LESSON PLANS, READINGS & ACTIVITIES

CHEMISTRY: PROPERTIES OF MATERIALS

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 3 HOURS

CHEMISTRY: PROPERTIES OF MATERIALS

1 READING | 2 ACTIVITIES

INTRODUCTION

World War II came at a time when most manufacturing used natural materials. Clothes were mostly cotton and wool, with some linen and silk. Tires were made of rubber from the sap of a tropical plant, and shoes were made of leather, wood, and that very same kind of rubber. The makeup of the furniture in a house or classroom from World War II and even the clothes that students would have worn is radically different from those today.

One of the key things for students to learn in elementary and middle school science is that materials can be identified by their physical and chemical properties. Engineers, manufacturers, and inventors design materials to have specific properties. Leading up to World War II, this design was done by creating different metallic alloys and by choosing plant and animal products to make fibers. Shortages caused by the outbreak of the war and the diminished access to materials were the impetus for scientists to create new materials. The world of today, dominated by materials made from petroleum products, is a result of the revolution in materials science that started in World War II.

OBJECTIVE

Starting with a reading that asks students to consider the makeup of the built world they live in and to compare it to the past, these resources introduce students to the field of Materials Science. One activity is an experience with an unusual material, that also gives students experience with electricity and circuits. You could supplement this, if you want, with students making and/or testing the properties of other unusual materials, like slime, or oobleck, or bubble solutions. The second activity has students exploring how WWII-era advertisements promoted new technologies and manufacturing, and comparing them to the way science and technology are communicated today.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI PS3.A
Definitions of Energy

NGSS DCI ETS2.A
Interdependence of Science, Engineering, and Technology

NGSS DCI ETS2.B
Influence of Engineering, Technology, and Science on Society and the Natural World

NGSS SEP
Developing and Using Models

NGSS SEP
Obtaining, Evaluating, and Communicating Information

NGSS CCC
Patterns

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

3-5-ETS1-3
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

5-PS1-1
Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-3
Make observations and measurements to identify materials based on their properties.

MS-PS1-3
Gather and make sense of information to describe that synthetic materials that come from natural resources and impact society.

READING (1)

1. THE MOTHER OF INVENTION

Description
This short reading introduces the idea of material properties and gets students to think of how things are made and modified to match the needs of a community, population, or country. The reading will set up the activities in this unit. You can try grouping students in pairs or fours to read together or in turns, and to answer the questions.

ACTIVITIES (2)

1. SOFT CIRCUITS

Description
This is an activity that explores the properties of materials, conductivity, and complex circuits. Working in groups, students will be able to answer questions about these concepts through experiments making complex circuits. The worksheet that is included with this activity asks students to draw one of their circuits to demonstrate how electricity flows. Additional activities can consist of having students create parallel and series circuits, and then drawing both circuits on their worksheet.

Supplies (per group)
A tennis-ball sized lump of dough (see recipe below)
2 9V batteries with snap wires
A handful of small LED lights of 3-5V

To make the dough:
Recipe is enough for one class — dough will stay fresh for at least one month when wrapped in plastic.

Ingredients:
- 4 Cups water
- 6 Cups white flour
- 1 Cup table salt
- 3/4 Cup cream of tartar
- 4 Tbsp vegetable oil
- Food coloring

Combine five cups of flour and all other ingredients in a pot. Place the pot on the stove over medium heat and stir continuously. The mixture will begin to boil and start thickening. With the heat still on, keep stirring until the mixture forms a single ball. Remove the mixture from the heat, and place the ball of dough on a lightly floured surface and allow it to cool. Once cool, knead the remaining flour into the dough until it reaches a nice consistency.

The high concentration of salt is what makes the dough conductive. The cream of tartar makes the dough smooth and not so sticky.

Instructions
Demonstrate where everyone can see, under a document camera or at the front of the room, how to construct a simple circuit with the dough. Make two small balls of dough that are close together but not touching. Insert one battery wire in each ball, and then connect one of the lights across the balls. Explain that students might have to rotate the wires across the balls (LED bulbs are polar) before the LED lights up. Students are likely to be very surprised when they see the light go on. Next, show them what happens when the two lumps touch—that the light short circuits and goes out. Go around the room, making sure everyone understands, and ask questions to encourage further exploration. Exploration can include setting up multiple batteries and lights in different types of circuits.

2. ANTIQUE ADS

Description
An activity that uses a modified version of Claim Evidence Reasoning to discuss the relationship between technology, engineering, and society. This activity is a thinking scaffold that has students make a claim, provide evidence to support their claim, and then connect the two with reasoning. Students will work in small groups to analyze WWII advertisements and share and compare their findings with those of the rest of the class.

Supplies
Copies of the handout and reproductions (available from Real World Science site) for each student.

Instructions
Lead students in discussions by having students compare WWII advertisements from *Time* or *Newsweek* to modern technology and other ads they have seen. Use the modified Claim Evidence Reasoning framework to structure their thinking.

READING
MOTHER OF INVENTION

Many things have to come together to make an invention. The timing has to be right, and the inventor has to have a vision of how the creation will fill an important need. One of the major areas of innovation in World War II was in developing new kinds of materials.

PLASTICS IN THE PAST

Today when we say plastic, what we mean is a synthetic polymer, but really all plastic means is a material that is easy to shape. A polymer is a chemical that is made of a repeated chain of smaller chemicals or molecules.

Humans have been using polymers (wood, paper, horn, cotton, linen) for millennia. Rubber and other polymers from plant sap were used for many purposes for centuries until in the 1840s engineers learned to strengthen rubber by treating it with sulfur.

The first synthetic polymers were made in 1860 when John Wesley Hyatt treated cotton fiber with camphor to create celluloid. Celluloid, which could be carved or shaped and then polished, was meant to replace expensive and rare substances like horn, tortoiseshell, and ivory. Although celluloid was important in some manufacturing, in most areas natural polymers were still cheap and plentiful enough to be used instead of human-made ones.

In the early 1900s, chemical engineers began working with a new substance called coal tar.

