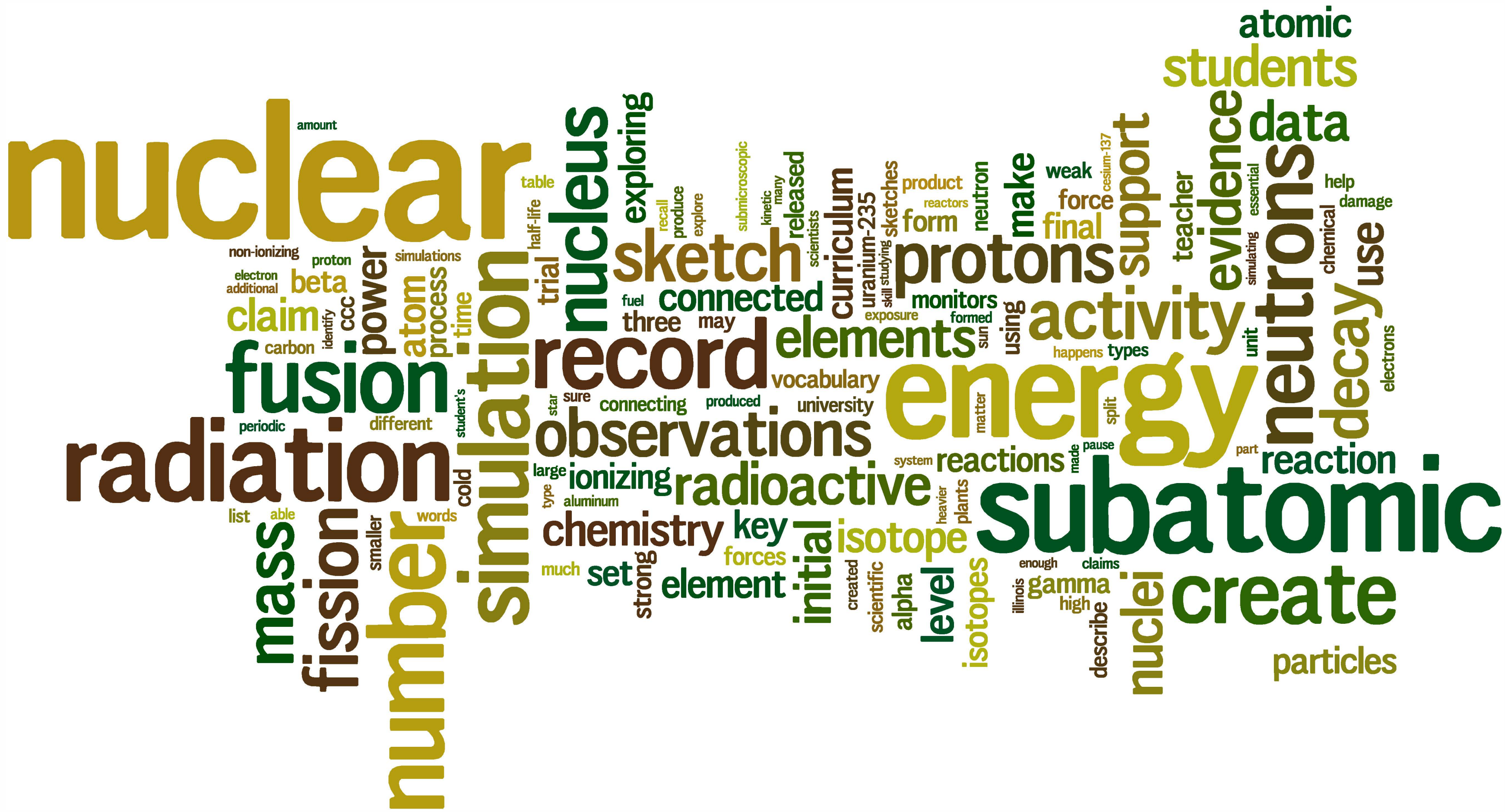
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The Connected Chemistry Curriculum

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The Connected Chemistry Curriculum

Technology

System Requirements

The Connected Chemistry Curriculum has a software component (a set of *Simulations*) which is available at The Connected Chemistry Curriculum website, connchem.org. This software is necessary to use the curriculum, and is open-source and free of charge.

Besides the CCC software, you will need:

- **A personal computer of recent vintage, with an OpenGL-enabled graphics card.**
- **A 13" screen (or larger), with at least 1280 × 800 (WXGA) pixel resolution**
  For most computer monitors this is not a problem. Projectors, on the other hand, sometimes only manage VGA resolution (640 x 480), which will not allow sufficient room for our Simulations.
- **The latest Java runtime environment (JRE)**
  As of this writing, the latest JRE is Java 6, version 29. Java is free of charge: http://www.java.com/en/download/
- **Macintosh OS X 10.6 (Snow Leopard) or later, or Windows 7 or later**
  Earlier versions of the Macintosh OS or Windows may run, but may suffer performance issues. The software should also run on Linux. None of these options have been tested, however, so make sure you run all simulations before using them live in the classroom.

Troubleshooting

Please consult The Connected Chemistry Curriculum website (connchem.org) for up-to-date troubleshooting information, and to download software.

Connected Chemistry

Nuclear Unit

Contents

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The Connected Chemistry Curriculum

Welcome

Welcome to *The Connected Chemistry Curriculum*! The Connected Chemistry Curriculum, or CCC, is designed to help students learn about chemistry by directly exploring the submicroscopic level of matter and phenomena that form the basis of study in chemistry. Educators designed CCC using direct feedback from teachers, students and researchers. CCC uses computer-based simulations to provide a unique submicroscopic perspective of the chemical world for students.

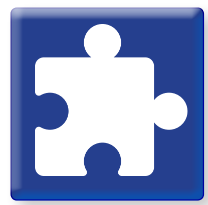
Activity Icons

These icons will be found throughout the teacher and student manuals.
The icons designate the purpose/theme of the activity or section.


Connecting


Hands-On Activity

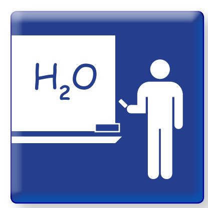

Student Simulations


Putting It All Together


Questions


Lab Safety

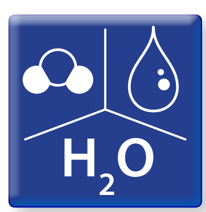

Sketching (without simulations)



Teacher Demonstration


Wet Lab


Teacher Facilitated Discussion



Chemistry Levels


Introductory Reading

Connected Chemistry

Nuclear Unit

Lesson 1: Exploring the Subatomic Level

Student's Lesson at a Glance

Lesson Summary

This lesson has five activities. Students look deeper into the structure of an atom by exploring the subatomic level. Students begin the lesson by connecting energy, isotopes, and the subatomic level with the 2011 nuclear disaster in Japan. Following a teacher demonstration, students use a CCC simulation to look at the subatomic makeup of three different elements. Students receive a short introduction to the four fundamental forces and explore weak and strong forces in the subatomic structure of an atom by adjusting them in the CCC simulation.

