Introduction

You have learned what atoms are, and in this unit, you will add to that knowledge. You will be introduced to theories about how atoms behave. You will also begin to see how scientists can predict behavior.

Reviewing the Atom

Think about what you have learned about the atom. The atom is the smallest unit of an element. An atom of silver still has all the properties of silver. You should also remember that atoms can combine with other atoms to form molecules and compounds.

History of the Atom

How did man learn about the atom? Atoms are too small to be seen. But as long as 2,000 years ago, the Greeks were curious about matter. They wondered how it was made. Many guesses were made about the atom. At first they guessed that atoms could not be split apart. Today we know that is not true, but these early ideas helped scientists study atoms.

About 150 years ago, an English chemist named John Dalton studied atoms. His **theory** about atoms stated the following:

- Elements are made of atoms.
- All atoms in an element have the same mass.
- Atoms cannot be split apart.
- Atoms combine with atoms of other elements to make new substances.

Some of Dalton's theory has been disproved, but it was the beginning of the modern study of atoms.

There have been many modern inventions that helped scientists study atoms. Scientists can study the atom by breaking it up into electrons, protons, and neutrons. These small parts still cannot be seen. However,

the path they leave can be photographed. It's a little like knowing a jet is in the sky by watching the path it leaves.

Atomic Number

The total number of elements is not known. It is often stated that there are about 120 elements. This means that there are essentially 120 different kinds of atoms. How are these atoms different from each other? The atoms of different elements have different numbers of protons. The protons are found in the center of the atom. The **atomic number** of any element tells how many protons are in the atom. All atoms of a particular element have the same number of protons. This is why the atomic number identifies the element. Remember also that atoms without a charge have the same number of electrons as protons. This is why the atomic number also tells the number of electrons in an atom. If an atom has 15 protons, it also has 15 electrons, and its atomic number is 15.

Periodic Table of Elements

Suppose someone gave you a box filled with different kinds of balls. They asked you to arrange them in order so that you could always find the one you wanted. How would you begin? Would you arrange them by color, size, weight, or some other property?

People who studied matter had the same problem. They had a set of elements they wanted to arrange in some kind of order, so they tried a few ways. Among the earliest groups of people during the Middle Ages to try to arrange matter in an ordered way were the **alchemists**. The alchemists wanted to change ordinary **metals** into the element gold. As you have learned, chemical changes don't alter elements. The alchemists did not succeed in creating gold. However, they did learn a great deal about elements. This set the stage for modern chemistry.

At one time, it was believed that substances burned because of some inner property. This theory was widely accepted. Although some scientists could use this theory to predict combustion, it didn't work well. Then scientists theorized that the element oxygen might exist. The theory stated that when oxygen combined with substances, changes took place. Eventually the old theory was discarded. Because the new theory better described the world, it was eventually accepted.

In this way, many elements were discovered. Each time a new finding was made, it was subjected to many tests. If other scientists could not show it was wrong, then the new theory might be accepted. After a while, scientists began to see a better picture of the world.

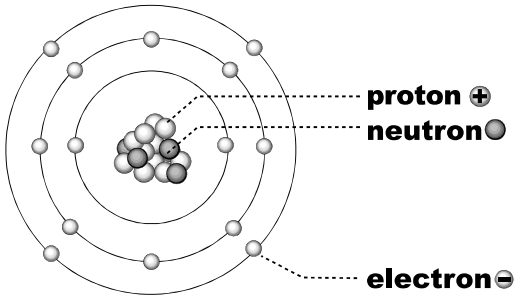
Now, scientists had quite a group of elements. They decided to make a chart or table based on the atomic number of each atom. Since hydrogen has an atomic number of one (1), it became the first element on the table. However, there were some problems with the table, because it had some missing spaces. Scientists theorized that there were unknown elements, so they experimented to find the missing elements. A few were discovered in the natural world, and a few were created in the laboratory. Some of the new elements are very **rare**. Today we generally count about 120 elements. Their atomic numbers range from one to 120. Scientists who discovered the new elements were allowed to name them. More elements may be discovered in the future.

Of course, new discoveries will be tested. If they do not fit well with what is already accepted, they may be criticized. If in the long run they do work well, then they should help predict new findings. If not, they will be discarded.

