Subject Area(s): Biology and Chemistry

Associated Unit: Stand Alone Activity

Activity Title: Biology's Molecular Magnet

Header:

Image 1
Image file: chelate_molecule_plants-photosynthesis_lesson_labactivity1_image1.jpg
ADA Description: Two bundles of fresh green cilantro, *Coriandrum sativum*.
Source/Rights: self

Grade Level: 9 (9-12)

Time Required: One 50-minute Class Period

Group Size: 4 students per group

Expendable Cost per Group US $30

Summary

The objective of this activity is for the students to undertake and experience qualitative and quantitative processes while working with the chelating properties of a common herb. There is an unidentified factor in cilantro (*Coriandrum sativum)*, which can be isolated through a simple aqueous extraction. The effectiveness of the extraction's metal binding properties is assessed using a colormetric analysis via a solution of Iron (III) chloride ($FeCl_3$) and potassium thiocyanate (KSCN). The results of the qualitative analysis are then quantified with the use of a spectrophotometer.

Engineering Connection

The water purification process is associated with various methods and concepts utilized by several science and engineering disciplines. It is a process that incorporates project development and an assortment of qualitative/quantitative testing. For instance, the use of qualitative colorimetric analysis is essential in determining concentrations of particular aggregates such as fluoride, nitrite, nitrate, and cyanide just to name a few. Additionally, molecular compounds may be formulated to remove metals and other complexes (chelates) the during the process. The use of quantitative instruments is also a vital component. Various instruments, such as the spectrophotometer, determine the presence and concentrations of inorganic/organic compounds or other elements found in samples of water.

Engineering Category

Relating science and/or math concept(s) to engineering

Keywords

Organic Compounds, Inorganic compounds, ligands, dentate, chelate, metal, non-metal, magnets, cilantro, colormetric, Iron Chloride, Potassium thiocyanate, and nanoparticles.

Educational Standards

Texas Essential Knowledge and Skills (TEKS) Source: TEA Version: 01/14/2016

Biology:
B.1 Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices.
B.2 Scientific processes. The student uses scientific methods and equipment during laboratory and field investigations.
B.3 Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom.

Chemistry:
C.1 Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices.
C.2 Scientific processes. The student uses scientific methods to solve investigative questions.
C.3 Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom.
C.4 Science concepts. The student knows the characteristics of matter and can analyze the relationships between chemical and physical changes and properties.

ITEEA Standards for Technological Listing:

3. Students will develop an understanding of the relationships among technologies and connect between them and other fields of study.

6. Students will develop an understanding of the effects of technologies and the environment.

NGSS Standards:

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Pre-Requisite Knowledge

Students must show an understanding of the following prior to the activity:

Laboratory: Instruments, Procedures, Safety, Measurements, Instruments, and appropriate glassware use.
Magnets: The basic understanding of magnetic properties.
Chemistry: Compounds, molecules, bonds, and chemical / physical properties.
Plants: Anatomy and molecular processes
Biochemistry: knowledge of essential biochemical molecules and minerals.

Learning Objectives

After this activity, students should be able to:

- Identify the importance and function of chelates in biological, chemical, and engineering processes.
- Evaluate the differences and implementations of qualitative and quantitative studies.
- Assess how naturally occurring chelates may be engineered for industrial processes.
- Create a chelate model, explain its molecular/binding properties, and provide a name for their creation.

Materials List:

Each group needs:

Test Tube Rack

4-40mL Beakers

6-1mL Graduated Plastic Pipets

6-Test tubes/cuvettes

Spectrophotometer

Kim wipes or tissues

Roll of Paper Towels

Disposable Latex Gloves for each member

Window Markers or Dry-erase markers

To share with the entire class:

Stock solutions:

1% $FeCl_3$
0.1% $FeCl_3$
0.01% $FeCl_3$
0.1M KSCN
Aqueous Cilantro (*Coriandrum sativum*) Extraction

Introduction / Motivation:

Teacher Introduction:

Teacher passes out the activity's handout. Then asks, "Who knows how magnets work?" "Please write your responses onto your handout." "I will then call on some of you." Teacher allows the students to write down their responses. "Before we begin make sure to take down any information you did not know or were confused about. This is important. These will be your notes for the remainder of the activity. See page 3 of your handout." (*Teacher then accepts responses accordingly. Most common response will be about polarity or how opposites attract. Possible explanations on how magnets are attracted to metal or vice versa.)*

"How can magnets be used with water?" "Please write your responses onto your handout." "I will then call on some of you." (*Teacher accepts responses accordingly. More than likely the teacher will have a broad range of responses. Teacher is searching for the response associated with the thought that magnets do no work in water.)* As the teacher facilitates the discussion and corrects any misconceptions the teacher states, “Be sure you write down your notes or corrections.”

