

Periodic Table

THE PERIODIC TABLE is an important chemistry reference. All the known elements are arranged in an informative and organized manner: blocks, rows, and columns. Each element's location on the table signifies how that chemical reacts with other elements. Scientist, chemists, and students use the periodic table to explore and study elements. How is the periodic table used in manufacturing?



Objective:



Review and explain the organization, patterns, and features of the periodic table.

Key Terms:



alkali metals
alkaline earth metals
atom
atomic number
atomic radius
atomic symbol
atomic weight
ductile

electron configuration
halogens
malleable
metalloids
metals
noble gases
nonmetals
period

periodic
periodic table
post-transition metals
rare earth metals
transition metals
trans-uranium
valence electrons

Understanding the Periodic Table

The **periodic table** is a chart that arranges all of the known chemical elements based on atomic number in such a way that the periodic property of each element is clear. Some characteristics of the elements are related to their position on the periodic table. The table predicts the chemical behavior of the elements and is divided into three basic categories: metals, nonmetals, and metalloids.

- ◆ **Metals** are typically shiny substances that are silvery in color and are excellent conductors of electricity and heat. Metals are **malleable**—able to be beaten into thin sheets—

PERIODIC TABLE of the ELEMENTS

ELEMENT CATEGORIES

- ALKALI METALS
- ALKALI EARTH METALS
- TRANSITION METALS
- OTHER METALS
- NONMETALS
- OTHER NONMETALS
- HALOGENS
- NOBLE GASES
- UNKNOWN CHEMICAL PROPERTIES

ELEMENT STATE at 0°C and 1 atm

- * Solid
- ** Liquid
- *** Gas

FIGURE 1. The periodic table is a chart that arranges all of the known chemical elements based on atomic number in such a way that the periodic property of each element is clear. Some element characteristics are related to their position on the periodic table. The table predicts the chemical behavior of the elements and is divided into three basic categories: metals, nonmetals, and metalloids. This periodic table image includes element name, atomic number, element symbol, and element states: solid, liquid, and gas.

and ductile. **Ductile** is able to be drawn into thin wires. Metals occupy the left three-fourths of the periodic table.

- ◆ **Nonmetals** are substances that are typically dull in color and are poor conductors of electricity and heat. Solid nonmetals tend to be brittle. Nonmetals (except for hydrogen) occupy the top right corner of the table.
- ◆ **Metalloids** (semimetals) are substances with properties intermediate between metals and nonmetals; they have similar properties to the metal and the nonmetal categories.

ATOMIC STRUCTURES AND ELEMENT CHARACTERISTICS

It is important to be familiar with atomic structures and the various element characteristics. An **atom** is a unit of matter; it is the structure of an element. A typical atom consists of a

positively charged nucleus composed of protons and neutrons and a cloud of *negatively charged* electrons orbiting the nucleus.

Atomic Structures

Atomic Number

The **atomic number** is the number of protons (a part of the atomic nucleus with a mass of 1 and a charge of +1) in an element; it is sometimes known as the proton number. For example, the atomic number of hydrogen is 1, and the atomic number of carbon is 6. The atomic number determines the chemical properties of an element and where that element is located on the periodic table. Each element has a different number of protons. The protons determine the chemical behavior of the element. The elements are arranged on the periodic table from left to right and top to bottom as the number increases.

Atomic Symbol

An **atomic symbol** is a letter or letters used to represent the element on the periodic table. The symbol is usually an abbreviated (or truncated) version of the name in English or Latin. For example, hydrogen's atomic symbol is "H," and oxygen's atomic symbol is "O."

Atomic Weight

The **atomic weight** is the average mass of each element given in atomic mass units (amu). Atomic mass relates directly to the total num-

