Chapter 02: Atoms, Molecules, & Ions

Dalton’s Atomic Theory
• **Mass Conservation**: Mass is neither created nor destroyed in chemical reactions.
• **Definite Proportions**: Different samples of a pure substance always contain the same proportion of elements by mass.
• **Multiple proportions**: If two elements combine to form different substances, the mass ratios are small, whole number multiples of each other.

Dalton came up with atomic theory to explain these observations i.e. matter is made up of small discrete bits, called “atoms.”

Subatomic particles
It was found that atoms are composed of 3 types of fundamental particles which were given names.

<table>
<thead>
<tr>
<th>particle</th>
<th>symbol</th>
<th>mass (g)</th>
<th>mass (amu)</th>
<th>charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron</td>
<td>e</td>
<td>9.1 x 10^{-27}</td>
<td>5.5 x 10^{-4}</td>
<td>-1</td>
</tr>
<tr>
<td>proton</td>
<td>p</td>
<td>1.673 x 10^{-24}</td>
<td>1.007</td>
<td>+1</td>
</tr>
<tr>
<td>neutron</td>
<td>n</td>
<td>1.675 x 10^{-24}</td>
<td>1.009</td>
<td>0</td>
</tr>
</tbody>
</table>

Rutherford’s Scattering: Discovery of Nucleus
Original model for atomic structure involved a random “plum pudding” of electrons, protons, and neutrons. Rutherford found that the particles were not evenly distributed throughout the atom.

Atomic Structure
• Atomic mass is concentrated in the nucleus (Rutherford).
• Therefore, protons and neutrons are in the nucleus.
• Overall charge neutrality requires that # electrons = # protons in neutral atoms

Z = # protons
N = # neutrons
Mass number A = Z + N

Molecular Shape
**Ball-and-stick or space-filling models show molecular geometry**

Hydrogen chloride (HCl) Water (H₂O) Ammonia (NH₃) Methane (CH₄)

Demo: molecular models
### Ionic Compounds
- Held together by ionic bonds to form an ionic solid.
- No individual molecules

**Monatomic Ions**
- One atom transfers one or more electrons to another atom.
- Atom losing electron becomes a positively charged ion, a “cation” (Na⁺)
- Cations are generally from metal atoms
- Atom gaining electron becomes a negatively charged ion, an “anion” (Cl⁻)
- Anions are generally from non-metals

Positive and negative ions attract each other by Coulomb forces. Ions combine in the ratio that results in charge neutrality: 
\[
\text{Mg}^{2+} + 2 \text{Cl}^- \rightarrow \text{MgCl}_2
\]

### Ions of Main Group Elements
Most main group elements form ions with predictable charges:
- 1A, 2A, 3A: charge = group # (K⁺, Ca²⁺, Al³⁺)
- 5A, 6A, 7A: charge = [8 – group #] (Br⁻, S²⁻, N³⁻)

Transition metals can form several different ions: (Fe²⁺, Fe³⁺)

<table>
<thead>
<tr>
<th>Ions of Main Group Elements</th>
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</thead>
<tbody>
<tr>
<td>H⁺</td>
<td>Br⁻</td>
<td>N⁺</td>
</tr>
<tr>
<td>Li⁺</td>
<td>Ca²⁺</td>
<td>Mg²⁺</td>
</tr>
<tr>
<td>K⁺</td>
<td>Ca²⁺</td>
<td>Ca²⁺</td>
</tr>
</tbody>
</table>

### Monatomic Ion names
- Main group cations named after atom: Na⁺ = sodium ion
- Anions get “ide” suffix: Cl⁻ = chloride
- Transition metal ions get Roman numeral label: Fe²⁺ = Fe(II)