Key: Yellow highlight = required component

Creating Silver Nano-Particles

Subject Area(s) **Chemistry**

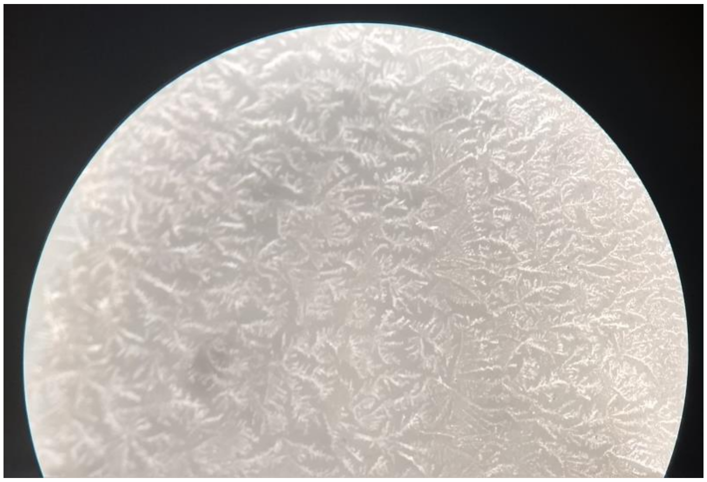
Associated Unit

Associated Lesson

Activity Title **Creating Silver Nano Particles**

Header

Image 1
Image file: Nano Silver Image 1.jpg
ADA Description: Photo of silver dendrites formed from silver nano particles at 30x magnification.
Source/Rights: © Richard Daines, Arizona State University
Caption: None



Grade Level **10** (8-11)

Activity Dependency **None**

Time Required 250 minutes (five 50 minute class periods)

Group Size 3

Expendable Cost per Group US $0.80 ($0.60 Petri Dishes, $0.15 Silver Nitrate, and $0.05 Pu'erh tea)

Summary

The activity starts with students making silver metal from silver nitrate. Students find that both copper and tannins reduce silver nitrate, forming silver. Students see the silver created from copper but they cannot see the silver created from tannins. That silver is nano sized. Second, they complete the reaction and evaporate the water, so they can see the silver they created in petri dishes using a 30x stereoscope. Last, students use inquiry to test if they can improve the formation of silver nano particles and they report their findings and recommendations.

Engineering Connection

The lesson introduces students to the complex idea that the configuration of a system is important. A large piece of silver does not have the same properties, uses, and value as nano sized pieces, for instance.

Students experience some of the engineering design process. They choose and test a modification to the nano silver creation process. Some discover that improving one outcome can make another outcome worse.

Engineering Category = #2 **Engineering analysis or partial design**

Keywords
Silver, nano-particles, silver nitrate

Educational Standards
Arizona State Standard 2005, grades 9-12, Science, Strand 5, Concept 4, PO11

Predict the effect of various factors (e.g., temperature, concentration, pressure, catalyst) on the equilibrium state and on the rates of chemical reaction.

ITEEA 2000, grades 9-12, 8.K

Strand 8. Students will develop an understanding of the attributes of design. In order to realize the attributes of design, students should learn that:

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

ITEEA 2000, grades 6-8, 10.H

Strand 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. In order to comprehend other problem-solving approaches, students should learn that:

H. Some technological problems are best solved through experimentation.

Next Generation Science Standard: HS-PS1-6

Matter and Its Interactions
Students who demonstrate understanding can:
Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

Pre-Requisite Knowledge
The only pre-requisite knowledge is basic lab procedures and safety. An understanding of high school chemistry is beneficial but not necessary.

Learning Objectives
After this activity, students should be able to:
- Know the signs of a chemical reaction.
- Understand the principle of limiting reactants
- Know that light is scattered by small particles
- Experience refining a chemical process through experimentation.

Materials List

Each group needs:
- Stereoscope 30x
- 3 plastic dishes (petri dish or petri dish lid)
- 1.5” piece of copper wire (16-24 gauge)
- Test tube rack
- 5 10mmx75mm test tubes

- Copy of Student Workbook (1 per student)

To share with the entire class:
- Hot plate and ice (optional)
- Refrigerator (Tannins storage)
- Silver nitrate, 60mL of 0.2M Solution with a pipette dropper
- Pu'erh tea, 250mL of Tannin Solution (40% concentration tea) with a pipette dropper
- Sodium hydroxide, 50mL of 0.1M with a pipette dropper
- Acetic acid, 50mL distilled vinegar with a pipette dropper

Introduction / Motivation

(The introduction is purposefully vague to allow students to discover that they created nano particles. The introduction introduces chemistry terms but does not assume the students have a chemistry background. It is the first part of the workbook handout, **1.0 Lab:Introduction**.)

An atom of silver found in silver metal has an equal number of protons and electrons. Silver metal is metallic, shiny, and makes great jewelry. Silver ions are missing one electron. Silver ions become part of some other substance, such as silver nitrate. Silver nitrate is clear, brittle, and dissolves in water. Today we are going to give an electron to the silver ion in silver nitrate, and see if we can make silver metal. When an ion gains an electron it is said to be **reduced**. Earlier research hints that both copper metal and tannin, found in tea, may reduce silver nitrate.

(This is the introduction for the second part of the activity after they discovered that they created silver nano particles. It is found in the reading, **7.0 Reading:Nano-Silver**.)

Silver metal nano particles (nano-silver) have beneficial properties. Nano-silver can treat drinking water and can be used as an antibiotic. Silver metal is expensive but the same mass of nano-silver is worth ten times more. Both are silver metal, but nano-silver is more useful. If you found a way to make nano-silver better not only could you help make better drinking water and antibiotics but you could also make a lot of money. Ways you could make nano-silver better include:

- Make more nano-silver in each test tube, because creating more means more to sell.
- Make nano-silver faster, because creating more means more to sell.
- Use less silver nitrate, because silver nitrate is expensive.
- And the most important improvement - make nano-silver even smaller.

A smaller silver metal nano particle is the best improvement. Smaller nano-silver makes better antibiotics, treats drinking water better, and costs less because each particle contains less expensive silver metal.

Vocabulary / Definitions

Word	Definition
Reduced	A chemical reaction where a substance gains an electron, e.g. silver ions (Ag^+)

	become silver metal (Ag).
Oxidized	A chemical reaction where a substance loses an electron, e.g. copper metal (Cu) become copper ions (Cu+).
Limiting Reactant	The reactant that runs out first, stopping a chemical reaction.
Nano Particle	A particle with a length of about a nanometer.
Tannins	A brown substance in tea that has many phenol groups. Phenol groups reduce silver ions. One tannin is tannic acid which is C76H52O46.
Silver Nitrate	The Substance $AgNO_3$. It is composed of a silver ion and a nitrate ion.
Precipitant	A solid created by a chemical reaction in a solution.

