Catalytic Ability of TiO_2 Functionalized on Ag-coated Fe_3O_4 Microspheres

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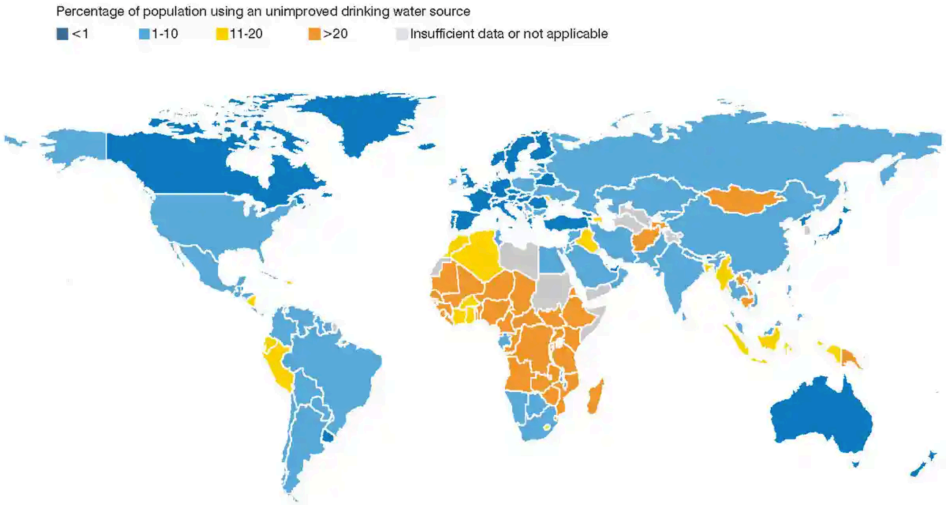
Introduction

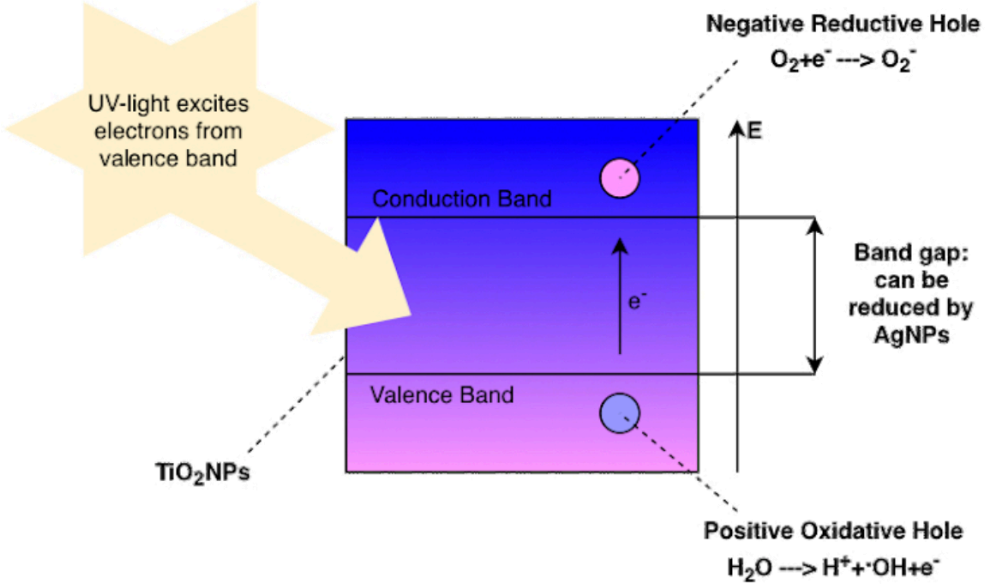
- Water pollution has become an increasingly severe problem worldwide
- Chemicals in wastewater are toxic to wildlife in aquatic ecosystems
- Consuming fish that accumulate toxins from polluted water can cause cancer and other potent diseases
- 606,000 people have died from contaminated water sources in 2021
- By 2025, half of the world's population are estimated to be living under stress for clean water



Estimation from WHO and NRDC (Natural Resources Defense Council)

Project Background

- Organic Pollutants in Water
  - Fats, oils, and greases
  - Harmful to animals and soil
- Photocatalysts
  - Use UV light to catalyze reactions
  - TiO_2 nanoparticles can purify water by decomposing organic molecules
  - $TiO_2 + Fe_3O_4$
    - Magnetism and recyclability
  - A noble metal coating
    - Increased catalytic efficiency



