Name: ______Answers______ Date: ________________

Gold Nanoparticles-Electrolyte Experiment Worksheet

Background

Since ancient times, gold and silver nanoparticles have been used for staining glass with intense colors. In fact, it is recorded that ancient Romans used gold colloid for this very purpose. This is just one example in which nanomaterials have been around of for hundreds of years, but only recently have we been able to see and control this technology at its very small length scale. Why is gold so special?

Gold, in its bulk form is a very intense yellow appearance and similarly silver is very reflective or white color. This is explained as a phenomenon called surface plasmon resonance (SPR). Although it sounds complicated, it is easy to understand if you visualize electron interactions resulting from metallic bonding. Because metallic bonding does not require sharing of valence electrons and that sub-shell energy levels are filled, free electrons become present in the atomic structure. These free electrons are present in cloud form and create a barrier to specific electromagnetic radiation (light) energy. Any light that is not absorbed is reflected. Because bulk gold absorbs infrared light, all visible light is reflected and elucidates the shiny-yellow appearance. However, at the nanometer scale, gold interacts differently with light where absorption wavelengths and reflect select portions of the visible wavelength range In fact, depending upon the specific size and shape of gold nanoparticles, they can appear red, purple, blue or other colors.

We know that increasing gold nanoparticle size yields a blue-green color shift from yellow-red color. When synthesizing gold nanoparticles, a chemist or material scientist does not rely on physically growing larger-diameter gold spheres as with quantum dots. S/he relies on cluster forming or particle agglomeration during experimentation to increase the net nanoparticle size. Consider a 5 nm gold nanoparticle that has a corresponding negative charge on the surface (electron cloud) that repels neighboring gold nanoparticles. When an electrolyte (salt) is dissolved in water, cations (positive) and anions (negative) are formed and free floating. Chemistry and physics tell us that the positive cations will bind to the negatively charged gold nanoparticle surface because of charge attraction, creating a neutral cation-gold nanoparticle. As more and more cations bind to gold nanoparticle surfaces, the particles begin to agglomerate into clusters. These clusters are much larger than the original gold nanoparticle and are accompanied by a change in solution color. Thus, by forming clusters, the net size of gold nanoparticles have increased, changing their surface plasmon resonance susceptibility and changing the wavelength of absorption. What you end up seeing is a different color, consistent with the size-color effect.

Today, we want to understand this phenomenon first-hand by experimenting with gold nanoparticles and sports drinks of varying electrolyte content. By using our gold nanoparticle biosensor, we will determine which sport drink has more electrolytes. While doing this, we will explore the electromagnetic radiation spectrum, nanoparticle size-color effect and other questions that relate chemistry and physics to nanotechnology. When we are finished you will *at least* know what sports drink to consume after *breaking a mental sweat*. ☺

Materials

- 20 ml gold colloid
- Gatorade Ice
- pickle juice
- Pedialyte
- PowerAde
- 41-dram glass vials
- 4 disposable plastic pipets
- distilled water
- gloves and goggles
- waste container

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Pre-Activity Questions

1. What do you see athletes drink when they want to replenish their bodies' liquids?

   Gatorade or PowerAde—anything with electrolytes (salts).

2. What do they lose a lot of when they sweat?

   Important salts, such as potassium and sodium.

3. Which of the four liquids in this experiment (Gatorade, PowerAde, pickle juice and Pedialyte) do you predict will make the best sports drink? Why?

   Prediction. Answers will vary.

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Lab Procedure

1. Take four glass vials and add 3-4 drops of the gold nanoparticles to each.
2. To each vial, add 2 drops of a different electrolyte and observe what happens to the color of the nanoparticles. Carefully keep track of which liquid was added to which vial.
3. Record your observations in the data table below.
4. After recording your observations, answer the remaining worksheet questions.
5. Clean up your lab station.

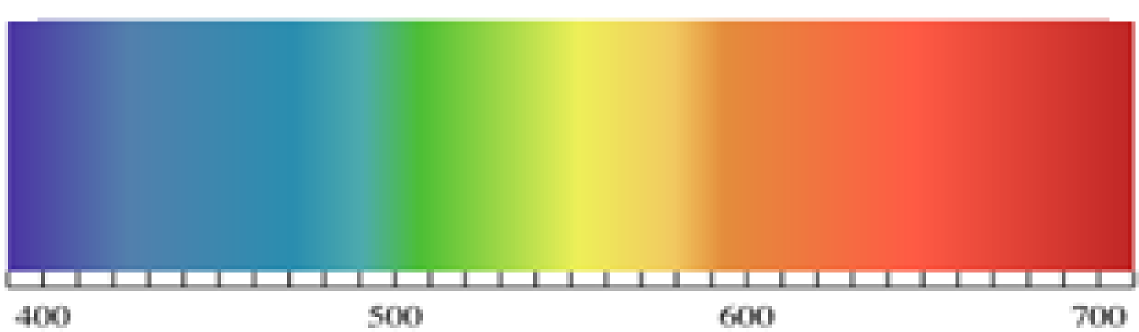
Data Collection

Complete the lab procedure and record all your observations in the table below.

Table 1: Data Collection

Gold Nanoparticle Solution #	Electrolyte used (indicate electrolyte color)	Nanoparticle starting color	Emitted Color	Approximate Wavelength (m)
1				
2				
3				
4				

Visible light spectrum (1×10^{-9} m).