Procedure

Background

In the first part of the lab students are asked to look for evidence of a chemical reaction.

- Students discover in test tube A that silver is being created because they can see silver. They also discover that very small pieces of silver appear black or silver depending on lighting.
- Students discover in test tube B that silver nitrate by itself does not show any signs of a reaction. Additionally they discover the appearance of silver nitrate under a microscope so they can spot excess silver nitrate later.
- Students discover in test tube C that tannins by themselves do not react and do not get darker brown by themselves. They discover the appearance of tannins under a microscope so they can spot tannins later.
- Students discover in test tube D that there is a color change (more brown) that came from the mixing of tannins and silver nitrate. Students created silver nano particles.

In the second part of the lab students change a part of the procedure creating silver nano particles to try to make them better (more, faster, less wasted reactants, and/or smaller). They compare their new results to test tube D results and then communicate if their change made better nano particles.

Before the Activity

- Create Tannin Solution (brew tea)
    - Rinse a 250mL piece of glassware with DI water
    - Add 10g of Pu'erh Tea broken into small pieces
    - Fill to 150mL with DI water
    - Heat to a boil and then boil for 15 minutes
    - Filter about 100mL of tea using a medium speed filter in a funnel into a clean 500mL piece of glassware
    - Add 150mL DI water (40% concentration tea)
    - Label Tannin, cover, and add dropper
    - Keep refrigerated when not in use (tea is food and spoils)

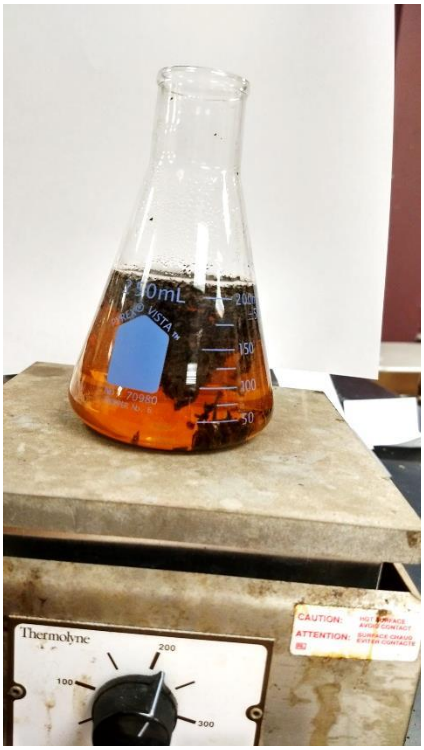


Image 2

Image file: NanoSilver Image 2.jpg

ADA Description: Photo of tea brewing in a 250mL flask on a hot plate. The tea will be used as a source of tannins.

Source/Rights: © Richard Daines, Arizona State University

Caption: None

Image 3

Image file: NanoSilver Image 3.jpg

ADA Description: Photo of a funnel filter over a 500mL flask. The filter is removing pieces of tea after brewing.

Source/Rights: © Richard Daines, Arizona State University

Caption: None

- Create Silver nitrate solution
    - The molar mass of silver nitrate is 170 g/mol
    - Rinse a 100mL piece of glassware with DI water
    - Add 2g of Silver Nitrate to 60mL of DI water
    - Label 0.2M Silver Nitrate, cover, and add dropper

- Create Sodium Hydroxide Solution
    - The molar mass of sodium hydroxide is 44 g/mol
    - Rinse a 100mL piece of glassware with DI water
    - Add 0.22g sodium hydroxide and 50mL of DI water
    - Label 0.1M sodium hydroxide, cover, and add dropper

- Create acetic acid Solution
    - Rinse 100mL piece of glassware with DI water
    - Fill to 50mL with distilled vinegar (not diluted)
    - Label 0.8M Acetic Acid, cover, and add dropper

Make copies of Student Workbook for each student.

Students will need a spot to set their plastic dishes to dry overnight.

<u>With the Students</u>

<u>Day 1 (Workbook Sections 1.0 to 2.1)</u>

Students will set up 4 test tubes labeled A, B, C, and D. A and D will create silver metal. The silver in A will be visible because its reduction happens only on the copper wire. It may appear black, but it is silver. The silver color is more obvious as more silver grows and as more light is shined on it. It probably will be missed, but the reaction also produces aqueous copper nitrate. It is pale green and the solution will have a very slight color.

The silver in D is not directly visible because its reduction happens everywhere and the size of the silver particles is only 50-100 atoms each (too small to see even with a microscope). Tannic acid is a huge molecule so it limits the size of the reduced silver particles. Each silver particle is the length of a nanometer so we call them nano particles. The solution appears brown because the nano-silver scatters light. Students should deduce that there was a chemical reaction because of the color change, but probably won't deduce that it is nano-silver yet.

Test tubes B and C have no reaction because they only have one reactant. This is designed to get students to think about limiting reactants and help them deduce that test tube D created silver. It will also give them a visual of what silver nitrate and tannins look like in the dried samples, so they can spot them later.

Students will need to have a spot to leave plastic (petri) dishes to dry overnight. They will be able to see the silver in both test tubes A and D using a stereoscope on day 2. They should avoid moving the dishes – have them place them where they will be stored first.

Clean testubes work best. DI water, soap, and long Q-tips cleaned well.

Day 2 (Workbook Section 3.0 to 5.4)

Students will examine the dried samples in their dishes using a stereoscope. This will give them more evidence that they created silver in test tubes A and D and that nothing happened in test tubes B and C. This is giving them the tools for day 4 and 5.

The silver in D will be in a small sheet near the edge where the nano particles accumulate as the water evaporates. There will also be dendrites of pure silver throughout the dried sample. Each millimeter of a dendrite is 1 million nano particles in a line. There will be brown staining from the tannins. Using less tannin means less staining but also less silver and longer reaction times. There will probably be some unreacted silver nitrate in the corners. The reaction in D actually takes a couple hours already. It is still reacting in the dish as it dries. It would be better to use less tannin and allow the sample to stay in the test tube overnight, but that would take too many class periods.

At the end of class, and probably for homework, students have a reading that discusses what happened in the test tubes. There is also a particle diagram that gives a visual representation of what happened. They will read about light scattering and why test tube D looked brown when it contained silver. There is another particle diagram that explains three reasons why a solution could look brown.

