

Matter of Opinion

Kitchen Spectroscopy: Shining a (UV) Light on Everyday Objects

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Fluorescent objects often lead to a sense of joy and intrigue. While the current COVID-19 pandemic limits the synthesis of “glowy things” like quantum dots, many household objects fluoresce, providing an opportunity to brighten your day while learning fundamental chemistry.

The ongoing COVID-19 crisis has completely changed life as we know it. Universities and schools are closed, restaurants are deserted, bars are shuttered, and people are working remotely from the safety of their homes. Lectures are moved from the classroom to Zoom chats, exams are taken online, and PhDs are defended remotely. We rarely venture outside our homes; and if we do, we are armed to the teeth with hand sanitizer. However, the pandemic is taking an unarguable toll on our mental health and is increasing stress levels. With our lives turned upside down, we are all seeking for ways to spread joy and keep our idle hands and minds busy. For many, this has been sharing pictures of their new four-legged “work colleagues” on social media, while many others are baking, running, knitting, or pursuing other hobbies. Many are struggling to juggle childcare and homeschooling with job responsibilities and expectations.

With research labs closed, this situation may provide a unique opportunity for many researchers to instill an interest in science into the next generation while simultaneously spreading some joy and laughter. I have vivid memories of my first encounters with science as a child: watching the tablecloth pulled out from under a set table without a single glass wobbling, dry ice as “smoking” ice cubes during childhood birthday

parties, or performing simple chemistry experiments such as making slime using Borax and Elmer’s glue. For many children, science can come very close to appearing as magic. Changing colors, textures, and smells are just a few of the things that can easily excite children. The curiosity to understand the science behind the “magic” will drive future generations to pursue careers in science.

The Nienhaus group at Florida State University is interested in materials properties, including bulk semiconductors like lead halide perovskites and quantum confined materials like CdSe quantum dots (QDs). We are interested in these materials due to their optoelectronic properties and their potential for commercial applications, but we are arguably also interested in these materials because they are simply beautiful due to their vibrant colors. Looking at our Twitter account (@NienhausFSU) and our research group website, it is clear that as a research group, we are collectively fascinated by “glowy things,” as we often refer to them (Figure 1).

Specifically, this glow occurs as a result of photoluminescence. For photoluminescence to occur, an incident photon must be absorbed by the fluorophore, promoting it to its excited state. Then, as the excited state relaxes back to the ground state, a photon is emitted. The

energy of this emitted photon corresponds to the color of the light observed. In semiconductor materials like QDs, the emission wavelength is governed by the bandgap.

QDs—specifically CdSe and CsPbBr₃ perovskite QDs, which are both routinely synthesized in our lab—exhibit bright photoluminescence. As demonstrated by Figures 2A and 2B, QDs have tunable bandgaps based on their size due to the quantum confinement effect, meaning that we can change the color of our glowy things by simply changing the synthetic conditions and therefore the size of the QDs. Additionally, in perovskite QDs, changing the halide can also shift the bandgap post-synthesis; for example, adding LiI to a CsPbBr₃ QD gradually shifts the emission redder, while adding LiCl blueshifts the emission (Figure 1C). Bright, tunable emission leads to some beautiful pictures, as evidenced by Figures 2B and 2C, but also is important in applications like lighting and displays, which has led to the development of QLED TVs. Additionally, QDs are relevant in the field of photon upconversion, where two or more photons are combined into one that is relatively higher in energy than the incident photons absorbed. Specifically, this can occur in polyaromatic hydrocarbons, through the process of triplet-triplet annihilation, but requires a triplet state sensitization source. QDs can efficiently sensitize these triplet annihilators,¹ allowing for relatively efficient photon upconversion systems, which is where our primary scientific focus lies with respect to these materials.

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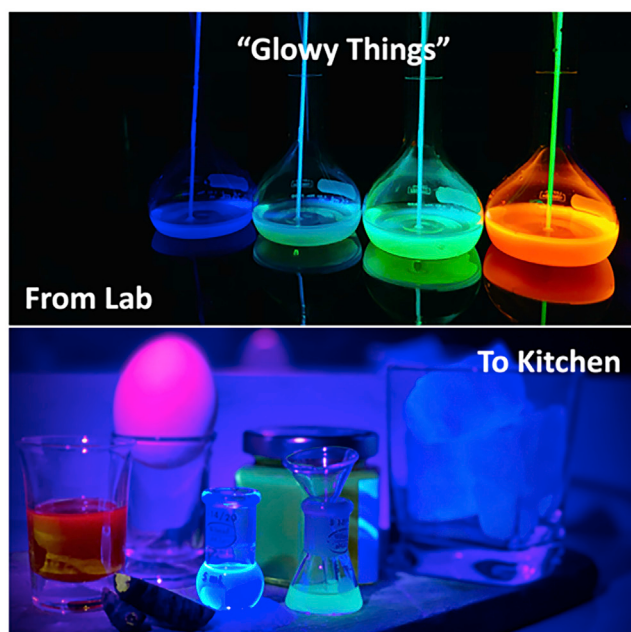