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Data Analysis Questions

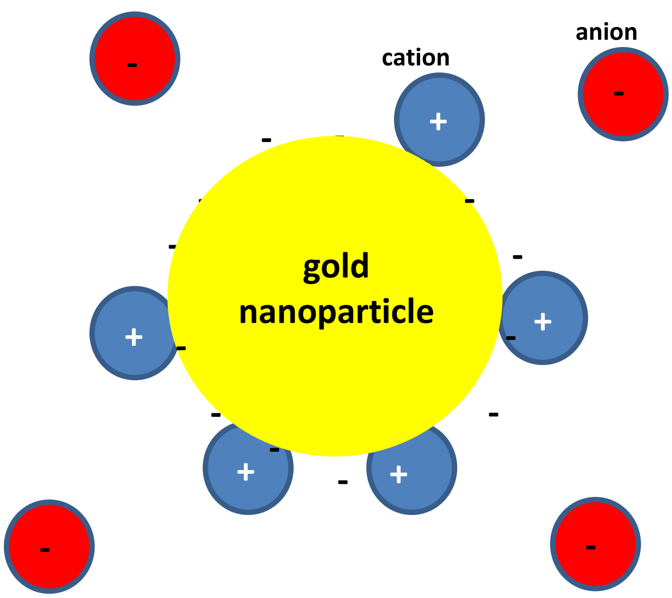
1. Based on observed color changes, rank the ending nanoparticle cluster size from smallest to largest. Use the nanoparticle solution number for ranking.

   Answers will vary.

2. According to your experiment, which sports drink has the most electrolytes? Explain the experiment indicator(s) as part of your answer.
   1. **Pickle juice – blue/violet**
   2. **Pedialyte - green**
   3. **Gatorade Ice – slight green tint**
   4. **PowerAde (any colorless flavor) – red/green tint**

Post-Activity Discussion Questions

1. Explain why electrolytes make the gold nanoparticles clump together. As part of your explanation, make a drawing that shows a gold nanoparticle interacting with electrolytes. Label all parts of your diagram.



Electrolytes (salts) are made of two parts (ions), one with positive charges (cations) and the other with negative charges (anions).

When electrolytes are dissolved in water, the cation and anion parts split up. Each gold nanoparticle carries a negative electrical charge on its surface due to how it was made, which makes the individual gold nanoparticles repel each other. As electrolytes are added to the nanoparticle solution, the cations (positive) are attracted to the nanoparticles (negative), and effectively "cancel out" some of the negative charge that prevented the gold nanoparticles from touching. Thus they are able to come together and clump, leading to larger nanoparticles.

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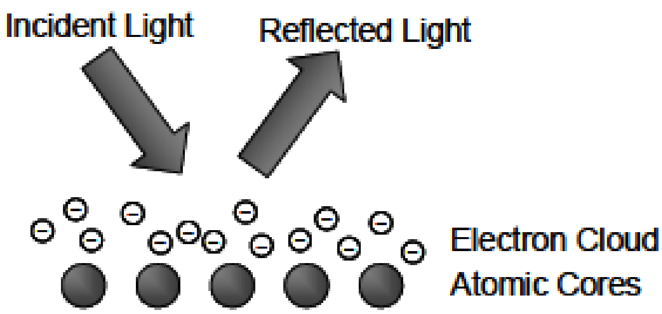
2. You have witnessed color changes with nanoparticle size increase. Describe with an illustration how incoming light interacts at the atomic level of metallic gold. How is some light absorbed and some light reflected? How does this change from bulk scale to nanoscale?

Electrons can be regarded as waves with associated energy. If an incident lightwave is of the same size as the electron cloud wave, then that light can be absorbed, thus causing electron cloud resonance and energy dissipation. This plasmon resonance occurs only at the surface.

With bulk materials, a reduced amount of total surface area to volume is available for this resonance phenomenon and larger wavelengths are absorbed, thus all visible light is reflected. However, at the nanoscale, the large increase in available surface area to volume ratio makes more surfaces available for this phenomenon. Ultimately, nanoparticle electron clouds can absorb smaller wavelength light, thus reflecting select portions of visible light, depending on nanoparticle size.



3. Name three practical applications for gold nanoparticles.
Provide 1-2 sentence explanations for each application.

Bio sensing:

1. ***DNA indicators:*** **Use surface plasmon resonance phenomena to indicate base DNA presence by measuring color change. Gold nanoparticles are layered with a compatible hormone that attracts selective DNA bases.**
2. ***Home pregnancy tests:*** **Coated gold nanoparticles are compatible with selective antibodies to seek out pregnancy hormones. Since nanoparticles begin to aggregate, they get caught in a filtering process (because of size increase) and are indicated on the results window. The color change is a result of surface plasmon resonance.**
3. ***Cancer cell detection:*** **If an antibody selectively seeks out proteins found in cancer cells, the nanoparticles effectively attach themselves to affected areas. In addition, nanoparticles may begin to clump, changing the solution color, making cancer indication or imaging easier.**

4. **BONUS:** For DNA testing, gold nanoparticle solutions are used to separate DNA bases. How is the starting nanoparticle solution different from the solution we used for indicating electrolyte level?

In DNA testing, gold nanoparticles start out in an agglomerated state. When a complementary DNA base is added to the solution, nanoparticles begin to disassemble (break-up). This process is indicated by the dark blue starting solution color that transitions to a red color, provided the correct DNA base is added.