Preparation of Gold-Coated Magnetic Nanorods for Lung Cancer Treatment

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Introduction

•Purpose: **Evaluate experimental methods used for the preparation of gold coated nanorods.**

•Gold-coated magnetic nanorods are a possible means for achieving selective destruction of lung cancer cells through plasmon resonance.

• Particles can be delivered to the lung by inhalation and can be detected by the non-invasive imaging technique of magnetic resonance imaging (MRI).

•Theoretically, temperature of the particle can be raised to 500-1000 ° C by laser irradiation at the proper wavelength, which would cause non-specific thermal death of the cell (photothermal therapy)

•The magnetic core will allow not only detection by MRI but also opens the possibility of aligning the particles to maximize the absorption of light, that is, increase the optical cross sectional area.

Objectives

•Use different experimental methods (reaction conditions) to create iron particles

•Coat magnetite particles with gold

•Determine particle size dynamic light scattering and microscopy

Hypotheses

•The rate of addition of base is inversely related to the resulting particle size

•Changing mole ratio of Fe to OH in KNO_3 oxidation reaction modulates the size and shape of particles

Iron Chlorides: $2Fe^{III}Cl_3 + Fe^{II}Cl_2 + NH_4OH \rightarrow Fe_3O_4 + 8NH_4Cl$

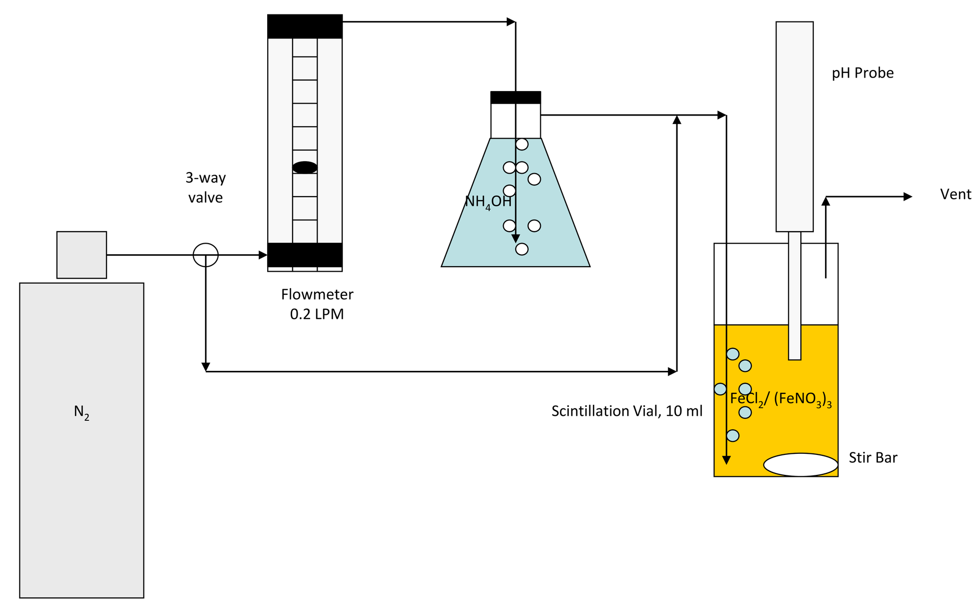


Figure 1: Schematic of reaction set up. Rate of addition of NH_4OH depends on pressure from N_2. More rapid ammonia vapor addition resulted in a more rapid rise in pH and extent of reaction.

pH	1-2	1.5-2.6	1.8-7	3.4-7.1
Color	Yellow/Orange	Reddish brown	Brown	Black

Table 1: Color of reaction mixture at measured values of pH. Target pH level is around 12. The brown color occurred at a pH level of 3.8 and by pH 6, the dispersion was black.

