Chemistry Across the Spectrum:
Application and Exploration of Chemistry and Light
in CMS Chemistry Standards

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This curriculum unit is recommended for:
Chemistry, Physical Science, grades 10-12

Keywords: chemistry, light,

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: Chemistry can be seen by many as an intimidating topic. To better engage students and help make the information accessible to greater numbers, this curriculum unit employs a variety of ways that color can be incorporated in Charlotte-Mecklenburg Schools chemistry standards. The topics were selected and developed with the simplicity of application by other teachers in mind. Each topic can easily fit into these standards to enhance the chemistry units. These activities can be used to differentiate based on interest (to engage students that are not typically interested in chemistry) or to give students a real-world application of chemistry. Topics will include: Bohr model, periodic table, nomenclature, bonding, acids/bases and other solutions.

I plan to teach this unit during the coming year to 90 students in standard and honors chemistry classes.

Introduction

The goal of this curriculum unit is to provide resources for chemistry teachers to incorporate how light is used in chemistry in a variety of ways based on the CMS chemistry standards. Chemistry is a class that is enjoyable to teach because there are so many ways to incorporate real world applications, labs, demonstrations, and other projects that allow students to become an active participant in their own learning. Using active learning teaching strategies, students become more engaged with the content develop into more self-sufficient learners. This progressions towards students becoming gatekeepers of their knowledge better prepares students for life outside of high school and can be designed to incorporate: working with a different groups of people, group leadership, problem solving, public speaking to share results, and, using data tables or figures to concisely express ideas. That's a very short list of how I use chemistry activities in my class. I want my students to be prepared and confident with a wide range of skills that may not be necessarily practiced in many of their other classes.

Class Demographics

I teach at William A. Hough High School. There are approximately 2700 students. The ethnic demographics of the school is shown in table 1. Hough currently has standard, honors, and advanced placement levels of chemistry. The school day is 90 minute block schedule.
The goal of this curriculum unit is give alternative learning opportunities/connections for students in the chemistry class. There will be connections regarding the following topics: Bohr model and light, the periodic table, and acids/bases.

Learning objectives for this Bohr model and Light include:

1. Students will know the relationship between wavelength and frequency.
2. Students will know the relationship between energy of a wave and color.
3. Students will be able to use the Bohr model to explain how fireworks work. .

Learning objectives for the periodic table include:

1. Students will be able to explain what kind information does the periodic table quickly relay to the reader?
2. Students can explain the organization of the periodic table.

Learning objectives for solutions/acids and bases include:

1. Students will be able to perform a simple titration.
2. Students will be able to determine the concentration of an unknown acid based on titration results.

Background Information

Bohr Model and Light

The atom is composed of a positively charged nucleus (containing protons [positively charged particles] and neutrons [neutral particles]) with negatively electrons occupying space outside of the nucleus. As science has advanced, the standard model of the atom has changed over time (see below). Although the most correct model currently adopted is the Quantum Mechanical model, generally chemistry classes initially focus on the Bohr model (planetary model). One of the primary reasons that I begin chemistry discussing the Bohr model is due to the relative simplicity and ease for visualization.

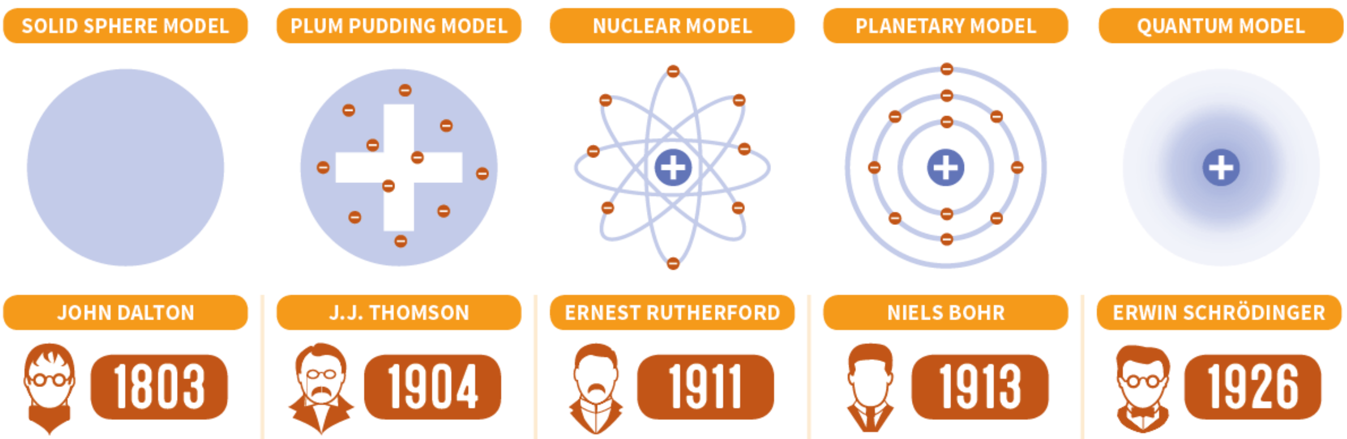


Figure 1: Summary of the Development of the Model of the Atom[5]

The Bohr model uses Hydrogen (which has one electron) to help illustrate the results of an electron absorbing or releasing energy when moving energy levels. Excitation or absorption is defined as the electron having energy input and going from a lower energy level to a higher energy level. Emission or relaxation is defined as the electron losing energy and going from a higher energy level to a lower energy level. The law of conservation of energy states that energy is neither created or destroyed. When an electron is relaxed, that energy is typically lost as light waves. Light involves more than just the colors that we see (the visible spectrum). The visible spectrum is a small portion of what is known as the electromagnetic spectrum (which includes gamma, ultraviolet, and radio waves). Light waves can be described, mathematically, using wavelength and frequency. The equation used to represent this relationship is $c = \lambda\nu$. This is an inverse relationship, meaning that if the wavelength (λ) increases, then the frequency (ν) decreases and vice-versa. When multiplying the wavelength and frequency of any light wave, you get the speed of light (c), which is usually represented by the value 3.0×10^8 meters per second. Because the speed of light is a known and constant value, we can calculate an unknown variable given that we know either the wavelength of the frequency.