SWBAT (Student will be able to)

- Identify the subatomic particles that make up the structure of an atom
- Describe the characteristics and role of each of the subatomic particles
- Define what an isotope is, how they are formed, and what part isotopes play in nuclear reactions
- Identify and describe the two nuclear interactions of strong and weak nuclear forces
- Describe how elements are created

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- The nuclear unit focuses on the nucleus of atoms.
- Many questions will ask you "what you think" or "to make predictions." The only answer that is wrong is the answer that is left blank.
- The subatomic level is smaller than the submicroscopic level.
- Use the vocabulary section and note section to take notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time.
- When making subatomic observations, location of the particles in the simulation does not indicate the phase of matter.

Notes

Homework

Upcoming Quizzes/ Tests

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Activity 1: Connecting

1. What do you think an isotope is? Draw a subatomic picture that illustrates your definition.

Draw a subatomic sketch

2. What subatomic particles make up an atom? Describe their location and relationship to one another in an atom. You may want to create a simple diagram with a written explanation to clearly convey your ideas.

On March 11, 2011, a 9.0 magnitude earthquake occurred off the eastern coast of Japan. This earthquake caused extensive damage to business, industrial, and residential areas, including one nuclear power plant that was responsible for supplying energy to millions of people. Japan relies on electricity provided by the numerous nuclear power plants around the coast. The Fukushima Daiichi Nuclear Power Plant, a six *reactor* electric power-generating station, automatically shut down some of the reactors for safety following the earthquake. A reactor is a specially designed device for containing and controlling a nuclear reaction in nuclear fuel rods. A series of large destructive waves, also known as a tsunami, were created from the powerful underwater disturbance. The flooding and earthquake damage caused the reactors to be cut off from the main power grid and emergency generators. Pumps that helped circulate water around the reactors stopped working ,causing the reactors to overheat. In a few hours, three of the six reactors went into full *nuclear meltdown*, which is a potentially serious condition when the fuel rods inside a reactor overheat.

The nuclear fuel rods have an exterior that is composed mostly of zirconium and have uranium-235, a *radioactive isotope,* inside them. Fuel rods are normally cooled with a pool of cold water surrounding them. When the power was knocked out by the earthquake and tsunami, the safety devices that kept the water cool malfunctioned. The water began to boil and *chemically react* with the outer walls of the fuel cells to produce a high *concentration* of hydrogen gas. Hydrogen gas is extremely flammable and this ultimately led to explosions in the reactor that caused even more damage.

Over the next few days, electrical power was slowly restored to the plant so that automated cooling could resume. The length of time it took to stabilize the reactors allowed large amounts of *radiation* to be released into the atmosphere, ground, and ocean around the nuclear power plant. Nine days after the earthquake, the government announced that the power plant had to be *decommissioned* when the cleanup was complete, which could take several years.

Despite this disaster in Japan, nuclear power still remains a popular alternative energy source because it is a more *efficient* and cleaner energy source than energy sources that rely on *fossil fuels.* Recall from studying thermodynamics that energy cannot be created or destroyed (also called the **Law of Conservation of Energy**). Additionally, the **Law of Conservation of Mass** states that matter cannot be created or destroyed. Combined, these two laws help us understand the process of how nuclear power is generated. In contrast to fossil fuels, which generate power from chemical reactions, nuclear power is generated through the conversion of energy from one form to another in a *nuclear reaction*. In a nuclear reaction, uranium-235 is used as radioactive fuel that undergoes a *nuclear reaction* that releases energy. Nuclear energy is the direct result of splitting the nucleus of a radioactive isotope inside a nuclear reactor in a process that is different from a chemical reaction. To understand why so much energy is generated in a nuclear reaction, you will explore how an atom is composed and what happens at the *subatomic l*evel.

3. What is the difference between a chemical reaction and a nuclear reaction?

4. From your past experience, what do you know about nuclear energy?

5. From your past experiences, what do you know about radiation?

6. How are elements ordered on the periodic table based on their subatomic composition?

7. Hydrogen has three isotopes: H-1, H-2, and H-3. Each isotope has a different mass number. Use the table below to calculate the atomic mass for hydrogen.

Isotope	Atomic Mass	% in sample
H-1		
H-2		
H-3		

Activity 2: Exploring the Subatomic Level

Demonstration: *Use Simulation 1, Set 1*

At this point in CCC, you have only studied substances on the macroscopic and submicroscopic levels. Recall that the smallest part of an element that can take part in a chemical reaction is the atom, and the chemical properties of an element are related to the atomic number of the element. The chemical characteristics of cesium-137 and all other radioactive isotopes and elements are related to two distinctive **subatomic** properties: atomic number and mass number. An atom is very small, but the subatomic particles that make up the atom are even smaller and just as important to understanding matter and energy.

- *Using the simulation, your teacher will show a single atom of helium. Because colors represent types of elements in CCC, subatomic particles are represented by different types of patterns on the circles in order to not confuse subatomic particles with elements.*
- *Create a subatomic sketch including a key. Include a written description and record data from the monitors.*

	Create a subatomic sketch	Record Data from Monitors			
		Number of protons		Number of neutrons	
		Atomic number		Mass number	
		Create a written description of sketch			
Key					

8. Is the nucleus visible on the subatomic, submicroscopic, macroscopic, or microscopic level? *Support your claim with evidence.*

9. What determines an element's mass number?

10. What determines an element's atomic number?

11. What determines an element's atomic mass?

12. If you were to look out from the edge of the nucleus, would you be able to see the electrons that are in orbit around the nucleus? *Support your claim with evidence.*

13. Is your sketch from the simulation an isotope of helium? *Support your claim with evidence.*

Activity 3: Students Exploring the Subatomic Level

Simulation: *Use Simulation 1, Set 1*

- *Using the same simulation as your teacher's demonstration, explore the three additional elements in the simulation.*
- *Add each element individually to the simulation and zoom in to examine their features.*
- *Create a subatomic sketch including a key. Include a written description and record data from the monitors.*

Carbon	**Create a subatomic sketch**	**Record Data from Monitors**			
		Number of Protons		Number of Neutrons	
		Atomic Number		Mass Number	
		Record Your Observations			
Aluminum	**Create a subatomic sketch**	**Record Data from Monitors**			
		Number of Protons		Number of Neutrons	
		Atomic Number		Mass Number	
		Record Your Observations			

Potassium	Create a subatomic sketch	Record Data from Monitors			
		Number of Protons		Number of Neutrons	
		Atomic Number		Mass Number	
		Record Your Observations			
Key					

- *Several tables have been provided below to help complete the analysis questions for carbon, potassium, and aluminum.*

Isotope	Atomic Mass	% present in sample
C-12	12.0	98.92%
C-13	13.003	1.07%
C-14	14.003	0.001%
Total Carbon	**39.006**	**100%**
K-40	39.964	0.0001%
K-39	38.964	93.26%
K-41	40.962	6.73%
Total Potassium	**119.89**	**100%**
Al-27	26.982	100%
Total Aluminum	**26.982**	**100%**

14. What is the most common isotope of carbon based on the data above? *Support your claim with evidence.*

15. What is the most common isotope of potassium based on the data above? *Support your claim with evidence.*

16. What is the most common isotope of aluminum based on the data above?

17. Based on the table above, how does aluminum differ from potassium and carbon?

18. Based on the data from the simulation, what isotope of carbon was simulated?

19. Based on the data from the simulation, what isotope of aluminum was simulated?

20. Based on the data from the simulation, what isotope of potassium was simulated?

21. How is it possible to distinguish why one nucleus is an isotope of carbon and not an isotope of any other element?

Activity 4: Subatomic Forces

Demonstration

22. Your teacher holds a small ball above the ground then drops it. What happens to the ball? *Explain why you think this happens.*

23. Your teacher places the north pole end of a magnet next to the south pole end of another magnet. What happens to the magnets? Why?

