MIME 262, Lecture #09,
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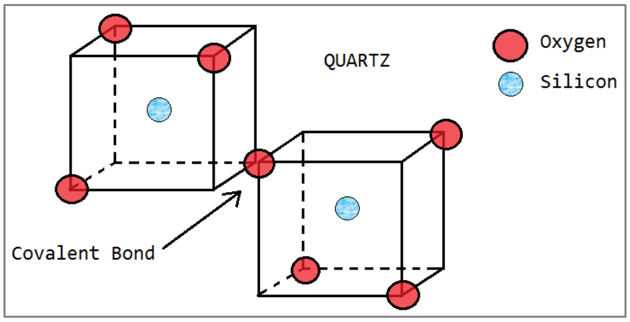
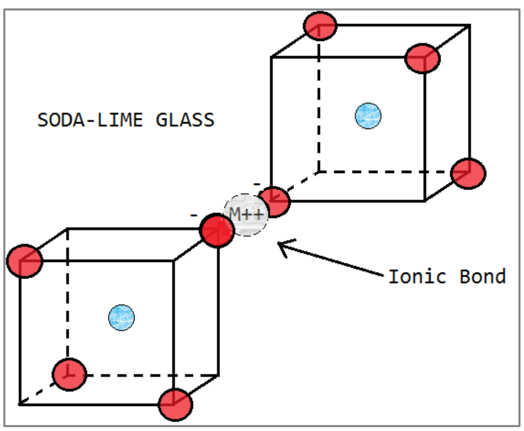
Melting points

Quartz (SiO_2): **~1700°C**



- Covalent bond requires higher energy to break

Soda-Lime Glass: **~550°C**



❖ Production is less expensive
- Lower melting point than Quartz
- Ionic bonds requires less energy than covalent bonds

Lead (Pb) Crystal Glass: **~800°C**

- Crystal but amorphous

Index of Refraction

Higher index (**n**) → Greater spreading of white light into its substituting colors → "Prettier to look at"

Quartz: **n = 1.5**
Soda-Lime glass: **n = 1.5**
Lead crystal glass: **n = 1.7**
Diamond: **n = 2.42**

Artificial Fibers

Glass Fibers:

- Inexpensive, light & strong

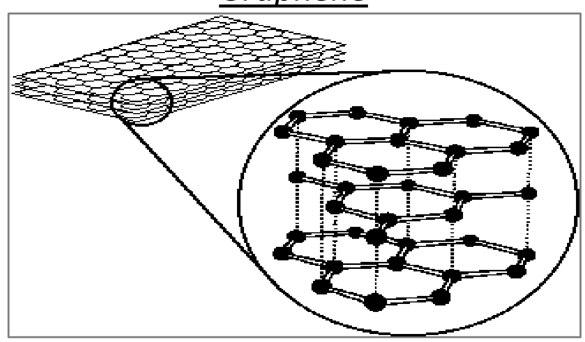
e.g. Fiberglass (mix of epoxy and glass):
- Good insulator

Carbon (Graphite) Fibers:

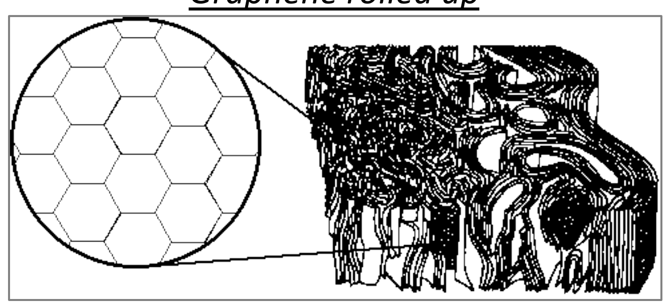
- Light and very low density
- Graphite is used as dry lubricant

e.g. pencil, aircrafts, tennis rackets, cars,…

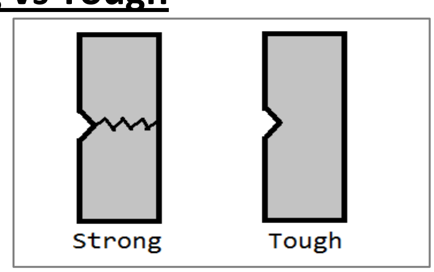
Graphene



Graphene rolled up



Strong vs Tough



- *Strong (brittle):* Cracks propagates
- *Tough (ductile):* Cracks don't propagate

