Gold and Silver Nanoparticles
Objectives

You will:

• Make gold nanoparticles
• Make silver nanoparticles
• Determine the color of the nanoparticles
• Determine the size of the nanoparticles
How Big is a Nanometer?

• 1 meter (m): Doorway ~2 meters high
• 1 millimeter (mm): Thickness of a dime
• 1 micrometer (μm): Size of a bacterium
• 1 nanometer (nm): Diameter of DNA ~2 nm
Nanoparticles

- **Nanoparticles** of a material behave differently than larger amounts of the same material.
What Color is Gold?

• For instance, a nugget of gold large enough to hold has the same chemical and electrical properties as another nugget.

• But two nanoparticles of pure gold exhibit markedly different physical properties - such as different colors – at differing distances between particles.
How Big are the Nanoparticles?

- How big are the particles of gold and silver we will make?
- We can get idea by looking at three properties.
  - Settling
  - Tyndall effect
  - Filtering
Settling

• Settle out
  – See particles on bottom
  – Large particles (more than 1000 nm)

• Remain dispersed
  – Never see particles on bottom
  – Smaller particles (less than 1000 nm)
  – May be clear or cloudy
Tyndall Effect

- Tyndall effect is based on light scattering when it hits the particles in the mixture.
  - Tyndall effect – light scattered by particles
    - See line of light
    - Particles larger than 1 nm
  - No Tyndall effect – light passes without scattering
    - No line
    - Particles less than 1 nm
## Classifying Mixtures

<table>
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<tr>
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<th>Settling</th>
<th>Tyndall effect</th>
<th>Size</th>
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<tbody>
<tr>
<td><strong>Solution</strong></td>
<td>Doesn’t Settle</td>
<td>No Light Scattering</td>
<td>Less than 1 nm</td>
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<tr>
<td><strong>Colloid</strong></td>
<td>Doesn’t Settle</td>
<td>Light Scattering</td>
<td>1 to 1000 nm</td>
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<tr>
<td><strong>Suspension</strong></td>
<td>Settles</td>
<td>Light Scattering</td>
<td>More than 1000 nm</td>
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Solutions

- Particles in a solution are so small that they do not settle; the movement of molecules is enough to keep them dispersed.
- Light passes through these objects without scattering.
- Many familiar substances, including salt water, soda, and tea are solutions.
Colloids

• Colloidal particles are so small they do not settle; the movement of molecules is enough to keep them dispersed.
• Light scatters when passing through.
• Many familiar substances, including butter, milk, cream, asphalt, ink, paint, and glue are colloids.
Suspension

- Particles in a suspension are large enough that they will settle. Gravity will overcome the movement of molecules.
- Light scatters when passing through.
- Examples of suspensions include sand in water and orange juice with pulp.
Get Closer Size Estimate

• Filter nanoparticles through a 20 nm filter, see if they will pass through or not.

  – What would you predict if the particles are larger than 20 nm?

  – What would you predict if the particles are smaller than 20 nm?
How to Make Gold Nanoparticles

• Put 2 mL .5 mM HAuCl$_4$ in a test tube.
  – Start with a compound that has gold in it.
  – Our solution is hydrogen tetrachloroaurate.
How to Make Gold Nanoparticles

• Put 2 mL .5 mM HAuCl\textsubscript{4} in a test tube.

• Heat in boiling water bath for 5 minutes.
  – Heating it will speed the reaction.
• Put 2 mL .5 mM HAuCl₄ in a test tube.
• Heat in boiling water bath for 5 minutes.
• Add 5 drops of 1% sodium citrate.
  – Carefully add the sodium citrate.
    Remember the solution is **HOT**!
  – This will allow the gold in solution to form stable gold nanoparticles.
How to Make Gold Nanoparticles

• Put 2 mL .5 mM HAuCl$_4$ in a test tube.
• Heat in boiling water bath for 5 minutes.
• Add 5 drops of 1% sodium citrate.
• Continue heating; wait for gold nanoparticles to form.
  – Watch for a change in color to indicate the gold has formed.
  – Let it heat a few more minutes to be sure the color change is complete.
How to Make Silver Nanoparticles

- Put 2 ml .5 mM AgNO₃ in a test tube.
- Heat in boiling water bath for 5 minutes.
- Add 5 drops of 1% sodium citrate.
- Continue heating; wait for silver nanoparticles to form.
Size Estimate

- Use settling and the Tyndall effect to get a size range for the particles of gold and silver.
Filtering Particles

- Draw 1 mL air into a syringe.
- Draw \( \frac{1}{2} \) mL of the liquid into a syringe.
- Attach filter.
- Push the liquid through the filter.
- Check the color of filtrate (the liquid which passed through).
• The distance between the gold nanoparticles changes by adding a salt.
• Notice the color change.
• Determine if the new gold nanoparticles are smaller or larger than 20 nm.
  – How can you do this?
Nanoparticle Stabilization

Gold Nanoparticle

Citrate
Distance Between Nanoparticles
Nanoparticle Stabilization
Nanoparticle Stabilization

New Distance Between Nanoparticles
Seeing the Particles

• Microscope, but what kind?
• Light microscope can’t see particles this small.
Seeing the Particles

- Microscope, but what kind?
- Scanning Electron Microscope (SEM)
SEM Picture of Colloidal Gold
Early Nanotechnologists

• Medieval glass artists unknowingly became nanotechnologists when they made a color of stained glass by mixing tiny amounts of gold into hot liquid glass.

• The gold nanoparticles in the stained glass interact with light in a way that produces a rich color.
Using Colloidal Gold

- Gold nanoparticles are currently manufactured for targeted delivery of biomolecules and drugs to selected cells.
- Trials are underway using this method to treat cancer cells in mice.
- The drug appears to accumulate in the tumor but not in the healthy cells.
Today we:

• Learned about nanotechnology
• Made and filtered nanoparticles
• Learned about the relationship between size and properties
• Looked at applications