24. Your teacher tears a piece of aluminum foil apart into smaller pieces. Could a single atom of aluminum be torn apart by hand? *Support your claims with evidence.*

All of the examples given above represent processes that result from the interaction of forces. **Gravity**, **electromagnetism**, **strong nuclear force,** and **weak nuclear force** are the four fundamental forces of the universe. These forces are responsible for all of the physical and chemical properties of a substance as well as the conversion of energy. For the remainder of this unit, you will focus on the properties of strong and weak nuclear forces, which are the forces that hold the nucleus of an atom together.

The weak nuclear force holds the protons and neutrons together within the nucleus. The strong nuclear force is the strongest of the four fundamental forces. The strong force holds together particles called **quarks**, which are smaller than protons and neutrons. Although the strong nuclear force is stronger than the other three forces, its effects are felt at extremely short ranges. The following CCC simulations will help visualize the difference between the weak and strong force.

Activity 5: Simulating Subatomic Forces

Simulation: *Use Simulation 1, Set 2*

In the following CCC activity, you will explore what happens to the nucleus of a carbon atom when you manipulate strong and weak forces. Create an initial subatomic sketch and record your observations. Be sure to include a key. Use the simulation to decrease the strong force. Create a subatomic picture and record your observations. Reset the simulation and then decrease the weak force. Create a subatomic picture and record your observations.

Initial	**Create a subatomic sketch**	**Record Your Observations**
Decreased Strong Force	**Create a subatomic sketch**	**Record Your Observations**
Decreased Weak Force	**Create a subatomic sketch**	**Record Your Observations**
Key		

25. Compare and contrast the decreasing strong force to the decreasing weak force.

26. Is it possible to have a "weak" strong force? *Support your claim with evidence.*

27. Is it possible to have a "strong" weak force? *Support your claim with evidence.*

28. How would increasing the strong or weak force affect the stability of a nucleus?

Lesson Reflection Questions

29. What are two modern uses of isotopes in everyday life? *Explain how isotopes are used for each example.*

30. Are all isotopes radioactive? *Explain your answer and include a discussion about what it means for an isotope to be radioactive.*

Student's Lesson at a Glance

Lesson Summary

This lesson has three activities. Students explore how energy is generated at a nuclear power plant through the fission of heavy radioactive isotopes. In the Connecting Activity, students learn about what the process of fission is, the fuels that are commonly used, how much energy is converted during fission, and the products of a nuclear reaction. Following a teacher demonstration of the simulation using uranium-235, students create subatomic sketches, record observations, and answer analysis questions. Students then use the same simulation to explore nuclear reactions of cesium-137. Using the data and subatomic sketches from the simulations, students answer analysis questions.

SWBAT (Student will be able to)

- Define and describe the process of fission
- Describe the flow of energy in a nuclear reaction

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Thermodynamics processes and nuclear reactions are closely related. Looking back on concepts related to thermodynamics may be helpful to understand the concepts in this lesson.
- Nucleus is singular. Nuclei is the plural.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Arrows will be helpful in showing both the direction and velocity in your submicroscopic sketches. In nuclear, you may use zig zag arrows to represent energy. Make sure to define the meaning of arrows in your key.
- You know that the electrons are part of the atomic structure; however, if you were to stand on the edge of the nucleus of an atom and look out you would not be able to see them because of their great distance from the nucleus. This is why electrons are not represented in the simulations.
- There is a periodic table and list of common elements used in the back of this book. You will need to refer to the periodic table often.
- When making subatomic observations, location of the particles in the simulation does not indicate the phase of matter.

Notes

Homework

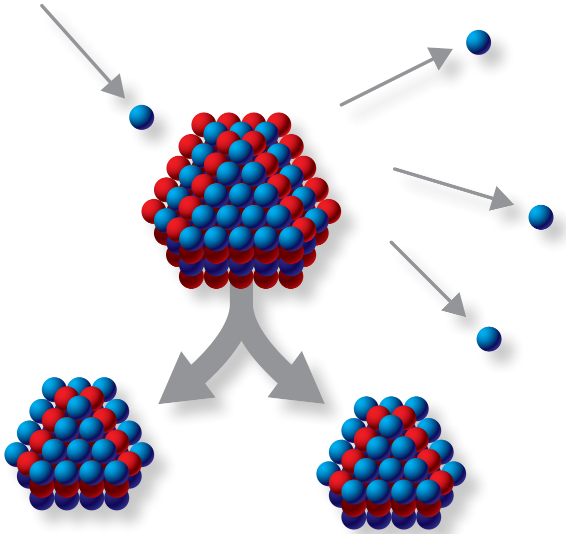
Upcoming Quizzes/ Tests

Activity 1: Connecting

According to the the International Atomic Energy Agency, nuclear power plants across the planet generate 14% of the world's electricity. The United States, Japan, and France account for the largest number of these nuclear power plants. There are 104 licensed plants across the U.S. with the majority of the plants located east of the Mississippi River. These plants produce 19.2% of the country's energy. In contrast, there are over 10,000 fossil fuel plants across the U.S. that produce around 80% the country's energy. How do so few nuclear power plants generate such large amounts of energy? Nuclear power plants rely on **fission reactions** to produce power.

Fission is a nuclear reaction in which the nucleus of a very heavy atom is split into two lighter nuclei, which usually releases three free neutrons and 200 million *electron volts* (eV) of energy. Nuclear power plants use isotopes of the elements cesium, uranium and plutonium as fuel. Uranium-235, cesium-137, and plutonium-239 are used in fission reactions because these isotopes can be split easily into lighter elements. Recall that isotopes have the same number of protons, but the number of neutrons varies, which changes the mass number and the atomic mass of the isotope as shown in the chart below. The difference in the mass number is reflected in the number that follows the name of the element.

Name	Protons	Neutrons	Mass Number	Atomic Mass (amu)
Uranium-238	92	146	238	238.0507
Uranium-235	92	143	235	238.0289
Cesium-133	55	78	133	132.9054
Cesium-137	55	82	137	136.9071



Fission reactions are possible because some isotopes have a large number of protons and neutrons in their *nuclei* with a large amount of potential energy that make them unstable. A fission reaction is initiated by shooting a neutron at high speeds into the nucleus of a radioactive isotope, such as uranium-235. One nucleus of uranium-235 is split into two smaller radioactive nuclei by the collision with the neutron. During the fission reaction, 3.2×10^{-11} joules of energy is released from each atom that is split. Initially this seems like a small amount of energy, but note that this small amount of energy is released when only one atom is split. Remember that one mole of uranium has 6.022×10^{23} atoms, so 1 kg of uranium would produce a massive amount of energy if every atom were split during a nuclear reaction. In fact, splitting one kilogram of uranium-235 would produce as much energy as burning 20,000 kg of coal or 11,000 kg of oil.

