Chem 261 September 5, 2023

Definitions

- **Chemistry**: Study of matter
- **Science**: way of worldview
- **Organic Chemistry**: Study of compounds containing carbon. Chemical symbol of carbon is C
- **Chemical symbol**: Code for chemical element
- **Atom**: Is the smallest possible particle that defines a complete chemical element. Fundamental building blocks of chemistry.
    - They are composed of neutrons, protons (+), and electrons (-)
- Every atom is composed of a **nucleus** (positively charged - composed of protons and neutrons) and one or more electrons bound to the nucleus
- **Molecules**: Discrete (bonded) arrangement of atoms. Bonds can be covalent or ionic.
    - Changing the arrangement or connections changes the molecule and its physical properties (color, density, solubility, melting point, boiling point)
- **Compound**: Collection of molecules of the same type
    - Water (H_2O), Cholesterol (27 carbons, white crystalline powder, average male contains 80 g)
- **Atomic Number:** Number of protons in the nucleus of an atom (Z)
- **Atomic Weight**: Mass of protons (p^+) and neutron (n) (unit: amu)

Isotopes

- Isotopes – same element that contain equal number of protons but different number of neutrons

Example 1:

- ^1H = Hydrogen = $1p^+ + 1e^-$
    - 90% of electron density of the hydrogen atom is within one Angstrom
- ^2H = Deuterium = $1p^+ + 1n + 1e^-$ (Isotope of Hydrogen)
- ^3H = Tritium = $1p^+ + 2n + 1e^-$ (Isotope of Hydrogen, radioactive, $T_{1/2}$ = 12.2 yrs)

Example 2:

- ^{12}C = $6p^+ + 6n$ (^{12}C : 12 amu atomic weight, atomic No. 6)
- ^{13}C = $6p^+ + 7n$ (Isotope of Carbon, Stable, 1.1% abundance)
- ^{14}C = $6p^+ + 8n$ (Radioactive isotope with long half-life, $T_{1/2}$ = 5740 yrs; used in Carbon dating)
    - $1n \rightarrow 1p^+ + 1e^-$ to become ^{14}Nitrogen

- **Molecular Weight (MW)**: Mass of atoms in a molecule
    - H_2O: MW = [(2 x 1 g/mol)H + (1 x 16 g/mol)O] = 18 g/mol

Physical Properties

- Defined by chemical structure
- Melting point (mp) and boiling point (bp): Each compound has a characteristic mp and bp.
- Taste, appearance, odour, and biological properties (how it interacts with other molecules).
- Light Absorption (hν): h stands for Planck's constant (6.626×10^{-34} Js; ν stands for frequency
- Density (symbol is ρ, rho) (unit = g/cm^3)
- Density of water is 1.0 g/cm^3, compounds that are less dense than water will float on top if they are not miscible (infinitely soluble)
- Absorption of radiation (light)
- Solubility ~ most organic solvents dissolve in other organic solvents (like dissolves like); some organic molecules dissolve in H_2O which is inorganic (ex. Sugar)

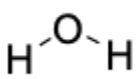
Typical Molecule

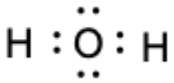
- A few Angstroms (Å) in length: Bond length C-H is 1 Å, C-C is 1.5 Å
- 1 Å = 10^{-8} cm
- 1 Å = diameter of 1 hydrogen atom

Example: Cholesterol is 17 Å across. If you lined all of the cholesterol molecules in an 80 g bottle end to end it would wrap around the earth roughly 5,000,000 times.....

Basic Principles

1. Like charges repel, unlike charges attract.
2. Atoms want inert gas configuration of electrons
   - Same configuration as Helium, Neon, Argon, Xenon, and Krypton.
   - Can be attained through either ionic bonding or covalent bonding





Mole Concept

- **1 mole = 6.02×10^{23} (Avogadro's number)** (can be atoms, molecules etc.)
- 1 mole H = 1 g
- Mole concept relates to MW and Atomic weight
- 18 g of H_2O is 6.02×10^{23} molecules = 1 mole of H_2O or 6.02×10^{23} molecules of water
- Carbon has 12 grams per mol, Oxygen has 16 g per mol, so for CO_2 we can calculate that it has 44 g/mol
- D (deuterium) = ^2H, $1p^+ + 1n = 2$ g/mol, it's an isotope
- D_2O = 20g/mol, known as heavy water.

