Chem 1311

Chapter 1.

Chemistry → Wikipedia says:
science of atoms and molecules:
their structures, interactions, and transformations

example - cleaning power of dish and laundry detergent
↳ complex chemistry!

example - making paint that doesn't fade in the sun.

Scientific Method → progress comes from a combination of theory and experiment

organization & generalization of data → scientific law

Need both parts to make progress:
data leads to a working hypothesis (initial explanation), which leads to new experiments to test/explore the hypothesis, which may lead to a theory (tested explanation), ...

example of a theory: Atomic theory → chemical substances are formed from atoms and molecules.

Useful for understanding chemical reactions

Properties of Materials

Physical properties can be observed without changing the chemical composition

ex ice melts at 32 °F

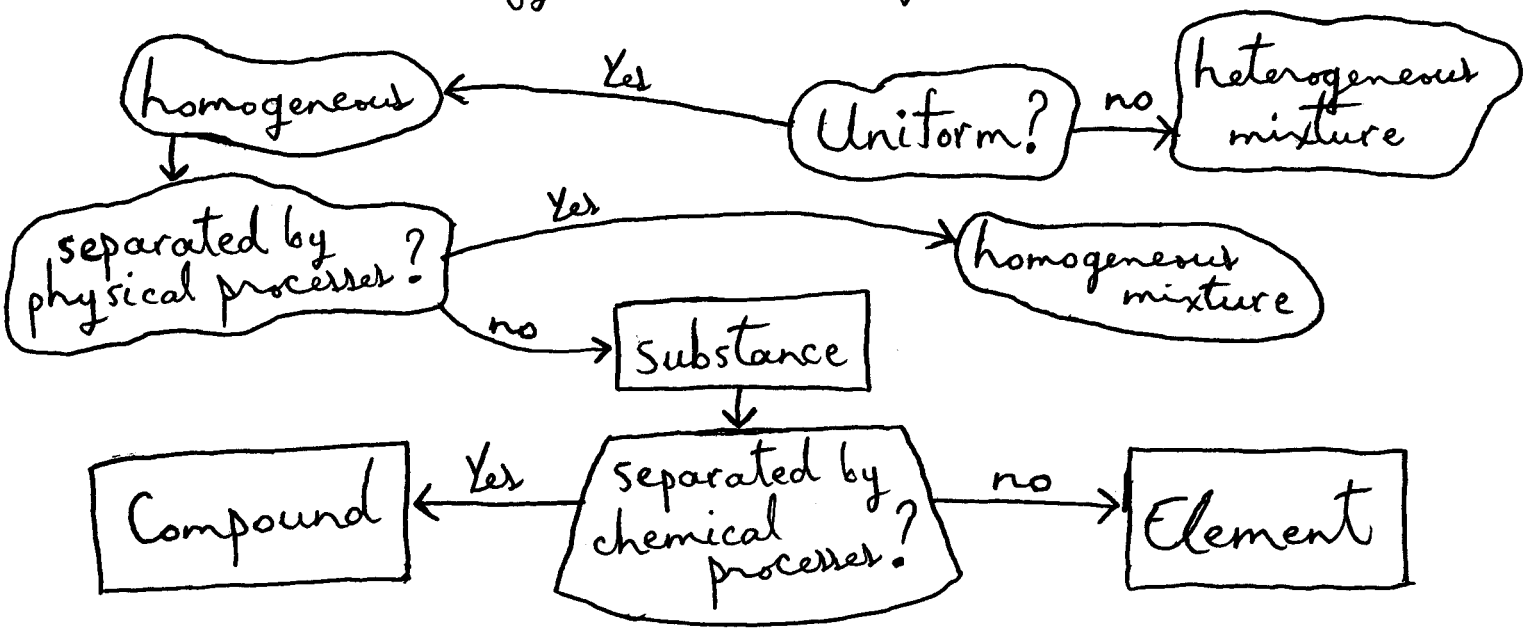
ex diamond has a hardness of 10 (Mohs scale)