In addition to energy, three neutrons are usually released during a fission reaction. Of the three free neutrons released, two come from the original nucleus and the other is from a neutron being shot in to initiate the fission reaction. These neutrons move at a high velocity with tremendous kinetic energy and ultimately collide with up to three other uranium-235 nuclei. More neutrons are thus released, causing a chain reaction. In nuclear reactors, this process must be controlled carefully to prevent it from progressing too quickly and releasing too much energy at once. The energy that is given off from the fission reaction is used to heat water to produce steam. The steam is used to turn giant turbines and produce electricity that is carried by power lines to homes and businesses.

1. If a neutron with very low kinetic energy is fired at the uranium-235 nucleus, what do you think will happen when it hits the nucleus? *Support your claim with evidence.*

2. What types of energy are involved to produce electricity from a fission reaction? *Support your claim with evidence.*

3. The process of fission is one type of nuclear reaction. Are nuclear reactions the same as chemical reactions? *Support your claim with evidence.*

4. During fission, a massive uranium-235 nucleus splits into two smaller nuclei. Using the simulation, how would you be able to determine what elements those nuclei are?

Activity 2: Demonstrating Fission

Demonstration: *Use Simulation 2, Set 1*

- *Create an initial sketch of uranium-235. Record your observations and the mass number. Make sure to include a key.*
- *Using the simulation, your teacher will shoot a high speed neutron at the nucleus of uranium-235.*
- *Your teacher will pause the simulation immediately after the nucleus is split. Create a sketch of the two smaller nuclei that were created. Record observations and the mass number of each of the new nuclei.*
- *Your teacher will reset the simulation for a second trial.*
- *For trial 2 you do not need to create an initial and final sketch. Shoot the neutron at the nucleus. Pause the simulation immediately after the nucleus is split.*
- *Create a sketch of the two smaller nuclei that were created. Record observations and the mass number of each new nuclei.*

	Create a Subatomic Sketch	Record Data from Monitors				
Initial			Mass Number		Protons	
			Neutrons		Atomic Number	
		Record Your Observations				
Trial 1		**Element 1**	Mass Number		Protons	
			Neutrons		Atomic Number	
		Element 2	Mass Number		Protons	
			Neutrons		Atomic Number	
		Record Your Observations				

	Create a Subatomic Sketch	Record Data from Monitors				
Trial 2		Element 1	Mass Number		Protons	
			Neutrons		Atomic Number	
		Element 2	Mass Number		Protons	
			Neutrons		Atomic Number	
		Record Your Observations				
Key						

5. How many neutrons are released per one nucleus hit?

6. In Trial 1, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

7. Do the two elements that are formed after fission have more or less chemical potential energy than the original uranium-235? *Support your claim with evidence.*

8. In Trial 2, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

9. Were the same elements made in trial 1 and 2? How do you know?

Activity 3: Simulating Fission

Simulation: *Simulation 2, Set 1*

- *Select cesium-137 as the element to use in the simulation.*
- *Create an initial sketch of cesium-137. Record observations and the mass number. Make sure to include a key.*
- *Using the simulation, shoot a high-speed neutron at the nucleus of cesium-137.*
- *Pause the simulation immediately after the nucleus is split. Create a sketch of the two smaller nuclei that were created. Record observations and the the atomic mass number of each of the new nuclei.*
- *Reset the simulation for a second trial.*
- *For trial 2, you do not need to create an initial and final sketch. Shoot the neutron at the nucleus. Pause the simulation immediately after the nucleus is split.*
- *Create a sketch of the two smaller nuclei that were created. Record observations and the the atomic mass number of each of the new nuclei.*

	Create a subatomic sketch	Record Data from Monitors			
Initial		Mass Number		Protons	
		Neutrons			
		Record Your Observations			

<table>
<tr><td rowspan="6">Trial 1</td><td rowspan="6">Create a subatomic sketch</td><td colspan="5">Record Data from Monitors</td></tr>
<tr><td rowspan="2">Element 1</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Element 2</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">Record Your Observations</td></tr>
<tr><td rowspan="6">Trial 2</td><td rowspan="6">Create a subatomic sketch</td><td colspan="5">Record Data from Monitors</td></tr>
<tr><td rowspan="2">Element 1</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Element 2</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">Record Your Observations</td></tr>
<tr><td colspan="7">Key</td></tr>
</table>

10. In Trial 1, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

11. Do the two elements that are formed after fission have more or less chemical potential energy than the original cesium-137? *Support your claim with evidence.*

12. In Trial 2, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

13. Were the same elements made in Trials 1 and 2? How do you know?

14. Recall that matter cannot be created or destroyed as defined by the Law of Conservation of Mass. The sum of the atomic masses of the two elements produced by the fission of the heavier nucleus is always less than the atomic mass of the element. Why?

15. What types of energy occur in a fission reaction when the chemical potential energy from the heavier nucleus is converted into a new form of energy?

16. What type of energy is being utilized to initiate the nuclear reaction?

Lesson Reflection Question

17. Now that you have explored the concept of **nuclear fission**, describe what you think happens inside nuclear fuel rods to create nuclear energy.

Student's Lesson at a Glance

Lesson Summary

This lesson has three activities. Students learn in the introduction that stars, such as the Sun, have such extreme conditions that fusion reactions occur. Students discover that fusion is the joining of two lighter nuclei into a more massive one. Following a teacher demonstration in which two different hydrogen nuclei are fused, students use the same simulation to make helium-4 (He-4), beryllium-8 (Be-8), carbon-12 (C-12), and oxygen-16 (O-16) from the lighter nuclei provided. Students create subatomic sketches and gather data to answer analysis questions. In Part 2 of the activity, students are provided with the five outcomes of the fusion of two C-12 nuclei to explore how elements heavier than iron are formed. In the final activity, students have an opportunity to watch a video, to research fusion reactions, and to present on the controversial topic of cold fusion.

SWBAT (Student will be able to)

- Describe how elements are created from fusion reactions.
- Define and describe the process of fusion.
- Describe the flow of energy in a nuclear reaction.

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

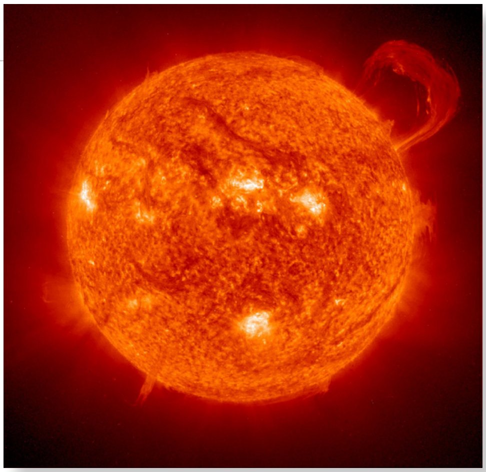
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Keys can help you and others decode your sketches at a later time.
- Arrows will be helpful in showing both the direction and velocity in your submicroscopic sketches. In nuclear you may use zig zag arrows to represent energy. Make sure to define the meaning of arrows in your key.
- There is a periodic table and list of common elements used in the back of this book. You will need to refer to the periodic table often.
- Remember all elements are isotopes. The isotopes on the periodic table are the most commonly occurring. Isotopes have the same number of protons, but different number of neutrons.
- When making subatomic observations, location of the particles in the simulation does not indicate the phase of matter.