Coal tar is a by-product of coal production, and engineers learned to make many products from it including dyes and sulfa drugs that were used to fight infections in the human body before penicillin.

A soldier inventories the pharmaceuticals in the hospital at a training camp. *(Image: The National WWII Museum, 2011.065.1960.)*

Medical technicians in a laboratory at Cape Gloucester, New Britain, August 1944. *(Image: The National WWII Museum, 2008.354.216.)*

In 1907, Leo Baekeland made the first completely synthetic plastic. He made it from coal tar and called it Bakelite. Throughout the decades before World War II, more and more plastics were made from coal tar and oil. Although radios, telephones, fancy furniture, jewelry, and sculptures were made from synthetic polymers, most manufactured products still used natural materials.

That all changed with the beginning of World War II.

Suddenly electronics systems were needed for tens of thousands of aircraft, boats, ships, radios, and radar systems. All of this equipment needed plastic insulation around their wires. The United States needed rubber for Jeep and airplane tires, tank treads, and soldiers' boots; however the plants that supplied the natural rubber were primarily grown on islands now controlled by the Japanese. Silk, also grown in Asia, was used for both parachutes and pantyhose. Women turned in their pantyhose to make more parachutes, but it wasn't enough, and at the same time plant polymers commonly produced in the tropics were harder to get.

By 1935, a polymer named nylon had been discovered, but it was more expensive than the silk and linen it was meant to replace. During wartime those natural materials were in short supply, and so nylon was used to make parachutes, ropes, and parts of clothing. The balance between the cost of synthetic and natural polymers had changed—manufacturers began developing ways to make products out of polymers from oil to replace plant materials. During World War II, plastic production in the United States increased 300 percent.

NAME: **DATE:**

PLASTICS TODAY

Look around the room you are in. What are all the objects in the room made of? What are your clothes, your backpack, your shoes made of? Chances are most of the objects are made of polymers, and many are synthetic. Synthetic means that it is made from polymers engineers created from oil or another source.

A B-29, the only WWII aircraft with a pressurized cabin, flying over Guam. *(Image: The National WWII Museum, 2010.216.358.)*

1. Fill in the data table below. What are objects in the classroom made of? Are they natural or synthetic?

OBJECT	MADE OF	SYNTHETIC OR NATURAL

2. Are the materials mostly natural or synthetic?

3. What is one object on the list that is synthetic and that you think would have been made of natural materials during World War II? Explain.

ACTIVITY
SOFT CIRCUITS

INTRODUCTION

With the onset of World War II, the United States needed to produce much-needed supplies and equipment fast. However, this rush to become an arsenal of democracy also created shortages in materials. This situation was made worse by interrupted supply chains from other countries. For the first time it became necessary to make polymers synthetically instead of just modifying natural products. During the war, manufacturers rushed to design polymers for specific purposes, but polymers didn't truly become a big industry until the end of the war. Once the process began, however, synthetic polymers dominated industrial manufacturing, and they still do today.

You are going to investigate a material with unusual properties. Follow your teacher's instructions, and use the materials you are given to conduct your investigation.

Rolls of copper signal wire (for telephones) are stacked at a signal camp in Naples, Italy, 1944.
(Image: The National WWII Museum, 2002.337.455.)

NAME: **DATE:**

1. What do you think is unusual about the material you are investigating?

2.What do you think gives it this unusual property?

3. Draw a diagram of one of the circuits you made, and show how electrical energy flows through it:

4. What is a substance on which you would like to experiment? Describe its properties and what need it would fulfill.

ACTIVITY
ANTIQUE ADS

INTRODUCTION

New materials and new solutions to pressing problems were critical to the victory of the Allied powers in World War II. Manufacturers advertised what they were making for the war effort in popular magazines even though people couldn't always buy these products. Companies believed that by communicating their efforts to support American troops in the war, people would be generally supportive of their company and would buy other products they made.

You will get a copy of a WWII magazine advertisement to investigate.

Ballpoint pens were a WWII innovation, and this *Time* advertisement for Parker Pens highlights this.
(Image: Education Collection of The National WWII Museum.)

Cadillac didn't make cars during the war years, but made engines and parts for planes.
(Image: Education Collection of The National WWII Museum.)

NAME: **DATE:**

1. What product is advertised? Is it a product people could buy?

2. Summarize the advertisement—Describe what you see, what you read, and what the images used are communicating.

3. How is it different than advertisements you might see today?

LESSON PLANS, READINGS & ACTIVITIES

CHEMISTRY: MIXTURES AND REACTIONS

GRADE LEVEL: 5-8 | TIME REQUIREMENT: 3 HOURS

CHEMISTRY: MIXTURES AND REACTIONS

1 READING | 2 ACTIVITIES

INTRODUCTION

World War II required massive changes in the everyday lives of Americans, whether on the Home Front or serving overseas. While many Americans had learned to be creative to make ends meet and to keep food on the table during the Great Depression, the changes brought on by World War II were huge by comparison. All through World War II, growing Victory Gardens, cooking your own produce, and canning to preserve foods were both family survival strategies and government programs.

Although you might not initially think so, cooking is, to put it simply, applied chemistry. Recipes are instructions to make both mixtures and controlled chemical changes. Physical and chemical properties and physical and chemical changes are important topics for elementary and middle school science. The difference between physical and chemical changes can be difficult for students to comprehend. Thus, examples, especially those that connect to everyday life, are valuable.

OBJECTIVE

Use these three resources together to introduce the ideas in an engaging sequence that will introduce chemistry concepts while connecting them to nutrition and cooking. You can start by introducing rationing, and the limits on resources and consumption that created challenges during WWII. Then students will make some food that they might like to eat, exploring chemistry, physical and chemical changes, and properties of materials.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI PS1.B
Chemical Reactions NGSS DCI PS3.A: Definitions of Energy

NGSS DCI LS1.A
Structure and Function

NGSS DCI LS1.C
Organization For Matter and Energy Flow in Organisms

NGSS SEP
Developing and Using Models

NGSS SEP
Constructing Explanations and Designing Solutions

NGSS CCC
Structure and Function

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

5-PS1-1
Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-4
Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

MS-PS1-2
Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-LS1-2
Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.