Figure 1. An Abundance of Photoluminescent “Glowy Things” Synthesized in the Lab, Discovered in the Kitchen

While these materials are industrially relevant and may hold promise in many applications and fields, they also serve an additional, albeit less scientific purpose. Aesthetically pleasing bright, fluorescent materials not only bring joy to a stressful research environment but also allow us to share our research with both colleagues and the general public, which might not otherwise get a chance to be exposed to the unique beauty of these materials. Dissemination of our research through a more aesthetic channel also allows for us to show our passion in a new (fluorescent) light.

However, with the recent COVID-19-related lab closures, many of us are working from home—an environment not conducive to the synthesis and characterization of nanomaterials and other fluorescent materials we commonly synthesize in lab. This situation, however, does not mean the fun should end. Even during a quarantine, glowy things surround us in our everyday life. Common household items, including honey, olive oil, and

tonic water (containing quinine) all exhibit varying amounts of fluorescence. While the emission of fluorescent compounds can be studied using both steady-state and time-resolved methods in the lab, the types of lasers used in a lab environment are too dangerous to take out of lab. However, the same working principles that guide these instruments can be brought home to study the fluorescent emission of household objects. Even though just taking pictures of these objects can be fun, those looking for a fun experiment for themselves or children studying the emission of objects around the home can actually build a fluorimeter out of a shoebox, using a bowl of water and a mirror as a dispersion element, plastic wrap as a filter, and the eye as a detector.² While an ultraviolet (UV) lamp is probably the best option as a light source to see the emission, other

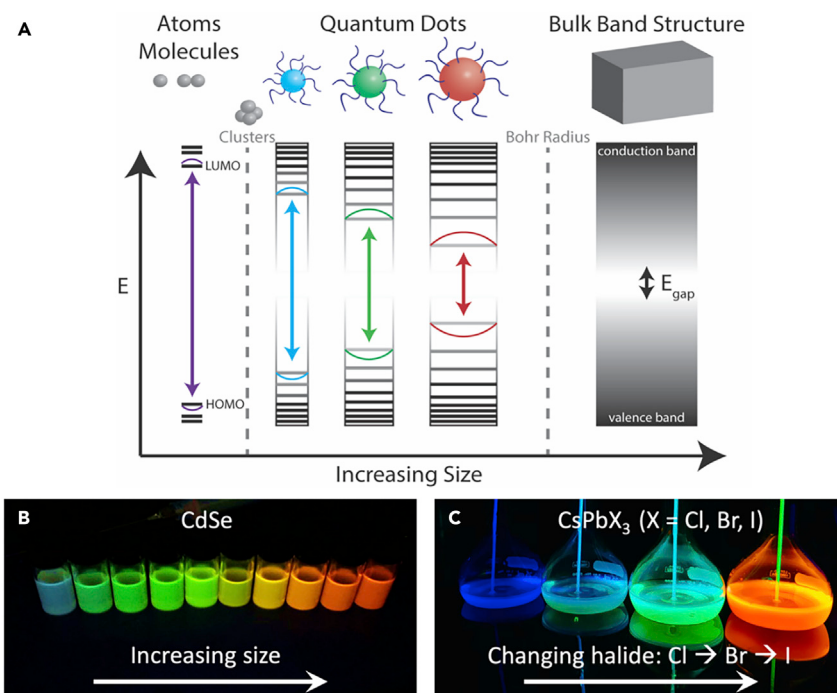


Figure 2. Photoluminescent Quantum Dots

(A) The quantum confinement effect on semiconductor quantum dots affects the bandgap and therefore the emission wavelength, as larger quantum dots feature redder emission. As the size of the semiconductor increases, it begins to exhibit more bulk-like behavior. (B) Emission of different sized CdSe quantum dots excited via a UV lamp. (C) CsPbX₃ quantum dots with varying halide compositions. The halide is primarily Cl in the left flask, going to Br in the middle, and I on the right.

