

Internal Energy U

The internal energy (or total internal energy) of a substance is the total energy possessed by all the particles of the substance.

Various Energy Forms:

① Translational Kinetic Energy

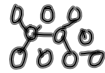
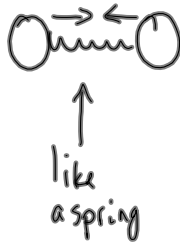
- due to the translational or linear motion.
- random  $\Rightarrow$  random translational kinetic energy
- gases + liquids, not solids.

② Rotational Kinetic Energy

- due to the rotational motion
- gases + liquids (fluids) not solids
- rotational kinetic energy of large polyatomic molecules is a very large part of the total internal energy. Single atoms have no rotational kinetic energy

③+④ Vibrational kinetic + potential energy.

- some particles have internal vibratory motion
- all types of substances (solids, liquids + gases) may have this if the structure of their molecules is complex
- solid  $\rightarrow$  lattice structure



⑤ Bonding Potential Energy

- occurs if there are forces between particles.
- cohesive forces in solids + liquids  $\Rightarrow$  if particles are pulled apart, then there will be an increase in potential energy.
- the cohesive forces in gases is very small

↑  
Van der Waals forces (zero in an "ideal" gas)

## Total Internal Energy

$$U = \sum (\text{the energies of all the particles in a substance})$$

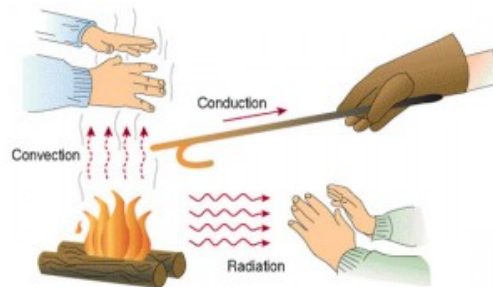
$$U = \sum_{i=1}^N \left( E_{k_i \text{ translation}} + E_{k_i \text{ rotation}} + E_{k_i \text{ vibration}} \right. \\ \left. + E_{p_i \text{ vibration}} + E_{p_i \text{ bonding}} \right)$$

We cannot actually measure the total internal energy of a substance, but only the change.

Referring to the energy within the substance not energy due to motion of the substance.

## Macroscopic + Microscopic (Temperature/Internal Energy/Thermal Energy)

Recall convection } ways to transfer internal energy.  
 conduction  
 radiation



Macroscopic → big/large scale.

- things that we can measure in the lab.
- mass of a gas, number moles, pressure, volume, temperature, internal energy, thermal energy.
- thermal physics ⇒ thermodynamics.

Microscopic → small

- individual atoms or molecules that make up a substance
- mass an atom, number of particles, particle speed, particle kinetic energy, particle momentum.
- thermal physics ⇒ kinetic theory or statistical mechanics.

Temperature  $T$  or  $\theta$

macro  $\rightarrow$  direction of flow of internal energy.

micro  $\rightarrow$  average random translational kinetic energy

Internal energy  $U$

Thermal energy  $Q$  or  $\Delta Q$

\* Heat is something that is transferred (like work transferring energy)