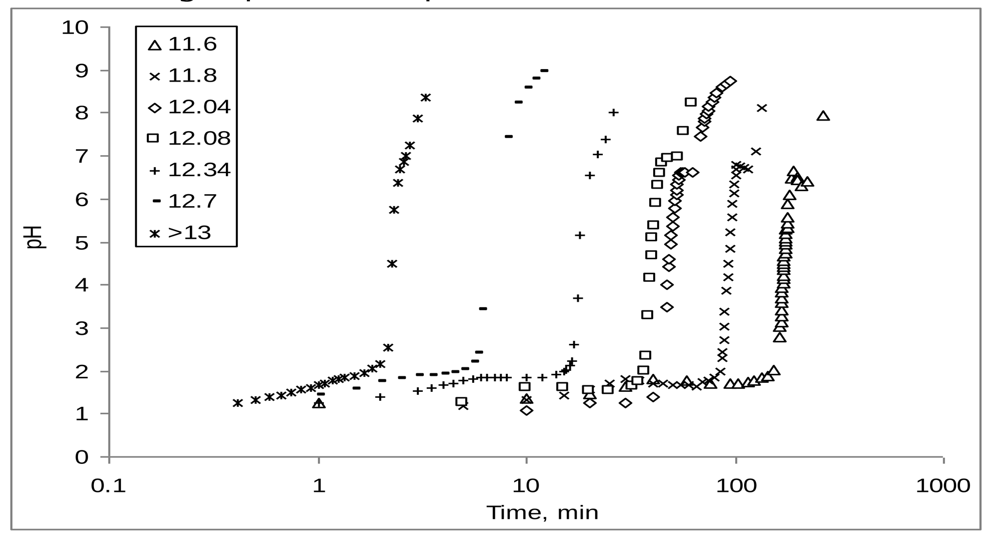
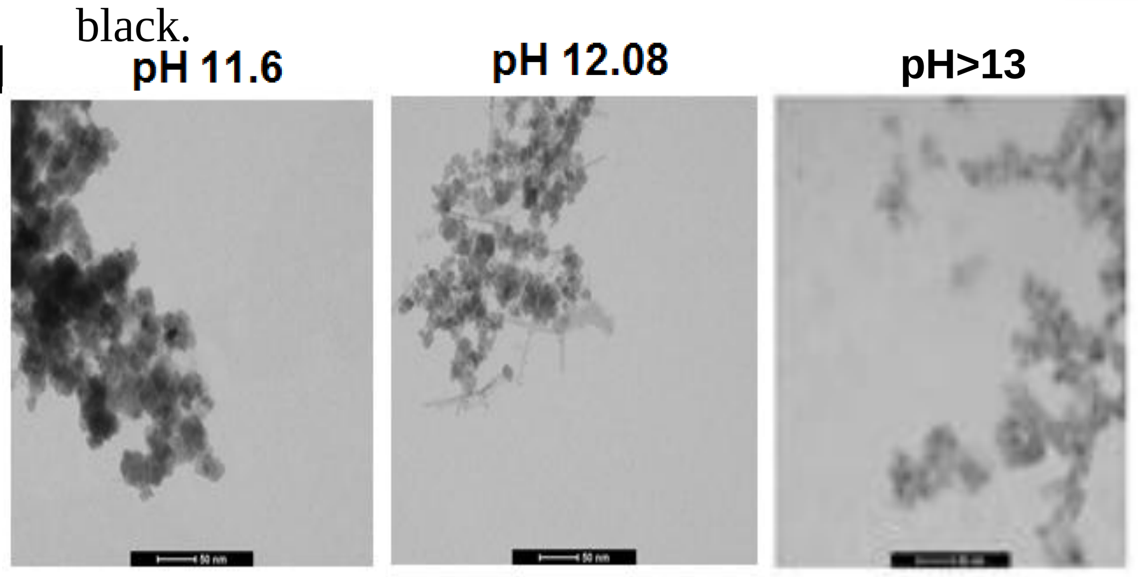


Figure 2: Observed pH plotted as a function of time on a logarithmic scale for seven different reactions. The legend indicates the pH of the ammonium hydroxide solution through which N_2 was passed to control the rate of addition of ammonia vapor to the reaction mixture. The steep increase in pH occurs when the particles turn jet black.



