§. Thermo. D. in "Materials"

Component (元): element, compound

1. One component / Multicomponent
   Unary / Binary. Ternary. Quaternay

2. Homogeneous / Hetrogeneous

3. Closed / Open

4. Non-reacting / Reacting

5. Simple / Complex
   Q.W.U. E.M.Opt...

§ Thermodynamics Variables

$\boxed{T \cdot P \cdot V \cdot n_i \ldots U \cdot Q \cdot W \; H.S.A.G}$

Z

U: internal E.

Q: Heat.

W: work

H: enthalpy (焓)

S: entropy (熵)

Free. E. (A.G)

ΔZ

dZ

δZ

State 1 ⟶ State 2 ΔZ

18°C 100°C

Math

任意2個

☆ State Function: T. P. V. n_i, U. H. S. A. G

Indep. of Path

$\Delta Z = \int_1^2 dZ$

Process variables: Q. W

dep. on path

$\Delta Z \overset{?}{\neq} \int_{path} \delta Z$

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   Binary. Ternary. Quaternay

2. $\boxed{\text{Homogeneous}}$ / Hetrogeneous

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4. $\boxed{\text{Non-reacting}}$ / Reacting

5. $\boxed{\text{Simple}}$ / Complex ✗
   Q. W. U.   E. M. Op…

$$\Delta U = \int_1^2 dU$$

$$\Delta Q = \int_{path} \delta Q$$

State 1 ⟶ state 2

$$dZ \longrightarrow \Delta Z = (Z_2 - Z_1) = \int_1^2 dZ$$

$$\oint dZ = 0$$

$$\delta Q \longrightarrow \Delta Q = \int_{path} \delta Q$$

$$\oint \delta Q \neq 0$$

$$\delta W_{rev} = (\vec{F} \cdot d\vec{x}) = P \cdot dV$$

reversible

System.

☆ 任意[illegible]2個

$\boxed{\text{Intensive Variables}}$: T. P.

Idep. of $\boxed{\begin{matrix}\text{mass}\\ \text{size}\\ \text{moles}\end{matrix}}$

d

☆ 外延

$\boxed{\text{Extensive variables}}$: n_i, U. S

dep. on mass
size

tate 2

$) = \int_1^2 dz$

$gdz = 0$

δQ

$\neq 0$

$P \cdot dV$

System.

☆ 注意這2個

$\boxed{\text{Intensive variables:}}$ $T.\ P.\ \rho.\ X_i.$

ρ — density g/cm^3

X_i — mole fraction.

Idep. of $\boxed{\begin{matrix}\text{mass}\\ \text{size}\\ \text{moles}\end{matrix}}$

☆ 外延

$\boxed{\text{Extensive variables:}}$ $n_i,\ U.\ S.\ H.\ A.\ G.\ Q.\ W$

dep. on mass

size

X_i.

mole fraction.

$.G.Q.W$

§ $\boxed{\text{State}}$

$\boxed{\text{Unary system:}}$ (one mole) $\Rightarrow$ Any Two Indep Variables

e.g. $V = V(\underbrace{T.\ P.\ \cancel{H}.\ U.\ S\ldots}_{})$

equation of state

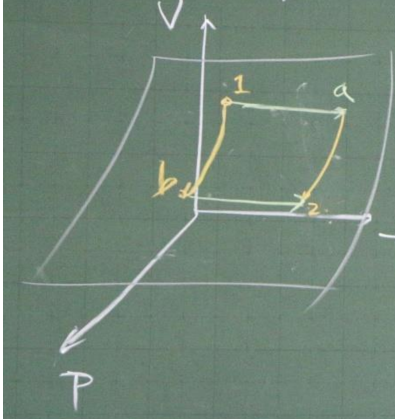
most convienient variables: $\boxed{T.\ P}$ V

state 1 $\longrightarrow$ state 2

e.g. $V_1 \longrightarrow V_2$. $\Delta V = \int_{V_1}^{V_2} dV$ $\quad V = V(T.p) = 2\ldots$