Chemical properties involve a chemical reaction

ex sugar caramelizes upon heating

ex bleach whitens clothes

We can classify materials by their properties



Common forms of matter : solid / liquid / gas

Solid → ordered arrangement of atoms / molecules

Liquid → less order, fills bottom of container

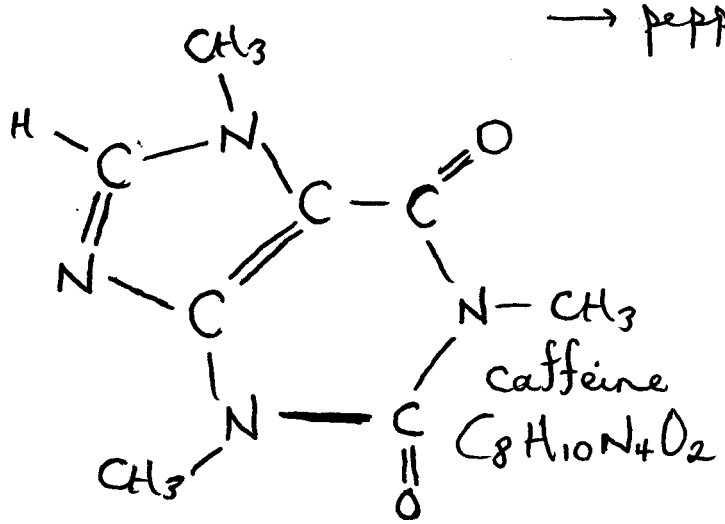
Gas → least amount of order, fills entire container uniformly

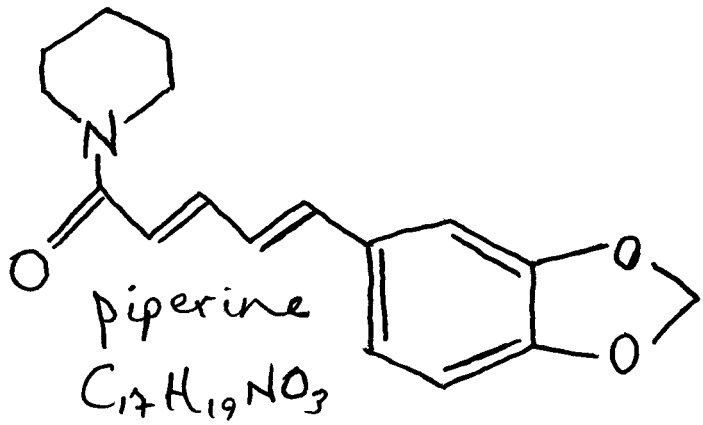
what about powder & dust?

- need concept of diffusion → color a few particles and see if they move around.

heterogeneous mixture → ice / water
light bulb (glass / metal)

homogeneous mixture → coffee (% caffeine varies)
→ pepper (black) % piperine varies





Compounds are composed of two or more elements in fixed proportion (by mass)

ex CO_2, caffeine, piperine, H_2O

- can be decomposed by chemical means:

Elements are substances that cannot be decomposed into simpler materials by chemical means

90 are naturally occuring
~25 more have been created in the lab

ex Carbon	C
Chlorine	Cl
Iron	Fe
Gold	Au
Oxygen	O

Compounds formed from elements

ex caffeine = $C_8H_{10}N_4O_2$

piperine = $C_{17}H_{19}NO_3$

Atomic Theory of Matter

there is a lower limit beyond which matter cannot be divided into smaller parts.

from Greek: "not divisible"

atom Democritus (460-370 B.C.)

but no scientific proof until much later

LAW of Conservation of Mass Antoine Lavoisier

Mass is conserved in chemical reactions

ex burn wood, get ashes – is mass conserved?

