The Periodic Table

from the six-part

Elements of Chemistry Series

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1560 Sherman Avenue | Suite 100 | Evanston, IL 60201

800.323.9084 | FAX 847.328.6706 | www.unitedlearning.com

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The Periodic Table

from the six-part ***Elements of Chemistry Series***

Grades 9 to 12

Viewing Time: 20 minutes

◆ INTRODUCTION

The Periodic Table is part of the ***Elements of Chemistry Series***, a six-part series of programs to help students understand the fundamental concepts of chemistry. The attractive images and engaging narration of the program have been designed by educators and filmmakers to help students understand the sometimes complicated and obscure explanations of this important branch of science.

As early as ancient times, separate elements were identified, but it took until the middle of the nineteenth century for scientists to understand that there was a relationship between elements. With these insights, the periodic table was developed. Today the periodic table is the most important theoretical tool of chemistry. This program describes the development of the table and shows how it is related to the structure of atoms. It provides a comprehensive introduction to this fascinating area of science appropriate for high school students.

◆ LINKS TO CURRICULUM STANDARDS

The Elements of Chemistry Series is based on the "National Science Educational Standards" for "Physical Science," grades 9-12, (Content Standard B).

◆ STUDENT OBJECTIVES

After viewing the program and participating in the various follow-up activities, students should be able to:

• Explain that the periodic table describes the relationship of elements.

• Describe how Demitri Mendeleev used atomic weight as the principle to organize his periodic table and explain why modern chemistry organizes the periodic table by atomic number.

• Explain that the position of an element on the periodic table explains the structure of the element's atom and helps to explain how it will react with other elements.

• Explain the organization of the periodic table into periods and groups.

• List the reasons why the radius of elements varies.

• Describe the information about elements that is contained in each square of the periodic table.

• Define the meaning and importance of amu.

• Explain why the electrons in the valence energy level are so important in explaining the chemical properties of an element.

• Explain how the electron configurations of elements are related to the periodic table.

• Define the Octet Rule.

• Relate electron configurations to orbital shapes.

• Define the principles of writing electron configurations.

• Describe the division of the periodic table into four blocks of elements with similar properties.

◆ SUMMARY OF THE PROGRAM

As long ago as ancient times, it was understood that matter consisted of different elements. By the middle of the nineteenth century, scientists began to look for patterns of how the different elements related.

The first success in this area was a list of elements made by a Russian scientist Demitri Mendeleev, who developed a forerunner of the periodic table that we use today. Mendeleev organized the elements by atomic mass. Today the periodic table is a list of elements by atomic number—the number of protons in an element.

The periodic table is a type of map of all of the elements. Most list 114 elements but there are only 92 elements found naturally in the universe. The others, called transuranium elements, have only been created in laboratories.

The periodic table is organized into horizontal rows, called periods, and vertical columns, called groups. Every element has its own square and vital information about the element is listed in the square. The information includes the atomic number, the element's symbol, its atomic mass, and its electron configuration.

It is the valence electrons in the outermost energy level that gives an element its chemical characteristics. Electrons can move and create bonds with other elements. Each energy level can only take a limited number of electrons. Each atom attempts to interact with other atoms so that the electron configuration of its outer valance energy level is full. It does this by borrowing, lending, or sharing electrons.

The last line in the square of the element in the periodic table is the precise description of the electron configuration of the element. It describes the number of electrons and the orbital shape of the electrons in the valence energy level.

The electron configurations determine the chemical properties of the elements but they also provide a way of dividing the table into four blocks of elements with similar properties. These are the s Block, or alkali metals, the d Block of transition metals, the f Block, and the p Block.

The development of the periodic table is a remarkable achievement. It remains the most important principle of modern chemistry.

◆ PRE-TEST and POST-TEST

Blackline Master #1, Pre-Test, is an assessment tool intended to gauge student comprehension prior to viewing the program. Remind your students that these are key concepts upon which they should focus while watching the program.

Blackline Master #7, Post-Test, can be compared to the results of the Pre-Test to determine the changes in student comprehension after viewing the program and participation in the activities.

◆ TEACHER PREPARATION

Before presenting this program to your students, we suggest that you preview the program and review this guide and accompanying Blackline Master activities in order to familiarize yourself with the content. Feel free to duplicate any of the Blackline Masters and distribute them to your students.