READING (1)

1. RATIONALE FOR RATIONING

Description
This reading provides a real-world context for the activities in this unit. This resource answers the questions of why people needed to grow and make their own food and why they had to understand the chemistry of how prepared food is made. Have students work in groups using Kagan structures to discuss the reading. How do students think rationing would work today? How much of products like sugar do they consume compared to the WWII-rationed amount? What do students think might be rationed today that was not rationed then?

ACTIVITIES (2)

1.KITCHEN SCIENCE: GUMMIES

Description
Engage students in exploring changing properties of materials by making mixtures. Is the result of this recipe a chemical or a physical change? The process in this recipe is a physical change in which the long molecular strands of gelatin dissolve in the heated mixture and then, as they cool, stretch and tangle to form a gel. Vitamin C is a nutritional benefit that also lowers the pH, which humans also find to be yummy. To add a demonstration of chemical change, cook some pancakes on a hotplate. The key difference between chemical and physical change is in what molecules are present before and after. At both the beginning and the end of this activity, you will have gelatin, water, and vitamin C. The molecules have mixed and changed their form after warming and then cooling—an example of physical change. In the pancakes, there is odd-tasting baking soda present before while carbon dioxide gas makes bubbles and fluffs the batter. The chemical composition and the types of molecules present, are different before and after cooking—an example of chemical change. Another activity that can be added to demonstrate physical change in a dramatic way uses only two supplies—a pint mason jar and a half-cup of heavy cream. The mixture will first become whipped cream, and then with continued shaking will separate into butter and finally into buttermilk. Before and after, it is water, fat, and a small amount of protein and sugar; the shaking separates the mixture into parts.

Supplies (per group)
Silicone candy mold and dropper
1/2 Cup fruit juice
1/2 Tbsp vitamin C powder (optional)
2 Tbsp powdered gelatin (unflavored)
2 Tbsp sugar
Small saucepan, rubber spatula, and hotplate

Instructions
Remind students to be very careful with the hotplate, and enforce the use of safety goggles to avoid hot splatter. Students will need to keep the temperature at medium so that they don't evaporate too much juice. Add the vitamin C, and then add the gelatin very slowly. Refrigerate or freeze the gummies if you can so that it cools quickly. If not, the activity will still work, but will take longer to solidify. There are more detailed instructions in the student activity on page 56.

An alternate activity that demonstrates physical change is the making of butter. All you need for this activity is a pint mason jar with a lid and 1/2 cup of heavy whipping cream. Have the students take turns shaking the mason jar. If it starts cold, it will take about 5-10 minutes of shaking to become whipped cream. You'll notice this change because there is no more sloshing in the jar. It will then take another five minutes to separate into butter and buttermilk. If it starts warm, the mixture will go straight to butter in about 10 minutes.

For the pancake demonstration, bring some batter, or prepare it in front of the students and cook it on a hotplate in a small pan. Show the bubbles forming and break open a pancake to show the bubbles that make it fluffy.

If you do make butter AND pancakes, they go pretty well together.

2. KITCHEN SCIENCE: PICKLES

Description
An activity that demonstrates physical change, but one that has further connections to chemistry and biology. Give each group of students sliced cucumbers, or give them a safe butter knife and a whole cucumber. With the butter knife students will make relatively thick slices, but the activity will still work. Ideally the pickles would sit in the briny vinegar for 24 hours, but they are pretty crunchy and yummy an hour after. The pickles will stay good in the fridge for a month. This is an example of physical change because there is no change in the arrangement of molecules. Brining in this way creates a greater concentration of salt and acid in the liquid outside the membranes of the fresh cucumber. The salt and vinegar molecules move inside the cucumber (diffusion), pickling it. Some water may also leave the cucumber (osmosis), which is why you don't want to make the solution too strong. If you leave a cucumber slice on a plate covered in salt, it will become limp, because of osmosis. A variation of this activity would be to pickle other vegetables, like beets or green beans.

Supplies (per group)
1 Pint-sized mason jar with lid
1 Cucumber, thinly sliced
3/4 Cup hot water
3/4 Cup white vinegar
1 Tbsp kosher salt or sea salt
Dill, peppercorns, or other seasonings (optional)

Instructions
Add the sliced cucumbers to the jar with the seasonings (if you are using them). In a separate container, dissolve the salt in the hot water and mix with the vinegar. Add that mixture to the jar, and then close the lid. Shake well.

