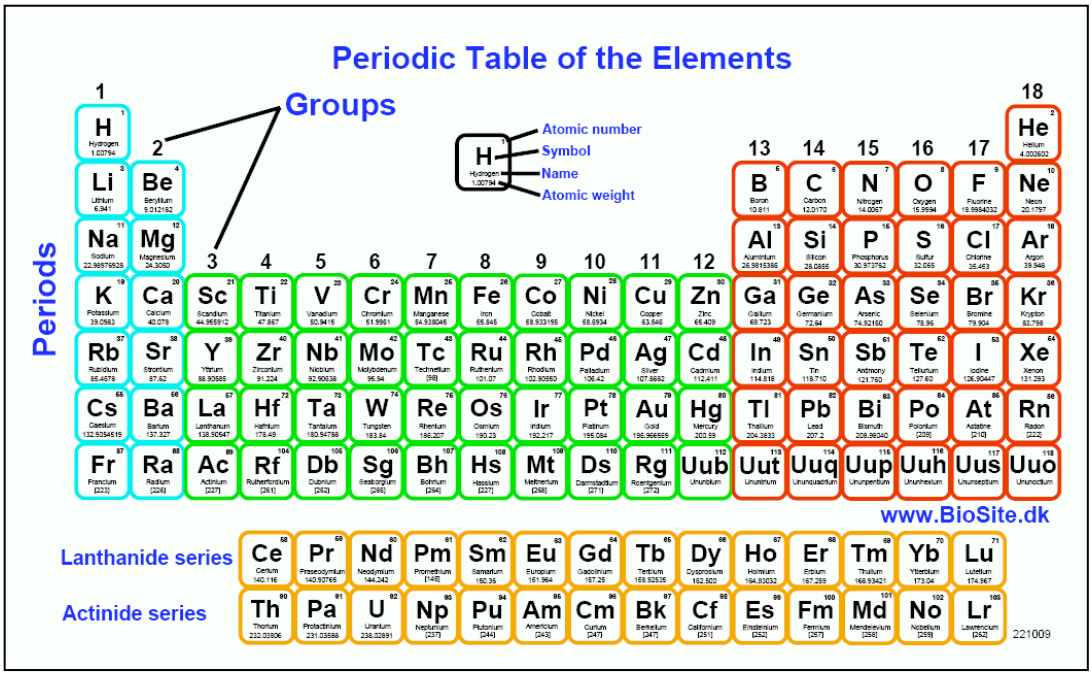
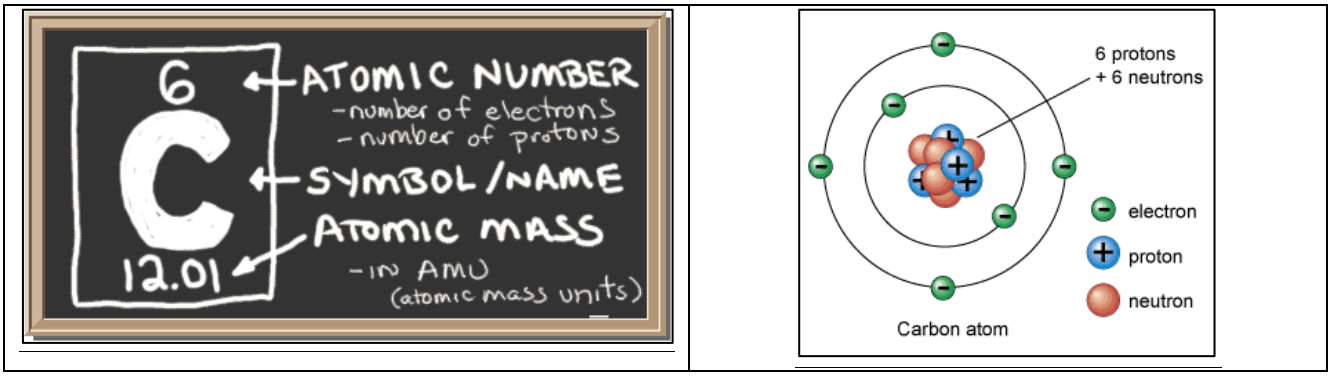
Fundamentals of Environmental Science: Balancing Chemical Reactions