As you review the materials presented in this guide, you may find it necessary to make some changes, additions, or deletions to meet the specific needs of your class. We encourage you to do this. Only by tailoring this program to your class will your students obtain the maximum instructional benefits afforded by the materials.

We suggest that you first show the program in its entirety to your students. This is an introduction to the complex subject of modern chemistry; and, at this stage, it is helpful that students gain an overview of the concepts and material in the program. A number of lesson activities will grow out of the content of the program and, therefore, the presentation should be a common experience for all students.

After the introduction, the program is divided into chapters with the following titles:

- **The Development of the Periodic Table**
- **Reading the Periodic Table**
- **The Squares of the Periodic Table**
- **Electron Configurations**
- **Writing Electron Configurations**
- **A Tour of the Table**

These chapters vary in length from three to five minutes. After the students have seen the entire program, lessons could be designed around these different chapters. A chapter could be shown at the beginning of the class, and the balance of the class time, and subsequent classes, could be spent examining the subject matter in the program in greater depth.

◆ STUDENT PREPARATION

It is important that students work through the material and familiarize themselves with the vocabulary, concepts, and theories that scientists use to understand this field.

If the students have a textbook that they are following, assign the relevant reading before the lesson. As students work through the material, they will encounter a number of unfamiliar words and concepts. Most of these words are highlighted in the program. An additional list of words is provided in **Blackline Masters #2a-c, Vocabulary Definitions and Activities**.

The program concludes with a ten-question **Video Quiz** that may be used to gauge students' comprehension immediately after the presentation of the program. **Blackline Master #6, Video Quiz,** is a printed copy of the questions, which may be reproduced and distributed to the students. The answers to the questions appear in the answer key of this Teacher's Guide.

◆ DESCRIPTION OF BLACKLINE MASTERS

Blackline Master #1, Pre-Test, should be given to students before viewing the program. When these answers are compared to the quiz results, it will help you gauge student progress.

Blackline Master #2a, Vocabulary Definitions, will introduce students to unfamiliar words and concepts used in this program. **Blackline Master #2b, Use the Right Word**, and **Blackline Master #2c, Word Match**, are activities designed to help reinforce key concepts and vocabulary.

Blackline Master #3, Connected and Not Connected, will help students identify their knowledge of key vocabulary terms and the context in which they are used.

Blackline Master #4, Crossword Puzzle, reinforces key concepts and vocabulary.

Blackline Master #5, Creative Writing Story Ideas, will allow students to think creatively while incorporating scientific principles and vocabulary covered in this program.

Blackline Master #6, Video Quiz, is a printed version of the Video Quiz that appears at the end of the program.

Blackline Master #7, Post-Test, may be used to evaluate student progress after completing this lesson.

◆ ANSWER KEY

Blackline Master #1, Pre-Test

1. False	6. False
2. True	7. False
3. True	8. True
4. False	9. True
5. True	10. False

Blackline Master #2b, Use the Right Word

1. electrons	6. unit
2. atomic number	7. orbitals
3. element	8. transuranium
4. periods	9. square
5. groups	10. valence

Blackline Master #2c, Word Match

amu-	atomic mass unit
element-	an atom with a unique number of protons
electron-	negatively charged particle
groups-	vertical columns of the periodic table
nucleus-	center of the atom
orbitals-	shapes of the orbits of electrons
periodic table-	elements arranged by atomic number
periods-	horizontal rows of the periodic table
proton-	positively charged particle
valence electrons-	outer ring of electrons

Blackline Master #3, Connected/Not Connected

1. protons	electrons
2. number	amu
3. periods	groups
4. Electronegative	electropositive
5. configurations	valence
6. Alkali	alkaline
7. Squares	elements
8. f Block	p Block
9. radius	nuclear charge
10. Hydrogen	uranium

Blackline Master #4, Crossword Puzzle

			1 O	R	B	I	T	2 A	L	S					
								M							
				3 R	A	4 D	I	U	S				5 A		
						B							T		
						L			6 P	E	R	I	O	D	S
						O			R				M		
			7 E	L	E	C	T	R	O	N					
						K			T						8 E
		9 G							O		10 N				L
	11 T	R	A	N	S	U	R	A	N	I	U	M			E
		O									C				M
12 S	Q	U	A	R	E				13 V	A	L	E	N	C	E
		P									E				N
		S						14 G	R	O	U	P	1		T
											S				

Blackline Master #6, Video Quiz

1. True
2. Protons
3. False
4. True
5. False
6. Periods
7. Groups
8. True
9. Valence
10. False

Blackline Master #7, Post-Test

1. element
2. transuranium
3. groups
4. periods
5. False. Mendeleev's periodic table was based on the atomic mass of elements. The modern periodic table is based on atomic number.
6. False. An element's position in the period and the group on the periodic table is vital in understanding its chemical characteristics.
7. True

8. False. All elements beyond atomic number 92 are called transuranium elements.
9. False. An atom attempts to interact with other atoms so that the electron configuration of its outer valence energy level is full. It is the valence electrons that give an element its chemical characteristics.
10. The periodic table lists all of the elements by their atomic number and organizes the elements into periods and groups. The position of an element in a period and group gives the atomic structure of the element and its electron configuration. It is the electrons in the valence energy level that gives an element its chemical characteristics.
11. The squares on the periodic table give precise information about each element. In the square is the atomic number of the element, its symbol, name, atomic mass, and electron configuration. All of this information is vitally important if chemists are to understand the element's chemical characteristics.
12. Each of the four blocks is named for the orbital shapes of the valence electrons. The valence electrons give the characteristics of the element. Those elements with similar electron configurations have similar chemical characteristics and are part of the same block of elements.

◆ **DISCUSSION QUESTIONS**

1. In ancient times the element of gold was very valuable and this value has continued to this day. Why is it considered so valuable?

Today gold is used for decoration and jewelry but it is not very useful for anything else. It is too soft to make tools and too rare to make building materials. The real reason that gold has value is because people and governments have given it value. In ancient times, coins were made out of gold and it became an international measure of wealth. Until recently the currency of all countries was quoted in gold. Today our monetary system has no relationship to gold, but the element is still so important that many countries, like the United States, hold large reserves of gold.

2. The 92 elements that are found naturally in the universe combine into about 12 million separate substances. Could there be billions or even trillions of substances in the universe?
Theoretically, that could be possible but, in practice, it is not the case. The vast majority of substances that are found on earth have the element carbon as their base. These are the millions of different types of molecular structures that make up living tissues in plants and animals. Carbon has a unique ability to combine with other elements to make new substances. Other elements do not combine as easily and that limits the number of substances that they can make.

3. Why was it so difficult for chemists to discover some of the elements?
Many of the elements have a fascinating history. Gold, silver, iron, copper, and others were discovered in ancient times, but a large number of other elements were found only in recent decades. Some elements, like copper, are sometimes found in almost pure forms. Others, like iron, can be readily released when the ore is heated. However, many of the elements are only found in combination with others, and some, particularly those with high atomic numbers, are very rare.

4. Are there other elements that have not been discovered?
Chemists are convinced that they have discovered all of the elements that are found naturally in the universe. The reason they are so confident is because the periodic table is based on the atomic structure of elements. The number of protons in the nucleus of the atom determines the number of each element. Each one of the squares from 1, hydrogen, to 92, uranium, is filled with an element that has been discovered, isolated and studied. The transuranium elements, beyond atomic number 92, have only been created in laboratories. It may be possible that somewhere in the universe a transuranium element may be found but it seems unlikely.

5. Why do chemists think the periodic table is so elegant?
The periodic table is one of the greatest achievements of mod-

ern science and is the key to understanding the makeup of matter. The table accurately predicts the structure of the atoms of each of the elements, it gives the atomic mass of elements, and gives detailed information on atomic orbitals. One of the most useful things that the table is used for is to predict how elements combine into compounds. There is a type of elegance in the table but there is also an elegance in the fundamental chemical structure of matter.

◆ FOLLOW-UP ACTIVITIES

The following activities and projects are designed to help students understand the periodic table.

1. Research the elements oxygen (O), sodium (Na), and iron (Fe). Write a brief history of the discovery and uses of each of these elements.

2. Compare the periodic table of Demitri Mendeleev with the modern periodic table. Mendeleev was able to predict the existence of some undiscovered elements because there were gaps in his table. What were some of those elements?

3. Research and write a brief biography of the English chemist, Henry Moseley. Why was his proposal to use atomic number rather than atomic mass so significant in the organization of the periodic table?

4. Research and write a brief history of the element mercury (Hg). Why is mercury useful in studying weather?

5. Draw a simple diagram of an internal combustion engine that uses hydrogen as a fuel. What are the advantages and disadvantages of using hydrogen rather than gasoline?

6. Study the atomic mass of elements on the periodic table. Does the atomic mass of elements invariably increase as the atomic number of elements increases? Describe any variations.

7. The p Block elements are some of the most common and important in the periodic table. Select one of these elements and write a brief history of it describing its discovery and usefulness.

8. Research the characteristics of the d Block elements. Why are they often used for building materials?

9. Draw the electron configuration of the following elements: sodium (Na), argon (Ar), and fluorine (F).

10. Write in full the electron configuration of the following elements: neon (Ne), gold (Au), and uranium (U).

◆ REFERENCES

There are many excellent books and websites dealing with the periodic table that are appropriate for students. The following is a short list.

Books:

LeMay, Eugene, Karen M. Robblie, Herbert Beall, Doug-las Brower, *Chemistry: Connections to Our Changing World*, Englewood Cliffs, New Jersey, Prentice Hall, 1996.

McMurry, John, Robert C. Fay, *Chemistry*, Englewood Cliffs, New Jersey, Prentice Hall, 1995.

Smoot, Robert C., Richard G. Smith, Jack Price, *Chemistry*, Glencoe: McGraw Hill, 1998.

Internet Sites:

www.chemicalelements.com

www.chemicool.com

www.periodic.table.com

www.howstuffworks.com/atom.htm

http://highschoolhub.org/hub/chemistry.cfm

http://dir.yagoo.com/Science/Chemistry/

www.dist214.k12il.us/users/asanders/chemhome2.html

◆ SCRIPT OF NARRATION

In the middle of the nineteenth century, before modern chemistry was established, a number of scientists experimenting with materials came to understand that matter was made up of different elements. They found that some elements were very similar while others were radically different. What they could not understand was why these differences existed. Solving this mystery led to the development of the periodic table of the elements, which remains the major analytical tool of chemistry.

THE DEVELOPMENT OF THE PERIODIC TABLE

Ancient metal workers were perhaps the first to learn about the elements. Gold, silver, copper, and iron were forged in foundries as long ago as ancient times. By 1800, some thirty elements were known and over the next 100 years, over sixty elements had been identified. As they studied these elements, scientists looked for patterns and how the different elements related together.

In 1869, a Russian chemist, Demitri Mendeleev, published this table of all the known elements. It is the forerunner of the periodic table we use today and one of the most brilliant insights of science.

Mendeleev's table was based on the increasing atomic mass of the elements. As he arranged the elements in his table, he found that some had similar properties. Those he arranged in vertical columns in his table. He also recognized that there were gaps in the patterns of the elements and predicted that there were undiscovered elements that must fill those gaps. Later, new elements were discovered that fit his predictions.

Today we do not list the elements in the periodic table by their atomic mass. We list them by atomic number. The number of protons in the nucleus of the atom determines the atomic number of an element.

The person who saw the importance of atomic number was a young English scientist by the name of Henry Moseley. He was a student of Ernest Rutherford, who had discovered the nucleus, and gave a preliminary explanation of the atomic structure. Moseley understood that the significant difference between the elements was their number of protons. Once the number of protons is known, it is possible to determine the number of electrons in a neutral atom.

It was not that Mendeleev was wrong in the way that he listed the elements. The atomic mass of elements increases as the number of protons in the nucleus increases, but atomic number tells us more about the element.

The Periodic Law is the basis of the periodic table. It states: "When elements are arranged in order of increasing atomic number, their physical and chemical properties show a periodic pattern." As we will see, the pattern of the table is tied to the very structure of the atom itself. That is what makes it such a useful tool.

READING THE PERIODIC TABLE

The periodic table is a type of map of all of the elements. The position of the element on the table explains the structure of the atom and helps us understand how it will react with the other elements.