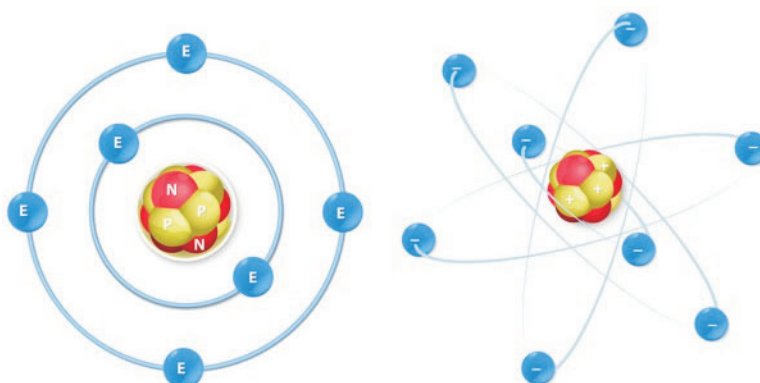


FIGURE 2. An atom is a unit of matter; it is the structure of an element. A typical atom consists of a positively charged nucleus composed of protons and neutrons and a cloud of negatively charged electrons orbiting the nucleus. Carbon is represented on the periodic table with the letter "C" and the atomic number "6." How does the atomic number "6" relate to this image? Can you find six protons?

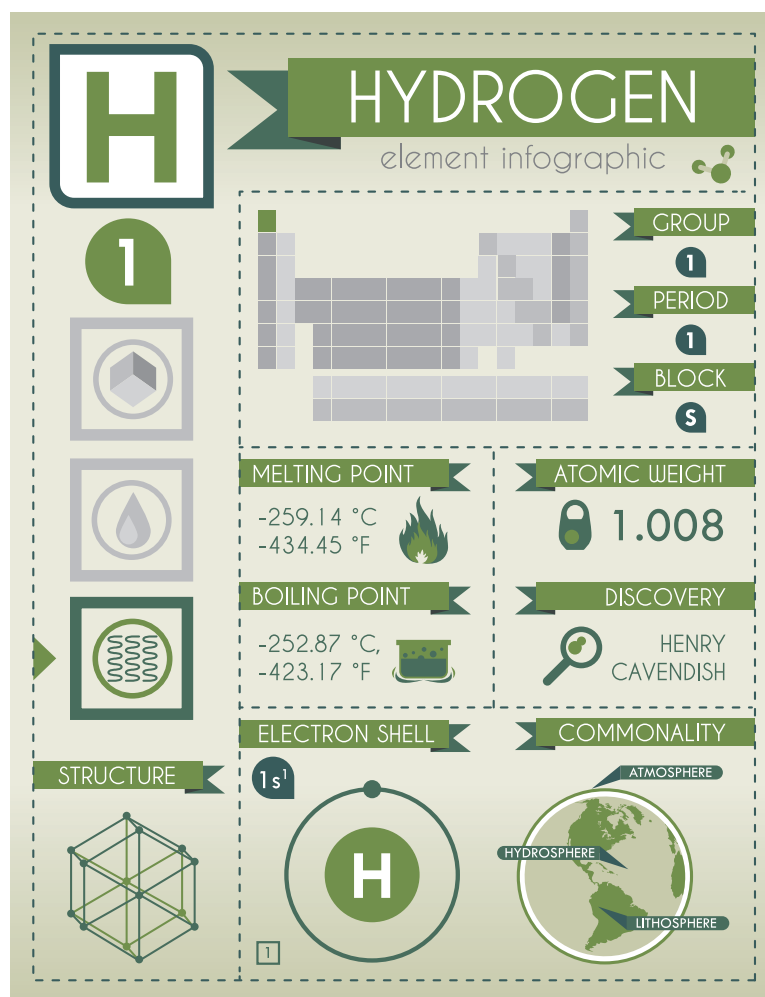


FIGURE 3. Hydrogen is element 1, with an atomic weight of 1.008. What other information is available about hydrogen in this infographic?

ber of protons and electrons; they are responsible for weight. To find the total amount (or average amount) of electrons in an element, subtract the atomic number from the atomic weight.

Atomic Radius

Atomic radius is a way to describe the size of an atom. However, no standard definition of the process exists. For example, atomic radius can refer to ionic radius, covalent radius, metallic radius, or van der Waals radius. In all measurement methods, the size of the atom depends on how far out the electrons extend. In general, the atomic radius of elements tends to increase as you move down an element group. The two common measurement methods are:

- ◆ The van der Waals radius is equal to half the distance between two unbounded atoms when the electrostatic forces between them are balanced.
- ◆ The covalent radius is the size of an atom that forms part of a covalent bond radius of the atoms of an element when covalently bound to other atoms. A covalent bond is a chemical link between two atoms in which electrons are shared between them. For instance, a covalent bond exists between the oxygen and between each of the hydrogen in a water molecule— H_2O .

