How can you detect lead and anthrax?

Gold Nanoparticle Biosensors

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Content Area: Chem, Bio, Phys, General
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Grade Level: 7-12

LESSON OVERVIEW

Estimated Time of Lesson: 4 hours (can be shortened significantly as needed)

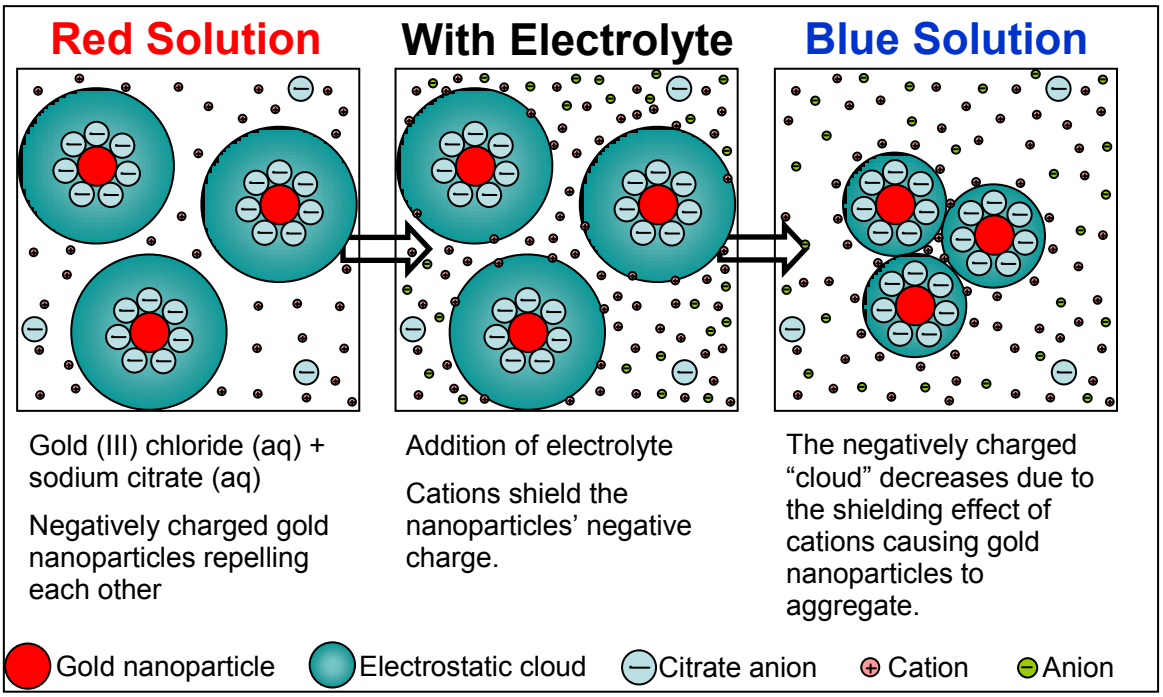
Lesson Description:

- Topic: How gold nanoparticles can be used as biosensors due to their optical properties. This lesson specifically looks at color changes due to shielding of charges.
- How the lesson is contextualized: This lesson is contextualized in lead and anthrax biosensors.
- Importance of topic: This lesson is important in the realm of nano as it indicates the size-dependent properties of nano-particles, specifically color in this lesson. This lesson also begins to touch on how nano is affecting society.
- Connection of the topic to other science concepts: This topic touches on concepts in several of the science disciplines depending on how the lesson is taught including: solutions, suspensions, colloids, electrolytes, spectroscopy, shielding of charges, light, electromagnetic waves, electric forces, oscillation of electrons, and DNA.
- Description of what the students will do to investigate the topic: Students will synthesize gold nanoparticles and then investigate how the property of color changes with the addition of non-, weak, and strong electrolytes, with the electrolytes being a model for how lead and anthrax biosensor work. Students will then determine why these changes occur or do not occur and relate their model to lead and anthrax biosensors.

Learning Goals

- Students will be able to explain how shielding of charges changes the interactions between materials.
    - As shielding between particles increases, the gold nanoparticles agglomerate. This is because the strong negative charge of the nanoparticles which were keeping them separate is no longer felt with the shielding.
- Students will be able to articulate that some of the properties of matter at the nanoscale are different than those at the macroscale, specifically color.
    - Students will discover how agglomeration affects the color of a gold nanoparticle solution.

- Red (nanoparticles are not aggregated, ~13 nm)
- Blue (nanoparticles are aggregated)



- Students will be able to explain that indirect detection methods can be used to detect things too small to see with the naked eye.
    - Students will be able to describe how biosensors are used to detect particles that we are unable to see with our eyes.
- Students will be able to explain various types of biosensors: what they are, what they are used for, and how they work.
    - "A biosensor can be defined as a compact analytical device incorporating a biological or biologically-derived sensing element (such as an enzyme, antibody, microbe or DNA) either integrated within or intimately associated with a physicochemical transducer" (Deisingh, 2003).
    - Specifically, students will be able to explain how lead and anthrax sensors that use gold nanoparticles work.
        - Lead: Gold nanoparticles have complementary strands of DNA, designed specifically for detecting lead, attached to them causing the DNA to bind the gold nanoparticles together. This causes a blue solution. If lead is present, it will cleave the DNA in a specific location on the DNA strand causing the gold nanoparticles to separate. As the gold nanoparticles separate, the color changes to be red. The amount of lead in the system can be found by the change in color to the system. If lead is not present, the DNA will not cleave and the color will remain blue.

- Anthrax: Gold nanoparticles all of the same strand of DNA attached to them which is complementary to anthrax DNA. Since they all have the same strand, there will be no attraction between the DNA strands and therefore the gold nanoparticles are separated and the solution is red in color. If anthrax is present, the anthrax DNA will bind to the complementary DNA on the gold nanoparticles causing the gold nanoparticles to come together changing the solution to blue. If anthrax is not present, the solution will remain red.

Big Ideas

- Size-Dependent Properties: The properties of matter can change with scale. In particular, as the size of a material approaches the nanoscale, it often exhibits unexpected properties that lead to new functionality.
    - In this lesson, students will learn that at the nanoscale, some properties of matter change. Specifically in this case, color changes. Instead of gold being "gold/ yellow color," it can instead vary (such as red or blue) depending upon the size of the particles.
- Forces: All interactions can be described by multiple types of forces, but the relative impact of these forces change with scale. On the nanoscale, a range of electrical forces with varying strengths tend to dominate the interactions between objects.
    - In this lesson, students will understand how forces affect interactions between particles. Specifically, they will learn that shielding of particles allows particles that would normally repel each other, come together.

