Chapter 1 - Matter and Structure of Atoms

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>
> Key point of the chapter:
>
> - Classification of Matter(states, particles)
> - *Change of State
> - Structure of Atoms(History, Electronic *Structure)
> - *Chemical Formulae
> - Oxidation Numbers
> - Physical and Chemical Properties
> - Separation of Mixtures

Classification of Matter

States of Matter

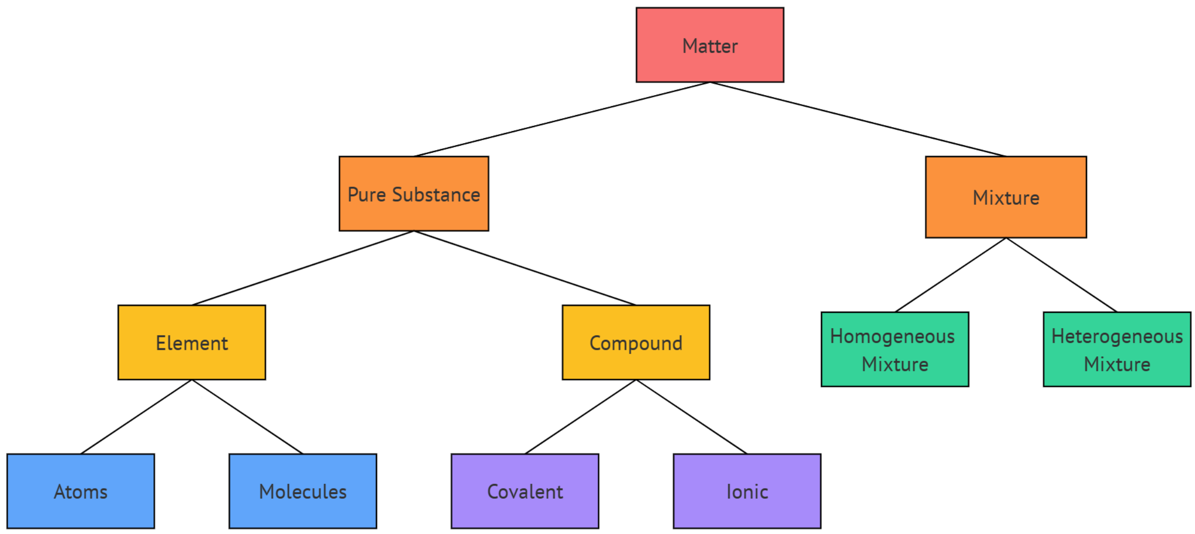
- Matters have **volume** & **mass**
- Matter can exist in three different **physical states**: **solid**, **liquid**, **gas**
- The states of matter can be changed by changing the **temperature** and/or **pressure**
    - Changes in pressure of temperature have greater impact on **gas**

Physical State	solid	liquid	gas
Volume	fixed volume	fixed volume	no fixed volume
Density	high	moderate to high	low
Shape	fixed shape	no fixed shape	no fixed shape
Fluidity	does not flow	generally flows	flows easily
Movement	vibrate in a fixed position	free to move	move freely
Particles	closely packed	slightly further apart	far apart from one another
Attraction Force & Kinetic Energy	$E_k < F$	$E_k \approx F$	$E_k > F$

- Attraction forces (F) between the particles won't change, but the kinetic energy (E_k) of particles will be affected by heat.

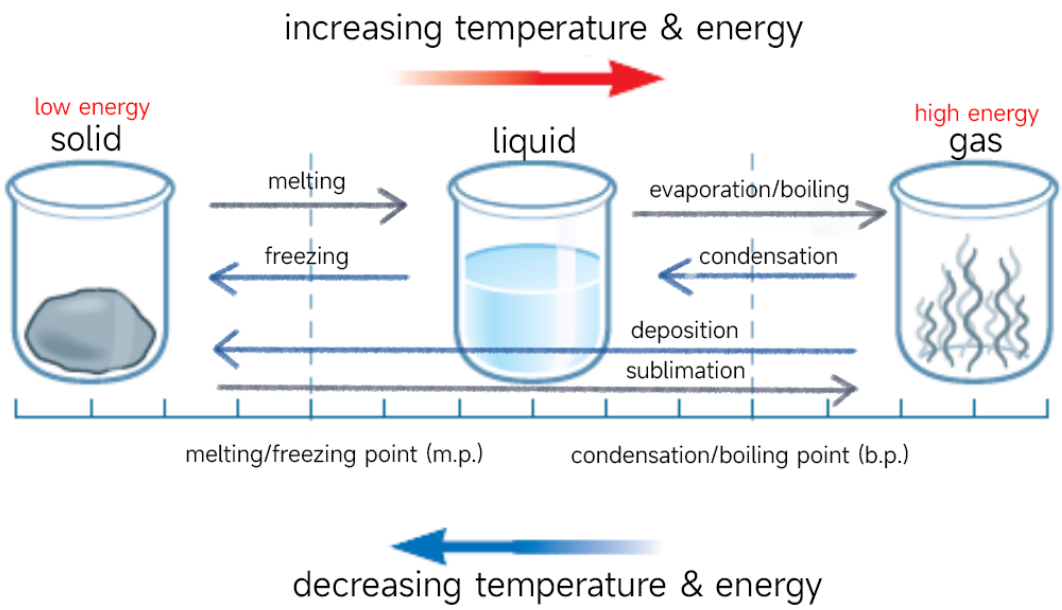
Particles

- There're three types of particles that made up matters: **atoms**, **molecules**, **ions**



The Change of State of Matter

- All states of matter show an increase in volume (**expansion**) when the **temperature** is **increased** and a decrease in volume (**contraction**) when the **temperature** is **lowered**
- Large **increases/decreases** in **temperature** and **pressure** can cause a substance to **change** its **physical state**