Matter: has mass and takes up space
Atomic theory: all elements are made of atoms

Subatomic particles
Protons with positive charge and **neutrons** with no charge in **nucleus**
Negatively charged **electrons** orbit the nucleus

Atomic number= Number of protons in nucleus
Mass number= Number of protons + neutrons in nucleus



Matter Consists of Elements and Compounds
Elements
Unique properties
Cannot be broken down chemically into other substances
Gold (Ag) and Mercury (Hg) Are Chemical Elements
Compounds
Two or more different elements bonded together in fixed proportions
Sugar (sucrose) is a compound $C_{12}H_{22}O_{11}$

Study Table 2-1 *Chemical Elements Used in This Book* on page 38.
Study Table 2-2 *Chemical Ions Used in This Book* on page 40.
Study Table 2-3 *Compounds Used in This Book* on page 40

Molecule
A molecule is formed when two or more atoms join together chemically. Ex. → **oxygen → O_2**
Compounds
A compound is a molecule that contains at least two different elements. Ex. → carbon dioxide → **CO_2**
All compounds are molecules but not all molecules are compounds.
Chemical formula: Ex. → **H_2O** (2 hydrogen + 1 oxygen atoms = water)
Ex. → **$C_6H_{12}O_6$** (6 carbon + 12 hydrogen + 6 oxygen = glucose)
Chemical Reaction: atoms separate from molecules they are a part of and recombine to form other molecules (shown in chemical equations).
Photosynthesis can be represented using a chemical equation.

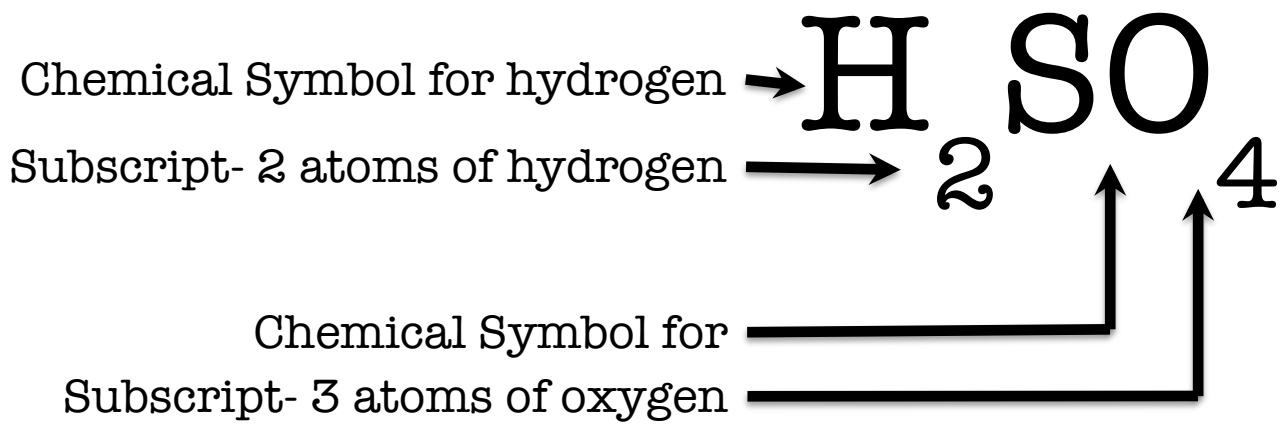
$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Sunlight energy}} C_6H_{12}O_6 + 6\ O_2$$

Ions
Gain or lose electrons
Form ionic compounds

Isotopes forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei, and hence differ in relative atomic mass

Matter Undergoes Physical & Chemical Change
Physical Change
No change in chemical composition; Ex. phase change, dissolving
Chemical change, chemical reaction
Change in chemical composition; chemical reaction
Reactants and products; new substances formed

Compounds and Formulas
Hydrogen (H), sulfur (S), and oxygen (O) combine to form the compound sulfuric acid, a pollutant when present in the environment.
Subscript means "written below". A subscript number written after a symbol tells how many atoms of that element are in the compound.
Sulfuric acid is composed of two hydrogen atoms, one sulfur atom, and four oxygen atoms.



