

EQUATIONS OF STATE

• MACROSCOPIC DESCRIPTION OF HOW STATE VARIABLES RELATE TO EACH OTHER IN EQUILIBRIUM

- EXAMPLE: IDEAL GAS (POINT PARTICLES, NON-INTERACTIONS)

$PV = Nk_B T$

- EXAMPLE: VAN DER WAALS (PARTICLES WITH VOLUME, WEAK INTERACTIONS)

$(P + \frac{N^2}{V^2} a) (V - \frac{N}{NA} b) = Nk_B T$

FITTING {  $a \rightarrow$  AVERAGE INTERACTION BETWEEN PARTICLES  
 PARAMETERS {  $b \rightarrow$  EXCLUDED VOLUME

IDEAL GAS (NON-INTERACTING POINT PARTICLES)

- MONATOMIC  $E_{TH} = \frac{3}{2} Nk_B T$
- COMPOSED OF ATOMS, OR MOLECULES, OR EVEN FUNDAMENTAL PARTICLES LIKE ELECTRONS
- RANDOM MOTION OBEYS NEWTON'S LAWS
- # OF PARTICLES IS VERY LARGE FOR STATISTICS
- VOLUME OF CONTAINER  $\gg$  VOLUME OF PARTICLES (LOW DENSITY)... ENSURES NON-INTERACTIONS

ENERGY TRANSFORMATIONS

TOTAL ENERGY:  $E = KE + U^g + U^s + E_{TH} + E_{chem} + E_{core} + \dots$

MECHANICAL ENERGY:  $KE \rightarrow U$

MICRO MECHANICAL ENERGY:  $E = mc^2$

COLLECTIVE MOTION OF CENTER OF MASS

1<sup>ST</sup> LAW OF THERMODYNAMICS

$\Delta E_{TH} = W + Q$

work HEAT

- IF  $W(+)$  AND  $Q(+)$ ; ENERGY INTO SYSTEM
- IF  $W(-)$  AND  $Q(-)$ ; ENERGY OUT OF SYSTEM
- IF  $W(+)$  AND  $Q(-)$  } DEPENDS ON  $|W|$  AND  $|Q|$
- IF  $W(-)$  AND  $Q(+)$  }

\* NOTHING POSSES WORK OR HEAT, THEY ARE MECHANISMS FOR WHICH TO TRANSFER ENERGY

• FUNCTIONAL DEPENDANCE

$\Delta E_{TH}(N, T) = W(P, V) + Q(T, S)$

Pressure Volume OR Entropy

$W(\text{FORCE}, \text{DISTANCES})$

Entropy and 2<sup>nd</sup> LAW

- Entropy
- MICROSCOPIC: MEASURE OF MULTIPICITY OR ORDER OR RANDOMNESS
- MACRO: RELATED TO ENERGY NOT AVAILABLE TO DO WORK

$Q = k_B \ln \sum_i T_i \Delta S_i$

HEAT IS FROM A CHANGE IN ENTROPY

IF  $Q(+)$  THEN  $\Delta S (+)$

• ENTROPY DRIVES ISOLATED SYSTEMS TO INCREASED DISORDER

• MORE DISORDER HAS LARGER MICROSCOPIC MULTIPLICITY

• LARGE MULTIPLICITY MEANS MORE MICRO CONFIGURATIONS WITH SAME MACRO OBSERVABLE

(eg.) T, P,  $E_{TH}$  ...

2<sup>nd</sup> LAW OF THERMODYNAMICS

• ISOLATED SYSTEMS HAVE ENTROPY INCREASE UNTIL EQUILIBRIUM IS REACHED, AT EQUILIBRIUM, ENTROPY IS AT ITS MAXIMUM AND DOESN'T INCREASE ANY MORE.