CHAPTER 7 THERMODYNAMICS

Laws of Thermodynamics

1st Law: "Energy (E) is conserved"

- Energy can be changed from one form to another, but it cannot be created or destroyed

$E_k = \frac{1}{2}mv^2$

$E_w = \hbar w$ $\hbar$: Planck Constant

$E = mc^2$ c: Speed of Light

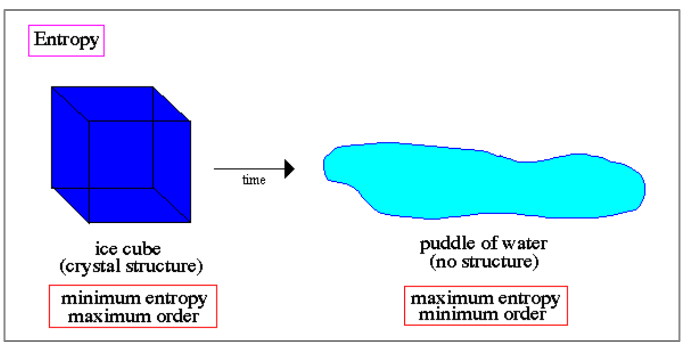
2nd Law: Entropy (S)

- In any closed system, the entropy of the system will either remain constant or increase.

- Entropy is the change or disorder of a microstate (Temperature (T), Pressure (P), Volume (V), Energy (E) or Molecule (N)) in a particular system

Example

- Ice melting in water



S = f(E, V, {N})

Entropy is a function of:

- E: Energy
- V: Volume
- N: Content of the system

Mathematical definition

① $\frac{dS}{dE} = \frac{1}{T}$ $\quad$ $\mathrm{T} \triangleq \text{"Absolute"} = [°\mathrm{K}]$

② $\frac{dS}{dV} = \frac{P}{T}$ $\quad$ P: Pressure

③ $\frac{dS}{dN_k} = \frac{-\mu_k}{T}$

④ $dS = \left[\frac{dS}{dE}\right] dE + \left[\frac{dS}{dV}\right] dV + \sum_k \left[\frac{dS}{dN}\right] d\,N_k$

$\boldsymbol{\mu_k} \triangleq$ *"Chemical Potential of k^{th} particle"*

$\boldsymbol{N_k} \triangleq$ *"Mole number k^{th} component"*

- Change in Energy, Volume, or Particle
  → Entropy changes

$$dE = TdS - PdV - \sum_k \mu_k$$

TdS: Thermal Work (e.g. Steam Engine)

PdV: Mechanical Work (e.g. Pressure)

Boltzmann Entropy Formula

$$S(E, V, \{N\}) = k_b \ln\Omega\,(E, V, \{N\})$$

k_b: Boltzmann Constant

Ω: degeneracy of states in a system (total number of distinct ways of assigning positions and momenta to the particles)

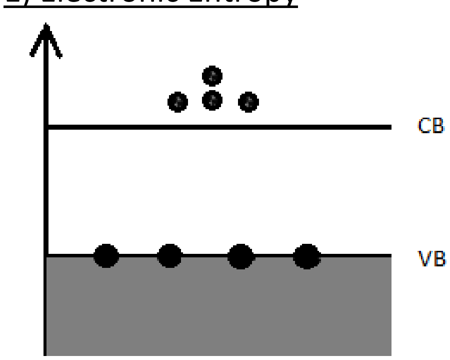
Analogy of degeneracy of states (**Ω**)

Volume:	$V_1 = V_2$
Temperature:	$T_1 < T_2$
# of people (molecules):	$N_1 < N_2$

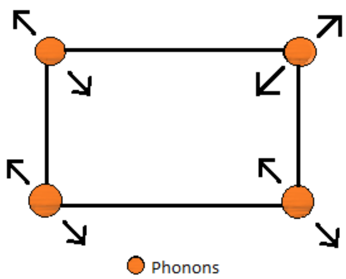
- Ways of assigning positions increased
- Momenta of people increased
- Thus, **Ω** increases