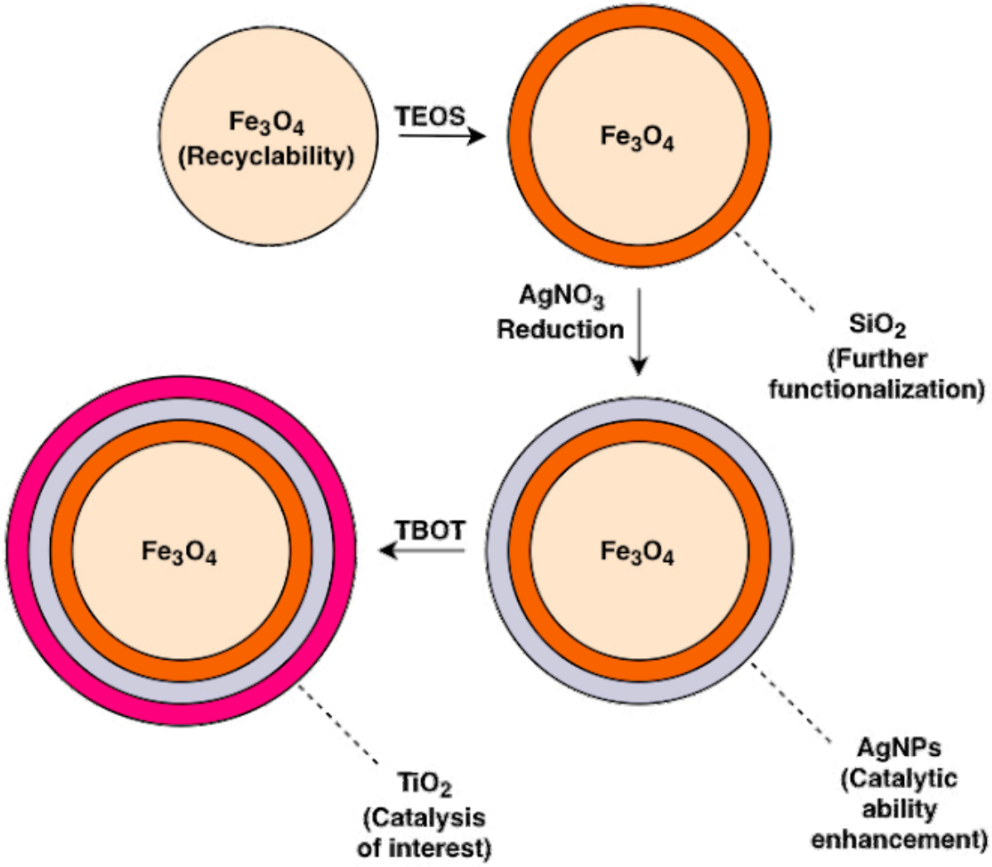
The Mechanism of TiO_2 Catalysis Drawn by Me

J. Mater. Chem., 2012, 22, 13341

Solid State Sciences 52 (2016) 42-48

Project Overview

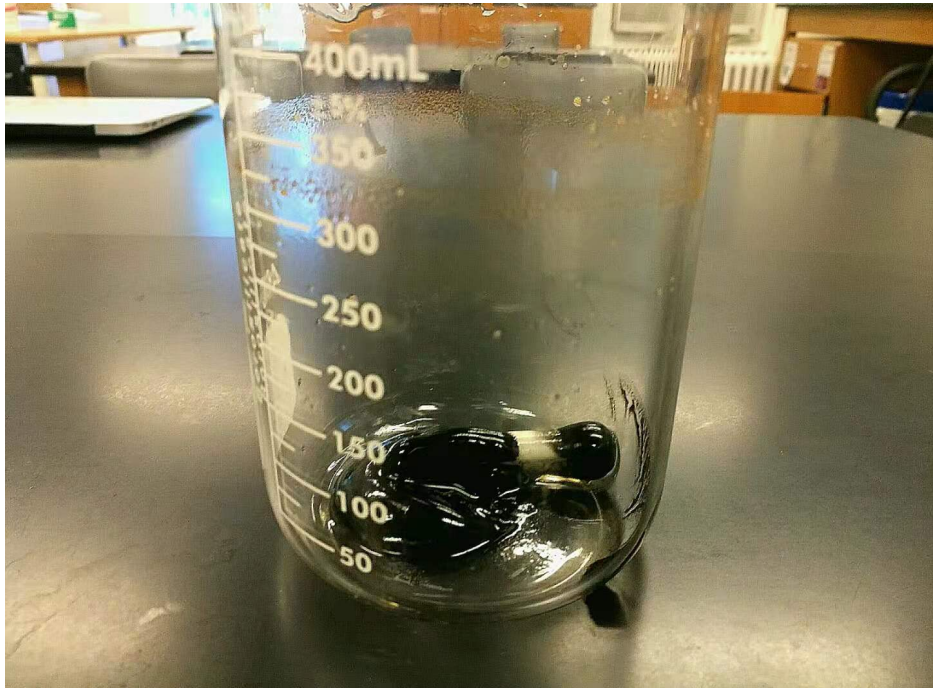
- We will synthesize Fe_3O_4@SiO_2@Ag@TiO_2 nanoparticles to purify polluted water sources
- Specifically, we will use a layer-by-layer approach to complete the synthesis of the aforementioned nanoparticles with magnetic properties and high catalytic activity to decompose organic pollutants
- The efficiency of the catalyst will be tested with spectroscopy on methyl blue



