Atomic Models
Democritus to Rutherford

Democritus (460–370 BC)
- Greek Philosopher
- Atomism
- Nothing exists but atoms and empty space; everything else is opinion.
- Atom comes from atomos meaning uncuttable.

Do Atoms Have Internal Structure?
- Democritus: Atoms determine properties
  - Water: 
  - Iron: 
- Dalton: Atoms determine composition
  - 

Democritus to Rutherford
- Around 400 B.C.
- 1830
- 1906
- 1913
- 1924
Democritus Atomic Theory

1. All matter consists of **INVISIBLE PARTICLES**...called atoms
2. Atoms are **INDESTRUCTIBLE & UNCHANGEABLE**
3. A **VOID** (empty space) exists between atoms
4. Atoms are **SOLID**
5. Atoms are **HOMOGENEOUS**...(no internal structure)
6. Atoms **DIFFER** in size, shape, mass, position, arrangement....

John Dalton (1766–1844)

- *A New System of Chemical Philosophy*
- Developed the 1st useful Atomic Theory
- Good at experiments
- 1st to associate atoms with stoichiometry

Dalton’s Atomic Model

1. All matter consists of **TINY PARTICLES**
2. Atoms are **INDESTRUCTIBLE & UNCHANGEABLE**
3. Elements are characterized by **ATOMIC MASS**
4. When elements react, their atoms combine in **WHOLE NUMBER RATIOS**

- Solids are made of small, pointy atoms.
- Liquids are made of large, round atoms.
- Oils are made of very fine, small atoms that can easily slip past each other.
- Sweet things are made of smooth atoms, bitter things of sharp atoms
Dalton’s Laws

- Law of Constant Composition (aka Law of Definite Proportions)
  for a given compound, the composition is always the same:
  $$\text{H}_2\text{O}, \text{CO}_2, \text{CH}_4$$

- Law of Multiple Proportions
different compounds may be formed from the same elements in different, but fixed, ratios:
  $$\text{H}_2\text{O} & \text{H}_2\text{O}_2 \quad \text{CO}_2 & \text{CO} \quad \text{CH}_4 & \text{C}_2\text{H}_6$$

J. J. Thomson (1856–1940)

- Discovered electrons in 1891
- Cathode ray tubes
- Plum Pudding Atomic Model

A Cathode Ray Tube

Cathode Rays

cathode: anode
\[ \text{deflection} \text{ towards: positive plate: negative charge?} \]
any metal wires: constituent of all metals?
\[ \text{sharp shadows: streams of particles?} \]
metal target
**Thomson’s Plum Pudding Atom**

- Electrons
- Positively charged "pudding" forming a positive ion
- Conduction of electricity

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**Rutherford** (1871–1937)

- Discovered the nucleus in 1911
- **Gold Foil Experiment**
- **Planetary Atomic Model**

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**Probing Atomic Structure: Alpha Rays**

- Lead casing
- U, Th, or Po sample
- Alpha particle
- Paper
- Aluminum sheet
- Gamma rays

**Properties of Alpha Particles:**
- Much more massive than electrons
- Positively charged
- Expose photographic film

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**Discovery of the Nucleus**

- Rutherford’s Scattering Experiment
- Alpha particles
- Metal foil
- Gamma rays
- Recoiling of alpha particles

**What he expected:**

**What he got:**
Rutherford’s explanation for both large- and small-angle scattering, was the nucleus.

The Nuclear Atom

- Thomson’s Atom
  • diffuse mass and charge
- Rutherford’s Atom
  • concentrated mass and positive charge at the nucleus
  • electrons roam empty space around the nucleus

Empty space!!

If an atom were the size of a baseball stadium, the nucleus would be the size of a PEA.
Structure of the Nucleus

- Nuclei are composed of nucleons: protons and neutrons.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Charge</th>
<th>Mass, kg</th>
<th>Mass, amu</th>
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<td>proton (p⁺)</td>
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<tr>
<td>neutron (n⁻)</td>
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- Hydrogen nucleus
- Helium nucleus
- Lithium nucleus
- Beryllium nucleus

A Model of Helium

- 2 protons
- 2 neutrons
- 2 electrons

Elements Chart

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic #</th>
<th>Atomic Mass</th>
<th>Mass #</th>
<th># Protons</th>
<th># Electrons</th>
<th># Neutrons</th>
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</table>

Nuclear Tug-of-War

- Electrostatic force pulls nuclei apart.
- Strong nuclear force holds nuclei together.
  - Range ~ 10⁻¹⁵ cm: nuclei are small.
  - Large nuclei tend to be unstable.
### Isotopes

Some Atomic Number, Different Atomic Mass

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Protons</th>
<th>Neutrons</th>
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<tbody>
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<td>Hydrogen</td>
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<tr>
<td>Deuterium (heavy hydrogen)</td>
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<td>1</td>
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<tr>
<td>Tritium (heavier hydrogen)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Carbon-12</td>
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<td>6</td>
</tr>
<tr>
<td>Carbon-13</td>
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<tr>
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<td>Carbon-12</td>
<td>6</td>
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### Source of Images and Text

- [http://antoine.frostburg.edu/chem/senese/101/atoms/dalton.shtml](http://antoine.frostburg.edu/chem/senese/101/atoms/dalton.shtml)
- [http://dbhs.wvusd.k12.ca.us/Rutherford-Model.html](http://dbhs.wvusd.k12.ca.us/Rutherford-Model.html)