1/4 tsp clear PVA glue (about 20 drops),  b. 2 drops of Cdot suspension.  c. Mix well using the toothpicks.  2. Obtain a clean glass microscope slide (*only handle by the edges*!).   * + - * 1. Rub your finger or thumb on the skin of your nose or forehead to pick up natural skin oils.         2. Carefully press that finger onto the clean glass surface. (*Don’t slide or smear it*!)  1. Using a plastic pipette, apply multiple drops of the PVA glue/Cdot mixture to the glass surface, completely covering your fingerprint.    1. Allow to air dry. (You can use the hairdryer with *cool air only* – don’t heat as the glue may cloud up.) 2. When the PVA coating is dry, bring to your teacher to *carefully* use the razor blade (teacher discretion for teacher or student step) to scrape up the end of the film, and then *carefully* peel off the coating.    1. *In a darkened room*, point the UV flashlight beam at the side of the film that was in contact with the glass.    2. Can you see your fingerprint?   Station 4: (Optional) Sample Prep station: Students can measure out samples for the next class.   * 1. Measure 1 g (~1/4 tsp) of table sugar   2. Place in Pyrex container or 250 mL Erlenmeyer flask   3. Add 10 g of water (10 mL, 2 tsp) to the container. Stir until the sugar is dissolved   Teacher Note: You can combine all samples and prepare in the microwave according to procedure in “Setting Up” section 2-6 for the next class |
| **Conclusion** | | Have students do the following at each station or all together at the end of the activity.  1. For each station, write a summary of what you observed or a claim about Cdots based on your observations. Use the following vocabulary words in your summaries:   * Nanoparticles * Florescence * UV * Energy   2. Compare the glow of the Cdots under the UV light, the red laser, and the green laser. How can you explain the differences? What does this show you about how molecules react to different amounts of energy (i.e. different wavelengths of light)?  Teachers Note: Students will learn more about quantization of light in Activity 3. This would be a great introduction to that. However, don’t give anything away until they have done that activity. |

| **Student’s Guide** | |
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| **Intro:** Why does lemonade look yellow, but grape juice looks purple? It has to do with the molecules in the juice – the colored materials, or pigments, in lemons and those from grapes are different molecules, and absorb different colors (wavelengths) of light. You see the colors that are *not* absorbed. The particular wavelengths absorbed or not are a characteristic of the substance and are used as a way to categorize substances. This is another way that scientists determine structure (like what you witnessed in Activity using X-crystallography). Electromagnetic radiation, including visible light, can supply energy, depending on its wavelength and we can use the energy of light, both absorbed and emitted, to understand something about the molecules in a substance. You are going to do this today!  In this activity you will use a chemical reaction that converts everyday materials to a substance that glows under special lights. That substance is a type of ‘nanomaterial’ called a ‘carbon quantum dot’ or Cdot, for short. Nanoparticles like Cdots can be billions of times smaller than the diameter of a hair. Nanoparticles are of great interest to scientists because they “fluoresce” (or glow) under ultraviolet light (like a blacklight). The color of the glow can be changed by making the particle larger or smaller, or changing the types of atoms that are in it. Can you make Cdots that glow? What can we do with them? Let’s investigate! | |
| **Objective:**  Students will experiment with Cdots to understand how materials can be changed in a chemical reaction to florescence and how scientists can use the florescent properties to identify materials and apply them for several applications. | |
| **Before the Experiment** | 1. Watch video of your teacher preparing the Cdot solution. As you watch, write down important procedures they used. Ask any questions you have at this point about the Cdot solution. 2. Read the introduction to get an idea of what you will be doing, and what you are looking for. 3. Listen carefully to your teacher’s instructions, especially about SAFETY! 4. After reading the introduction and objective, write a sentence or two about what you would like to learn or understand after this completing this activity. Share with your partner. |
| **Setting Up** | 1. Wear googles and follow all safety instructions. 2. Your teacher will give you a small amount of the Cdot solution to use at the stations. 3. In your lab notebook, draw the following table. Make sure to leave plenty of space in each box for your writing and observations.   **Depending on what type of dots the teacher makes for the class, or the students make, examples of data tables:** |
| **During the Experiment** | **-Collecting Data**  Follow the basic procedure described below. Record the actual amounts that you used. Note colors of materials and other details in each part of the activity – you often don’t recognize what is important until you can compare results!  **DARKROOM STATION**  UV light   1. Your teacher will provide a sample of non-cooked sugar water solution with no Cdots. 2. Bring the **non** Cdot solution up to the UV flashlight. Record your observations in the table. 3. Bring your Cdot solution up to the UV flashlight. Record your observations in the table. 4. Make note of differences between the two.   Red laser   1. Your teacher will provide a sample of non-cooked sugar water solution with no Cdots. 2. Bring the **non** Cdot solution up to the red laser. Record your observations in the table. 3. Bring your Cdot solution up to the red laser. Record your observations in the table. 4. Make note of differences between the two.   Green laser   1. Your teacher will provide a sample of non-cooked sugar water solution with no Cdots. 2. Bring the **non** Cdot solution up to the green laser. Record your observations in the table. 3. Bring your Cdot solution up to the green laser. Record your observations in the table. 4. Make note of differences between the two.   **SECRET MESSAGES STATION**   1. Saturate a cotton swab with your Cdot sample. 2. On a piece of filter paper (or notebook paper), use the swab to write your initials (or a short secret message). You may have to re-wet the swab with the Cdots. If the message is wet enough to look dark on the paper, that is probably enough. 3. Allow the marks to dry (use the hair dryer on low if available). When dry, see if you can find the marks in room light. 4. In a darkened room, use the UV flashlight to look for your marks. Can you see them now? 5. Record your observations.   **FINGERPRINT CAPTURE STATION**   1. In a small disposable container (e.g. plastic weigh boat) add   a. ~1/4 tsp clear PVA glue (about 20 drops),  b. 2 drops of your Cdot suspension.  c. Mix well with the toothpick.   1. Obtain a clean glass microscope slide (*only handle by the edges*!)   a. Rub your finger or thumb on the skin of your nose or forehead to pick up natural skin oils.  b. Carefully press that finger onto the clean glass surface. (*Don’t slide or smear it*!)   1. Using a plastic pipette, apply drops of the PVA glue-Cdot mixture to the glass surface, completely covering your fingerprint.   a. Allow to air dry. (You can use the hairdryer with *cool air only* – don’t heat as the glue may get cloudy.)   1. When the PVA coating is dry, pass your slide to your teacher.   a. They will *carefully* use the razor blade to scrape up the end of the film, and then *carefully* peel off the coating.  b. Try not to tear or stretch the film, and only handle by its edges.   1. In a darkened room, point the UV flashlight beam at the side of the film that was in contact with the glass.   a. Can you see your glowing fingerprint?  b. How well can you distinguish details?   1. Record your observations.   **CDOT SAMPLE PREPARATION STATION (optional according to teacher’s needs)**   1. Measure out about 1 g of table sugar. Place into a Pyrex container or 250 mL volumetric flask. 2. Add about 10 g of water to the container. Stir until the solid is dissolved. Note the appearance of the sample. 3. Place the container in a microwave oven. Set the microwave to heat at about 40% power for approximately 10 minutes. 4. Start the microwave. Pay careful attention to your experiment! 5. After a few minutes check the sample. Pause and restart heating as needed. 6. The mixture may begin to smell like burnt sugar. 7. Stop the heating when the mixture has a syrupy orange appearance. 8. The glass will be very hot! Use potholders to remove from the oven. 9. Add about 50 mL of water and swirl until the material is fully dissolved. The solution should be yellowish-orange (lighter than iced tea; if darker, add more water). 10. Describe the product, comparing it to the starting material. Colored or not colored? Clear or cloudy? Thick (“viscous”) or thin?   -Analyzing Data  You can try to understand the results of your chemical reactions that formed Cdots by comparing each experiment, either your own or those of your classmates. In the scientific method, results should be replicated with consistency in order to draw conclusions or make claims about an experiment. Compare your observation table to other students or groups and determine if your results are consistent with theirs.  If you were to change something about this experiment (a variable), what could you change to find out more about Cdots? |
| **Conclusion** | 1. For each station, write a summary of what you observed or a claim about Cdots based on your observations. Use the following vocabulary words in your summaries:   * Nanoparticles * Florescence * UV * Energy   2. Compare the glow of the Cdots under the UV light, the red laser, and the green laser. How can you explain the differences? What does this show you about how molecules react to different amounts of energy? |

THESE WILL BE ADDED in SUMMER 2025

| **Additional Resources:** | | | |
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| **Assessment/Extension activities\*\* (optional to extend thinking after the lesson):**   * Real world connections -   + Sign up for [Physicists To-Go](https://www.aps.org/programs/outreach/physiciststogo.cfm) to have a scientist talk to your students. * Suggestions for drawing, illustrating, presenting content in creative ways * Engineering and design challenges connected to the content   + if engineering challenges have a time constraint, students are allowed to keep iterating and developing their ideas outside of class time and continue to participate in the challenge at a later date   \*\*Real world situations/connections can be used as is, or changed to better fit a student’s own community and cultural context. | | | |