The teacher then demonstrates (with the assistance of volunteers) the properties of magnets and how they may be utilized to purify water. See Image 2 for assistance. Teacher uses a clear rectangular container partly filled with colored water (food coloring of choice) and some iron fillings. Then the teacher allows student volunteers to run a magnet through the water. Then the class records their observations into their handout upon the removal of the magnet from the water.

Image 2 **Image file:** magnets_water_demo_cilantro_activity_image_2.jpg **ADA Description:** A clear plastic container containing iron fillings and blue colored. The iron fillings have been removed from the water with a magnet. **Source/Rights:** self **Caption:** Magnet and Water Demonstration

Once the students document their observations the teacher then grabs a bundle of cilantro (*Coriandrum sativum*) and displays it to the class. The following question is asked by the teacher, “Who believes this plant is a magnet?”. The students then write their hypothetical responses onto their handout. (*The teacher accepts responses accordingly. Students will more than likely state “No”.)*

The teacher then runs the bundle of cilantro through the container filled with water and iron fillings. Students record their observations onto the handout. This demonstration would substantiate the most common prediction (*the plant has no magnetic properties*). An optional route after the demonstration is to question those who believed the cilantro is a magnet and have them support their prediction. To conclude the introduction portion the teacher has the students write a summary of the demonstration and their analysis onto their handout.

Teacher asks, “Who knows what a spectrophotometer is and what is it used for?”. (*The most probable answer would be “No”, which a majority of the students answer. If there are some “Yes” responses then allow the students to elaborate on their response.)* Teacher then explains the use of a spectrophotometer by stating, “A spectrophotometer is a versatile measuring instrument used in the laboratory.” Then explains the term quantitative analysis. To introduce the function of the spectrophotometer the teacher asks the students the following, After the question and answer portion the teacher then briefly explains the function of a spectrophotometer via a demonstration. With the use of a flash light the teacher uses three pieces of plastic with varying transparency.   For example, a clear piece of plastic cover, a frosted sheet protector, and a sheet of white paper. (See Image 3 for assistance.) While holding a lit flashlight the teacher then places the piece of clear plastic and asks the class the following, "Who knows the difference between light transmittance and absorbance?". *(The common response will be "No", however, if there are a few who do know then ask them to elaborate.)*

Next the teacher explains that transmittance is the amount of light that moves through a medium and absorbance if the amount of light absorbed by the medium, which is measured by a spectrophotometer. To conclude this portion of the introduction, the teacher then performs the flash light procedure with the frosted sheet protector and the white sheet of paper. Students will then document their observations of transmittance and absorption onto their handout.

Image 3

Image file: light_demo_cilantro_acitivty_image_3.jpg

ADA Description: A demonstration of light transmittance using a lit flashlight and a clear plastic plate. Light shining through the plate onto a wall.

Source/Rights: self

Caption: Transmittance Explanation

Finally, the teacher presents an overall summary of the activity with a demonstration displaying the chelating properties of cilantro. During the demonstration the teacher must utilize the activity's key terms and allow the students to take notes.

The teacher grabs two 40mL beakers. Partially fills one beaker with 1% aqueous iron chloride and the other with the 0.1% iron chloride to demonstrate a qualitative analysis. Then the teacher adds a small amount of the KSCN solution to both beakers until the solution turn red. Next the teacher explains to the class the process of the aqueous cilantro extraction and pours enough to change the color of the solution (clear) in both beakers. To conclude the teacher asks the students to provide a brief summary of the Iron Chloride (III), Potassium Thiocyanate, and

Cilantro Extraction demonstration utilizing the key vocabulary. Teacher will give them five minutes to write the summary. Prior to dismissing them teacher to their lab tables the teacher explains the objective of the activity and provides the further instructions regarding safety and procedures.