Atomic Mass

The center of an atom is called the nucleus. It contains protons and neutrons. An atom is very small, but it has mass. It would be impossible to measure the mass of an atom using grams, so a special unit of measure is used. It is called the **atomic mass unit (amu)**.

One proton has the mass of one amu. A neutron also equals one amu. The **atomic mass** of an atom equals the sum of the number of protons and neutrons. For example, a neon atom has 10 protons and 10 neutrons. Its atomic weight equals 20.



What about electrons? They are so small that they add almost no mass to the atom. For the work in this course, the mass of electrons will be ignored.

The atomic mass of atoms is usually compared to the atomic mass of carbon. Carbon has an atomic mass of 12.

Using the Periodic Table

You have already learned that the **periodic table** is arranged by atomic number (the number of protons in an element). The table also gives other important information. (See the periodic table on pages 98-99.)

Group

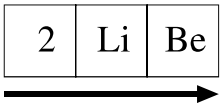
Each column of elements from the top to the bottom is called a **group**. Groups of elements have properties that are alike. The elements have properties that are alike because of their electrons. All the elements in a group have the same number of electrons in their atoms' outer shells. The outer shell is farthest from the nucleus. The electrons in the outer shell can be thought of as being on the outside of the atom.

Group 1
H
Li
Na
K
Rb
Cs
Fr

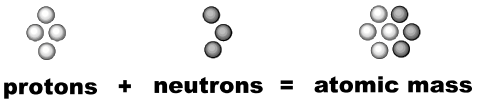
Each group has a letter and a number. All of the elements in Group 1 have one electron in their atoms' outermost shell.

Period

The groups of elements going across on the table are called **periods**. Each period has a number. The elements in a period have different properties. All elements in the left-hand side of a period tend to lose electrons. The atoms of the elements toward the right side of the period tend to gain electrons. All the atoms at the far right neither gain nor lose electrons. Although the elements in a period have very different properties, we can predict these properties.



On most tables, like the one on pages 98 and 99, there is a heavy line going down the right side. It looks like steps. All of the elements to the left of the line are *metals*; all the elements to the right are **nonmetals**. The elements that are manmade have an asterisk (*) in front of the symbol. When you study the table, you will recognize some common elements and their symbols. You will also become familiar with some new elements.



Remember that the atomic number equals the number of protons (which is also the same as the number of electrons in neutral atoms). Atomic mass is the sum of protons and neutrons. The periodic table arranges the elements by atomic number.

Elements and their symbols are listed in numerical order and grouped based on the atomic number.