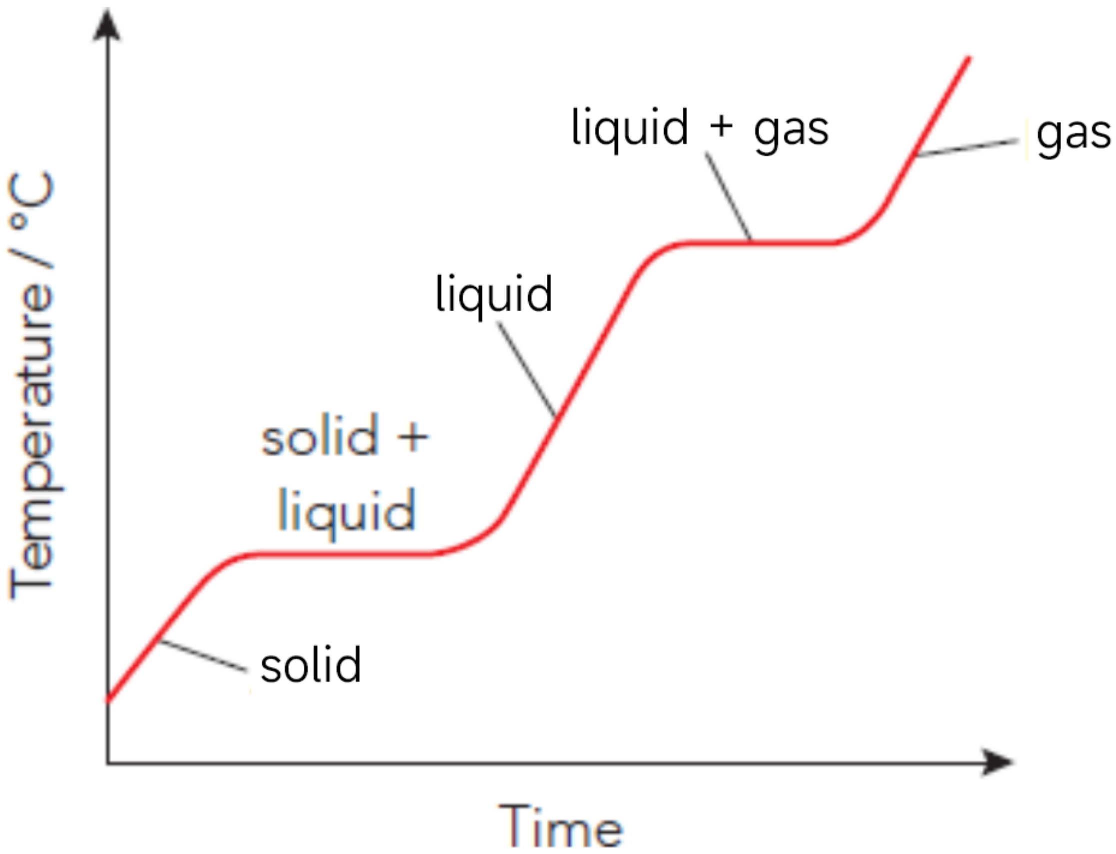
Boiling & Evaporation

- **Evaporation** take place over a range of temperatures, only take place from the surface of the liquid
  - the rate of evaporation may be affected by the temperature and surface area
  - *volatile* : term that describes a liquid that evaporates easily
    - usually a liquid with low boiling point because there're weal intermolecular forces between the molecules in the liquid
- **Boiling** takes place at a **specific temperature**

Sublimation

- Example of substances that sublimes:
  - iodine, dry ice (solid CO_2), mothballs, ammonium chloride (NH_4Cl)
- Ammonium chloride doesn't REALLY sublime, at a certain temperature, it decomposes to ammonia and hydrogen chloride (both gases), which appears to be sublimation but is not.
- Iodine can exist in liquid state. The iodine seems to miss out the liquid stage if heated strongly because the temperature rises very quickly, the m.p. and b.p. are close together, the liquid stage is not seen as it boils quickly
  - To make iodine melt to form a liquid at atmospheric pressure:
    - heat the solid slowly
    - use some tools(electrical heater, oil bath) to control the rise of temperature carefully

Heating and Cooling Curves



- The **temperature stays constant** during the state changes.
- During heating, all the energy absorbed at m.p. and b.p. goes into weakening the attraction forces between particles without temperature rise.
- During colling, all the heat energy released at condensation point and freezing point is given out into increasing of the intermolecular forces without temperature falls.
- *exothermic changes* : freezing, condensing
- *endothermic changes* : melting, boiling, evaporation

Effect of impurities

- **A pure substance melts and boils at definite temperature**.
- The presence of any **impurity** will **lower the freezing/melting point** of the solid
  - It makes it harder for the particles to arranged closely in fixed positions which is necessary if a substance is changed into a solid
  - It disrupts the formation of the lattice of the solid, less energy is required to break the lattice, this leads to a lower melting point
  - *lattice* : a regular 3D arrangement of particles in a crystalline solid
- The presence of any **impurity** will **increase the condensing/boiling point** of the liquid

    - It makes it harder for the particles to gain high kinetic energy which is necessary if a substance is changed into a gas/vapour(mixture of two states)
    - the molecules need more energy(heat) than normal in order to escape from the liquid and become vapour.
- Thus, **purity of substance** is checked by **determining the m.p. and b.p.**
- These values can also be used to **identify an unknown substance**.

Structure of Atoms

The Historical Development of Atomic Model

1. John Dalton
    - atomic model: all matter was made up of atoms
2. J.J. Thomson
    - plum pudding model: discovered electron(negatively charged particles)
3. Ernest Rutherford
    - Rutherford model: discovered protons(positively charged particles) and nucleus
4. Niels Bohr
    - Bohr model / planetary model: electrons move in specific energy levels or "shells" around the nucleus of an atom
5. James Chadwick
    - discovered the neutron(electrically neutral / no electrical charge)
    - completing the picture of the three main *subatomic particles* that make up atoms