Vocabulary / Definitions

Word	Definition
magnet	A piece of iron that has properties of magnetism to other pieces of iron or metals.
chelate	A compound that binds to metal ions at multiple points.
cilantro	A common herb (*Coriandrum sativum*) used for cooking.
colormetric analysis	The use of a reagent to produce a color change to measure the concentration of a certain molecule or element.
quantitative	Measuring the quantity of an object using instrumentation to validate its properties.
qualitative	Describing the physical properties of an object with the use of instrumentation.
chemical reaction	When substances, elements, or molecules combine/disassociate to create new constituents.
spectrophotometer	A quantitative instrument that employs a photoreceptor to measure light transmittance through a sample at a particular wavelength. Also, used to measure the light absorbance of a sample.
transmittance	The amount of light able to move through a medium or sample.
absorbance	The amount of light absorbed by a medium or sample.

Procedure:

Teacher Background Information:

Background Information for the Development of the Activity:

This activity provides students an opportunity to grasp an analogical interpretation of what is currently being conducted in a Nanotechnology-Enabled Water Treatment (NEWT) Center. NEWT is a research collaborative of several universities (Rice University, Yale University, Arizona State University, and University of Texas at El Paso) engineering an innovative method of purifying water at the microscale while remaining severed from the grid. This new technique relies on the use of nanoparticles. Nanoparticles are key in keeping the purification system at a microscale because of their properties and versatile effectiveness.

Leaching of the nanoparticles is probable during the water purification process. A quantitative/qualitative colorimetric analysis is currently being engineered as a detection system. This system incorporates the use of organic chelates as the fundamental compounds for identifying nanoparticles specifically Titanium dioxide (TiO_2). The purpose of these chelates is to attach to the nanoparticles and create a distinct colometric analysis which can be measured through spectrophotometric analysis. Chelates are compounds that adhere to metal ions through several molecular bonds forming a multidentate molecular complex. Within this activity students employ and observe key elements of the scientific method and engineering project development. (See Figure 1 for assistance.)

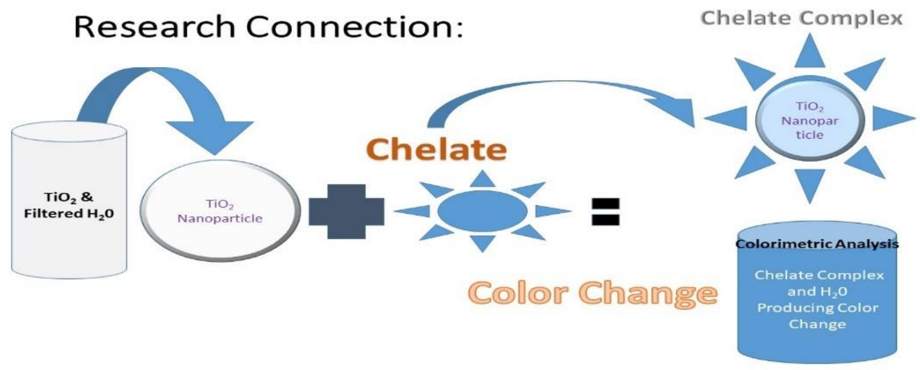

Figure 1

Image file: research_connection_cilantro_activity_figure_1.jpg

ADA Description: A diagram displaying the research connection between the cilantro chelate activity and research currently being conducted via nanoparticles and the water purification process.

Source/Rights: self

Background Information for Qualitative Colormetric Analysis and Spectrophotometric Analysis:

Potassium thiocyanate (KSCN) forms complex with free Fe^{3+} ions (from $FeCl_3$) found in a solution to produce a bright red color, which was documented in first portion of the activity. (See image 6) This is a reversible reaction. As a result of this, there are free Fe^{3+} ions in solution. The chelating compound in the extraction stalwartly binds to the free iron ions when added to the FeSCN solution. This decreases the amount of free Fe^{3+} ions in solution to react with the KSCN so the intensity of the red color decreases.

