Unit Title: Nuclear Chemistry	**Content Area:** Chemistry	**Grade Level:** 9-12

Unit Summary: This unit explores nuclear chemistry - a topic that is often shrouded in danger, myth and overall confusion for students. The unit begins by teaching students about nuclear stability and types of radiation. It helps to provide safe examples of radiation throughout the unit as well as dangerous ones so nuclear processes are less feared. The unit goes on to discuss fission, fusion, half-life and uses of nuclear chemistry. The end of the unit is an excellent time to discuss nuclear energy with students and its implications on the future. Energy sources are constantly in focus now and will be more so for future generations so this can be an empowering discussion for the end of the year. Teachers can feel free to even end the unit with an optional investigation into all forms of alternate energy - not just nuclear.

Cross cutting concepts:
1. Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
5. Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Science and Engineering Practices:
2. Developing and using models
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Unit Essential Questions:	**Unit Enduring Understandings:**
• What are the benefits, hazards and practical implications of nuclear chemistry?	• Nuclear reactions such as fission and fusion can be used to produce large quantities of heat and energy. If contained these reactions can be safe and efficient when producing power. If not monitored these reactions can go out of control resulting in injury or death. Not all nuclear chemistry applications are as grand or dangerous. • Radioactive isotopes are used daily in many aspects of life saving medical procedures, anthropological dating and forensics.

Possible Student Misconceptions: Students often have many misconceptions about radioactivity and nuclear stability. Even after explaining how stability is predicted, students should have some knowledge that it is dependent on temperature and pressure - therefore stability will change in space - i.e. sun radiation. Students often have fear associated with the idea of radiation. This unit should help students determine that radiation is present in our daily lives and can be used safely and beneficially. Students also confuse the terms fission and fusion; try to have the class determine a fun way to remember these words.

NJCCCS: 5.2.12.A.4 In a neutral atom, the positively charged nucleus is surrounded by the same number of negatively charged electrons. Atoms of an element whose nuclei have different numbers of neutrons are called isotopes. 5.2.12.D.3 Nuclear reactions (fission and fusion) convert very small amounts of matter into energy.

NGSS Performance Expectations: *Students who demonstrate understanding can…*
- HS-PS1-8.Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Primary CCSS ELA/Literacy Connections:	**Primary CCSS Mathematics Connections:**
RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1) WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3) WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)	HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-8), (HS-PS2-6) MP.4 Model with mathematics. (HS-PS1-8)

Lesson Pace & Sequence

Lesson Title/Number: Lesson 1 Nuclear Stability		**Learning Objective(s):** SWBAT identify stable and non-stable isotopes using nuclear stability isotopes.			**Lesson Duration:** 40 minutes
Learning Cycle ***What lesson elements will support students' progress towards mastery of the learning objectives(s)?*** ****Elements do not have to be in conducted in sequence.***	***Learning Activities*** ***What specific learning experiences will support ALL students' progress towards mastery of the learning objective(s)?***	***Resources/Materials*** ***What curricular resources/materials are available to facilitate the implementation of the learning activities?***	***Science and Engineering Practices*** ***What specific practices do students need to use in order to progress towards mastery of the learning objective(s)?***	***Disciplinary Core Ideas*** ***What core ideas do students need to understand in order to progress towards mastery of the learning objective(s)?***	***Crosscutting Concepts*** ***What crosscutting concepts will enrich students' application of practices and their understanding of core ideas?***
Elicit: How will you access students' prior knowledge?	Do Now: Have students define the terms proton, neutron, atomic number, mass number and isotope. (Not only is this a good introduction for this unit it helps to begin spiraling review for the final as often as possible. Keep this in mind when creating homework assignments or class work. Consider adding a few review questions to every assignment this unit.)			PS1.A: Structure and Properties of Matter Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)	
Engage: How will you capture students' interest and get students' minds focused on the concept/topic?	Teacher-lead discussion and demonstration: Ask students if protons, neutrons and electrons can be broken into smaller particles. Most will argue no, but surprise them with the knowledge of quarks! You can even spin it as you 'lied' to the students but now want to bring them into the inner circle of what the average person doesn't know. Make it exciting. DEMONSTRATION OPTION: Use magnets to demonstration repulsion and attraction of particles inside an atom.	• Demonstration Pg. 643 Holt Chemistry TE		PS1.A: Structure and Properties of Matter Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)	