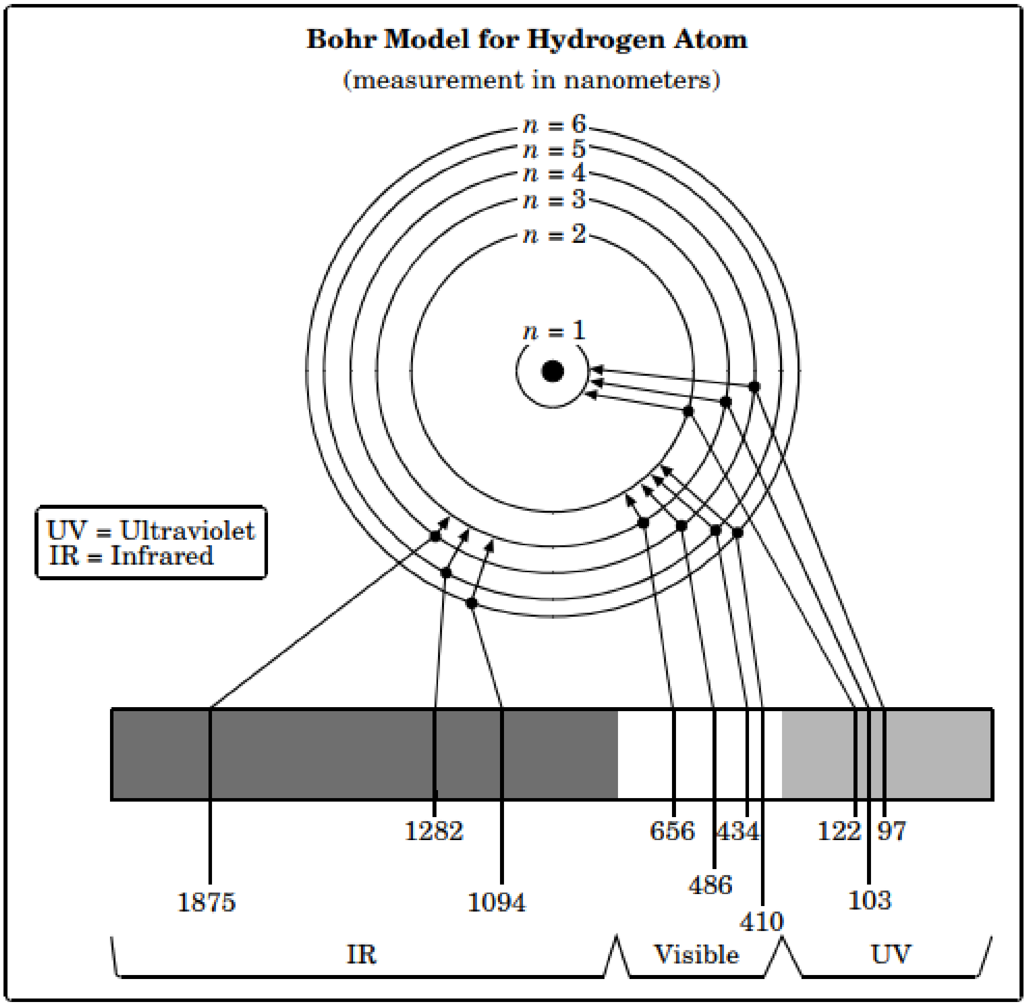


Figure 2: North Carolina Chemistry Reference Table Bohr model[1]

Fireworks can be explained using the Bohr model. The excitation and relaxation of electrons in different energy levels result in variety of colors in fireworks. By altering the amount and combinations of compounds, the pattern, color, and duration of emission spectrum can be refined to give colorful and interesting displays[7,8].

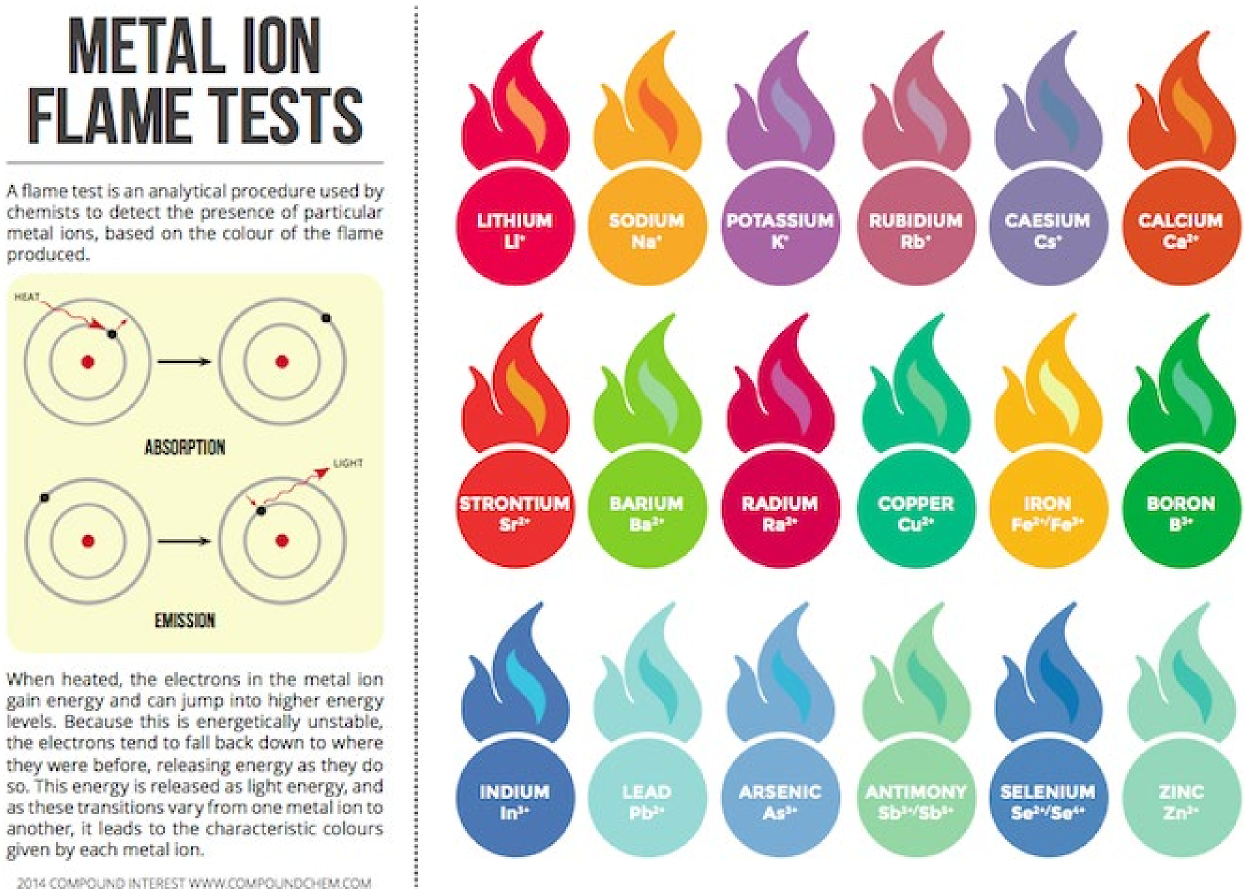


Figure 3: Flame Test of Various Metals[3]

Periodic Table

Light (in terms of color) is used in the periodic table in order to categorize or organize large amount of information in a concise manner. There are many iterations of the periodic table and each may use color to convey different meanings. Some versions of the conventional (Mendeleev) periodic table (see below) use color to categorize elements that have similar characteristics or properties[6]. This is helpful, because it quickly allows the reader to identify which elements have similarities and inferences can be made regarding other elements in the same group (column).

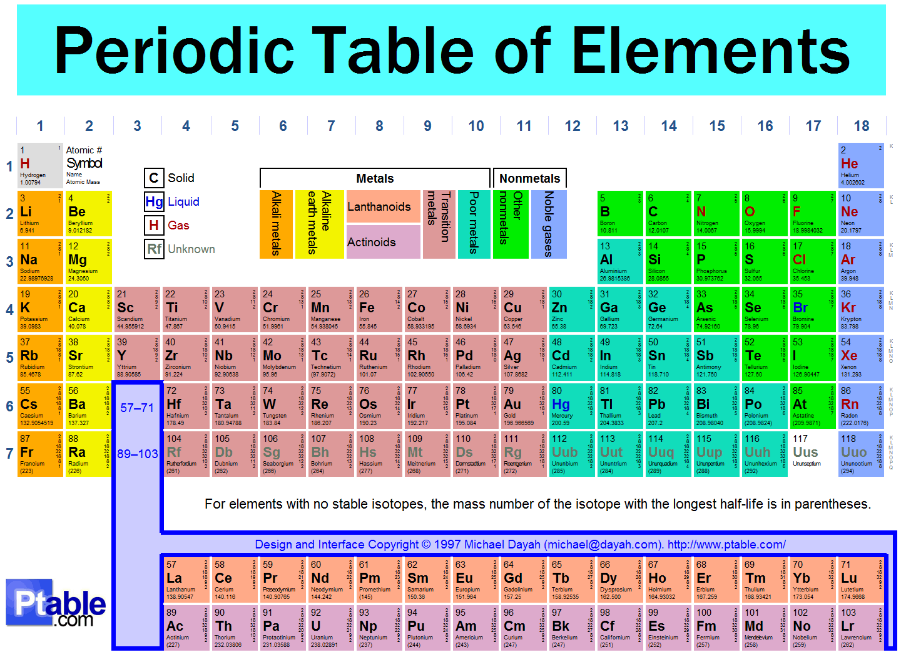


Figure 4: Conventional (Mendeleev) Periodic Table[2]

There are various versions of the periodic table and each organizes information differently. With any model, there are some shortcomings[8]. The above periodic table does have issues, but this is true for every model that is used in science. An example of a shortcoming of the above periodic table is that Helium has two valence electrons (outermost electrons generally take place in bonding), but all other elements have a full 8 and obey what is known as the octet rule. Helium is placed is this group because like other elements in this group (Noble gases), it is stable and generally unreactive (this is just an example to show there can be potentially confusing aspects of any model, I can change or remove the example).

Mendeleev organized the most identifiable periodic table by comparing properties of different elements. Mendeleev had the monumental task of first separating elements from a compound, then used observations to organize elements by various properties (such as reactivity with different substances)[6]. Mendeleev was even able to identify properties of elements that had yet to be discovered based on these observations. Mendeleevs' periodic table is organized by horizontal portions called "groups" that have similar chemical properties and each subsequent elements has a greater number of protons. Other versions of periodic tables can be found in appendix with descriptions and how they are organized listed at: http://www.chemistry-blog.com/2009/04/26/alternative-periodic-tables/comment-page-1/.

Stoichiometry and Solutions

In an acid and base reaction, neutralization is defined as an acid and base combining to form salt (ionic compound made of a metal and nonmetal, not necessarily NaCl) and water. This completion of this type of reaction can be monitored electronically using a pH probe or using a chemical known as an indicator. An indicator is a chemical compound that changes color within a certain pH range. One commonly used indicator used in neutralization labs is known as phenolphthalein. Phenolphthalein is a weakly acidic compound that changes from colorless (in an acidic solution) to pink (in a basic solution). When the color change occurs, this is known as endpoint. The get the most accurate results from this process, you want endpoint to be the lightest pink color that is perceptible. This is challenging, because the color change can occur very quickly. If too much base is added, the solution with change color to a vibrant pink. This result requires further work to get accurate results (back titrating, adding a known amount of acid and correcting your calculations to get the very light pink colored solution).

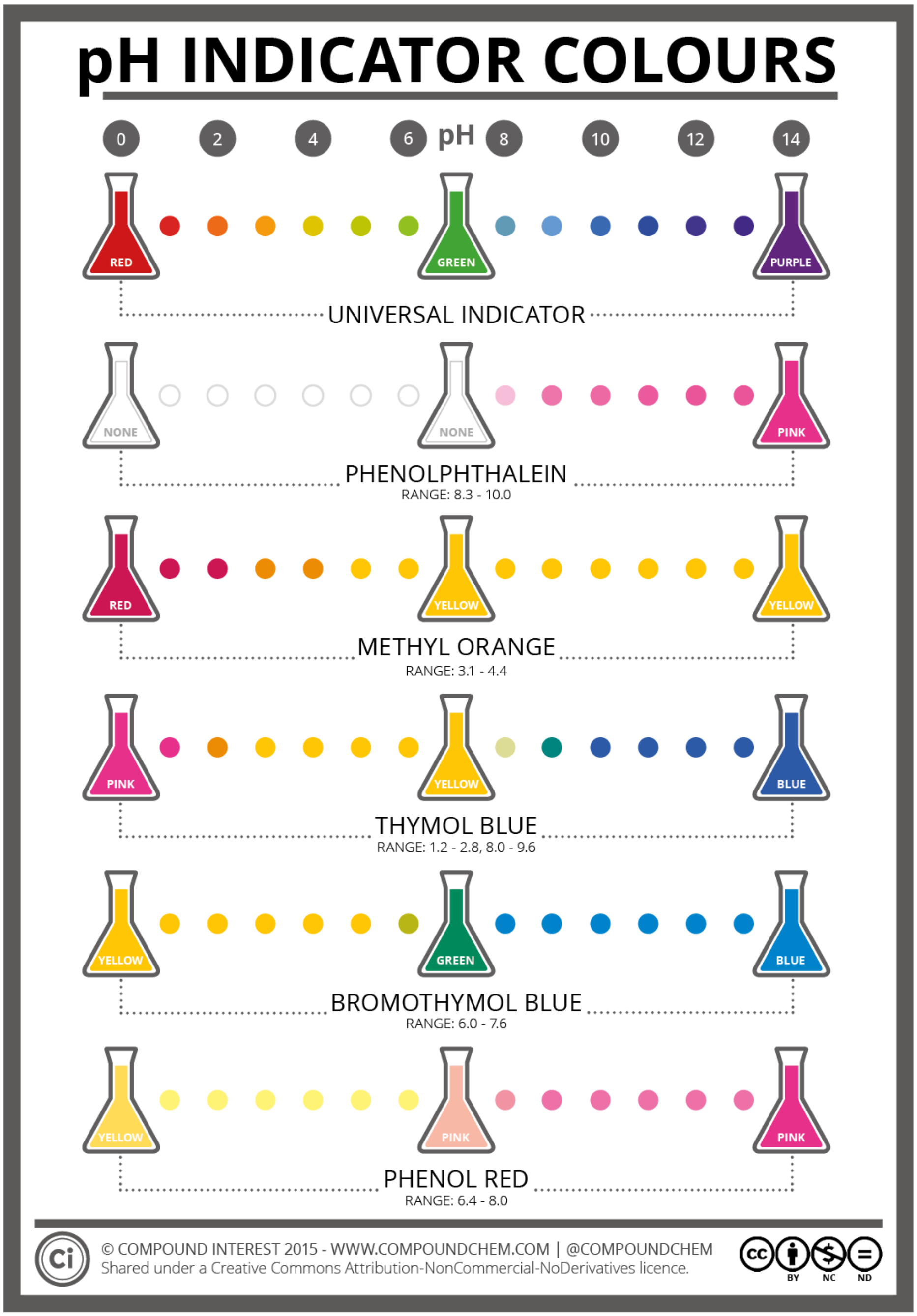


Figure 7: pH Indicator Colors[4]

Another interesting color based chemistry lab is known as clock reaction. Essentially, you add the different chemicals together and the resulting solution changes color after a certain amount of time. In my classroom, I use this as an inquiry lab for students to vary the amount of the different solutions to see how this affects the amount of time it takes for the color change to occur. After students investigate these different variables, I will give each group a specific time. Groups are then challenged to try and get their reaction to change at that specific time.

Learning Experiences

Activity 1: Wavelength and Frequency of Light

Learn: Students will be introduced to the relationship between frequency and wavelength during class instruction. Students should be able to calculate frequency, wavelength, or the speed of light given two of the three variables.

Apply: Students will complete a simulation activity that visually shows the relationship between frequency and wavelength of different parts of the electromagnetic spectrum.
http://www.glencoe.com/sites/common_assets/science/virtual_labs/CT05/CT05.html

Assess: Given a specific wavelength of light, students will create a scaled model that specific wavelength of light calculating the frequency. The scaled models can then be displayed in the class to help give a visual summary of the information. For this model, we will consider 1 nm = 1 mm to simplify the project.

Color	Wavelength (nm)	Frequency (Hz)
Red	750	
Orange	620	
Yellow	590	
Green	570	
Blue	495	
Violet	450	

Activity 2: Fireworks to Illustrate the Bohr Model

Students will continue to develop the ideas covered in class, but in an interactive manner. At this point, students should understand the terms: excitation/absorption and relaxation/emission, but this activity will help to ingrain those terms. Students should see that the emission of colors does not occur if energy is not first absorbed. This exposure helps to clarify the terminology of this topic.

Explore: Students will be given known samples of chemical compounds that produce a variety of colors when burned in a flame test. Students will collect data regarding what chemicals produce certain colors.

Apply: Students will then determine the identity of unknown chemical sample using flame tests based on the data they have previously collected.

Assess: Students will collaborate within their group to summarize the data from the activity. Special care will be given to ensure the correct terminology is used during this summarization. To scaffold this activity, the teacher can play a video of fireworks and assign groups a specific time interval. Students should do their best to identify the elements used during their part of the video with explanations based on the data collected from the activity.

Activity 3: Periodic Table

Explore: Students will be distributed in groups and provided with a copy of a periodic table. The group will have 3 minutes to try and record how the periodic table is organized. After three minutes, the group will pass their work and periodic table to another group and the new group will have 2 minutes to continue to adding information that can be extracted based on the organization of the periodic table. This rotation will occur one more time with the time interval decreasing again. The original group will receive their work and periodic table to summarize the finding of this shared data.

Learn: Students will develop their understanding of the periodic table through class instruction. Near the end of the unit, the explore activity can be revisited to see if there are any updates to the summaries that were developed through the above activity.

Activity 4: Identification of an Unknown Acid Concentration

From topics covered in class, students should be able to solve problems using molarity formula (Molarity = moles/Liter). Students will apply this understanding to calculate the concentration of an unknown acid. The setup of this lab can readily be found online.

Explore: Students will watch a short video that walks them through the process of setting up a titration https://www.youtube.com/watch?v=sFpFCPTDv2w&t=31s. Students will then answer questions based on the information they have finished watching and discussing as a group.

1. How do you prepare your buret for the lab?
2. How do you know you are finished adding acid?

Apply: Students will then complete the titration lab using the lab sheet provided in appendix.

Assess: Students will calculate the concentration of their unknown acid. The percent error of the theoretical (what they should have gotten) and the experimental (what they actually got in the lab) will determine how many points the students lose. The formula for percent error is: |theoretical - experimental| * 100% theoretical

Activity 5: Iodine Clock Reaction

Students will investigate factors that affect the kinetics of a reaction. Students will collect quantitative data over several reactions to get an ideas of how changing concentration will change how quickly a reaction will occur. The students will be assess based on how accurately they are able to cause the reaction to change colors based on a provided time interval. Instructions for the setup of this lab are readily found online.

Learn: Students will have already discussed molarity and dilution calculations in class.

Explore: Students will use the lab data sheet in the appendix to collect their data. Students will look into how changing concentration will change the time is takes for the reaction to take place.

Assess: Students will provided a certain time will make the reaction change at that time. The percent error of the theoretical (what they should have gotten) and the experimental (what they actually got in the lab) will determine how many points the students lose. The formula for percent error is: |theoretical - experimental| * 100% theoretical

Appendix 1: North Carolina Essential Standards

Chm.1.1.3
Explain the emission of electromagnetic radiation in spectral form in terms of the Bohr model.

Chm.1.3.1 Classify the components of a periodic table (period, group, metal, metalloid, nonmetal, transition).

Chm.1.3.2 Infer the physical properties (atomic radius, metallic and nonmetallic characteristics) of an element based on its position on the Periodic Table.

Chm.1.3.3 Infer the atomic size, reactivity, electronegativity, and ionization energy of an element from its position on the Periodic Table.

Chm.3.2.1 Classify substances using the hydronium and hydroxide concentrations.

Chm.3.2.3
Infer the quantitative nature of a solution (molarity, dilution, and titration with a 1:1 molar ratio).

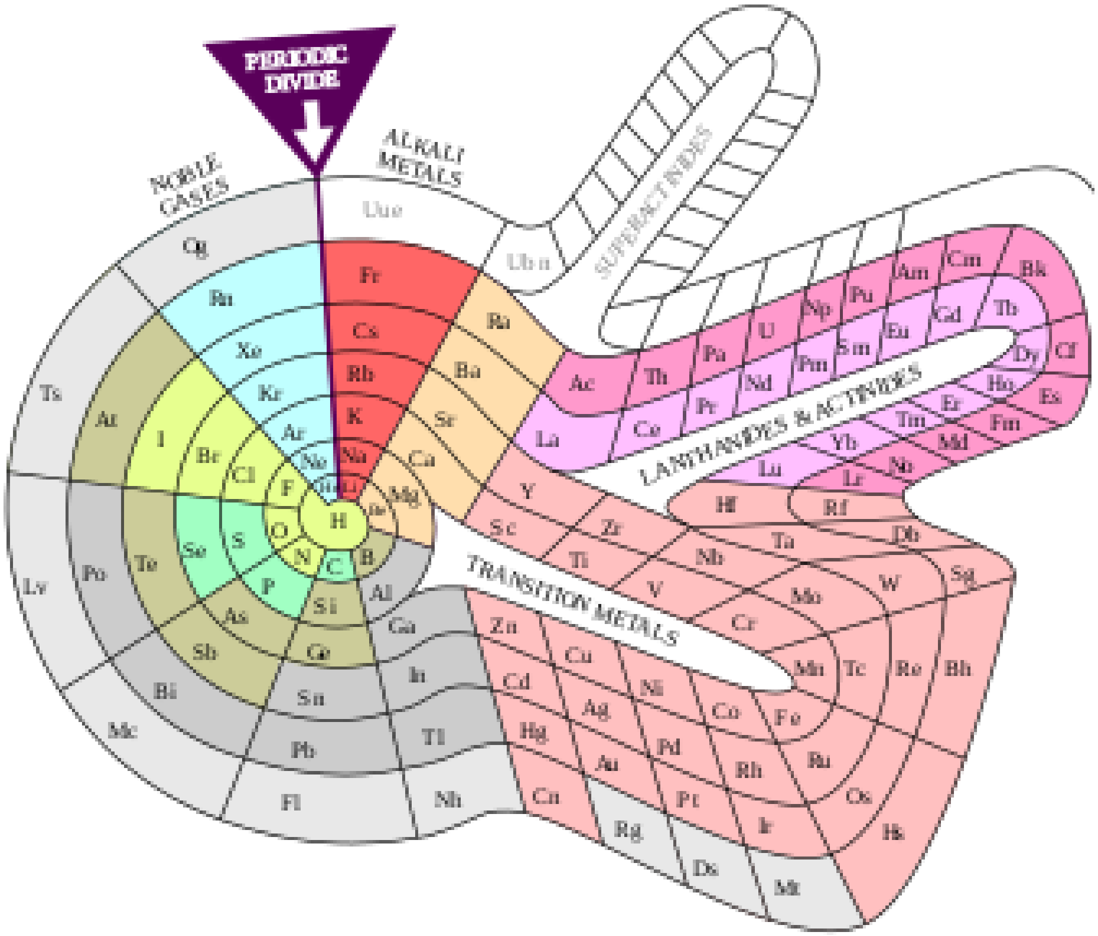
Students will explore the relationship between art and light from a chemical perspective.

Students will recognize how chemistry uses art to organize large pieces of information in relatively simple and concise ways.

Appendix 2: Teacher Resources

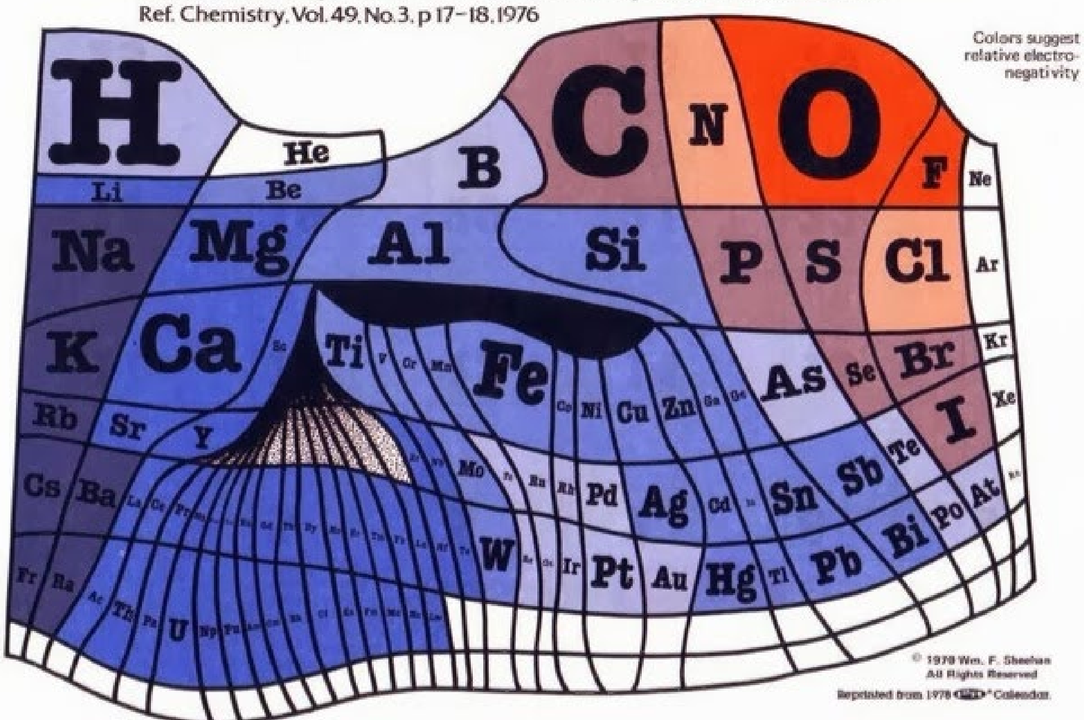
Periodic Tables for Activity 3: Periodic Tables

Print out in color if possible (or give students the periodic tables electronically)
http://www.chemistry-blog.com/2009/04/26/alternative-periodic-tables/comment-page-1/



The Elements According to Relative Abundance

A Periodic Chart by Prof. Wm. F. Sheehan, University of Santa Clara, CA 95053
Ref. Chemistry, Vol. 49, No. 3, p 17–18, 1976

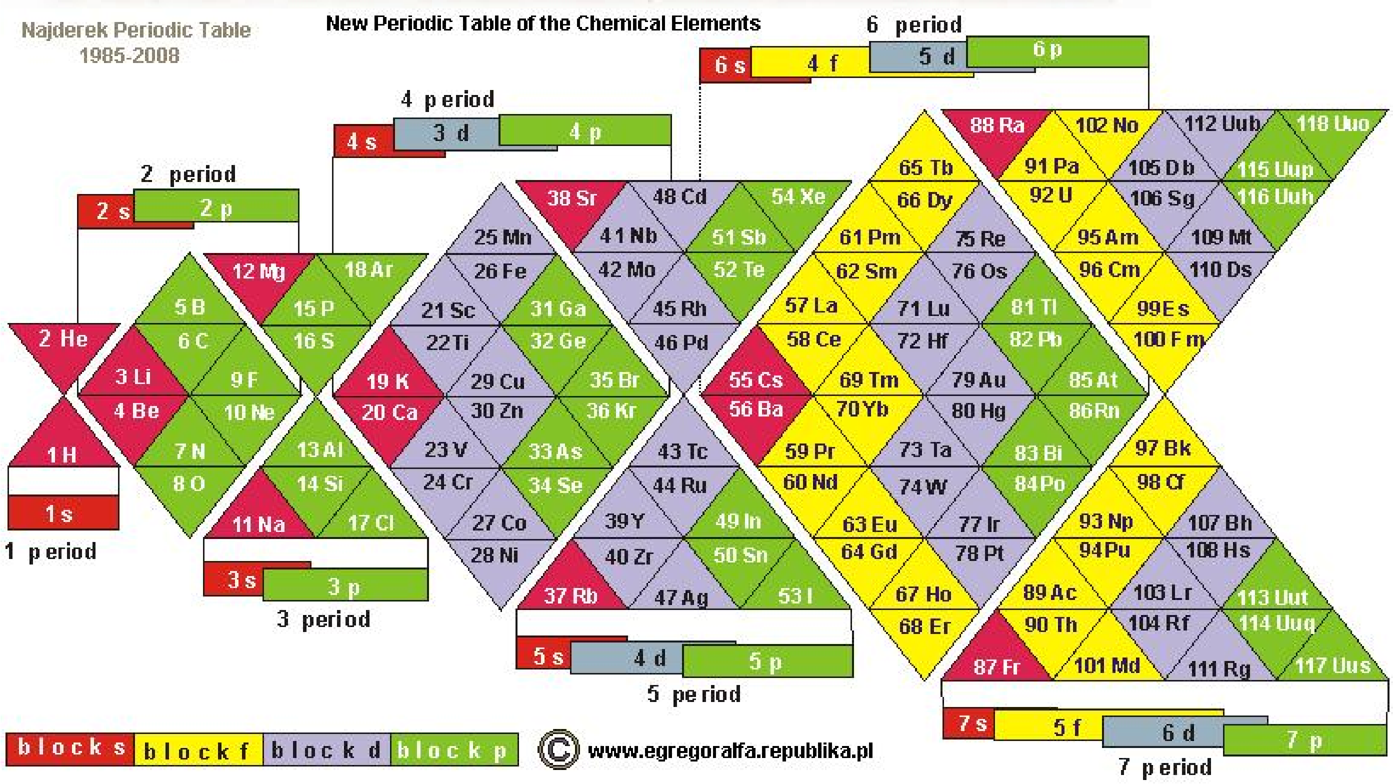


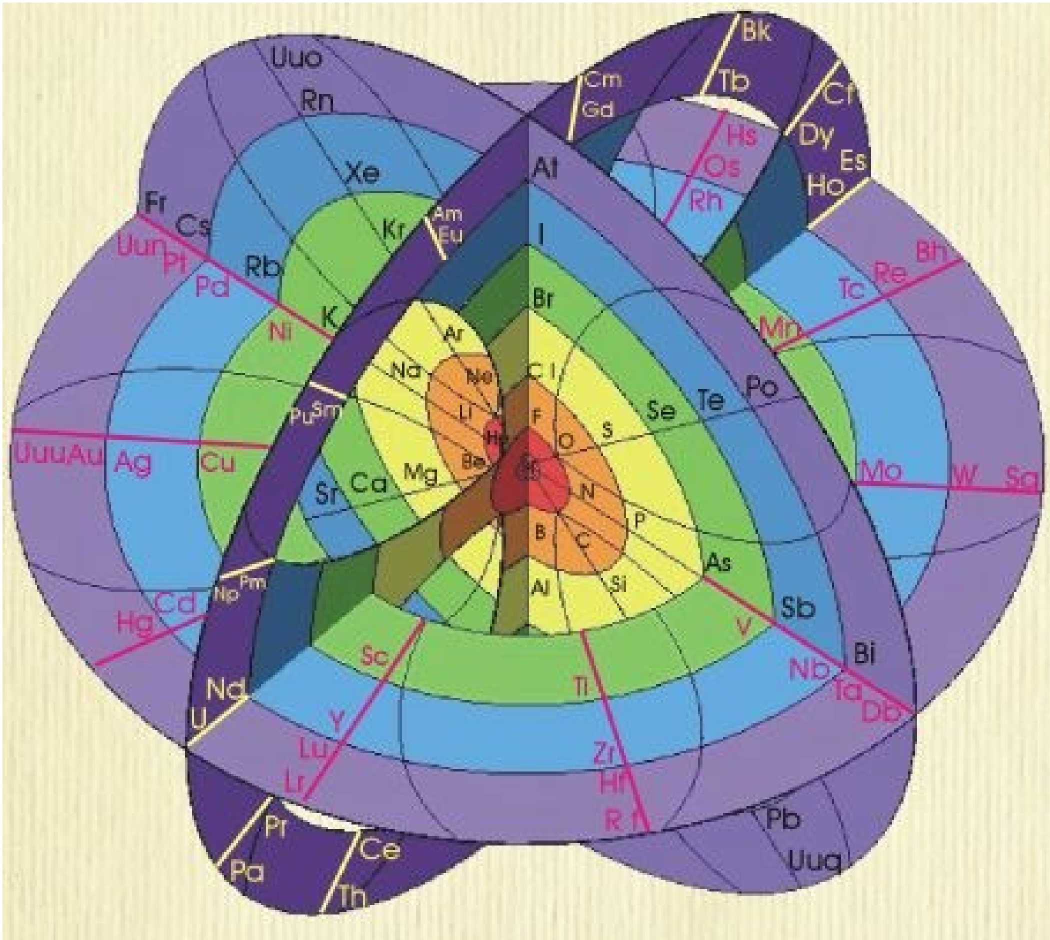
Roughly, the size of an element's own niche ("I almost wrote square") is proportioned to its abundance on Earth's surface, and in addition, certain chemical similarities (e.g., Be and Al, or B and Si) are suggested by the positioning of neighbors. The chart emphasizes that in real life a chemist will probably meet O, Si, Al, . . . and that he better do something about it. Periodic tables based upon elemental abundance would, of course, vary from planet to planet. . . W.F.S.

NOTE: TO ACCOMMODATE ALL ELEMENTS SOME DISTORTIONS WERE NECESSARY, FOR EXAMPLE SOME ELEMENTS DO NOT OCCUR NATURALLY.

