Introduction to a Unit on the Periodic Table of Elements: 90-minute lesson plan for Middle School Educators

Dmitri Mendeleev's periodic table of elements is a 150-year scientific achievement which still influences science today. Understanding how Mendeleev determined the organization of the periodic table can help students better understand atoms, the properties of elements, and how our world is formed. Additionally, it is important students understand that scientific discoveries can come from people of all kinds of backgrounds, including those outside the spaces of our geographic, socio-economic, and/or other communities. This lesson plan was created using a Newsela-adapted article by Michelle Feder from Big History Project as a base and in order to give educators more flexibility, contains links to other lesson plans and alternative activities. Ideally, this lesson plan is for middle-school science and chemistry teachers, but it could be adapted for other subjects and grade levels.

Objectives

By the end of this unit, students should be able to:

- Understand how the periodic table is organized and identify elements by name, symbol, atomic number, and atomic mass
- Compare elements based on their atomic properties and location on the periodic table
- Recognize that despite personal challenges, important scientific discoveries can still be made by individuals.
- Explain who is credited with creating the periodic table and why it is structured by families/groups and periods.

Indiana State Standards and Indicators Addressed:

6-8.LST.1.1: Read and comprehend science and technical texts within a range of complexity appropriate for grades 6-8 independently and proficiently by the end of grade 8.

6-8.LST.1.2: Write routinely over a variety of time frames for a range of discipline specific tasks, purposes, and audiences.

6-8.LST.2.2: Determine the central ideas or conclusions of a text; provide an accurate, objective summary of the text.

8.PS.3: Use basic information provided for an element (atomic mass, atomic number, symbol, and name) to determine its place on the Periodic Table. Use this information to find the number of protons, neutrons, and electrons in an atom.

8.PS.4: Identify organizational patterns (radius, atomic number, atomic mass, properties and radioactivity) on the Periodic Table.

Overview:

Pre-requisite knowledge – Atoms are the building blocks of our world and are made of protons, neutrons, and electrons. Protons have a positive charge are in the center of the atom. Neutrons are in the center of the atom and have no charge. As both protons and neutrons are in the center of the atom, they make up the nucleus. Electrons surround the nucleus and have a negative charge. The charge on protons and electrons are exactly the same size, but opposite, and thus attract each other.

Warm-up Activity (25 min):

- Periodic Table of Elements Puzzle from Teachers Pay Teachers
- Alien Activity from Sunrise Science blog
- Put your class in groups. As a class, ask them to brainstorm things which occur regularly or periodically. These can be things such as their class schedule, months of the year, etc. Assign each group one of the brain-stormed categories. Have the students organize the objects in their category. For example, students can organize the months of the year by season, number of days, alphabetically, etc. If you have time, have one representative from each group tell the class the organization structures their group came up with. Emphasize that there are lots of ways to categorize information.

Introduce the Periodic Table of Elements (25 min): On an overhead projector or with a computer projector, place a picture of the periodic table of elements. Explain that the periodic table shows all of the known atoms in the universe, building blocks which make up millions of substances. Review parts of the atom. Explain what the numbers and letters in each box within the table mean. Like their warmup activity, these numbers, or characteristics, determine their place on the table. Explain that atomic number is equal to the number of protons in the nucleus. The atomic mass is the number of neutrons and protons in the nucleus (and that the number of neutrons is not always, but is usually, the atomic number subtracted from the atomic mass). Ask them to identify some of the patterns they see. If you like, you can develop these ideas and talk about metals vs nonmetals.
Transition: how did the scientific community determine this way of categorizing them?

Mendeleev Reading and Writing Activity (30 min): Handout copies of the periodic table and article on Mendeleev. Students read part 1 of the article on Mendeleev and answer questions on the worksheet below (Appendix A & B). Have students Think-Pair-Share. After working on the reading and questions on their own, have them discuss their answers with a partner. When you notice students are winding down their partner discussions, come together as a class and compare answers/discuss part 1 of the article.
Reading: 10 minutes, Answer questions: 10 minutes, Pair: 5 minutes, Share: 5 minutes

Wrap-up (10 min): Remind students the definition of an element, atom, atomic number, and atomic mass/weight. You may explain and/or assign homework. Answer questions students may have.

Possible Homework Assignments:

- The Disappearing Spoon Reading Assignment/Questions from the American Association of Chemistry Teachers
- Activity Sheet from Middle School Chemistry (will have to modify and will need to explain in class the assignment)
- Appendix D: Writing Assignment
- Appendix F: Reading Assignment

Modifications for more/less advanced students: This version of the article, "Inventors and Scientists: Dmitri Mendeleev," by Michelle Feder of Big History Project used in this lesson plan is an adaptation by Newsela staff. A more advanced version and several less advanced versions of the article can be found on their website (maximum word count: 2178, minimum word count: 1086).

