Modern Chemistry

- There's a lot of it
- Ph.D. def:
  - Learn more & more about less & less
  - Focus on a narrow topic & do something new
- All of Chemistry
  - Biochem
  - Analytic
  - Physical
  - Organic
  - Inorganic
    - Drug discovery
    - Metabolism
    - Biotech
    - Measure how much
    - Measure what's there
    - Make new molecules
    - Make synthetic drugs
    - Improve plastics
    - Lots of math
    - Fundamentals of chem
  - Work with metals
  - Make pretty colors
  - Paint bees

- Organic chemists use Analyt. Chem. almost every day
- Some anal. chemists work on biochem systems
  - E.g., blood glucose monitors
  - Smaller sample
  - Faster analysis/time
  - More reliable

"Chemometrics"

Working to use math, anal. chem. to measure blood glucose into blood!
Fig 1.4: ~20 ft stack of Chem. Abstracts

- an Abstract is a short 200-300 word description of a scientific paper (6-25 pages)
- a paper usually takes 3 mo - 2 years to produce
- not all work gets published (corporate secrets)

↑ up to ~1/6 of knowledge?
Matter & Energy

Topics:
- matter
- scale
- states
- chem/phys properties & change
- mixtures
- elements & compounds

Matter = stuff
→ something with mass

Examples?

What's not matter?
- light
- time
- energy

Scale - how we look at something

Chemistry uses properties of atoms (very small things)

To describe properties of big stuff

Atoms = particulate scale

Big stuff = macroscale

Our book puts things on 3 scales: (sizes)

Macroscale - big, visible, "bulk properties"

Microscale - small, visible w/microscope, "bulk" prop.

Particulate scale - very small, not visible,
**WARNING:** Many books/people think "microscopic" refers to particulate scale. That is, they use macroscopic if microscopic only.

Since we can't see particulate scale items, we use models for them so we can talk about them:

\[
\text{H}_2\text{O} \quad \overset{\text{H}}{\text{O}} \quad \overset{\text{H}}{\text{H}}
\]

- Big models

Get \[\text{H}_2\text{O}\] overhead
Figure 1.6  States of matter—ice and water
3 States

In Chem 139, we will study matter in 3 states:

- **Solid**: Particles are close together & stick to each other in a firm "Lattice".
  - Particles may vibrate but stay in their fixed position.
  - Solids are hard, have fixed shape & volume.

- **Liquid**: Particles are close together but not stick together. Particles can move around in a liquid, lightly sticking to other particles.
  - Liquids have fixed volume but no fixed shape.

- **Gas**: Particles move freely and rarely meet one another if they do, the interaction is brief.

Water
- most familiar
- H\textsubscript{2}O

- we know: write in the sink is liquid. Boiling it makes steam, gas.
  - boil the water \( \rightarrow \) steam (gas)
  - freeze it \( \rightarrow \) ice (a solid)
- electrolysis will make water bubble on both sides;
  - there are H\textsubscript{2} and O\textsubscript{2} gas. H\textsubscript{2} will burn (explode), O\textsubscript{2} stabs toddler.

Chemistry terms:
- water is a compound
- the smallest particles of water is a molecule, with one oxygen atom and two hydrogen atoms
- boiling (or condensing), freezing (or melting) are physical changes
- electrolysis & burning are chemical changes

Chemical representation:
- atoms are spherical particles which, when sticking together, overlap a little bit.
  - water particles is planar and takes a bent form
  - H-O-H
- to simplify our nomenclature (i.e., descriptions) we do the following
  - H\textsubscript{2}O: O is the oxygen molecule, - H\textsubscript{2} represents two bond(s) (dihydrogen)

- to type the "chemical formula"...

- H\textsubscript{2}O
- subscript 2 means 2 H\textsubscript{2}, O has no subscript so assume a 1
- O has no symbol in the order (left to right)
Let’s revisit what we know about H₂O: assume we already know the ion form.

