EE113FZ
Solid State Electronics
Lecture 1: Matter

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What is to be discussed today?

- What is matter?
- Different states of matter.
- Physical properties.
- Chemical properties.
- Phase transitions (from one state to another).

What is Matter?

The million-dollar question

- According to the Merriam-Webster dictionary:
  - The substance of which a physical object is composed;
  - Material substance that occupies space, has mass, and is composed predominantly of atoms consisting of protons, neutrons, and electrons, that constitutes the observable universe, and that is interconvertible with energy.

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Matter includes any physical substance around us.

States of Matter

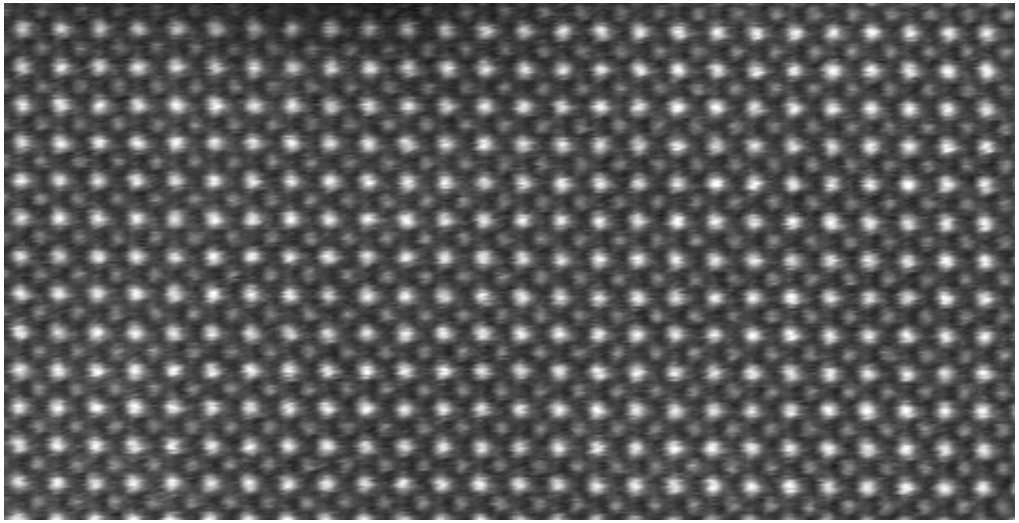
- 4 fundamental states of matter:
  - Solid
  - Liquid
  - Gas
  - Plasma
- Other states:
  - Glass
  - Liquid crystal
  - Magnetically ordered states
  - Low-temperature states (superconducting, superfluidity, etc)
  - High-energy states

Solids

The most important state of matter for this course!

- 3D: height, width and depth.
- Stable in structure and retains its own shape.
- Has a definitive volume.
- Its constituent atoms/molecules are closely packed.
- Strong bonding between atoms.
- Small amount of kinetic energy leading to very little movement of atoms.
- Atoms/molecules arranged in a regular pattern.

Examples of Solids

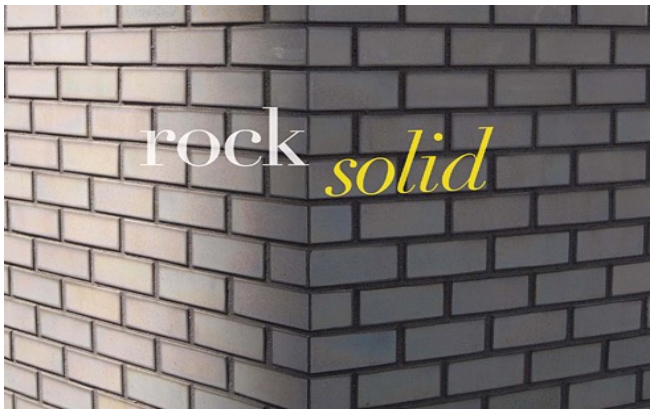


This is a sample of Strontium Titanate

Note the very ordered and regular arrangements of atoms.

Brighter atoms are Sr and darker ones are Ti.