LAW of Definite Proportions Joseph Proust

In a given chemical compound, the elements are always present in the same proportion by mass, independent of the origin of the compound or its mode of preparation.

ex pure sodium chloride (NaCl) contains 60.66% chlorine by mass from salt mines, ocean water, or synthesizing it from its elements.

Atomic Theory of Dalton

Took these two laws, and in 1808 published "A new system of chemical philosophy" which contained 5 statements on the atomic theory of matter

1. Matter consists of indivisible atoms
2. Atoms are indestructible and retain their identity in chemical reactions
3. All of the atoms of a given chemical element are identical in mass and in all other properties
4. The atoms of different elements are different in mass and other properties
5. A compound forms from its elements through the combination of atoms of unlike elements in small whole-number ratios.

After this theory, chemists began determining chemical formulas (CO_2, ...) and formulated a new law.

Law of Multiple Proportions

When two elements can form more than one compound, the masses of one element that combine with a fixed mass of the other element are related to one another as the ratio of small integers.

ex chlorine & oxygen form 4 different binary compounds

Compound	Mass of O combined with 1.0000 g of Cl
A	0.22564 g
B	0.90255 g
C	1.3539 g
D	1.5795 g

this law strengthened Dalton's atomic theory

Relative Mass of Elements

If we know the ratio in which the atoms occur in a compound, we can determine relative masses

Isotopes #3 of Dalton's theory not quite correct

The number of neutrons in an element can vary, which changes the mass but not the chemical properties

This variation is what allows for carbon dating

Notation: ${}^{A}_{Z}X$ — A → mass # (protons + neutrons); X → chemical symbol; Z → atomic # (of periodic table) = # of protons

ex ${}^{12}_{6}C$

Atoms are made of electrons, protons, and neutrons

Sub-atomic particle	Mass (g)	Mass (u)	Electric charge
Electron	9.1×10^{-28}	0.00055	−1
Proton	1.7×10^{-24}	1.007	+1
Neutron	1.7×10^{-24}	1.009	0

u = atomic mass unit

${}^{12}C$ atom $\equiv$ 12 u

g = grams

1 ounce = 28.35 g

1 pound = 453.6 g

The relative proportions of the different isotopes of an element are the same no matter where on earth they come from (comets can be different).

This is reflected in the mass that appears in the periodic table

ex silicon = Si

Isotope	Atomic Mass (u)	Natural Abundance %
^{28}Si	27.977	92.23
^{29}Si	28.977	4.68
^{30}Si	29.974	3.09

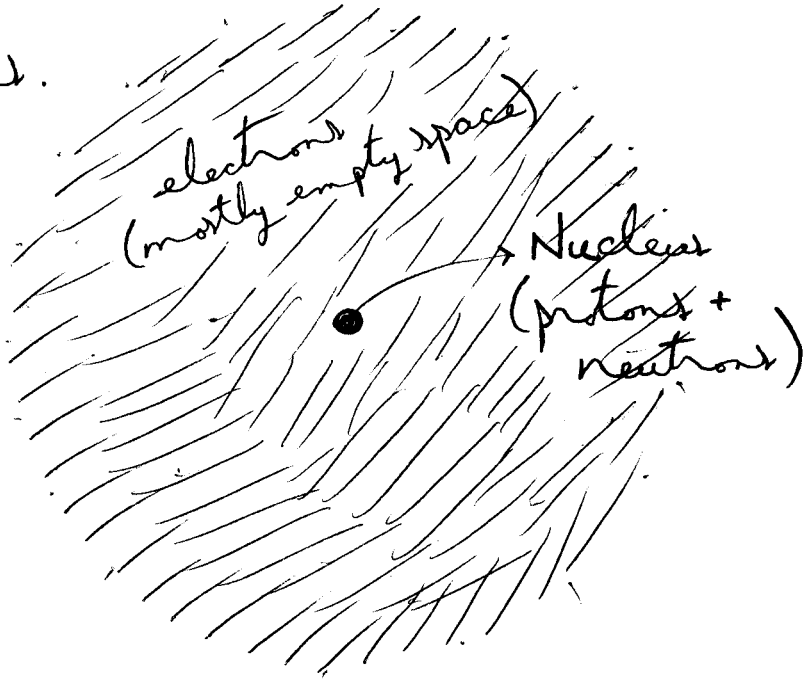
How can the mass of ^{28}Si be < 28 ?

Seems wrong... reason → some mass is converted into energy. See "binding energy" in www.wikipedia.org

Average mass: need to perform a weighted average

Back to subatomic particles:

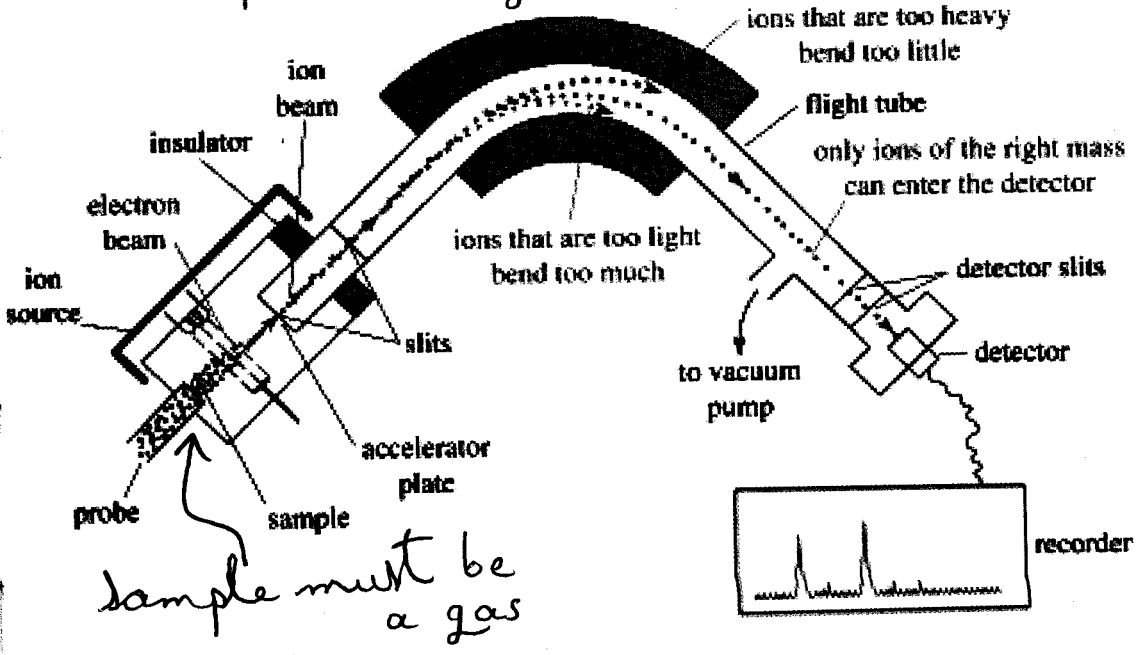
Matter (and especially liquids) tends to be neutral (no net electric charge) which means that the # of electrons = # of protons.