By utilizing the iron binding properties of both the extract and KSCN solutions the students quantify the efficacy of the chelate found in cilantro through the use of a spectrophotometer. A spectrophotometer measures the amount of light transmitted across a solution based on the light frequency and concentration of the complex to be measured. In this activity the concentration of FeSCN (red color) is measured through absorbance at 450nm to determine the effectiveness of the chelating properties of cilantro. See Figure 2

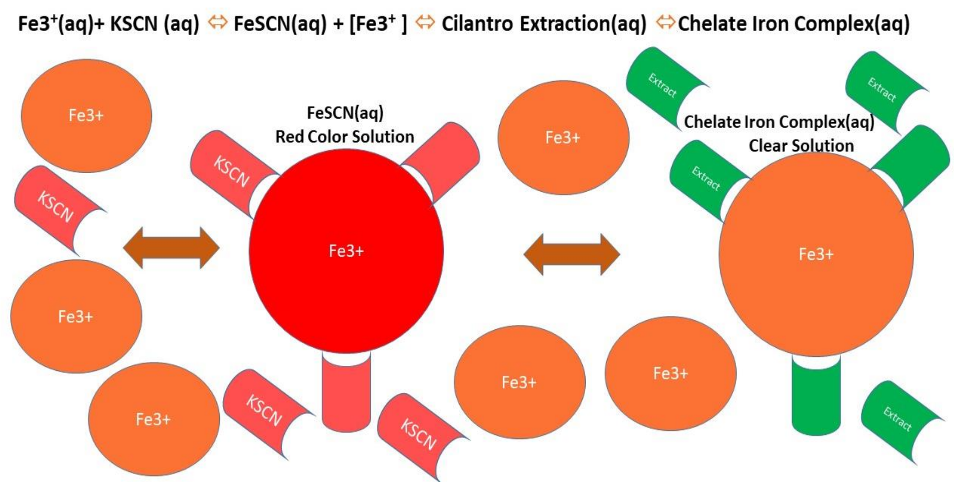

Figure 2

Image file: activity_reaction_cilantro_activity_figure_2.jpg

ADA Description: A diagram displaying a model of the reaction which occurs with iron chloride and potassium thiocyanate and then the addition of cilantro extraction with chelating properties.

Source/Rights: self

Caption: Reaction Progression

Teacher Stock Solution Preparation:

The teacher will prepare three solutions as seen in Image 2. This includes a simple aqueous extraction of cilantro (*Coriandrum sativum,* solution of potassium thiocyanate (KSCN), and an iron (III) chloride solution. This should be done a day prior to the activity.

Cilantro Aqueous Extraction:

1. Boil fresh cilantro @ 80°C in a large beaker using a 5:100mL (mass/volume ratio) for approximately 3-4hrs. The amount is dependent on the number of classes and class size.

   Example: 2L Beaker with 50g of cilantro leaves and 1.0L of distilled water.

2. Pour the cilantro and solution through a kitchen strainer into a 600mL beaker. Dispose of cilantro and keep the solution.

3. Place a large funnel lined with 4-5 coffee filters into a clean 500mL Erlenmeyer flask as seen in Image 7. Pour the solution into the funnel slowly and allow for gravitational filtration. Use a clean flask and unused filter papers for each of the filtrations. Repeat this 3x.

4. After the final filtration cover the flask with parafilm or clear kitchen wrap.

5. Refrigerate or place the solution in an ice bath until it is utilized.

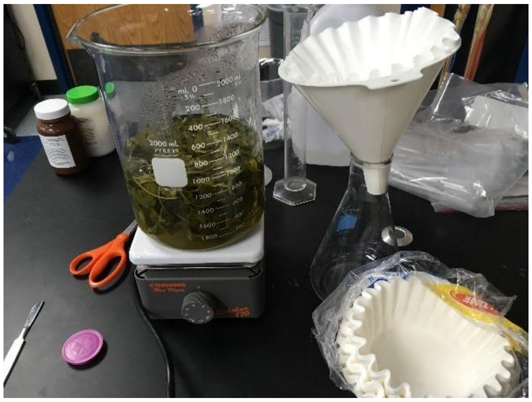

Image 2

Image file: cilantro_extraction_setup_cilantro_activity_image_3.jpg

ADA Description: Laboratory set-up of the cilantro extraction, which includes a hot plate heating a 2000mL with cilantro and water. An Erlenmeyer flask topped with a large funnel that is lined with coffee filters.

Source/Rights: self

Caption: Aqueous Extraction of Cilantro

0.1M Potassium Thiocyanate Solution (KSCN):

1. Weigh 1.95g of KSCN. Dissolve the KSCN with 200mL of distilled water in a 250mL Erlenmeyer flask. Solution amount is dependent on the number of classes and class size. Please refer to the attachment file *Basic Concepts of Preparing Solutions* by Flinn Scientific for further information on the solution making process.