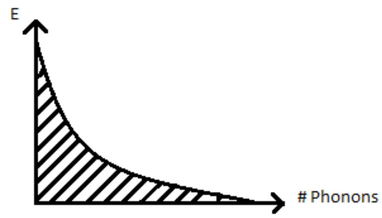
TYPES OF ENTROPY

1) Electronic Entropy

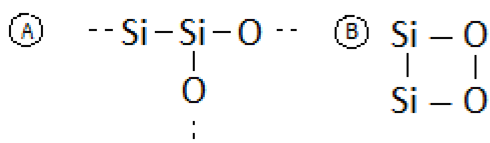


2) Vibrational Entropy





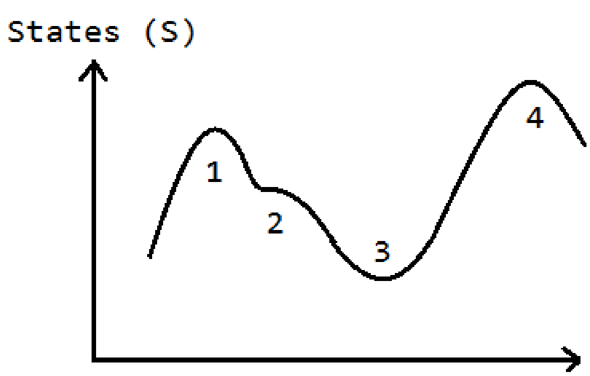
3) Configurational Entropy



3rd Law: 0°K "nothing happens"

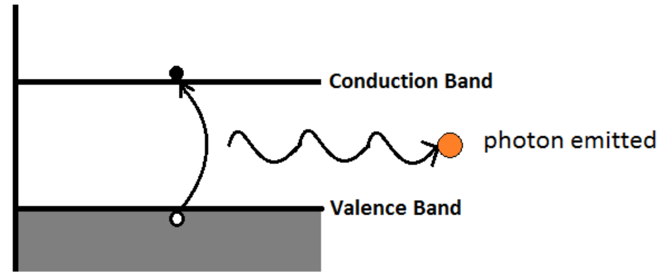
- The entropy of a system at absolute zero is typically zero, and in all cases is determined only by the number of different ground states it has.

T → 0°K
Ω → 1
S → 0



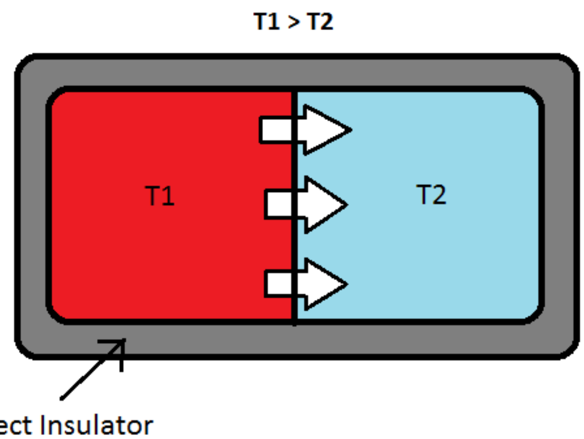
① Meta Stable
② & ③ Unstable
④ Global Minimum

Emitting light on a photocell



Eventually the electron will fall back down to the valence band → emitting photon

Entropy: Mathematical Example



$$dS = \frac{dE}{\mathrm{T}} + \frac{P}{\mathrm{T}}dV - \sum_k \left[\frac{\mu_k}{\mathrm{T}}\right] d\,N_k$$

$$dS = dS_1 + dS_2$$

$$dS = \frac{dE_1}{T_1} + \frac{dE_2}{T_2}$$

$$dE_1 = -dE_2$$

$$dS = -dE_2\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \geq 0$$

$$T_1 > T_2;\ \left(\frac{1}{T_1} - \frac{1}{T_2}\right) < 0$$

$$-dE_2\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \geq 0$$

$$\mathrm{d}E_2 > 0$$