Electron Configuration

Electron configuration is the orbital description of the locations of the electrons in an *unexcited* atom. The configuration tells you how the electrons are distributed around an atom or a molecule. The electrons exist in different shells or layers around the nucleus. The outermost shell is typically the only one that matters in chemistry, so the full description is abbreviated. The abbreviation notates the number of electrons assigned to each orbital (or shell) and the type of orbit. This information is important because it is used to *predict* how atoms will react.

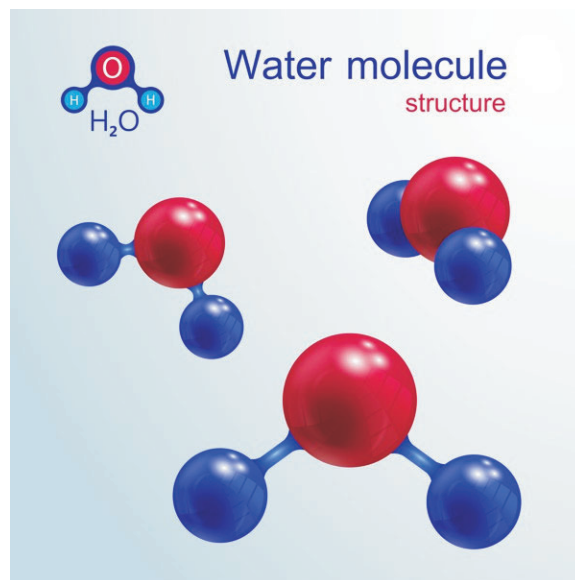


FIGURE 4. A covalent bond is a chemical link between two atoms in which electrons are shared between them. For example, a covalent bond exists between the oxygen and between each of the hydrogen in a water molecule— H_2O .

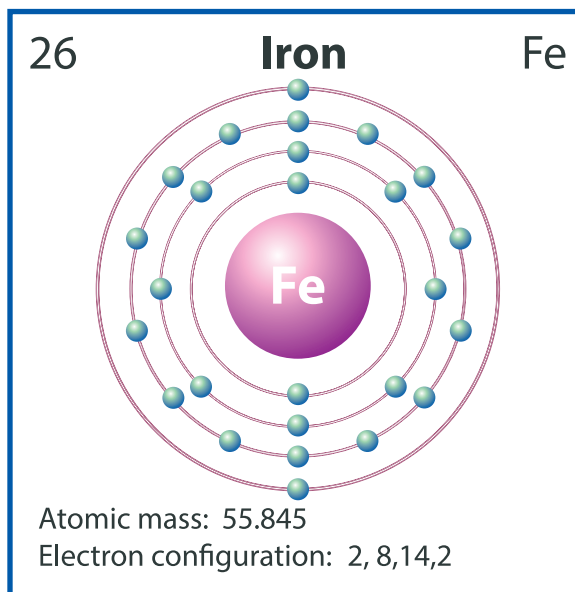


FIGURE 5. Electron configuration is the orbital description of the locations of the electrons in an *unexcited* atom. This iron configuration tells you how the electrons are distributed: 2, 8, 14, and 2 (a total of 26). The electrons exist in different shells or layers around the nucleus. Electron configuration can predict the following about an atom: stability, boiling point, and conductivity.

The electron configuration can predict the following about an atom: stability, boiling point, and conductivity.

PERIODIC TABLE ORGANIZATION AND PATTERNS

You need to know how the periodic table is organized to be able to find elements more quickly and to understand the patterns based on relationships.

Patterns

The periodic table of elements displays the organizing principles of matter. Scientists needed a way to organize the elements: an organizational plan that represented the properties of each element and how elements are related. Dmitri Mendeleev looked for patterns among the known elements and noted that when elements are listed in order of mass, their properties are periodic. **Periodic** is anything with a repeating pattern.

What is the pattern in the way numbers are written? Zero to 9 are unique numbers. Then the pattern starts over with 10 through 19, etc. This pattern could be seen on the table. Is temperature periodic? If a person tracks the temperature readings for a specific geographic area every four hours for five days, is there a pattern? Yes. The overall pattern is periodic: warmer in daylight and colder at night. This pattern could be seen on a graph.

On the periodic table:

- ◆ Rows increase in atomic number and mass.
- ◆ Columns represent elements with similar properties.

Organization: Blocks, Rows, and Columns

The elements are in blocks, rows, and columns.

Blocks

Each block of the periodic table of elements represents one element and contains a/an:

- ◆ Atomic number
- ◆ Symbol
- ◆ Name
- ◆ Atomic mass

Rows

Each row of elements is a **period**. The period number is based on the highest energy level an electron in the element occupies. Periods are numbered from top to bottom.



FURTHER EXPLORATION...

ONLINE CONNECTION: Elements and the Periodic Table

All the elements on the periodic table have a range of uses and applications. Learn more about what they look like, how they react with other elements, how they are used, and how they are organized by watching the Khan Academy Periodic Table of Elements video at https://www.youtube.com/watch?v=t_f8bB1kf6M.

PERIODIC TABLE OF THE ELEMENTS

Group of elements

- Non-metals
- Alkali Metals
- Alkaline Earth Metals
- Transition Metals
- Metalloids
- Poor metals
- Halogens
- Noble gases
- Lanthanides
- Actinides

STANDARD STATE (25 °C, 1013 kPa)

- SOLID
- LIQUID
- GAS
- SYNTHETIC

Can you point out the organization of the periodic table?

Columns

Columns are called families or groups. Most columns are named for the first element in the family. However, some families have specific names (e.g., alkali metals, carbon family, halogens, and noble gases).

ELEMENT GROUP ORGANIZATION

The chemical elements of the periodic table are grouped and arranged based on certain common characteristics. The elements are organized in vertical columns called groups. Each element in a group has the same valence electron configuration in the outer energy level (with the exception of some transition metals), meaning the elements in each group react in a similar manner.

Valence electrons are the particles in an atom that are able to combine with other elements. The number of valence electrons each atom has determines how reactive the element would be. When the valence electrons are not full, they react. The electrons in the outermost level are the valence electrons.

The element groups are metals, nonmetals, and metalloids. Metals are alkali metals, alkaline earth metals, transition metals, and post-transition (or other metals). About 75 percent of the periodic table is classified as a metal. Metals are solid and shiny. In addition, they are good conductors of electricity and heat. The base metals include aluminum, gallium, tin, and lead. In contrast, nonmetals are halogens and noble gases.

Metals

Alkali Metals

Alkali metals are soft, highly reactive metals in their pure form: Group 1. All react with water to form hydrogen gas that ignites. They are located on the far left side of the periodic table, and all have one electron in their outer shell. The single electron can be lost or joined to another element in an ionic bond. They are softer than most metals and are malleable (flexible or plastic), ductile, and good conductors of heat and electricity. Hydrogen is in this group, but it has few properties of the metals and is sometimes grouped with the nonmetals. Alkali metals include lithium, sodium, and potassium.

Alkaline Earth Metals

Alkaline earth metals are reactive, silver-colored, soft metals: Group 2. They are harder and denser than the alkali metals and are less reactive. The alkaline earth metals have high melting points and stay solid in a fire. They react with water, but not as vigorously as the alkali metals. An oxidation number of +2 makes them highly reactive. They are located in the second column on the far left of the table. The alkaline earth metals are not found free in nature. They are found in the earth's crust and include magnesium, calcium, barium, and radium.

Transition Metals

Transition metals are malleable and ductile substances that conduct electricity and heat; Groups 3 through 12 (columns 3 through 12 on the periodic table). They have a partially filled subshell that allows the electrons they use to combine with other elements (the valence electrons) to exist in more than the outer shell and can produce a magnetic field. This group has numerous uses, including jewelry, fine art, housewares, auto technology, magnets, etc. The elements are iron, cobalt, nickel, platinum, gold, silver, copper, zinc, and mercury.

Rare Earth Metals

Rare earth metals are silver, silvery-white, or gray metals with a high luster that tarnish easily when exposed to air and have high electrical conductivity. They include 30 elements composed of the lanthanide and the actinide series: Group 3 (or as a subgroup under transition metals).