READING

THE RATIONALE FOR RATIONING

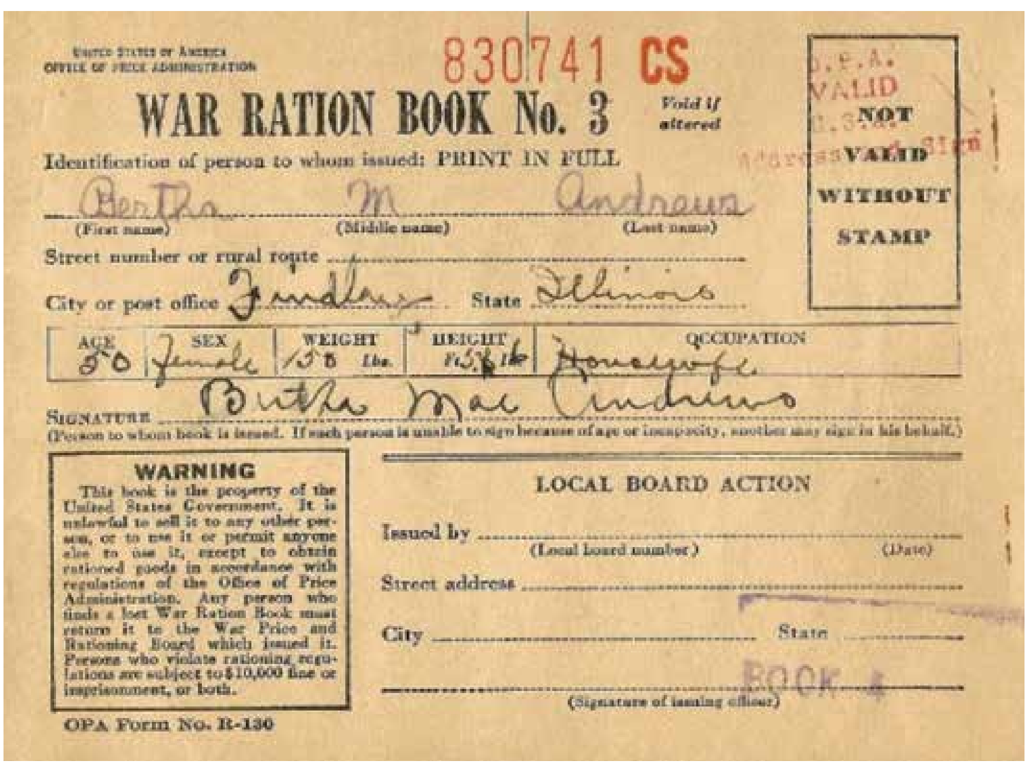
Many materials were in short supply during World War II. There were 16 million US troops fighting for victory, and 117 million people on the Home Front working hard to support them. Propaganda posters displayed throughout communities all told Americans how important it was to support the war effort in any way they could. People grew their own food, saved and reused material as much as possible, and went without some household items and personal comforts in order to aid the war effort.

One of the most dramatic ways World War II affected people's lives was rationing. Rationing is a systematic program or regimen that limits the amount of materials and supplies that an individual can purchase or consume. During the war, rationing controlled prices and supported equitable distribution of resources. Tires (and anything else made of rubber), sugar, meat, butter, cheese, milk, eggs, tea, chocolate, cloth, wood, metal, leather, paper, ink, bicycles, cars, fuel, and shoes were all rationed at times during World War II.

In the spring of 1942, every family registered for rationing through their local schools. On a trip to a grocery store for any rationed item you wished to purchase, you needed to be able to pay for it with both money and ration stamps. As supplies and conditions changed, the types of stamps and what was rationed also often changed. Stamps had to be torn out in front of the grocer at the time of sale so that people wouldn't try selling individual stamps.

To make groceries last longer, families were encouraged to can their own food. Since canning usually needed sugar, families who were canning could apply for more rations of sugar. Otherwise, families could only get one pound of sugar every two weeks for each person in the house.

Along with rubber for new tires, gasoline for cars was also rationed. The amount of gasoline you were entitled to depended on your job. This method allowed drivers to buy enough gas to get to and from work. If you could take the bus to work, or if you worked at home, you got an A-sticker for your car and you got about three gallons of gas a week. Supplies got even tighter in early 1945. As the Allies began to liberate parts of Europe, the United States took responsibility for providing food to refugees. The war had caused a great deal of damage to farms and manufacturing in Europe, and supplies to clothe and feed the people there had to be brought in. Rationing didn't last long in the United States after the war, but in England, which suffered a great loss of production of food and goods from the war, rationing lasted until 1954—nine years after the end of World War II.


UNITED STATES OF AMERICA
OFFICE OF PRICE ADMINISTRATION

830741 CS

WAR RATION BOOK No. 3

Void if altered

NOT VALID WITHOUT STAMP

Identification of person to whom issued: PRINT IN FULL

(First name) (Middle name) (Last name)

Street number or rural route

City or post office State

AGE SEX WEIGHT HEIGHT OCCUPATION

SIGNATURE
(Person to whom book is issued. If such person is unable to sign because of age or incapacity, another may sign in his behalf.)

WARNING
This book is the property of the United States Government. It is unlawful to sell it to any other person, or to use it or permit anyone else to use it, except to obtain rationed goods in accordance with regulations of the Office of Price Administration. Any person who finds a lost War Ration Book must return it to the War Price and Rationing Board which issued it. Persons who violate rationing regulations are subject to $10,000 fine or imprisonment, or both.

OPA Form No. R-130

LOCAL BOARD ACTION

Issued by (Local board number) (Date)

Street address

City State

(Signature of issuing officer)

The front cover of a WWII ration book.
(Image: The Education Collection of The National WWII Museum.)

NAME: **DATE:**

A US Government poster explaining how to use ration books.
(Image: The Education Collection of The National WWII Museum.)

1. What circumstances do you think could lead the government to start rationing today?

2. Do you go grocery shopping with your family? How would your shopping trips change if you had to use a ration book like the ones in World War II? Think about butter and sugar or about things that might not have been necessities then, but are today.

ACTIVITY
KITCHEN SCIENCE: GUMMIES

INTRODUCTION

During World War II people were encouraged to make do with what they had, so many grew and prepared their own food. These activities were due to prices, shortages, and rationing. One ingredient that families were able to incorporate into their recipes was gelatin. This ingredient was universally used in creating dishes and desserts using fruit, juice, or vegetables, but could also be used with dishes made with meat and broth!

GELATIN
is a protein that comes from the tissues of animals. Proteins are one of the basic molecules that make up all living things.

SUGAR
is a carbohydrate, which is another one of those molecules that make up living things.

In this activity you are going to use the physical properties of materials to make a delicious snack out of protein and sugar.

You will need the following:

- Silicone candy mold and dropper
- 1/2 Cup fruit juice
- 1/2 Tbsp vitamin C powder (optional)
- 2 Tbsp powdered gelatin (unflavored)
- 2 Tbsp sugar
- Small saucepan, rubber spatula, and hotplate

Mix the juice, sugar, and vitamin C together in the pan.

Heat them up, but do not bring them to a boil. Very slowly, while stirring constantly, add the gelatin. Use the spatula to smash any bubbles of gelatin powder so that the mixture isn't lumpy. The mixture will start to get thick.

When you've added all the gelatin, turn the heat off.

Use the dropper to transfer the mixture to the mold.

Place the mold in the freezer and wait 20 or 30 minutes.

