2-1 The Nature of Matter

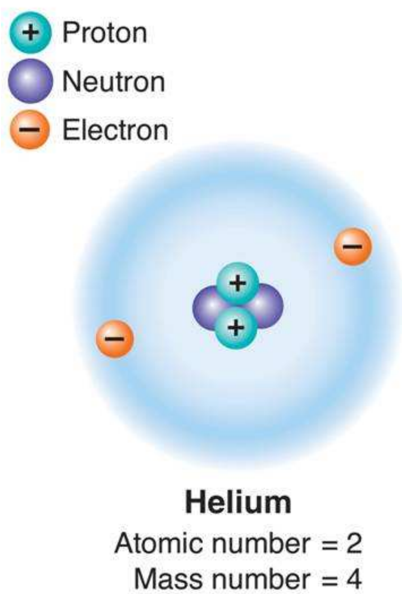
Atoms

The study of chemistry begins with the basic unit of matter, the **atom**.
The Greek philosopher Democritus called the smallest fragment of matter the atom, from the Greek word *atomos*.
Placed side by side, 100 million atoms would make a row only about 1 centimeter long.
Atoms contain subatomic particles that are even smaller.

What three subatomic particles make up atoms?
The subatomic particles that make up atoms are

- **protons**
- **neutrons**
- **electrons**
-

The subatomic particles in a helium atom.



Protons and neutrons have about the same mass.
Protons are positively charged particles (+).
Neutrons carry no charge.
Strong forces bind protons and neutrons together to form the **nucleus**, which is at the center of the atom.
The **electron** is a negatively charged particle (−) with 1/1840 the mass of a proton.
Electrons are in constant motion in the space surrounding the nucleus.
Electrons are attracted to the positively charged nucleus but remain outside the nucleus because of the energy of their motion.
Because atoms have equal numbers of electrons and protons, and because these subatomic particles have equal but opposite charges, atoms are neutral.

Elements and Isotopes

A chemical **element** is a pure substance that consists entirely of one type of atom.
Elements are represented by a one- or two-letter symbol.

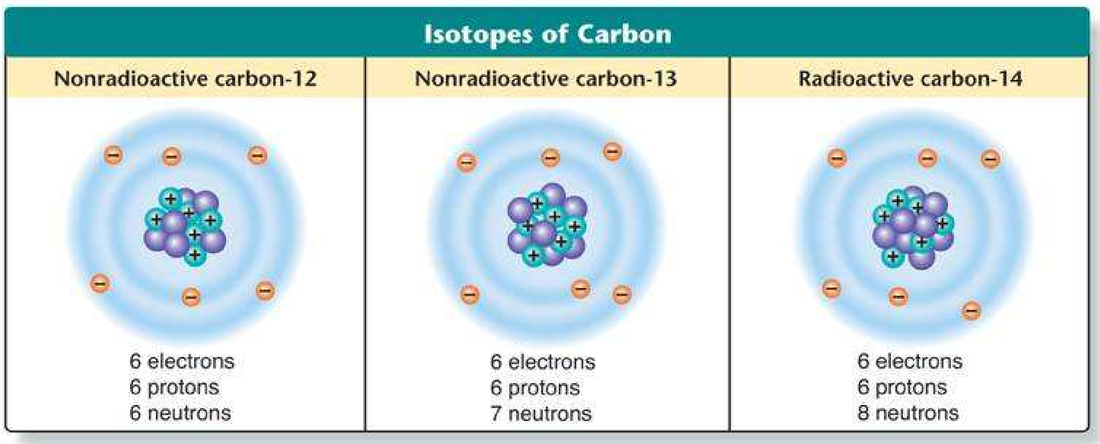
- C stands for carbon.
- Na stands for sodium.

The number of protons in an atom of an element is the element's atomic number.

Carbon has 6 protons, so its atomic number is 6.

More than 100 elements are known, but only about two dozen are commonly found in living organisms.

Isotopes
Atoms of the same element that differ in the number of neutrons they contain are known as **isotopes**.
The sum of the protons and neutrons in the nucleus of an atom is called its mass number.
Isotopes are identified by their mass numbers.
For example, carbon has three isotopes—carbon-12, carbon-13, and carbon-14. Each isotope has a different number of neutrons.
How are all of the isotopes of an element similar?
Because they have the same number of electrons, all isotopes of an element have the same chemical properties.



