

Lumidot™ FAQ: Frequently Asked Questions About Using QD Nanocrystals

1. How do I store Quantum Dots?

Ideal storage conditions would be in a dark room or refrigerator at a temperature of 4° Celsius. The samples are air-sensitive and the optical properties might be affected if exposed to air for a long time. Solutions should be stored and handled under nitrogen.

2. How do I handle Quantum Dots?

The particles are sensitive to photo-oxidation. We recommend flashing glassware with inert gas (argon or nitrogen) and avoiding prolonged exposure to direct fluorescent light or sun-light. Extensive handling (e.g. ligand or solvent exchange) should be performed in a glove box or under argon/nitrogen.

3. What solvents are Quantum Dots soluble in?

The surface of the quantum dots is coated with organic ligands, and because of this the dots are soluble in a range of non-polar organic solvents such as toluene, chloroform and hexane. Some solvents may be aggressive towards the material, and we recommend cautious small-scale trials when using an unusual solvent system.

4. What excitation should I use?

The best excitation source for visible emitting quantum dots is UV light (360–380nm). It is important that the excitation source has a lower frequency than the desired emission maximum.

5. What does QY mean?

Quantum Yield (QY), also called quantum efficiency, is the percentage of photons absorbed by the quantum dots to those emitted. The ideal scenario would be 100% energy going into the quantum dot with an output of 100%. Typically QYs range between 30–50% depending on the material.

6. How are the Qys measured?

Quantum Yields of quantum dots are measured relative to a number of standard fluorescence dyes according to the formula

$$QY = QY_{st} \left(\frac{I_{st}}{I} \right) \left(\frac{A_{st}}{A} \right) \left(\frac{n}{n_{st}} \right)^2$$

where I (sample) and I_{st} (standard) are the integrated emission peak areas, A (sample) and A_{st} (standard) are the absorbances at the excitation wavelength, n (sample) and n_{st} (standard) are the refractive indices of the solvents and QY_{st} is the QY of the standard. Commercially available dyes DPA-diphenylanthracene (Product No. **D205001**), Rhodamine 123 (Product No. **R8004**) and Rhodamine 6G (Product No. **252433**) can be used as fluorescence standards to measure QYs across the full visible region.

7. What does FWHM mean?

Typically the emission spectra of quantum dots have the shape of a Gaussian curve. The width of the Gaussian is defined as the full width at half-maximum (FWHM) and gives an idea of the size distribution of the particles. A smaller FWHM corresponds to a narrower quantum dot nanocrystal size distribution. FWHM is also dependent upon the emission wavelength maximum.

8. How many Quantum Dot particles do I get in 1 mg?

The number of quantum dots present in 1 mg of dry sample depends on the particle size and can be established by using the extinction coefficient. To measure the number of particles in 1 mg of dots, Beer's law can be used. According to Beer's Law, $A = \epsilon b [c]$ where A = absorbance of the solution of dots measured by UV-vis spectrometry, ϵ is the extinction coefficient, b is the cell path length and $[C]$ is the concentration of the particles in solution.

9. How were the extinction coefficients determined?

Extinction coefficients were determined according to the method illustrated by Peng et al. "Experimental Determination of the Extinction Coefficient of CdTe, CdSe, and CdS Nanocrystals" *Chem. Mater.* **2003**, *15*, 2854–2860.

10. How much material should I use for my application?

Depends on the application – experiment and explore!

11. Can I just mix the Quantum Dots into my application?

Depending on the application, this may be possible. Quantum dots mix well into plastics and can be formulated into a resin in a similar fashion to other additives. Quantum dots capped with hexadecylamine (HDA) ligands prefer hydrophobic, oil or solvent-based medias, which should be kept oxygen free while drying.

12. How do I exchange Quantum Dot surface ligands?

Surface derivatization of the quantum dots is very much a ligand-specific process and the procedure varies according to the desired ligand. For example, ligand exchange might be achieved by prolonged exposure of the dots to an excess of a competing capping group and in this case the exchange is driven through mass action. The procedure consists of stirring a mixture of HDA-capped dots with a 10-20-fold excess of the competing ligand at room temperature for several hours (at least 72h). Mild heating can speed up the process of surface exchange however, depending on the ligand, heat treatment can cause a substantial decrease of the QY. Ligand exchange reactions should be performed under inert gas (argon or nitrogen) atmosphere and with care taken to protect the reaction from exposure to light.

Note: we do not recommend ligand exchange to be performed on core Lumidots™. They are less stable than core-shell nanocrystals and may substantially degrade during the ligand exchange process.

13. How do I precipitate the particles from solution?

The particles can be precipitated from solution by addition of a polar solvent followed by centrifugation of the resulting suspension. The QY of the quantum dots might change after precipitation from solution and isolation as a powder.

14. Are Quantum Dots also available in powder form?

Quantum dots can be precipitated into powder form. The solvent has to be evaporated. The QY of the powdered samples might be lower than that of the original solution when re-dissolved, because of capping agent loss and semiconductor surface re-construction. Aldrich Material Science will consider offering Lumidots™ in nanopowder form in the future: please send your request to matsci@sial.com.

15. How long do the samples last?

Under correct storage conditions, quantum dots can last 12 months and longer, however a drop in quantum yield and photo oxidation maybe observed if they are not stored under anaerobic conditions.

16. How hot can I heat Quantum dots?

Quantum dots are usually stable at temperatures used for polymer curing or processing. Stability is, however, highly dependent on the chemical composition of the plastic.

17. What concentrations will I need and what are the recommended dilution guidelines?

It depends on the application.

18. How do I minimize photobleaching and what can I expect (power/time guide)?

Quantum dots are susceptible to photo-oxidation process, which is accelerated in the presence of the oxygen and UV light. Extent of the photobleaching can vary and depends on when is oxygen present, the concentration of the quantum dots (with lower concentrations suffering a faster bleaching rate) and the power of the irradiation. As a general guideline, the QY of the solution can decrease up to half of the original value after 5 min of direct exposure to a UV lamp ($\lambda_{exc} = 370 \text{ nm}$) in air. To minimize photobleaching, samples should be stored in the darkness and in an inert atmosphere.

19. What are the sizes of the particle cores and ligands?

Lumidot™	Approx. Core Size (nm)	Size Incl. Ligands (nm)
480nm	2.5	4.4
510nm	3.0	4.9
530nm	3.3	5.2
560nm	3.4	6.0
590nm	4.0	6.2
610nm	5.2	7.7
640nm	6.3	8.6