NAME: **DATE:**

1. What do you see happening to the mixture as it cools?

2. Is mixing these ingredients an example of a chemical or a physical change?

3. As the gummies cool and solidify is this a chemical or physical change?

4. Design an investigation to figure out what one component of the mixture adds to the gummies: What if you used tea instead of juice? What if you added less gelatin or more vitamin C?

ACTIVITY
KITCHEN SCIENCE: PICKLES

INTRODUCTION

During World War II, many kinds of foods were in short supply. Families were encouraged to keep Victory Gardens in which they grew their own produce. People were urged to can what they could not eat fresh so that they could eat later when those foods were out of season. Because citizens were coming out of the Great Depression, growing and cooking food at home was not unusual. Such home-based activities are less common today because of how dependent we have become in many parts of the country on industrial agriculture.

CANNING

takes advantage of the principles of biology. Microbial growth can be reduced and food can be altered with the addition of some simple ingredients. Refrigerator pickles are an example of this simple use of technology to extend the shelf life of fresh produce. This process will allow fresh vegetables to be kept for a month or more while refrigerated.

You will need the following:

- 1 Pint-sized mason jar with lid
- 1 Cucumber, thinly sliced
- 3/4 Cup hot water
- 3/4 Cup white vinegar
- 1 Tbsp kosher salt or sea salt
- Dill, peppercorns, or other seasonings (optional)

Add the sliced cucumbers to the jar with the seasonings (if you are using them).

In a separate container, dissolve the salt in the hot water and mix with the vinegar.

Add that mixture to the jar, and then close the lid. Shake well.

Your pickles can be enjoyed in an hour or two and can be preserved at cool temperatures for a month.

NAME: **DATE:**

1. What is happening to the cucumber slices in the jar? Is this an example of a chemical change or a physical change?

2. Draw a diagram to explain your thinking:
- **Define diffusion.**
- **Define osmosis. (diagram of osmosis and diffusion)**

3. Go back to your diagram and explain where osmosis and diffusion are occurring in the jar.
Why does pickling slow microbial growth?

LESSON PLANS, READINGS & ACTIVITIES

CHEMISTRY: ELEMENTS AND THE PERIODIC TABLE

GRADE LEVEL: 6-8 | TIME REQUIREMENT: 4 HOURS

CHEMISTRY: ELEMENTS AND THE PERIODIC TABLE

1 READING | 3 ACTIVITIES

INTRODUCTION

If you refer to the Adopt-Adapt-Apply model, most innovations are of the **Adapt** kind in that they take something and modify it for a new purpose, or they improve it to better fulfill its original purpose. Very few innovations are of the **Apply** kind—where pure science and basic facts are developed into a technology. **Apply** innovations are very exciting because they are often some of the most ground-breaking and furthest-reaching innovations.

The Manhattan Project represents an example of an **Apply** innovation. The basic knowledge of how atoms are structured and of what makes something one element and not another, all culminated in an investigation in a Berlin lab in 1938. That basic knowledge, combined with the discovery of a new element seven years and countless hours of work later, unlocked the secret of atomic energy and atomic weapons.

The Manhattan Project succeeded because of the work of some of the best scientists in the world, but it also took huge investments by two Allied countries, as well as lots of work from civilians and military personnel who had no idea what they were working on. The Manhattan Project at once represented a pinnacle of human scientific achievement, but also a led to a new era of fear and danger.

Many scientists were uncomfortable with what they had accomplished, and those results certainly changed the world forever, in profound ways.

OBJECTIVE

Together these resources introduce students to the basis of chemical diversity—the periodic table and nuclear structure. They start with historical context, describing the Manhattan Project and its race to understand and control fission. Then they have students explore the periodic table and nuclear structures, looking at patterns and building models. Electrons are not explicitly discussed, because the phenomena discussed have to do with nuclear physics and chemistry. But you could easily add in electrons if you need to.

STANDARDS

NGSS DCI PS1.A
Structure and Properties of Matter

NGSS DCI PS3.A
Definitions of Energy

NGSS DCI ETS2
Links Among Engineering, Technology, Science, and Society

NGSS SEP
Developing and Using Models

NGSS CCC
Structure and Function

NGSS CCC
Energy and Matter

PERFORMANCE EXPECTATIONS

NGSS DCI MS-PS1-1
Develop models to describe the atomic composition of simple molecules and extended structures.

NGSS DCI MS-PS1-3
Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

READING (1)

1. BIG SCIENCE

Description
This reading introduces the context for the rest of the unit and outlines for students the problem of understanding how to manipulate elements. Have students discuss what it might have been like to work in the Manhattan Project as a scientist. There are some great video selections on the Real World Science website to flesh out this reading.

ACTIVITIES (3)

1. BUILD A TABLE

Description
In this activity students will have the information about all the elements known when Mendeleev developed the first Periodic Table. Have the students work in structured groups to organize the elements based on their characteristics. If the students have learned already about the periodic table, you might find that they are trying to reproduce it here. Any form of organization is acceptable, as long as there is group consensus on the organization and group members can justify that choice based on characteristics of the atoms.

Supplies
A set of Element cards for each group

Instructions
Set up groups using your strongest Kagan structures or other cooperative learning methods to make sure groups reach consensus and everyone participates. Explain what the information on each card means, and ask the students to arrange the cards in a structure that makes sense to them. Be sure to have groups present to the whole class their organization and thinking so that they can see alternate ways of organizing the elements.

2. BUILD AN ATOM

Description
Students will use periodic tables to build small atomic nuclei. Then they will look at models you provide of larger atoms to identify them based on the number of particles they contain. If you want, you can use these models as a base for exploring electrons and ions. Since electrons and ions were largely irrelevant to the nuclear physics at the heart of the Manhattan Project, these activities don't focus on those aspects of atoms, but can be easily added.

Supplies (for each group)
3 Containers (small mason jars or pill bottles will work)
1 Cup each of 2 kinds of dried beans
1 Periodic table

Instructions
To make the best model, the two kinds of beans should be similar in size but different in color—kidney beans and pinto beans or black beans, for example. If you want to extend your model to electrons, you can use lentils or another small bean.