e.g. $\underset{(P_1, T_1)}{V_1} \longrightarrow \underset{(P_2, T_2)}{V_2} \rightarrow \Delta V = ?$

consider a pure gas



Two Paths

$1 \xrightarrow{\text{constant } P} a \xrightarrow[\text{constant } T]{} 2$

$1 \xrightarrow[\text{constant } T]{} b \xrightarrow[\text{constant } P]{} 2.$

path 1: $\Delta V_{path\,1}$

$$V_a - V_1 = \int_{T_1}^{T_a} \left(\frac{\partial V}{\partial T}\right)_P \cdot dT$$

$$+$$

$$V_2 - V_a = \int_{P_a}^{P_2} \left(\frac{\partial V}{\partial P}\right)_T \cdot dP$$

path. 2

$$V_b - V_1 = \int_{P_1}^{P_b} \left(\frac{\partial V}{\partial P}\right)_T \cdot dP$$

$$+$$

$$V_2 - V_b = \int_{T_b}^{T_2} \left(\frac{\partial V}{\partial T}\right)_P \cdot dT$$

$\Delta V_{path\,2}$

If $\Delta V_{path\,1} = \Delta V_{path\,2}$.

$V \Rightarrow$ state Function

dV exact differential

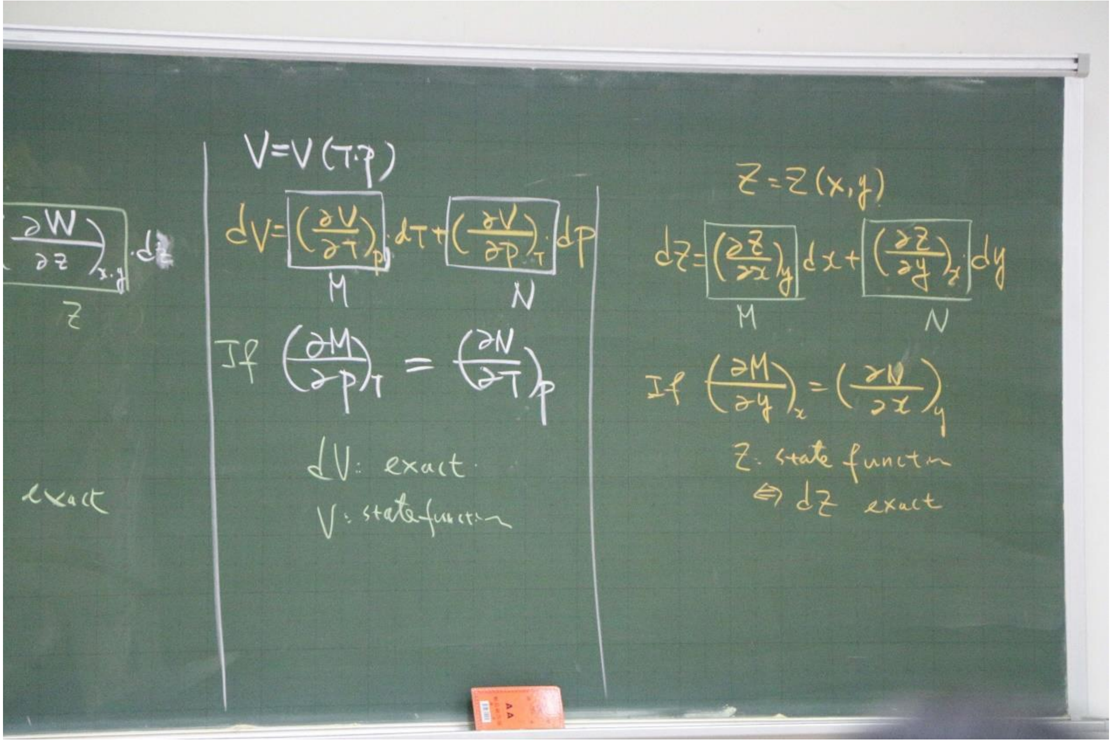
$V = V(T, P)$

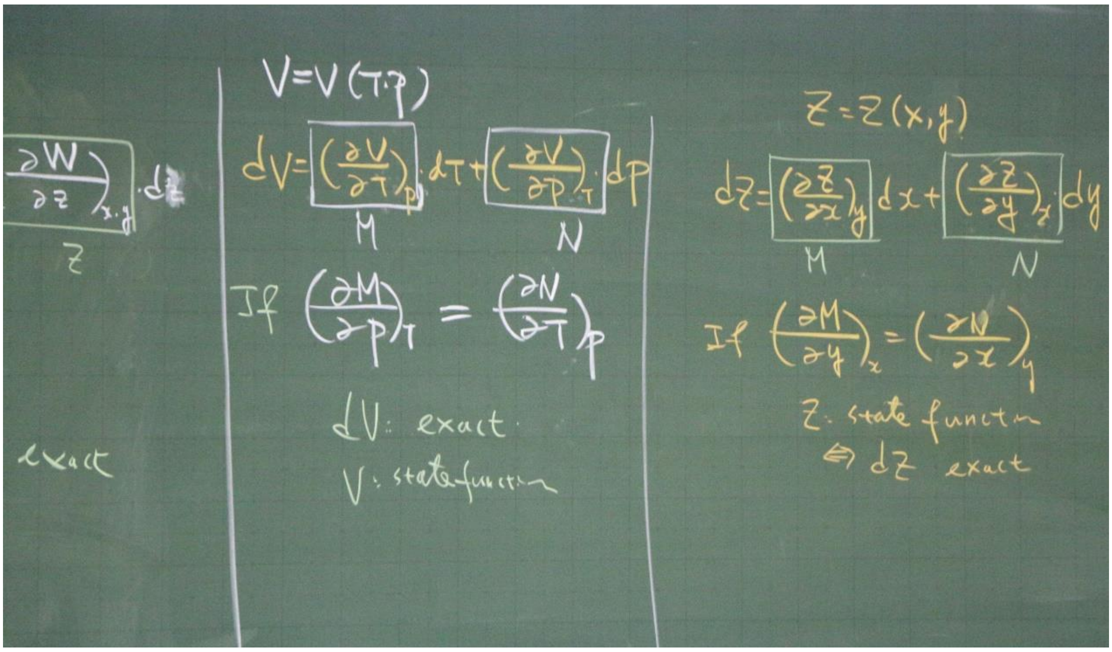
$$dV = \underbrace{\boxed{\left(\frac{\partial V}{\partial T}\right)_P}}_{M} dT + \underbrace{\boxed{\left(\frac{\partial V}{\partial P}\right)_T}}_{N} dP$$

