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Detection of Heavy Metals by Colorimetric Nanoparticles

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Introduction

In the United States, there are 6.1 million lead water service lines.[1] This poses a threat to many Americans since changes in water, such as pH, can cause lead (Pb^{2+}) to leech into their water supply. Exposure to lead can result in brain damage, kidney damage and cancer. Most current methods of heavy metal detection require a highly trained user, whereas the proposed method can be carried out inexpensively, by any individual. This will be made possible by incorporating metal sensitive dye-modified polymer nanoparticles into a lateral flow assay.

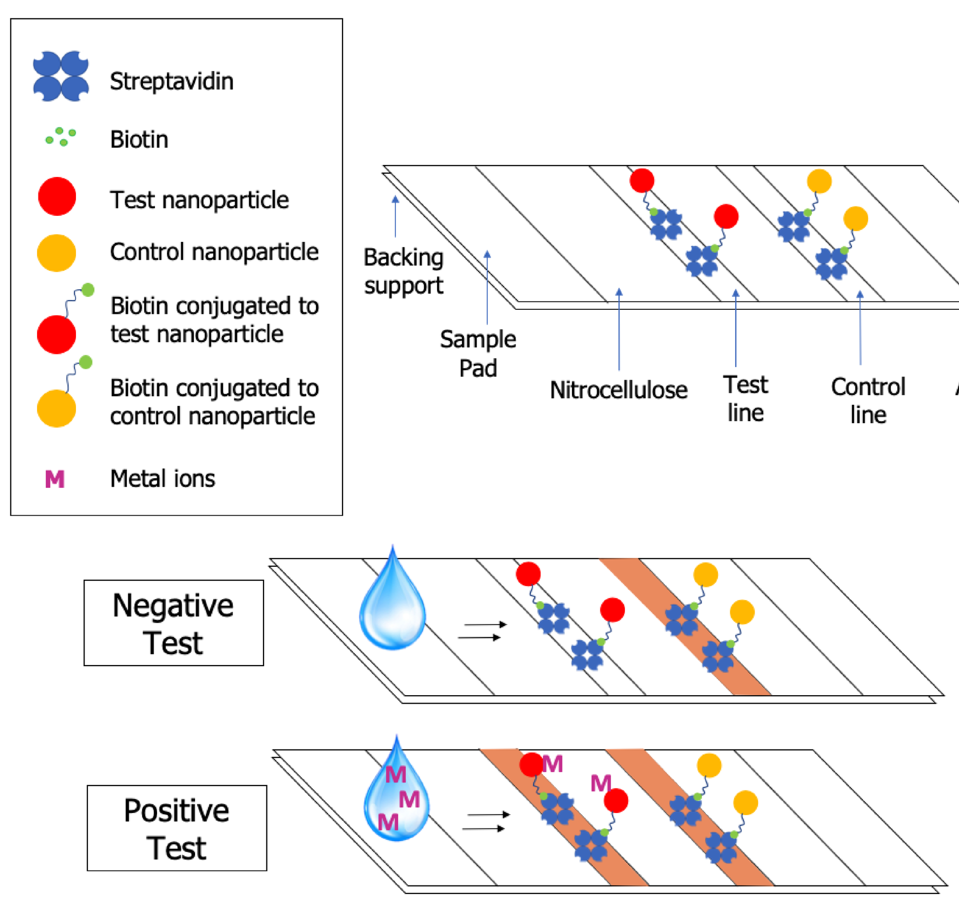

Figure 1: Layout of lateral flow assay with positive and negative test examples

Phenanthroline Probe for Pb^{2+}

- A probe to detect lead synthesized from 1,10-phenanthroline-5,6-dione and 4-nitrobenzhyrazide has been reported[2]
- Binding to Pb^{2+} induces a color change from yellow to red