Standards

- Indiana Learning Standards

  7th Grade

  7.1.7, 7.1.9, 7.3.11, 7.3.19, 7.3.20, 7.4.14

  8th Grade

  8.2.7, 8.3.8, 8.7.3

  Chemistry

  C.1.27

  Integrated Chemistry – Physics

  CP.1.11, CP.1.25

- National Science Education Standards

  Content Standards 5-8

  Content Standard A: Science as Inquiry

  Content Standard B: Physical Science

Content Standard E: Science and Technology

Content Standard F: Science in Personal and Social Perspectives

Content Standard G: History and Nature of Science

Content Standards 9-12

Content Standard A: Science as Inquiry

Content Standard B: Physical Science

Content Standard C: Life Science

Content Standard E: Science and Technology

Content Standard F: Science in Personal and Social Perspectives

Content Standard G: History and Nature of Science

- Benchmarks for Science Literacy – Project 2061

Grades 6 – 8

3A: The Nature of Technology- Technology and Science

3C: The Nature of Technology- Issues in Technology

4D: The Physical Setting- Structure of Matter

4F: The Physical Setting- Motion

4G: The Physical Setting- Forces of Nature

6E: The Human Organism- Physical Health

8F: The Designed World- Health Technology

9B: The Mathematical World- Symbolic Relationships

9C: The Mathematical World- Shapes

11B: Common Themes- Models

12D: Habits of Mind- Communication Skills

Grades 9 – 12

1B: The Nature of Science- Scientific Inquiry

1C: The Nature of Science- The Scientific Enterprise

3A: The Nature of Technology- Technology and Science

3C: The Nature of Technology- Issues in Technology

4D: The Physical Setting- Structure of Matter

4F: The Physical Setting- Motion

4G: The Physical Setting- Forces of Nature

8B: The Designed World- Materials and Manufacturing

8F: The Designed World- Health Technology

LESSON PREPARATION

Teacher Background Content Knowledge

- This is an interesting area because this topic touches on so many aspects of science. This lesson can easily be done in any science classroom from grades 7-12.
- Citrate anions are adsorbed onto each nanoparticle creating electrostatic repulsions. These electrostatic repulsions cause the nanoparticles to be highly separated. Addition of a strong electrolyte/ high concentration of ions shield the repulsive electrostatic forces between the nanoparticles. Due to the shielding of the electrostatic forces, there is a smaller repulsive force causing the nanoparticles to aggregate.
- The color wheel helps to explain the colors that are observed. You see the solution as red because it is absorbing green light and you see the solution as blue/ purple because it absorbs in the orange/ yellow area. Using a spectrophotometer also indicates this as well.

Materials for Needed Before Activity

Item	Where to Get	Amount
Hydrogen tetrachloroaurate trihydrate, $HAuCl_4 \cdot 3H_2O$	Fisher Scientific Education: AC41107-0010	0.1 grams will give 500 mL of desired solution
Sodium citrate dihydrate, $Na_3C_6H_5O_7 \cdot 2H_2O$	Fisher Scientific Education: S80177	0.5 grams will give 50 mL of desired solution
Brown bottle		Stock solution of 1.0 mM $HAuCl_4$

Materials for Students to Have (Groups of 2-3 students)

Item	Number/Amount
Spectronic 20	1
1.0 mM $HAuCl_4$	30 mL
38.8 mM $Na_3C_6H_5O_7$ (sodium citrate)	3 mL
Hot/ Stir plate	1
Magnetic stir bar (0.5 - 1 cm)	1
Distilled water	33 mL
50-mL beaker	1
50-mL Graduated cylinder	1

10-mL Graduated cylinder	1
Small clear cups, beakers, or vials	6
NaCl (table salt) solution	3 mL
Sucrose (table sugar) solution	3 mL
Vinegar ($HC_2H_3O_2$)	3 mL
Household ammonia	3 mL
$MgSO_4$ solution	3 mL
KI solution	3 mL
Isopropyl alcohol (C_3H_7OH) solution	3 mL
Disposable pipet (or dropper)	6
Balance	1
Spectrophotometer tubes/ cuvettes	4

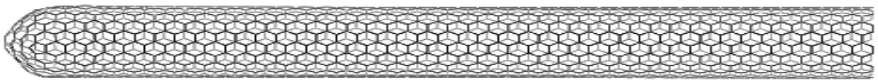
Pre-Class Preparation

Getting the Materials Ready

- Prepare a stock solution of 1.0mM $HAuCl_4$ (dissolve 0.1 g of solid in 500 mL of distilled water). Note: Creating 1-L will be enough for 33 groups to perform the activity.
- Prepare a stock solution of 38.8 mM $Na_3C_6H_5O_7$ (sodium citrate); (dissolve 0.5 g of the solid in 50 mL of distilled water). Note: Creating 100-mL will be enough for 33 groups to perform the activity.
- Prepare stock solutions of test reagents (150 mL is enough for 50 groups)

	Solute	**Amount of DI water**
1 M NaCl solution	8.766 g	150 mL
1 M sucrose solution	51.34 g	150 mL
1 M MgSO4 solution	18.057 g	150 mL
1 M KI solution	24.90 g	150 mL
1 M KBr solution	17.85 g	150 mL

- To save time, you could also have everything measured out for your students.
- To save time, you could also have the gold nanoparticles pre-made, however, students will not be able to see how the solution changes as the nanoparticles are created.
- Create enough copies of DNA and Red Signals Lead Part 1 (if having students read and not telling it as a story) and Part 2.
- Have computers or a computer with projection to show the movie.



Safety

- Students must wear goggles and gloves for this experiment.
- Student bench hoods should be used in the preparation.
- Students will be using hot plates, so remind them that glass gets hot even if it does not look it, and to therefore exercise caution with heat.
- Hydrogen tetrachloroaurate (III) trihydrate ($HAuCl_4 \bullet 3H_2O$) is corrosive and may cause eye, skin, and respiratory tract burns. Avoid contact!

Doing the Lesson

Opening

- Hand out DNA and Red Signals Lead: Part 1 to students and have them read independently OR tell the story to the students to get them engaged. Students should then get in groups and discuss the following questions with access to other reading materials or the Internet:
    - What are some effects of lead poisoning?
    - How much lead can a person or pet have in their system before falling ill or dying?
    - Brainstorm some possible ways to quickly determine the presence of lead.