Examples of Solids



https://www.google.ie/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0CAYQjB1qFQoTCJj0hKuf-8YCFeRm2wodvfgO6Q&url=http%3A%2F%2Fkirknielsen.com%2Fproject%2Fmetal%2F&ei=_hq2VZj9C-TN7Qa98bvIDg&bvm=bv.98717601,d.ZGU&psig=AFQjCNGolhe5kQ6LRD7POsmnUCq4xpTJWg&ust=1438084205050590

Liquids

- Fixed volume but not a definite shape.
- Takes the shape of the container it is placed in.
- Unstable structure as it can take any shape.
- Its constituent atoms are loosely packed with weaker bonding when compared with solids.
- Atoms in a liquid have reasonable amount of kinetic energy meaning that they can move around easily.
- Atoms are NOT arranged in a regular pattern.

Examples of Liquids

https://newatlas.com/supercooling-liquid-stop-freezing/55864/

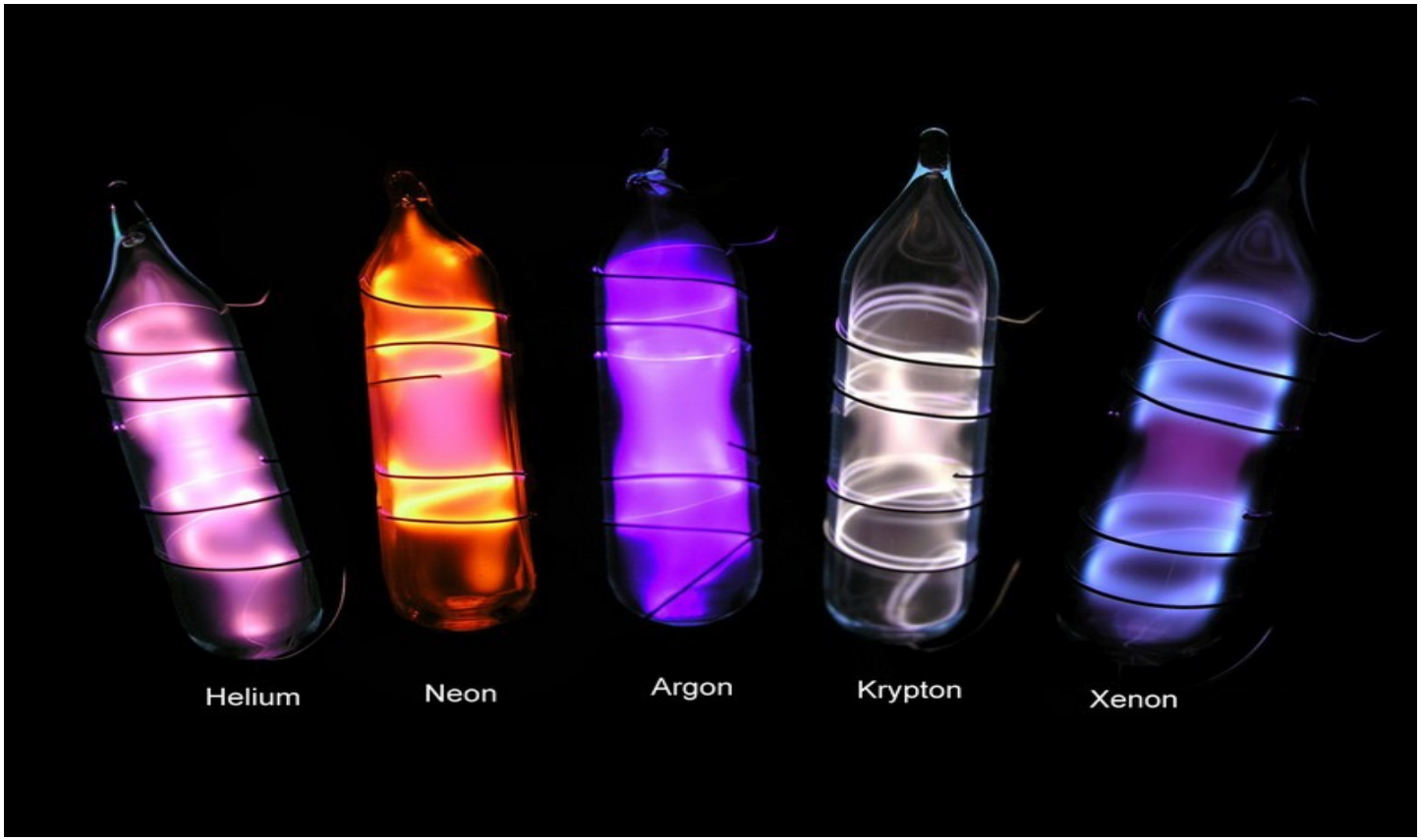
www.livescience.com

Gases

- Has volume but no definite shape (gasses can also be easily compressed).
- Its constituent atoms and molecules are far apart (in molecular length scales).
- The atoms/molecules have high kinetic energy and can move nearly freely.
- No regular arrangement of atoms/molecules.
- No bonding between the atoms/molecules.