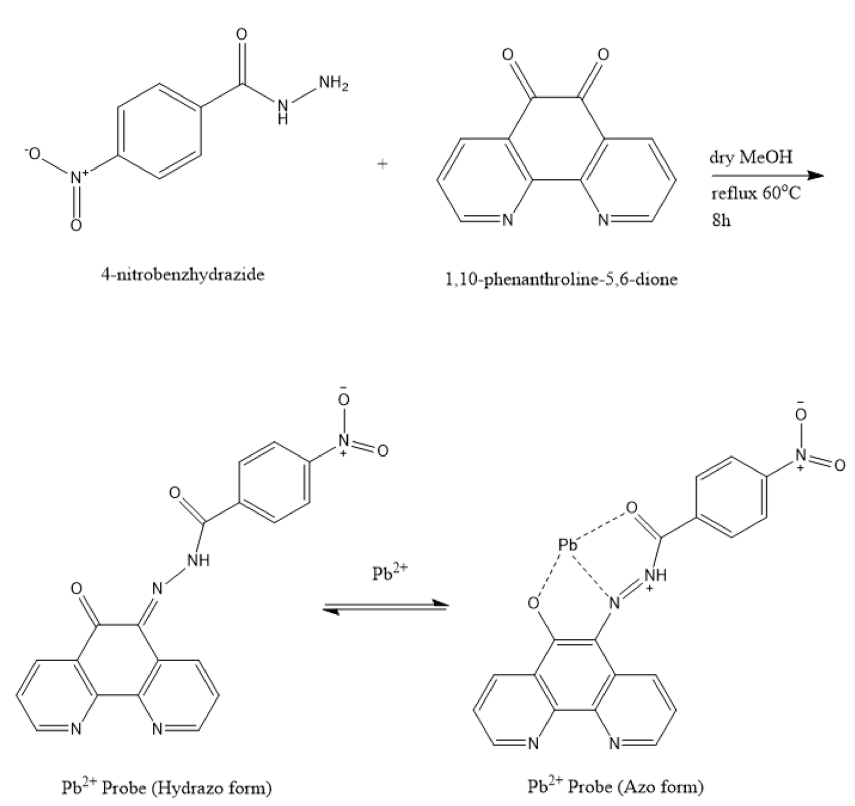

Figure 2: Synthesis scheme for phenanthroline probe and its interaction with lead[2]

pH Responsive Control Bromocresol Green

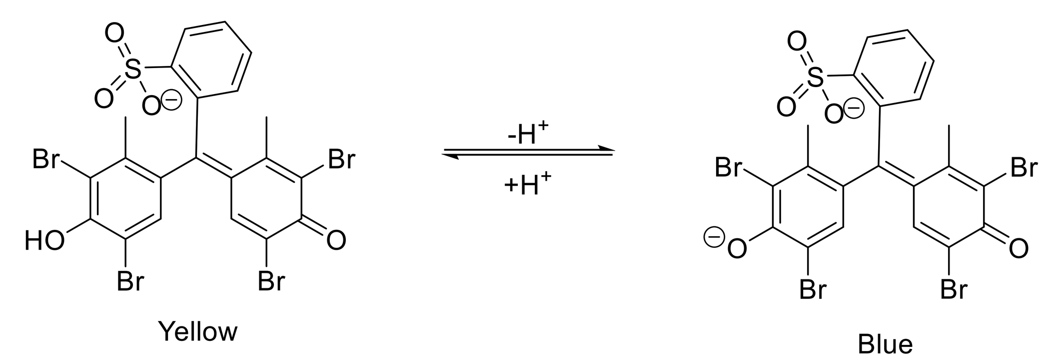

Figure 3: Structural change of bromocresol green that occurs upon color shift

Synthesis of Phenanthroline Probe

- Test probe was synthesized with a 44% yield
- Purified by column chromatography