H₂O

→ Tap water is a liquid H₂O(l)
→ We can make steam & ice H₂O(g), H₂O(s)

→ Making steam doesn’t change the formula of water so it is a physical change. We can summarize a process as follows:

\[
H₂O(\text{g}) \xrightarrow{\text{heat}} H₂O(\text{g}) \quad \text{or} \quad H₂O(\text{g}) + \text{Heat} \rightarrow H₂O(\text{l})
\]

Think of the arrow as an equal sign → now we have an equation (for the physical process of boiling)

we use whichever format is best for the current situation,

condensing to H₂O(\text{l}) \xleftarrow{\text{heat}} H₂O(\text{g}) or H₂O(\text{g}) \rightarrow H₂O(\text{l}) + \text{heat}

we could do the same for freezing/melting

→ Electrolysis splits the water into elemental hydrogen and oxygen.

These gases are chemically, e.g., \( \text{H}_2 + \text{O}_2 \). Hydrogen prefers to be H₂(g) while oxygen becomes O₂(g). This is a chemical change and H₂ & O₂ have new properties compared to water:

\[
\begin{align*}
\text{E.g.} & \quad \text{H}_2 & \quad \text{H}_2 \text{O} \\
\text{bond} & \quad \text{match} & \quad \text{match}
\end{align*}
\]

the chemical formula for this process

\[
H₂O(\text{l}) \xrightarrow{\text{electrolysis}} H₂(\text{g}) + O₂(\text{g}) \quad \text{count the Hs for O}s
\]

\[
2 \quad 2
\]

(electrolysis is complex so we leave it on the arrow)
for the burning H₂ balloon:

\[ H_2 (g) \xrightarrow{\text{match, in air}} H_2O(l) \text{ + boom} \]

\[ 2 H_2 (g) + \text{O}_2(g) + \text{spark} \rightarrow 2 H_2O(l) \text{ + energy} \]

for the water balloon:

\[ H_2O(g) \xrightarrow{\text{match, in air}} \text{nothing} \text{ (NR for no reaction)} \]

Changes:

- chemical: convert substrate into new form, new formula
- physical: change the state (s) \rightarrow (g)
- no change to underlying chemicals
- physical

Example:

- (substance)
- (substance)

Properties:

- physical: what we observe, describe in the lab, odor, color...
  - density, boiling point, state
- chemical: we can electrolyze water & burn hydrogen
Mixture: 2+ substances (air)

Pure substance: a single chemical, cannot be separated by physical means

Homogeneous mixture: coffee (with ice and cream)
Heterogeneous pure substances: pure ice water

Elements: a type of atom e.g. H, F, O, Au, Ag, Lead, Argon
- only ~100 elements in nature (88)
- cannot be chemically decomposed

Compounds: 2 or more elements joined by chemical bonds
- can be decomposed
- still qualifies as pure substance

Elements (cont.)

→ Note that the format symbols generally match 1st 2 letters.

H  Hydrogen
He  Helium

Li  Lithium
Be  Beryllium

Na  Sodium
Mg  Magnesium

AI  Aluminum
Si  Silicon

P  Phosphorus
S  Sulfur

Cl  Chlorine
Ar  Argon

· This arrangement is the "periodic table", more to tonight.
· Note that the table lists symbol, its name if there's room, then the atomic for now.

Notes about this table
- #s increase left-right, then next row
- Columns generally mean similar properties
- Some sections

Left shall, reactive → non-metal → noble gases

- We will learn a lot about left of right edges, top row
Fammy Elements

Natron

Sodium

Kalium

Potassium

Korn Im

Iron

Sb

Antimony

Hg

Mercury

Au

Gold

From a mineral (red)

Hydrocarbons

Liquid silver

Natural States

Elements come in solid, liquid, or gas

Most are solids

Gases

H, He, N, O, F, Cl, Ne, Ar, Kr, Xe, Rn

Liquids

Br, Hg

Almost Liquid: Cs, Fr, Ba, Ra

Solid

Dichotomic

Some elements are naturally found in pairs that is a
molecule of two of the atoms

H O N C E Br IF

3 position on table


Elements

- What do we notice about the gases?
  - liquids or not liq?
  - dusts or other?