Figures 3: TEM was performed on particles at pH levels ranging from 11.6-13. As the reaction rate increased, a corresponding reduction in size of the particles was observed.

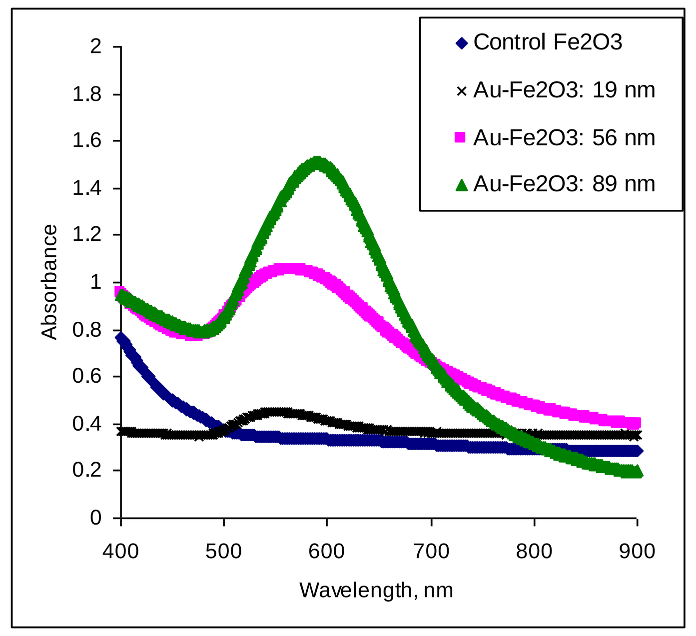
Plasmon Resonance:

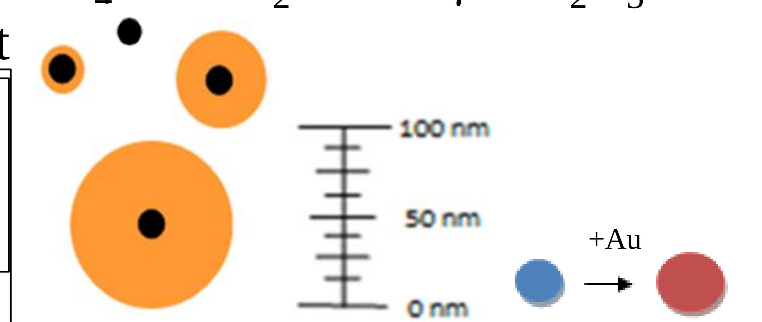
(1) $Fe_3O_4 + HNO_3 \rightarrow \Delta \rightarrow \gamma\text{-}Fe_2O_3$

(2) $\gamma\text{-} Fe_2O_3 + Na_3Citrate \rightarrow \gamma\text{-} Fe_2O_3\text{- Citrate}$

(3)$\gamma\text{-} Fe_2O_3Citrate + HAuCL_4 + NH_2OH \rightarrow \gamma\text{-}Fe_2O_3\text{-Au coated}$

(4)$\gamma\text{-} Fe_2O_3\text{-Au coated} + HAuCL_4 + NH_2OH \rightarrow \gamma\text{-} Fe_2O_3\text{-Au}$ increased thickness of Au coat





Legend 1: The absorbance increased and underwent a red shift as more gold was added to the particles (■) and (▲). There was also a corresponding increase in the particle size as noted in the figure legend.

Figure 4: Absorbance as a function of wavelength of the control and different levels of coating of the gold (Au) on oxidized magnetite particles with the corresponding size as determined by dynamic light scattering. The control scan consisted of the background scattering of the iron particles (♦ $\gamma\text{-}Fe_2O_3$, maghematite). The addition of gold chloride ($HAuCl_4$) and the mild reducing agent, hydroxylamine (NH_2OH), resulted in the formation of the Plasmon resonance band at 550 nm (x).