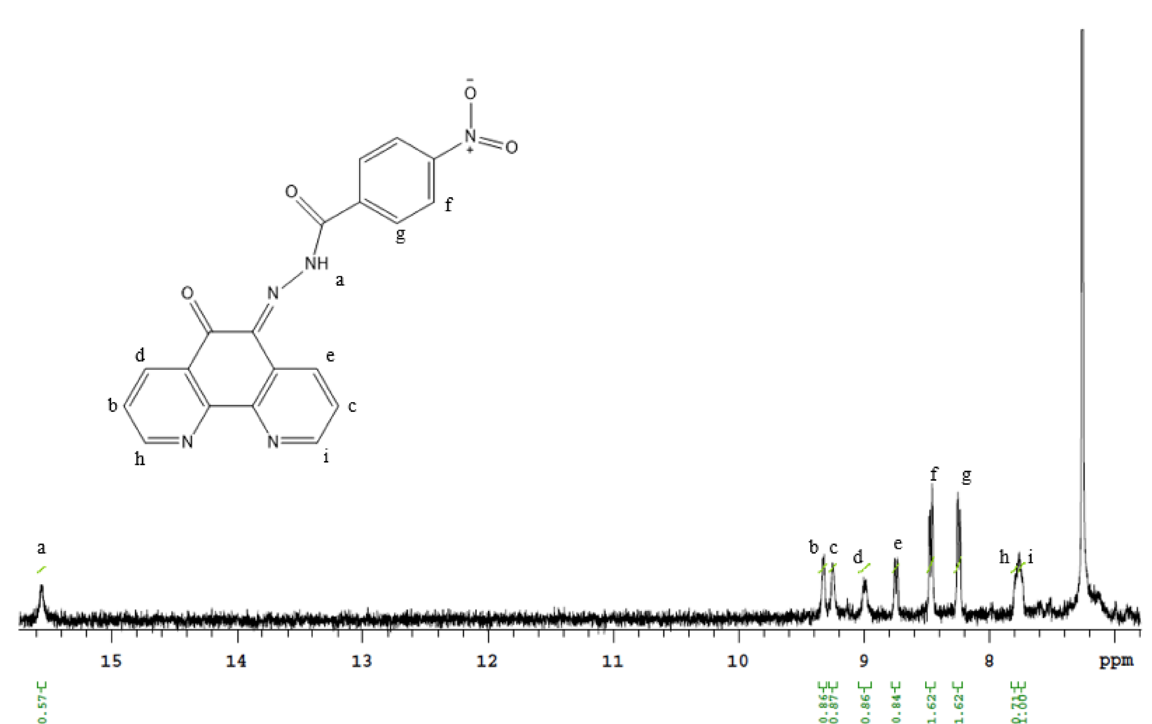

Figure 4: NMR of purified phenanthroline probe

Phenanthroline Probe Response to Pb^{2+}

- Upon addition of Pb^{2+} an increase in absorbance at 490 nm occurs

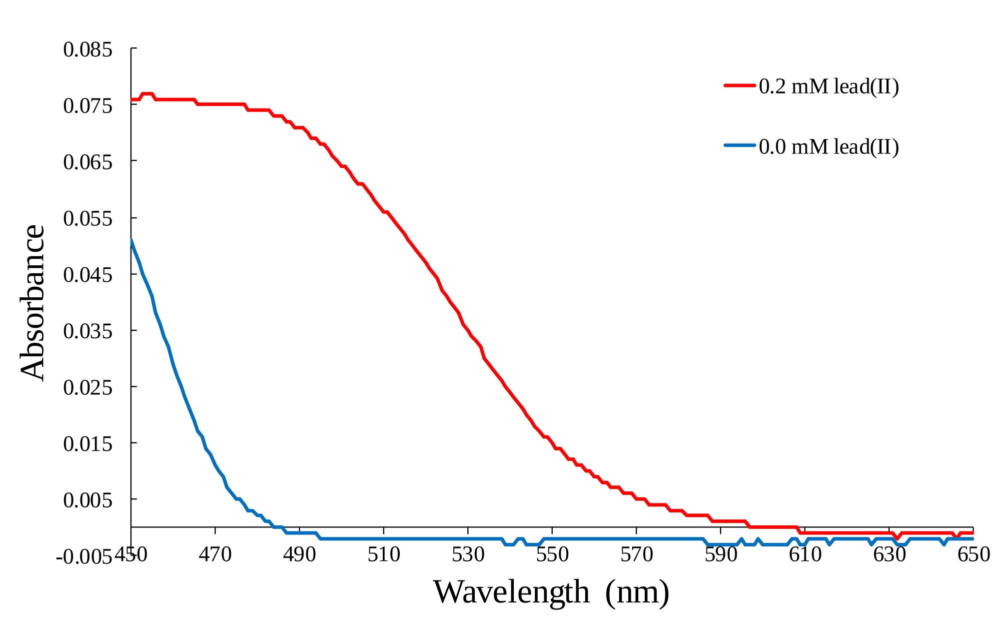

Figure 5: Absorbance response of test probe exposed to Pb^{2+}

Synthesis of Control Nanoparticles

- A solution of bromocresol green and PLGA in ethyl acetate and a 1% PVA solution were prepared separately
- The PVA solution was stirred while the bromocresol green solution was added dropwise
- The solution was sonicated, DI water was added and the organic solvent evaporated[3]

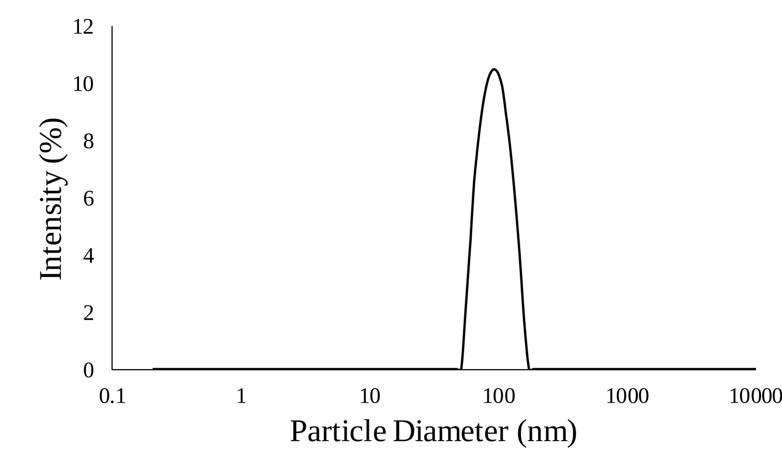

Figure 6: Size distribution of dialyzed control nanoparticles

- Dynamic light scattering confirmed successful nanoparticle synthesis
- Hydrodynamic diameter: 106 ± 17 nm
- PdI: 11 ± 2%