Examples of Gases

Noble (Inert) Gases

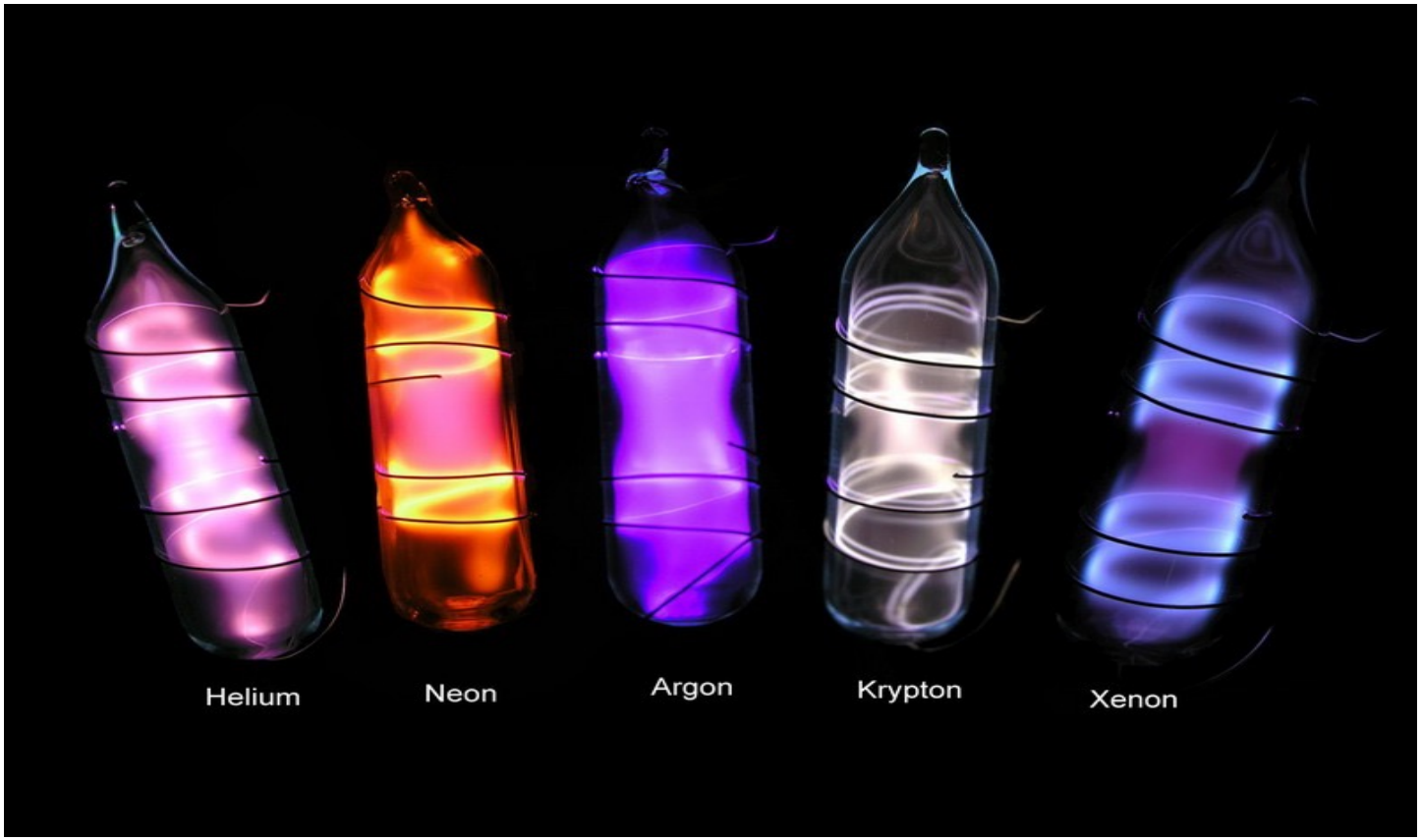


en.wikipedia.org

Noble gases fill the gas-discharge lamps and they turn into different colours when energized.

