Atoms

Lecture four (Chapter two)

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Atomic Structure
Electrical charges of the same type repel one another, and charges of the opposite type attract one another.

J.J. Thompson (1856-1940)
English physicist

At the turn of the century, Thompson experimented with what he called a cathode-ray tube. He found that the beam was made up of negatively charged particles, now called electrons.

Radioactivity
**Alpha Radiation**
- composed of 2 protons and 2 neutrons
- thus, helium-4 nucleus
- +2 charge
- mass of 4 amu
- creates element with atomic number 2 lower

**Beta Radiation**
- composed of a high energy electron which was ejected from the nucleus
- “neutron” converted to “proton”
- very little mass
- -1 charge
- creates element with atomic number 1 higher

**Gamma Radiation**
- nucleus has energy levels
- energy released from nucleus as the nucleus changes from higher to lower energy levels
- no mass
- no charge

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**Robert Millikan** (1868-1953)
University of Chicago

Conducted his famous “oil drop” experiment. Measured charge of electron by seeing how much electrical force is needed to counterbalance gravity. Knowing charge, he calculated the mass.
But what does an atom look like?

The negative electrons were thought to be embedded in a positive matrix. The “plum pudding” model.

**Ernest Rutherford** (1871-1937)
from New Zealand

Bombarded gold foil with positive charged He atoms (α-particles).
Later the nucleus is shown to consist of combinations two particles, the positive charged proton and the neutron, which has no charge.

<table>
<thead>
<tr>
<th>The atomic particles</th>
<th>mass</th>
<th>charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron (e)</td>
<td>$9.109 \times 10^{-31}$ kg</td>
<td>$-1.60 \times 10^{-19}$ C</td>
</tr>
<tr>
<td>Proton (p)</td>
<td>$1.6726 \times 10^{-27}$ kg</td>
<td>$+1.60 \times 10^{-19}$ C</td>
</tr>
<tr>
<td>Neutron (n)</td>
<td>$1.6749 \times 10^{-27}$ kg</td>
<td>0</td>
</tr>
</tbody>
</table>

Ions

- charged single atom
- charged cluster of atoms

Ions

- cations
  - positive ions
- anions
  - negative ions
- ionic compounds
  - combination of cations and anions
  - zero net charge
**Metric Prefixes**

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Abbreviation</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mega</td>
<td>M</td>
<td>$10^6$</td>
<td>1 megaton = $1 \times 10^6$ tons</td>
</tr>
<tr>
<td>Kilo</td>
<td>k</td>
<td>$10^3$</td>
<td>1 kilometer (km) = $1 \times 10^3$ meter (m)</td>
</tr>
<tr>
<td>Deci</td>
<td>d</td>
<td>$10^{-1}$</td>
<td>1 decimeter (dm) = $1 \times 10^{-1}$ meter (m)</td>
</tr>
<tr>
<td>Centi</td>
<td>c</td>
<td>$10^{-2}$</td>
<td>1 centimeter (cm) = $1 \times 10^{-2}$ meter (m)</td>
</tr>
<tr>
<td>Milli</td>
<td>m</td>
<td>$10^{-3}$</td>
<td>1 milligram (mg) = $1 \times 10^{-3}$ gram (g)</td>
</tr>
<tr>
<td>Micro</td>
<td>µ</td>
<td>$10^{-6}$</td>
<td>1 micrometer (µm) = $1 \times 10^{-6}$ m</td>
</tr>
<tr>
<td>Nano</td>
<td>n</td>
<td>$10^{-9}$</td>
<td>1 nanogram (ng) = $1 \times 10^{-9}$ g</td>
</tr>
<tr>
<td>Pico</td>
<td>p</td>
<td>$10^{-12}$</td>
<td>1 picometer (pm) = $1 \times 10^{-12}$ m</td>
</tr>
<tr>
<td>Femto</td>
<td>f</td>
<td>$10^{-15}$</td>
<td>1 femtogram (fg) = $1 \times 10^{-15}$ g</td>
</tr>
</tbody>
</table>

**Atomic number, Z**
- the number of protons in the nucleus
- the number of electrons in a neutral atom
- the integer on the periodic table for each element

**Isotopes**
- atoms of the same element which differ in the number of neutrons in the nucleus
- designated by mass number
Isotopes of Hydrogen
H-1, \(^1\text{H}\), protium

- 1 proton and no neutrons in nucleus
- only isotope of any element containing no neutrons in the nucleus
- most common isotope of hydrogen

Isotopes of Hydrogen
H-2 or D, \(^2\text{H}\), deuterium

- 1 proton and 1 neutron in nucleus

Isotopes of Hydrogen
H-3 or T, \(^3\text{H}\), tritium

- 1 proton and 2 neutrons in nucleus

Mass Number, \(A\)

- integer representing the approximate mass of an atom
- equal to the sum of the number of protons and neutrons in the nucleus
Isotopes: atoms with identical Z but a different number of neutrons

Z: atomic number equal to number of protons
A: atomic mass number equal to number of protons plus the number of neutrons

\[
\begin{array}{ccc}
A & X & 12 \text{ C} \\
Z & 6 & 13 \text{ C}
\end{array}
\]

98.9% 1.1%
Natural abundance

Mass Spectrometer

Mass spectrum of neon.
(a) actual appearance,
(b) bar graph representation.

[Diagram of Mass Spectrometer]

Pb
82
\[208 \text{ A} - 82 \text{ protons} \]
126 neutrons
Mass Spectroscopy of Molecules

CH\textsubscript{4} is ionized to give a series of ions:

- CH\textsubscript{4}\textsuperscript{+} 16
- CH\textsubscript{3}\textsuperscript{+} 15
- CH\textsubscript{2}\textsuperscript{+} 14
- CH\textsubscript{1}\textsuperscript{+} 13
- C\textsuperscript{+} 12
- H\textsuperscript{+} 1

When an atom loses electrons, **E. ions** are formed.