Explore: What hands-on/minds-on common experience(s) will you provide for students?	Students can play "Around the World" game to practice whether an isotope is stable or not. Everyone sits at their own desk/chair except for student 1. Student 1 stands next to their opponent's seat and they also stand. The teacher holds up a card with an isotope and the first person to call out 'stable' or 'unstable' correctly gets to move on to another seat. If student 1 got it wrong, they take their opponents seat as the opponent moves on. The first person to make it all the way 'around the world' to their original seat is the winner. The first few rounds discuss as a class why the isotope is stable or unstable. After a few rounds of just saying stable or unstable, require that students justify which rules of stability they used to decide in order to be 'correct'.	• Pg. 647 Holt Chemistry "Rules to help you Predict Nuclear Stability"	Use Mathematics and Computational Thinking. Use mathematical representations of phenomena to support claims. (HS-PS1-7)	PS1.A: Structure and Properties of Matter A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4) PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2), (HS-PS1-7) PS1.C: Nuclear Processes Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)	Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)
Explain: How will you help students connect their exploration to the concept/topic under investigation?	Direction Instruction: Teacher must present lesson on all vocabulary terms used in this unit. Students can use a graphic organizer to define the terms strong force, mass defect, electrostatic forces, nucleons, nuclide and quarks.			PS1.C: Nuclear Processes Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) Energy and Matter The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)
Evaluate: How will students demonstrate their mastery of the learning objective(s)?	Administer an exit ticket, quiz or other assessment	• Holt Chemistry Pg. 647 Section 1 Review			
Extend: How will students deepen their conceptual understanding through use in new context?	As an extension for homework, have students think about how new elements could be formed. As a starting point perhaps have them watch the video or read the article linked to the right. They	• Video on creating new elements: http://vitalnj.pbslearningmedia.org/resource/lsps07.sci.phys.matter.stability/island-of-stability/	Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8)	PS1.A: Structure and Properties of Matter Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-	Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)

	could then write a short reaction paper or propose what element they would like to form and what they would name it.	• Article on creating new elements: http://vitalnj.pbslearningmedia.org/resource/arct14.sci.nvmakelem/how-to-make-an-element/		PS1-1) PS1.A: Structure and Properties of Matter A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4)	
Lesson Title/Number: Lesson 2 Nuclear Change		**Learning Objective(s):** SWBAT identify fission/fusion reactions and predict products. SWBAT identify the three kids of radioactive particles and the reactions they produce.			**Lesson Duration:** 80 minutes
Learning Cycle ***What lesson elements will support students' progress towards mastery of the learning objectives(s)?*** ****Elements do not have to be in conducted in sequence.***	***Learning Activities*** ***What specific learning experiences will support ALL students' progress towards mastery of the learning objective(s)?***	***Resources/Materials*** ***What curricular resources/materials are available to facilitate the implementation of the learning activities?***	***Science and Engineering Practices*** ***What specific practices do students need to use in order to progress towards mastery of the learning objective(s)?***	***Disciplinary Core Ideas*** ***What core ideas do students need to understand in order to progress towards mastery of the learning objective(s)?***	***Crosscutting Concepts*** ***What crosscutting concepts will enrich students' application of practices and their understanding of core ideas?***
Elicit: How will you access students' prior knowledge?	Ask students to review notes on Rutherford's Gold Foil Experiment - what particles did he use and what category do they fall into? Answer: Alpha particles and they are radioactive particles.			PS1.A: Structure and Properties of Matter Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)	
Engage: How will you capture students' interest and get students' minds focused on the concept/topic?	Direct Instruction: Teacher must present lesson on radioactive particles, fission, fusion and how to balance reactions.	• Holt Chemistry Pg. 648-657			
Explore: What hands-on/minds-on common experience(s) will you provide for students?	Activity: Students can build models of atoms undergoing beta decay, alpha decay or fission/fusion.	• Online simulation of fission and teacher's guide: http://www.agiweb.org/education/energy/nuc/act2.html • Visual representation of both fission and fusion as well as guiding questions for students: http://galileo.phys.virginia.edu/outreach/8thGradeSOL/NuclearReactions.htm • ACTIVITY DESCRIPTION Hole Chemistry TE Pg. 650	Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8)	PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2), (HS-PS1-7) Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) Energy and Matter The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

				(HS-PS1-8)	
Explain: How will you help students connect their exploration to the concept/topic under investigation?	Students will need practice balancing Nuclear Equations. Some form of differentiation should be used here as some students will find this easy and others difficult. Perhaps the three leveled "Training Wheel" Worksheet activity explained in earlier units. Don't forget to remind students that changing the atomic number changes the element. They should always check the atomic number on the periodic table to get the element correct.		Use Mathematics and Computational Thinking. Use mathematical representations of phenomena to support claims. (HS-PS1-7)	PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2), (HS-PS1-7) PS1.C: Nuclear Processes Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)
Elaborate: How will students apply their learning and develop a more sophisticated understanding of the concept/topic?	Have students create a Venn diagram on how fission and fusion are different/similar. Then have them create a balanced reaction to place in both sides demonstrating fission and fusion.		Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8) Use Mathematics and computational thinking. Use mathematical representations of phenomena to support claims. (HS-PS1-7)	PS1.C: Nuclear Processes Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) Energy and Matter The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)
Evaluate: How will students demonstrate their mastery of the learning objective(s)?	Administer an exit ticket, quiz or other assessment	• Pg. 657 Holt Chemistry Section 2 Review			

