Chapter 1

Review of General Chemistry:
Electronic Structure and Bonding

What is Organic Chemistry?

Organic compounds: from living organisms

Inorganic compounds: from minerals

[Chemical reaction image]

ammonium cyanate an inorganic mineral

heat

urea an “organic” compound

Organic compounds are compounds that contain carbon.
Isotopes

Isotopes: atoms of the same element with different mass

All Carbon Atoms Have the Same **Atomic Number** = # of protons

Carbon Atoms Can Have the Different **Mass Numbers**

\[ \text{Mass Number} = \text{# of protons} + \text{# of neutrons} \]

The Structure of an Atom

**Protons** are *positively* charged.

**Neutrons** have *no* charge.

**Electrons** are *negatively* charged.
**The Structure of an Atom**

- **Protons** are positively charged.
- Neutrons have no charge.
- **Electrons** are negatively charged.

\[
N, \text{ atomic number} = \# \text{ of protons} \\
N \text{ for carbon} = 6
\]

- carbon atom has **six protons** and **six electrons**.

**The Distribution of Electrons in an Atom**

<table>
<thead>
<tr>
<th>Table 1.1 Distribution of Electrons in the First Four Shells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic orbitals</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Number of</td>
</tr>
<tr>
<td>atomic orbitals</td>
</tr>
<tr>
<td>Maximum number of</td>
</tr>
<tr>
<td>electrons</td>
</tr>
</tbody>
</table>

- The **first** shell is closest to the nucleus.
- The **closer** the atomic orbital is to the nucleus, the **lower** its energy.
- Within a shell, **s < p**.
Aufbau principle: An electron goes into the atomic orbital with the lowest energy.
\[ 1s < 2s < 2p < 3s < 3p < 3d \]

Pauli exclusion principle: No more than two electrons can be in an atomic orbital.

Hund’s rule: An electron goes into an empty degenerate orbital rather than pairing up.

### Atoms in the First Column of the Periodic Table Lose an Electron

An atom is most stable if its outer shell is either filled or contains 8 electrons.

Lithium and sodium achieve a filled outer shell by losing an electron.

<table>
<thead>
<tr>
<th>Atom</th>
<th>Name of element</th>
<th>Atomic number</th>
<th>1s</th>
<th>2s</th>
<th>2p$_x$</th>
<th>2p$_y$</th>
<th>2p$_z$</th>
<th>3s</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Hydrogen</td>
<td>1</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>He</td>
<td>Helium</td>
<td>2</td>
<td>↑↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Li</td>
<td>Lithium</td>
<td>3</td>
<td>↑↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be</td>
<td>Beryllium</td>
<td>4</td>
<td>↑↓</td>
<td>↑↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Boron</td>
<td>5</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Carbon</td>
<td>6</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
<td>7</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>Oxygen</td>
<td>8</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Fluorine</td>
<td>9</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Ne</td>
<td>Neon</td>
<td>10</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>Sodium</td>
<td>11</td>
<td>↑↓</td>
<td>↑↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
</tbody>
</table>

**Li**<sup>*</sup> lithium has 1 valence electron... → e\(^-\)... so it loses an electron... to form a ion with a filled outer shell

Li<sup>+</sup> lithium ion

**Na**<sup>*</sup> sodium atom → e\(^-\) + Na<sup>+</sup> sodium ion
Atoms on the Right Side of the Periodic Table Readily Gain an Electron

Fluorine and chlorine achieve a filled outer shell by gaining an electron.

- Fluorine has 7 valance electrons... so it gains an electron... to form an ion with a filled outer shell
  \[ \text{fluorine atom} + e^- \rightarrow \text{fluoride ion} \]

- Chlorine atom
  \[ \text{chlorine atom} + e^- \rightarrow \text{chloride ion} \]

A Hydrogen Atom Can Lose or Gain an Electron

A hydrogen atom achieves an empty shell by losing an electron or a filled outer shell by gaining an electron.
Achieving a Filled Outer Shell by Sharing Electrons

A bond formed by sharing electrons is called a covalent bond.

Each fluorine shares 1 of its 7 valence electrons... ...to form a covalent bond... which can be denoted by a solid line.

\[
\begin{align*}
\text{F}^+ & \quad + \quad \text{F}^- \\
\rightarrow & \\
\text{F}^\cdots & \quad \text{F}^- \\
\end{align*}
\]

Each fluorine is surrounded by 8 electrons.

Each hydrogen shares its valence electron... ...to form a covalent bond.

\[
\begin{align*}
\text{H}^+ & \quad + \quad \text{H}^- \\
\rightarrow & \\
\text{H}^\cdots & \quad \text{H}^- \\
\end{align*}
\]

Each hydrogen is surrounded by 2 electrons.

Achieving a Filled Outer Shell by Sharing Electrons

\[
\begin{align*}
\text{H}^+ & \quad + \quad \text{Cl}^- \\
\rightarrow & \\
\text{H}^\cdots & \quad \text{Cl}^- \\
\end{align*}
\]

H is surrounded by 2 electrons.
Cl is surrounded by 8 electrons.
How Many Bonds Does an Atom Form?

Nonpolar and Polar Covalent Bonds

Nonpolar covalent bond = bonded atoms are the same or have similar electronegativities.

$$\begin{align*}
\text{H—H} & \quad \text{F—F} & \quad \text{C—C} & \quad \text{C—H}\\
\text{H—:\text{Cl}^+:} & \quad \text{H—:\text{O}^+:} & \quad \text{H—:\text{N}^-} & \quad \text{H—:\text{C}^-}\\
\end{align*}$$

Polar covalent bond = bonded atoms have different electronegativities.

$$\begin{align*}
\text{H—:\text{Cl}^+:} & \quad \delta^+ \quad \text{H—:\text{O}^+:} & \quad \delta^+ \quad \text{H—:\text{N}^-} & \quad \delta^+ \quad \text{H—:\text{C}^-} & \quad \delta^+ \\
\end{align*}$$

The negative end of the bond

Notice that each O, N, C is surrounded by 8 electrons, and each H is surrounded by 2 electrons.