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

This page has been left blank.
Please turn to the next page.

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* level.

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			

<table>
<tr><td rowspan="4">Potassium</td><td rowspan="4">Create a subatomic sketch</td><td colspan="4">Record Data from Monitors</td></tr>
<tr><td>Number of Protons</td><td></td><td>Number of Neutrons</td><td></td></tr>
<tr><td>Atomic Number</td><td></td><td>Mass Number</td><td></td></tr>
<tr><td colspan="4">Record Your Observations</td></tr>
<tr><td colspan="6">Key</td></tr>
</table>

- *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.

	Create a subatomic sketch	Record Your Observations
Initial		
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.*