Purity of Compounds

- 1 mole of H_2O (6.02×10^{23} molecules) = 18 g, then add 1×10^6 other molecules (e.g. sugar) → the purity of the water would be 99.999 999 999 999 999%.
- Purity: A pure compound shows no change in physical properties upon attempts to further purify (purity is a relative term).
- Purity: A pure compound has a discrete and unique physical properties.

Qualitative Test for Inorganic or Organic Compound

Qualitative Analysis: Determine if you have the compound of interest

Note that the structure of a molecule defines its physical properties

Organic	Inorganic
- Contains carbon - Low mp < 200 °C, low bp - Burns frequently in air - Non-polar - Soluble in non-polar solvents (e.g. oil)	- Generally no carbon - High mp & bp (due to ionic bonding e.g. NaCl) - "Does not burn" - Polar - Soluble in H_2O

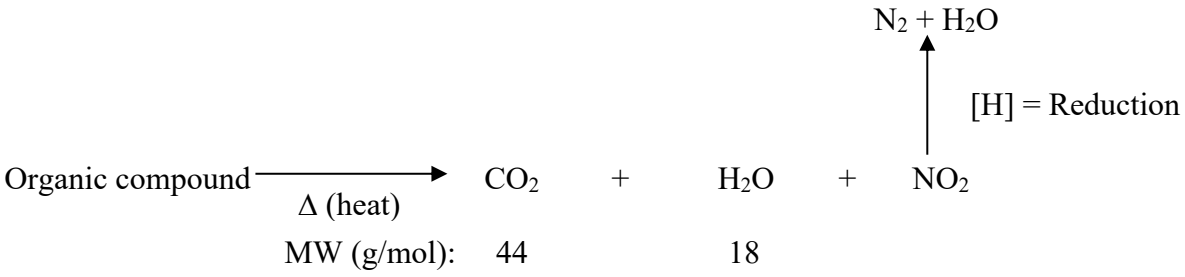
Non-Polar solvent: Hexane, Benzene, Diethyl ether etc

THERE ARE MANY EXCEPTIONS!!!

E.g. Common table sugar is an organic molecule, however it dissolves in water

Quantitative Analysis

Quantitative: How much of the compound of interest (quantity)
Amounts of atoms in a compound



Compound (4.34 mg) Contains C, H, O	$\xrightarrow{O_2}$	10.35 mg	3.42 mg	0 mg
		CO_2	H_2O	NO_2

Note: Matter cannot be created or destroyed in a chemical reaction; therefore the amount of carbon in the CO_2 is equal to the amount of carbon in the starting sample.

Percent Composition – how much of each atom is present in the sample

Weight of carbon (in sample) = $\frac{12 \text{ g/mol of C}}{44 \text{ g/mol } CO_2}$ x 10.35 mg of CO_2 = 2.82 mg of C

Molecular Weight (MW) of CO_2 = 12 (C) + 2×16 (O) = 44 g/mol

Weight of hydrogen = $\frac{2(1 \text{ g/mol of H}) \text{ x}}{18 \text{ g/mol of } H_2O}$ 3.42 mg of H_2O = 0.383 mg of H

NB: H_2O contains two hydrogen. MW of H_2O = (2×1) + 16
H_2 O

Weight of oxygen = 4.34 mg sample – (2.82 mg of C + 0.383 mg of H) = 1.14 mg of O

Now one can calculate percentage composition:

% Composition:

% C = $\frac{\text{Mass of carbon}}{\text{Mass of sample}}$ x 100% = $\frac{2.82 \text{ mg of C}}{4.34 \text{ mg}}$ x 100% = 65.1%

% H = $\frac{0.383 \text{ mg of H}}{4.34 \text{mg}}$ = 8.83%

% O = 100% - 65.1% - 8.83% = 26.1%