0.01% Aqueous Iron Chloride III ($FeCl_3$):

1. Create a 1% $FeCl_3$ aqueous stock solution. Weigh 2g of $FeCl_3$ anhydrous and dissolve in 198mL of distilled water in a 200mL Erlenmeyer flask.

2. Then complete two serial dilutions in steps of ten-fold. Measure 10mL of the 1% $FeCl_3$ stock with a graduated cylinder. Pour the 10mL of 1% $FeCl_3$ into a 200mL Erlenmeyer flask. Then add 190mL of distilled water to the flask to create a 0.1% $FeCl_3$ stock solution. Then repeat the dilution process with the 0.1% $FeCl_3$ stock solution to create the final stock of 0.01% $FeCl_3$. The 1% and 0.1% solutions of $FeCl_3$ are for demonstration purposes.

3. Quantities of each solution are dependent on the number of classes and class size. Please refer to the attachment file *Basic Concepts of Preparing Solutions* by Flinn Scientific if larger amounts are required.

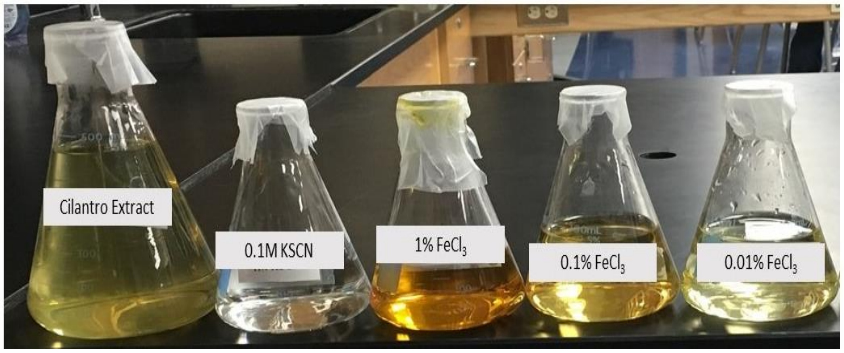

Image 4

Image file: stock_solutions_cilantro_lab_activity_image_4.jpg

ADA Description: Stock solutions in 4 different Erlenmeyer flasks labeled accordingly with Cilantro Extract. 0.1M KSCN, 1% $FeCl_3$, 0.1% $FeCl_3$, and 0.01% $FeCl_3$

Source/Rights: self

Caption: Stock Solutions

Procedure:

Teacher prepares each group station prior to class as seen in Image 4:

1. The following items will be required for each group.
   i. If possible one Spectrophotometer per group. A Spectronic 20 was used for this activity.
   ii. 4-40mL beakers. Labels include: 0.01% $FeCl_3$, 0.1M KSCN, Cilantro Extraction, and H_2O. Transfer the solutions from the stock into labeled 40mL beakers. Fill each of beakers to approximately 30mL
   iii. 6 empty test tube/cuvettes and test tube rack.
   iv. 6 1mL graduated disposable plastic pipettes.
   v. Thin Dry Erase/Window Markers.
2. Divide the class in groups of four students each after the introduction/motivation.

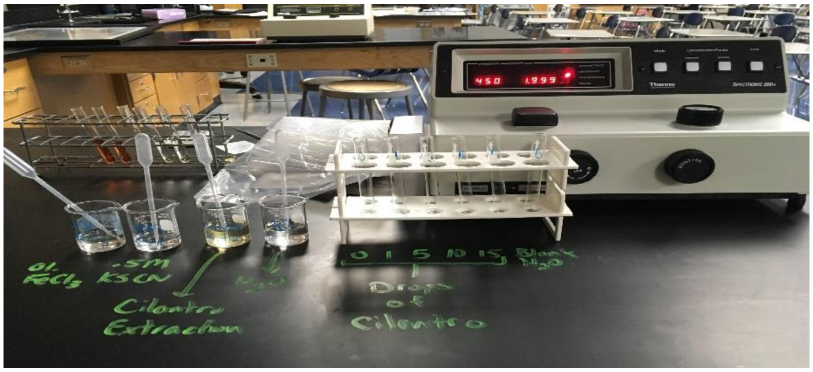

Image 5

Image file: lab_table_set_up_cilantro_activity_image_5.jpeg

ADA Description: Suggested lab table set-up for Cilantro Chelate Activity. Includes 4-4mL beakers with solutions and plastic graduated pipettes, test tube rack with 5 empty test tubes, and a spectrophotometer.

Source/Rights: self

Caption: Suggested lab table set-up for activity.

Perform with Students:

1. The teacher will then distribute activity procedure handouts to each student.
2. Perform the introduction/motivation while utilizing the key words.
3. Prior to students beginning the activity the teacher demonstrates the objective of the activity using two 40mL beakers. One with 10-20mL of the 1% $FeCl_3$ solution and the other beaker with the 10-20mL 0.1% $FeCl_3$. Teacher then adds enough KSCN solution to create a color change to both beakers as seen in Image 5. Finally, the teacher adds enough cilantro extract until color returns to its original state. Teacher then allows the students write a summary.
4. The teacher then allows the students to get into their groups at the lab tables.
5. Provides any further instructions and safety precautions.
6. Teacher will then walk around and facilitate the ongoing activity.

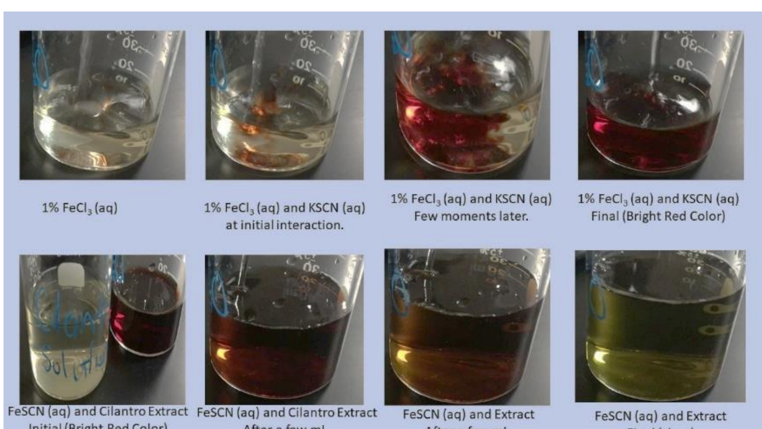

Image 6

Image file: demonstration_3_lab_activity_cilantro_image_6.jpg

ADA Description: A color progression of the chelating properties of cilantro via the iron chloride (III) and potassium thiocyanate reaction.

Source/Rights: self

Students Perform the Following:

Colormetric Analysis:

1. All students will adhere to all lab safety rules.
2. Gloves and goggles are mandatory for this the activity.
3. Label each of the test tubes with the following: 0, 1, 5, 10, and 15, which coincides with the number of drops to be placed into the test tubes. Each label must be on the top portion of the test tube.
4. Label the last test tube with the letter "B" for Blank. Fill about ¾ full with distilled water. The blank will be used to calibrate the spectrophotometer. Place into the rack.
5. Add 4mL of the 0.01% $FeCl_3$ aqueous solution via a plastic graduated pipet to each of the test tubes (except the blank). Record your observations on Page 3.
6. Then add 1mL of the aqueous 0.1M KSCN to each of the test tubes using a graduated plastic pipette (except the Blank). Record your observations.
7. Add the cilantro extraction to the test tubes using a plastic graduated pipet according to the number of drops labeled on them. (0, 1, 5, 10, and 15) and record observations None will be added to the blank.
8. Each of the test tubes must be inverted several times. To invert you will place your finger on the opening of the test tube. Make sure you have applied enough pressure to keep the solution from spilling out of the test tube. Then invert. Wipe your finger with a paper towel. Repeat until all test tubes have been inverted. Record their observations.
9. Allow the test tubes to sit for 3 minutes before beginning the spectrophotometer analysis.

Spectrophotometer Analysis:

1. Set the mode to Transmittance.
2. Set the wavelength to 450nm using the wavelength knob. Sample compartment must be closed and empty.
3. Zero the instrument with the left-hand knob in front of the instrument.
4. Wipe the "Blank" test tube with a Kim wipe or tissue. Then place into the compartment. Close the compartment.
5. Set the transmittance to 100 by using the right-hand knob in front of the instrument.
6. Remove the blank, close the compartment, and the transmittance must return to 0. If not, then recalibrate using the previous three steps.
7. Use the mode key and select absorbance. Display reading should be at 19.9999.
8. Grab the test tube labeled "15". Wipe and clean the test tube with Kim wipe or tissue. Place test tube "15" into the compartment. Close the compartment. Record the reading onto the data table found on the following page. Remove the test tube and close the compartment.
9. Repeat steps 10 and 11 with the remaining test tubes (10, 5, 1, and 0).

