

Section 1

Arranging the Elements

Key Concept Elements are arranged on the periodic table according to their atomic number and their chemical properties.

What You Will Learn

- Elements on the periodic table are arranged in order of increasing atomic number.
- Elements on the periodic table are classified as metals, nonmetals, or metalloids.
- Elements in a horizontal row, or period, are listed in order of increasing atomic number.
- Elements in a vertical column, or group, usually have similar chemical properties.
- The periodic law states that the properties of elements form a pattern according to increasing atomic number.

Why It Matters

If you understand the arrangement of the elements on the periodic table, you can use the table as a tool for predicting the structure of atoms.

Suppose that you are at a video store and all the videos are mixed together. How can you quickly find a comedy or an action movie? If the videos are not arranged in a pattern, you won't know where to look!

Scientists in the early 1860s had a similar problem. At that time, scientists knew some of the properties of more than 60 elements. However, no one had organized the elements according to these properties. Finding patterns among the elements would help scientists understand the elements. And organizing the elements according to their properties would help scientists understand how elements interact with each other.

Discovering a Pattern

Dmitri Mendeleev (duh MEE tree MEN duh LAY uhf), who was a Russian chemist, discovered a pattern to the elements in 1869. First, he wrote the names and properties of the elements on cards. Then, he played "chemical solitaire" with the cards. He arranged his cards, as shown in **Figure 1**, by different properties, such as density, appearance, and melting point. After much thought, he arranged the elements in order of

increasing atomic mass. When he did so, a pattern appeared.



Figure 1 By playing “chemical solitaire” on long train rides, Mendeleev organized the elements according to their properties.

Periodic Properties of the Elements

Mendeleev saw that when the elements were arranged in order of increasing atomic mass, those that had similar properties fell into a repeating pattern. That is, the pattern was periodic. **Periodic** means “happening at regular intervals.” The days of the week are periodic. They repeat in the same order every seven days. Similarly, Mendeleev found that the elements’ properties followed a pattern that repeated every seven elements. His table became

known as the *periodic table of the elements*.

Predicting Properties of Missing Elements

Figure 2 shows part of Mendeleev's first try at arranging the elements. The question marks show gaps in the pattern. Mendeleev predicted that elements yet to be found would fill these gaps. He used the pattern he found to predict their properties.

Table 1 compares his predictions for one missing element—germanium—with its actual properties. By 1886, all of the gaps that he had noted had been filled. His predictions were right.

		Ni=Co=59	
H=1			Cu=63,4
	Be=9,4	Mg=24	Zn=65,2
	B=11	Al=27,4	?=68
	C=12	Si=28	? =70
	N=14	P=31	As=75
	O=16	S=32	Se=79,4
	F=19	Cl=35,5	Br=80
Li=7	Na=23	K=39	Rb=85,4
		Ca=40	Sr=87,6
		?=45	Ce=92
		?Er=56	La=94
		?Yt=60	Di=95
		?In=75,6	Th=118?

Figure 2 Mendeleev used question marks to note elements that he thought would be found later.

Table 1 Properties of Germanium		
	Mendeleev's predictions (1869)	Actual properties
Atomic mass	70	72.6
Density*	5.5 g/cm ³	5.3 g/cm ³
Appearance	dark gray metal	gray metal
Melting point*	high melting point	937°C

*at room temperature and pressure

Changing the Arrangement

A few elements' properties did not fit the pattern in Mendeleev's table. Mendeleev thought that more-accurate atomic masses would fix these flaws in his table. But new measurements showed that the masses he had used were correct. In 1914, Henry Moseley (MOHZ lee), a British scientist, determined the number of protons—the atomic number—in an atom. All elements fit the pattern in Mendeleev's periodic table when they were arranged by atomic number.

Look at the periodic table on the next two pages. The elements are arranged horizontally in order of increasing atomic number. Elements that have similar chemical properties are grouped in vertical columns.