Examples of Gases

Noble (Inert) Gases



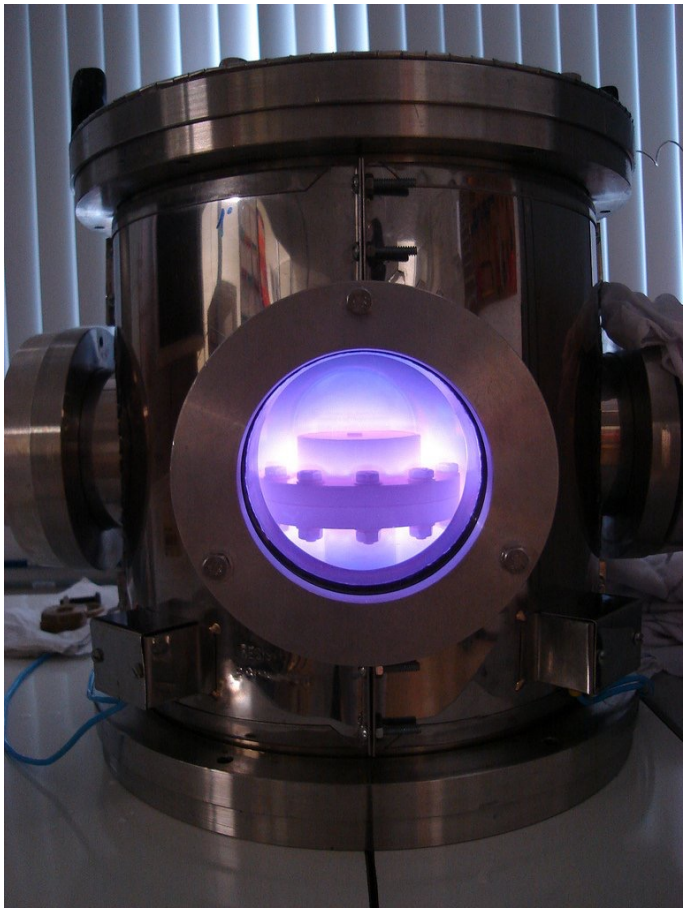
en.wikipedia.org

Be careful! What you see are not really the gases.

Plasma

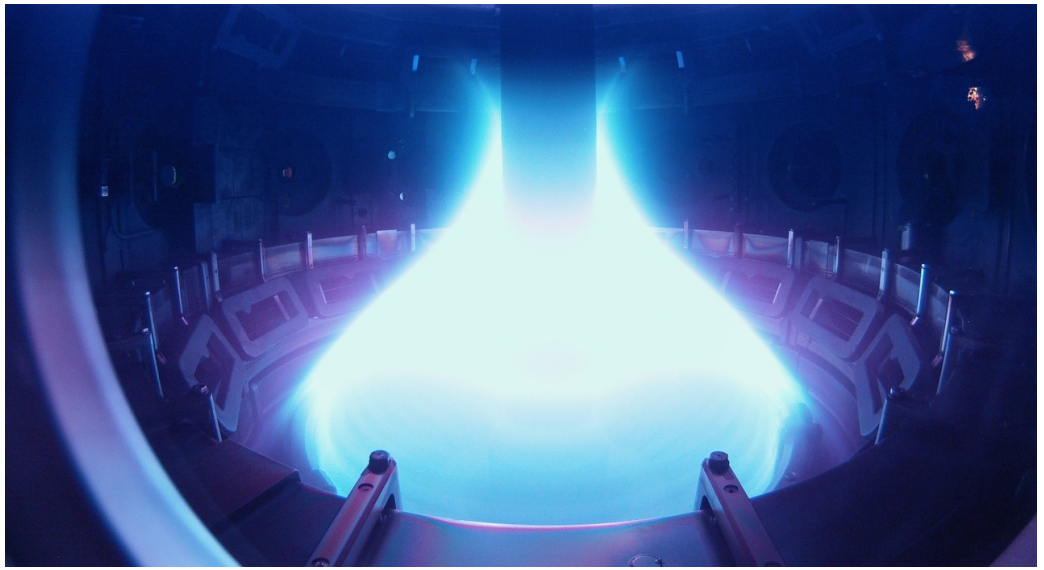
- Free moving, within constraints, with a changing volume, its particles are charged but loosely aligned.
- Plasma is made of ions (NOT atoms) and free electrons.
- Plasma is most abundant form of ordinary matter in the universe!

