Atoms, Elements, and the Periodic Table

Part 1: The Atomic Model
The **atomic model** has changed over time.

For over two centuries, scientists have created **different models** of the atom.

As scientists have learned more and more about atoms, the atomic model has changed.
Here is a timeline of some of the major ideas.
Democritus was a **Greek philosopher** (470-380 B.C.) who is the father of modern atomic thought.

He proposed that matter could **NOT** be divided into smaller pieces forever.

He claimed that matter was made of small, hard particles that he called **“atomos”**
John Dalton created the very first **atomic theory**.

Dalton was an English **school teacher** who performed many experiments on atoms.

Dalton viewed atoms as **tiny, solid balls**.

His atomic theory had 4 statements...
Dalton’s Theory

1. Atoms are tiny, invisible particles.

2. Atoms of one element are all the same.

3. Atoms of different elements are different.

J.J. Thomson discovered **electrons**.

He was the first scientist to show that the atom was made of **even smaller things**.

He also proposed the existence of a **(+)** particle…

His atomic model was known as the “raisin bun model”…
Atoms are made mostly out of (+) charged material, like dough in a bun.

The (-) charged electrons are found inside the (+) dough.
Ernest Rutherford (1911)

Rutherford discovered **protons** and the **nucleus**.

He showed that atoms have (+) particles in the center, and are **mostly empty space**.

He called these (+) particles **protons**.

He called the center of atoms the **nucleus**.
Rutherford’s Experiment

Radioactive material emits beam of (+) alpha particles

Most particles went right through!

Strangely, some particles are deflected
Rutherford’s Experiment

Most $\alpha$ particles went through the gold. The atom is mostly empty space.
Rutherford’s Experiment

The atom had a very dense (+) center. Rutherford called it the nucleus.
Niels Bohr (1913)

Niels Bohr improved on Rutherford’s model.

He proposed that electrons move around the nucleus in specific layers, or shells.

Every atom has a specific number of electron shells.
Chadwick discovered neutrons.

Working with Rutherford, he discovered particles with no charge.

He called these particles neutrons.

Neutrons are also found in the nucleus.
The Modern Model (1932-)

Work done since 1920 has changed the model.

The new atomic model has electrons moving around the nucleus in a cloud.

It is impossible to know where an electron is at any given time.
The Current Atomic Model

- Protons
- Neutrons
- Electrons
Any Questions?
Atoms, Elements, and the Periodic Table

Part 2: The Periodic Table
There are \( \approx 110 \) different elements in the universe.

The Periodic Table of Elements organizes these 110 elements in a simple way.

Remember!

Elements differ from each other by the number of protons, neutrons, and electrons they have.
Before the Periodic Table was invented, the field of Chemistry was a gigantic mess!

The known elements were not organized in any way.

It was very difficult to find information on any element AND to predict how each element would react.
A Russian scientist named Dmitri Mendeleev discovered patterns in the properties of the elements.

I placed the elements in order of increasing atomic weight. When I did that, I noticed patterns in their properties and their reactivity.
I put the first 7 known elements in a row by increasing atomic weight...
I put the first 7 known elements in a row by increasing atomic weight… Then I put the next 7 in a new row, and filled rest of the table like that.

<table>
<thead>
<tr>
<th>Li</th>
<th>Be</th>
<th>B</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
</tr>
<tr>
<td>23</td>
<td>24</td>
<td>27</td>
<td>28</td>
<td>31</td>
<td>32</td>
<td>35.5</td>
</tr>
<tr>
<td>K</td>
<td>Ca</td>
<td>Ti</td>
<td>V</td>
<td>Cr</td>
<td>Mn</td>
<td>Fe</td>
</tr>
<tr>
<td>39</td>
<td>40</td>
<td>48</td>
<td>51</td>
<td>52</td>
<td>55</td>
<td>56</td>
</tr>
<tr>
<td>Cu</td>
<td>Zn</td>
<td>As</td>
<td>Se</td>
<td>Br</td>
<td></td>
<td>Ni</td>
</tr>
<tr>
<td>63</td>
<td>65</td>
<td>75</td>
<td>78</td>
<td>80</td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>Rb</td>
<td>Sr</td>
<td>Zr</td>
<td>Nb</td>
<td>Mo</td>
<td>Pd</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>87</td>
<td>90</td>
<td>94</td>
<td>96</td>
<td>106</td>
<td></td>
</tr>
</tbody>
</table>
Then I put the next 7 in a new row, and filled rest of the table like that. I left gaps for elements that I predicted would be discovered.
I left gaps for elements that I predicted would be discovered. Elements in the same column share similar chemical properties.
Elements in the same column share similar chemical properties. This allowed me to even predict the properties of the unknown elements.
The elements were soon found, and they matched my predictions!
Mendeleev’s Table

Mendeleev was amazingly accurate with his table.

The Periodic Table has been updated since then with new elements and information.

Once protons were discovered, elements were rearranged by atomic number.

Some elements changed spots, making the pattern of properties even more regular.
The new periodic table has over 100 squares.