The elements are organized from atomic number 1, hydrogen, to atomic number 114, ununquadium. Actually there are only 92 elements that are found naturally in the universe. Uranium is atomic number 92. Beyond uranium are the transuranium elements, which have only been created in laboratories.

The elements are organized in horizontal rows, called periods. The numbers of the periods are printed along the side. They are called the principal quantum numbers, or simply "n." In period 1, there are only two elements, hydrogen, on the extreme left and helium on the extreme right hand side of the table. Periods 2 and 3 each have 8 elements. Periods 4 and 5 have 18 elements. Period 6 has 32 and period 7 goes from element 87 to 114 on this table. Where are the extra elements in periods 6 and 7? They are printed below for convenience because that is the only way they can be fitted on a page.

Not only is the position of the element in the period significant, but so is its position on the vertical column. These columns are called groups. Their numbers are listed along the top of the table. Elements in each of the groups have similar characteristics and because of this they have been given names. The elements in group 1, for example, are called the alkali metals and group 18 is called the noble gases.

The size, or radius, of atoms is an important factor in their bonding. The radius of elements decreases from left to right across each period of the periodic table. The numbers of electrons increase across the period from left to right, but there is also an increase in the nuclear charge due to the additional protons in the nucleus, which hold the electrons more tightly to the nucleus. The radius of elements also increases moving down the groups of elements. This is because there are more electrons, protons, and neutrons in the atoms.

There is one element that is unique. It is hydrogen, atomic number 1, the most prevalent element in the universe. Hydrogen is listed in group 1, but it is separated a little from the others. It has many of the characteristics of the other elements in group 1, the alkali metals, but it is a gas, and definitely not a metal.

THE SQUARES OF THE PERIODIC TABLE

Every element has its own square in the periodic table and within that square is contained the vital information of the element.

This is the square of nitrogen. Its atomic number of 7 is written at the top. We immediately know that there are 7 protons in the nucleus of the atom and when it is electrically neutral, the element has 7 electrons.

Every element has a symbol that is used by chemists around the world. Some periodic tables, like this one, have the name of the elements but many do not. Nitrogen's symbol is N and uranium is U, but not all of the symbols are that easy to remember. Gold, for example, is Au, which comes from the Latin word for gold, aurum. Some of the more rare elements are named after countries where they were discovered or scientists. Chemical formulas are always written using the letter symbols so it is helpful to remember some of the most common ones.

The atomic mass of the element is the number written immediately below the symbol and name of the element. Nitrogen, for example, has an atomic mass of 14.0067 amu. Amu stands for atomic mass unit. Chemists often need to know the atomic mass of an element in order to accurately measure the quantity of substances.

The atomic mass of elements almost always increases as the atomic number increases. The reason is that as the atomic number increases, there are more protons, neutrons, and electrons in the atom. Each proton or neutron equals about 1 amu. Electrons have much smaller mass. As a result, the higher the atomic number, the greater the mass of the element.

The last number at the bottom of each square describes the electron configuration of the element. Because of the importance of electron configurations, we are going to look at them in more depth.

ELECTRON CONFIGURATIONS

The nuclei of atoms are relatively stable but the electrons move about the nucleus and can move from atom to atom. When atoms react with other atoms, the electrons often interact so that two or more atoms become molecules, or they lose or gain one or more electrons. In either case, it is only the outermost electrons of the atoms, called the valence electrons, that are involved in bonding and they are responsible for the chemical properties of the element.

Each energy level can only take a limited number of electrons. The first energy level can take 2 electrons. The second and third can each take 8. The fourth and fifth can take 18 and the sixth can take 32. Notice anything? The number of electrons that can be accommodated in the energy levels is the same as the number of elements in the periods of the periodic table. The table reflects the structure of the atoms of elements. This is why the table is so useful.

The first energy level can only take two electrons and the first row of the periodic table has only two elements: hydrogen and helium. Hydrogen only has one electron, but the energy level can take two electrons. As a result, hydrogen is a relatively unstable element and often interacts with other elements.

Helium has two electrons and the first energy level can accommodate two electrons. As a result, helium is very stable and rarely interacts with other elements. In fact, helium is one of the noble gases that are on the right hand side of the periodic table.