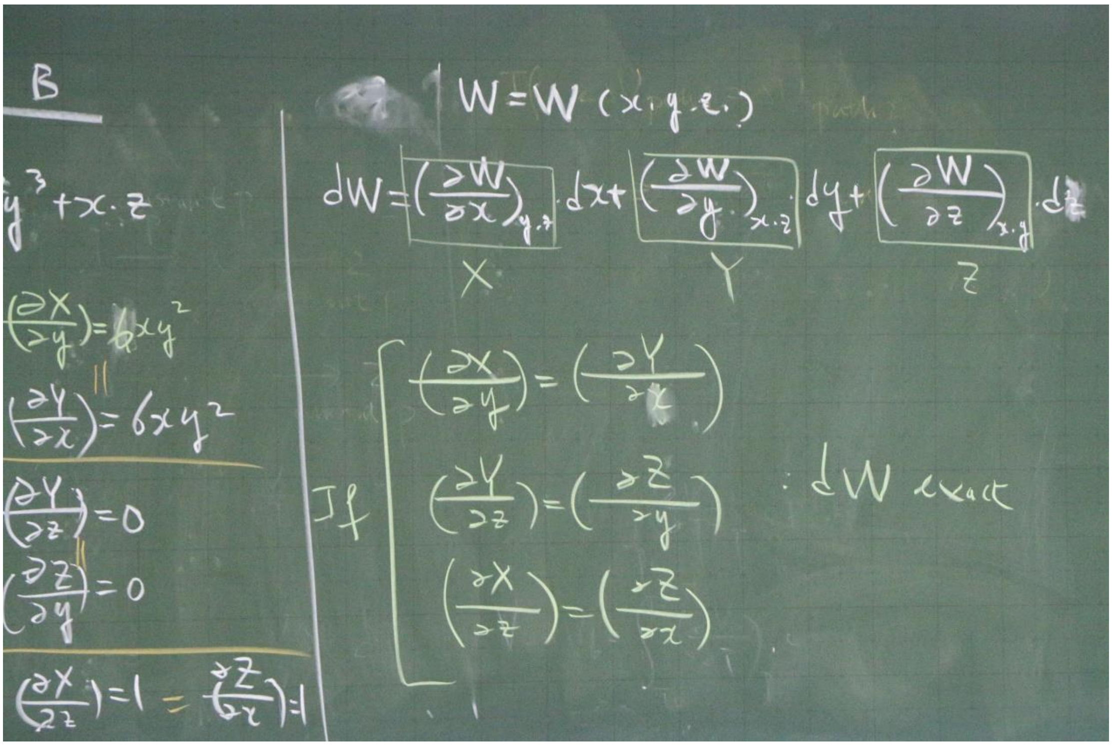
If $\left(\frac{\partial M}{\partial P}\right)_T = \left(\frac{\partial N}{\partial T}\right)_P$

