Cadmium Selenide Quantum Dots – 16 Marks Answer

1. Introduction

- Quantum dots are **very small semiconductor particles** (2–10 nanometers).
- **CdSe (Cadmium Selenide)** is a type of quantum dot with **tunable optical properties**.
- Their **color changes** based on size due to a principle called **quantum confinement**.
- They **emit bright light** when excited – useful in many high-tech devices.

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2. Properties / Characteristics

- **Size-dependent emission:** Smaller dots emit blue, larger ones emit red light.
- **High quantum efficiency:** They absorb and emit light very efficiently.
- **Nanoscale size:** ~2 to 10 nm diameter.
- **Stability:** Stable under UV light and moisture when coated.
- **Bright and pure colors:** Better than organic dyes.
- **Broad absorption, narrow emission:** Useful for multicolor displays.

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3. Synthesis / Working

Synthesis methods:

- **Hot injection method** (most common):
    - Cadmium and selenium precursors are mixed at high temperatures in organic solvents.
    - Size is controlled by reaction time and temperature.
- **Colloidal synthesis:** Produces CdSe in a solution with surfactants to prevent clumping.

Working principle:

- When light hits a CdSe quantum dot:
    - An electron is excited to a higher energy level.
    - When it returns to normal, it emits light (fluorescence).
- The **color** of emitted light depends on **dot size**.

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4. Applications

- **Display technologies:** QLED TVs and monitors.
- **Bio-imaging:** Used as fluorescent markers in cells.
- **Solar cells:** Improve efficiency in photovoltaic devices.
- **LEDs and lasers:** Tunable light sources.
- **Sensors:** For detecting toxins, gases, or biological markers.

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5. Advantages

- **Tunable emission color** (just by changing dot size).
- **High brightness** and **long-lasting fluorescence**.
- **Better than dyes** for biological imaging.
- **Can be coated** for chemical and physical stability.
- **Compatible** with various materials (glass, polymers, etc.).

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6. Disadvantages

- **Toxicity:** Cadmium is highly toxic and harmful to humans/environment.
- **Complex synthesis:** Requires high temperature and careful conditions.
- **Costly for large scale use.**
- **Stability issue** without proper coating (oxidation).

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8. Summary

- CdSe quantum dots are tiny, colorful, and powerful materials.
- They work by emitting light depending on their size.
- Useful in electronics, imaging, and energy fields.
- Though toxic, with proper control they have a bright future in technology.