NOTE:

- These questions are for student brainstorming to get them thinking for the activity. You may want to say that they will not be graded on it, allowing the students to feel more comfortable in responding.

Activity-Changing the Color of Gold (2-3 hours to make and test nanoparticles)

***Suggestion for short periods: Make the nanoparticles and design the experiment on day 1 and on day 2 perform the testing of the nanoparticles.

1. Give each student a copy of the lab experiment they are to perform.
2. Students should prepare 13 nm-diameter gold nanoparticles.
    a. See student handout.
    b. After adding the citrate, the solution goes clear then to a blue violet and finally to a red solution.
        i. This indicates the progression of particles getting smaller.
    c. After you get the red solution, the solution does not change anymore.
    d. It takes approximately 5 minutes for the reaction to occur.
3. While the gold nanoparticles are cooling, students can begin creating a procedure for using the nanoparticles as a chemical sensor, following the directions given. Students should get the procedure approved before continuing.

4. Students will run their procedure for using gold nanoparticles as chemical sensors.
    a. Students will test various chemicals with their gold nanoparticles and determine that electrolytes cause a color change, whereas non-electrolytes do not affect the color of the gold nanoparticle suspension.
5. After students complete the laboratory, there should be a student-led discussion.
    a. If the solution is red to our eyes, what does this mean (what color is it absorbing)?
        i. If the solution is red to our eyes, it is absorbing green. Looking at the color wheel, green and red are complementary to each other.
    b. How does a spectrophotometer relate to the color of the solution?
        i. Looking at the spectrophotometer data, there are large peaks for the red solutions around 530 nm which corresponds to the green wavelength of light on the electromagnetic spectrum. The blue/ violet solutions are absorbing more the 750 nm. This wavelength is higher than expected, which is due to the settling of particles. The particles continue getting bigger when electrolytes are added and therefore settle out of solution while measurements are being made. Also, if you look at vinegar (a weak electrolyte) it started off red and you could see the strong absorbance in the green area of the spectrum and as the reaction continues, the particles are becoming larger and the color changed towards blue during the measurements. (NOTE: This may not be true for your students. This is true for the data provided in this lesson. Students should back up their statements with their data.)
    c. Why does the solution change color (what are the particles doing)?
        i. The solution changes color due to the aggregation of particles. It starts as red due to the large distance between the gold nanoparticles. There is this distance due to the electrostatic repulsions. When electrolytes were added, the there is more shielding between the particles and therefore the particles can begin to aggregate causing the color to change from red to blue.
    d. What do the chemicals that change the nanoparticles have in common (what types of chemicals are changing the color)?
        i. The chemicals that cause a color change are electrolytes. Strong electrolytes cause an immediate color change, whereas weak electrolytes cause a minimal color change, and non-electrolytes do not cause any color change.
    e. How is this experiment a model of a biosensor (a device containing a biological sensing element that alerts you to the presence of particular molecules)?
        i. This is a model of a biosensor as with the addition of a particular chemical, the color changed. A biosensor is designed to determine if a particular molecule/ compound/ chemical is present. Currently, there are biosensors that just use a simple red to blue color change of gold nanoparticles to determine if these particular compounds are present.

6. COMING SOON!!!! Students can now investigate the effects of shielding either in the form of an animation or activity using magnets. In the animation or activity, students will discover that the strong "negative" charge can be shielded which then allows the strong "negatively" charged objects to move closer together. This animation or activity should give them the knowledge needed to create a representation of what is occurring when an electrolyte is added to the gold nanoparticles. COMING SOON!!!!
7. Perform the NanoHub simulation: Nanosphere optics lab-biosensors from www.nanohub.org
8. From the data and simulations, students will construct results and conclusions and complete a laboratory report.