dV: exact

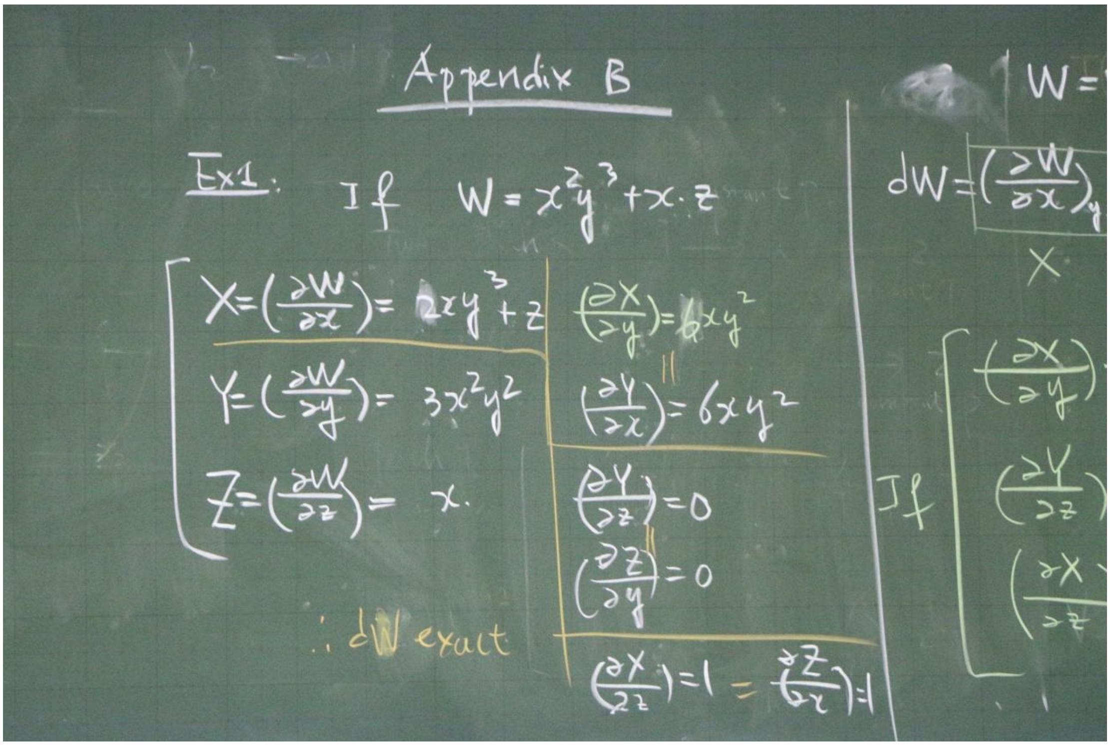
V: state function


$\left(\frac{\partial W}{\partial z}\right)_{x,y} \cdot dz$
Z
exact
$V = V(T, p)$
$dV = \boxed{\left(\frac{\partial V}{\partial T}\right)_p} dT + \boxed{\left(\frac{\partial V}{\partial p}\right)_T} dp$
M N
If $\left(\frac{\partial M}{\partial p}\right)_T = \left(\frac{\partial N}{\partial T}\right)_p$
dV: exact
V: state function
$Z = Z(x, y)$
$dZ = \boxed{\left(\frac{\partial Z}{\partial x}\right)_y} dx + \boxed{\left(\frac{\partial Z}{\partial y}\right)_x} dy$
M N
If $\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$
Z: state function
$\Leftrightarrow$ dZ exact


$\left(\frac{\partial W}{\partial z}\right)_{x,y} \cdot dz$
Z
exact
$V = V(T, p)$
$dV = \boxed{\left(\frac{\partial V}{\partial T}\right)_p} dT + \boxed{\left(\frac{\partial V}{\partial p}\right)_T} dp$
M N
If $\left(\frac{\partial M}{\partial p}\right)_T = \left(\frac{\partial N}{\partial T}\right)_p$
dV: exact
V: state function
$Z = Z(x, y)$
$dZ = \boxed{\left(\frac{\partial Z}{\partial x}\right)_y} dx + \boxed{\left(\frac{\partial Z}{\partial y}\right)_x} dy$
M N
If $\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$
Z: state function
$\Leftrightarrow$ dZ exact



B
$y^3 + x\cdot z$
$\left(\frac{\partial X}{\partial y}\right) = 6xy^2$
$\left(\frac{\partial Y}{\partial x}\right) = 6xy^2$
$\left(\frac{\partial Y}{\partial z}\right) = 0$
$\left(\frac{\partial Z}{\partial y}\right) = 0$
$\left(\frac{\partial X}{\partial z}\right) = 1 = \left(\frac{\partial Z}{\partial x}\right) = 1$
$W = W(x, y, z)$
$dW = \underbrace{\boxed{\left(\frac{\partial W}{\partial x}\right)_{y,z}}}_{X} dx + \underbrace{\boxed{\left(\frac{\partial W}{\partial y}\right)_{x,z}}}_{Y} dy + \underbrace{\boxed{\left(\frac{\partial W}{\partial z}\right)_{x,y}}}_{Z} dz$
If $\left\{ \begin{array}{l} \left(\frac{\partial X}{\partial y}\right) = \left(\frac{\partial Y}{\partial x}\right) \\ \left(\frac{\partial Y}{\partial z}\right) = \left(\frac{\partial Z}{\partial y}\right) \\ \left(\frac{\partial X}{\partial z}\right) = \left(\frac{\partial Z}{\partial x}\right) \end{array} \right.$ $\therefore dW$ exact



Appendix B
Ex1: If $W = x^2 y^3 + x\cdot z$
$X = \left(\frac{\partial W}{\partial x}\right) = 2xy^3 + z$
$Y = \left(\frac{\partial W}{\partial y}\right) = 3x^2y^2$
$Z = \left(\frac{\partial W}{\partial z}\right) = x$
$\left(\frac{\partial X}{\partial y}\right) = 6xy^2$
$\left(\frac{\partial Y}{\partial x}\right) = 6xy^2$
$\left(\frac{\partial Y}{\partial z}\right) = 0$
$\left(\frac{\partial Z}{\partial y}\right) = 0$
$\left(\frac{\partial X}{\partial z}\right) = 1 = \left(\frac{\partial Z}{\partial x}\right) = 1$
$\therefore dW$ exact
$W =$
$dW = \left(\frac{\partial W}{\partial x}\right)_y$
X
If

$\underbrace{\boxed{x^2}}_{Y} dy + \underbrace{\boxed{x^2}}_{Z} dz$

$\left(\frac{\partial Y}{\partial x}\right) = 2x$

$\left(\frac{\partial Z}{\partial y}\right) = 0$

$\left(\frac{\partial Z}{\partial x}\right) = 2x$

xact.

$V_1 \rightarrow V_2$. $\Delta V = \int \underline{\underline{dV}}$.

$V = V(T, p) = ?$

equation of state?

Ideal gas: $\underline{pV = nRT}$

Ch 1. Introduction

Definitions of Terms

Heat → Me

1. Why do we learn "Thermodynami

What determines

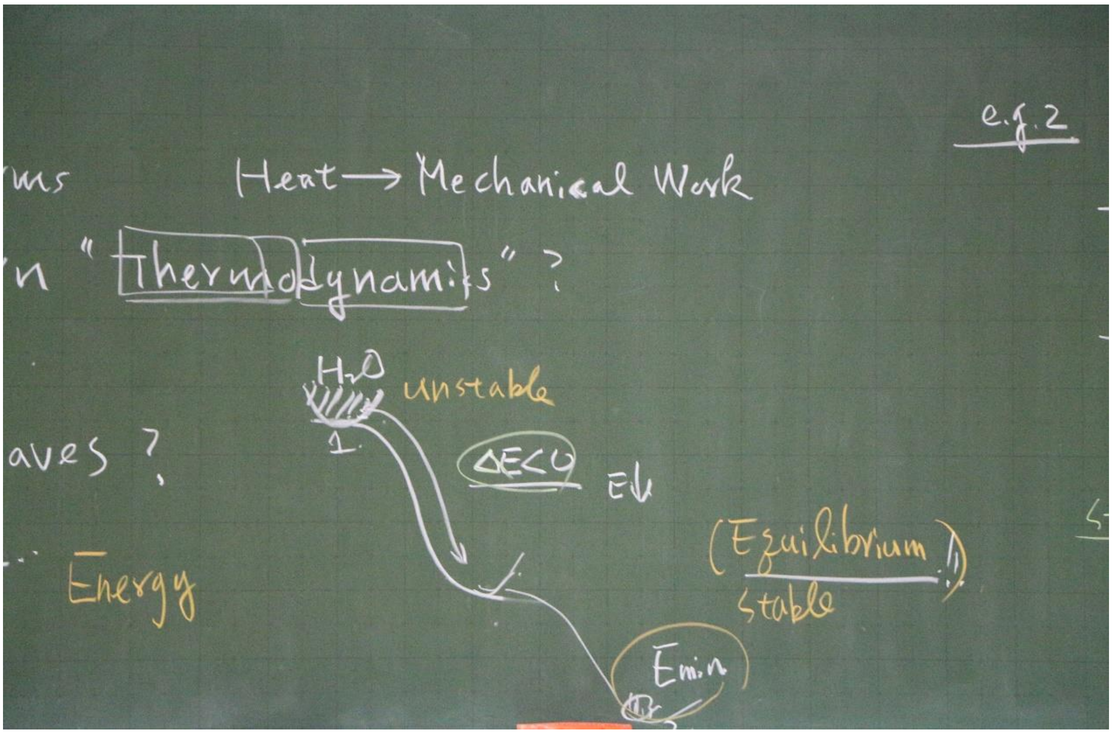
how matter behaves?

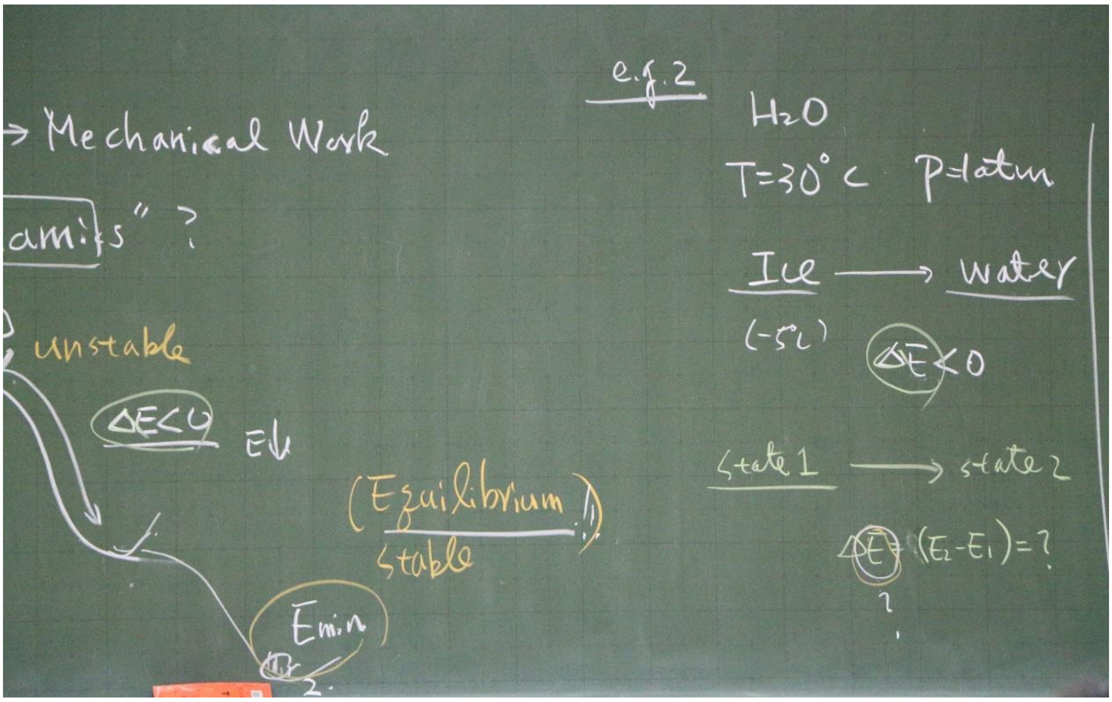
material
subject

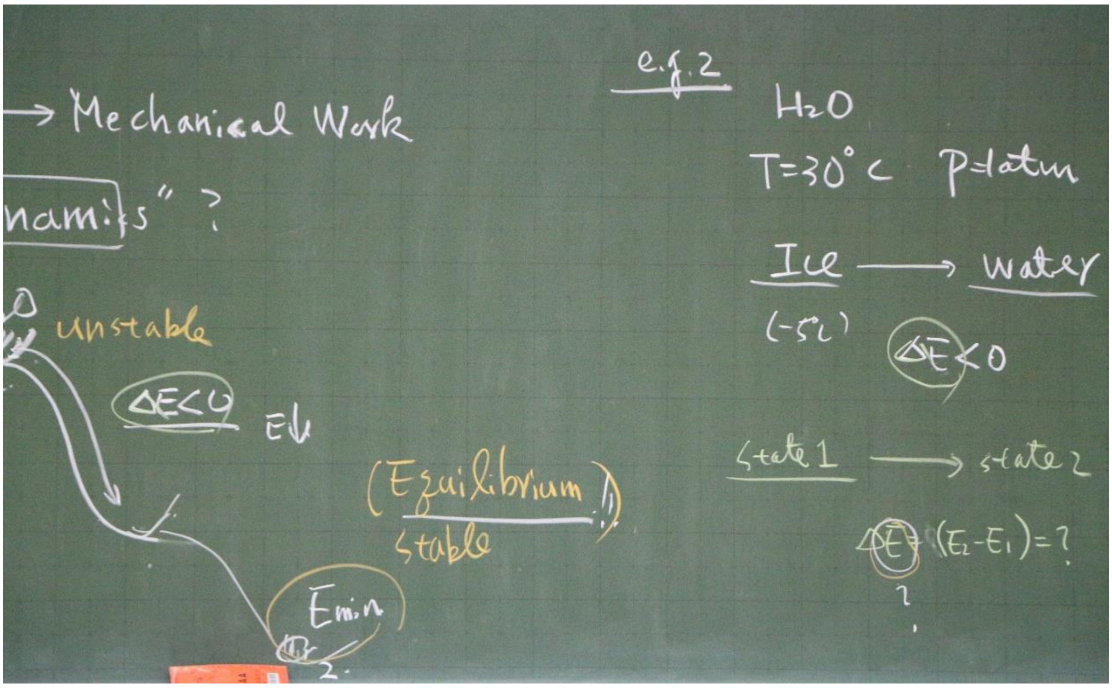
e.g. 1.. Energy

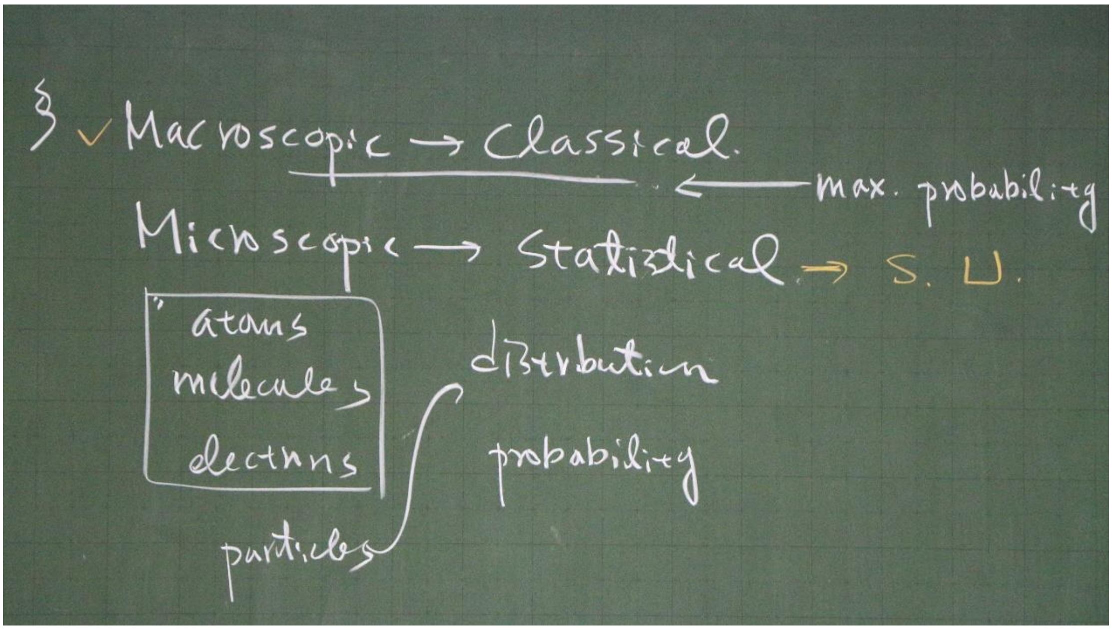
H_2O uns

1.


e.g.2
ms
Heat → Mechanical Work
n “Thermodynamics” ?
H2O
unstable
1.
aves ?
ΔE<0
E↓
Energy
(Equilibrium !)
stable
Emin


e.g.2
H2O
→ Mechanical Work
T=30°C P=1atm
amics” ?
Ice → water
(-5°C)
ΔE<0
unstable
ΔE<0
E↓
state 1 → state 2
(Equilibrium !)
stable
ΔE=(E2-E1)=?
Emin
2.


→ Mechanical Work
namics" ?
unstable
ΔE<0
E↓
(Equilibrium)
stable
Emin
e.g.2
H2O
T=30°C P=1atm
Ice → water
(-5°C)
ΔE<0
state 1 → state 2
ΔE = (E2-E1) = ?


§ ✓ Macroscopic → Classical.
← max. probability
Microscopic → Statistical → S. U.
atoms
molecules
electrons
particles
distribution
probability