Each group will make a model of three small elements and will fill in the responses to the prompts. Then you will give students some atomic models, and they will count the parts of the models and use a periodic table to identify them. For these unknowns, pick smaller atoms like sodium and chlorine. You could make one different unknown for each group and then have the groups trade unknowns.

3. BUILD AN ISOTOPE

Description
This activity follows naturally from the previous. In building and discussing models of isotopes, students will naturally analyze what makes an atom one element and not another. The activity also gets students to look at what makes some nuclei less stable than others.

Supplies
(The same supplies used in Build an Atom)
Corn puffs, extra beans, salad spinner (optional)

Instructions
If you do this activity immediately following Build an Atom, students can just modify the models they have already built. After they make their own isotopes, you will show them the isotopes of Uranium and a Plutonium model. The main objective of this is to get students to see how comparatively large the nuclei of these elements are and how small the difference in physical characteristics between isotopes is. If you wish, you can demonstrate how centrifuges are used to separate isotopes. Put kidney beans and corn puff cereal inside a salad-spinner. When you spin this kitchen centrifuge, you will see that the beans tend to go to the outside and the cereal to the inside. However, the difference in mass is small, so it is still hard to separate the mixture. Such differences are why the Manhattan Project had so much trouble getting enough Uranium 235 to make an atomic bomb.

ADDITIONAL RESOURCES
To accompany these activities, try these books:

+ *Bomb: The Race to Build—and Steal—the World's Most Dangerous Weapon* by Steve Scheinken, Square Fish 2018 (middle school, fiction).
+ Trinity: A *Graphic History of the First Atomic Bomb* by Jonathon Fetter Vorm, Hill and Wang, 2013 (middle and high school, graphic non-fiction).

READING

BIG SCIENCE

Lise Meitner, an Austrian physicist, was in Stockholm, Sweden, in December 1938. She had been head of the Chemistry Department at the University of Berlin, but was forced to leave in April 1938 because of the Nuremberg laws against people of Jewish descent like herself. Meitner fled with forged papers and a diamond ring to bribe border officials, first to The Netherlands and then on to Sweden.

That December, Meitner got a letter from colleagues in Berlin. She had begun a series of experiments together with these colleagues. Her colleagues had collected the data from the experiments and could not explain the results. The experiment involved aiming a ray of neutrons at a sample of Uranium. Instead of producing a new, larger element, they observed a large burst of energy and some smaller elements. Meitner had talked with the Nobel Prize-winning physicist Nils Bohr while in The Netherlands. Based on these conversations and others with her nephew who was also a physicist, Meitner made some calculations and explained what had happened using a new term—nuclear fission.

Two papers, published in early 1939, described the experiment and explained the results. Nils Bohr went to a conference in the United States and discussed the discovery there. When World War II began in Europe in September 1939, there was concern that Berlin, where the discovery of this new source of great energy had been made, was also the capital of a ruthless fascist country.

Within two years, the United States and Great Britain agreed to collaborate on turning this basic science discovery of nuclear fission into a practical application. Worried that German scientists were ahead in a race to build a new kind of bomb, Britain sent many of its top nuclear scientists to the United States where a giant top-secret project was given the code-name the Manhattan Project.

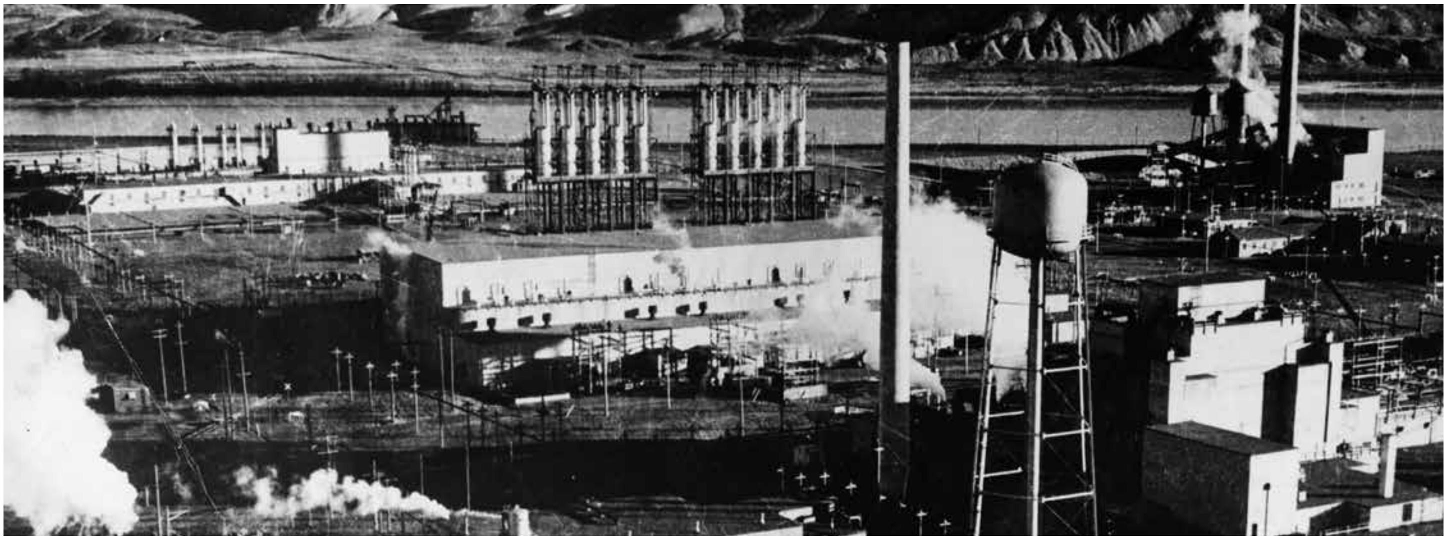
With a budget of about $2.2 billion in today's money, the Manhattan Project grew to employ about 130,000 people across the United States. Almost all of the people knew what their individual jobs were, but they had no idea about the true nature of the project. All they knew was that it was important and very secret. Cities sprang up in rural Tennessee and Washington around science research complexes there. A town was built in the mountains of New Mexico where 5,000 residents shared a single post office box. Twenty-one of the scientists working in the Manhattan Project were, or eventually received, a Nobel Prize. Many of them were refugees from Axis-occupied territories. This huge effort and unprecedented investment in science research led to amazing accomplishments and to a complicated legacy.