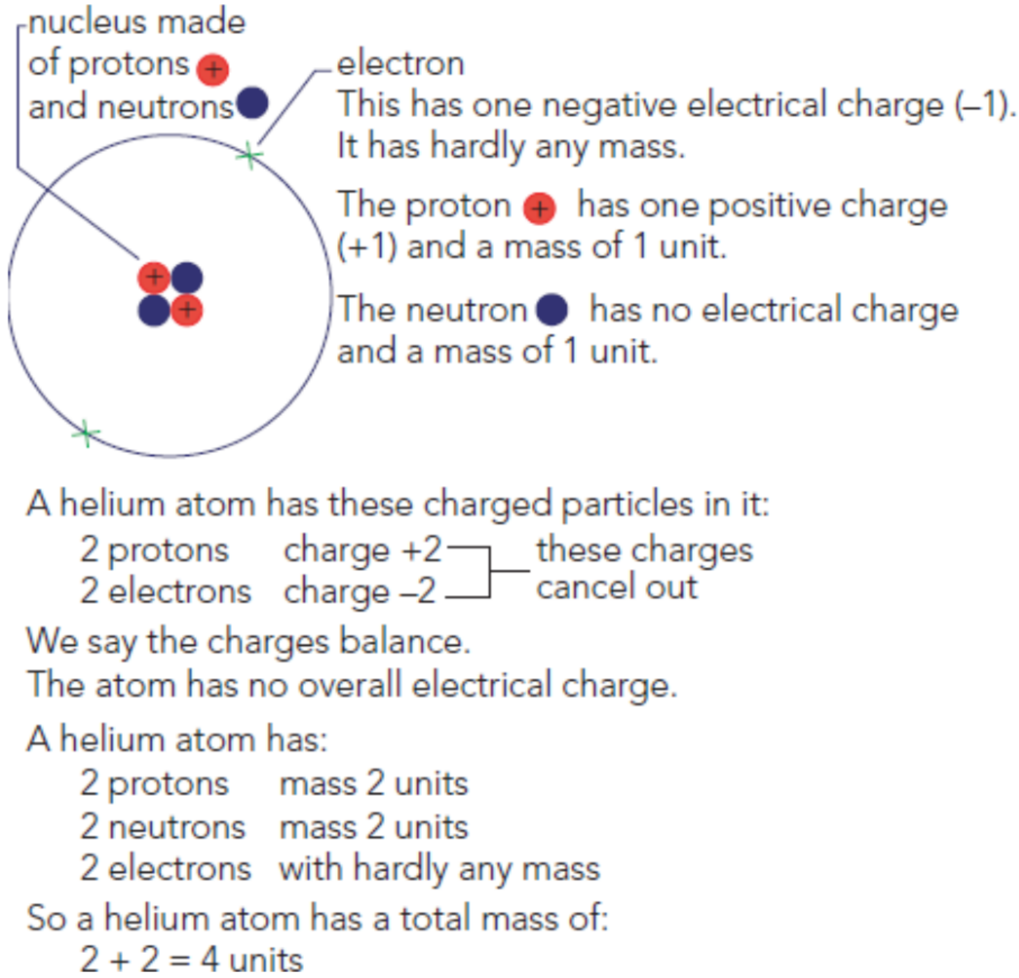
Characteristics of Protons, Neutrons and Electrons

Subatomic Particle	proton(p)	neutron(n)	electron(e)
Relative Mass	1	1	1 / 1840 (negligible)
Relative Charge	+1	0	-1
Location in Atom	in nucleus	in nucleus	surrounding/outside nucleus

- **Atoms are electrically neutral**, so every atoms have an **equal number of protons and electrons** to cancel out the charges
- The **number of neutrons** required to hold the nucleus together **increases** as the **atomic size (atomic number) increases**
    - **Hydrogen** atom is the only atom that has **no neutron**

- Neutrons are important in making the nucleus of an atom stable
  - Protons are positively charged and would therefore repel each other.
  - The presence of the neutrons counteracts this repulsion and means that the nucleus can hold together.

- **Example: Helium**



Atomic Number and Mass Number

- We can represent a particular atom of an element by combining the chemical symbol of the element with the nucleon(A) and atomic(Z) numbers of the atom.