Wrap-Up

1. Give students DNA and Red Signals Lead: Part 2. Allow them to read and understand the article (or the more advanced research article) then play the accompanying animation.
    a. Liu, J. and Lu, Y. (2004). A Colorimetric Lead Biosensor Using DNAzyme-Directed Assembly of Gold Nanoparticles. *Journal of the American Chemical Society Communications*.
    b. The WaterCAMPWS Center for Advanced Materials for Purification of Water with Systems at the University of Illinois at Urbana-Champaign. Red signals red video. http://www.watercampws.uiuc.edu/waterclear/webquests/red-lead-webquest/RedSignalsLeadAnimation.html
2. Discussion of DNA and Red Signals Lead: Part 2 article and video
    a. Students should refer back to their Conclusion answer for question 3 (How could we use what we have found out to determine if lead (or another type of poison) is in a person's or animals' body), and discuss how their answered either remained the same or changed and what else have they learned new.
    b. How was the changing color of gold experiment a model of a biosensor (a device containing a biological sensing element that alerts you to the presence of particular molecules)?
3. Students should then read another article on the anthrax colorimetric biosensor. This biosensor is almost identical to the experiment they preformed.
    a. Mirkin, C.A. (2000). Programming the assembly of two- and three-dimensional architectures with DNA and nanoscale inorganic building blocks. Inorganic Chemistry, 39, 2258-2272.
        i. Students need to only read pgs. 2260-2267.

Assessment

1. Students answers to the conclusion questions of the experiment, the follow-up of the biosensor articles and how they relate to the lab, and discussions comprise the bulk of the assessment for this activity.

2. Students should find another article that discusses gold nanoparticle biosensors (HIV, pregnancy, etc.) and then in groups of 2-3 create a short 5 minute poster presentation or discussion around the following guiding questions:
    a. What was the biosensor designed to test for?
    b. How did the biosensor work?
    c. How was the biosensor in your article similar to and different from using the gold nanoparticles to detect electrolytes in the laboratory experience?
    d. How was the biosensor in your article similar to and different from the biosensor used to detect the presence of lead?

ADAPTATIONS

- Extensions
    - Teach about solution vs. suspension/ colloids.
        - Nanoparticles are in a suspension and are colloids. You can show this by shining a laser beam through the various liquids. If you shine a laser beam through the suspension, it will reflect indicating a colloid. If there is no reflection through, it means there is no colloid and it is a solution.
    - To add more math/ calculations, students can answer the following questions:
        - Calculate the mass of gold in a 13-nm Au nanoparticles assuming that the particles are spheres. The density of gold is 17.0 g/cm3. The volume of a sphere is 4/3 pi r3.
        - Calculate the number of gold atoms in a 13-nm Au nanoparticle.
        - Calculate the mass of gold in 30.0 mL of 1.0 mM HAuCl4. What is the theoretical number of 13-nm gold nanopartilces that could be formed in this solution?
    - To help reinforce the concept of electrolytes, students could also test the conductivity of their test reagent solutions.
- Simplifications
    - Pre-measure all the solutions for students to save time.
    - Prepare the 13nm gold nanoparticles in advance. Having students prepare the gold nanoparticles teach lab technique and allows students to observe the color changes of the solution as the 13nm gold nanoparticles are formed.
    - Instead of having students take the absorbance measurements on the Spec. 20, you could give them in the information (found in supplemental material).

RESOURCES

- Chaplin, M. (2004). What are biosensors? Retrieved March 12, 2007 from: http://www.lsbu.ac.uk/biology/enztech/biosensors.html
- Deisingh, Anil. (June 2003). Biosensors for microbial detection. *Microbiologist*, pgs. 30-33. Retrieved March 12, 2007 from: http://www.sfam.org.uk/pdf/features/biosensors.pdf
- Hampton, T. (2004). Nanotech Group's "Bio-Barcode" Test a Promising Diagnostic, Research Tool. *Journal of the American Medical Association, 292*, pgs. 1291-1293.
- Liu, J. and Lu, Y. (2004). A Colorimetric Lead Biosensor Using DNAzyme-Directed Assembly of Gold Nanoparticles. *Journal of the American Chemical Society Communications*.
- McFarland, A.D., Haynes, C.L., Mirkin, C.A., Van Duyne, R.P., and Godwin, H.A. (2004). Color my nanoworld. *Journal of Chemical Education, 81,* pgs. 544A-544B.
- Biosensors and Gold Nanoparticles. www.nanohub.org
- National Center for Learning and Teaching in Nanoscale Science and Engineering. Gold Nanoparticles. Retrieved March 12, 2007 from: http://brahms.scs.uiuc.edu/lssrl/software/nclt/Au_Colloid_Course_120606.swf
- The WaterCAMPWS Center for Advanced Materials for Purification of Water with Systems at the University of Illinois at Urbana-Champaign. Red means lead. Retrieved March 12, 2007 from: http://www.watercampws.uiuc.edu/waterclear/labs/lessons/lead_teacher_guide.pdf
- The WaterCAMPWS Center for Advanced Materials for Purification of Water with Systems at the University of Illinois at Urbana-Champaign. Red signals red video. http://www.watercampws.uiuc.edu/waterclear/webquests/red-lead-webquest/RedSignalsLeadAnimation.html