Save the dried samples for reference.

Day 3 (Workbook Section 6.0 to 8.0)

Students will revisit the questions they answered the first day now that they have more information – the evidence from the dried samples and the information in the readings. This is really a reflection to gauge if they understood the reading and the evidence of their observations.

The reading introduces the value of nano-silver. It also presents some ideas that can be explored to improve the making of nano-silver. Students will explore some of these ideas by completing particle diagrams and predicting the outcome. Students will be picking a change to try in day 4.

The reading refers to temperature changes. It is easy to use a 100mL beaker on a hot plate as a hot water bath or a 100mL beaker filled with ice as an ice bath for the test tubes. The reaction rate was much faster in the hot water bath and slower in the ice bath, but only for the 30 minutes of class. I let it off because only 30 minutes of hot or cold did not show a lasting difference by the next day. Slower reactions seem to produce smaller nano-particles, so a student could try leaving a sample in the fridge, but that would take extra time.

There is no wet-lab activities today. Check for student understanding. Have students work in their groups. Ask questions to individuals in the small groups like:

- How do you know that there was no reaction?
- What was your answer to question 9? Why did your answer change?
- What evidence is there that there was silver?
- Why did it look brown?
- What would happen if I added more silver nitrate? Why?
- Let’s compare your particle diagram to the one for test tube D in 5.2. What is the same and what is different?

Day 4 (Workbook Section 9.0 to 10.0)

Students are doing the same lab as day 1 except only test tube D and a new, their choice, test tube E. They predict the outcome. They are looking for evidence that E is different from D.

Day 5 (Workbook Section 10.1)

Students will combine the information from their observations of the chemical reaction in test tubes D and E, their analysis of the D and E dried samples, their previous experience analyzing samples, and the information in the readings. They will qualitatively deduce differences in nano-silver production.

Each group will present to the class the answers in section 10.1 and give their recommendation to improve the process. Recommendations may be in conflict between groups but should be considered correct if the groups present enough evidence. Ask specific individuals in the group questions like:

- Why would producing more silver be beneficial?
- What evidence did you have that…?
- You saw ball like shapes in your sample. What could they be?
- You created smaller nano particles but you wasted a lot of tannin. Was it worth it?
- This other group suggested that it would be better to …. Do you agree?

Without advanced equipment, analysis is very squishy and qualitative. There are some general patterns. Slower reactions produce smaller silver nano particles (the best change). Lower temperatures, excess silver nitrate, and adding acid all slow down the reaction. Faster reactions produce larger silver nano particles. Higher temperatures, excess tannins, and adding sodium hydroxide increased the reaction rate.

Some of the evidence students may describe:

- Evidence of producing more silver metal:
  - Reading/prior knowledge: We added more silver nitrate and tannins so we created more silver.
  - Test Tube: The color is darker than expected.
  - Dried Sample: We see less silver nitrate in the corner - it all reacted so we produced more silver metal. We see a larger sheet of silver near the edges, so there were more nano particles. We see tighter packed and thicker dendrites.
- Evidence of producing less silver metal:
  - Reading/prior knowledge: We used less of one or both of the reactants.
  - Test tube: The color is lighter than expected.
  - Dried Sample: There is more silver nitrate, so less reacted. The size of the silver sheet is smaller. Dendrites are thin and sparse.
- Evidence of producing silver metal faster:
  - Reading/prior knowledge: Hotter temperatures produce a faster reaction. Adding sodium hydroxide speeds up the reaction (Le Chatelier's Principle).
  - Test Tube: The color changed faster.
  - Dried Sample: A faster reaction produces larger nano particles. The sheet of silver is less smooth, more grainy. There are fewer dendrites and more thick clumps of silver.
- Evidence of producing silver metal slower:
  - Reading/prior knowledge: Colder temperatures produce a slower reaction. Adding acetic acid slows down the reaction. Changing the reactant concentrations may change the reaction rate.
  - Test Tube: The color changed slower.

    - Dried Sample: A slower reaction produces smaller nano particles. The silver dendrites are finer.
- Evidence of wasting more silver nitrate:
    - Reading/prior knowledge: We added more silver nitrate and there already was excess silver nitrate. We added less tannin, so there would be excess silver nitrate.
    - Test Tube: Excess silver nitrate produces smaller particles. The color is lighter because the silver nano particles are smaller.
    - Dried Sample: We see a lot more silver nitrate on the edges and corners.
- Evidence of wasting less silver nitrate:
    - Reading/Prior knowledge: I added excess tannin.
    - Test Tube: Excess tannin produces larger particles. The color is darker because the nano particles are larger.
    - Dried Sample: There is no visible silver nitrate. There might be a lot of visible tannin.
- Evidence of smaller nano particles
    - Reading/Prior Knowledge: The reaction is slower.
    - Test Tube: The color is lighter.
    - Dried Sample: The dendrites are thinner but the amount of silver is the same. The sheet of silver is smoother and thinner.
- Evidence of larger nano particles:
    - Reading/Prior knowledge: The reaction is faster.
    - Test Tube: The color is darker.
    - Dried Sample: The sheet of silver is less smooth, more grainy. There are fewer dendrites and more thick clumps of silver.

Attachments

SilverNanoParticles Student Workbook.docx

Safety Issues

There is glassware and dilute sodium hydroxide. Both require goggles and closed-toes shoes. I added the phrase “nothing in this lab is safe to consume” because some people use silver nitrate and silver nano particles as nutrition supplements.

[From lab instruction handout]

We will be using glassware, so everyone needs to wear goggles and closed-toes shoes. Never touch broken glass: broom, dustpan, and glass disposal box. No horseplay. Nothing in this lab is safe to consume.

Troubleshooting Tips

The tannin solution is weak or not reacting well

Hotter water, longer brewing, smaller pieces, and more tea during brewing produces more tannins.

I want to eliminate the brown tint of the tea

Some substances that make the tea brown can be filtered out using vacuum filtration with micron filters – this may reduce the brown tint if you have access to them. Additional filtering with medium speed funnel filters provides no benefit.

Pu'erh tea actually isn't required; any substance that is soluble and reduces silver works. Pu'erh tea just contains lots of tannins. Tannins are a class of large molecules that have lots of phenol groups. Phenol groups reduce silver and the large size of the tannins limit the size of the silver nano particles formed. Others have used phenols extracted from fruit and leaves to produce the same results. It's referred to as "green" silver nano particle production. Other phenols may not have a brown tint.