Standards Check How are the elements arranged horizontally and vertically on the periodic table?



Periodic Table of the Elements

Each square on the table includes an element's name, chemical symbol, atomic number, and atomic mass.

The color of the chemical symbol indicates the physical state at room temperature. Carbon is a solid.

6
C
Carbon
12.0

Atomic number
Chemical symbol
Element name
Atomic mass

The background color indicates the type of element. Carbon is a nonmetal.

Period 1	Group 1		Group 2											
	1 H Hydrogen 1.0													
Period 2	Group 1		Group 2											
	3 Li Lithium 6.9	4 Be Beryllium 9.0												
Period 3	Group 1		Group 2											
	11 Na Sodium 23.0	12 Mg Magnesium 24.3												
Period 4	Group 1		Group 2		Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9			
	19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9					
Period 5	Group 1		Group 2		Group 3		Group 4	Group 5	Group 6	Group 7	Group 8	Group 9		
	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9					
Period 6	Group 1		Group 2		Group 3		Group 4	Group 5	Group 6	Group 7	Group 8	Group 9		
	55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2					
Period 7	Group 1		Group 2		Group 3		Group 4	Group 5	Group 6	Group 7	Group 8	Group 9		
	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)					

Background
Metals (light blue)
Metalloids (light green)
Nonmetals (yellow)

Chemical symbol
Solid (pink)
Liquid (blue)
Gas (green)

A row of elements is called a *period*.

A column of elements is called a *group* or *family*.

Values in parentheses are the mass numbers of those radioactive elements' most stable or most common isotopes.

Lanthanides

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4
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Actinides

90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)
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These elements are placed below the table to allow the table to be narrower.

The Periodic Table and Classes of Elements

At first glance, you may think that studying the periodic table is like trying to explore a thick jungle without a guide— you can easily get lost! However, the table itself contains a lot of information that will help you along the way.

Elements are classified according to their properties as metals, nonmetals, and metalloids. Regions of the periodic table correspond to classes of elements. The number of electrons in the outer energy level of an atom helps determine the category in which an element belongs. The zigzag line on the periodic table can help you recognize which elements are metals, which are nonmetals, and which are metalloids.

Metals

Most elements are metals. Metals are found to the left of the zigzag line on the periodic table. Atoms of most metals have few electrons in their outer energy level. Most metals are solid at room temperature. Mercury, however, is a liquid at room temperature. Some more information on metallic properties is shown in **Figure 3**.

Figure 3 Properties of Metals



Metals tend to be **shiny**. You can see a reflection in a mirror because light reflects off the shiny surface of a thin layer of silver behind the glass.

Most metals are **ductile**, which means that they can be drawn into thin wires. All metals are **good conductors of electric current**. The wires in the electrical devices in your home are made of copper.



Most metals are **malleable**, which means that they can be rolled or pounded into shape and will not shatter. Aluminum is flattened into sheets to make cans and foil.



Most metals are **good conductors of thermal energy**. An iron griddle can conduct thermal energy from a stove top to cook foods.



Standards Check Identify where metals are found on the periodic table.

□

Nonmetals

Nonmetals are found to the right of the zigzag line on the periodic table. Atoms of most nonmetals have an almost complete set of electrons in their outer level. More than half of the nonmetals are gases at room temperature. Many properties of nonmetals are the opposite of the properties of metals.

Metalloids

Metalloids, also called *semimetals*, are the elements that border the zigzag line on the periodic table. Atoms of metalloids have about half of a complete set of electrons in their outer energy level. Metalloids have some properties of metals and some properties of nonmetals. **Figure 4** compares some of the properties of nonmetals and metalloids.

Figure 4 Properties of Nonmetals and Metalloids



Standards Check Name two properties that metals have and that nonmetals do not have.

Decoding the Periodic Table

The periodic table may seem to be in code. In a way, it is. But learning what the symbols and numbers mean can help you find your way around the table.

