Module 3: Atoms and Molecules

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1 Overview

1. the **Law of Mass Conservation** says matter can't be created or destroyed
2. **Elements** are the color palette for matter
3. **Compounds** are made of elements that are chemically combined
4. the **Periodic Table** is a thing of rare beauty that will haunt your dreams

2 Mass Conservation

Law 1 (The Law of Conservation of Mass) *Matter cannot be created or destroyed, it can only change forms.*

- this is another conservation law, like the energy conservation law in Module 2
- we can't actually create matter, and we can't actually destroy it, all we can do is convert it from one form to another [1]
- we can convert matter with chemical processes (*e.g.* we can burn wood or wax)
- we can change the state of matter with physical processes (*e.g.* we can freeze water to make ice or evaporate water to make water vapor)
- but we generally can't make more of it, and we can't make less of it

[1] OK, so this isn't *exactly* true: Lavoisier (1743 – 1794) came along when people were still trying to digest Newton (1642 – 1727), they weren't ready for Einstein (1879 – 1955) yet. Let's leave this one here for now, but you should be aware that nuclear reactions really do convert matter into energy.

3 Elements

Definition 1 (Decomposition) *Decomposition is breaking down a substance into two or more other substances.*

Definition 2 (Element) *An element is a substance that cannot be decomposed into a less massive substance.*

- **decomposition** is breaking down a substance into other substances
- many (most) substances can be decomposed, but some cannot
- substances that cannot be decomposed are called **elements** [Wile, 2003, p. 74]
- every physical thing is made up of one or more elements:
  - water is made up of two gasses: Oxygen and Hydrogen
  - sulfuric acid is made up of three gasses: Hydrogen, Sulfur, and Oxygen
  - steel is made up of two solids: Iron and Carbon
  - Iron is made of Iron — it's an element [2]

3.1 The Periodic Table

- each entry in the Periodic Table contains four pieces of information:
  1. the element's **symbol** (*e.g.* H, He, Li, Be, B, C, ...)
  2. the element's **atomic number**
  3. the element's **atomic mass**
  4. the element's location on the chart
- in general terms, the element's symbol acts as a mnemonic, although they don't always work the way we might think (why is lead called "Pb"?)
- the atomic number is unique: it's the defining feature of an element[3]
- we'll get to the atomic mass later
- be aware that not all the elements occur naturally [Wile, 2003, p. 76], there are more elements now than when I was in school(?!)

[2] It's iron all the way down!

[3] On some Periodic Tables, you'll see Hydrogen (H) listed twice, because Hydrogen is weird.

- elements on the *left* of the Periodic Table are metals; elements on the *right* are non-metals, *except Hydrogen (H)*[4]

4 Compounds

Definition 3 (Compound) *A compound is a substance that can be decomposed into elements by chemical means.*

Law 2 (The Law of Definite Proportions) *The proportion of elements in any compound is always the same.*

- there are basically two types of matter: elements and compounds
- a compound is a substance made up of elements (*e.g.* water, steel, sulfuric acid)
- note compounds are made of elements combined *chemically*: bolting a piece of Iron to a piece of Tin doesn't make a compound

5 The Law of Multiple Proportions

Law 3 (The Law of Multiple Proportions) *If two elements combine to form different compounds, the ratio of masses of the* second *element that react with a fixed mass of the* first *element will be a simple, whole-number ratio.*

- this one is easier to understand than it seems:
  - if we have two compounds made up of two elements
  - and if they use the same amount (mass) of one of the elements, then:
  - the amount (mass) of the *other* element in one compound will be a simple ratio of the mass of that same element in the *other* compound
- so if you compare water (H_2O) and hydrogen peroxide (H_2O_2), if you have the same amount of H in each compound (by *mass*), then you'll have twice as much O in the second compound as in the first
- or if you compare water and hydronium (H_3O^+), if you have the same amount of O in each compound, the ratio of H in the two compounds will be $2 : 3$, a simple, whole-number ratio
- or if you compare hydrogen peroxide and hydroxyl (OH^-), if you have the same amount of O in each compound, the ratio of H in the two compounds will be $1 : 1$, a simple, whole-number ratio

[4] I told you Hydrogen is weird.

6 Dalton's Atomic Theory

- John Dalton (1766 – 1844) came up with an atomic theory [Wile, 2003, p. 83–85]
  1. all elements are composed of small, indivisible particles called "atoms"
  2. all atoms of the same element have exactly the same properties
  3. atoms of different elements have different properties
  4. compounds are formed when atoms are joined together — since atoms are indivisible, they can only join in simple, whole-number ratios
- as far as it goes, Dalton's Atomic Theory is [mostly] correct
- chemical reactions are just atoms rearranging: they don't create new atoms, nor do they destroy existing atoms
- the total number of atoms stays the same, so the total amount of mass stays the same (see Law 1)
- since atoms are indivisible, they can only combine in consistent ratios (see Law 2)
- since atoms are indivisible, they can only combine in whole-number ratios (see Law 3)
- it turns out atoms aren't actually indivisible: they, too, are made of smaller particles [Wile, 2003, p. 85]
- it turns out atoms of a single element aren't actually identical: there are slight variations in mass between *isotopes* [Wile, 2003, p. 85]

References

[Wile, 2003] Wile, D. J. L. (2003). *Exploring Creation with Chemistry*. Apologia Educational Ministries, Inc., 2 edition.