Bags of uranium ore are unloaded as a soldier guards the shipment. Fort Smith, Canada, August 20, 1945. *(Image: The National WWII Museum, 2021.019.464.)*

By July 1945, less than seven years after the discovery of nuclear fission, this new source of energy had been **applied** to make three atomic bombs. Two of those bombs were made of an element discovered in the project—plutonium. Along the way, many useful discoveries, including the use of nuclear reactors as electrical power plants, were made and also led to an understanding of how nuclear radiation could lead to death and disease. Many of the scientists who worked on the Manhattan Project later said they had regrets about what they had produced.

Along with atomic energy and atomic weapons, another enduring legacy of the Manhattan Project is what has come to be called Big Science, a term for research projects so large that they can only be managed and supported by the government. The three main scientific sites of the Manhattan Project (Oak Ridge, Tennessee; Hanford, Washington; and Los Alamos, New Mexico) are still sites of National Laboratories. Other examples of Big Science are the Human Genome Project and the National Aeronautics and Space Administration (NASA). Scientists and engineers at these sites and at universities and private labs across the country, all work to develop knowledge that can inform and enrich our understanding of the world.

NAME: **DATE:**



Aerial view of the Hanford Site of the Manhattan Project, where reactors produced uranium, August 15, 1945.
(Image: The National WWII Museum, 2012.019.567.)

1. What type of innovation—Adopt, Adapt, or Apply—was the development of nuclear power from the discovery of nuclear fission? Explain your thinking.

2. Do you think that government investment in Big Science research projects is a good idea? Explain your thinking.

3. Do you know of any other problems in history that have been solved by Big Science?

4. What is a big problem in the world today that might be solved with a Big Science approach? Describe the problem and how Big Science might be organized to solve it.

ACTIVITY

BUILD A TABLE

INTRODUCTION

The 1800s were an era in which human understanding of science advanced rapidly. One of the fastest developing fields of science at that time was chemistry. By 1863, chemists had identified 56 elements. An element was considered a fundamental substance in chemistry. Some chemists had noticed that there was a pattern to the elements if they were arranged by their mass. However, Dmitri Mendeleev, a Russian chemist, was the first to arrange elements into groups and to organize them in a table.

With his table, Mendeleev was even able to predict the existence of several elements that had not yet been discovered. Mendeleev's accomplishment was very impressive, given how little the scientists of his time knew about atomic structure. For example, the existence of electrons, neutrons, and protons—all packed into the atoms—was unknown.

In this activity, you will organize elements, just like Mendeleev did.

In the cards your teacher will give you, you will have all the information Mendeleev knew about the chemical elements.

Use these cards and the information in them to make your own table of elements. You will do this as a group. Your group must have come to consensus on the table's organization, and each member of your group must be able to explain why that structure was chosen and what data were used to make your choice.

Using the symbols on your cards, draw a diagram of how you organized the elements.

Se
Selenium
Gray or red solid
Atomic Mass 79

Br
Bromine
Very reactive reddish liquid
Atomic Mass 80

Rb
Rubidium
Reactive, soft gray metal
Atomic Mass 85

Sr
Strontium
Soft silvery metal
Atomic Mass 88

In
Indium
Soft silvery metal
Atomic Mass 115

Sn
Tin
Silvery-white metal
Atomic Mass 119

Sb
Antimony
Blue-white metallois, semiconductor
Atomic Mass 122

Te **Tellurium** Silver-white metalloid, semiconductor Atomic Mass 128	**I** **Iodine** Reactive, purple solid Atomic Mass 127	**B** **Boron** Gray metalloid, semiconductor Atomic Mass 11	**C** **Carbon** Black solid (graphite) or transparent (diamond) Atomic Mass 12
N **Nitrogen** Odorless gas, unreactive Atomic Mass 14	**H** **Hydrogen** Flammable odorless gas Atomic Mass 1	**Li** **Lithium** Soft metal, reactive Atomic Mass 7	**Be** **Beryllium** Grayish metal Atomic Mass 9
O **Oxygen** Flammable, reactive odorless gas Atomic Mass 16	**F** **Flourine** Very reactive yellowish gas Atomic Mass 14	**Na** **Sodium** Soft, highly reactive metal Atomic Mass 23	**Mg** **Magnesium** Flammable gray metal Atomic Mass 24
Al **Aluminum** Silvery metal Atomic Mass 27	**Si** **Silicon** Gray metalloid semiconductor Atomic Mass 28	**P** **Phosphorus** Spontaneously combustible solid of variable color Atomic Mass 31	**S** **Sulfur** Solid yellow powder Atomic Mass 32
Cl **Chlorine** Extremely reactive greenish gas Atomic Mass 35	**K** **Potassium** Reactive soft metal Atomic Mass 39	**Ca** **Calcium** Flammable silvery metal Atomic Mass 40	**As** **Arsenic** Gray metalloid Atomic Mass 74

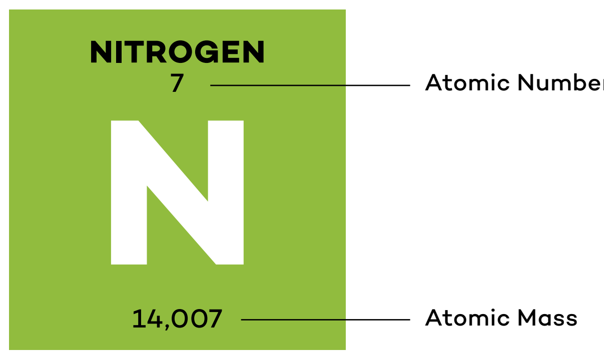
ACTIVITY
BUILD AN ATOM

INTRODUCTION

Use a periodic table to follow along with this explanation. You will need the table for the activity later in this lesson.