nucleus → dense, solid, impenetrable

electron cloud: will study this region in Ch. 8

Mass Spectrometry



charged particles feel a force in a magnetic field

sample must be a gas

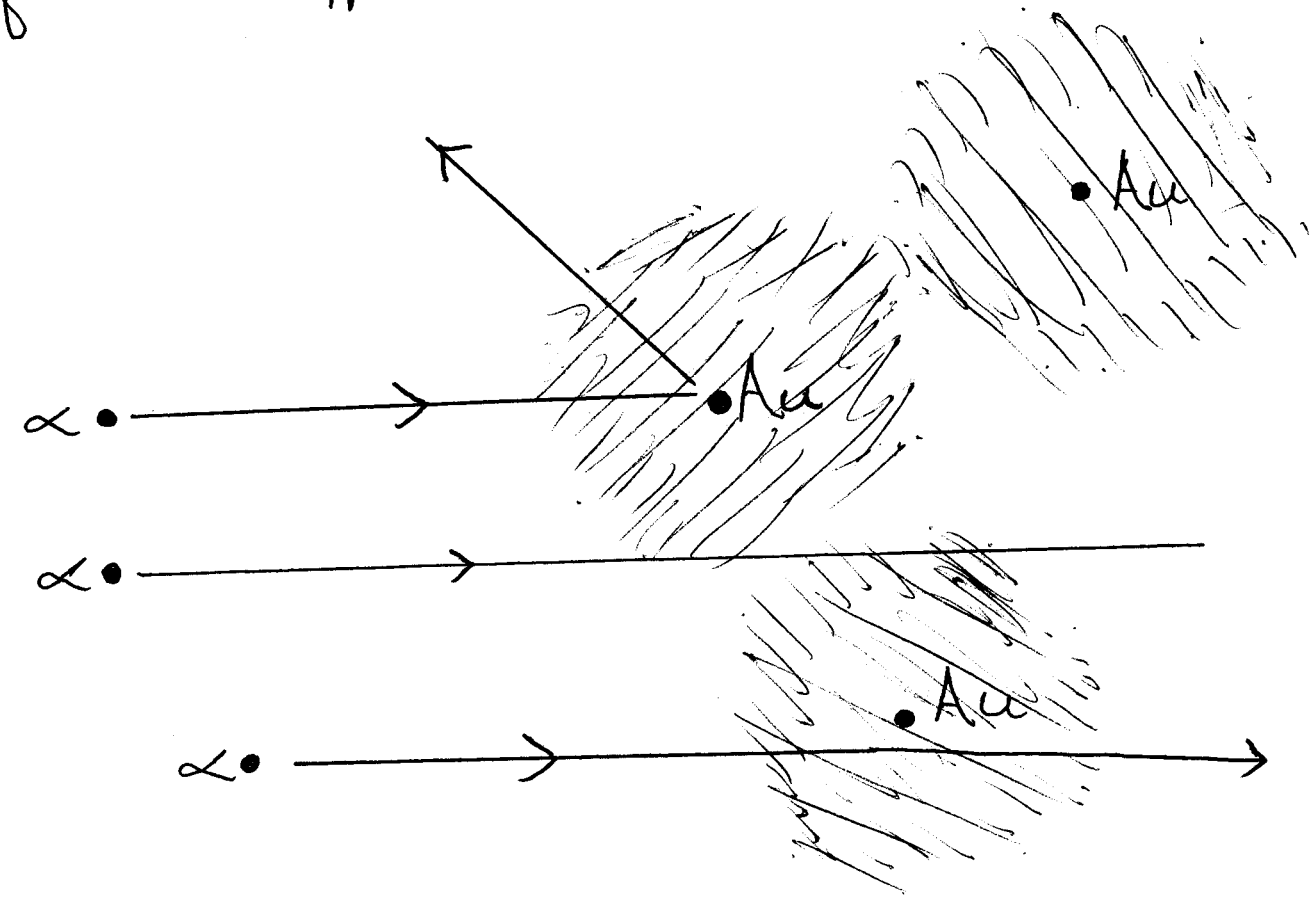
Goal: determine the mass of the original sample

Discovery of the Nucleus – pg. 22 of textbook

Ernest Rutherford (1871–1937)
from New Zealand
worked in England & Canada

Studied α particles (He^{2+}) hitting gold foil

Most α particles pass through the foil, but a few are stopped and bounce back.



Periodic Table

We organize the elements based on their chemical and physical properties into the periodic table of the elements

- ordered by atomic # (# of protons)

- 7 rows, called periods
- each column is called a group (1-18 or IA - VIII A / IB - VIII B)

Families (specific groups)

- representative or main group elements : A groups (taller columns)
- transition elements : B groups (all metals)
- inner transition elements : below main periodic table (lanthanides, actinides)

Some groups have common names (nicknames)

Alkali metals → group IA (except H = hydrogen)
form compounds with oxygen that dissolve in water to give a basic solution (alkaline)

Alkaline earth metals → group IIA
form compounds with oxygen that are alkaline but tend not to dissolve in water.