The second energy level can accommodate 8 electrons and there are 8 elements in the second period of the periodic table. Lithium has only one valence electron, beryllium has two, and so on, until we get to neon, which has 8 valence electrons. The valence energy level of neon is full. Neon, like helium, is one of the noble gases.

Elements do not interact in a random way. Each atom attempts to interact with other atoms so that the electron configuration of its outer valence energy level is full. It does this by borrowing, lending, or sharing electrons. This is known as the Octet Rule. As a general rule, the elements on the left-hand side of the periodic table are termed "electropositive" because they tend to easily lose their outer valence electrons, while those on the right hand side of the table are "electronegative," tending to attract electrons so they can fill their outer energy level. The noble gases are very stable elements because their valence energy level is full of electrons.

Chemists can tell almost at a glance how an element will interact with other elements simply by looking at the location of the element on the periodic table.

WRITING ELECTRON CONFIGURATIONS

The last line in the square of each element on the periodic table is the precise description of the electron configuration of the element. These letter symbols refer to the electron orbitals—specially-shaped regions where we might find electrons moving around the nucleus. Chemists are mainly concerned with the orbitals of the valence electrons because they determine how atoms bond together, and the chemical behavior of the element.

There are four important orbital shapes: s, p, d, and f. The s orbital can take a maximum of 2 electrons, the p orbitals can take up to 6 electrons, the d orbitals can take up to 10 and the f orbitals can hold a maximum of 14 electrons. There is a direct connection between how many electrons it takes to completely fill the orbitals at each energy level and the number of elements in that period of the table.

Let's look at some examples of how the electron configurations of atoms are written. Hydrogen has only one electron in an s-shaped orbital. It is written $1s^1$. Helium has two electrons in an s orbital. It is written $1s^2$. This is saying in the first energy level, the s-shaped orbital is filled to capacity with 2 electrons. Lithium has atomic number 3 and is in the next period of the table, but look how its electron configuration is written. This is a shorthand that chemists have developed. [He] says that the electrons in the inner energy level are exactly like the electron configuration of helium. $2s^1$ is a description of the valence electrons. It is saying that in the second energy level, the s-shaped orbital, is half-filled with one electron.

Reading electron configurations takes some practice. Let's read one more: gold. The inner energy levels have the same configuration as the noble gas xenon, whose symbol is Xe. The valence electrons are the following: 14 electrons in the fourth energy level in f orbitals, 10 electrons in the fifth energy level in d orbitals, and 1 electron in an s orbital in the sixth energy level.

It was only when chemists understood the electron configurations of elements that they could understand how atoms interact to make the millions of substances that we find in the universe.

A TOUR OF THE TABLE

The electron configurations determine the chemical properties of elements but they also provide a way of dividing the table into four blocks of elements with similar properties. Each of the blocks is named for the shapes of the orbitals of the valence electrons.

The s Block is made up of elements whose valence electrons are in s orbitals only. They are the elements in the first two groups on the left-hand side of the table. Group 1 are called the alkali metals and group 2 are called the alkaline earth metals. They are soft metals, like sodium, potassium, and calcium that react readily in air and water. The s Block is only two elements wide because s orbitals can only take two electrons.

The d Block elements occupy the middle of the table. These elements are called transition metals. They are strong metals, such as titanium, chromium, gold, and iron, that make useful building materials. The d Block is ten elements wide because d-shaped orbitals can accommodate ten electrons.

The f Block elements are placed below the main body of the periodic table. The two periods are 14 elements wide because the f-shaped orbital can hold 14 electrons. These elements are rarely found and become increasingly unstable the higher the atomic number. The most familiar is uranium, element 92, which is used as fuel in nuclear reactors and atomic bombs.

The p Block elements are on the right-hand side of the periodic table. These are some of the most common and important elements and include carbon, iodine, oxygen, nitrogen, and sulfur. The p Block is six elements wide because the p-shaped orbitals can accommodate six electrons. Included in the p Block are the noble gases at the right-hand side of the table. Because their valence energy levels are full of electrons, the noble gases rarely interact with other elements.

Chemists sometimes talk about the elegance of the periodic table, and the reason they see elegance is because the table reflects perfectly the structure of atoms. It remains the most important organizing principle of chemists because it helps us understand the atomic structure of the elements and their chemical reactions.