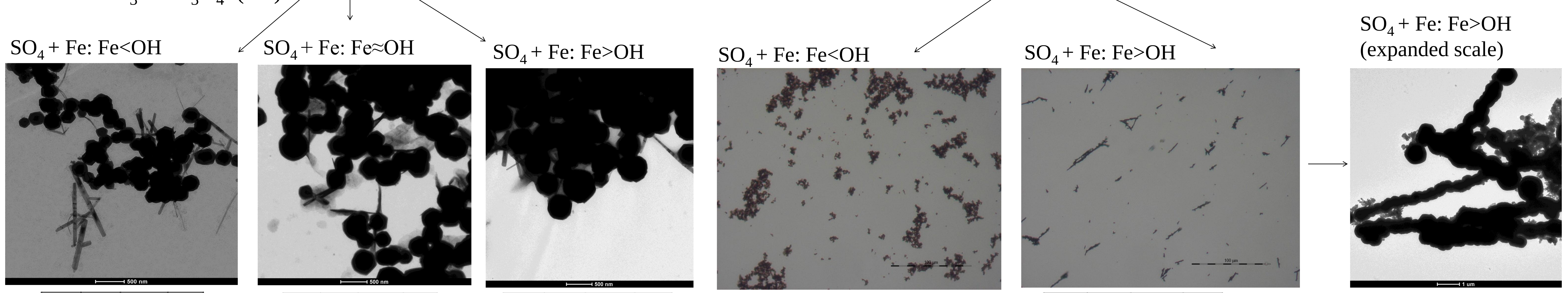
Summary: A series of reactions were carried out in which the rate of addition of ammonium hydroxide was varied. A series of colloidal dispersions were obtained that contained magnetite. The particle size distribution appeared to vary in that a larger particle size was obtained as the rate of addition of ammonium hydroxide was reduced.

Precipitation with base and oxidation with KNO_3 (Light Microscopy)

(1) $Fe^{II}SO_4 \bullet 7H_2O + KOH \rightarrow FeOOH$

(2) $FeOOH + KNO_3 \rightarrow Fe_3O_4$ (ox.)

Magnetic Field



KOH	KNO_3	$FeSO_4xH2O$	FeEx
150 mM	409 mM	73 mM	-2.0 mM

KOH	KNO_3	$FeSO_4xH2O$	FeEx
150 mM	397 mM	76 mM	0.6 mM

KOH	KNO_3	$FeSO_4xH2O$	FeEx
150 mM	392 mM	78 mM	2.7 mM

KOH	KNO_3	$FeSO_4xH2O$	FeEx
124 mM	196 mM	56 mM	-5.6mM

KOH	KNO_3	$FeSO_4xH2O$	FeEx
86 mM	190 mM	54 mM	10.9mM

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86 mM	190 mM	54 mM	10.9mM

Figure 5: Because there was no expected dependency on the absolute concentration of the $Fe^{II}SO_4$, a range of 30 to 70mM of $Fe^{II}SO_4$ was mixed with KOH in first step. In the chemical reaction, 1 mole of Fe reacts with 2 moles of KOH. The outcome of the reaction depends on the ratio of Fe and OH, which was expressed as "excess Fe". When there is a 1:2 Fe/OH ratio, the reaction has zero excess. If there is excess Fe, the particles were on the order of 400nm and spherical; if the ratio is ca 1:2 (no excess), the particles were spherical/hexagonal on the order of 1-2µm; if there is negative excess of Fe (excess OH), small hexagonal particles resulted. If this reaction is carried out in the presence of a permanent magnet, the particles aligned to form very large, beaded nanofibers.

Conclusions

- *Iron Chloride:* The reaction time and thereby particle size was dependent on the pH level of the NH_4OH through which the N_2 was bubbled through.
- *Plasmon Resonance*: Citrate must be added and left to react with the particles for ~10 minutes to allow Au bind to iron
- *Precipitation with base and oxidation with KNO_3:* when excess Fe present (Fe>OH), particles were spherical in shape, and small; when negative excess Fe (Fe<OH), particles were hexagonal and cubical in shape; when Fe≈OH, mixture of larger spherical and hexagonal particles
- When KNO_3 reaction carried out in presence of magnet and Fe>OH, particles grew like beaded nanofibers

Acknowledgements

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References

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