There is a brown/black substance that covers the dried silver – how can I remove it so I can see the silver underneath?

The brown material from the tannins was not soluble in either ethanol or hot DI water. Mechanical removal will also remove the silver nano particles underneath.

Can I use a drying oven to speed things up?

Yes and no. The normal reaction takes hours. Using a drying oven soon after class will produce a lot less silver and leave a lot more silver nitrate because the reaction did not go to completion. Using a drying oven the next morning is a good idea if the sample are not completely dry.

I see threads in the samples

Those are carpet fibers from the air. Some might even get silver plated. You can cover the petri dishes.

I want to change the concentration of the silver nitrate solution or tannins.

About 1 drop of 0.4M Silver nitrate reacts with about 1 drop of undiluted pu-reh tea. Scale to any concentration.

The silver nitrate is cloudy

Don't rinse or use tap water. It's mostly harmless and the silver nitrate should work well enough. Also don't let the droppers switch between bottles.

I want to filter out the nano particles

High school grade filters will not work.

I want to use a centrifuge to settle out the nano particles

A high school grade centrifuge will not work.

I want to use hydrochloric acid or sulfuric acid

Yes. Both 0.1M HCl and H2SO4 worked as well as distilled vinegar. HCl, H2SO4, and vinegar produce silver chloride, silver sulfate, and silver acetate respectively. All are partly soluble and reduces like silver nitrate. An excess would be seen in the dried sample. All worked, but acetic acid is inexpensive and safer than starting with concentrated acid.

I want to avoid using sodium and acetate ions.

I have not tested it, but I imagine that using nitric acid for the acid and substituting some of the silver nitrate molecules with silver hydroxide molecules and then using nano pure water would eliminate all of the other ions

When using sodium hydroxide I see light brown crystal nodules

The substance is silver hydroxide. There was inadequate tannin concentration or chemical reaction time.

Investigating Questions

Assessment

Pre-Activity Assessment

None

Activity Embedded Assessment

Sections 2.0, 2.1, 4.0, 6.0, 8.0, and 10.0 all provide opportunities for embedded assessment.

Post-Activity Assessment

Section 10.1 provides a framework where the students can present their final recommendation for improving the process of creating silver nano particles.

Activity Extensions

- Students could do the inquiry part with a range of samples. Students could examine the effects of adding 0, 1, 2, 3, and 4 drops of excess tannin in five different samples, for instance, instead of doing just one sample.
- Students could collect all of the results from each group. Students could then find patterns in multiple outcomes, refine the process to optimize the production of nano particles, and repeat the experiment with the refined process.
- Students could expand on the reduction of silver by metals other than copper, such as iron. Students could develop some of the activity series of metals. If a metal reduces silver nitrate it is more active than silver metal.
- Students could explore Mie scattering, Rayleigh scattering and Willis-Tyndall scattering. Students could make connections between their lab observations and light scattering principles and determine which type of scattering is occurring.
- Students could use REDOX titration to determine the strength of the tannins reduction potential. Dilute a sample of the tannins, add iodine and starch as indicators then titrate with hydrogen peroxide or some other oxidizing solution.

Activity Scaling

- For lower grades, students could create their own phenols for reducing silver. Some could boil green apples, some red, and some plant leaves in water to see which extracts reduce silver. Use fruits and leaves that contain many flavonoids and antioxidants. The lab could be which fruits have the most antioxidants – they produce the most silver nano particles when mixed with silver nitrate.
- For higher grades, students can explore it as single replacement and oxidation-reduction reactions. They could balance the equations, use molarity, and apply stoichiometry to determine percent yield.

- For higher grades, students could apply Le Chatelier's Principle to predict changes in nano particle production before they attempt them.

Additional Multimedia Support

References

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Zainal Abidin Ali, Rosiyah Yahya, Shamala Devi Sekaran, and R. Puteh, "Green Synthesis of Silver Nanoparticles Using Apple Extract and Its Antibacterial Properties," Advances in Materials Science and Engineering, vol. 2016, Article ID 4102196, 6 pages, 2016. doi:10.1155/2016/4102196

Other
None

Redirect URL
None

Contributors
Richard Daines

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NEWT: NSF Nanotechnology Research Experience for Teachers, National Science Foundation Grant EEC-1449500.

Name:________________________________ Period:________ Date:______ Silver Student Workbook

1.0 Lab: Introduction

An atom of silver found in silver metal has an equal number of protons and electrons. Silver metal is metallic, shiny, and makes great jewelry. Silver ions are missing one electron. Silver ions become part of some other substance, such as silver nitrate. Silver nitrate is clear, brittle, and dissolves in water. Today we are going to give an electron to the silver ion in silver nitrate, and see if we can make silver metal. When an ion gains an electron it is said to be **reduced**. Earlier research hints that both copper metal and tannin, found in tea, may reduce silver nitrate.

1.1 Lab: Safety

We will be using glassware, so everyone needs to wear goggles and closed-toes shoes. Never touch broken glass: broom, dustpan, and glass disposal box. No horseplay. Nothing in this lab is safe to consume.

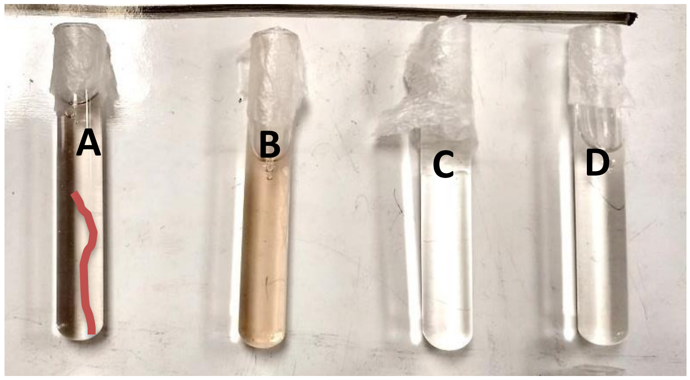
1.2 Lab: Setup

Collect the following materials: 4 small test tubes, 1 piece of copper wire, 2 plastic dishes (a petri dish and its lid), and a DI water wash bottle. DI stand for De-Ionized which means very pure water. Do not use tap water for anything in this lab.

Mark the 4 test tubes A, B, C, and D using a permanent marker. Mark the bottom of both plastic dishes with your period number and table. If it was period 2, and you were at lab table 5, mark them with “2-5”.

