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.

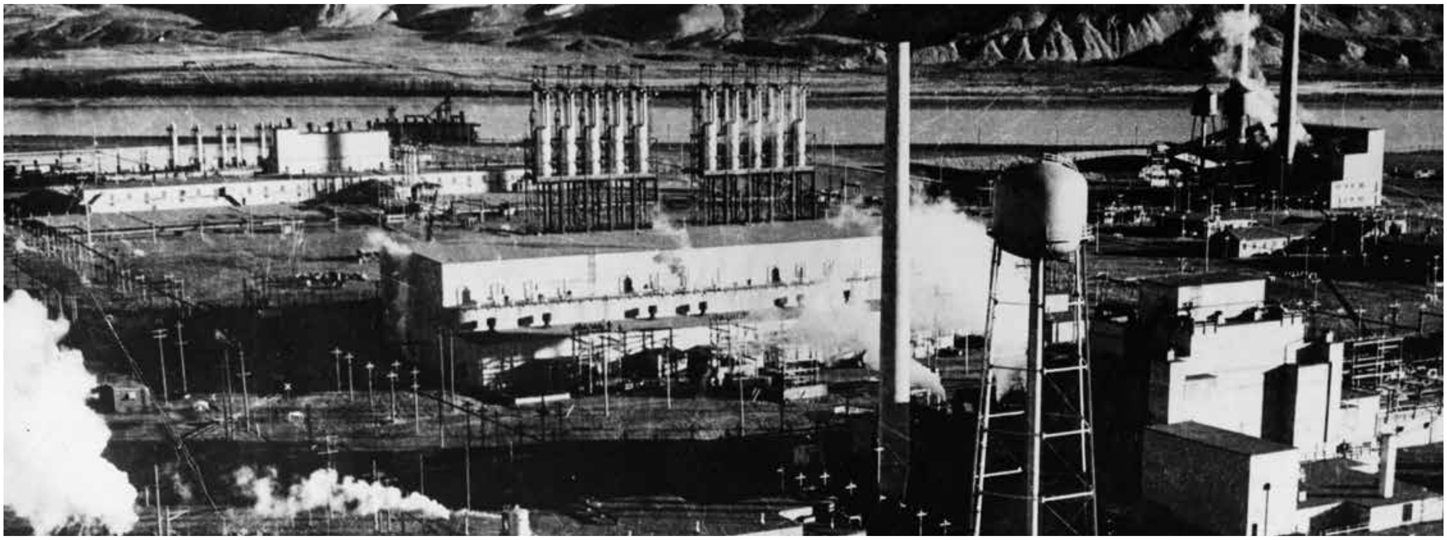
With a budget of about $2.2 billion in today's money, the Manhattan Project grew to employ about 130,000 people across the United States. Almost all of the people knew what their individual jobs were, but they had no idea about the true nature of the project. All they knew was that it was important and 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.