Atoms, Molecules, and Ions

Fundamental Chemical Laws

1. Law of Conservation of Mass
    - Mass is neither created nor destroyed in a chemical reaction.

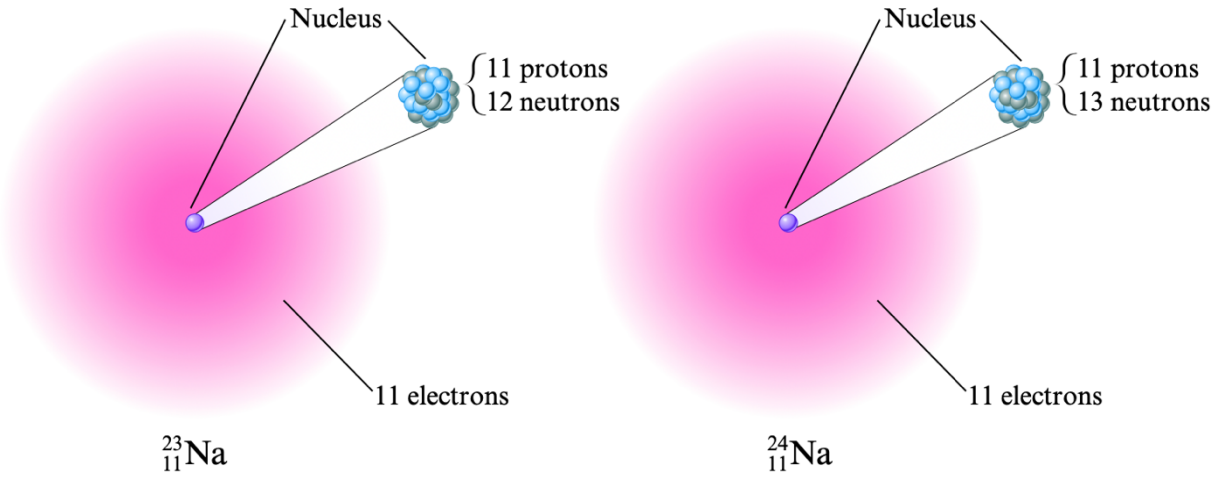
2. Law of Definite Proportions
    - A given compound always contains exactly the same proportion of elements by mass.

Atomic Structure

Atoms consist of a dense center of positive charge (the **nucleus**) with **electrons** moving around the nucleus at a large distance relative to the nuclear radius. The nucleus contains **protons**, which have a positive charge $(+1)$ equal to the electron's negative charge (-1), and **neutrons**, which have virtually the same mass as a proton but no charge.

Particle	Mass (amu)	Charge	Location
Electron	0	–1	orbits
Proton	1	+1	nucleus
Neutron	1	none	nucleus

The number of protons in an atom is equal to its **atomic number**, Z. Since atoms have no net charge, the number of electrons must equal the number of protons. The number of neutrons in an atom varies. For example, there are two different sodium atoms pictured below.

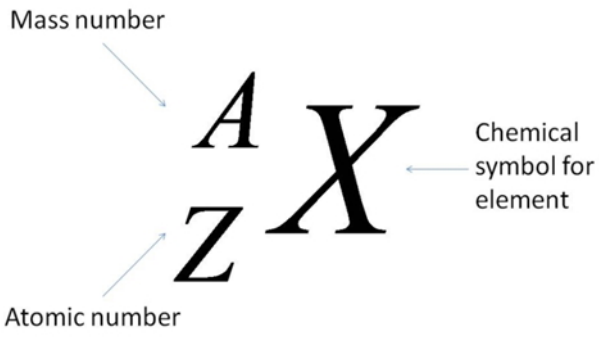


The atom on the left has 12 neutrons while the atom on the right has 13 neutrons. These two atoms are **isotopes**, or atoms with the same number of protons but different numbers of neutrons.

To distinguish between them, isotopes are identified by their mass number. The **mass number**, A, of an atom is equal to the total of the number of protons and neutrons in its nucleus. Thus, the atom on the left is called sodium-23, while the atom on the right is called sodium-24.

Atomic Notation

Standard atomic notation is a common notation used in chemistry and physics to indicate the atomic number and mass number of an element. It is written by writing an element symbol, preceded by a subscript indicating its atomic number and a superscript indicating its mass number, as shown in the diagram below.



Example 1
Write the standard atomic notation for iron-56. How many protons, electrons, and neutrons does iron have?