Radioactive Isotopes
Some isotopes are radioactive, meaning that their nuclei are unstable and break down at a constant rate over time
Although the radiation these isotopes give off can be dangerous, they have important scientific and practical uses.
Radioactive isotopes can be used:

- to determine the ages of rocks and fossils.
- to treat cancer.
- to kill bacteria that cause food to spoil.
- as labels or "tracers" to follow the movement of substances within an organism.

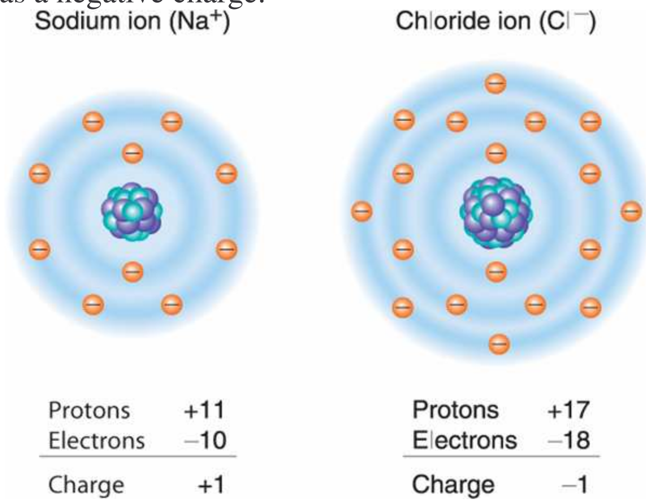
Chemical Compounds
In nature, most elements are found combined with other elements in compounds.
A chemical **compound** is a substance formed by the chemical combination of two or more elements in definite proportions.
The physical and chemical properties of a compound are different from the elements from which it is formed.
Scientists show the composition of compounds by a kind of shorthand known as a chemical formula.
Water, H2O, contains two atoms of hydrogen for each atom of oxygen.
The formula for table salt, NaCl, indicates that sodium and chlorine combine in a 1 : 1 ratio.

Chemical Bonds
The atoms in compounds are held together by **chemical bonds**.
Bond formation involves the electrons that surround each atomic nucleus.
The electrons that are available to form bonds are called valence electrons.

What are the two main types of chemical bonds?
The main types of chemical bonds are:

- **ionic bonds**
- **covalent bonds**

Ionic Bonds
An **ionic bond** is formed when one or more electrons are transferred from one atom to another.
An atom that loses electrons has a positive charge.
An atom that gains electrons has a negative charge.

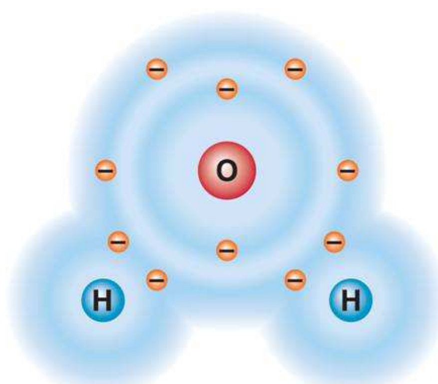


These positively and negatively charged atoms are known as **ions**.

Covalent Bonds
Sometimes electrons are shared by atoms instead of being transferred.
Sharing electrons means that the moving electrons actually travel in the orbitals of both atoms.
A **covalent bond** forms when electrons are shared between atoms.

- When the atoms share two electrons, the bond is called a single covalent bond.
- When atoms share four electrons it is called a double bond.
- When atoms share six electrons it is called a triple bond.

The structure that results when atoms are joined together by covalent bonds is called a **molecule**.
A molecule is the smallest unit of most compounds.
In a water molecule, each hydrogen atom forms a single covalent bond with the oxygen atom.



Water Molecule

Van der Waals Forces
When molecules are close together, a slight attraction can develop between the oppositely charged regions of nearby molecules. Chemists call such intermolecular forces of attraction **van der Waals forces**, after the scientist who discovered them. Although van der Waals forces are not as strong as ionic bonds or covalent bonds, they can hold molecules together, especially when the molecules are large.