



ENVIRONMENTAL CHEMISTRY

- Stoichiometry

Changha Lee

School of Chemical and Biological Engineering
Seoul National University



Environmental Chemistry

- Almost every pollution problem (and solution) has a chemical basis
- Arise from chemical transformation/reactions of compounds
- Effects of chemical properties of waste

Environmental Chemistry

√ **To understand and control natural systems, we must understand chemical and biochemical reactions**

- Biodegradation of hazardous wastes
- Greenhouse gases
- Ozone hole and urban ozone
- Acid deposition
- Water pollution
- Air pollution

Definitions

- **Atom** (Gr. “unbreakable”): basic structural unit
- **Protons** (+1): positively charged particle
 - Determines atomic number
- **Neutron** (0): no charge
 - With protons, determines atomic mass unit (AMU)
- **Electrons** (-1): negatively charge particle
 - Determine chemical properties
- **Atomic Weight**: mass of atom in AMU
 - e.g. Carbon weighs 12 amu (6 protons, 6 neutrons)
- **Isotopes**: atoms with same number of protons and different number of neutrons
- **Molecule**: combination of atoms (covalent bonds)
- **Molecular weight**: sum of atomic weights
 - e.g. MW of methane, $\text{CH}_4 = 1(12) + 4(1) = 16 \text{ g/mole}$
- **Mole**: Avogadro’s number of molecules (6.0221413×10^{23})

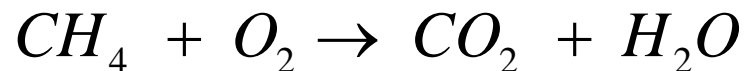
$$\text{Number of moles} = \frac{\text{mass}}{\text{molecular weight}}$$

Chemical Reactions Stoichiometry

✓ **Stoichiometry** (Gr. stoikheion = element):

Study of quantitative relationships between reacting species and products

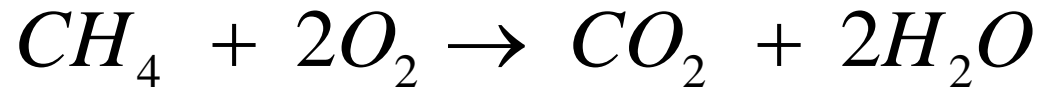
- Basis for material balances (inputs/outputs) for chemical processes
- First step: balance reaction equation by balancing the key element being oxidized or reduced (e.g., C)
e.g., combustion of methane with oxygen (to get energy)



- Need more H on RHS, more O on LHS
- By trial and error
 - Balance C (OK)
 - Balance H (double water to get H)
 - Balance O (double oxygen to get O)



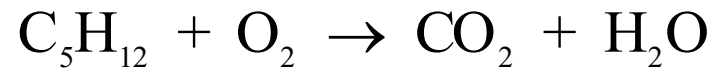
Stoichiometry



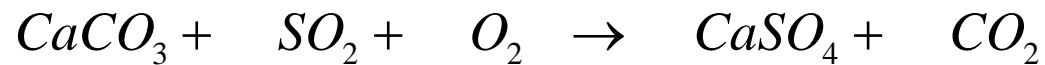
- In units of mass:
 - 1 mol CH_4 = 16 g
 - 1 mol of O_2 = $2 \cdot 16 = 32$ g
 - 1 mol of CO_2 is $12 + 2 \cdot 16 = 44$ g
 - 1 mol of water is 18g

Examples

- Combustion of pentane



- Use limestone to neutralize SO_2
 - Limestone is CaCO_3
 - Product is gypsum CaSO_4



Example

- If 50 g of pentane were combusted, how many grams of water would be formed?

Write a balanced equation

50 g of pentane is how many moles?

Example

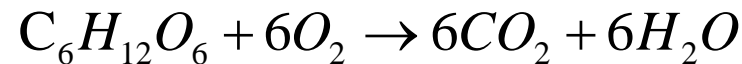
- 0.83 mM glucose solution ($C_6H_{12}O_6$) is completely biodegraded to CO_2 and water.
How much oxygen is required (mg/L)?

Example (solution)

- Write a balanced equation

- Find MW of each component
 - Glucose – 180 g/mol
 - Oxygen – 32 g/mol
 - Carbon Dioxide – 44 g/mol
 - Water – 18 g/mol

- Calculate O₂ requirement on a mass basis



Example (solution)

- We have 0.83×10^{-3} M of glucose:



Oxygen Demand

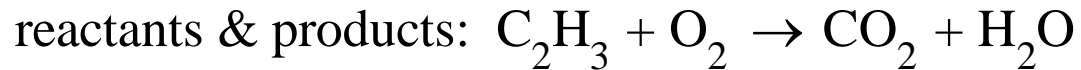
- This oxygen demand calculated in the previous example is **theoretical oxygen demand**:
 - The oxygen needed to fully oxidize organic material to carbon dioxide and water
- There is also **biochemical oxygen demand**:
 - The actual amount of oxygen required for oxidation (stabilization) of organic wastes carried out by bacteria
- $BOD \leq TOD$ (since some carbon is converted to cell material rather than fully oxidized all the way to CO_2 , and some carbons are non-biodegradable)
 - We will discuss BOD and other oxygen demands later in the course

Example

- Energy consumption in North America is 85×10^{18} J/yr.
If all energy came from a fuel with composition C_2H_3 and an energy content of 43×10^6 J/kg,
At what rate would CO_2 be emitted?

Example (solution)

- Write a balanced equation



balance C, H, O₂:

- What mass of fuel is used in a year?

- Use MWs to calculate mass of CO₂ emitted

- C₂H₃: $2(12) + 3(1) = 27 \text{ g/mol}$
- CO₂: $1(12) + 2(16) = 44 \text{ g/mol}$

Example (solution)



Stoichiometry of Some Important Reactions

- Aerobic biodegradation of benzene in an aquifer



- Biodegradation of sewage in activated sludge



- Acid mine drainage



- Nitrification