Examples of Plasma



https://www.digivac.com

Magnetically confined plasma in a Tokamak.



Courtesy of Eye Steel Film on flickr.

Question

- We learnt that as electronic engineers, we mostly deal with solids on our jobs.
- Do we deal with liquids, gases, and plasma at all?

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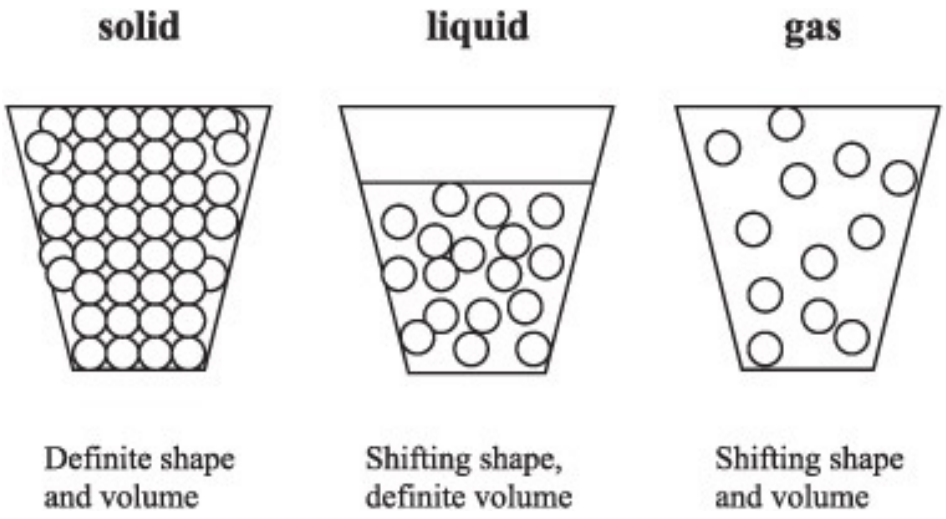
Yes, we do. At least when microelectronic devices are fabricated, liquids, gases, and plasma are heavily used.

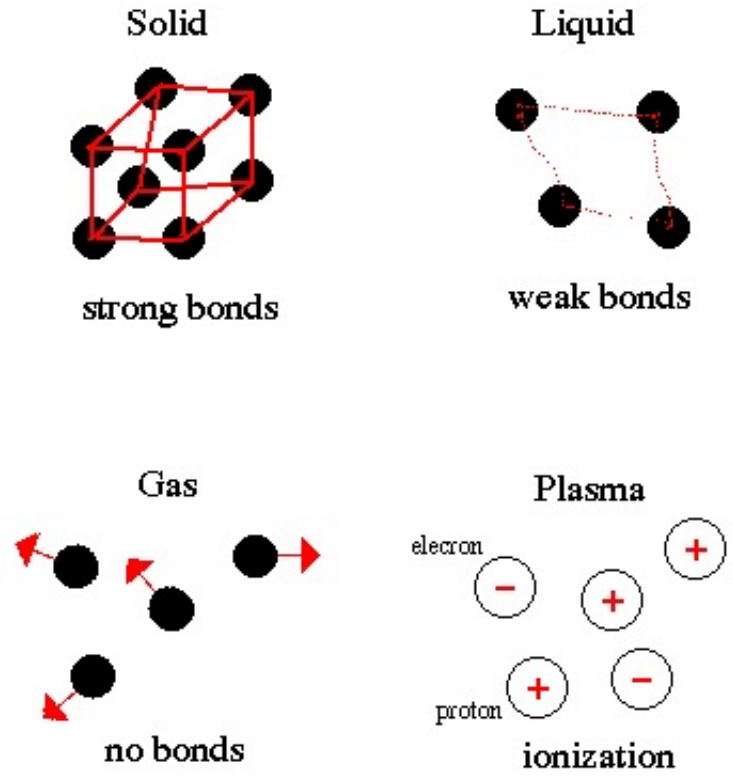
Other States of Matter

- Glasses (amorphous solids): gate oxide in MOSFET.
- Magnetically-ordered state: used heavily in data storage in hard drives.
- Superconductivity: carrying electric current without any resistance.
- Superfluidity: helium-4 at low temperatures.
- Bose-Einstein condensates.