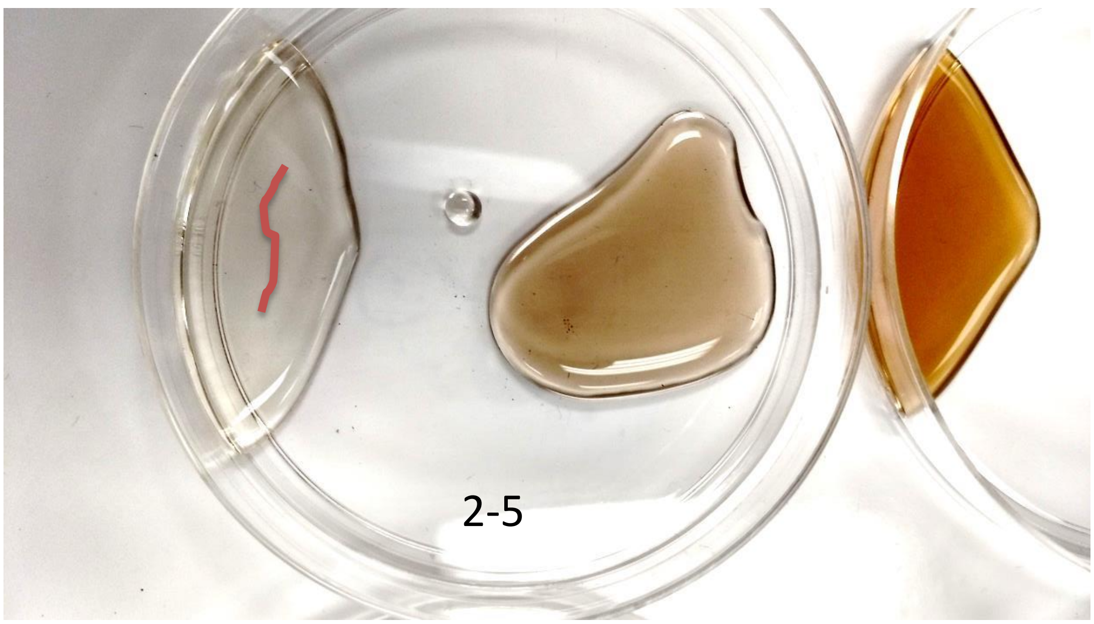
1.3 Lab: Procedure

- Use the wash bottle to rinse out the test tubes
- Fill each test tube 2/3 with DI water (more than half but less than full)
- Drop the copper wire into Test tube A
- Put 2 drops of silver nitrate into test tubes A, B, and D (not C)
- Put 2 drops of tannin into Test Tube C and D (not A or B)
- Cover all 4 test tubes with plastic wrap (sticky side down)
- Shake each test tube to make sure everything is well mixed
- Start a stopwatch
- Use the test tube rack holder between observations
- Fill out Table 1 in **2.0 Worksheet: Observations**
- Answer Questions 1-12 in **2.1 Worksheet: Questions**



1.4 Lab: End

Set your plastic dishes where they can dry overnight. You will know it is your dishes because you marked them with your period and table. Dump the contents (including wire) of Test Tubes A and B into the left and right sides of the first plastic dish (see picture). Dump the contents of Test C and D into the left and right sides of the second plastic dish. Clean up lab area. Clean out the 4 test tube with soap and DI water for the next class.



2.0 Worksheet: Observations

You are looking for **signs of a chemical reaction**: unexpected temperature change, unexpected color change, formation of gas bubbles, or the formation of a new substance (**precipitant**).

Table 1: Observations of Copper, Silver nitrate, and Tannin				
	Test Tube A: **Silver Nitrate** **Copper Metal**	**Test Tube B:** **Silver Nitrate**	**Test Tube C:** **Tannin**	**Test Tube D:** **Silver Nitrate** **Tannin**
Time	**Record Observations and Evidence of chemical reaction**			
0 min				
5 min				
10 min				
15 min				
20 min				
25 min				

2.1 Worksheet: Questions

1. Did Test Tube A have a chemical reaction?
2. How do you know?

3. Did Test Tube B have a chemical reaction?
4. How do you know?

5. Did Test Tube C have a chemical reaction?
6. How do you know?

7. Did Test Tube D have a chemical reaction?
8. How do you know?

9. Why didn't test tubes B and C have a chemical reaction?

10. In test tube A, there was only water, copper metal, and silver nitrate. So what could the black-silver substance be?

11. In test tube C, there was only tannin. Did it change color?
12. In test tube D, there was only water, tannin, and silver nitrate. So what made the solution a darker color?

3.0 Lab: Stereoscope

Place each plastic dish under the stereoscope. The samples should be completely dry. Focus on different areas (edges, corners, and middle) of the sample and record what you observe in Table 2 of **4.0 Worksheet: Observations** and answer questions 13-17.

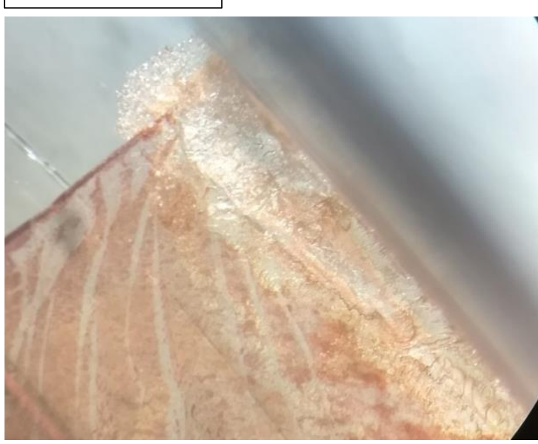
- Tannin is brown. The best way to see tannin is to turn the bottom light on and leave the top light off. Sometimes it looks like torn brown paper. Sometimes it stains other things brown.
- Silver Nitrate looks like clear sugar or melted glass. The best way to see silver nitrate is to turn both lights on. It is not shiny. It is clear. It may look like wet sugar crystals pouring over the edge or it may look like glass pine tree branches. Check corners and edges.
- Copper nitrate is a pale green. It looks like moss. The best way to see Copper Nitrate is to turn on the top light but leave the bottom off. The grey parts are silver metal.
- Silver metal is silvery and shiny. The best way to see silver metal is to turn on the top light but leave the bottom off. In test tube A, silver may be coating the copper wire, growing like trees from the copper wire, or in silver clumps that fell off. If it sparkles it's silver. In test tube D, silver particles may form sheets like sand forms a beach. They may form lines called **dendrites** that look like shiny-white pine branches or snowflakes.
- When finished, do **5.0-5.4 Reading** and then **6.0 Worksheet: Questions 2.**