Yields, Produces, or Forms

$$\text{Reactants} \longrightarrow \text{Products}$$

Conservation of Mass

In the early 1700's Antoine Lavoisier performed many experiments to determine the answer to this question:

What happens to the masses of the reactants and the products in chemical reactions?

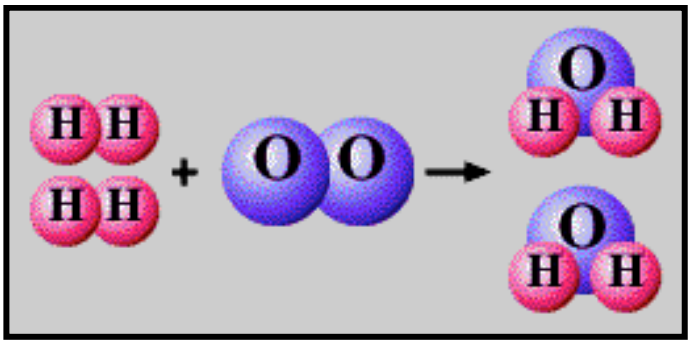
In one experiment Lavoisier placed a carefully measured amount of mercury (II) oxide into a sealed flask. When he heated this flask, oxygen gas and liquid mercury were produced.
Lavoisier found that the mass of the oxygen and the mercury produced was equal to the mass of the mercury (II) oxide that he started with.

Mercury (II) oxide produces oxygen plus mercury

10.0 g = 0.7g + 9.3 g

Conservation of Mass

Before: 4 atoms of hydrogen & 2 atoms of oxygen

Reactants  **Products**

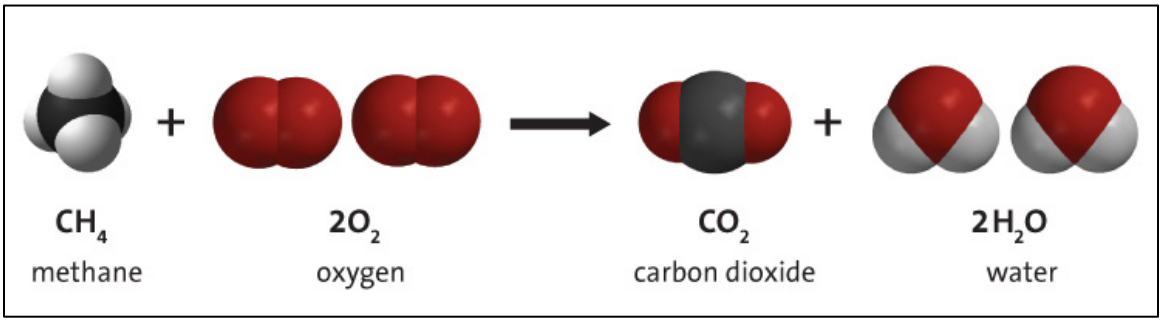
After: 4 atoms of hydrogen & 2 atoms of oxygen

The Law of Conservation of Mass
In a chemical reaction, matter is not created or destroyed but is conserved.
Atoms can only rearrange.

Chemical Reactions
For a chemical reaction in which all of the reactants change to products, the law of conservation of mass means that the starting mass of the reactants equals the final mass of the products.
The law of conservation of mass must be satisfied when describing a chemical reaction.

A chemical equation:
-is a shorthand method to describing a chemical reaction.
-is an expression that describes a chemical reaction using chemical formulas and other symbols.
-uses coefficients to show that atoms a are rearranged but never lost or destroyed; mass is conserved.

SYMBOL	MEANING
→	produces, forms
+	plus, and
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous (solid dissolved in water)
$\xrightarrow{\Delta}$	the reactants are heated



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

The symbols to the right of the formulas are (*s*) for solid, (*aq*) for aqueous, which means "dissolved in water", (*g*) for gas, and (*l*) for liquid.

Coefficients

The numbers to the left of the formulas are called coefficients.
Coefficients represent the number of units of each substance taking part in the reaction.

Remember that the law of conservation of mass states that matter is neither created nor destroyed during chemical reactions. Atoms are rearranged but never lost or destroyed.

By conducting an element inventory it is easy to see that this equation is not balanced.

Element Inventory		
$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(l)$		
C		
H		
O		

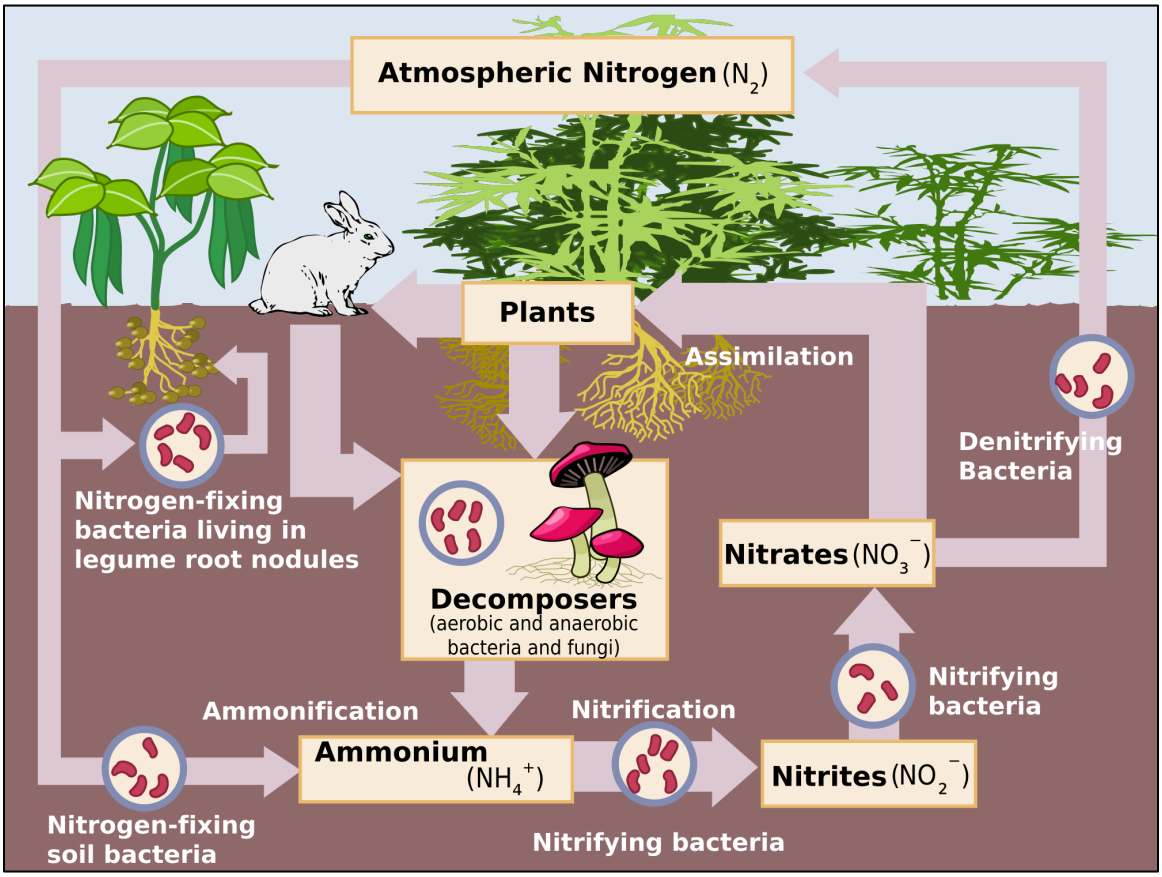
Is this chemical equation is balanced?