Summary: States of Matter



Kinetic Energy Increasing!!



http://abyss.uoregon.edu/~js/ast122/lectures/lec03.html

Physical Properties

- These are aspects that can be measured or observed without changing the composition of that matter under study.
  - Colour – Is it blue? Still blue after you've looked at it.
  - Appearance – Is it smooth? Rough, dimpled?
  - Melting point – always the same at STP for a pure sample.
  - Boiling point – always the same at STP for a pure sample.
  - Solubility – always the same at STP for a pure sample.

  Note: STP – Standard Temperature and Pressure.

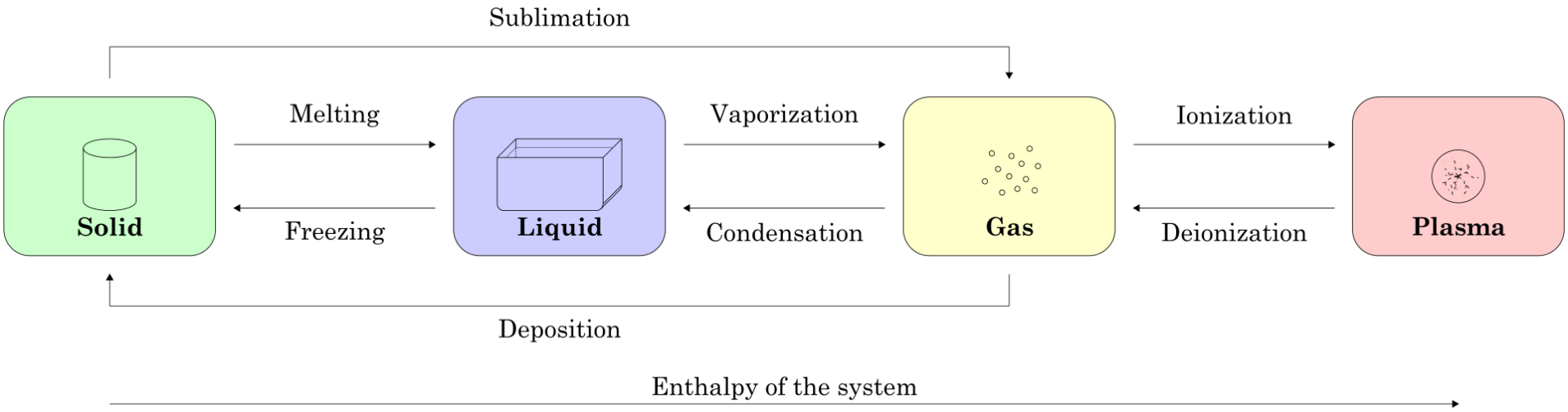
Chemical Properties

- These aspects can only be observed or measured by changing the matter under study.
- Combustibility: Does it burn? In what temperature does it burn?
- Reaction with air: Does it oxidise? For example, rusting iron.
- Reaction with acid, alkaline or other substances.
- Decomposition: Does it degrade?

How are Different States of Matter Related?

- Energy – we used kinetic energy in our definitions of solids, liquids and gases. Kinetic energy is the movement of atoms, this is less in solids than gas, one moves around, the other doesn't.
- Giving, or taking away, enough energy will change the state of that matter.
- The state of matter can change depending on temperature or pressure conditions.
- Only the physical state of the matter changes!

Phase Transitions



https://en.wikipedia.org/wiki/State_of_matter

Enthalpy is a thermodynamic state function. It is defined as the sum of the system's internal energy and the work required to reach its pressure and volume (the energy required to create the system + the work required to "make room" for it).

Phase Transitions

- The 8 different types of phase transitions:
  1. Melting: adding energy, solid -> liquid.
  2. Freezing: removing energy, liquid -> solid.
  3. Vaporisation (boiling): adding energy, liquid -> gas.
  4. Condensation: removing energy, gas -> liquid.
  5. Ionisation: adding energy, gas -> plasma.
  6. Deionisation: removing energy, plasma -> gas.
  7. Sublimation: adding energy, solid -> gas.
  8. Deposition (desublimation): removing energy, gas -> solid.

Take-Home Messages

- The 4 fundamental states of matter are solid, liquid, gas and plasma.
- Solids contain strongly bonded and closely packed atoms/molecules that are regularly arranged. A solid has a definite shape and volume. Atoms/molecules in a solid contain the least amount of kinetic energy.
- Phase transition takes place when matter transfers from one state to another. Typical phase transitions are melting, freezing, vaporisation, condensation, ionisation, deionisation, sublimation and deposition.