Synthetic Overview Drawn by Me

Experimental Procedures

- **Fe_3O_4**: Ammonia Method
  - Fe^{2+} + Fe^{3+} in HCl followed by addition of NH_3
- **SiO_2**: Modified Stöber Method
  - Fe_3O_4, NH_3, and TEOS in 95% ethanol
- **AgNPs**: $AgNO_3$ + Citrate Reduction
- **TiO_2**: hydrothermal synthesis with TBOT
- Characterization: TEM/FT-IR
- Catalytic testing: UV spectroscopy
  - Real-time monitoring of dye concentration



Co-precipitation Product of Fe_3O_4

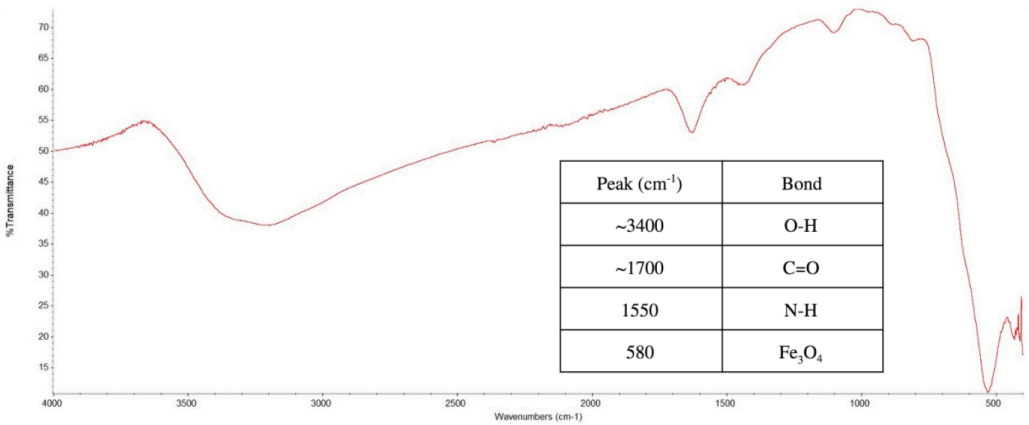
Journal of Chemical Education 2018 95 (1), 121-125

J. Chem. Educ. (2004) 81, 544A

World Journal of Condensed Matter Physics, 2011, 1, 49-54

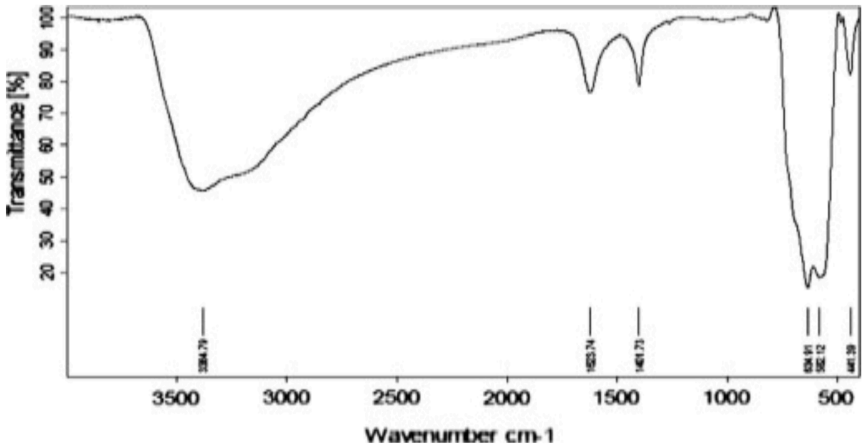
FT-IR Spectrum of Fe_3O_4 Core

- FT-IR measures the vibration of chemical bonds
- Characteristic peaks of Fe_3O_4 are shown in the table