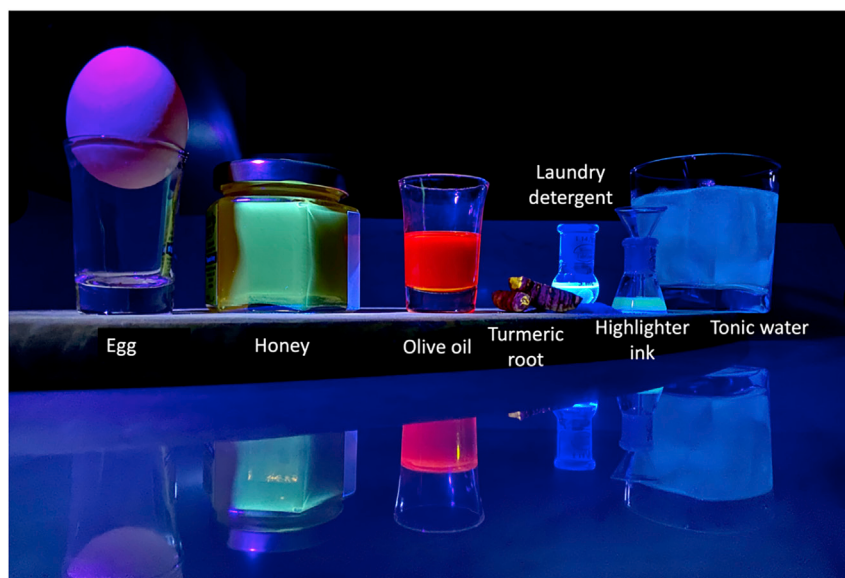


Figure 3. Photoluminescent Household Items

The fluorescence of common household objects excited via a UV lamp. The objects are (from left to right): an egg, honey, olive oil, a turmeric root, laundry detergent, highlighter ink (in water), and tonic water.

more common options (e.g., a phone flashlight) can also be used, provided the object's emission is bright enough to observe.

To highlight the possibilities, we used a UV lamp to excite some fluorescent molecules found in common household items and used a standard phone camera to capture the image (Figure 3). The reddish emission of an egg, specifically the eggshell—which features the compound protoporphyrin IX, which is found in varying amounts in different types and colors of eggs—can be observed.³ The bright green emission of honey was also observed, likely the emission of an ensemble of different aromatic fluorophores.⁴ Olive oil is also very fluorescent, and depending on the excitation source and/or filters used, many fluorescence bands can be observed depending on the purity, as the presence of chlorophyll and vitamin E can lead to redder emission.⁵ Turmeric, a common spice, curry ingredient, and source for tea, is also fluorescent. The source of this fluorescence in turmeric is curcumin, which exhibits a

readily observable yellow emission upon excitation.⁶ Optical brighteners, compounds commonly added to laundry detergents, are also brightly fluorescent (by design) under UV fluorescence, typically exhibiting blue fluorescence.⁷ While highlighter ink appears bright on its own, and it can be used to create a fluorescent solution in water, as described by Wahab² in the construction of a fluorimeter from a shoebox. The source of this fluorescence stems from a variety of organic compounds, including a pyrene dye for the typical fluorescent yellow color.⁸ Tonic water has a characteristic blue glow under UV excitation, due to the presence of quinine. While this list and the accompanying picture serve as an example, the list does not end here. Some vitamins, including the B vitamin family, exhibit fluorescence. Additionally, some added dyes in both food and fabric are brightly fluorescent, meaning your clothes, shoes, and some foods may exhibit fluorescence. The chemistry of these compounds is beyond the scope of this discussion, but they offer another

possibility of fluorescence in your house.

Our fascination with glowy things has led to many tweets utilizing the #FluorescenceFriday Twitter hashtag coined by C&EN (@cenmag), but it is also a source of pride and a vessel for spreading our passion and excitement for our research. Additionally, sharing these photos allows for the broad communication of scientific information in a more aesthetically pleasing form.

Although the COVID-19-related quarantine currently has shut down our lab and so many others, disallowing the synthesis of our emissive QDs and other nanomaterials, fluorophores in household objects can still be examined to brighten up our day. In this short piece, we have demonstrated that through the use of a UV lamp and some household items typically found in the kitchen, bright fluorescent emission can be observed, allowing for a fun and easy (and really cool-looking) scientific scavenger hunt to do at home during quarantine. We would like to take this opportunity to challenge you to find out how many glowy things can be found inside your homes and then take the time to learn about the underlying cause.

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DECLARATION OF INTERESTS

Lea Nienhaus is a member of the Advisory Board of Matter.

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