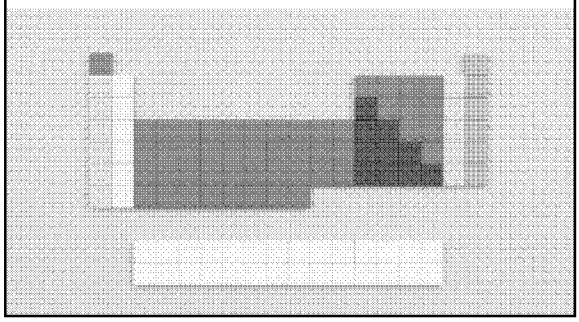
Thursday, September 30

The Chemical Revolution: What is Stuff Made of?



The Chemical Revolution Key Concepts

1) The concepts of "elements" and "atoms" date back to ancient Greece.

2) Experimental advances in the 18th & 19th century led to modern chemistry.

3) **Spectroscopy** is a powerful tool for detecting elements far from Earth.

Ancient Greeks thought matter was composed of 4 elements: Earth, Air, Fire, and Water.

Two schools of thought:

Atomists (Democritus & followers)
- Elements are made of indivisible tiny "**atoms**".
- Same matter in the heavens as on the Earth.

Aristotelians
- The 4 elements are found **only** on the Earth.
- Heavens are composed of a 5th element (the "**aether**" or "**quintessence**").

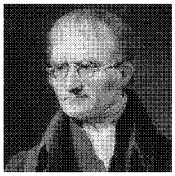
Antoine Lavoisier (1743-1794) was the first quantitative chemist.

He described 33 distinct chemical elements, including hydrogen and oxygen.

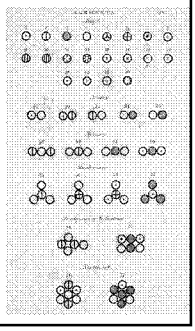
These elements are *immutable*.

Compounds are combinations of these elements.

David – *Lavoisier and his wife* (1788)



John Dalton (1766-1844) introduced a new atomic theory to explain the elements.



Each chemical element is made of atoms of a single, unique type.

Atoms can't be changed or destroyed by chemical means.

They can combine to form compounds (simple or complex).

Dmitri Mendeleev (1834 – 1907) found patterns in the properties of elements.

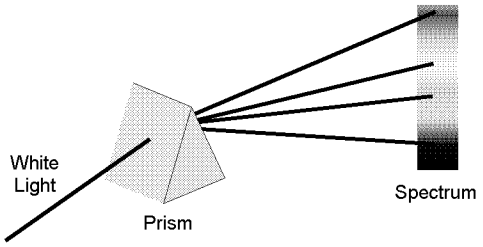
In 1869, he arranged 67 known elements by weight and bonding type, noting repeating patterns.

The result was the first **periodic table**.

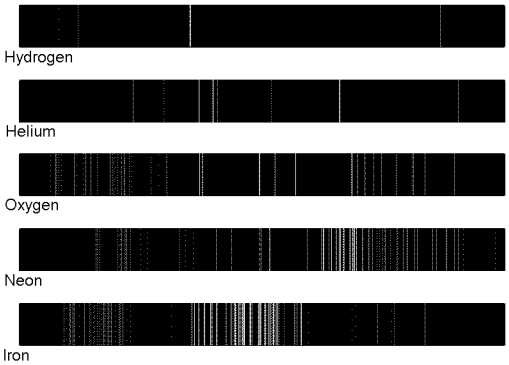
Mendeleev noted gaps in the table, and **predicted** previously unknown elements like gallium & germanium.

Spectroscopy is a technique for sorting light from a source by its component colors.

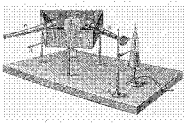
Spectra are observed by passing light from a source through a prism or grating.



Each element has a unique emission-line spectrum.

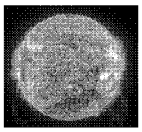


Spectroscopy was a powerful tool that revealed new elements.

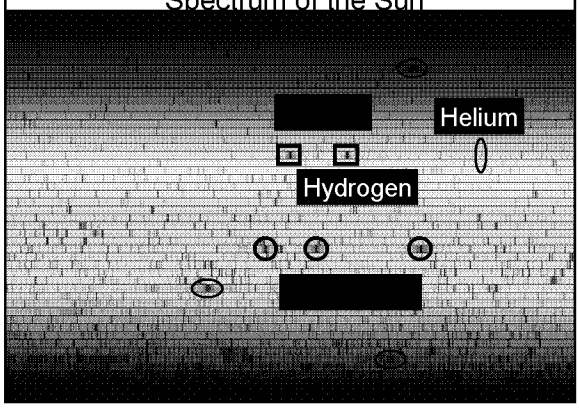


Kirchhoff & Bunsen discovered the elements cesium & rubidium using spectroscopy.

Helium was discovered in the spectrum of the Sun before it was identified on Earth (1895)!

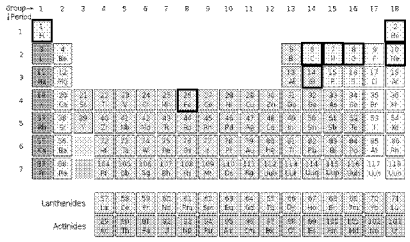


Spectrum of the Sun



The Eight Most Abundant Elements in the Universe are…

Hydrogen
Helium
Oxygen
Carbon
Neon
Nitrogen
Silicon
Iron



The main elements of life on Earth are **C**, **H**, **O**, and **N**.

The Earth itself is largely **Fe**, **O**, and **Si**.

Why does each element have a characteristic line spectrum?

The spectral lines reflect the detailed structure of the atom.

Which lines are produced depends on the number and arrangement of electrons in orbit around the nucleus.

The arrangement of electrons also determines the chemical bonding properties of the element.

Atoms are composed of a heavy nucleus of protons & neutrons orbited by electrons.

Nucleus made of subatomic particles:
- proton: positively charged
- neutron: uncharged (*neutral*)

Electrons orbit the nucleus:
- Electrons are negatively charged particles, much less massive than a proton.

Atoms are mostly empty space:
- Only 1 part in 10^{15} of the space is occupied.

The chemical elements are distinguished by the **number of protons** in the nucleus.

Number of protons = **Atomic Number** of the element:

1 proton = Hydrogen

2 protons = Helium

3 protons = Lithium ... and so on

An element can have one or more **isotopes** with different numbers of neutrons.

Example: Isotopes of carbon.

^{12}C has 6 protons and 6 neutrons (most common isotope)

^{13}C has 6 protons and **7** neutrons

^{14}C has 6 protons and **8** neutrons

All isotopes of a given element are chemically identical, but they have different atomic masses.

If a nucleus has too many or too few neutrons, it is unstable to **radioactive decay**.

Example: Decay of carbon-14

^{14}C (6p+8n) $\rightarrow$ ^{14}N (7p+7n) + e^- + ν_e

(half-life = 5700 years)

Free neutrons are also **unstable**:

$n \rightarrow p + e^- + \nu_e$

Spectroscopy of stars & planets reveals that they are made of the same elements found on Earth.

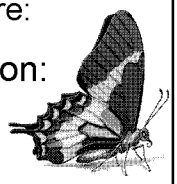
Not only do the same **physical laws** apply to other stars & planets…

Stars & planets are made out of the **same elements** as the Earth (but in different proportions).

Lessons about chemistry on Earth will apply to other worlds!

Tomorrow's Lecture:

Biological Revolution: What is Life?



This week's reading:

Chapters 2 & 3