<u>The Law of Conservation of Mass</u>
In a chemical reaction, matter is not created or destroyed but is conserved.
Atoms can only rearrange.

Diatomic molecules

- ***Diatomic molecules are molecules composed only of two atoms, of either the same or different chemical elements***
- ***There are seven elements that exist as diatomic molecules in their natural state.***

$$H_2,\ Cl_2,\ N_2,\ O_2,\ F_2,\ Br_2,\ \&\ I_2$$



Element Inventory- Unbalanced		
$N_2\,(g) + H_2\,(g) \rightarrow NH_3\,(l)$		
N		
H		

Choosing Coefficients

To balance an equation, **never change the subscripts** of a correct formula. Instead, place a whole number to the left of the formulas of the reactants and products so that equal numbers of nitrogen and hydrogen atoms are on both sides of the equation.
If no number is written the coefficient is understood to be 1.

Choosing the correct coefficient, to balance a chemical equation,
is a trial and error process and requires patience.
Look at the formulas containing nitrogen and hydrogen molecules.
2 atoms of nitrogen are on the left and only 1 is on the right.
2 atoms of hydrogen are on the left and there are 3 is on the right.

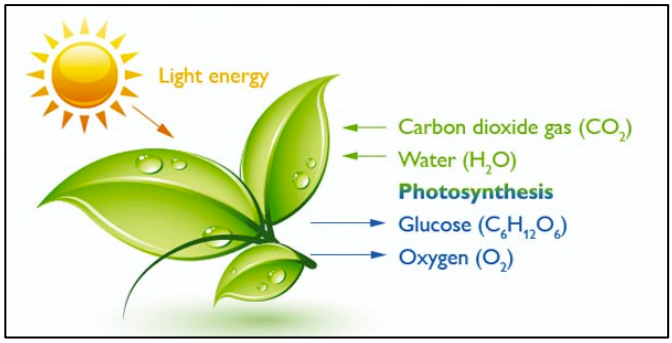
Element Inventory- Balanced		
$N_2\ (g) +$	$H_2\ (g) \rightarrow$	$NH_3\ (l)$
N		
H		

There are 2 hydrogen atoms on the reactants side and 3 hydrogen atoms on the products side. The least common multiple of 2 & 3 is 6. Let's see if this will help us balance this chemical equation. If we put a coefficient of 3 before H_2 on the reactants side, and a coefficient of 2 before NH_3 on the products side, **the equation is balanced** because there are 2 nitrogen atoms on each side and 6 hydrogen atoms on each side.

Writing Balanced Chemical Equations

To write a balanced chemical equation for most reactions follow these five steps.

1. Write the unbalanced equation.
2. Count atoms on each side. Use an element inventory table.
3. Add coefficients to make #s equal. Coefficient × subscript = # atoms. Use an element inventory table.
4. Reduce coefficients to lowest possible ratio. (If necessary)
5. Double check atom balance!!!



Writing Balanced Chemical Equations- Photosynthesis

Step 1- Write the unbalanced equation:

$CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$

(Oxygen is a diatomic molecule, so there must be 2)

Step 2- Count atoms on each side: (Use an element inventory table.)

None of the carbon, oxygen, and hydrogen atoms are balanced. The equation is not balanced.

Element Inventory- Unbalanced		
$CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$		
C		
O		
H		

Step 3- Add coefficients to make #s equal.
Coefficient × subscript = # atoms
6 CO_2 + 6 H_2O → $C_6H_{12}O_6$ + 6 O_2

Step 4- Reduce coefficients to lowest possible ratio.
(not necessary)
Step 5- Double check atom balance!!!

Element Inventory- Balanced		
6 CO_2 + 6 H_2O → $C_6H_{12}O_6$ + 6 O_2		
C		
O		
H		