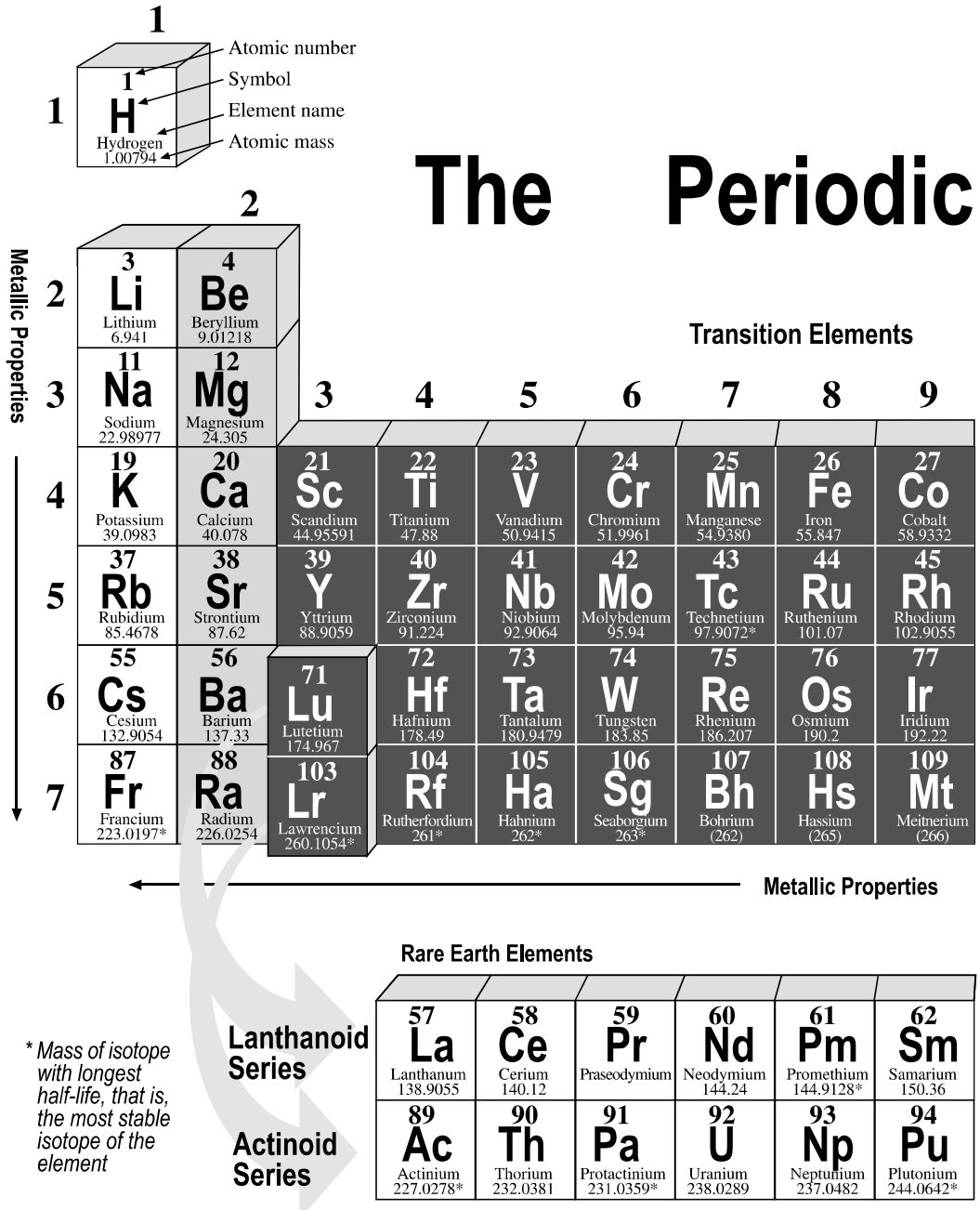
Scientists did a great deal of work to create the periodic table. Do you think they knew it would succeed when they started? Although they did not know, they did assume it would work. Chemistry demonstrates one of the fundamental ideas in science. Virtually all scientists see the whole universe as a system. That is, they see it almost as a machine with countless parts.

Your family's car has many parts. A mechanic assumes he can study your car and figure out how to fix it. He assumes this because he knows the different parts relate to each other. In much the same way, scientists believe the parts of the universe affect each other. Sometimes, they work together simply. Other times, the relationship is very complex. However, by studying the relationships, scientist learn. They hope to learn by what rules the universe works. In developing the periodic table, they learned many rules about atoms.