SUPPLEMENTAL MATERIALS

Summary

This inquiry lesson is designed for 7-12 grade students. Although some of the main concepts discussed in this lesson are Chemistry, there are extensions to Biology and Physics making it a general science lesson. Students are to learn about electrolytes, which are determined by either ionic or covalent bonding as well as an understanding of absorbance and the color wheel by using spectroscopy. Students will develop communication skills through reading scientific journals and presenting their work.

The lesson begins with a scenario of lead poisoning in an attempt to capture students' interests in the topic of biosensors as this is one way in which biosensors are being developed. Students discuss the scenario and brainstorm ways to determine if lead is present quickly and inexpensively. The laboratory experiment then begins in which students initially follow a protocol to make 13-nm gold nanoparticles. Students are then given a set of chemicals to test on the gold nanoparticles to see if the color changes from red to blue. They are to design a procedure to test these chemicals and must take into

account the variables that should be kept the same and those that they can vary given only a limited amount of material. Students then test their procedure to determine which chemicals cause a color change and which chemicals do not. They should conclude that strong electrolytes changed the color, while non- and weak electrolytes did not change the color. To assist with creating a better understanding of the laboratory and to create well-written conclusions, students will use the Internet to run a simulation and investigate more in-depth the lesson they did with animations.

As a follow-up to this lesson, students will read about a lead sensor that has been developed that changes color in the presence of lead, similar to what was performed in the lab. They will also watch an animation of how the lead is detected. Students will investigate biosensors, either on their own, or given a few articles followed by a discussion.

For assessment, students should read another article on biosensors and present the article to the class in a clear, coherent fashion so students that did not read the article can still gain an understanding of the article.

Standards

- Indiana Learning Standards

7th Grade

7.1.7 – Explain how engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems.

7.1.9 – Explain how societies influence what types of technology are developed and used in fields such as agriculture, manufacturing, sanitation, medicine, warfare, transportation, information processing, and communication.

7.3.11 – Explain that the sun loses energy by emitting light. Note that only a tiny fraction of that light reaches Earth. Understand that the sun's energy arrives as light with a wide range of wavelengths, consisting of visible light and infrared and ultraviolet radiation.

7.3.19 – Explain that human eyes respond to a narrow range of wavelengths of the electromagnetic spectrum.

7.3.20 – Describe that something can be "seen" when light waves emitted or reflected by it enter the eye just as something can be "heard" when sound waves from it enter the ear.

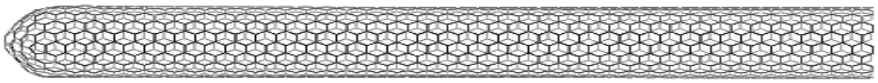
7.4.14 – Explain that the environment may contain dangerous levels of substances that are harmful to human beings. Understand, therefore, that the good health of individuals requires monitoring the soil, air, and water as well as taking steps to keep them safe.

8th Grade

8.2.7 – Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.

8.3.8 – Explain that all matter is made up of atoms which are far too small to see directly through an optical microscope. Understand that the atoms of any element are similar but are different from atoms of other elements. Further understand that atoms may stick together in well-defined molecules or may be packed together in large arrays. Also understand that different arrangements of atoms into groups comprise all substances.

8.7.3 – Use technology to assist in graphing and with simulations that compute and display results of changing factors in models.



Chemistry

C.1.27 – Describe chemical changes and reactions using sketches and descriptions of the reactants and products.

Integrated Chemistry – Physics

CP.1.11 – Understand and give examples to show that an enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.

CP.1.25 – Understand and explain that waves can superpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material.

- National Science Education Standards

Content Standards 5-8

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties. *NOTE: These characteristic properties do change at the nanoscale!*
- Light interacts with matter y transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object – emitted by or scattered from it – must enter the eye.

