A Brief History of Atomic Theory

The “modern” atomic picture has evolved over many centuries
Often fraught with religious and philosophical overtones

John Dalton – Early 1800’s
Developed first fairly refined atomic picture in response to two “laws”. Developed using mass measurements!

Law of Conservation of Matter: (Lavoisier 1780’s)

Law of Definite Proportions: (Proust ~1800)

Dalton’s Atomic Theory

4 main components
1. All matter is made of Atoms
2. All atoms of a given element are identical
3. Compounds are the result of a combination of two or more different kinds of atoms
4. Chemical reactions involve the combination, separation or rearrangement of atoms

Dalton’s theory leads to the Law of Multiple Proportions:
Modern Atomic Picture
(With thanks to Thompson, Millikan, Rutherford…[Read these sections])

Components of Atoms:

<table>
<thead>
<tr>
<th>Name</th>
<th>Charge</th>
<th>Symbol</th>
<th>Location</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron</td>
<td>-1</td>
<td>( ^0 \text{e} ) or ( ^-1 \text{e} )</td>
<td>outside of nucleus</td>
<td>( 9.11 \times 10^{-31} )</td>
</tr>
<tr>
<td>proton</td>
<td>+1</td>
<td>( ^1 \text{p} )</td>
<td>in nucleus</td>
<td>( 1.67 \times 10^{-27} )</td>
</tr>
<tr>
<td>neutron</td>
<td>0</td>
<td>( ^0 \text{n} )</td>
<td>in nucleus</td>
<td>( 1.67 \times 10^{-27} )</td>
</tr>
</tbody>
</table>

Characteristics:
- Atoms are small (30 - 150 pm)
- Most of the atom is empty space
- Nucleus is extremely small and massive (~0.1 pm)
  - A pea in Busch stadium
- \( ^-1 \text{e} \) occupy the region around the nucleus
- Atoms are electrically neutral

**Key to Chemical Behavior:** electrons determine chemical behavior

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Identifying Atoms

**Atomic Number:** number of protons in an atom (if atom is neutral, then it also measures the number of electrons).

**Mass Number:** allows a measure of the total number of protons and neutrons in an atom.

**Atomic Mass (Weight):** represents the mass of an average atom of the element. Atomic mass is the weighted average factoring in all naturally occurring isotopes and their abundance.

**Isotope:**

\[
\text{number p + number n} \\
\text{number p} \quad \text{number n} \\
\]
Calculating Atomic Masses

The Atomic Mass Unit (amu): 1/12 of the atomic mass of a carbon atom with 6 protons and 6 neutrons. Allows quantitation of mass ratios.

1 amu = \(1.661 \times 10^{-24}g\)

Actual masses:

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass (g)</th>
<th>Mass (amu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>(9.11 \times 10^{-28})</td>
<td>0.0005486</td>
</tr>
<tr>
<td>Proton</td>
<td>(1.6726 \times 10^{-24})</td>
<td>1.0073</td>
</tr>
<tr>
<td>Neutron</td>
<td>(1.67 \times 10^{-24})</td>
<td>1.0087</td>
</tr>
</tbody>
</table>

Mass Number allows estimation of mass of an isotope (in amu)

Even given all this, adding up the masses of p, n, and e- ≠ experimentally determined mass! Why?

More isotopes

How do we know what isotopes exist?

Revisiting Isotope Abundance:
Example: Bromine exists as two isotopes, \(^{79}\text{Br}\) and \(^{81}\text{Br}\). If the atomic mass of Bromine is 79.904 amu, what are the relative abundances of the two isotopes?
### Periodic Table:
(with kudos to Mr. Mendeleev)

Categorizes the information about the elements

**Contained on the Table:**
- Symbol, Atomic number, Atomic Mass (at least)
- Elemental Symbols for ~111 elements. (learn the 1st 36 for now, will want knowledge of the remainder except the lanthanides and actinides within the next few weeks)
  - Allows prediction of metal, non-metal, or semi-metal behavior by position.
  - Can also make predictions of ionic charge of elements and chemical behavior by knowledge of the element's group. (periodicity) Position in periods also can allow some predictability of atomic properties too.

**Items of note**
- Some elements exist as diatomic molecules
- Many nonmetals have allotropes

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**1A**
- H

**2A**
- He

**3**
- Li, Be, B, C, N, O, F, Ne

**4**
- Na, Mg, Al, Si, P, S, Cl, Ar

**5**
- K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, At, Rn

**6**
- Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe

**7**
- Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn

**8**
- Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr

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*Lanthanides* series
- La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er

*Actinide series*
- Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr