Introduction to Physical Science

Atomic Theory

Presented by Robert Wagner

Dalton's Atomic Theory

- Matter is composed of atoms. An atom is the smallest unit that participates in a chemical change
- An element consists of only one type of atom
- Atoms of one element differ in properties from atoms of other elements

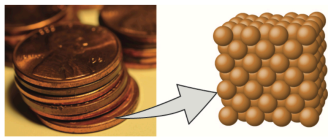

Figure 2.2 A pre-1982 copper penny (left) contains approximately 3×10^{22} copper atoms (several dozen are represented as brown spheres at the right), each of which has the same chemical properties. (credit: modification of work by "slgckgc"/Flickr)

Image Credit: OpenStax Chemistry - Figure 2.2 (Modification of work by "slgckgc"/Flickr)

Dalton's Atomic Theory (2)

- A compound consists of two or more elements combined in a small, whole-number ratio.
- Atoms are neither created nor destroyed during a chemical change, but are rearranged to yield new substances

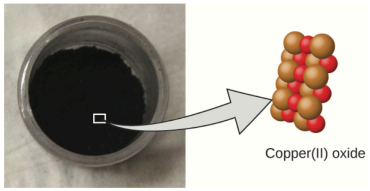

Figure 2.3 Copper(II) oxide, a powdery, black compound, results from the combination of two types of atoms—copper (brown spheres) and oxygen (red spheres)—in a 1:1 ratio. (credit: modification of work by "Chemicalinterest"/Wikimedia Commons)

Image Credit: OpenStax Chemistry - Figure 2.3 (Modification of work by "Chemicalinterest"/Wikimedia Commons)

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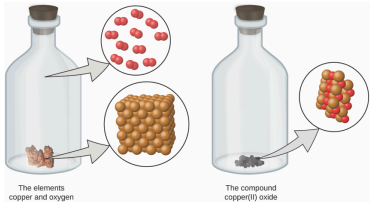
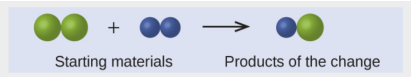


Figure 2.4 When the elements copper (a shiny, red-brown solid, shown here as brown spheres) and oxygen (a clear and colorless gas, shown here as red spheres) react, their atoms rearrange to form a compound containing copper and oxygen (a powdery, black solid). (credit copper: modification of work by http://images-of-elements.com/copper.php)

Image Credit: OpenStax Chemistry - Figure 2.4 (Copper: modification of work by http://images-of-elements.com/copper.php)

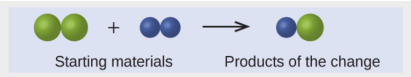
Example



- Would this reaction violate Dalton's rules?
- Remember, atoms cannot be created to destroyed!
- Look at this version

Image Credit: OpenStax Chemistry - Example 2.1 CC BY 4.0

Example



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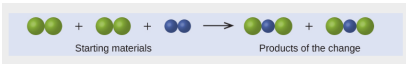

Image Credit: OpenStax Chemistry - Example 2.1 CC BY 4.0

Law of Definite Proportions

- The numbers of atoms of the elements in a given compound always exist in the same ratio
- Example: isooctane

Constant Composition of Isooctane

Sample	Carbon	Hydrogen	Mass Ratio
A	14.82 g	2.78 g	$\frac{14.82\text{ g carbon}}{2.78\text{ g hydrogen}} = \frac{5.33\text{ g carbon}}{1.00\text{ g hydrogen}}$
B	22.33 g	4.19 g	$\frac{22.33\text{ g carbon}}{4.19\text{ g hydrogen}} = \frac{5.33\text{ g carbon}}{1.00\text{ g hydrogen}}$
C	19.40 g	3.64 g	$\frac{19.40\text{ g carbon}}{3.63\text{ g hydrogen}} = \frac{5.33\text{ g carbon}}{1.00\text{ g hydrogen}}$

Image Credit: OpenStax Chemistry - Table 2.1 CC BY 4.0

Law of Multiple Proportions

- When two elements react to form more than one compound, a fixed mass of one element will react with masses of the other element in a ratio of small, whole numbers
- Carbon and chlorine:
  - Green solid: 1.116 g Cl to 1 g Cu
  - Brown solid: 0.558 g Cl to 1 g Cu