Chemical Symbols

Each square on the periodic table includes an element's name, chemical symbol, atomic number, and atomic mass. A scientist who discovers an element can suggest a name for it. Some elements, such as curium, einsteinium, seaborgium, and mendelevium, are named after scientists. Others, such as californium, are named after places. Some element names vary by country. But the chemical symbols are the same worldwide.

For most elements, the chemical symbol has one or two letters. The first letter is always capitalized. Any other letter is always lowercase. When you see a chemical formula, you can use the periodic table as a tool to quickly identify the elements that make up the compound.

Periods

Each horizontal row of elements (from left to right) on the periodic table is called a **period**. The physical and chemical properties of elements in a row follow a repeating, or periodic, pattern as you move across the period.

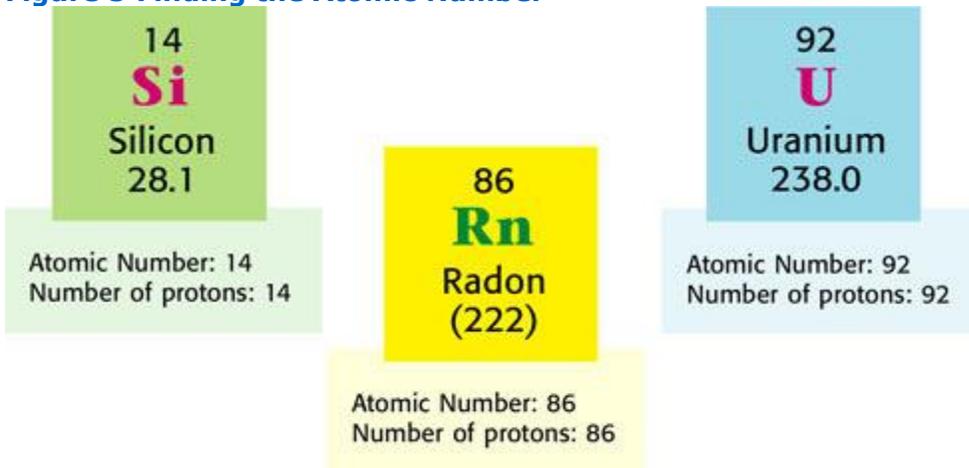
Groups

Each vertical column of elements (from top to bottom) on the periodic table is called a **group**. Elements in the same group often have similar chemical and physical properties. For this reason, a group is also called a *family*.

Atomic Number

All of the elements follow the periodic law. The **periodic law** states that the repeating chemical and physical properties of elements change periodically with the elements' atomic numbers. The atomic number of an element is the number of protons in the nucleus of an atom of that element. All atoms of a given element have the same number of protons in the nucleus. Atoms with different atomic numbers are atoms of different elements. Look at **Figure 5**. The atomic number is above the chemical symbol of each element on the periodic table.

Figure 5 Finding the Atomic Number



Although each element has a specific number of protons, the number of neutrons for an element can vary. Atoms that have the same number of protons but different numbers of neutrons are *isotopes* of each other.

Each isotope of an element has a specific number of neutrons in the nucleus.

Standards Check What does an element's atomic number equal?



Section Summary

- Mendeleev developed the first periodic table by listing the elements in order of increasing atomic mass. He used his table to predict that elements with certain properties would be discovered later.
- Properties of elements repeat in a regular, or periodic, pattern.
- Moseley rearranged the elements in order of increasing atomic number.
- Elements in the periodic table are classified as metals, nonmetals, and metalloids.
- Each element has a chemical symbol that identifies elements that make up compounds.
- A horizontal row of elements is called a *period*. Physical and chemical properties of elements change across each period.
- A vertical column of elements is called a *group* or *family*. Elements in a group usually have similar properties.
- The periodic law states that the repeating chemical and physical properties of elements relate to and depend on elements' atomic numbers.