Name: _____ **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

Pre-Activity Questions

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

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

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?

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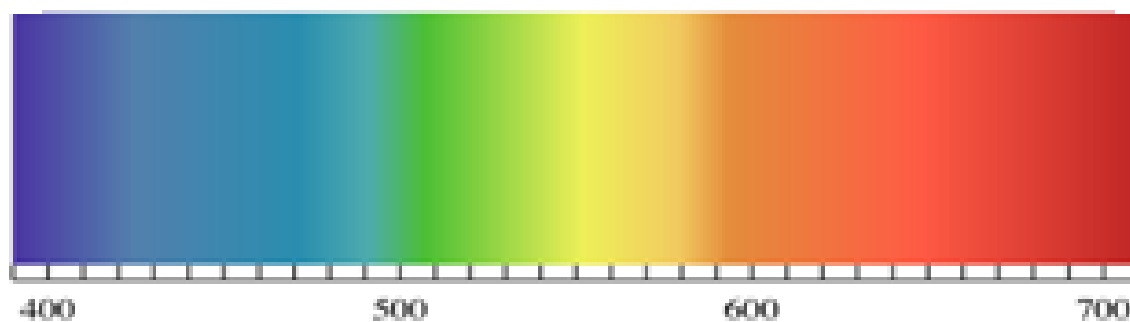
Lab Procedure

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 x 10⁻⁹ m).

$$\text{Visible light spectrum } (1 \times 10^{-9} \text{ m}).$$

400   500   600   700

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.

2. According to your experiment, which sports drink has the most electrolytes? Explain the experiment indicator(s) as part of your answer.

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.

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?

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

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?