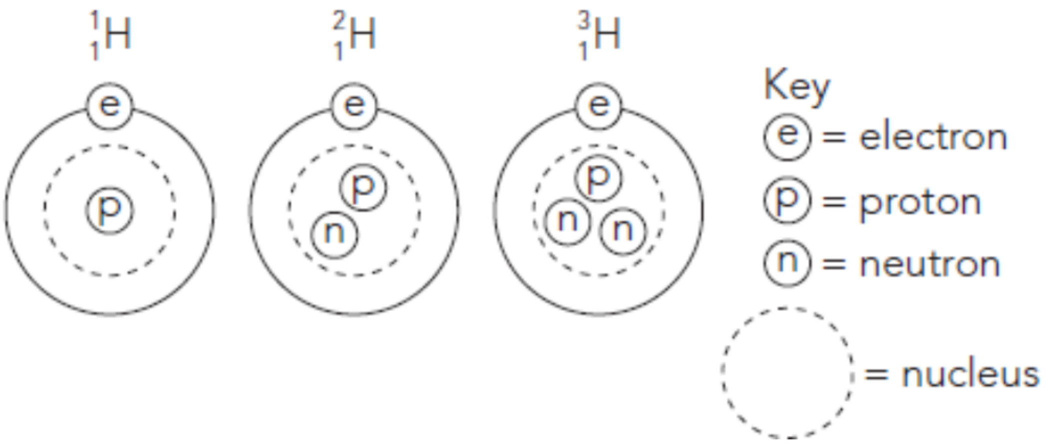
$$^{A}_{Z}\mathrm{X}$$

- Example: representing the structure of iodine atoms, using the above format
  - $$^{127}_{53}\mathrm{I}$$
    $$Iodine - 127$$
- Atomic number / proton number (Z) = number of protons in the nucleus of an atom
- Nucleon number / mass number (A) = number of protons + number of neutrons
- number of electrons = number of protons = atomic number

- number of neutrons = mass number - atomic number (A-Z)

Isotopes

- *Isotopes* are atoms of the same element that have the **same proton number** but a **different nucleon number**. Many Isotopes are **radioactive** because their nuclei are unstable (radioisotopes).
- Many elements have naturally occurring isotope.
- Hydrogen, the simplest element, has two naturally occurring isotopes: hydrogen and deuterium. A third Isotope, tritium, can be made artificially.



- The isotopes of an element have the **same chemical properties**.
  - Isotopes have the same electronic configuration. It determine the way it forms bonds and react with other atoms.
- The isotopes **differ in some of their physical properties** (such as density, rate of diffusion)
  - Examples
    - difference in density between ordinary ice and heavy-water ice(deuterium oxide, D_2O)
    - radioactivity of tritium and carbon-14 (radioisotopes)

Relative Atomic Mass (A_r)

- A single atom cannot be weighed on a balance.
- Masses of all atoms are compared to the mass of a **carbon-12 atom**.
- One atom of carbon-12 is given the mass of 12 precisely.
- $$1 \text{ atomic mass unit (a.m.u)} = \frac{1}{12} \times \text{mass of one atom of carbon-12}$$
- Examples of value obtained for other element

Element	Atomic Symbol	Relative Atomic Mass (A_r)
carbon	C	12
hydrogen	H	1
copper	Cu	64

- **Most elements exist naturally as a mixture of isotopes**, therefore, the value we use for the **atomic mass** of an element is an **average mass**.

$$A_r(X) = (\text{isotope}_1 \text{ abundace} \times \text{mass of isotope}_1) + (\text{isotope}_2 \text{ abundace} \times \text{mass of isotope}_2)$$

- Examples
  - Iridium has two isotopes. These isotopes are iridium-191 and iridium-193. A natural sample of iridium consists of 37.3% of iridium-191.
  - $$\begin{aligned} A_r(Ir) &= (191 \times 37.3\%) + (193 \times (100 - 37.3)\%) \\ &= (191 \times 37.3\%) + (193 \times 62.7\%) \\ &= 192.254 \end{aligned}$$

Electronic Configuration of Elements

Bohr's atomic theory