Peak (cm^{-1})	Bond
~3400	O-H
~1700	C=O
1550	N-H
580	Fe_3O_4

FT-IR of Obtained Particles



FT-IR from Background Research

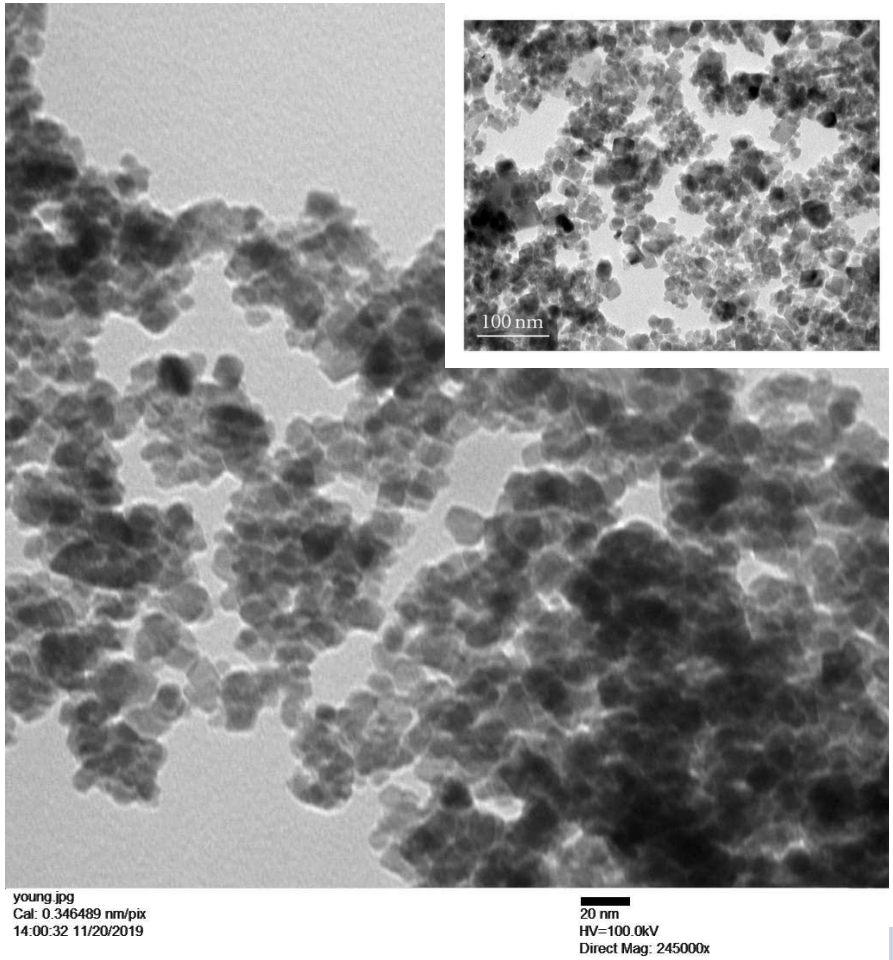
- Matching peaks with background literature except at 1100 cm^{-1}, which can be attributed to S=O in sulfate used in co-precipitation

Arabian Journal of Chemistry 8, 2, 2015, 279-284

TEM Image of Fe_3O_4

- Mean diameter: 15 nm
- Mean distance between two adjacent particles: short
- NH_3 can be added at a slower rate to reduce aggregation
- The stirring of the solution can be slowed to allow the formation of larger nanoparticles
- Suitable for further functionalization

TEM Image of Fe_3O_4 from Background Research

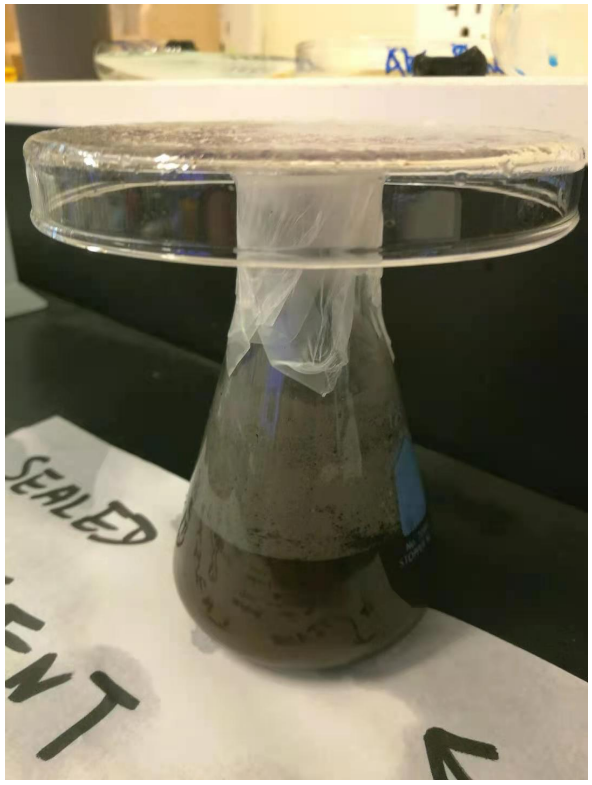


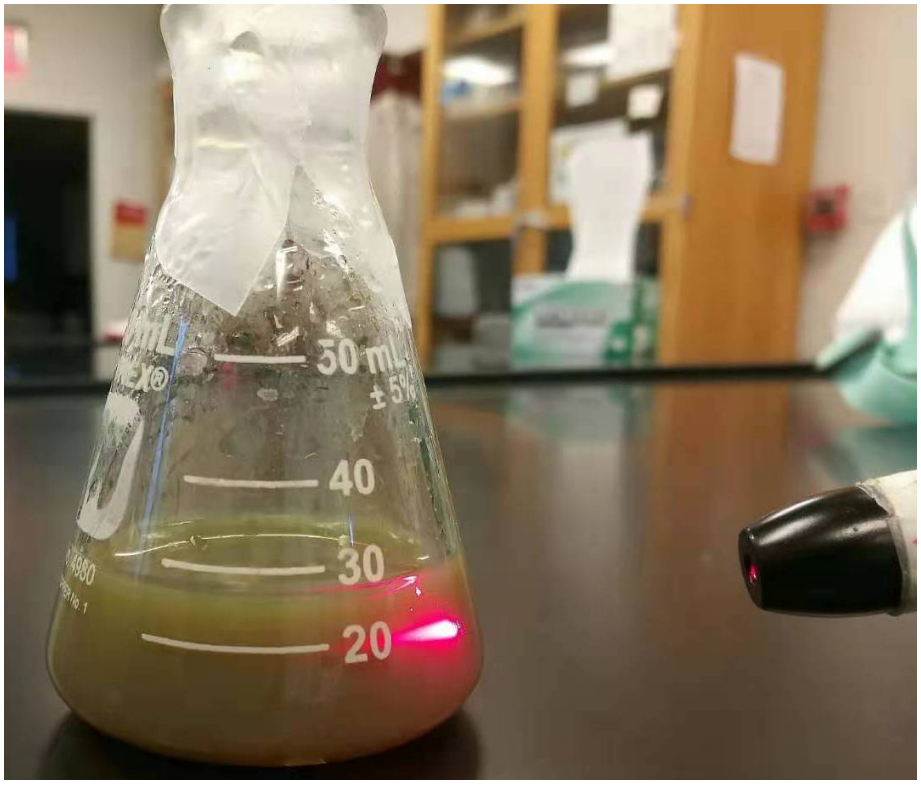
Journal of Nanomaterials, 2009, Special Issue

TEM Image of Obtained Fe_3O_4 Nanoparticles

Synthesis of the SiO_2 Layer and AgNPs

- SiO_2 precursor TEOS has been reacted with Fe_3O_4 to create a magnetic mixture
- AgNPs are successfully synthesized through Citrate Reduction
- Tyndall effect is observed on AgNPs and proves the presence of nanoparticles