Each element is represented by one or two letters as an abbreviation for its name. This abbreviation is called the element's symbol. In the example to the right, the full name of the element is also included, but in many tables only the symbol is used. The symbol is often, but not always, similar to the full name. For example, the symbol for carbon is C. However, sometimes the table abbreviates the Latin names for the elements; thus, the symbol for lead is Pb and the symbol for copper is Cu.

The number above the symbol is the Atomic Number of the element. The Atomic Number represents the number of protons in the element's nucleus. Each element has a unique number of protons—if you change the number of protons, you change the element. The Atomic Number also represents the default number of electrons in the element. That means the element has no charge because the number of negative charges (electrons) is the same as the number of positive charges (protons). Those electrons orbit the nucleus. If an atom of an element has lost or gained an electron, it will carry a charge and is referred to as an ion. In their normal state, elements are not ions.



The nucleus can also hold another kind of particle—neutrons. Neutrons have no charge, but like protons they do have mass. Electrons have a negative charge and are so small that their mass is insignificant. To find the number of protons in the nucleus, you will subtract the Atomic Number from the Atomic Mass. The Atomic Mass is the number under the element's symbol. Atomic mass is rarely a whole number because it is an average of different forms of the element. Elements can have different numbers of neutrons. Round the number to the closest whole number to get the default number of protons in an element.

For example, Carbon (C) has an Atomic Number of 6 and an Atomic Mass of about 12. This means it has by default, 6 protons, 6 electrons, and 6 neutrons.

Here is another example: Aluminum (Al) has an Atomic Number of 13 and an Atomic Mass of about 27. So, it has 13 protons, 13 electrons, and 14 neutrons normally.

NAME: **DATE:**

Directions: Now, you are going to make your own atoms. Your teacher will give you three small containers and two kinds of beans.

1. Using your three containers and two beans, make models of the following elements: hydrogen, oxygen, and carbon. With masking tape and pen, label the three containers. Complete the table below to keep track of the data on your models of elements.

ELEMENT	PROTON	NEUTRON
Hydrogen		
Carbon		
Oxygen		

2. Now, using your periodic table, take the unknown elements your teacher gives you and identify them using their Atomic Number and Atomic Mass in the last rows of the table above.

ACTIVITY
BUILD AN ISOTOPE

INTRODUCTION

Isotopes are forms of elements with different numbers of neutrons. Scientists can use isotopes for many purposes, including to find out how old a bone is or how cold it was when a glacier was formed. An isotope is represented by the Atomic Symbol followed by the number of neutrons in the isotope. For example, U235 is the form of uranium scientists were trying to isolate in the Manhattan Project.

Your teacher will give you three containers representing models of three elements—hydrogen, carbon, and oxygen.

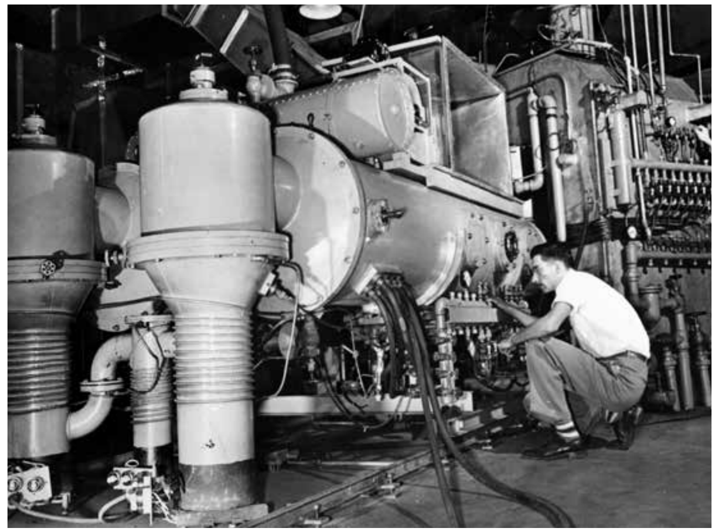
You are going to modify these models to make isotopes of each element. To make an isotope, you will change the number of neutrons in the model. Make the most common isotope of each element: for hydrogen, that is H2; for carbon, that is C14; and for oxygen, that is O16.

In the Manhattan Project, scientists were trying to isolate enough of the specific isotope of uranium they needed to construct what would be the first atomic bomb. The most common isotope of uranium is U238. The isotope needed in the Manhattan Project was U235. U235 is only 0.72 percent of all uranium.

At first, Manhattan Project scientists tried to get enough U235 by separating atoms by the difference in their mass. That, as you can imagine, is very hard, and some very special kinds of centrifuges had to be used. In the end, scientists made only enough U235 for one bomb.

Along the way, Manhattan Project scientists discovered that when U238 is hit by a fast neutron, it becomes a different element—plutonium. It was easier to make plutonium than to get U235, and it takes less plutonium than uranium to make a bomb. By the summer of 1945, Manhattan Project planners had made a large reactor that produced enough plutonium for the cores of three bombs. One of these plutonium bombs was used for testing in what would be called the Trinity Test. Another was used in the war against Japan. The third was used for research.

Your teacher will show you models of uranium and plutonium atoms.



Technicians working on a cyclotron built to create radioactive phosphorus, in St Louis, Missouri, in 1945.
(Image: The National WWII Museum, 2012.019.501.)

NAME: **DATE:**

1. Just by looking, can you tell the difference between model C and O atoms? Does one model look like it has more beans (protons and neutrons) than the other? Do you think the models have different weights?

2.What about the difference between O16 and O18? Can you tell these models apart?

3. Your teacher will give you models of U238 and U235, and of plutonium.

Can you tell the difference between the model isotopes by looking at them?

What about between plutonium and uranium?

4. Is there another way you could find the difference between these isotopes? Without opening the models and counting? Brainstorm an idea and describe your method in the space below: