Module 4: Classifying Matter and Its Changes

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1 Overview

1. **Mixtures** contain multiple types of elements and/or compounds.
2. Matter is made up of moving atoms and/or molecules: the higher its temperature, the faster those atoms and/or molecules are moving.
3. **Physical Changes** are when a substance is changed, but remains the same substance.
4. **Chemical Changes** are when a substance changes from one type of thing to another type of thing.

2 Classifying Matter

Definition 1 (Pure Substance) *A substance that contains only one element and/or compound*

Definition 2 (Mixture) *A substance that contains different elements and/or compounds*

- a mixture contains multiple elements and/or compounds, but they haven't lost their individual identities and properties
- *e.g.* air is a mixture of many different gases[1]: each gas in air is still whatever kind of gas it would be without the others... air is not a compound
- it's possible to separate parts of a mixture *physically* (*e.g.* by filtering)

Definition 3 (Homogenous Mixture) *A mixture with a composition that is always the same, regardless of which part of the sample you are observing*

[1] See the table in the textbook, p. 105

Definition 4 (Heterogenous Mixture) *A mixture with a composition that differs depending on which part of the sample you are observing*

- air *seems like* a homogeneous mixture: it pretty much looks the same everywhere... if you go past a dairy farm, you'll realize it's actually heterogeneous on a large enough scale
- paint is a heterogenous mixture, which is why you have to mix it up before you can use it

3 Classifying Changes in Matter

Definition 5 (Chemical Change) *a change that affects the type of atoms or molecules in a substance*

Definition 6 (Physical Change) *a change in which the atoms or molecules in a substance stay the same*

- the idea here is that if we physically alter a substance, that's not a chemical change
- dissolving one substance into another is a physical change[2], because we haven't actually changed the kinds of atoms and/or molecules involved
- chewing a steak is a physical change, but digesting a steak is a chemical change

4 Phase Changes

- one interesting type of physical change is the *phase change*
- in general, there are three phases of matter: solid, liquid, and gas[3].
- we can convert matter between these phases with heat [4] (see Table)

5 The Kinetic Theory of Matter

Theory 1 (The Kinetic Theory of Matter) *Molecules and atoms are in constant motion, and the higher the temperature, the greater their speed.*

- we already know all matter is made of *atoms* and/or *molecules*

[2] I realize we could argue differently based on our definitions, but let's just go with it. Check out p. 107 for more.

[3] Let's not get hung up on plasma right now.

[4] And pressure!

Name	Phase Change	Beginning Phase	Ending Phase
freeze	add heat	liquid	solid
melt	take heat away	solid	liquid
evaporate	add heat	liquid	gas
condense	take heat away	gas	liquid
sublimate[5]	change pressure	solid	gas

Table 1: Phase Changes for Matter

- those atoms and molecules are in constant motion:[6]
  1. in *solids*, they move more-or-less in place, vibrating
  2. in *liquids* they move faster, and don't really stay in place
  3. in *gases*, they move much faster, and are free to travel really far from each other
- since motion requires energy,[7] we can say that the atoms and/or molecules in liquid have more energy than in a solid.
- so we can think of **thermal energy** as being the energy associated with the movement of the atoms and/or molecules in a substance
- similarly, we can think of **temperature** as being the average thermal energy of the substance

6 Chemical Reactions and Chemical Equations

Definition 7 (Homonuclear Diatomic) *Homonuclear diatomic molecules are made up of two atoms of the same type.*

- homonuclear diatomic molecules are the natural form[8] of several elements: N_2, O_2, Cl_2, F_2, Br_2, I_2, At_2, H_2
- you'll find all these at the right-hand side of the periodic table
- we only care about homonuclear diatomic molecules when we discuss the substances in terms of their natural form: we don't care about them when we deal with these substances in terms of their roles in molecules (*e.g.* water (H_2O) contains a *single* O, not two O atoms)

[6] This doesn't break the Law of Conservation of Momentum, as long as they all sort of cancel each other out.

[7] Remember energy is the ability to do work, and work is related to force and distance moved.

[8] "Natural" here means, "found in nature."

- we think of chemical changes in terms of **chemical reactions**, *e.g.* "carbon plus oxygen yields carbon dioxide"
- we write chemical reactions like an equation in math:

$$\mathrm{C} + \mathrm{O_2} \longrightarrow \mathrm{CO_2}$$

- when we write a chemical reaction as an equation, we call it a **chemical equation**
- we write the **reactants** on the left-hand side, and the **products** on the right-hand side
- we can add phase information too:

$$\mathrm{C\ (s)} + \mathrm{O_2\ (g)} \longrightarrow \mathrm{CO_2\ (g)}$$

6.1 Balancing Chemical Equations

- let's consider the burning of methane [Wile, 2003, p. 117ff]: "methane plus oxygen yields carbon dioxide plus water"
- we can write that one as:

$$\mathrm{CH_4\ (g)} + \mathrm{O_2\ (g)} \longrightarrow \mathrm{CO_2\ (g)} + \mathrm{H_2O\ (g)}$$

- written that way, we have matter both created and destroyed:
  1. we have one C atom on the left, and one on the right... that works, but
  2. we have four H atoms on the left, and two on the right... so, did we create atoms?
  3. we have two O atoms on the left, and three on the right... so once again, we're creating atoms
- in order to tell the truth about not creating atoms, we need to conserve the atoms on each side
- so our equation is:

$$\mathrm{CH_4\ (g)} + \mathrm{O_2\ (g)} + \mathrm{O_2\ (g)} \longrightarrow \mathrm{CO_2\ (g)} + \mathrm{H_2O\ (g)} + \mathrm{H_2O\ (g)}$$

- now we have:
  1. one C atom on the left, and one on the right
  2. four H atoms on the left, and four on the right

3. four O atoms on the left, and four on the right

- so now we're not creating or destroying atoms!
- we can write that more simply[9]:

$$CH_4\,(g) + 2\,O_2\,(g) \longrightarrow CO_2\,(g) + 2\,H_2O\,(g)$$

- this is called a **balanced chemical equation**
- and notice what it tells us:

1. CH_4 takes twice as many O_2 molecules to burn as CH_4 molecules
2. for every CH_4 molecule we burn, we'll get one CO_2 molecule
3. for every CH_4 molecule we burn, we'll get one H_2O molecule

Hint 1 (Balancing Chemical Equations) *A chemical equation is balanced when the same number of atoms of each type are on both the left-hand-side and the right-hand-side.*

References

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

[9] Just like we would in a math equation.