Copper Nitrate

Silver metal

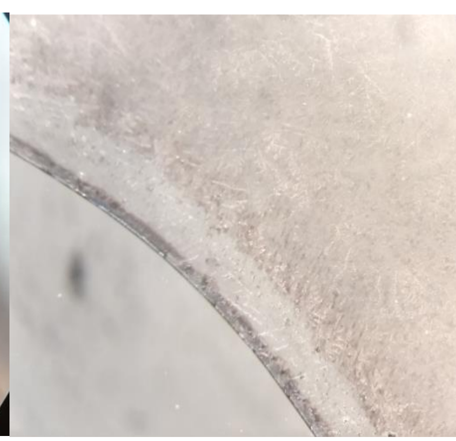
Silver Metal

Copper Metal



Tannin

Silver Nitrate



Silver Metal

4.0 Worksheet: Observations 2

Table 2: Stereoscope Observations			
Record Observations and Evidence of Silver Metal, Silver nitrate, Tannin, Copper Metal, and copper nitrate from the Dried Samples			
Test Tube A: Silver Nitrate Copper	**Test Tube B: Silver Nitrate**	**Test Tube C: Tannic Acid**	**Test Tube D: Silver Nitrate Tannic Acid**

13. In your own words, what does silver look like in dried sample A?

14. In your own words, what does copper nitrate look like in dried sample A?

15. In your own words, what does silver nitrate look like in dried sample B?

16. In your own words, what does tannic acid look like in dried sample C?

17. In your own words, what does silver metal look like in dried sample D?

5.0 Reading: What happened in test tube A?

In test tube A the only **reactants** present were copper and silver nitrate, so the only substances that can be in the test tube and the **desiccated** (dried) sample have to be from copper, silver, and nitrate. Silver was **reduced** (gained an electron) and copper was **oxidized** (lost an electron). This type of reaction is called a **single replacement reaction** because copper replaces silver in silver nitrate. The chemical reaction looks like:

Copper + Silver Nitrate → Silver Metal + Copper Nitrate

- Silver nitrate produces silver metal when it reacts with copper.
- Silver metal is visible because it forms in one place – the copper wire.
- Another product is copper nitrate, a pale green substance.
- It is hard to see, but the solution in test tube A at the end is not perfectly clear. It is a little pale green because it contains copper nitrate.
- Silver metal appears black at first. This is just an optical effect when the amount of silver is small.
- In the desiccated sample, sometimes the green copper nitrate coats the silver metal.
- Silver metal forms dendrites like pine trees.

5.1 Reading: What happened in test tubes B and C?

In test tube B, the only **reactant** is silver nitrate. There is nothing to **reduce** silver so no reaction happens. There is no temperature change, color change, bubbles, or **precipitants**. There is no **signs of a chemical reaction**. In test tube C, the only reactant is tannin. There is no silver to reduce so no reaction happens. By themselves, neither changed color.

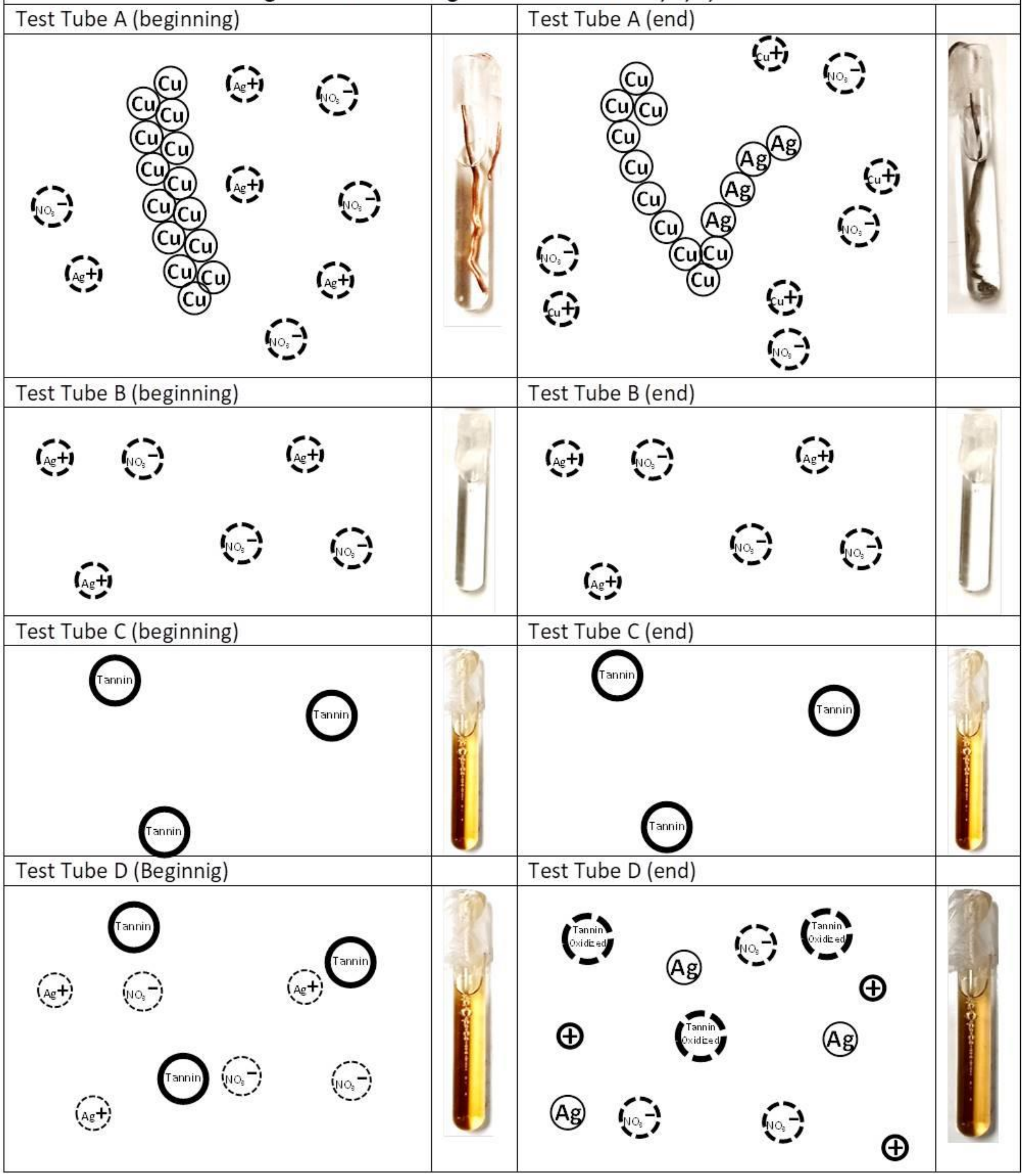
- Silver nitrate did not become silver metal by itself.
- Silver nitrate did not turn brown by itself.
- Tannin did not become silver metal by itself.
- Tannin is brown but did not become a darker brown by itself.

