Chapter 2-2: Atoms and Molecules

Atomic structure determines the behavior of an element

- Each element consists of unique atoms.
- An **atom** is the smallest unit of matter that still retains the properties of an element.
  - Atoms are composed of even smaller parts, called subatomic particles.
    - **Protons –** positively charged particles in the nucleus of an atom – weight of about 1 dalton
    - **Neutrons –** particles that have no charge in the nucleus of an atom – weight of about 1 dalton
    - **Electrons –** negatively charged particles found in orbitals surrounding the nucleus – negligible weight
- The attractions between the positive charges in the nucleus and the negative charges of the electrons keep the electrons in the vicinity of the nucleus.

- All atoms of a particular element have the same number of protons in their nuclei.
  - Each element has a unique number of protons, its unique ***atomic number***.
  - The atomic number is written as a subscript before the symbol for the element (for example, $_2He$).
- Unless otherwise indicated, atoms have equal numbers of protons and electrons - no net charge.
  - Therefore, the atomic number tells us the number of protons and the number of electrons that are found in a neutral atom of a specific element.
- The ***mass number*** is the sum of the number of protons and neutrons in the nucleus of an atom.
  - The mass number is written as a superscript before an element's symbol (for example, ^4He)
- While all atoms of a given element have the same number of protons, they may differ in the number of neutrons.
- Two atoms of the same element that differ in the number of neutrons are called ***isotopes***.
- In nature, an element occurs as a mixture of isotopes.

- Most isotopes are stable; they do not tend to loose particles.
  - Both ^{12}C and ^{13}C are stable isotopes.
- The nuclei of some isotopes are unstable and decay spontaneously, emitting particles and energy.
  - ^{14}C is a one of these unstable or **radioactive isotopes**.
  - In its decay, a neutron is converted to a proton and electron.
  - This converts ^{14}C to ^{14}N, changing the identity of that atom.
- Radioactive isotopes have many applications in biological research.
  - Radioactive decay rates can be used to date fossils.
  - Radioactive isotopes can be used to trace atoms in metabolism.

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To gain an accurate perspective of the relative proportions of an atom, if the nucleus was the size of a golf ball, the electrons would be moving about 1 kilometer from the nucleus.

- Atoms are mostly empty space.
- When two elements interact during a chemical reaction, it is their electrons that are actually involved.
  - The nuclei do not come close enough to interact.
- Electrons have potential energy because of their position relative to the nucleus.
- The different states of potential energy that the electrons of an atoms can have are called **energy levels** or **electron shells**.
  - The first shell, closest to the nucleus, has the lowest potential energy.
  - Electrons in outer shells have more potential energy.
- The chemical behavior of an atom is determined by its electron configuration - the distribution of electrons in its electron shells.

- The first electron shell can hold only 2 electrons.
- Atoms with more than two electrons must place the extra electrons in higher shells.
- The second shell can hold up to 8 electrons.
- The chemical behavior of an atom depends mostly on the number of electrons in its outermost shell, the **valence shell**.
  - Electrons in the valence shell are known as **valence electrons**.
- Atoms with the same number of valence electrons have similar chemical behavior.
- An atom with a completed valence shell is unreactive.
- All other atoms are chemically reactive because they have incomplete valence shells.

Atoms combine by chemical bonding to form molecules

- Atoms with incomplete valence shells interact by either sharing or transferring valence electrons.
- These interactions typically result in the atoms remaining close together, held by an attractions called **chemical bonds**.
  - The strongest chemical bonds are covalent bonds and ionic bonds.
- A **covalent bond** is the sharing of a pair of valence electrons by two atoms.
- Two or more atoms held together by covalent bonds constitute a **molecule**.
- We can abbreviate the structure of this molecule by substituting a line for ***<u>each pair of shared electrons</u>***, drawing the **structural formula**.
  - H-H is the structural formula for the covalent bond between two hydrogen atoms.
- The **molecular formula** indicates the number and types of atoms present in a single molecule.
  - H_2 is the molecular formula for hydrogen gas.

  - Two oxygen atoms can form a molecule by sharing *two* pairs of valence electrons.
  - These atoms have formed a **double covalent bond**.

- The attraction of an atom for the electrons of a covalent bond is called its **electronegativity.**
- If electrons in a covalent bond are shared equally, then this is a **nonpolar covalent bond**.
  - A covalent bond between two atoms of the same element is always nonpolar.
  - A covalent bond between atoms that have similar electronegativities is also nonpolar.
- If the electrons in a covalent bond are not shared equally by the two atoms, then this is a **polar covalent bond.**
  - The bonds between oxygen and hydrogen in water are polar covalent because oxygen has a much higher electronegativity than does hydrogen.
  - Compounds with a polar covalent bond have regions that have a partial negative charge near the strongly electronegative atom and a partial positive charge near the weakly electronegative atom.
- An **ionic bond** can form if two atoms are so unequal in their attraction for valence electrons that one atom strips an electron completely from the other.

Weak chemical bonds play important roles in the chemistry of life

- In a cell, weak, brief bonds between molecules are important to a variety of processes.
  - For example, signal molecules from one neuron use weak bonds to bind briefly to receptor molecules on the surface of a receiving neuron.
  - This triggers a momentary response by the recipient.
- Weak interactions include ***ionic bonds*** (weak in water), and ***hydrogen bonds***
- **Hydrogen bonds**
  - form when a hydrogen atom that is already covalently bonded to a strongly electronegative atom is attracted to another strongly electronegative atom.
  - These strongly electronegative atoms are usually nitrogen or oxygen.

A molecule's biological function is related to its shape

- The three-dimensional shape of a molecule is an important determinant of its function in a cell.
- Biological molecules recognize and interact to one another based on molecular shape.

Chemical reactions make and break chemical bonds

- In **chemical reactions** chemical bonds are broken and reformed, leading to ***new arrangements of atoms***.
- The starting molecules in the process are called **reactants** and the end molecules are called **products.**
- In a chemical reaction, **all** of the atoms in the reactants must be accounted for in the products.
  - The reactions must be "balanced".