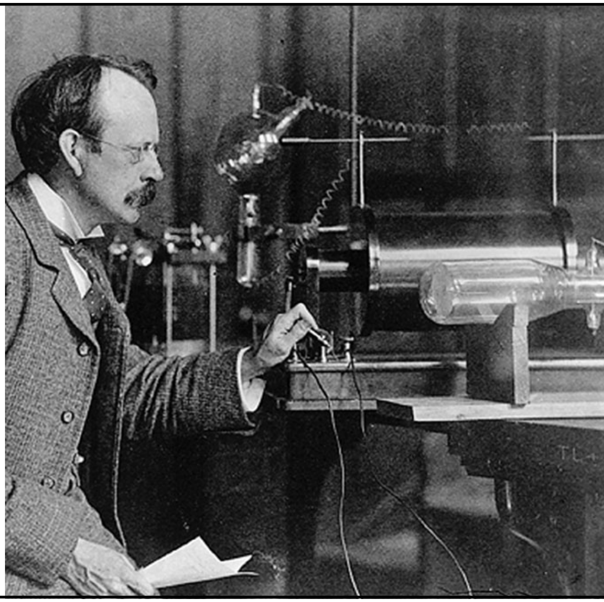

The Components of Matter

- Elements – the basic building blocks of matter
  - Ancient Greeks – four elements: earth, air, fire and water
- The atomic idea
  - Democritus – "… there are atoms and void."
  - Boyle (17th century) – "… simple bodies not made of any other bodies …"
  - Lavoisier (18th century) – natural laws
  - Dalton's atomic theory (19th century)
  - Atomic structure (20th century)

2.1 Elements, Compounds and Mixtures

- **Pure substances** – elements and compounds
  - Have constant composition
- **Elements** – consist of only one kind of atoms;
  - Can't be broken down to simpler substances
  - Have unique properties
  - Some elements consist of **molecules** (independent units made of 2 or more atoms)
- **Compounds** – consist of 2 or more chemically combined elements;
  - Can be broken down to simpler substances
  - Have properties unlike those of their component elements
  - Can't be separated into their components by physical means

- **Mixtures** – two or more elements or compounds that are physically intermingled
  - Have variable composition
  - Retain the properties of their components
  - Can be separated into their components by physical means

Examples:

- Silicon, sodium, chlorine, … – elements
- Water, sodium chloride, … – compounds
- Salt water, air, … – mixtures

2.2 Laws Leading to the Atomic View

- **Law of mass conservation** (Lavoisier) – the total mass of substances does not change during a chemical reaction
  - Matter cannot be created or destroyed

reactant 1 + reactant 2 ⟶ product

total mass = *total mass*

calcium oxide + carbon dioxide ⟶ calcium carbonate

56.08g + 44.01g ⟶ 100.09g

- **Law of constant composition** (Proust) – a pure compound always contains definite proportions (fractions) of its elements by mass

$$Mass\ fraction = \frac{Mass\ of\ element}{Mass\ of\ compound}$$

$$Mass\ \% = Mass\ fraction \times 100\%$$

Example: 9.0 g of water contains **8.0 g** of oxygen and **1.0 g** of hydrogen.

Mass fraction of H = 1.0/9.0 = 0.11 (or 11%)

Mass fraction of O = 8.0/9.0 = 0.89 (or 89%)

$$Mass\ of\ element = Mass\ of\ compound \times Mass\ fraction$$

Example: Analysis shows that **180.2 g** of glucose contains **72.1 g** of carbon, **96.0 g** of oxygen and the remainder is hydrogen. How many ***g*** of hydrogen are in **55.5 g** of glucose?

Mass of H in 180.2 g glucose =

= 180.2 g – 72.1 g – 96.0 g = 12.1 g H

$$Mass\ of\ H = 55.5\ \mathrm{g}\ \cancel{\mathrm{glucose}} \times \frac{12.1\ \mathrm{g\ H}}{180.2\ \mathrm{g}\ \cancel{\mathrm{glucose}}} =$$

$$= 3.73\ \mathrm{g\ H}$$

- **Law of multiple proportions** (Dalton) – if elements A and B form two different compounds, the different masses of B that combine with a fixed mass of A can be expressed as a ratio of small whole numbers

Example: Sulfur has 2 different oxides:

Oxide I $\rightarrow$ 1.0 g oxygen : 1.0 g sulfur

Oxide II $\rightarrow$ 1.5 g oxygen : 1.0 g sulfur

$$\frac{1.0\ \mathrm{g\ O}\ \cancel{\mathrm{per\ 1\ g\ S\ in\ I}}}{1.5\ \mathrm{g\ O}\ \cancel{\mathrm{per\ 1\ g\ S\ in\ II}}} = \frac{1.0}{1.5} \times \left(\frac{2}{2}\right) = \frac{2}{3}$$

2.3 Dalton's Atomic Theory

- Postulates of Dalton's atomic theory (1808)
  1. Matter consist of small, indivisible and indestructible atoms.
  2. All atoms of an element are identical in mass and different from the atoms of other elements.
  3. Compounds result from chemical combinations of different elements in specific atomic ratios
  4. Atoms don't change their identities in chemical reactions. They only recombine to form different compounds.

- Explanation of the mass laws
  - Conservation of mass – postulates 1 and 4
  - Constant composition – postulates 2 and 3
  - Multiple proportions – postulates 1, 2 and 3
- Relative atomic masses
  - Hydrogen was assigned a mass of **1** (lightest)
  - In water: **8g O : 1g H**

  ⇒ If the formula of water is HO, O should have relative mass of 8

  ⇒ If the formula of water is H_2O, O should have relative mass of 16 (16:2 = 8:1)

Example:

The two different oxides of sulfur have formulas SO_2 and SO_3.

$$\frac{\textbf{2 atoms O per 1 atom S in I}}{\textbf{3 atoms O per 1 atom S in II}} = \frac{2 \times 16}{3 \times 16} = \frac{2}{3}$$