Appendix A

By Michelle Feder, Big History Project, adapted by Newsela staff

Inventors and Scientists: Dmitri Mendeleev

Organizing Matter

In the mid-1700s, chemists began identifying elements, which are substances made up of just one kind of atom. But a century later, they still used a variety of symbols and acronyms to represent the different materials. No common language existed to show how they related to each other. In 1869, the Russian chemist Dmitri Mendeleev changed all that. His diagram of elements, which make up all matter that exists, became known as the periodic table.

Here's what's especially amazing: Mendeleev's chart left spaces for elements that were yet to be discovered. For some of these missing pieces, he predicted what their atomic masses and other chemical properties would be. When scientists later discovered the elements Mendeleev had expected, the world saw the brilliance behind the periodic table.

A Difficult Childhood

Mendeleev was born in 1834 in the far west of Russia's Siberia, the youngest of a dozen or more children. His family faced one crisis after another. When Dmitri was little, his father, a teacher, went blind, and his mother went to work. She became the manager of a glass factory. Tragedy struck again in 1848, when the factory burned down. The family faced poverty. Mendeleev's mother was determined to get him an education and traveled with him a great distance, to Moscow and then to St. Petersburg, to do so. Ten days after he was enrolled in school, his mother died of tuberculosis, a lung disease that had also taken his father, at least one of his siblings, and which Mendeleev himself would battle as a young adult.

A Young Professor

In 1861, Mendeleev returned to Russia from research in Europe. He found that few of the new developments in the field of chemistry had made their way to his homeland — something he was determined to change. He began lecturing enthusiastically about the latest advances. Only 27 years old, he had a quirky personality, with a flowing beard and long, wild hair that he was known to trim only once a year. Still, he became a popular professor.

Mendeleev recognized that there was no modern textbook on modern organic chemistry (concerned with carbon compounds, including living things). So he wrote one. His *Organic Chemistry* (1861) was considered his era's most authoritative book on the subject. But the professor was painfully aware that many of his students "could not follow" him, as one student observed. Mendeleev knew that a critical reason for peoples' difficulty in understanding chemistry was the lack of any clear system for classifying the known elements. Without one, he could only offer particulars about specific building blocks of matter. A framework that would explain the relationships between different substances was still needed.

A Missed Train and a Dream

Next, Mendeleev began a text for inorganic chemistry (concerned with substances that are not organic, such as minerals). *Principles of Chemistry* (written 1868–1870) would become the standard text for the field until early in the twentieth century. His research for this book would also lead him to his most famous work.

In 1867, when Mendeleev began writing *Principles of Chemistry*, he set out to organize and explain the elements. He began with what he called the "typical" elements: hydrogen, oxygen, nitrogen, and carbon. Next he included the halogens. These had low atomic weights, reacted easily with other elements, and were readily available in nature. Chlorine — used to keep pools clean — is a halogen.

Mendeleev began using atomic weights as a principle of organization, but these alone did not present a clear system. At the time, elements were normally grouped in two ways: either by their atomic weight or by their common properties, such as whether they were metals or gases. Mendeleev's breakthrough was to see that the two could be combined in a single framework.

Mendeleev was said to have been inspired by the card game Solitaire. In the game, cards are arranged both by suit, horizontally, and by number, vertically. To put some order into his study of chemical elements, Mendeleev made up a set of cards. Each represented one of the 63 elements known at the time. Mendeleev wrote the atomic weight and the properties of each element on a card.

He took the cards everywhere he went. On February 17, 1869, with a train to catch that morning, Mendeleev set to work organizing the elements with his cards. He carried on for three days and nights, forgetting the train. He continually arranged and rearranged the cards in various orders until he noticed some gaps in the order of atomic mass.

As one story has it, Mendeleev, exhausted from his three-day effort, fell asleep. He later recalled, "I saw in a dream, a table, where all the elements fell into place as required. Awakening, I immediately wrote it down on a piece of paper." He named his discovery the "periodic table of the elements."

While arranging these cards of atomic data, Mendeleev discovered what is called the Periodic Law. When Mendeleev arranged the elements in order of increasing atomic mass, the properties were repeated. Because the properties repeated themselves regularly, or periodically, on his chart, the system became known as the periodic table.

Appendix B, Worksheet: Part 1 Mendeleev

1. In the section, “A Difficult Childhood,” the author highlights the difficulties of Mendeleev’s early life. Name three of the challenges Mendeleev faced before becoming a professor.

2. Reread the two paragraphs highlighted from the section "A Missed Train and a Dream". Which BEST explains how the two paragraphs help to develop the central idea of the article?