Molecules and Ions

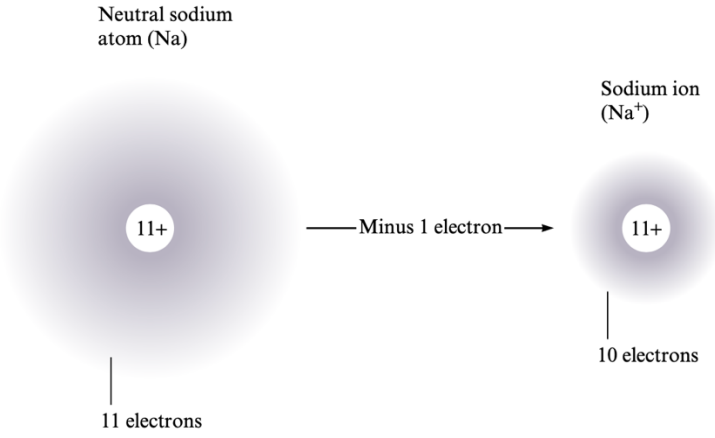
Atoms combine to form compounds. The forces that hold atoms together in compounds are called **chemical bonds**. One way that atoms can form bonds is by sharing electrons. These are called **covalent bonds**, and the resulting collection of atoms is called a **molecule**. The simplest method of representing a molecule is the **chemical formula**, in which the symbols for the elements are used to indicate the type of atoms present and subscripts are used to indicate the relative amounts of atoms.

Example 2
The chemical formula for methane is CH_4. What elements are present in methane, and how many atoms of each?

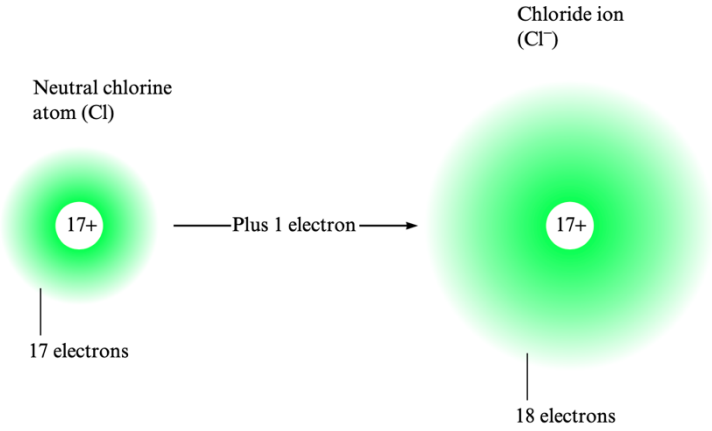
Another method of representing a molecule is a **structural formula**, in which the individual bonds are shown as lines.

Example 3
Draw the structural formula for methane.

A second type of chemical bond results from attractions among ions. An **ion** is an atom, or group of atoms, that has a net positive or negative charge. Ions are formed when electrons are transferred from one atom to another. For example, in the formation of sodium chloride, a single electron is transferred from sodium to chlorine.



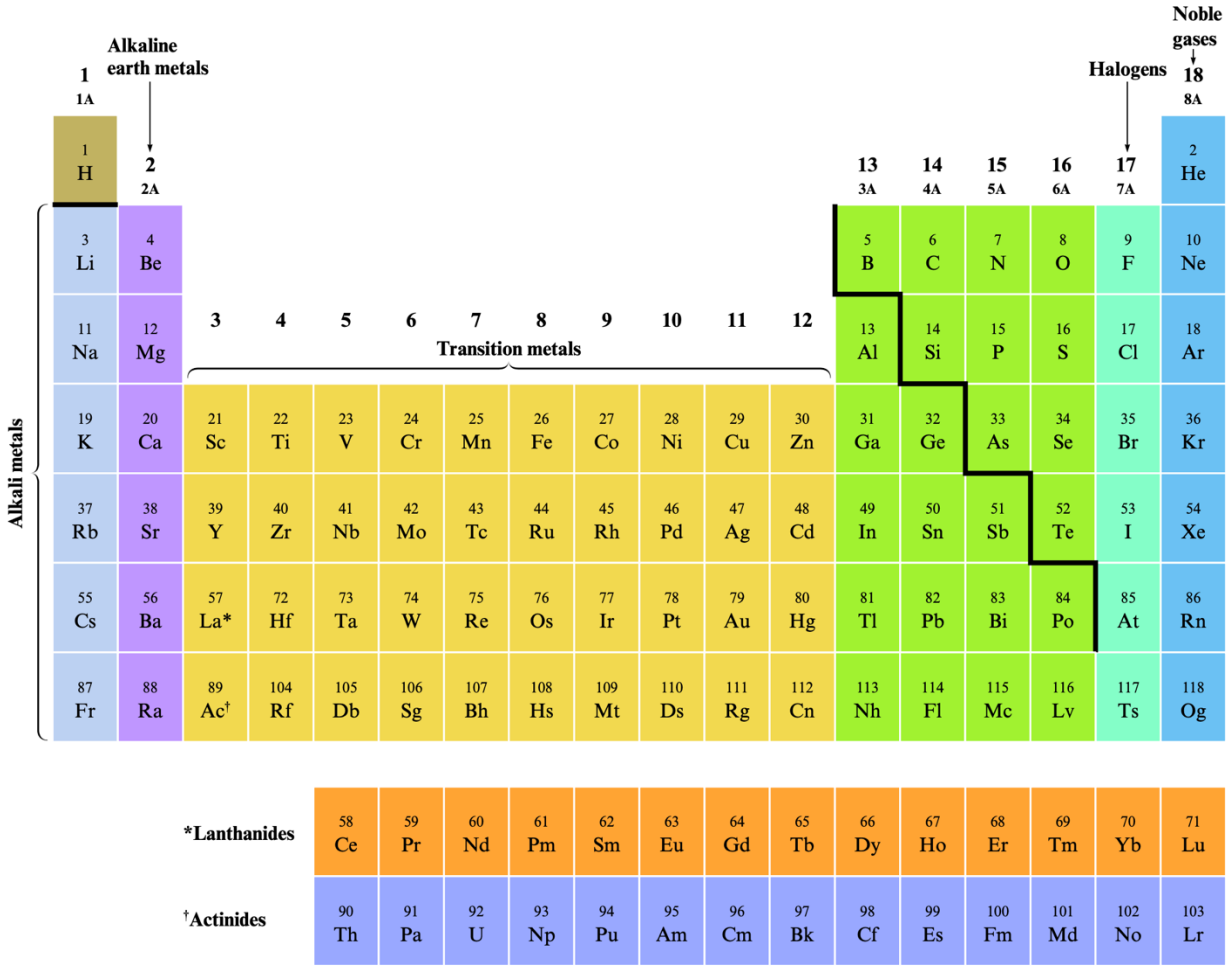
Removing an electron from sodium gives it a net charge of +1. It becomes a positive ion, or **cation**. Adding an electron to chlorine gives it a net charge of –1. It becomes a negative ion, or **anion**.