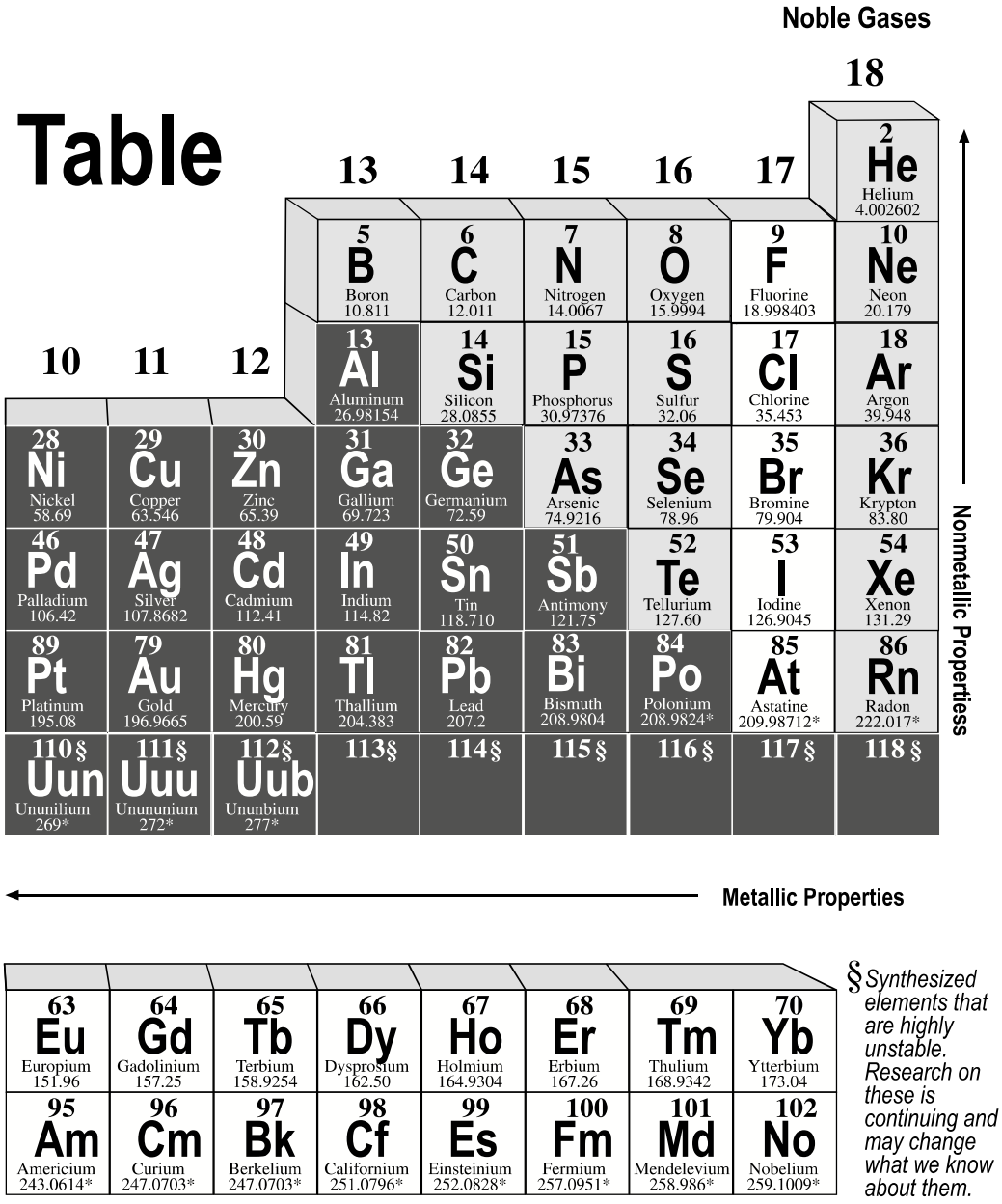
Summary

All atoms have an atomic number equal to the number of protons. In neutral atoms the number of protons and electrons are equal. The periodic table of the elements arranges atoms into groups based on the number of electrons in an atom's outermost shell. Atoms are also arranged by

increasing atomic mass. Atomic mass is the sum of the mass of protons and neutrons in a nucleus. The periodic table was developed in many stages. Theories were tried, tested, and discarded, if necessary. Old theories are replaced only when the new is better. The result is an ever-improving view of the universe. Scientists could develop the periodic table only because they assumed they could discover how the universe works. Study the periodic table and chart of symbols and elements that follow.



* *Mass of isotope with longest half-life, that is, the most stable isotope of the element*


Noble Gases
18
Table
13
14
15
16
17
2 He Helium 4.002602
5 B Boron 10.811
6 C Carbon 12.011
7 N Nitrogen 14.0067
8 O Oxygen 15.9994
9 F Fluorine 18.998403
10 Ne Neon 20.179
10
11
12
13 Al Aluminum 26.98154
14 Si Silicon 28.0855
15 P Phosphorus 30.97376
16 S Sulfur 32.06
17 Cl Chlorine 35.453
18 Ar Argon 39.948
28 Ni Nickel 58.69
29 Cu Copper 63.546
30 Zn Zinc 65.39
31 Ga Gallium 69.723
32 Ge Germanium 72.59
33 As Arsenic 74.9216
34 Se Selenium 78.96
35 Br Bromine 79.904
36 Kr Krypton 83.80
46 Pd Palladium 106.42
47 Ag Silver 107.8682
48 Cd Cadmium 112.41
49 In Indium 114.82
50 Sn Tin 118.710
51 Sb Antimony 121.75
52 Te Tellurium 127.60
53 I Iodine 126.9045
54 Xe Xenon 131.29
89 Pt Platinum 195.08
79 Au Gold 196.9665
80 Hg Mercury 200.59
81 Tl Thallium 204.383
82 Pb Lead 207.2
83 Bi Bismuth 208.9804
84 Po Polonium 208.9824*
85 At Astatine 209.98712*
86 Rn Radon 222.017*
110§ Uun Ununilium 269*
111§ Uuu Unununium 272*
112§ Uub Ununbium 277*
113§
114§
115§
116§
117§
118§
Nonmetallic Properties
Metallic Properties
63 Eu Europium 151.96
64 Gd Gadolinium 157.25
65 Tb Terbium 158.9254
66 Dy Dysprosium 162.50
67 Ho Holmium 164.9304
68 Er Erbium 167.26
69 Tm Thulium 168.9342
70 Yb Ytterbium 173.04
95 Am Americium 243.0614*
96 Cm Curium 247.0703*
97 Bk Berkelium 247.0703*
98 Cf Californium 251.0796*
99 Es Einsteinium 252.0828*
100 Fm Fermium 257.0951*
101 Md Mendelevium 258.986*
102 No Nobelium 259.1009*
§ Synthesized elements that are highly unstable. Research on these is continuing and may change what we know about them.

Symbols and Elements

H	Hydrogen (1)
He	Helium (2)
Li	Lithium (3)
Be	Beryllium (4)
B	Boron (5)
C	Carbon (6)
N	Nitrogen (7)
O	Oxygen (8)
F	Fluorine (9)
Ne	Neon (10)
Na	Sodium (11)
Mg	Magnesium (12)
Al	Aluminum (13)
Si	Silicone (14)
P	Phosphorus (15)
S	Sulfur (16)
Cl	Chlorine (17)
Ar	Argon (18)
K	Potassium (19)
Ca	Calcium (20)
Sc	Scandium (21)
Ti	Titanium (22)
V	Vanadium (23)
Cr	Chromium (24)
Mn	Manganese (25)
Fe	Iron (26)
Co	Cobalt (27)
Ni	Nickel (28)
Cu	Copper (29)
Zn	Zinc (30)
Ga	Gallium (31)
Ge	Germanium (32)
As	Arsenic (33)
Se	Selenium (34)
Br	Bromine (35)
Kr	Krypton (36)
Rb	Rubidium (37)
Sr	Strontium (38)
Y	Ytterbium (39)
Zr	Zirconium (40)
Nb	Niobium (41)
Mo	Molybdenum (42)
Tc	Technetium (43)
Ru	Ruthenium (44)
Rh	Rhodium (45)
Pd	Palladium (46)
Ag	Silver (47)
Cd	Cadmium (48)
In	Indium (49)
Sn	Tin (50)
Sb	Antimony (51)
Te	Tellurium (52)
I	Iodine (53)
Xe	Xenon (54)
Cs	Cesium (55)
Ba	Barium (56)
Hf	Hafnium (72)
Ta	Tantalum (73)
W	Tungsten (74)
Re	Rhenium (75)
Os	Osmium (76)
Ir	Iridium (77)
Pt	Platinum (78)
Au	Gold (79)
Hg	Mercury (80)
Ti	Thallium (81)
Pb	Lead (82)
Bi	Bismuth (83)
Po	Polonium (84)
At	Astatine (85)
Rn	Radon (86)
Fr	Francium (87)
Ra	Radium (88)
Rf	Rutherfordium (104)
Ha	Hahnium (105)
Sg	Seaborgium (106)
Bh	Bohrium (107)
Hs	Hassium (108)
Mt	Meitnerium (109)
Uun	Ununilium (110)
Uun	Unununium (111)
Uub	Ununbium (112)

Rare Earth Elements

La	Lanthanum (57)
Ce	Cerium (58)
Pr	Praseodymium (59)
Nd	Neodymium (60)
Pm	Promethium (61)
Sm	Samarium (62)
Eu	Europium (63)
Gd	Gadolinium (64)
Tb	Terbium (65)
Dy	Dysprosium (66)
Ho	Holmium (67)
Er	Erbium (68)
Tm	Thulium (69)
Yb	Ytterbium (70)
Lu	Lutetium (71)

Actinide Series

Ac	Actinium (89)
Th	Thorium (90)
Pa	Protactinium (91)
U	Uranium (92)
Np	Neptunium (93)
Pu	Plutonium (94)
Am	Americium (95)
Cm	Curium (96)
Bk	Berkelium (97)
Cf	Californium (98)
Es	Einsteinium (99)
Fm	Fermium (100)
Md	Mendelevium (101)
No	Nobelium (102)
Lr	Lawrencium (103)