Control Nanoparticle Signal

- Control nanoparticle signal was tested with citrate and phosphate buffers pH 3-8
- Color changes from yellow to blue were observed with increasing pH

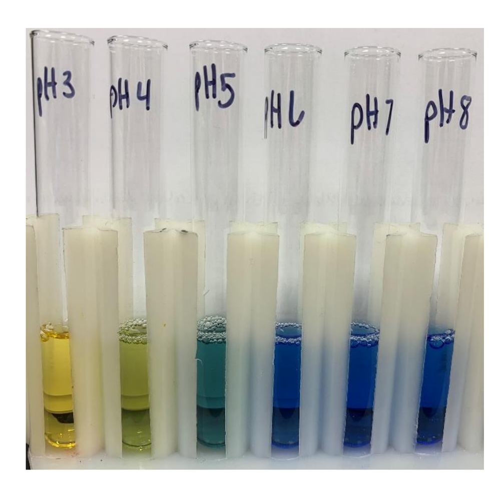

Figure 7: Visible color change over pH range 3-8

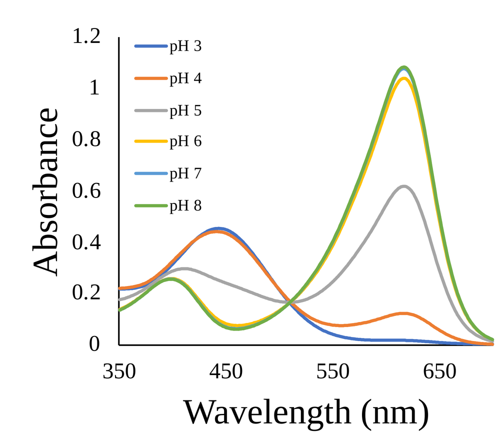

Figure 8: Absorbance data for bromocresol green control nanoparticles

- Figure 7 shows utility of bromocresol green control nanoparticles for incorporation in lateral flow assay

Control Nanoparticle Optimization

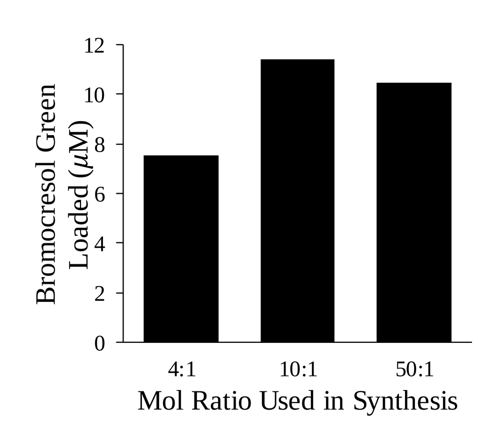

Figure 9: Loading of control nanoparticles when mole ratio of bromocresol green:PLGA was varied

- Molar absorptivity of bromocresol green (ε_{616} = 17,700 L/mol•cm) was used to determine nanoparticle loading
- Optimal loading occurred with 10:1 mol ratio

Model Lateral Flow Assay

- Filter paper was used as the test strip and paper towel as the absorbent pad
- pH 3 buffer was added to control nanoparticles, changing their color to yellow
- Blue line observed upon addition of aqueous solution with neutral pH

Figure 10: Model lateral flow assay displaying blue control line

Conclusions

- The proposed phenanthroline probe was synthesized and purified by column chromatography
- Colorimetric response to Pb^{2+} was observed
- Bromocresol green control nanoparticles with a size of 106 nm were synthesized
- Visual signal results with increasing pH

Future Work

- Lead Test Nanoparticles:
  - Encapsulate phenanthroline probe in polymer nanoparticles
  - Test nanoparticle response to Pb^{2+}
  - Explore alternative probes
- Control:
  - Attach control nanoparticles to the lateral flow assay using streptavidin and biotin interaction

References

1. Cornwell, D. A.; Brown, R. A.; Via, S. H. *J. Am. Water Works Ass.* **2016**, *108* (4), E182-E191.
2. Goswami, S.; Chakrabarty, R. *Eur. J. Org. Chem.* **2010**, *2010* (20), 3791-3795.
3. Cooper, D.; Harirforoosh, S. *PLoS ONE* **2014**, *9* (1): e87326.

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