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Halogens ⟶ group VII A

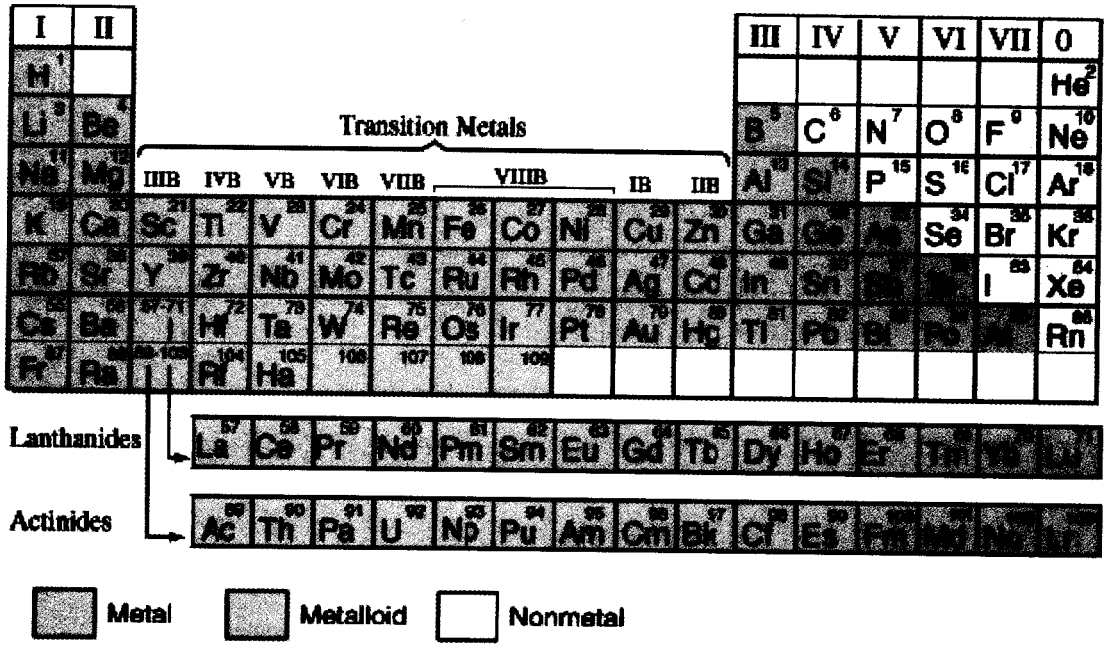
from Greek, meaning sea or salt

Noble gases ⟶ group VIII A

inert towards chemical combination

the free elements have a range of properties

Periodic Table of the Elements



Metals

- luster (shine)
- conduct heat & electricity
- malleable
- ductile
- solid at room temperature except for Hg (mercury)
- W (tungsten) is used in incandescent lights because it has the highest melting point (6150°F)
- reactivity varies

Non-metals
- insulators
- brittle (for the solids)

Metalloids
- semiconductors
- behave more like non-metals than metals

CHAPTER 2 : Compounds & Chemical Reactions

Elements combine to form compounds whose properties are, in general, completely different from those of the elements

Formulas some elements occur naturally as diatomics H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2

compounds have a fixed composition

ex rust = iron oxide = Fe_2O_3 two atoms of iron combine with three atoms of oxygen to form a molecule of Fe_2O_3

urea = $CO(NH_2)_2$

brackets used to indicate structure

Hydrates are solids that contain water that can be removed

blue $CuSO_4 \cdot 5H_2O \xrightarrow{\text{heat/dry}} CuSO_4 + 5H_2O$

· denotes a hydrate

white

anhydrous means no water attached to the compound