Notes

Homework

Upcoming Quizzes/ Tests

Activity 1: Connecting



1. In your own words, define what the term "fuse" means.

At the center of our Solar System is a star that has contributed extensively to sustaining life on Earth for millions of years. Recall that the energy of the Sun has been captured in fossil fuels. This energy is in the form of chemical potential energy that we convert so we can heat our homes and power machines. Another way that the Sun produces large of amounts of energy for the Earth is in the form of heat and light through a process called **fusion**. This process releases energy that is responsible for creating all the known elements. Fusion is the process by which two or more atomic nuclei are fused together to form a single more massive nucleus. During the fusion of nuclei, a large quantity of energy is released.

Inside the Sun and other stars, the temperature, pressure, and gravity are so extreme that hydrogen nuclei are forced together as part of a fusion process to form helium. This releases more energy that fuels additional fusion reactions in the Sun. When a star consumes all of its hydrogen, helium nuclei begin to fuse to form carbon. The fusion process continues to form all the essential elements of life, including nitrogen and oxygen. Inside the star, the final element that is created from fusion is iron. Iron cannot fuel additional fusion reactions in the star, and all nuclear reactions in the star eventually stop. When this happens, the star "dies." As the star dies, a large explosion called a *supernova* occurs, which releases enough energy to fuse the iron nuclei into many of the other known elements. Fusion is not easily achieved outside of the environment of stars. Scientists have tried for many years to create the precise conditions that would allow a fusion reaction to take place on Earth. Hypothetically, properly harnessed fusion reactions could provide limitless sources of power for the entire human population and make our reliance on non-renewable and environmentally damaging resources unnecessary.

2. How likely would it be for a fusion reaction to occur in the Sun, if the temperature of the Sun were to suddenly decrease? *Support your claim with evidence.*

3. What are the products of a fusion reaction?

4. Why does a star need to become a supernova to form elements more massive than iron?

Activity 2: Demonstrating Fusion

Demonstration: *Use Simulation 3, Set 1*

During the fusion process, multiple isotopes of an element can be formed. Recall that the temperature and pressure inside the Sun and other stars is extremely high, which permit fusion reactions to occur. This simulation creates conditions that allow fusion to occur.

- *Using the simulation, your teacher will select two nuclei to fuse. The product of this fusion must be helium-3 (He-3).*
- *Create a subatomic sketch, record observations and data. Make sure to include a key.*
- *Your teacher will push the play button so that fusion occurs.*
- *After a few seconds pause the simulation, create a final subatomic sketch, record observations and data.*

5. What is the difference between hydrogen-1 (H-1) and hydrogen-2 (H-2)?

6. What would happen if the two smaller nuclei had small kinetic energies before the collision?

	Create a subatomic sketch	Record Your Observations
Initial		
	Create a subatomic sketch	Record Your Observations
Final		
Key		

Activity 3: Simulating Fusion

Part 1: Simulation: *Use Simulation 3, Set 1*

Using the simulation, you must create three substances: Helium-4 (He-4), Beryllium-8 (Be-8), and Carbon-12 (C-12).

You may select two smaller nuclei at a time to fuse in order to create these substances. You may use two of the same kind.

- *Record the two nuclei needed to make He-4 in the initial box of the nuclei column.*
- *Create a subatomic sketch, record observations. Make sure to include a key.*
- *Push the play button so that fusion occurs.*
- *After a few seconds pause the simulation, create a final subatomic sketch and record observations. Record any additional products in the final box of the nuclei column.*
- *Repeat procedure to make Be-8 and C-12.*

		Initial	Final
Trial 1: He-4	Create a Subatomic Sketch		
	Record your Observations		
Trial 2: Be-8	Create a Subatomic Sketch		
	Record your Observations		

		Initial	Final
Trial 3: C-12	Create a Subatomic Sketch		
	Record your Observations		
Key			

7. Were there any other products made as a result of the fusion of two lighter nuclei? *Support your claim with evidence.*

8. What is the relationship the temperature at which fusion occurs and the size of the nuclei involved? *Support your claim with evidence.*

Part 2: Creation of Heavier Elements

As stars use the last of their helium fuel, if they are massive enough, then they will collapse. When they collapse, even greater temperatures and pressures are reached, which permit other elements to fuse together. The temperatures at which this happens is 600-700 million Kelvin! At this temperature range, two C-12 nuclei can fuse. Their fusion can result in the five possible combinations of products.

- C-12 + C-12 + ***Energy*** → O-16 + 2 He-4
- C-12 + C-12 → Ne-20 + He-4 + ***Energy***
- C-12 + C-12 →Na-23 + ***proton*** + ***Energy***
- C-12 + C-12 + ***Energy*** → Mg-23 + ***Neutron***
- C-12 + C-12 → Mg-24 + ***Energy***

9. Which of these combinations are endothermic? *Support your claim with evidence.*

10. Which of these combinations are exothermic? *Support your claim with evidence.*

Lesson Reflection Questions

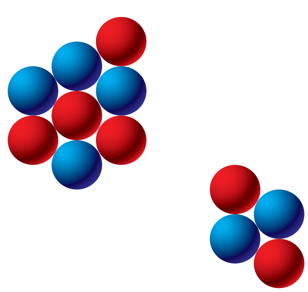
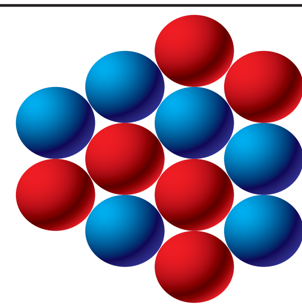
11. Explain the difference between **nuclear fission** and **nuclear fusion**. *Be sure to include a discussion at the subatomic level.*

12. Both nuclear fission and nuclear fusion can be used to produce nuclear energy. Which do you think is the more efficient and better method of energy production? *Be sure to include a discussion about the amount of energy released, the conditions necessary for each process to occur, and the potential impacts on the environment.*

Activity 4: Capstone Activity

13. Consider the following two scenarios. For Scenario 1, determine the initial element(s) and final element(s). The red circles are protons and the blue circles are neutrons. Decide whether the subatomic picture is depicting fusion or fission and provide evidence for your answer. Write a symbolic equation for the nuclear reaction represented in the subatomic pictures in the scenario.

Scenario 1

Before	After
	

Scenario 2

Using the table provided, construct a subatomic picture before and after the nuclear reaction occurs. Determine the identity of the initial element(s) and the final element(s). Decide whether the subatomic picture is depicting fusion or fission and provide evidence for your answer. Write a symbolic equation for the nuclear reaction represented in the subatomic pictures in the scenario.