5.2 Reading: Particle Diagram

Figure 1: Particle Diagram Key

Silver Metal		Silver Ion		Copper Metal	
Copper Ion		Nitrate Ion		Tannin ($C_{76}H_{52}O_{46}$)	
Tannin Oxidized ($C_{76}H_{52}O_{46}$)		Acid (hydronium ion)		Base (hydroxide ion)	

Figure 2: Particle Diagrams of Test Tubes A, B, C, and D



5.3 Reading: What happened in test tube D?

In test tube D there are two **reactants**, silver nitrate and tannin. There is a color change so there is a **sign of a chemical reaction**. The color change did not come from the silver nitrate or the tannin by themselves but the chemical reaction between them. The chemical reaction looks like:

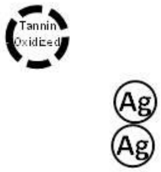
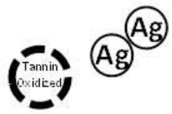
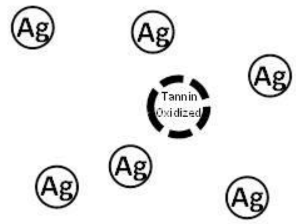
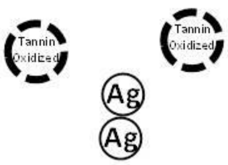
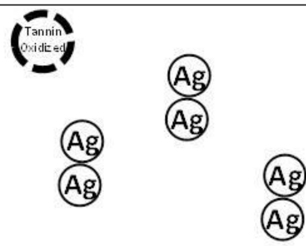
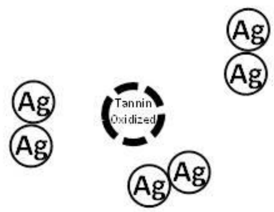
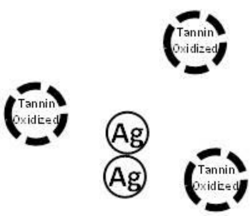
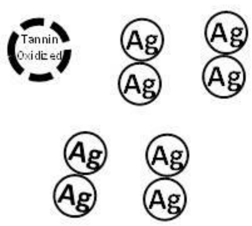
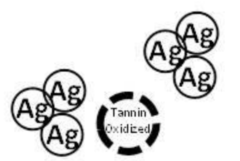
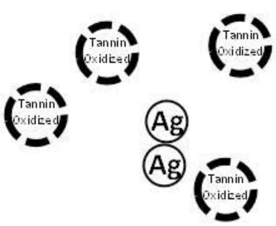
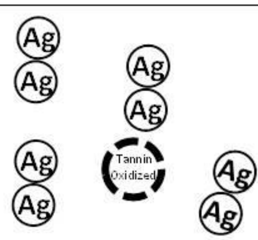
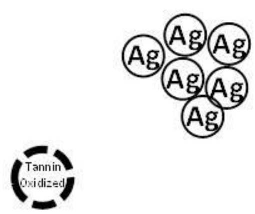
Tannin + Silver nitrate → Silver Metal + Oxidized Tannin + More Acidic Solution

Just like in test tube A, the reaction produces silver metal. The particles of silver metal are so tiny that you can't see them. They are only a nanometer across (a millionth of a millimeter) so we call them **nano particles**. The amount of silver metal you made in test tube A and D were the same.

But why did silver metal look brown? Tiny particles scatter light. When light scatters we see colors. Clouds are made of water droplets. Water is not white, but we see white because the droplets of water scatter sunlight. Blue eyes and green eyes don't have blue or green particles in them. They have tiny particles of brown melanin. Melanin scatters light reflected in eyes. If there is some melanin you see blue. If there is more melanin you see green. When nano particles of silver metal scatter light you see shades of yellow, amber, and brown.

The color seen from scattered light changes by how many silver metal particles there are and by their size. More particles scatter more light so you see a darker color. Larger particles also scatter more light so you also see a darker color. Unfortunately, tannin is naturally brown so it is difficult to know the reason why a test tube looks brown. Figure 3 uses particle diagrams to describe the three reasons why a solution containing silver metal nano particles might look brown.

5.4 Reading: Color Change

Figure 3: Three reasons why the color changes in a test tube.			
More Tannin (Tannins are brown)	More nano-partices (scatter more light)	Fewer but Larger nano-particles (larger particles scatter/block more light)	Color
			Clear to almost clear.
			Light yellow to amber to light brown
			Darker brown
			Dark brown to black

6.0 Worksheet: Questions 2

Use the information from the dried samples, the information from reading 5.0 to 5.4, and the observations in table 1 to answer these questions:

18. What is the evidence that no chemical reaction happened in test tube B?

19. What is the evidence that no chemical reaction happened in test tube C?

20. What is the evidence that the black-silver substance in test tube A was silver metal?

21. In test tube D what substance made the solution a darker color?

22. Look at questions 9, 10, and 12. How did your new answers change?

7.0 Reading: Nano-Silver

Silver metal **nano particles** (nano-silver) have beneficial properties. Nano-silver can treat drinking water and can be used as an antibiotic. Silver metal is expensive but the same mass of nano-silver is worth ten times more. Both are silver metal, but nano-silver is more useful. If you found a way to make nano-silver better not only could you help make better drinking water and antibiotics but you could also make a lot of money. Ways you could make nano-silver better include:

- Make more nano-silver in each test tube, because creating more means more to sell.
- Make nano-silver faster, because creating more means more to sell.
- Use less silver nitrate, because silver nitrate is expensive.
- And the most important improvement - make nano-silver even smaller.

A smaller silver metal nano particle is the best improvement. Smaller nano-silver makes better antibiotics, treats drinking water better, and costs less because each particle contains less expensive silver metal.

7.1 Reading: Nano-Silver 2

When tannin reacts with silver nitrate, the solution becomes more acidic. This means that changing the solution to be more acidic or more basic may change the speed, amount, and size of the nano-silver formed. Initial testing suggests that changing the temperature of the solution may change the speed, amount, and size of nano-silver formed too. It is also possible to add extra silver nitrate and/or extra tannin which may also affect speed, amount, and size of nano-silver formed.