Each square shows the element’s name, symbol, atomic number and atomic mass...
Take the element Helium, for example:

- Atomic Number (p): 2
- Element Symbol: He
- Element Name: Helium
- Mass Number (p + n): 4
A row is called a “period”.

A column is called a “group”.

Elements organized by increasing atomic number.
The groups are numbered from left to right.

Elements in the same group have similar properties.
Each group is also called a “family” of elements.

Just like members of the same family, they share similar characteristics.

Each element family has a unique name as well!

Let’s look at them now…
Groups

Gp 1 - Alkali Metals
Gp 1: Alkali Metals

HIGHLY reactive metals.

They are so reactive that they are never found uncombined in nature.

Metals soft enough to be cut with a butter knife!

Sodium (Na)

e.g. Li, Na, K
Groups

Gp 2 - Alkaline Earth Metals
Gp 2: Alkaline Earth Metals

Fairly reactive metals.

Not as reactive as the Alkali Metals, but still never found uncombined in nature.

Serve as important minerals for our body.

e.g. Be, Mg, Ca

Calcium (Ca)
Groups

Gps 3-12 - Transition Metals
Less reactive metals.

Hard, dense metals that are useful as building materials, jewellery and coins.

Also used as oxides to make paints and pigments.

e.g. Fe, Cu, Au, Ag

Nickel (Ni) Gold (Au)
Groups

Gp 17 - Halogens
# Groups

Gp 18 - Noble Gases

<table>
<thead>
<tr>
<th>Period</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H, He</td>
</tr>
<tr>
<td>2</td>
<td>Li, Be,</td>
</tr>
<tr>
<td></td>
<td>Na, Mg,</td>
</tr>
<tr>
<td>3</td>
<td>K, Ca,</td>
</tr>
<tr>
<td></td>
<td>Sc, Ti, V,</td>
</tr>
<tr>
<td></td>
<td>Cr, Mn, Fe,</td>
</tr>
<tr>
<td></td>
<td>Co, Ni, Cu, Zn</td>
</tr>
<tr>
<td>4</td>
<td>Rb, Sr,</td>
</tr>
<tr>
<td></td>
<td>Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd</td>
</tr>
<tr>
<td>5</td>
<td>Cs, Ba,</td>
</tr>
<tr>
<td></td>
<td>La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg</td>
</tr>
<tr>
<td>6</td>
<td>Fr, Ra,</td>
</tr>
<tr>
<td></td>
<td>Ac, Rf, Db, Sg, Bh, Hs, Mt</td>
</tr>
<tr>
<td>7</td>
<td>84, 85, 86, 87</td>
</tr>
<tr>
<td></td>
<td>88, 89, 90, 91</td>
</tr>
<tr>
<td></td>
<td>92, 93, 94</td>
</tr>
</tbody>
</table>

The noble gases are highlighted in blue.
Gp 18: Noble Gases

Unreactive gases.

Do not react naturally - always found on their own in nature.

Used in “neon” signs, balloons and light bulbs.

Neon (Ne)

e.g. He, Ne, Ar
Any Questions?
Atoms, Elements, and the Periodic Table

Part 3: Isotopes
Each element has a unique # of **protons**.

Every single **atom** of that element must have the **same** number of protons.

So, each element has a unique **atomic number**.

**Atomic Number (p)**

**C**

Carbon

6

12
Isotopes

Atoms of one element must have the same # of protons, but can have a different # of neutrons.

Isotopes are atoms with the same # of protons and a different # of neutrons.

This gives an isotope a different mass number.
An Example

There are 3 isotopes of oxygen:

- $^8_{16}$O Oxygen
- $^8_{17}$O Oxygen
- $^8_{18}$O Oxygen

Each has **8 protons**: that's why it's oxygen!

How many **neutrons** does each isotope have?
Each has 8 protons: that’s why it’s oxygen!

How many neutrons does each isotope have?
A Second Example

There are 3 isotopes of carbon:

- $^6_{12}\text{C}$ Carbon
- $^6_{13}\text{C}$ Carbon
- $^6_{14}\text{C}$ Carbon

How many **neutrons** does each isotope have?
A Second Example

There are 3 isotopes of carbon:

- $^6_{12}\text{C}$ with 4 neutrons
- $^6_{13}\text{C}$ with 5 neutrons
- $^6_{14}\text{C}$ with 6 neutrons

How many \textit{neutrons} does each isotope have?
Why Decimals?

Mass numbers are normally **decimals**.

Why is this?

Mass numbers are decimals because some isotopes are **more common** than others.

Let's look at an example....
When you average out all of the masses, you get a number close to 12, but not exactly!

In the universe, there is much more C-12 than C-13 and C-14 isotopes. The mass # is always closest to the most common isotope.
An Example

The mass number of oxygen is 15.999

What’s the most common oxygen isotope?
What's the most common oxygen isotope?

This is because 15.999 is closest to O-16.
Another Example

The mass number of chlorine $35.45$

What is the most common chlorine isotope?
Another Example

The mass number of chlorine $^{35.45}_{17}$

What is the most common chlorine isotope?

Chlorine is found in roughly equal amounts.
Any Questions?