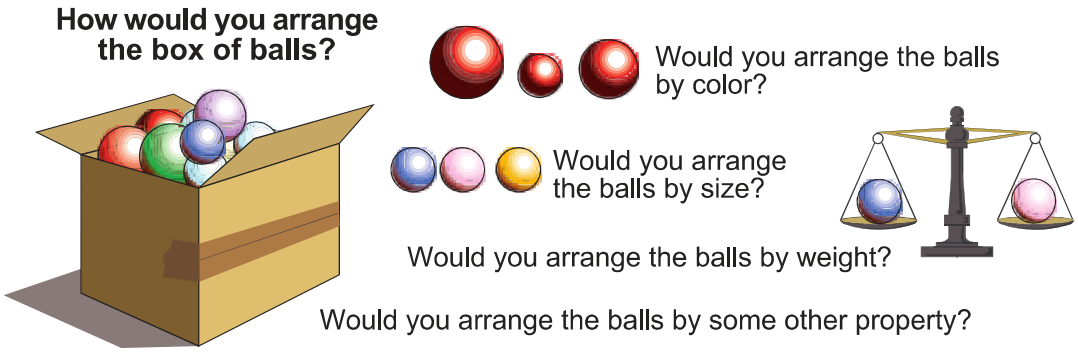
Introduction

You have learned what **atoms** are, and in this unit, you will add to that knowledge. You will be introduced to the **periodic table** and how it is arranged. You will also begin to see how scientists can predict behavior of *atoms*.

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.

Dimitri Mendeleev, a Russian chemist, gathered facts about the 63 elements that had been discovered by the mid-1800s. He searched for a pattern to organize the elements. He arranged the elements in order of increasing **atomic mass**. The way he had them arranged, the elements in columns had similar physical and chemical properties. There were spaces in the table but Mendeleev boldly said these would be filled with elements that were not yet discovered. His predictions later proved to be correct.

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 get a better picture of the world.

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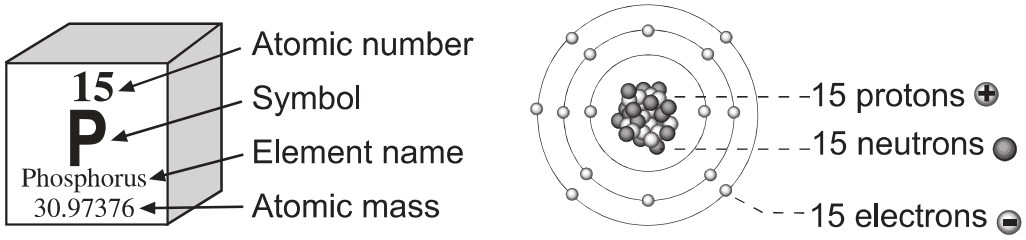
By this time, scientists had quite a group of elements. About 50 years after Mendeleev had developed his *periodic table*, Henry Moseley, a British scientist, determined for the first time the **atomic numbers** of the elements. This discovery led to a change in the arrangement of the periodic table. The modern periodic table is arranged in order of increasing atomic numbers. Since hydrogen has an *atomic number* of one (1), it became the first element on the table. The first 92 elements exist in nature. The elements on the periodic table after uranium were created in laboratories and may exist for an extremely short time. Some of the new elements are very **rare**, or hard to find. Today we generally count about 118 elements. Their atomic numbers range from one to 118. Scientists who discovered or created the new elements were allowed to name them. More elements may be created in the future.

Of course, these 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 Number

It is often stated that there are about 118 elements. This means that there are essentially 118 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, so its atomic number is 15.



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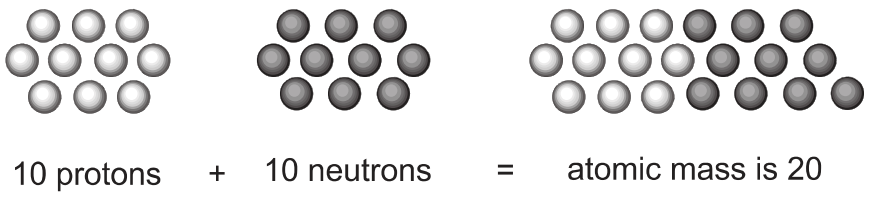
Atomic Mass

The center of an atom is called the **nucleus**. It contains protons and **neutrons**. An atom is very small, but it has **mass**. *Mass* is the amount of matter in a substance. 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 mass equals 20.



neon atom

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.

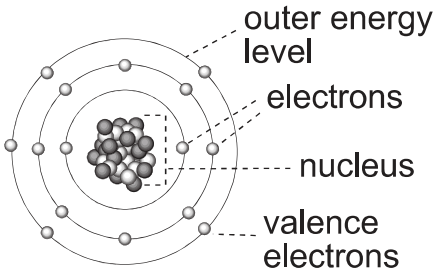
The atomic mass of atoms is usually compared to the atomic mass of carbon. Carbon has an atomic mass of 12.

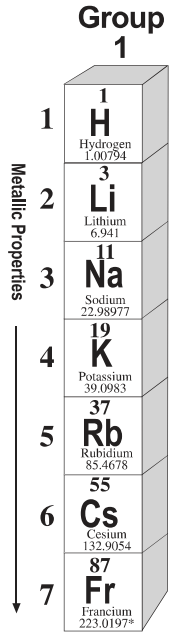
Using the Periodic Table

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 150-151.)

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' outermost **energy level**. The outermost *energy level* is farthest from the *nucleus*. The electrons in the outermost energy level are called **valence electrons**.

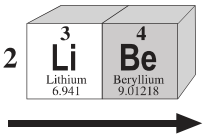




Each group has a letter and a number. All of the elements in Group 1 have one electron in their atoms' outermost energy level. Only because of hydrogen's electron arrangement is it part of group 1; hydrogen has its own set of properties.

Period

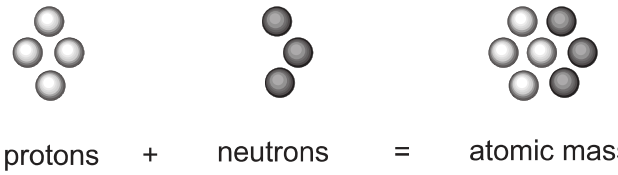
The groups of elements going across on the table are called **periods**. Each period has a number. The elements in a period have different properties. All elements in the left-hand side of a period tend to lose electrons. The atoms of the elements toward the right side of the period tend to gain electrons. 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 150-151, 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 human-made 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.

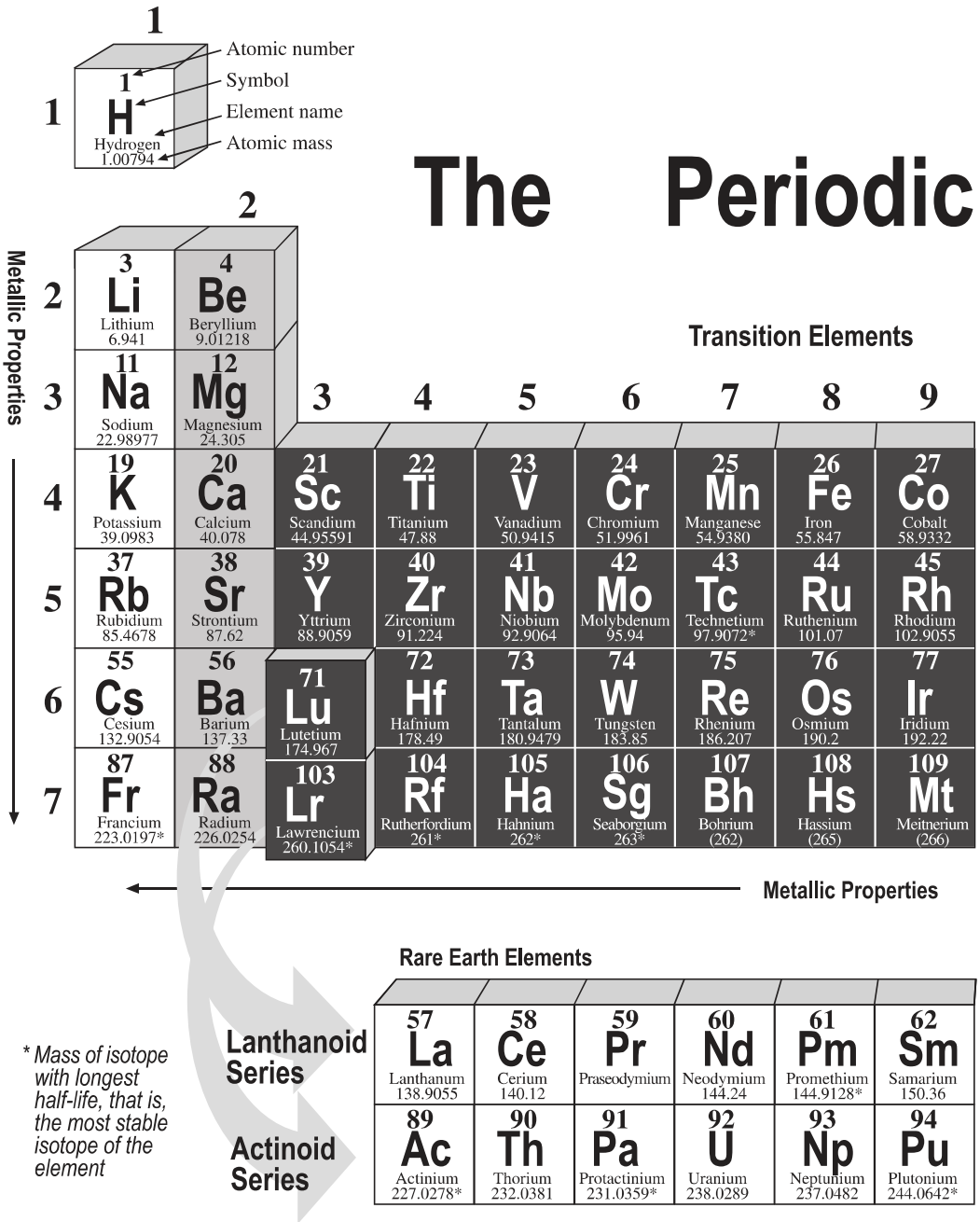
Scientists did a great deal of work to create the periodic table. Do you think they knew it would succeed when they started? Although they did not know, they did assume it would work. Chemistry demonstrates one of the fundamental ideas in science. Virtually all scientists see the whole universe as a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

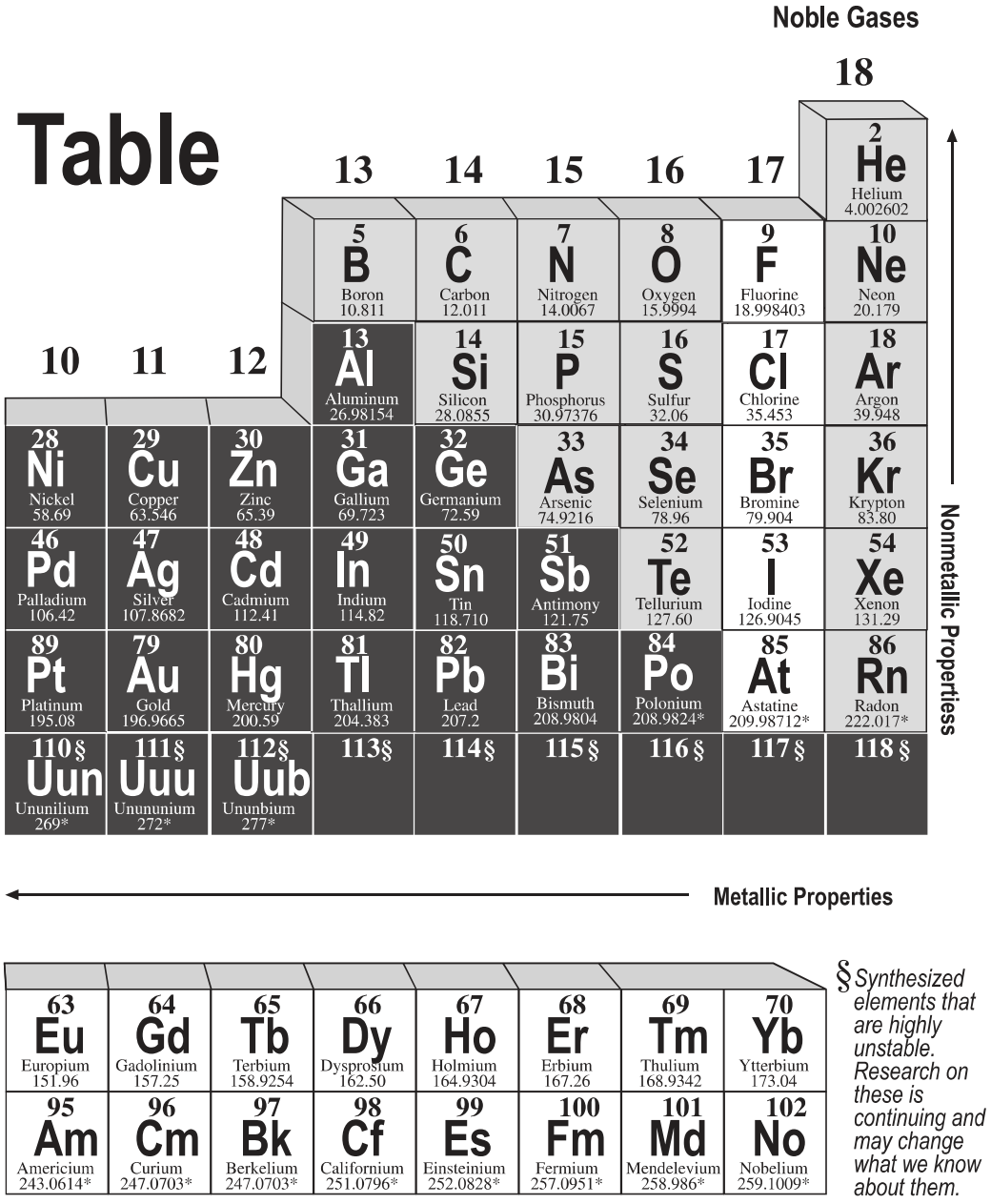
Your family's car has many parts. A mechanic assumes he can study your car and figure out how to fix it. He assumes this because he knows the different parts relate to each other. In much the same way, scientists believe the parts of the universe affect each other. Sometimes, they work together simply. Other times, the relationship is very complex. However, by studying the relationships, scientists 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 energy level. 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 theories are better. The result is an ever-improving view of the universe. Scientists could develop the periodic table only because they assumed the universe is a vast system and they could discover how the universe works. Study the periodic table and chart of symbols and elements that follow.





§ *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)