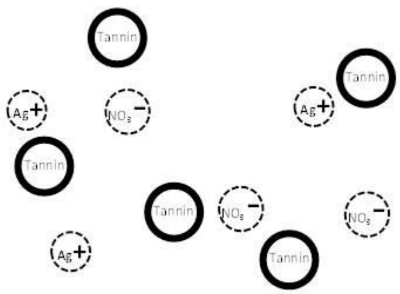
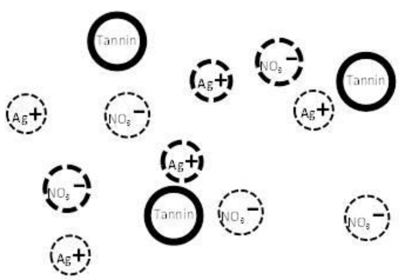
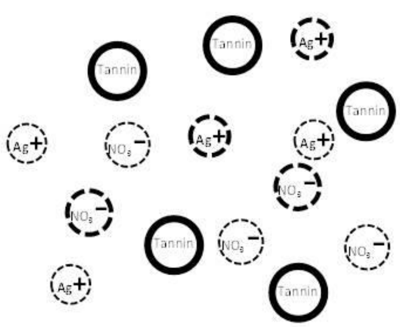
Mixing 2 drops of silver nitrate and 2 drops of tannin in DI water produced nano-silver. Pick a change to improve the process.

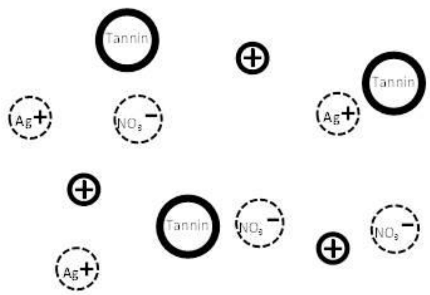
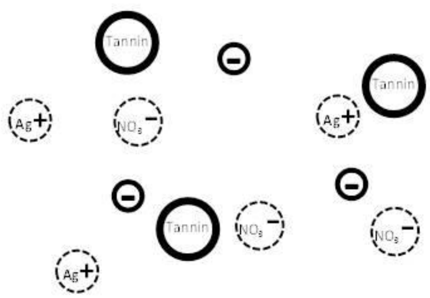
- Add 1 or 2 extra drops of silver nitrate to have extra silver nitrate.
- Add 1 or 2 extra drops of tannin to have extra tannin.
- Add 2 extra drops of silver nitrate and 2 extra drops of tannic acid.
- Add 1 drop less silver nitrate.
- Add 1 drop less tannic acid.
- Add 1 or 2 drops of acetic acid to make the solution more acidic.
- Add 1 or 2 drops of Sodium Hydroxide to make the solution less acidic (more basic).
- Some other change using available supplies and approved by the teacher.

Although our goal is to improve the process of making nano-silver, at this point finding something that makes it worse is also good, because there is the possibility that doing the opposite will make the process better next time.

8.0 Worksheet: Complete Particle Diagram

There is a particle diagram for Test Tube D in figure 2 in **5.2 Reading: Particle Diagram**. Table 3 changes the beginning conditions. Draw the particle diagrams at the end of the reaction. Predict what would change compared to what happened in test tube D.

Table 3: Predict the outcome		What changes? More? Faster? Smaller? Waste? Color?
Change: more tannins (beginning)	Draw the particle Diagram (end)	
		
Change: more silver nitrate		
		
Change: more tannin and silver nitate		
		

Change: add acid (acetic acid)		
		
Change: add base (sodium hydroxide)		
		

<u>9.0 Lab: Introduction 2</u>

Mixing silver nitrate and tannin produce silver metal nano-particles (nano-silver). The process is not optimized yet. Today your group will be exploring a way to improve the process.

<u>9.1 Lab: Safety</u>

We will be using glassware, so everyone needs to wear goggles and closed-toes shoes. Never touch broken glass: broom, dustpan, and glass disposal box. No horseplay. Nothing in this lab is safe to consume.

<u>9.2 Lab: Setup</u>

Collect the following materials: 2 small test tubes, 1 plastic dish, and DI water wash bottle.

Mark the 2 test tubes D and E using a permanent marker. Mark the bottom of the plastic dish with your period number and table.

<u>9.3 Lab: Procedure</u>

- Answer questions 23 and 24 in **10.0 Worksheet: Observations 3**.
- Use the wash bottle to rinse out the test tubes
- Fill each test tube 2/3 with DI water
- Put 2 drops of silver nitrate into test tubes D
- Put 2 drops of tannin into Test Tube D
- Add whatever your group decided to test tube E in whatever order you think best
- Cover both test tubes with plastic wrap (sticky side down)
- Shake each test tube to make sure everything is well mixed
- Start a stopwatch
- Fill out Table 4 in **10.0 Worksheet: Observation 3**

<u>9.4 Lab: End</u>

Dump the contents of Test Tubes D and E into the left and right sides of the plastic dish. Set it where it can dry overnight. Clean up lab area. Clean out the 2 test tubes using soap and DI water for the next class.

<u>9.5 Lab: Stereoscope 2</u>

Examine the dried samples using a stereoscope then answer questions 25-33 in **10.1 Worksheet: Questions 3.**

10.0 Worksheet: Observation 3

23. Group Choice to improve silver nano production:____

24. Do you think it will (circle all the answers that apply)

Produce more nano-silver	Produce the same amount	Produce less
Produce nano-silver faster	Produce them same speed	Produce them slower
Reduce Silver Nitrate waste	Keep same waste	Increase waste

And most importantly

Reduce nano-silver size	Produce the same size	Produce larger size

Table 4: Effect of changing Silver nano particle production		
	Test Tube D 2 drops silver nitrate 2 drops tannic acid Room Temperature	Test Tube E ___ drops of silver nitrate ___ drops of tannic acid _________ temperature ___ drops of ___________
Time	**Record Observations**	
0 min		
5 min		
10 min		
15 min		
20 min		

10.1 Worksheet: Questions 3

Use the stereoscope to examine the dried D and E samples. Use the information in table 4 along with everything you learned to answer questions 25-33.

25. Did you produce more/less silver?
26. How do you know?

27. Did you produce silver faster/slower?
28. How do you know?

29. Did you waste more/less silver nitrate?
30. How do you know?

31. Did you produce smaller/larger silver nano particles?
32. How do you know?

33. What is you final recommendation to improve the creation of silver nano particles?