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water, and air.
- Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), with biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting, and drinking).
- Science influences society through its knowledge and world view. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. The effect of science on society is neither entirely beneficial nor entirely detrimental.
- Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
- Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.

Content Standard G: History and Nature of Science

- Science as a human endeavor
- Nature of science

Content Standards 9-12

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square distance between them.
- Between any two charged particles, electrical force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to the electric forces acting between atoms and molecules.
- In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.

Content Standard C: Life Science

- In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule is a cell forms a single chromosome.

Content Standard E: Science and Technology

- Understanding about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.

Content Standard G: History and Nature of Science

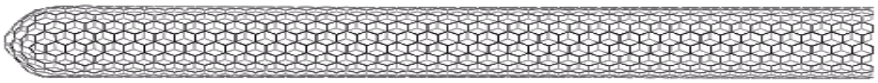
- Science as a human endeavor
- Nature of scientific knowledge

- Benchmarks for Science Literacy – Project 2061

Grades 6 – 8

3A: The Nature of Technology- Technology and Science

- Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.
- Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. But they usually have to take human values and limitations into account as well.



3C: The Nature of Technology- Issues in Technology

- Technology has strongly influenced the course of history and continues to do so. It is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.
- Societies influence what aspects of technology are developed and how these are used. People control technology (as well as science) and are responsible for its effects.

4D: The Physical Setting- Structure of Matter

- All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

4F: The Physical Setting- Motion

- Something can be "seen" when light wavers emitted or reflected by it enter the eye – just as something can be "heard" when sound waves from it enter the ear.
- Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation – visible light. Differences of wavelength within that range are perceived as differences in color.

4G: The Physical Setting- Forces of Nature

- Electric currents and magnets can exert a force on each other.

6E: The Human Organism- Physical Health

- Viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions. A person can catch a cold many times because there are many varieties of cold viruses that cause similar symptoms.
- The environment many contain dangerous levels of substances that are harmful to human beings. Therefore, the good health of individuals requires monitoring the soil, air, and water and taking steps to keep them safe.

8F: The Designed World- Health Technology

- The ability to measure the level of substances in body fluids has made it possible for physicians to make comparisons with normal levels, make very sophisticated diagnoses, and monitor the effects of the treatments they prescribe.

9B: The Mathematical World- Symbolic Relationships

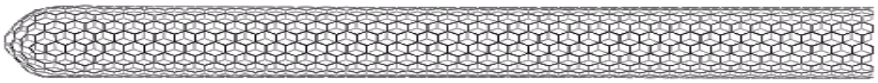
- Graphs can show a variety of possible relationships between two variables. As one variable increases uniformly, the other may do one of the following: increase or decrease steadily, increase of decrease faster and faster, get closer and closer to some limiting value, reach some intermediate maximum or minimum, alternately increase and decrease indefinitely, increase or decrease in steps, or do something different from any of these.

9C: The Mathematical World- Shapes

- The graphic display of numbers may help to show patterns such as trends, varying rates of change, gaps, or clusters. Such patterns sometimes can be used to make predictions about the phenomena being graphed.

11B: Common Themes- Models

- Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous.



12D: Habits of Mind- Communication Skills

- Make and interpret scale drawings.

Grades 9 – 12

1B: The Nature of Science- Scientific Inquiry

- Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories.

1C: The Nature of Science- The Scientific Enterprise

- Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments.

3A: The Nature of Technology- Technology and Science

- Technological problems often create a demand for new scientific knowledge, and new technologies make is possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.

3C: The Nature of Technology- Issues in Technology

- Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives.

4D: The Physical Setting- Structure of Matter

- The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others.

4F: The Physical Setting- Motion

- Waves can superpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material. All these effects vary with wavelength. The energy of waves (like any form of energy) can be changed into other forms of energy.

4G: The Physical Setting- Forces of Nature

- There are two kinds of charges – positive and negative. Like charges repel one another, opposite charges attract. In materials, there are almost exactly equal proportions of positive and negative charges, making the materials as a whole electrically neutral. Negative charges, being associated with electrons, are far more mobile in materials than positive charges are. A very small excess of deficit of negative charges in a material produces noticeable electric fields.

8B: The Designed World- Materials and Manufacturing

- Increased knowledge of the molecular structure of materials helps in the design and synthesis of new materials for special purposes.