Compounds

- 2 or more elements joined by chemical bonds
  - elements were balls
  - bonds are the sticks

- compounds are still "pure stuff."

- compounds have names?
  - general: water, ammonia, acetic acid,
  - systematic: dihydrogen monoxide, 2-propyl

- 16 arts - too many
- 16 arts is 1 way to # then: 2-propyl[67-63-0]

Formula

- we saw that H2O was a chemical formula
- use element symbols and subscripts to show how many

H2O  NH3  C2H4O   C3H8O
CH3COH  CH3CH2CH3

- more on this later!

Law of Constant Composition

- a compound is always made up of elements in some proportion
- old way: didn't know ratios, used fractions!
Figure 1.3  A classification scheme for matter

All matter

No

Can it be separated by physical process?

Yes

Mixture

Yes

Is it uniform throughout?

No

Heterogeneous

Substance

Can it be decomposed by chemical process?

Yes

Compound

No

Element

Homogeneous
Elements

Elements are pure subtopics that cannot be decomposed by chemical methods. (Super collider/particle accelerator)

There are ~ 115 known elements, 83 naturally occurring

- other group were "made" = nuclear physics

We identify elements as follows:

- Name: English with initial (a few are Greek)
- Symbol: 1 or 2 letters
- Number: 1... 115

E.g.

O  C  Cu
Oxygen  Carbon  Copper
8     6     29

We will learn about many of these elements, e.g. the first 18.

- Front of book has Table of Elements
  - Find #1-18 in list
  - Write down name, symbol, number

- These boxes arranged as follows:

  Row 1: #1-2
  Row 2: #13-18
  ...
Law of Definite Compositions or Law of Constant Composition

- ratio of different elements in a compound are whole numbers.
- always the same composition.
- e.g., H₂O is water, always H₂ + O₁.
  - O₂ is oxygen
  - O₃ is ozone
  - CO₂ is carbon dioxide
  - CO₂ is carbon monoxide

Conservation of Mass

- both sides of eqn have same # of atoms for each element in each process.

Conservation of Energy

- most chemistry is either exothermic or endothermic.
- chemical bonds &/or phase changes store energy.
- energy is not created or destroyed.
Electrical Matter

- gravity - apple falls, mass attracts other mass
  (really, big masses attract very strongly)

- electromagnetic force
  - charged objects attract opposite charge
    \[\text{\textcircled{+}} \rightarrow \text{\textcircled{-}}\]
  - like charges repel
    \[\text{\textcircled{-}} \rightarrow \text{\textcircled{-}}, \quad \text{\textcircled{+}} \rightarrow \text{\textcircled{+}}\]
  - balloon rubbed on hair

Energy

- chemistry involves energy. e.g., Boom
- when a rxn gives off energy, it is exothermic
- if it takes in energy, it is endothermic

\[\text{exo} \rightarrow \text{endo}, \quad \text{endo} \rightarrow \text{exo}\]

Diagram:

```
\text{"the system"}
\text{endo} \quad \text{ex}
\text{ex} \quad \text{endo}
```

- \(x\)
Conservation

- except under extreme circumstances, matter is never created or destroyed, energy is never created or destroyed.

- under extreme circumstances,
  \[ E = mc^2 \]

Law of Conservation of Mass

Law of Conservation of Energy

What about \( \text{H}_2 + \text{O}_2 \to \text{H}_2\text{O} + \text{Boom?} \)

1. conserve mass \( \Rightarrow \) balance # of elements
2. energy?

\( \text{H}_2 \) + \( \text{O}_2 \) are "less stable" than \( \text{H}_2\text{O} \);
energy is stored in their chemical bonds.

\[
\text{H} \quad \text{H} \\
\text{O} \quad \text{O}
\]

sharing less energy \( \text{H}_2 \) for \( \text{O}_2 \) share a little

\[
\text{H} \quad \text{O} \\
\text{H} \quad \text{H}
\]

\( \text{H}_2\text{O} \) share a lot.