    A. They identify the elements that Mendeleev considered to be typical elements.

    B. They give background information about how Mendeleev first started creating a system to organize the elements.

    C. They provide information about how Mendeleev came to learn that he could combine the two grouping systems.

    D. They make a connection between Mendeleev's work in the 1800s and today by describing the modern use of chlorine.

3. Which excerpt would be MOST important to include in an objective summary of the article?

    A. Only 27 years old, he had a quirky personality, with a flowing beard and long, wild hair that he was known to trim only once a year.

    B. But the professor was painfully aware that many of his students “could not follow” him, as one student observed.

    C. It’s possible that this happened because Mendeleev, confident in his theory, published his findings first.

D. The elements are arranged in a series of rows called “periods,” so that those with similar properties appear in vertical columns.

4. Which BEST explains how the card game Solitaire influenced Mendeleev's development of the periodic table?

   A. Mendeleev used cards from the card game to demonstrate how he could order the arrangement of the elements.

   B. Mendeleev had a dream about the card game that led to his discovery of a system to order the elements.

   C. The card game gave Mendeleev the idea of organizing the elements both by atomic weight and common properties.

   D. The card game gave Mendeleev the idea that if he placed elements in a certain order, some new elements would be need to be discovered

5. Why do you think the Periodic Table is comprised of groups/families (columns on the table) and periods (rows on the table), and not just by atomic number, or common properties?

Appendix C Key

1. In the section, “A Difficult Childhood,” the author highlights the difficulties of Mendeleev’s early life. Name three of the challenges Mendeleev faced before becoming a professor.

- Mendeleev’s father went blind
- In 1848 the factory where Mendeleev’s mother worked burned down
- When the factory burned down, Mendeleev’s family faced poverty
- Mendeleev’s father died of tuberculosis
- One of Mendeleev’s siblings died of tuberculosis
- Mendeleev’s mother died of tuberculosis ten days after he was enrolled in school
- Mendeleev battled with tuberculosis

2. Reread the two paragraphs highlighted from the section "A missed train and a dream". Which BEST explains how the two paragraphs help to develop the central idea of the article?

B. They give background information about how Mendeleev first started creating a system to organize the elements.

3. Which excerpt would be MOST important to include in an objective summary of the article?

D. The elements are arranged in a series of rows called “periods,” so that those with similar properties appear in vertical columns

4. Which BEST explains how the card game Solitaire influenced Mendeleev's development of the periodic table?

C. The card game gave Mendeleev the idea of organizing the elements both by atomic weight and common properties.

5. Why do you think the Periodic Table is comprised of groups/families (columns on the table) and periods (rows on the table), and not just by atomic weight, or common properties?

Something like: If the periodic table were organized solely by atomic weight or common properties, it would not be possible to predict the properties of new elements. *Or* When Mendeleev tried to create a table using only one of these categories, he felt that the system he created was still not clear.

Appendix D: Writing Assignment

1. Who was Dmitri Mendeleev and how did he discover Periodic Law? (Write at least 5 sentences.

2. Which element has an atomic mass of 55.845?

   _____

3. Which element has an atomic mass of 238.03?

   _____

4. Which element has an atomic mass of 22.990?

   _____

5. Which element has an abbreviation of Ag?

   _____

6. Which element has an abbreviation of Si?

   _____

7. Which element has an abbreviation of Ra?

   _____

8. Which element has 50 protons?

   _____

9. Which element has 22 protons?

   _____

10. Which element has 6 protons?

    _____

11. Which element has an atomic number of 6?

    _____

12. Which element has an atomic number of 17?

    _____

13. Which element has (usually) 32 neutrons?

    _____

14. Which element has (usually) 22 neutrons?

    _____

15. Which element has (usually) 8 neutrons?

    _____

16. Which element has 20 electrons?

    _____

17. Which element has 30 electrons?

    _____

Appendix E: Key to Writing Assignment

Who was Dmitri Mendeleev and how did he discover Periodic Law?

Something like: Dmitri Mendeleev was a Russian chemist who published the periodic table of elements in 1869. He had a fairly tragic childhood. Mendeleev wanted to create a system of organization for all of the known elements, because as a professor of chemistry, he noticed his students had a hard time keeping track of the information he was giving. Inspired by solitaire, Mendeleev wrote down the name of each element, its atomic mass, and its properties onto cards. When he arranged the cards, in order of increasing atomic mass, he noticed that the properties repeated regularly or periodically. This phenomenon is called Periodic Law.

2. Iron
3. Uranium
4. Sodium
5. Silver
6. Silicon
7. Radium
8. Tin
9. Titanium
10. Carbon
11. Carbon
12. Chlorine
13. Cobalt
14. Argon
15. Oxygen
16. Calcium
17. Zinc

Appendix F (Part 2 of Article)

Read the rest of the article on Mendeleev and his discovery. Using three sentences, write a summary for each of the 4 larger sections (“Put in Order of Increasing ‘Atomic Number,’” “Building on Others' Achievements,” “Completing the Puzzle,” and “A New Standard”). This means you will turn in 12 sentences total.