Because anions and cations have opposite charges, they attract each other. This force of attraction is called an **ionic bond**. A solid consisting of oppositely charged ions is called an **ionic solid**. They can be made of simple ions, or of **polyatomic ions** (many atom ions).

The Periodic Table

A simplified version of the periodic table is shown below.



The letters in the boxes are the element symbols, abbreviations that are based on the current element names or the original element names. The number above each symbol is the atomic number (number of protons) for that element.

Most of the elements are **metals** (located to the left of the "staircase"). Metals have the following properties in common:

1. Physical
   - good conductors of heat and electricity
   - malleable (can be hammered into thin sheets)
   - ductile (can be pulled into wires)
   - lustrous
2. Chemical
   - tend to lose electrons to form positive ions

The relatively few **nonmetals** (located to the right of the "staircase," except hydrogen) have the following properties in common:

1. Physical
   - poor conductors of heat and electricity
   - brittle (not malleable or ductile)
   - dull (not lustrous)
2. Chemical
   - tend to gain electrons to form negative ions
   - often bond to each other by forming covalent bonds

The periodic table is arranged so that elements in the same vertical columns (called **groups** or **families**) have similar chemical properties.

The horizontal rows of elements are called **periods**.

Worksheet

1. Which of the following statements is/are true? Correct the false statements.

   a) All particles in the nucleus of an atom are charged.
   b) The atom is best described as a uniform sphere of matter in which electrons are embedded.
   c) The mass of the nucleus is only a very small fraction of the mass of the entire atom.
   d) The volume of the nucleus is only a very small fraction of the volume of the entire atom.
   e) The number of neutrons in a neutral atom must equal the number of electrons.
   f) Most of the known elements are metals.
   g) Element 118 should be a nonmetal.
   h) Hydrogen has mostly metallic properties.
   i) A family of elements is also known as a period of elements.

2. Give the names of the metals that correspond to the following symbols: *Sn, Pt, Hg, Mg, K, Ag*.

3. For each of the following sets of elements, label each as either noble gases, alkali metals, alkaline earth metals, halogens, or transition metals.

   a) Ti, Fe, Ag
   b) Mg, Sr, Ba
   c) Li, K, Rb
   d) Ne, Kr, Xe
   e) F, Br, I

4. The most stable isotope of aluminum has a mass number of 27. The other isotopes of aluminum have mass numbers of 24, 25, 26, 28, 29, and 30. Write out the symbols $(^{X}_{Z}A)$ for the seven isotopes of aluminum.

5. How many protons and neutrons are in the nucleus of each of the following atoms? In a neutral atom of each element, how many electrons are present?

   a) ^{79}Br
   b) ^{81}Br
   c) ^{239}Pu
   d) ^{133}Cs
   e) ^{3}H
   f) ^{56}Fe

6. For each of the following ions, indicate the number of protons and electrons the ion contains.

   a) Ba^{2+}
   b) Zn^{2+}
   c) N^{3-}
   d) Rb^{+}
   e) Co^{3+}
   f) Te^{2-}
   g) Br^{-}

7. Would you expect each of the following atoms to gain or lose electrons when forming ions? What ion is most likely in each case?

a) Ra
b) In
c) P
d) Te
e) Br
f) Rb