EQUATIONS OF STATE

- MACROSCOPIC DESCRIPTION OF HOW STATE VARIABLES RELATE TO EACH OTHER IN EQUILIBRIUM
  - EXAMPLE: IDEAL GAS (POINT PARTICLES, NON-INTERACTING)

$$PV = Nk_BT$$

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

$$\left(P + \frac{N^2}{V^2N_A^2}a\right)\left(V - \frac{N}{N_A}b\right) = Nk_BT$$

FITTING PARAMETERS { a → AVERAGE INTERACTION BETWEEN PARTICLES

b → EXCLUDED VOLUME

IDEAL GAS (NON-INTERACTING POINT PARTICLES)

- MONATOMIC $E_{TH} = \frac{3}{2}Nk_BT$
- COMPOSED OF ATOMS, OR MOLECULES, OR EVEN FUNDAMENTAL PARTICLES LIKE ELECTRONS
- RANDOM MOTION OBEYING NEWTON'S LAWS
- # OF PARTICLES IS VERY LARGE FOR STATISTICS
- VOLUME OF CONTAINER >>> VOLUME OF PARTICLES (LOW DENSITY)... ENSURES NON-INTERACTING

ENERGY TRANSFORMATIONS

- TOTAL ENERGY:

$$E = \underbrace{KE + U^g + U^s}_{\substack{\text{MECHANICAL}\\\text{ENERGY}\\\text{COLLECTIVE}\\\text{MOTION OF}\\\text{CENTER OF MASS}}} + \underbrace{E_{TH}}_{\substack{\text{MICRO}\\\text{RANDOM}\\\text{MOTION}}} + \overbrace{E_{CHEM}}^{\text{JELLY DOUGHNUT}} + \underbrace{E_{CREATE}}_{E=mc^2} + \ldots$$

EXAMPLES:

$KE \rightarrow U$

$KE \rightarrow E_{TH}$

1ST LAW OF THERODYNAMICS

$$\Delta E_{TH} = \underset{\text{WORK}}{W} + \underset{\text{HEAT}}{Q}$$

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

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

- FUNCTIONAL DEPENDANCE

$$\Delta E_{TH}(N,T) = W(\underset{\text{PRESSURE}}{P},\underset{\text{VOLUME}}{V}) + Q(\underset{\text{TEMP}}{T},\underset{\text{ENTROPY}}{S})$$

OR

W(FORCES, DISTANCES)

ENTROPY AND 2ND LAW

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

$$\underbrace{Q = \lim_{\Delta S \to 0} \sum T_i \Delta S_i}$$

HEAT IS FROM A CHANGE IN ENTROPY

IF Q(+) THEN ΔS (+)

- ENTROPY DRIVES ISOLATED SYSTEMS TO INCREASED DISORDER
- MORE DISORDER HAS LARGER MICROSCOPIC MULTIPLICITY
- LARGE MULTIPLICITY MEANS MORE MICRO CONFIGURATIONS WITH SAME MACRO OBSERVABLE

(e.g.) T, P, E_{TH} ...

2ND 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.