Put in Order of Increasing "Atomic Number"

In devising his table, Mendeleev did not completely follow the order of atomic mass. He swapped some elements around. We now know that the elements in the periodic table are not all in atomic mass order. Although he was unaware of it, Mendeleev had actually placed the elements in order of increasing "atomic number." This number represents the amount of positively charged protons in the atom. It's also the number of negatively charged electrons that orbit the atom.

Mendeleev went even further. He corrected the known atomic masses of some elements. And he used the patterns in his table to predict the properties of the elements he thought must exist but had yet to be discovered. He left blank spaces in his chart as placeholders to represent those unknown elements.

He would guess at hypothetical elements' atomic mass, atomic number, and other properties.

Gallium, germanium, and scandium were all unknown in 1871, but Mendeleev left spaces for each and predicted their atomic masses and other chemical properties. Within 15 years, the "missing" elements were discovered. Amazingly, they conformed to the basic characteristics Mendeleev had recorded. The accuracy of those predictions led to the periodic table's acceptance.

Building on Others' Achievements

Mendeleev did not develop the periodic table entirely on his own; he inherited and built on knowledge that was handed down from many chemists who spent their lives investigating matter. In the early 1800s, about 30 elements were known. By then chemists knew that some of these elements acted in similar ways or had similar characteristics. However, no one had found an overall, accepted pattern in their behaviors.

In 1860, scientists met at one of the first international chemistry conferences. They decided that hydrogen, the lightest element, be given a weight of 1. All other elements' weights would be compared to that of a hydrogen atom. That means that if an element is eight times heavier than hydrogen, its weight is 8. The concept of a systematic measure for atomic weights greatly contributed to the success of Mendeleev's periodic table.

As can happen in scientific developments, other researchers arrived at the same theory as Mendeleev's at about the same time. In 1870, German chemist Julius Lothar Meyer published a paper describing the same organization of elements as Mendeleev's.

Was it fair that Mendeleev received all the credit for the periodic table while Meyer stayed unknown? It's possible that this happened because Mendeleev, confident in his theory, published his findings first.

Whatever the case, Mendeleev's periodic table proved invaluable at classifying the building blocks of matter. The spaces he reserved for upcoming discoveries reflected a confidence, also, in the continuing search for knowledge.

Completing the Puzzle

As invaluable a reference tool as it was, the periodic table left plenty of room for discovery and enhancement. In the 1890s, an entirely new and unexpected group of elements was detected: the noble gases. They were added to the table as a separate column. Helium, the second-most abundant element in the Universe, was not found on Earth until 1895. Another 60 or so elements have since been discovered and others may still be waiting to be found.

Beneath the main periodic table, you can see two rows. They're known as the "lanthanides" (atomic numbers 57–71) and "actinides" (atomic numbers 89–103). As scientists found the heavier elements and began to create many more, the newer elements have been separated to keep the table's shape intact.

As of 2012, the periodic table has a total of 118 elements. Some elements have been named after scientists, such as atomic number 99, Einsteinium, for Albert Einstein. Rutherfordium, atomic number 104, is named in honor of physicist Ernest

Rutherford, who developed the modern model of the atom. Atomic number 101, Mendelevium, is named after the periodic table's architect.

A New Standard

Mendeleev's periodic table presented a new paradigm, with all of the elements positioned within a logical matrix. The elements are arranged in a series of rows called "periods," so that those with similar properties appear in vertical columns. Each vertical column is called a "group," or family, of elements. This instantly shows one set of relationships when read up and down, and another when read from side to side.

Some groups have elements sharing very similar properties, such as their appearance and their behavior. For example, each element has its own melting and boiling point, the temperatures at which it changes from a solid to a liquid and from a liquid to a gas. Another characteristic is how "reactive" an element is, meaning how quick it is to join up with other elements. Scientists recognize how an element will react based on its location on the table.

The elements are known by an atomic symbol of one or two letters. For example, the atomic symbol for gold is "Au," the atom's name is "gold," and its atomic number is 79. The higher the atomic number, the "heavier" an element is said to be.

Hydrogen is 1 on the periodic table, in the upper left corner. Its atomic number is 1; its nucleus contains one proton and one electron. About 98 percent of the Universe consists of the two lightest elements, hydrogen and helium.

To Make Chemistry Clear

Scientists continue to adjust the periodic table as new elements are found. Mendeleev's mission, to clarify chemistry, lives on. He dedicated his textbook to his mother with what he claimed were her last words to him:

Refrain from illusions; insist on work and not on words. Patiently seek divine and scientific truth.