One element of the lanthanide series and most of the actinide series are called trans-uranium. **Trans-uranium** is a term for synthetic or humanmade elements. These elements are radioactive and are known as f-elements because their valence electrons exist in the f-shell. The only naturally occurring elements in this group are uranium and thorium.

Post-Transition Metals

Post-transition metals (or the other metals) are solid and shiny substances that have high densities, but they tend to be softer and do not conduct electricity or heat as well as the transition metals. They are ductile and malleable (flexible), similar to properties of the metals.

The post-transition metals are located in columns 13, 14, and 15 on the periodic table. Their valence electron only exists in the outer shell.

Nonmetals

As mentioned previously, nonmetals are substances that have the ability to gain electrons easily; they are poor conductors of heat and electricity. In addition, nonmetals are brittle and usually dull in color. They include carbon, nitrogen, oxygen, sulfur, and selenium.

Halogens

Halogens are a subset of the nonmetals and occur in pure form as diatomic molecules that are highly reactive: Group 17. At 70°F (room temperature), they are able to exist in all three states: gas, solid, or liquid—depending on the compound. They do not exist as pure elements in the environment but as compounds. The term “halogen” means salt-former. Compounds that contain halogens are called salts. The group is located in column 17 on the periodic table. They have 7 electrons in the outer shell and can be extremely chemically reactive. Each element combines with one hydrogen atom and one halogen atom to form highly acidic compounds. Each element combines with sodium to form a new compound. Each element combines with one halogen atom, one carbon atom, and three hydrogen atoms to form new methane compounds. Halogens and their compounds include:

◆ Fluorine

- Hydrogen fluoride (Acids: one hydrogen and one halogen atom)
- Sodium fluoride (New sodium compounds)
- Fluoromethane (New methane compounds: one halogen atom, one carbon atom, and three hydrogen atoms)

◆ Chlorine

- Hydrogen chloride
- Sodium chloride
- Chloromethane

◆ Bromine

- Hydrogen bromide
- Sodium bromide
- Bromomethane

◆ Iodine

- Hydrogen iodide
- Sodium iodide
- Iodomethane

Noble Gases

Noble gases are substances that occur in their pure form as colorless gases that are highly unreactive and chemically stable: Group 18. The stability of this group is due to electron configuration; most have two completely filled orbitals that result in stability. Their oxidation number is 0; they form few, if any, compounds with themselves or other elements. All give off light in gas discharge lamps. They reside in column 18 on the periodic table. All possible electrons are filled in their outer shell. Noble gases include:

- ◆ Helium
- ◆ Neon
- ◆ Argon
- ◆ Krypton
- ◆ Xenon
- ◆ Radon

10 Ne 20.1797 Neon	54 Xe 131.293 Xenon
-----------------------------	------------------------------

FIGURE 6. Each block of the periodic table of elements represents one element and contains a/an atomic number, symbol, name, and atomic mass. These two blocks are from the noble gas group: neon and xenon. How are the noble gases used in manufacturing?

Summary:



The periodic table is a chart that arranges all of the known chemical elements based on atomic number in such a way that the periodic property of each element is clear. Some element characteristics are related to their position on the periodic table. The table predicts the chemical behavior of the elements and is divided into three basic categories: metals, nonmetals, and metalloids.

Checking Your Knowledge:



1. Describe the information on a periodic table block.
2. What is the significance of the numbering system of the periodic table?
3. What determines the atomic weight of an element?
4. Explain electron configuration.
5. For which uses are the noble gases used in manufacturing?

Expanding Your Knowledge:



Many resources and Web pages have interactive graphics and information about the periodic table. Perhaps the most interesting is the Los Alamos National Laboratory Web site. The image here is the “Trinity” explosion at Los Alamos, Alamogordo, NM, on July 16, 1945, taken 9 seconds after the initial Trinity detonation. It shows the mushroom cloud. How did this explosion impact World War II? What manufacturing and innovation followed the Manhattan Project’s nuclear explosion at Los Alamos?



Web Links:



Interactive Periodic Table

<http://www.periodictable.com>

About the Periodic Table of Elements

<http://periodic.lanl.gov/about.shtml>

Periodic Table

<http://periodic.lanl.gov/images/periodictable.pdf>