Extend: How will students deepen their conceptual understanding through use in new context?	If the final lesson of the unit will lead to a full on discussion of whether nuclear power is safe/efficient, etc. - an excellent homework assignment would be one that gets students thinking on this topic. One option is to have students read an article on how nuclear power plants function. Another option is a video on the Fukushima power Plant disaster.	• Article from How Stuff Works: http://www.howstuffworks.com/nuclear-power.htm • Fukushima video: https://www.youtube.com/watch?v=fyIBlygNlcc	Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)		Structure and Function Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)
Lesson Title/Number: Lesson 3 Half Life and uses of Nuclear Chemistry		**Learning Objective(s):** SWBAT calculate the remainder of a radioactive sample over time using half-life SWBAT describe some of the uses of nuclear chemistry			**Lesson Duration:** 40 min - 80 min depending on how in depth the uses discussion becomes.
Learning Cycle ***What lesson elements will support students' progress towards mastery of the learning objectives(s)?*** ****Elements do not have to be in conducted in sequence.***	***Learning Activities*** ***What specific learning experiences will support ALL students' progress towards mastery of the learning objective(s)?***	***Resources/Materials*** ***What curricular resources/materials are available to facilitate the implementation of the learning activities?***	***Science and Engineering Practices*** ***What specific practices do students need to use in order to progress towards mastery of the learning objective(s)?***	***Disciplinary Core Ideas*** ***What core ideas do students need to understand in order to progress towards mastery of the learning objective(s)?***	***Crosscutting Concepts*** ***What crosscutting concepts will enrich students' application of practices and their understanding of core ideas?***

Elicit: How will you access students' prior knowledge?	Have students select one of the following words to complete this sentence "Radioactivity can be harmful/beneficial." Then have them give at least three reasons why they chose the way they did.		Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)		Structure and Function Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)
Engage: How will you capture students' interest and get students' minds focused on the concept/topic?	DEMONSTRATION: Show students an X-Ray, MRI or CAT scan image. Discuss the benefits of such procedures and any danger involved. DISCUSSION OPTIONS: Have students relate half-life back to reaction rates. See Discussion questions linked right.	• Half-life relating to Reaction Rates Discussion Pg. 659 Holt Chemistry TE	Obtaining, Evaluating, and Communicating Information Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)		
Explore: What hands-on/minds-on common experience(s) will you provide for students?	Have students use pennies, candy, buttons or other small objects to complete a half-life demonstration. See resource linked left.	• Half-life penny/candy activity Pg. 641 Holt Chemistry TE • Radioactive decay and half-life tutorial: http://serc.carleton.edu/quantskills/methods/quantlit/RadDecay.html	Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8) Use Mathematics and Computational Thinking. Use mathematical representations of phenomena to support claims. (HS-PS1-7)	PS1.C: Nuclear Processes Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) Energy and Matter The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

Explain: How will you help students connect their exploration to the concept/topic under investigation?	Direct Instruction: Teacher must present formulas for half-life and complete sample calculations.		Use Mathematics and Computational Thinking. Use mathematical representations of phenomena to support claims. (HS-PS1-7)		
Elaborate: How will students apply their learning and develop a more sophisticated understanding of the concept/topic?	Direct Instruction/Mini Lesson: After students have been introduced to half-life and completed sample problems, share real life uses of half-life and radioactivity: Carbon dating, nuclear medicine etc. This can also segue into other uses of nuclear chemistry such as power plants, smoke detectors, painting analysis and cancer treatments. This can also be a time for students to fully debate whether nuclear power is a safe alternative to fossil fuels. This conversation can be driven in many beneficial directions at the discretion of the teacher.	• Article on carbon dating: http://vitalnj.pbslearningmedia.org/resource/phy03.sci.phys.matter.date/the-dating-game-radioactive-carbon/	Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)	PS1.C: Nuclear Processes Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8) Energy and Matter The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)
Evaluate: How will students demonstrate their mastery of the learning objective(s)?	Administer an exit ticket, quiz or other assessment	• Pg. 666 Holt Chemistry Section 3 Review			
Extend: How will students deepen their conceptual understanding through use in new context?	Students can pick one use of nuclear chemistry and research it history, success, changes over time, etc. They can complete any level of assignment from answering a few short questions to writing a full research paper on the topic.	• Modern Uses of Radioactive Isotopes: http://people.chem.duke.edu/~jds/cruise_chem/nuclear/uses.html	Obtaining, Evaluating, and Communicating Information Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)		Structure and Function Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)
Lesson Title/Number: Lesson 4 TEST				**Lesson Duration: 40 min**	