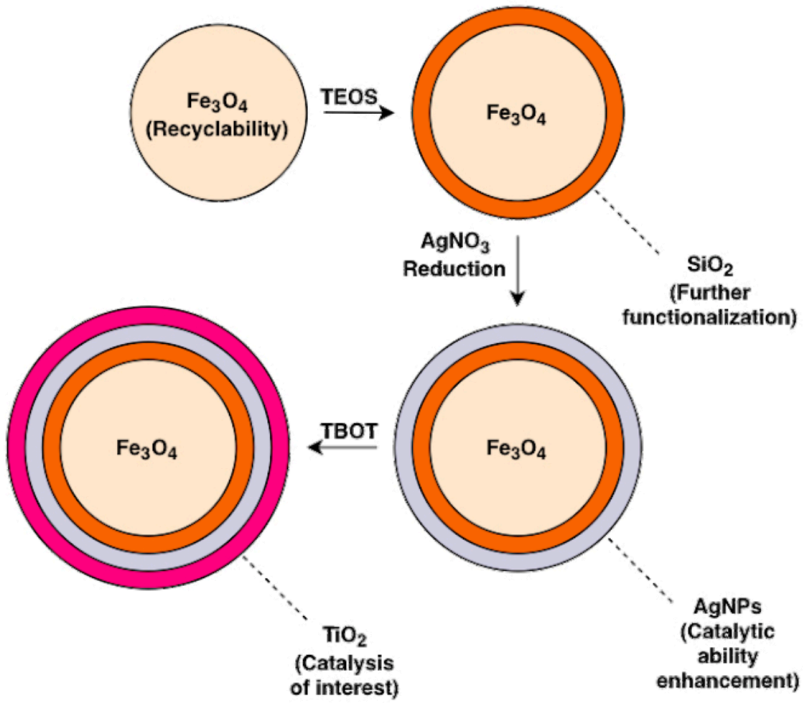


- The samples have yet to be characterized

Solutions of Fe_3O_4@SiO_2 Obtained from Stöber Method (left) and AgNPs (right) Obtained from Citrate Reduction

Future Plan

- Characterize the obtained nanoparticles with TEM and FT-IR
- Attach AgNPs to Fe_3O_4@SiO_2
- Synthesize TiO2 and add it as a layer to Fe_3O_4@SiO_2@Ag
- Use visible spectroscopy to measure catalytic ability



Synthetic Overview Drawn by Me

Visible Spectrophotometer
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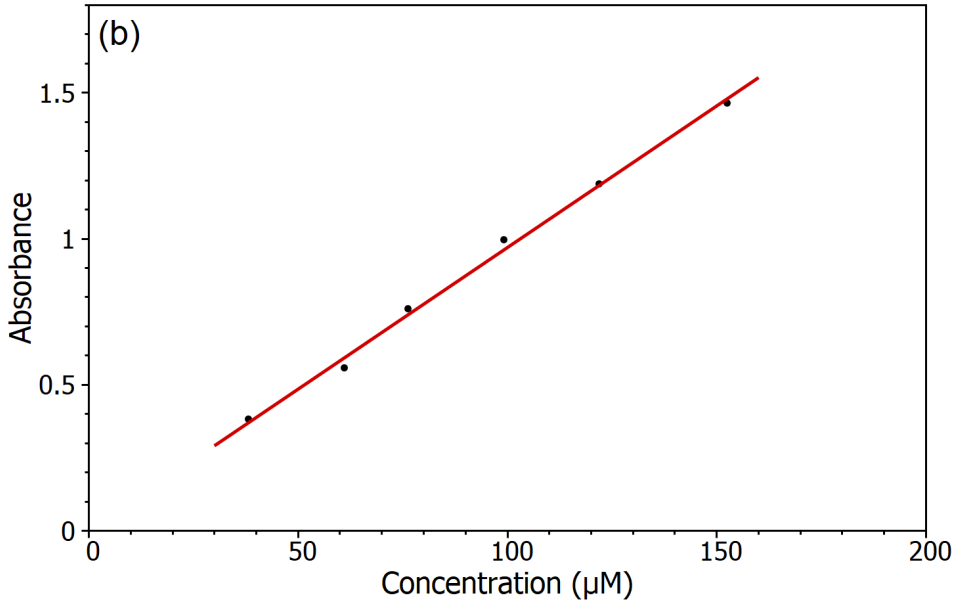
Catalytic Testing

- A methyl blue sample will simulate organic pollutants
- TiO_2 will be mixed with methyl blue
- A small portion of the dye is extracted with the MB solution every 5 minutes
- The concentration of MB will be measured by spectrophotometer
- Data points are plotted (time vs absorbance)
- The graph is compared to a calibrated curve of [MB] vs absorbance



Example Calibration Curve Expected from Catalytic Testing from *Edinburgh Instruments*, 18 Feb. 2021

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Equally importantly, thank you for listening!

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