Carbon and hydrocarbons

The element carbon and why it's essential to life as we know it. Properties and bonding patterns of carbon atoms.

Introduction

Carbon isn't a difficult element to spot in your daily life. For instance, if you've used a pencil, you've seen carbon in its graphite form. Similarly, the charcoal briquettes on your barbeque are made out of carbon, and even the diamonds in a ring or necklace are a form of carbon (in this case, one that has been exposed to high temperature and pressure). What you may not realize, though, is that about 18% of your body (by weight) is also made of carbon. In fact, carbon atoms make up the backbone of many important molecules in your body, including proteins, DNA, RNA, sugars, and fats.

These complex biological molecules are often called macromolecules; they're also classified as **organic molecules**, which simply means that they contain carbon atoms. (Notably, there are a few exceptions to this rule. For example, carbon dioxide and carbon monoxide contain carbon, but generally aren't considered to be organic.)

The bonding properties of carbon

Why is carbon so popular for making molecular backbones? Why don't we instead use, say, oxygen for the same purpose? For one thing, carbon-carbon bonds are unusually strong, so carbon can form a stable, sturdy backbone for a large molecule. Perhaps more important, however, is carbon's capacity for covalent bonding. Because a C atom can form covalent bonds to as many as four other atoms, it's well suited to form the basic skeleton, or "backbone," of a macromolecule.

As an analogy, imagine that you're playing with a Tinker Toy® set and have connector wheels with either two or four holes. If you choose the connector wheel with four holes, you'll be able to make more connections and build a complex structure more easily than if you choose the wheel with two holes. A carbon atom can bond with four other atoms and is like the four-hole wheel, while an oxygen atom, which can bond only to two, is like the two-hole wheel.

Carbon's ability to form bonds with four other atoms goes back to its number and configuration of electrons. Carbon has an atomic number of six (meaning six protons, and six electrons as well in a neutral atom), so the first two electrons fill the inner shell and the remaining four are left in the second shell, which is the valence (outermost) shell. To achieve stability, carbon must find four more electrons to fill its outer shell, giving a total of eight and satisfying the octet rule. Carbon atoms may thus form bonds to as many as four other atoms. For example, in methane (CH_4), carbon forms covalent bonds with four hydrogen atoms. Each bond corresponds to a pair of shared electrons (one from carbon and one from hydrogen), giving carbon the eight electrons it needs for a full outer shell.

Hydrocarbons

Hydrocarbons are organic molecules consisting entirely of carbon and hydrogen. We often use hydrocarbons in our daily lives: for instance, the propane in a gas grill and the butane in a lighter are both hydrocarbons. They make good fuels because their covalent bonds store a large amount of energy, which is released when the molecules are burned (i.e., when they react with oxygen to form carbon dioxide and water).

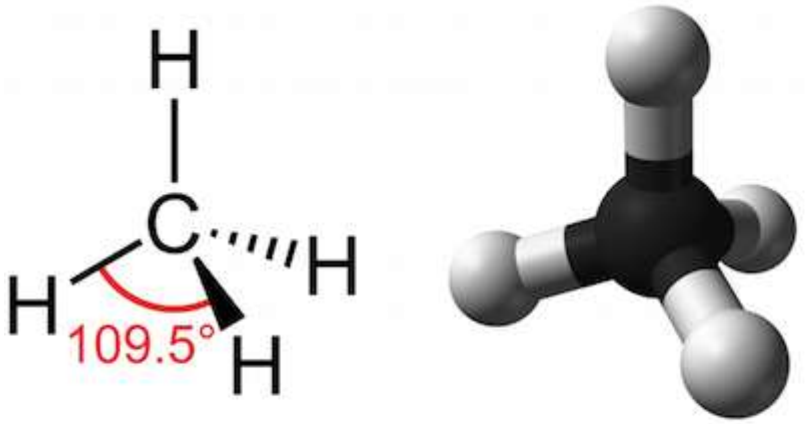

Image of a methane molecule, showing its tetrahedral shape and the bond angle of 109.5 degrees for each H-C-H unit.

Image credit: OpenStax Biology.

Methane (CH_4), the simplest hydrocarbon molecule, consists of a central carbon atom bonded to four hydrogen atoms. The carbon and the four hydrogen atoms form the vertices of a three-dimensional shape known as a tetrahedron, which has four triangular faces; because of this, methane is said to have a tetrahedral geometry. More generally, when a carbon atom is bonded to four other atoms, the molecule (or part of a molecule) will take on a tetrahedral shape similar to that of methane. This happens because the electron pairs that make up the bonds repel each other, and the shape that maximizes their distance from each other is a tetrahedron.

Most macromolecules are not classified as hydrocarbons, because they contain other atoms in addition to carbon and hydrogen, such as nitrogen, oxygen, and phosphorous. However, carbon chains with attached hydrogen’s are a key structural component of most macromolecules (even if they are interspersed with other atoms), so understanding the properties of hydrocarbons is important to understanding the behavior of macromolecules.