Najderek Periodic Table
1985-2008

New Periodic Table of the Chemical Elements





3D Periodic Table

Data Collection for Activity 4: Titration Lab

Titration Lab **Name**___________________________________

Titrating several trials will improve the reliability of the value reported for the molarity of the HCl solution

Purpose: To determine the concentration of an unknown acid using the concentration of a known base and indicator.

Procedure: Standardization of HCl

1. Obtain 2 burets and rinse them out with water – including the tip. Rinse your funnel and Erlenmeyer flasks too.
2. Secure the burets in a double buret clamp. Fill one with 0.100 M NaOH solution. Fill the other buret with unknown M HCl solution. Make certain that each solution fills the buret tip before taking the initial volume reading. Record the volumes to the closest 0.02 mL.
3. Dispense ~ 20 mL of HCl into an Erlenmeyer flask. Add 3 or 4 drops of phenolphthalein to the flask. Titrate the HCl sample until the faint pink endpoint is reached. Add the NaOH rapidly at first but slowly later as the endpoint is approached (indicated by the less rapid disappearance of the pink color). Add the final increments dropwise. The endpoint is reached when the faint pink color persists for at least 30 seconds. Exercise care to avoid overshooting the endpoint (intense pinkish-red color). "Back titrate" if needed.
4. Do not refill the burette. The initial reading for trial #2 will be the final reading from the trail #1. Repeat the titration at least two more times. Clean up!
5. Calculate the molarity of the HCl.

Reminder: You will need to show all your work (for every trial) in order to receive max points.

Unknown # : _____

	Trial #1	Trial #2	Trial #3	Demo/ Sample Calculations
Final Volume Acid Buret (0.01 mL)				
Initial Volume Acid Buret (0.01 mL)				
Volume used (0.01 mL)				
If you need to backtitrate				
Final Volume Base Buret (0.01 mL)				
Initial Volume Base Buret (0.01 mL)				
Volume used (0.01 mL)				
Molarity of HCl (use max # of sig figs)				

Average Molarity _____________

Data Collection for Activity 5: Iodine Clock Reaction

Note: You must show ___________ example calculation in order to receive full credit (all work must be shown, even if you put it in your calculator).

Trial	Volume of HSO_3^{1-} (mL)	Volume of IO_3^{1-} (mL)	dH2O (mL)	Total Volume (mL)	$[HSO_3^{1-}]$	$[IO_3^{1-}]$	Moles of IO_3^{1-} used	Reaction Time (s)
1	20	20	0					
1	20	20	0					
2	20	19	1					
3	20	18	2					
4	20	17	3					
5	20	16	4					
6	20	15	5					
7	20	14	6					
8	20	13	7					
9	20	12	8					
10	20	11	9					
11	20	10	10					

Bibliography

"Dynamic Periodic Table." n.d. Accessed September 19, 2018. //www.ptable.com/.
This resource is a visual way to view many different pieces of information on the periodic table.

"Flame Test | Compound Interest." n.d. Accessed September 22, 2018. https://www.compoundchem.com/?s=flame+test.
This resource summarizes the colors that certain elements generate when exposed to enough energy to excite and subsequently relax its' electrons.

Interest, Compound. 2015. "The Chemistry of Coloured Glass." Compound Interest. March 3, 2015. https://www.compoundchem.com/2015/03/03/coloured-glass/.
This resource shows how the inclusion of different metals in glass results in different colors. Similar to the flame test resource.

Interest, Compound. 2014. "The Colours & Chemistry of PH Indicators." Compound Interest. April 4, 2014. https://www.compoundchem.com/2014/04/04/the-colours-chemistry-of-ph-indicators/.
This resource shows the effect of various indicators and pH of a solution.

Interest, Compound. 2016. "The History of the Atom – Theories and Models." Compound Interest. October 13, 2016. https://www.compoundchem.com/2016/10/13/atomicmodels/.
This resource shows a visualization of how the atomic model has changed throughout history.

Mastin, John. 1911. The Chemistry,Properties and Tests of Precious Stones, . London,. http://hdl.handle.net/2027/mdp.39015030083789.
The above resource gives a description of the concentration of elements in different gemstones.

"Mendeleev's Revenge." 2015. New Scientist 228 (3046): 46–46. https://librarylink.uncc.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=110711885&site=ehost-live&scope=site.
This resource shows an activity that allows students to use logic and deductive skills to predict placement of elements on the periodic table in a way similar to Mendeleev.

Russell, Michael S. 2000. Chemistry of Fireworks . Cambridge, UNITED KINGDOM: Royal Society of Chemistry. http://ebookcentral.proquest.com/lib/uncc-ebooks/detail.action?docID=1185350.
This resource shows the composition and science of various popular fireworks.

Scerri, Eric R. 2006. The Periodic Table: Its Story and Its Significance. New York, UNITED STATES: Oxford University Press, Incorporated. http://ebookcentral.proquest.com/lib/uncc-ebooks/detail.action?docID=431246.
This resource outlines the history and importance of the periodic table.

Steinhauser, Georg, and Thomas M. Klapotke. 2011. "Using the Chemistry of Fireworks to Engage Students in Learning Basic Chemical Principles: A Lesson in Eco-Friendly Pyrotechnics." Journal of Chemical Education 87 (2): 150–156. https://doi.org/10.1021/ed800057x.
This resources outlines more information regarding fireworks and frames the topic in a way to engage students.

Endnotes

1. *http://www.ncpublicschools.org/docs/accountability/testing/eoc/Chemistry/chemistryreferencetable.pdf*
2. "Dynamic Periodic Table." n.d. Accessed September 19, 2018. //www.ptable.com/.
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9. Steinhauser, Georg, and Thomas M. Klapotke. 2011. "Using the Chemistry of Fireworks to Engage Students in Learning Basic Chemical Principles: A Lesson in Eco-Friendly Pyrotechnics." *Journal of Chemical Education* 87 (2): 150–156. https://doi.org/10.1021/ed800057x.