8F: The Designed World- Health Technology

- Owing to the large amount of information that computers can process, they are playing an increasingly larger role in medicine. They are used to analyze data and to keep track of diagnostic information about individuals and statistical information on the distribution and spread of various maladies in populations.

9B: The Mathematical World- Symbolic Relationships

- Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another.

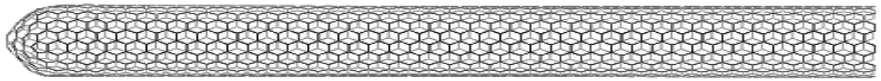
12D: Habits of Mind- Communication Skills

- Use tables, charts, and graphs in making arguments and claims in oral and written presentations.

Content Knowledge

The red color comes about because the electrons in spherical and isolated (both factors being important)gold nanospheres resonate with light at about 520 nm (this is green light). The resonance causes absorption of wavelengths around 520 nm (say from 500 to 550 nm in real samples). There is another factor (interband transitions of the electrons) that absorbs blue light (roughly 350 to 420 nm) light. So it is mostly red light that gets through and the colloid looks red. By the way, the energy that gets absorbs must go somewhere, and it gets turned into heat. This is the basis of using gold nanoparticles in some experimental types of cancer treatment.

Now, for the blue color when the nanospheres aggregate. Everything I said before relates to well separated gold nanospheres. When the particles agglomerate (a reversible phenomenon) or aggregate (irreversible sticking together, ASTM terminology)) the electron oscillations on each one are influenced by those in neighboring nanospheres. The result is to drag the resonant frequency over to the red side of the spectrum. So now all the red is absorbed (from 650 nm upwards)and the blue-green part from about 420 nm to 650 nm is free to be transmitted. The color is therefore blue, although as you have probably noticed it does not last long because the aggregated/agglomerated particles precipitate rather rapidly.



DATA TABLE

Wavelength	original	NaCl	MgSO4	KI	vinegar	ammonia	alcohol	sucrose
370	1.515	0.963	1.021	0.973	1.358	1.447	1.42	1.288
390	1.425	0.909	0.96	0.896	1.298	1.36	1.336	1.21
410	1.378	0.89	0.947	0.878	1.271	1.324	1.294	1.175
430	1.342	0.865	0.923	0.852	1.236	1.294	1.262	1.146
450	1.323	0.833	0.89	0.816	1.204	1.276	1.244	1.129
470	1.345	0.772	0.831	0.747	1.166	1.29	1.259	1.131
490	1.575	0.781	0.847	0.74	1.263	1.494	1.481	1.31
510	2.128	0.884	0.977	0.842	1.587	1.997	2.011	1.777
530	2.444	0.877	1.003	0.858	1.827	2.306	2.324	2.114
550	2.008	0.859	0.984	0.851	1.799	1.951	1.897	1.862
570	1.189	0.853	0.96	0.854	1.549	1.261	1.115	1.191
590	0.627	0.792	0.889	0.79	1.249	0.768	0.587	0.657
610	0.376	0.769	0.884	0.762	1.116	0.557	0.355	0.406
630	0.249	0.79	0.899	0.746	1.101	0.479	0.238	0.278
650	0.17	0.789	0.9	0.729	1.139	0.446	0.166	0.198
670	0.104	0.771	0.92	0.698	1.19	0.419	0.104	0.127
690	0.079	0.782	0.965	0.683	1.239	0.417	0.081	0.097
710	0.076	0.799	1.029	0.683	1.258	0.403	0.077	0.092
730	0.06	0.815	1.075	0.679	1.229	0.372	0.064	0.076
750	0.023	0.796	1.089	0.633	1.149	0.298	0.026	0.035
770	0.001	0.797	1.107	0.606	1.049	0.239	0.004	0.015
790	0.036	0.845	1.038	0.638	0.972	0.229	0.041	0.048
810	0.001	0.823	1.032	0.589	0.787	0.146	0.001	0.005
	red	started off purple but ended towards a grayish hue with smoke in it	started off purple but ended towards a grayish hue with smoke in it	started off purple but ended towards a grayish hue with smoke in it	started as a reddish purple but by the end of the scans it was more purple with very little red in it	similar to original; little more purple in it though	same as original	same as original

GRAPH OF DATA TABLE