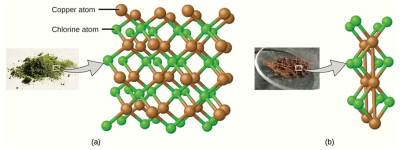

Figure 2.5 Compared to the copper chlorine compound in (a), where copper is represented by brown spheres and chlorine by green spheres, the copper chlorine compound in (b) has twice as many chlorine atoms per copper atom. (credit a: modification of work by "Benjah-bmm27"/Wikimedia Commons; credit b: modification of work by "Walkerma"/Wikimedia Commons)

Image Credit: OpenStax Chemistry - Figure 2.5 (a - modification of work by "Benjah-bmm27"/Wikimedia Commons ; b - modification of work by "Walkerma"/Wikimedia Commons

Example

- Compound A: 4.27 g Carbon and 5.69 g Oxygen
- Compound B: 5.19 g Carbon and 13.84 g Oxygen
- Ratios are not the same - different compounds
- Small whole number ratio - law of multiple proportions
  -

Compound A:

$$\frac{1.33\ g\ O}{1\ g\ C}$$

Compound B:

$$\frac{2.67\ g\ O}{1\ g\ C}$$

$$\frac{\frac{1.33\ g\ O}{1\ g\ C}}{\frac{2.67\ g\ O}{1\ g\ C}} = \frac{1}{2}$$

Development of Atomic Theory

- Thomson - used cathode ray tube to measure the charge to mass ratio of the electron
  -
- Millikan - oil drop experiment - Determine charge of electron
  -
- Combine these to determine the mass of electron
  -

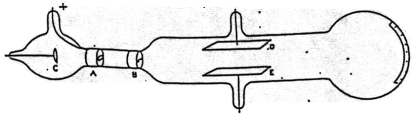

Image Credit: J.J. Thomson, Public domain, via Wikimedia Commons

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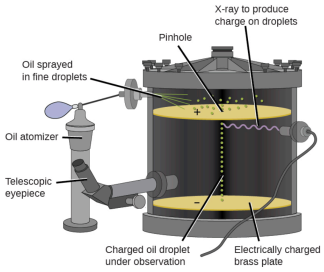

Image Credit: OpenStax Chemistry - Figure 2.7 CC BY 4.0

Atomic Theory

- Various models
  - "Plum Pudding" - electrons imbedded in positively charged mass
  - Saturn-like atom - Electrons orbit around a positively charged nucleus
- Rutherford Experiment
  - Volume - mostly empty space
  - Small, heavy, positively charged nucleus

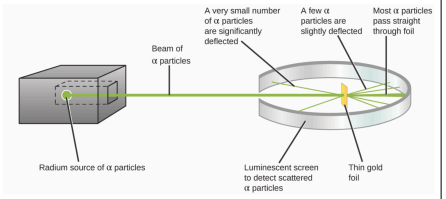

Figure 2.9 Geiger and Rutherford fired α particles at a piece of gold foil and detected where those particles went, as shown in this schematic diagram of their experiment. Most of the particles passed straight through the foil, but a few were deflected slightly and a very small number were significantly deflected.

Image Credit: OpenStax Chemistry - Figure 2.9 CC BY 4.0

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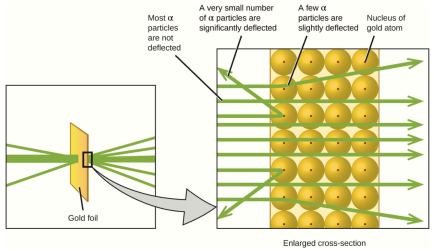

Image Credit: OpenStax Chemistry - Figure 2.10 CC BY 4.0

Isotopes & Neutrons

- Isotopes - apparently new elements found in the early 1900s
  - Same material, just differ in mass
- Neutron - discovered in 1932
  - Explain existence of isotopes. Isotopes have the same number of protons, but different numbers of neutrons

Summary

- Modern atomic theory began with the studies of Dalton
- The laws of definite and multiple proportions tell how atoms combine together in specific ratios
- Rutherford’s experiment explained atoms as mostly empty space with a massive, compact nucleus