	Mass Number	Neutrons	Protons
Reactant #1	137	82	55
Product #1	50	31	19
Product #2	85	49	36

Before	After

Connected Chemistry

Nuclear Unit

Lesson 4: Radioactive Decay

Student's Lesson at a Glance

Lesson Summary

The final lesson of the unit has five activities. In the Connecting Activity, students are introduced to ionizing and non-ionizing radiation. Students follow up with an activity in which they calculate their own personal radiation exposure. The teacher demonstrates the three types of ionizing radiation with a CCC simulation, and students will create subatomic sketches and gather data that allow them to correctly identify each process. Students use another simulation to explore the radioactive decay of three isotopes of different elements. Students create subatomic sketches and gather data so that they are able to identify the products of the decay. In the final activity, teachers may show students a video or other media regarding cold fusion and have them present a short presentation.

SWBAT (Student will be able to)

- Define and describe the process of radioactive decay
- Identify and describe alpha, beta, and gamma decay
- Define and describe half-life
- Calculate half-life
- Describe the flow of energy in a nuclear reaction
- Identify the costs and benefits of using nuclear reactions to generate energy

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Prefixes and suffixes on words can help you discover the meaning of a word.
- Use the vocabulary section and notes section to take good notes so that studying for tests and quizzes will be easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Keys can help you and others decode your sketches at a later time.
- Arrows will be helpful in showing both direction and velocity in your submicroscopic sketches.
- There is a periodic table and list of common elements used in the back of this book. You will need to refer to the periodic table often.
- Write out all your calculations so you can use them to study or see where you may have made mistakes if you had an incorrect answer.
- When making subatomic observations, location of the particles in the simulation does not indicate the phase of matter.
- The Greek symbols alpha, beta and gamma will be used in this lesson as a form of scientific shorthand. α is alpha, β is beta, and λ is gamma.

Notes

Homework

Upcoming Quizzes/ Tests

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Please turn to the next page.

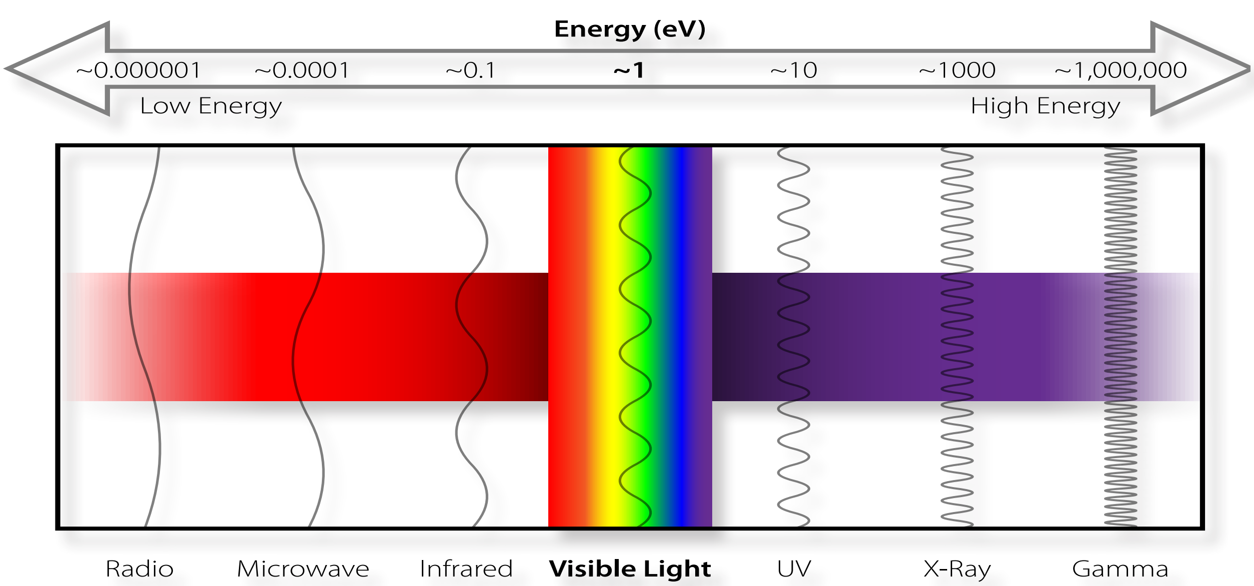
Activity 1: Connecting

1. What do you know about how radiation is used? Include both the positive and negative effects of radiation exposure.

Radiation is a process in which high energy particles or waves travel through empty space. Radiation is released from either naturally occurring or man-made fission reactions. People are exposed to some form of radiation every day. According to the Division of Environmental Health Office of Radiation Protection (2010), the average person in the US is exposed to 324 millirem (mrem) of background radiation, of which 81% comes from natural sources.

The type and amount of radiation determines whether the radiation is a cause of concern for human health. There are two types of radiation: **ionizing radiation** and **non-ionizing radiation**. For example, sunlight contains both ionizing and non-ionizing radiation.

In physics, students learn about radio waves, microwave waves, infrared, and visible light. All of these waves are all classified as non-ionizing radiation with very long wavelengths. Non-ionizing radiation increases the kinetic energy of the molecules of the substance that it passes through, but does not have enough energy to create ions. The non-ionizing radiation of sunlight provides light and warmth. You might remember learning about *radio waves*, *microwave waves, infrared*, and *visible light* from your physics class. These are all examples of non-ionizing radiation because they have long wavelengths.



Chemists study ionizing radiation in the form of *ultraviolet (UV) rays*, *X-rays*, and *gamma rays* because they are able to create ions. Ionizing radiation with very short wavelengths has enough energy to make an electron break away from an atom or molecule. Recall that losing an electron will cause an atom to become a *cation*, a positively charged ion. Ions are chemically reactive which can cause major damage to living cells. If the ionizing radiation is strong enough, damage can be done to *DNA*, the genetic building blocks of life on earth. Damage to DNA can cause mutations in the offspring of parents exposed to high levels. With enough exposure ionizing radiation from the Sun - in the form of UV rays - damage is done to living cells.

2. Compare and contrast ionizing radiation and non-ionizing radiation.

3. What types of energy are involved in ionizing and non-ionizing radiation? *Support your claim with evidence.*

Activity 2: Calculating Radiation Exposure

Recall that radiation can be natural and man-made. Some man-made radiation is used for medical reasons in the treatment of diseases such as cancer. The diagnoses for broken bones, tumors, and other internal damage that cannot be seen without exploring inside the human body involves man-made radiation produced by X-ray machines and computer tomography (CT) scanners.

We are constantly exposed to natural radiation from substances in the Earth, from naturally occurring radon in the air, and from outer space. Even some of the foods we eat have absorbed radiation from where it was grown. According to the American Nuclear Society (2011) people are exposed on average to 620 mrems of radiation each year. Standards dictate that individuals who work with or around radioactive materials should be exposed to no more than 5,000 mrems each year. There are surveys available from research and safety agencies that allow you to calculate how much radiation you are exposed to.
You can access the online or paper version for the American Nuclear Societies' Radiation Dose Chart at http://www.new.ans.org/pi/resources/dosechart/

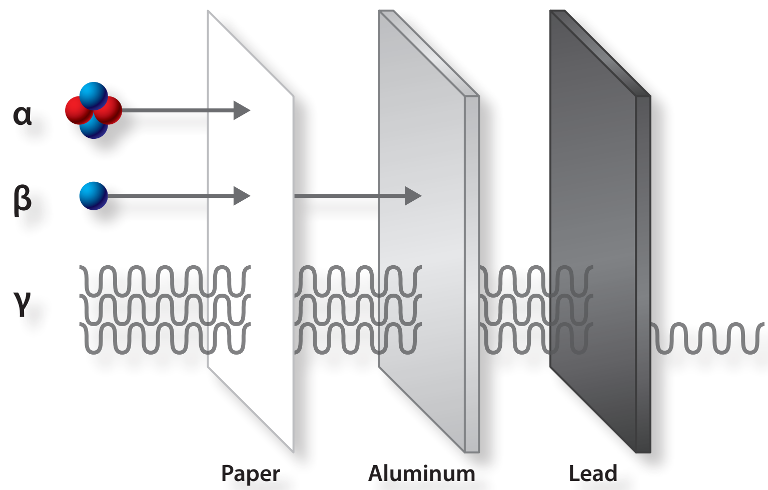
Activity 3: Simulating Ionizing Radiation

Use Simulation 4, Set 1-3

The amount of damage that ionizing radiation can do to living cells depends on the energy and type of particles that make up ionizing radiation. There are three types which include **alpha particles**, **beta negative particles**, and **gamma rays**.

Alpha particles, represented by the Greek symbol α, consist of two protons and two neutrons. Alpha radiation can penetrate a regular sheet of paper, but will not penetrate human skin or clothing, so it is unable to do cellular damage.

Beta negative particles, represented by the Greek symbol β^-, are released when the ratio of neutrons to protons in the nucleus is high. In this case, a neutron spontaneously transforms into a proton and a nuclear electron. Nuclear electrons are different than electrons that orbit the nucleus. The proton stays in the nucleus and the nuclear electron is ejected with high velocity. Beta radiation can be prevented from penetrating human skin using a thin layer of metal or a thicker layer of plastic.



If the ejection of the beta particle does not release enough energy for the nucleus to become stable, then the nucleus also releases a gamma ray. **Gamma radiation** is composed of photons and represented by the symbol γ. This release of energy is the most damaging form of ionizing radiation because it can pass through most matter and penetrate much farther than alpha or beta negative particles. Thick lead shielding is used to reduce exposure to gamma radiation.

You may be familiar with having an **X-ray** taken if you have broken a bone. Gamma rays should not be confused with X-rays. Both can have damaging effects, but gamma rays have shorter wavelengths and are much higher in energy than X-rays. X-rays are more powerful than alpha and beta radiation, but hospitals use shielding in the walls and in protective gear for patients and employees to limit exposure.

- *Using Simulation 4, Sets 1 -3 ,you will identify what type of ionizing radiation is released in each set.*
- *Select Set 1. Create an initial sketch and record initial data. Run the simulation until a particle or wave is emitted from the nucleus. Pause the simulation.*
- *Create a subatomic sketch and record your observations. Make sure to include a key.*
- *Repeat procedure for set 2-3.*

	Initial State		Final State	
	Create Subatomic Sketch	Record Data	Create Subatomic Sketch	Record Data
Set 1		Mass number		Mass number
		Protons		Protons
		Neutrons		Neutrons
	Record Observations			
Set 2		Mass number		Mass number
		Protons		Protons
		Neutrons		Neutrons
	Record Observations			
Set 3		Mass number		Mass number
		Protons		Protons
		Neutrons		Neutrons
	Record Observations			
Key				

4. What type of radiation is produced in Set 1? *Support your claim with evidence.*

5. What type of radiation is produced in Set 2? *Support your claim with evidence.*

6. What type of radiation is produced in Set 3? *Support your claim with evidence.*

7. Compare the composition of alpha and beta particles. Why do you think that alpha particles cannot penetrate paper, but beta particles can?

8. Why is the density of the shielding material important when designing buildings where radioactive materials will be used matter?

Activity 4: Calculating Radioactive Decay

Alpha, beta, and gamma radiation are produced during **radioactive decay**. Radioactive decay occurs when the nucleus of an unstable atom loses energy by emitting ionizing radiation. The emission is *spontaneous* because the atom decays without any physical interaction from particles outside the atom.

Radioactive decay is important for dating very old objects. Scientists use a process called *carbon dating* which involves analyzing the decay of a naturally occurring isotope of carbon, that is carbon-14 (C-14). Carbon-14 decay can give scientists, such as *paleontologists*, an estimate of the age of a sample of bone or other organic material. The amount of time it takes for an unstable substance to decay can happen in seconds or take years. The **half-life** of carbon-14 is 5,730 years, while the half-life of uranium-235 is 713,000,000 years. Half-life, represented by the symbol $t_{1/2}$, is the time required for half of the atoms in a given sample to decay. The half-life for any isotope can be calculated experimentally because each isotope has a unique half-life value. The value for the half-life is independent of how many atoms of the substance is in the sample. Recall when an isotope decays through fission, alpha decay, or beta decay, it becomes another element. Half-life can be calculated with the following equation:

$$t_{1/2} = \frac{-t \times 0.693}{\ln(m_f) - \ln(m_i)}$$

t = time that has passed

m_i = initial mass of undecayed sample

m_f = remaining mass of decayed sample

ln = The natural log or $\log_e(x)$

Use Simulation 5, Sets 1-3

- *Using the simulation, you will gather data to determine the half-life for three different isotopes of different elements. You will also identify the element that results from the decay of the isotope.*
- *Record the name of the initial isotope, initial mass, number of protons, and number of neutrons.*
- *Run the simulation for 10 seconds and then pause.*
- *Create a subatomic sketch. Create a sketch of the graph and record observations. Record final mass, product protons, product neutrons, and time. Make sure to include a key and labels for data.*
- *Repeat procedure with sets 2 and 3.*

		Subatomic Sketches	Simulation Data			
Set 1	Initial		Initial Isotope	Initial Protons	Initial Neutrons	m_i
			Record Your Observations		Sketch the Graph	
	Final					
			Time	Product Protons	Product Neutrons	m_f

Set 2	Initial		Initial Isotope	Initial Protons	Initial Neutrons	m_i
			Record Your Observations		Sketch the Graph	
	Final					
			Time	Product Protons	Product Neutrons	m_f

		Subatomic Sketches	Simulation Data			
Set 3	Initial		Initial Isotope	Initial Protons	Initial Neutrons	**m_i**
			Record Your Observations		Sketch the Graph	
	Final		Time	Product Protons	Product Neutrons	m_f
Key						

9. Calculate the half-life for each of the three isotopes. Show your work.

10. Arrange the isotopes in order from greatest to least half-life time.

11. Why do some isotopes decay over time?

12. What element is the product of the radioactive decay of beryllium-11 (Be-11)? *Support your claim with evidence.*

13. What element is the product of the radioactive decay of fluorine-21 (F-21)? *Support your claim with evidence.*

14. What element is the product of the radioactive decay of nitrogen-16 (N-16)? *Support your claim with evidence.*

15. A student allowed 5 grams of a Be-11 to decay in the simulation for 13.8 seconds. How much of the Be-11 should be left? *Support your claim with evidence.*

16. A student left 10 grams of F-21 decay in the simulation for 8.4 seconds. How much of the F-21 would be left? *Support your claim with evidence.*

17. How long would it take 20 grams of N-16 to decay into .625 grams?

Lesson Reflection Questions

18. How does the Law of Conservation of Mass apply to the half-life simulations in this lesson?

19. Give an example an application of half-life in everyday life. *Be sure to describe why this is an example of half-life and what is happening at the subatomic level.*

Activity 5: Putting it All Together

Nuclear power comes with great benefits and high risks. The amount of energy that is released from fission of large atomic nuclei is extremely large. Advocates for nuclear power believe that it is a cleaner source of energy than burning fossil fuels. Several nuclear power plant disasters across the globe have made some people question how safe nuclear power is relative to other sources of energy. The byproducts of fission reactions include radioactive waste, which must be handled with caution to prevent radiation from leaking into the environment. What would happen if there was a nuclear reaction that could produce just as much power as those in regular nuclear power plants, but used water as fuel and had no threat of radioactive byproducts?

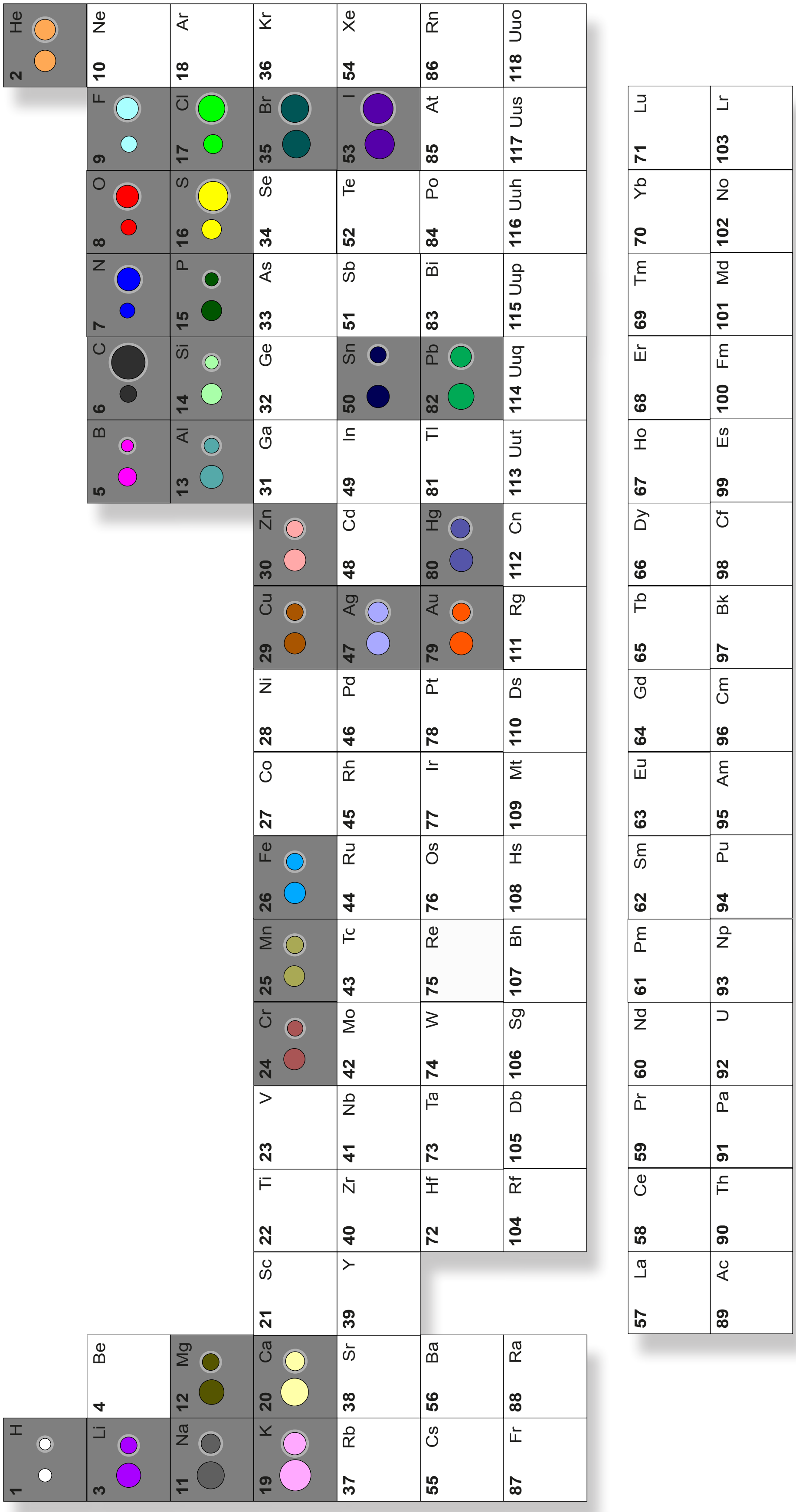
Fusion reactions only occur in the Sun. However, for many years some scientists have been experimenting with a process called cold fusion. With cold fusion, these scientists believe they can solve the energy crisis by providing an unlimited source of power. The promise of cold fusion has had many scientific highs, but ultimately many lows since it has yet to be achieved.

Using the media provided by your teacher and through your own research, you will explore what cold fusion is, how cold fusion works, and how the scientific community has responded to the findings from cold fusion experiments. You will present what you have learned in a group presentation to your class.

In your final presentation you must:

- *Define cold fusion*
- *Explain how cold fusion works using appropriate diagrams*
- *Explain how cold fusion is different from other forms of nuclear reactions, including fission and regular fusion.*
- *Describe the benefits and risks of cold fusion*
- *Explain the controversy surrounding cold fusion*
- *Explain the role of reproducibility in the scientific community and how it relates to cold fusion*

Elements Used in the Connected Chemistry Curriculum



Name	Symbol	Atomic Number	Atomic Weight
Hydrogen	H	1	1.00794
Helium	He	2	4.00260
Lithium	Li	3	6.941
Boron	B	5	10.811
Carbon	C	6	12.0107
Nitrogen	N	7	14.0067
Oxygen	O	8	15.9994
Fluorine	F	9	18.9984
Sodium	Na	11	22.9898
Magnesium	Mg	12	24.3050
Aluminum	Al	13	26.9815
Silicon	Si	14	28.0855
Phosphorus	P	15	30.9738
Sulfur	S	16	32.065
Chlorine	Cl	17	35.453
Potassium	K	19	39.0983
Calcium	Ca	20	40.078
Chromium	Cr	24	51.9961
Manganese	Mn	25	54.9380
Iron	Fe	26	55.845
Copper	Cu	29	63.54
Zinc	Zn	30	65.38
Bromine	Br	35	79.904
Silver	Ag	47	107.8682
Tin	Sn	50	118.710
Iodine	I	53	126.904
Gold	Au	79	196.967
Mercury	Hg	80	200.59
Lead	Pb	82	207.2