Table 1

Number of Drops	Absorbance of FeSCN @ 450nm
15	0.16
10	0.194
5	0.614
1	0.955
0	1.015

Table 1

ADA Description: A two column and six row table displaying sample data. First column titled Number of Drop and the second column titled Absorbance of FeSCN @ 450nm.

Source/Rights: self

Image 6

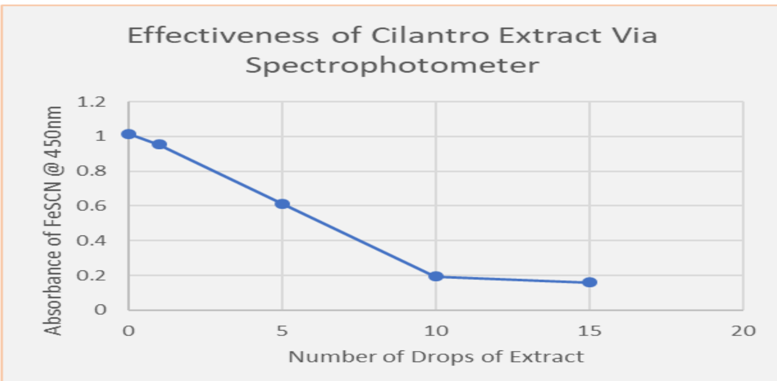

Image 7

Image file: graph_cilantro_lab_activity_image_6.jpg

ADA Description: An X-Y Line graph displaying the data relationships from the number of drops of the cilantro extract and the absorbance reading of FeSCN @ 450nm

Source/Rights: self

Safety Issues

- Students must wear latex gloves and goggles during the lab because of the chemicals and glassware being used.
- MSDS pages for each of the chemicals have been attached.
- Solutions may be poured down the drain at the end of the activity.

Troubleshooting Tips

- Recalibration of spectrophotometer may be required.

Assessment

Pre-Activity Assessment
During the introduction and motivation portion of the activity the teacher will assess the students' understanding through questions and answers. Furthermore, the teacher may view the responses and summaries found in their handout.

Activity Embedded Assessment
The teacher may walk around the laboratory and ask questions. The students' responses will provide the teacher with a gauge or level of understanding. Also, the time of progression through the lab activity may also provide a gauge of understanding.

Post-Activity Assessment
Based on the responses found on the students' handouts will help provide evidence of understanding and comprehension. The handouts will help the teacher see if the students have met the learning objectives. Furthermore, the final activity, the creations of the chelate model, will further prove if the students have met the learning objectives.

Activity Scaling
- For lower grades, exclude the spectrophotometer portion of the activity. However, complete the creation of a chelate assignment.
- For higher grades, complete the entire activity.

References

Bernstein, M. and Woods, M.. "Cilantro, That Favorite Salsa Ingredient, Purifies Drinking Water". American Chemical Society. Accessed on June 16, 2017. (Source used for background information.) https://www.acs.org/content/acs/en/pressroom/newsreleases/2013/september/cilantro-that-favorite-salsa-ingredient-purifies-drinking-water.html

Brooks, D.W.. "Simple Iron in Food Determinations". Accessed June 20, 2016. (Used as a resource to develop the lab activity protocol.) http://dwb4.unl.edu/Chem/CHEM869K/CHEM869KMats/SimpleIronLab.html

Jost Chemical. "What is a chelate?". Accessed June 20, 2017. (Used for reference for background information.) https://www.jostchemical.com/wp-content/uploads/pdf/Chelates.pdf

Sears, M. E. "Chelation: Harnessing and Enhancing Heavy Metal Detoxification—A Review". *The Scientific World Journal*. (2013) Vol 2013., Article ID 219840, 13 pages. http://dx.doi.org/10.1155/2013/219840

Wong, P.Y.Y and Kitts, D.D. "Studies on the dual antioxidant and antibacterial properties of parsley (Petroselinum crispum) and cilantro (Coriandrum sativum) extracts". *Food Chem* (2005) Vol. 97 Pages: 505-515

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Classroom Testing Information
Lab Activity was tested during a 47-minute 9th and 12th Grade Dual Credit Biology Classroom in December 2017 and again in January 2018 at Del Valle High School in El Paso, Texas. Both classes had 16 students each.